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ATOMS FOR PEACE: RETRIEVING A LOST IDEAL

SAURABH KUMAR
and
P.K. IYENGAR

RAJIV GANDHI INSTITUTE FOR CONTEMPORARY STUDIES

***Saurabh Kurnar** is Deputy Chief of Mission of the Embassy of India, Thimpu, Bhutan. He was Alternate to the Representative of India on the Board of Governors of the IAEA from 1991-92.*

***Dr. P.K. Iyengar** is former Chairman of Atomic Energy Commission and former Director of the Bhabha Atomic Research Centre.*

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I
INTRODUCTION

NEW POWER FOR OLD WEAPONS

The discovery of nuclear fission in 1939, and the subsequent research and development that made nuclear power technically and commercially feasible, heralded the dawn of the Atomic Age. Besides nuclear power stations, it witnessed the advent of nuclear power in the form of nuclear-propelled submarines, ice-breakers, satellite power sources, pace-makers etc. Scientists and philosophers saw in nuclear power a source of cheap and virtually inexhaustible energy and a unique opportunity for human civilisation to free itself from the drudgery of physical labour.

The early part of this atomic age, however, also saw unprecedented developments in nuclear science and technology for military purposes. In fact, the first application of nuclear technology was in the theatre of war: the infamous atom bomb that destroyed Hiroshima and Nagasaki and brought about a precipitous end to World War II. Even though the scale of devastation of the first nuclear weapon struck terror in the minds of those who discovered it, the political leadership of the time did not fully recognise the dangers of a world armed with nuclear weapons. Early negotiations between the communist and non-communist blocs failed, and the world was fated to witness a rapid growth in the number and complexity of weapons of mass destruction being accumulated between the two major powers, which could annihilate the world many times over. The arms race that ensued was like the proverbial tiger that once mounted could not be dismounted, with staggering amounts of resources being devoted to the development of ever more powerful and destructive weapons. The nuclear Non-Proliferation Treaty (NPT) of 1968 was slow in coming and failed to stop the nuclear-weapons states (NWS) from further research and development into, and the deployment of, more destructive and tactical nuclear weapons.

The 'hijacking' of nuclear technology for military purposes almost at the outset proved to be its undoing. Although the post-world war period did witness considerable growth of nuclear power in a number of developed countries, this promising technology was not shared with the rest of world. The main reason for this was the fear of the members of the oligopolistic nuclear weapons club, that the bad example they had set — of pressing ahead in using the technology for military purposes, unmindful that its larger negative consequences — might prove to be contagious. As a result, the nuclear industry came to acquire a most distorted structure, leading to the near-total identification, in popular perception, of nuclear technology with nuclear *weapons* technology, and the emergence of a misguided but powerful lobby against nuclear power.

Unquestionably, fear of the proliferation of nuclear-weapons capability was the main reason why the promotion of nuclear power never seriously figured on the international agenda-notwithstanding provisions to that effect in the Statute of the International Atomic Energy Agency (IAEA). So much so that today this situation has come to be accepted as inevitable on grounds of political realism, and even the developing countries do not seem to regard the dissemination of nuclear power to be within the realm of practical politics.

A fresh look at nuclear power

A number of factors, both - positive and negative, have come together in recent years to warrant a fresh look at the tenability of this 'existential nuclear order', whereby the immense potential of nuclear technology is left untapped for fear of the possible proliferation of nuclear-weapons capability.

First among these is the *spectre of global warming* that has been haunting the world for some time now. Among the conventional sources of energy that have potential for growth, nuclear power alone is free from green-house gas (GHG) emissions, and therefore does not contribute to the greenhouse effect. The need to provide developing countries with access to environmentally sound, and in particular GHG-emissions efficient, technologies is reiterated *ad nauseam* in multilateral discussions on the subject of climate change. And yet, because of an uncritical continuation of the political approach of the Cold War period, the foremost of these technologies - nuclear power - hardly finds a mention in this context amongst options worth promoting.

Secondly, the disintegration of the erstwhile Soviet Union, and the consequent emergence of a number of independent States with nuclear arsenals, has thrown up a number of new problems.

One of the most important of these is the question: what is to be done with the *debris of the thousands of undetonated nuclear weapons* left behind in the countries of the CIS? This has opened up a new chapter in the nuclear field that, for obvious reasons, was not an issue during the Cold War years.

In addition to the surplus weapons, there are *large inventories of weapons-grade fissile material* — highly-enriched uranium (HEU) and plutonium (Pu) — in the USA and Russia, with no military use for them now. These inventories were maintained by both countries in readiness for being fabricated into weapons, but have now been rendered surplus as a result of the changed situation. Furthermore, still larger surpluses would arise if, as is not improbable, more ‘arms control’ agreements are concluded in the near future, in view of the fact that maintenance of the huge existing arsenals, with their massive overkill capacity, after the end of the Cold War, is increasingly being recognised to be unnecessary and even counter-productive. Altogether, the amounts of weapons-grade fissile material that are surplus, or potentially surplus, have been estimated to be as high as over 1,000 tonnes of HEU and 250 tonnes of Pu.

Fissile nuclear materials

A few fundamental facts regarding nuclear materials and their energy content are worth recapping here. Most of the naturally occurring uranium is in the form of the non-fissionable isotope 238U. The isotope 235U, which is available in small proportions (0.7%) in natural uranium, is the only fissionable material provided by Nature. Man has managed to produce plutonium, an equally fissionable atom, out of the non-fissionable 238U, and thereby extended the fissionable frontier. The properties of 238U and 239Pu make them prime candidates for nuclear weapons. Typically only about 20 kg of 235U (in the form of HEU) or 5 kg of Pu are required to make an atomic bomb. In terms of energy, 1 kg of 235U or 239Pu can provide 24 million KW-hours of energy. One tonne of these materials would therefore suffice to fuel a 1,000 MW reactor for a whole year. In addition, nuclear reactors always produce at least half the quantity of the fuel they burn, thus extending the total output. In fact breeder reactors could produce surplus nuclear fuel by factors ranging up to 1.5.

It is important to recognise that *manufacturing a nuclear weapon is not a very difficult exercise technically*, once weapons-grade fissile material is acquired. It is the complexity of the process of production of weapons-grade fissile materials — enrichment of natural uranium from 0.7% of 235U to the concentrations of 90% or higher that are necessary for weapons use or for plutonium production — that is difficult to master. Therefore, with such large amounts of the fissile materials lying surplus, the world would be hostage to the risk of this material being recycled into nuclear weapons in the hands of any group that can lay its hands on even a negligibly small fraction of these stocks and garner the requisite expertise. The numerous incidents of the smuggling of fissile materials that have come to light since the collapse of the former Soviet Union are pointers to the shape of things to come — a first-rate black-market in nuclear materials and weapons.

In addition to the security risk, there is an environmental risk. These fissile materials are extremely hazardous because of their 'radioactive' toxicity, which they will retain over their long lives - 10,000 years or more - spanning twice as many generations of humanity as the civilised world has known in its existence so far. No matter what precautions are taken while storing them in *concentrated* form, preventing leakage into the environment (into ground-water aquifers or the atmosphere) in the course of such long periods of time can obviously not be guaranteed by anyone. Should this happen, it could very well mean a catastrophe on a scale not experienced hitherto, with consequences beyond the capacity of man to control or remedy. The occurrence of long-lived radioactive atoms in the earth, in very small concentrations, however, causes no hazard.

As against this danger, if the fissile material already available in the nuclear weapons that have been made redundant, or rendered surplus otherwise, were to be channeled for use in nuclear reactors, the energy-producing potential would be enormous. A noteworthy aspect is the highly enriched, and therefore highly efficient, nature of the fissile material in the weapons. These are ideal for fast-breeder reactors, as well as for bringing to fruition a variety of new concepts in nuclear power production presently being researched, that are 'environment-friendly' and place a premium on safety.

Spent fuel

The amount of spent fuel that has been accumulating world-wide as a result of operation of the 400-odd nuclear power reactors all over the world for close to five decades now, has grown to fairly substantial levels and continues to grow with every passing day. The spent fuel is, as is again well known, a mixture of usable fuel and fission products that are radioactive and toxic, and needs careful handling and disposal. Like the fissile materials that constitute the fuel of the reactors, it has a long life (over 10,000 years) and retains its radioactivity over this period, albeit at a declining rate.

The practice all over the world in regard to spent fuel so far has invariably been to 'store' it safely, after taking all possible precautions to prevent damage to the surroundings due to leakage or accidents. Although there is no known method yet of disposing of the spent fuel completely, it can be recycled and thus be 'consumed' away. Some countries 'reprocess' the spent fuel at the earliest possible opportunity (i.e. once it has 'cooled' enough to make it safe for handling), separate the Pu in the spent fuel that is the most toxic component, and store the rest of the spent fuel as waste. The separated Pu has, of course, to be stored equally carefully - in fact more so, because separated Pu can be used for making nuclear weapons, i.e. it is vulnerable to the added risk of theft as compared to spent fuel. But against this risk there is the advantage that the separated Pu can be consumed away as fuel in nuclear power reactors. Besides making it far less toxic and dangerous, reprocessing the spent fuel also cuts down its bulk (volume) drastically by separating out the useful, unburned, uranium in the fuel, and thus reduces the problem to manageable levels. The amount of such encapsulated waste from a 1,000 MW reactor would hardly be a few tonnes per year.

While a small proportion of the spent fuel from the world's reactors has been reprocessed in this way, yielding some 70 tonnes of separated Pu, most of the spent fuel, containing over 750 tonnes of Pu, remains unreprocessed and stored as such. This is because of restrictions imposed by the IAEA (under the NPT) on the non-nuclear-weapons states (NNWS), regarding the reprocessing of spent fuel. This, in turn, is due to the fear of 'proliferation' of nuclear-weapons capability in case these States gained access to the separated Pu. Of course, any such separated Pu would be subject to IAEA safeguards under the provisions of the NPT, but that has obviously not been considered to be adequate guarantee by the nuclear weapons states. As may be expected, this is a sore point with those non-nuclear-weapons states that are advanced in nuclear technology (Japan, Belgium, Germany, India and some others), and even nuclear-weapons states like France and UK, since it imposes fetters on their freedom to pursue rational nuclear policies, for political reasons stemming from Big Power interests. The UK, Japan, France, India and some others have established commercial reprocessing facilities and have successfully gone in for the reintroduction of the extracted Pu in light-water reactors. Japan has continued its policy of getting spent fuel reprocessed in France and UK, and has begun to use the Pu for energy production. However, the technology for reprocessing has not become universal as it could have. Whatever be the case for restrictions on reprocessing spent fuel hitherto, it appears unnecessary, from the political point of view, to maintain a closed mind on this question now. Indeed, such an approach is untenable from a technical and environmental standpoint since reprocessing of the spent fuel enables it to be recycled effectively. With the stockpiles of spent fuel having grown to stupendous levels, there has been a corresponding increase in the risk of contamination of the environment due to leakage, apart from a rise in the costs of storing ever larger quantities of spent fuel. What was so far a manageable problem has grown in scale gradually and reached a level where continuation of the earlier approach is no longer a feasible proposition.

The problem and challenge of disposal

How to dispose of the accumulated spent fuel and the 'surplus' weapons-grade fissile materials is therefore a question that requires in-depth consideration, with a cost-benefit analysis of all possible options carried out dispassionately and without any preconditions. Strangely enough, little is heard about this problem in public, even though hardly a day passes without a report or two in the media on the dangers of the proliferation of nuclear-weapons capability, and of the contamination of the Earth's atmosphere Or aquifers by radioactive wastes or materials left over by the misdoings of the Cold War period.

Of course, it could be argued that this is not a 'global' problem but only of the countries to whom the fissile materials and spent fuel belong. That is perhaps one reason why it has not attracted much international attention. But this cannot be allowed to mean that the rest of the world need not concern itself with questions concerning the safe storage and disposal of these dangerous materials. The consequences of an accident, were there to be one, would not respect political boundaries and, in any case, the sheer length of the time-span over which the risks would continue to cast their shadow over the world as a whole makes this a world-wide concern. At a time when even traditionally archetypal 'national' questions are sought to be given multilateral dimensions and the entire concept of national sovereignty is being called into question, there can be no escape for the big players in the nuclear field — the NWS — from subjecting these and related issues to international scrutiny and debate.

The situation has all the makings of a crisis. If it is not perceived as one, this is only because international public opinion is not adequately informed about ground-level realities. Governments, which are better informed, are however answerable to their respective peoples and will not be pardoned for their inaction should the world have the misfortune of experiencing a nuclear catastrophe of any kind. In the past, influential opinion makers have chosen to sidestep uncomfortable issues pertaining to nuclear technology under cover of the overarching divide of the Cold War. The question is: how much longer can they continue to turn their heads and pretend that they just don't see?

An escapist approach would have been understandable if there was no option but to live with the risk of nuclear contamination of our planet. Far from it. The flip side of the matter, as with any crisis, is an opportunity — provided there is the willingness to grasp it. If a decision can be taken to 'consume' away the weapons-grade fissile materials and the spent fuel in nuclear reactors, there would be multiple benefits for all nations — both developed and developing. The dangerous materials could then be made to yield energy — literally converting swords into ploughshares. Moreover, the energy that would thus be generated would be produced in an environmentally clean manner, i.e. without causing GHG emissions the way other conventional fuels do. It is, of course, true that the USA and Russia (and many of the other developed countries too) do not have much utility for additional supplies of nuclear energy because of problems with domestic public opinion. But if the question were to be approached from a broader point of view and the net cast a little wider to encompass the developing countries, finding willing recipients would be the least of the problems. The power-starved developing countries could lap up virtually any amounts of energy, with profit. (For example, if India and China, with a total population of nearly 2 billion, were to consume electricity at the rate of 5,000 KW-hours per year, they would need an additional installed capacity of one million MW.) This would, of course, require concerted multilateral action in the form of an internationally sponsored programme for the establishment of nuclear power plants in the developing world under the aegis of the L&EA or any other agency of the United Nations. The problematic materials could therefore easily he disposed of in this way, to the common benefit of all humanity.

A highly positive-sum game thus awaits the emergence of players willing to play. The critical stumbling block is a readiness to break mental shackles stemming from the mind-set of the Cold War era, and to think afresh, with an open mind, about practical ways of realising this unprecedented opportunity of *simultaneously addressing global concerns in the three important fields of international security, environment and development.*

II
SURPLUS STOCKS OF FISSILE MATERIALS:

MAGNITUDE OF THE PROBLEM

It is not commonly known how large the stocks of weapons- grade fissile material in the military inventories of the USA & Russia, and those resulting from dismantlement of nuclear weapons under the INF and START-I Treaties, are, and how much energy they could be made to yield. The even greater amounts that could potentially be rendered surplus, if the remaining nuclear weapons of the USA & Russia (and other nuclear weapon powers) were also to be dismantled, and if all the spent fuel in the world were to be reprocessed and plutonium extracted from it for use as fuel in nuclear reactors, are even lesser known. As may be expected, information in this regard is not easy to come by, naturally being amongst the most closely guarded military secrets.

The SIPRI estimates

A reasonable idea of the magnitudes involved can, however, is had from estimates by various experts. The most authoritative study on the subject is the one carried out by the prestigious Stockholm International Peace Research Institute (SIPRI) in 1993[1]. This study, which estimated world inventories of highly-enriched uranium (HEU) and Pu (including military inventories) at the end of 1990, reveals the following:

(a) *Military inventories*: The amount of weapons-grade uranium (HEU) in the military stockpiles of the USA and Russia, excluding that contained in the 50,000 nuclear warheads that comprise their nuclear arsenals, is about 250 tonnes each, i.e. some 500 tonnes in all. Likewise, they together have almost 60 tonnes of weapons-grade plutonium (Pu), in addition to that contained in the 50,000 nuclear warheads. These amounts of HEU and Pu would be adequate for fueling a sizable nuclear power programme for a decade and more, at the rate of 1 tonne per 1000 MWe.

(b) *Stockpiles of nuclear weapons:* With the implementation of the INF and START-I treaties, the fissile materials contained in the nuclear weapons have begun to become available for alternative uses. These are yet small, but if the beginning made by the USA and the ex-Soviet Union in cutting back on the number of nuclear weapons under these treaties were to be continued, and the size of their arsenals brought down to 5000 warheads each (which would still be over four times the size of the combined arsenals of France, UK and China), the amount of HEU and Pu released thereby would be *640 tonnes and 140 tonnes respectively.* Together with the HEU and Pu in military stockpiles outside nuclear warheads mentioned in (a) above, this would mean a 'surplus' stock of over *1150 tonnes of HEU and 200 tonnes of Pu.* These amounts of fissile material would be adequate for fueling a 120 GW (120,000 MW) nuclear power programme for over 10 years.

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[1]World Inventory of Plutonium and Highly-Enriched Uranium: 1992, D. Albright, F. Berkhout and W. Wailer, Stockholm International Peace Research Institute (1993).

Elimination of all the nuclear weapons, of the USA and the former USSR (and, of course, of the other NWS and materials in military reactors etc.) would add further to these amounts, bringing the totals to *1310 tonnes of HEU and 257 tonnes of Pu.*

(c) *Pu in civilian spent fuel:* In addition to the above, there are about 550 tonnes of Pu in civilian spent fuel, plus 72 tonnes of Pu separated from civilian spent fuel, world-wide. The former grows by about 70 tonnes every year as a result of the operation of all the nuclear reactors in the world. (This means that today there would be over 750 tonnes of Pu in the spent fuel accumulated world-wide.)

(d) *Others:* The above estimates exclude HEU and Pu of several categories, such as amounts of HEU in use in naval fuel cycles (nuclear powered submarines) and certain kinds of research and other specialised reactors, and Pu in power reactors currently in operation all over the world. However, their contribution would be small compared to the massive amounts listed in (a) to (c).

(e *Distribution of these fissile materials:* An overwhelming proportion - almost all - of the weapons-grade fissile materials in the world today are with the NWS, mainly USA and ex-USSR (CIS countries). In the case of HEU, which is easiest to turn into weapons and most readily available, 99% of it is with the NWS (95% of it with the USA and the CIS). In case of Pu, the proportions are even more skewed. Even if the civilian Pu separated from spent fuel were to be included, it turns out that 322 out of 330 tonnes are with the NWS; of the remaining 8 tonnes, 7 are with the NNWS signatory to the NPT and 1 tonne is with non-signatories to the NPT. Overall, i.e. including both military and civilian Pu, separated as well as that still in spent fuel (unreprocessed), 649 out of the 911 tonnes in the world's inventory in 1990 belonged to, and 719 was located in, the NWS. Most of the remainder in the NNWS belongs to the industrialised countries, like Japan, Germany, Belgium and Switzerland that have an advanced and a sizable nuclear industry.

The above estimates pertain to 1990 but there have not been any significant changes since then. Military production of these materials having been stopped in the USA and Russia (the main producers), the estimates in (a) and (b) above remain unchanged. That in (c) above would have increased, as mentioned, due to the annual accretion of spent fuel and also because some of the material excluded ((d) above) would have been transferred to (c). Thus the actual amounts are, if anything, likely to be even larger than the estimates presented above. These estimates are corroborated by data disclosed by the US Department of Energy in June 1994, following declassification of information previously held as secret.

The enormity of the problem

The above numbers point to a gigantic problem in the safe storage of these surplus stocks of fissile material. The enormity of the security risk involved can be gauged from the fact that only about 20 kg of HEU or 5 kg of Pu are required for making a nuclear weapon. These are minuscule quantities compared to the size of the surplus stocks (several hundred thousand kilograms each). It would be quite a task to ensure secure custody of large amounts of explosive material for indefinitely long periods of time. (The duration for which vigil will be required to be maintained is not a matter of years or decades but several generations.)

They would provide a standing temptation to terrorists and other disaffected groups. No matter how stringent the physical security measures for ensuring their safe custody, the possibility of such negligibly small fractions of these stockpiles being stolen, or leaked out to disaffected groups, can never be discounted. Even the existence of States over periods of time as long as the life of these materials cannot be taken for granted, not to speak of their stability. The break-up of the former Soviet Union is a fresh reminder that the NWS are no exception in this regard.

It is fortuitous that this material has not yet been recycled into making weapons. No known terrorist group has managed to gain access to these surplus stocks so far but the numerous cases of smuggling of nuclear materials detected over the last year and more are pointers to the shape of things to come. Likewise, the expertise required for fabricating nuclear weapons is not yet available, outside Governments, to any of the known terrorist groups in the world today. But the international community cannot remain complacent in the belief that there is no danger of their coming to possess nuclear weapons. Such a tenuous security situation is dangerous.

One immediate concern is the possibility of the surplus fissile material from the nuclear establishments in the territories of the former USSR finding its way into the hands of disaffected groups capable of enlisting experts from these countries, or elsewhere, as mercenaries in the service of their cause. This is obviously the reason why the USA has decided to buy off 500 tonnes of HEU (diluted into fuelgrade), worth some $12 billion, from the countries of the CIS over a 20 year period, and remove it to storage sites in the USA. However, even the USA has not been able to extend the purchase offer to mop up the entire stocks of the fissile materials, perhaps because of the high cost and because it has no utility for them. The USA decision may have been all right as an immediate measure in the wake of the political uncertainty prevailing in the countries of the CIS after the collapse of the former Soviet Union, but it can hardly be considered satisfactory as a long-term solution.

"Nuclear terrorism" has been talked about quite widely but no bold or imaginative initiatives have been taken for dealing with this historically unprecedented danger effectively. If the large amounts of weapons-grade fissile material rendered surplus continue to be left around as such, they would pose grave risks for the world as a whole from the security, health and environmental points of view. A 'do-nothing' approach in respect of disposal of these materials is, therefore, simply not tenable.

Besides, such an approach would be lop-sided, considering the amount of effort and expenditure incurred multilaterally in administering safeguards on other fissile material that is much less sensitive and far smaller in magnitude. The entire amount of HEU under IAEA safeguards world-wide, for instance, is not even 1% in quantity of these surplus stocks. In the case of Pu, the IAEA safeguards some 250 tonnes of Pu discharged from power reactors, less than 4% of which is of weapons grade (the rest being Pu in spent fuel and therefore a lesser danger as far as proliferation risks are concerned). This in contrast to the more than 250 tonnes of weapons-grade Pu in the military stockpiles of the NWS, described in (b) above. It- hardly makes sense to guard the least dangerous materials with great fervour but to leave the far more dangerous ones unaddressed.

III
DISPOSAL OF THE WEAPONS-GRADE

FISSILE MATERIAL

The following options can be considered for the disposal of the 'surplus' stocks of weapons-grade fissile material, HEU and Pu, left over from the Cold War era:

Option 1: *Storage as HEU/Pu, after dismantlement of nuclear weapons, without construction of any permanent storage sites.*

This would mean storage of the dismantled cores of weapons (the Pu spheres or 'pits', as they are called) virtually as they are, in containers at the disassembly sites, the way fissile materials are kept in intermediate storage. It would be a 'least cost' option but one that would, for obvious reasons, be fraught with the greatest risks of theft by potential terrorists, for building nuclear weapons. As pointed out earlier, it is not so difficult, technically, to fashion a nuclear weapon given the fissile material; the difficulty lies in manufacturing the fissile material.

Moreover, as part of nuclear weapons, the HEU and/or Pu contained in the nuclear warheads would at least be subject to the military procedures and drills applicable for accounting of all arms and ammunition. Once dismantled, however, they would fall in the category of dead stores (as distinct from live arms and ammunition), and would therefore be most unlikely to receive the same attention and vigil. Such human and other resources as would be necessary for ensuring their safe custody are increasingly likely to be looked upon as a recurring burden. The chances therefore are that with every passing year these materials would be remembered less and less and thus be more and more vulnerable to pilferage. Moreover, it is doubtful if the Pu in the containers can be stored without degradation for more than a few years.

Additionally, it would be rather anachronistic in this day and age, when efficiency in resource allocation and use has become conventional wisdom, to leave the energy value of what is essentially extremely concentrated nuclear fuel (worth some $20 billion even at the current rock bottom prices) unexploited and locked up in storage vaults at considerable cost. And even that would not free the world of the risks of radioactive contamination, in case of a leak, theft etc., for generations to come.

Option 2: *Extraction of the HEU and Pu from the nuclear weapons and storage in concrete shelters underground after vitrification, with high-level wastes or otherwise.*

This would be basically the same procedure as followed in treating the high-level wastes, which are at present mixed with molten glass (vitrified) and then stored underground with adequate concrete shielding to guard against radioactivity leaking out. It would. Mean mixing the HEU/Pu extracted out of the weapons as above with glass and high-level waste to make it non-pilferable, and then storing it in concrete underground shelters.

This process is obviously expensive, because of the paraphernalia of double-walled containers, robots etc. necessary for handling such highly radioactive and toxic substances, daily inspections necessary to check for radioactive leaks and so on. Consequently, according to present practice, not all the spent fuel from the nuclear reactors is treated in this way but only the 'high-level wastes' left over after the useful plutonium and uranium have been extracted from the spent fuel. As mentioned earlier, only a small fraction of the spent fuel from nuclear reactors worldwide has been reprocessed and the Pu extracted out of it, so it should be clear that this method of disposal through vitrification has, so far, only been tried out on a very small scale.

The implications of duplicating this process on the massive scale that would be necessary if the entire stock of the surplus HEU and Pu were to be covered can be imagined. Not only would it be frightfully expensive to vitrify all the HEU and Pu, it would, in the first place, be virtually impossible to find adequate numbers of sites for such storage or disposal. Public opinion in the USA (and almost all developed countries) has been extremely sensitive to nuclear dangers and is, in most places, not even ready to support the location of new nuclear power plants in their respective constituencies, not to speak of storage of nuclear wastes. Target dates for the establishment of repositories for permanent storage of waste have had to be shifted repeatedly for this reason — not only in the USA but also in France and Germany. It is extremely unlikely that public opinion in the USA would consent to a large-scale exercise of this kind and the only way of undertaking it might be to do it outside the territories of the USA. This could either be in the uninhabited islands or other parts of unsuspecting developing countries (as has been the case in respect of testing of nuclear weapons), or in the global 'commons' such as the ocean floors or the uninhabited continents of the Arctic and Antarctica.

Some idea of the costs involved can be had from a report in 'The Economist' in its November 26, 1994 issue that the US Department of Energy was spending approximately $700 million per year on cleaning up the former storage sites of nuclear weapons, since the cessation of the production of nuclear weapons in 1990, as compared to the peak production-period expenditure of $445 million. Another report, this one from the British Broadcasting Corporation (BBC), estimated that about $7.5 billion had been spent in the last 5 years on cleaning up a former weapons-assembly site without any significant results.

Option3: *Burial in deep bore-holes underground in geological repositories.*

This is evidently just a variant of Option 2, the only, slight, difference being that this method of disposal is not envisaged to be undone at any point of time in the future, i.e. it is meant to be irreversible (and would therefore be a little less expensive), whereas storage in underground vaults after vitrification caters, in theory at least, to retrieval in the future, if required. The latter, though no more than a remote possibility, has to be catered to mainly for cosmetic reasons. Since it is undeniable that this method of disposal of nuclear wastes could hardly be considered satisfactory if it was to be for perpetuity, the only way it could be made palatable to public opinion and the regulatory authorities was to declare it as' temporary', pending the evolution of techniques for permanent disposal. It was, in effect, a convenient way of papering over an inconvenient question - the absence of any satisfactory way of disposing nuclear wastes - and pre-empting opposition to an otherwise indefensible course of action. The disadvantages and limitations of this option are therefore the same as of Option 2 above.

Option 4: *Dilution into fuel-grade fissile materials and temporary storage, pending utilisation as fuel in nuclear reactors.*

It is well, but perhaps not widely, known that the basic ingredients of nuclear weapons - the weapons-grade fissile material, either HEU or Pu - are really nothing but highly concentrated nuclear fuel; in fact over-concentrated as compared to the fuel requirements of ordinary nuclear reactors (and precisely for that reason, raw material for explosives). There is in fact no qualitative difference between the basic process, the nuclear reaction, that take place in a nuclear reactor and in a nuclear bomb. Given this fact, the weapons-grade Pu and HEU can be diluted to make fuel for nuclear reactors.

In the case of HEU, the process is absolutely straight-forward - it has simply to be mixed with natural uranium (which contains only 0.7% of the fissile material 235U, and enrichment of which to concentrations of 90% or more has yielded the weapons-grade materials), to bring down the 235U content to the 20% and less that is required for fuel-grade fissile material (actually no more than 3% in case of light-water reactors).

In the case of Pu, the process involved is more complicated but only a little more so. Pu is not a substance that occurs naturally -it is an artificially created element - and so 'dilution' by mixing it with non-fissile plutonium, as in case of uranium, is not possible. It is highly fissile by itself (and hence its use in bombs) but can be tamed into less fissile, reactor-grade, material by mixing it with a non-fissile oxide of uranium to give 'mixed oxide' (MOX) fuel. MOX is increasingly becoming the standard fuel in nuclear reactors in countries with reprocessing capability, and with the intention to burn away the Pu in the spent fuel effectively and simultaneously produce more power. In addition, dilution with other non-fissile material can improve the desirable properties of nuclear fuel, especially for longer irradiation in reactors.

As regards the cost of converting the weapons-grade fissile materials into fuel-grade, the money already spent in production of the fissile materials is a 'sunk cost', not relevant for costing of the proposal for utilising them for power generation. Only the cost of fabricating the weapons-grade fissile material into fuel for reactors, as above, needs to be taken into account. This would be no more than what it takes to fabricate fresh enriched uranium or MOX fuel.

It should be mentioned here that it may not even be necessary to dilute the fissile material. Direct use of highly enriched uranium and pure plutonium in new reactors may open up possibilities of new kinds of power reactors that may allow refueling at long intervals (say 10 years). Of course, this needs detailed technical study, but if found feasible it would be an additional attractive feature for the promotion of nuclear power under an internationally sponsored programme, as discussed in the following chapter.

Option 5: ***Others*.**

Some people have proposed, and the media sometimes repeats in all seriousness, that the fissile materials be shot off into space in rockets, never to return to our planet. Presumably the idea is to have the rockets take them so far into space that, whatever the condition of the fissile materials, no radiation or harmful effects can reach the

Earth. Proposals to ‘dilute’ away the fissile materials in the oceans, or for sub-sea bed disposal, or to detonate the nuclear weapons themselves as ‘peaceful nuclear explosions’ (PNEs) are likewise advocated by some equally seriously. These ideas are so preposterous that they do not merit any comment and have been noted in this discussion only for the sake of completeness.

What is to be done?

It should be clear from the foregoing that there is no technical hitch in putting the HEU and Pu to use for power generation and it is evident that, irrational and narrow considerations or interests aside, Option 4 alone is a viable solution to the problem of fissile-material disposal, from an enlightened global perspective— especially in the context of the grim energy-environment scenario facing the developing world.

In fact, there really is no alternative to consuming the fissile materials away in the form of fuel for nuclear reactors, if the international community is to act with any sense of responsibility towards generations yet unborn, and with a modicum of concern for our planet. With tonnes of dangerous and toxic materials threatening the safety and security of all humanity, and indeed the very existence of life on Earth, we sit on a volcano commemorating the follies of the Cold War. We have a choice that can be overlooked only at our peril. All the other options discussed above are not viable solutions, for each one of them is profoundly problematic in one respect or another and is therefore unacceptable.

Consuming the fissile materials away in the form of nuclear fuel is also not a course of action free of problems - it carries with it the risk of proliferation of nuclear-weapons capability that inevitably accompanies dissemination of nuclear technology. Unlike the negative consequences of the other options, however, the risk, of proliferation, in consuming the surplus fissile materials away as fuel are not so unpredictable or unmanageable as to preclude remedial action. These risks can be countered by devising appropriately stringent safeguards. In any case, there are no easy choices: the question before the international community is not one of optimisation but to choose the least disagreeable course out of a set of difficult options.

IV
THE NEED FOR MORE NUCLEAR POWER

Problems in consuming fissile materials in existing nuclear reactors

Even though utilisation of the surplus fissile material for the generation of energy might be the most rational choice, this is not likely to happen unless concerted action to this end is taken multilaterally. This is because neither the USA nor Russia, to whom the 'peace dividend' belongs, appears to be in a position to utilise it for energy generation in the near term, though for different reasons.

The USA

In the USA, the level of electricity generation and consumption is so high that additional energy supplies have very little utility and the focus is on energy conservation through a more efficient use of energy. In particular, a saturation point has been reached as far as the demand for nuclear energy goes. Together with the adverse publicity earned by the nuclear industry there, over the Three Mile Island and other accidents, this has already resulted in a glut in the 'market' for uranium, and in large unutilised capacities in the existing fuel-fabrication facilities in the last few years, that have caused a sharp fall in the price of uranium fuel. Public opinion is unlikely to countenance any expansion of the nuclear power generating capacity even if the nuclear fuel for such additional capacity were to come free of cost, as in this case.

At the most, the HEU released from nuclear weapons could be used to meet the fuel requirements of the existing low enriched uranium (LEU) reactors in the USA. However, this would be totally inadequate, as the total installed capacity of nuclear power generation in the USA would be able to absorb no more than a small fraction of the surplus stocks of HEU. Moreover, this would aggravate the problem of idle capacities in the existing fuel-fabrication facilities.

The scenario with Pu is even bleaker. It cannot be consumed away by converting it to MOX fuel because unlike some other developed countries the USA does not, as a matter of policy, use MOX fuel in any of its reactors. According to media reports, a final decision on disposal of Pu in the USA awaits a legally mandated study of the environmental impact of the various options, that was due to be completed by March 1995, and is not expected to be taken before 1996. Meanwhile, temporary storage at military bases continues at an estimated cost of $2-3 billion, besides the several hundred million dollars reportedly spent on studying the problem.

Russia

In Russia the situation is different. Additional supplies of energy are not without value but these cannot be nuclear in origin as the nuclear industry there is in the doldrums. Ever since the Chernobyl accident, the Russian nuclear power industry has been at a standstill because of its poor safety record and is therefore in no position to contemplate expansion. The light-water, VVER type, reactors, which are the mainstay of the Russian (and Central European) civilian nuclear programme, need to be redesigned completely to improve their safety features to IAEA certified safety standards before any expansion of nuclear power plants can be considered. An IAEA sponsored technical assistance project is underway for this purpose, but this is likely to take time.

Other developed countries

Given the lack of demand for nuclear power in the home countries, it would appear that if the surplus fissile materials are to be utilised for energy generation this would have to be done in other countries. The developed world, with a significant civilian nuclear industry, would be a natural first choice in this regard as the necessary infra-structure (nuclear power plants) already exists there, and the fuel fabricated from the surplus fissile materials has only to be fed into them to be got rid of. However, this would only be a partial solution. Many of the developed countries have similar problems with their public opinion and so would not be able to join in any such endeavor. In any case, with the existing nuclear power generation capacity it would take well over a decade to consume the surplus HEU alone and several decades in case of the Pu. And that too only if no fresh fuels were to be fabricated and the entire fuel requirements of the world's reactors during this period were to be met from these stocks of surplus fissile materials. In that case, as noted above, a fresh problem would arise for the fuel-fabrication firms of the nuclear industry in these countries because of the idle capacities it would result in. Finally, even so, the problem of disposal of spent fuel would be left unaddressed.

New nuclear power plants

The harsh reality thus is that the quantities of 'surplus' fissile materials are much too large to be consumed away rapidly in the existing nuclear power plants, especially when the nuclear fuel production capacity already existing in the world today is taken into account. Given this basic picture, it follows that the stockpiles in question can be dissolved quickly only through augmentation of the world's installed nuclear power generation capacity. That would, of course, pose some fresh problems -new imbalances in the fuel fabrication capacity in the longer term - and may therefore not be regarded as an ideal solution by some, but it would still be far better than the alternatives discussed earlier in Chapter III, each of which entails letting the current stock of surplus fissile materials (or the bulk of it) be around for unacceptably long periods of time. The long-term demand for fuel (after the current surplus stocks have been exhausted) can be met by the establishment of additional fuel-fabrication capacities after a decade or so as part" of a natural process of growth. The important thing is to do everything possible now to dissipate the current surplus stocks at the earliest.

Unsuitability in the developed countries

If the nuclear power generating capacity is to be so augmented, the natural first choice for doing so would again be the countries in the developed world which have significant nuclear power programmes. It would be the quickest way to establish additional capacity. However, this would have to be governed by considerations of demand for (and economics of) electrical power in these countries. The nuclear industry in most of the developed countries is in private hands and operates strictly on commercial lines. If the nuclear firms in these countries had found it advantageous to establish additional capacities and/or switch to the (cheaper) fuel fabricated by the conversion of the weapons-grade fissile material (as compared to fabrication afresh from uranium ore or other fossil fuels etc.), they would already have turned to this source or would be in the process of doing so. There is not much of a role for policy intervention in such a situation - normal market forces would automatically lead to the desired result. The fact that this has not happened on any significant scale suggests that the scope is rather limited in the developed economies, perhaps because of sources of nuclear fuel supply having already been tied up over a long term and poor prospects of growth in the demand for power, as well as adverse public opinion.

Need for an international programme in developing countries

That leaves only the developing world as a possible arena for the establishment of additional nuclear power plants. Here we find a whole new ball-game - energy is a critical bottleneck constraining faster economic growth and, instead of diminishing returns, we are in a situation in which any amount of supplies of nuclear power are welcome and would be lapped up with great profit. The question is how to realise this possibility.

It would seem necessary for this purpose to think in terms of an internationally sponsored programme for the promotion of nuclear power in the developing countries. A multi-national consortium of firms capable of setting up nuclear power plants in the developing countries in a turn-key manner could be asked to undertake this task under the aegis of the IAEA or some other specialised agency of the UN so mandated, on a 'BOO' (Build, Own and Operate) basis. Suitable sites could be identified by the leading nuclear firms in the developed countries, depending on their areas of business interest and familiarity, in consultation with the Governments of the host countries, and these could serve as centres of regional nuclear power grids, with a network of transmission lines going into as many neighbouring countries as feasible.

The only limitation may lie in the capacity of the developing countries to absorb nuclear technology and provide the infrastructure necessary for the establishment of nuclear power plants. Many developing countries already have nuclear industries of their own and even those that have only fledgling ones should not have any difficulty in accepting additional nuclear power plants. In others, the less-developed countries (LDCs) in particular (where the utility of the energy supplies is perhaps greatest), substantial external inputs and major improvements in infrastructural facilities may be necessary.

New ideas for nuclear power

The reason why many developing countries have not yet experimented with nuclear power is that restrictive practices have been imposed on them by the NPT. Nuclear power stations continue to be the preserve of technically advanced nations and, as they have had no interest in dealing with, or recycling Pu, there have not been many innovations in the industry. However, the availability of highly enriched uranium and plutonium could trigger many changes in the design, operation and economics of nuclear power stations. They could be made more compact, perhaps even transportable in small capacities for generating energy for district level heating etc..

There should therefore be commercial interest in the developed world in the designing, installation and operation of smaller units to supply energy to developing countries as part of such a programme under IAEA safeguards.

Other possibilities need to be explored. It may not be necessary, for instance, to stick to the electrical power route for the utilisation of nuclear energy. The conversion of thermal energy generated in the reactors into electrical energy is only one particular route to harnessing nuclear energy. The advantage of electrical energy lies in its ease of transportation and in its ubiquity of use. However there are still specific applications for which it is not necessary to convert thermal energy into electrical. Thermal energy (heat), which is what is released in the nuclear reactors at first, and is only subsequently converted into electrical energy, can be utilised directly in many industrial and other processes. Desalination is one such example. (Like energy, water supplies are again a major factor constricting development in many countries.) Since there are unavoidable losses in the conversion from thermal to electrical energy, this would substantially raise the efficiency of the nuclear plants and thus bring down costs, besides reducing the infra-structural requirements.

Conclusion

A host of other questions of a legal and logistic nature (such as a comprehensive liability regime to deal with issues relating to compensation in the event of an accident, international insurance schemes, trans-boundary emergency management drills, return of spent fuel etc.) would, of course, also have to be resolved before this proposal can see the light of day. Given a sincere try, however, it should not be difficult to resolve all such matters by building upon existing multilateral Conventions and Agreements in these areas.

The idea may sound too ambitious politically, and therefore be dismissed as a non-starter by some, but that would be a grave error. Given the knotty nature of contemporary problems, and the near impasse that has been reached in translating the concept of sustainable development into practice, it is clear that there can be no escape from trying for innovative solutions and approaches. This can scarcely be possible if the test of 'political feasibility' is imposed at the stage of brainstorming. It is obviously necessary to stretch the imagination and then see *ex post facto,* after throwing up some ideas, how they can be made feasible, even if they do not seem to be practical today.

V
A COST-BENEFIT ANALYSIS OF AN

INTERNATIONAL PROGRAMME

Benefits of the programme

If an internationally sponsored programme for the establishment of nuclear power plants in the developing countries, and for reprocessing all the spent fuel in the world, could be agreed upon, there would be a number of far-reaching benefits for all nations, both developed and- developing:

(a) Reduced security risk. First, and foremost, it would enable the massive amounts of dangerous weapons-grade fissile materials that threaten the security, safety, health and environment of the world as a whole, to be dissipated away rapidly. With an international programme for the generation of nuclear power underway, there would be a purpose and a focus for immediate dilution of the weapons-grade material into commercial-grade fuel (something that will not happen otherwise because the expense involved in doing so would naturally be looked upon as an unjustified burden in the absence of any immediate use for the fuel). The programme would, hopefully, also siphon off all such material presently unaccounted for, by being able to offer an incentive price and an overarching outlet for it. This would go a long way in checking its leakage into the hands of potential nuclear terrorists. By thus facilitating proper accounting of weapons-grade fissile materials, the proposed programme would also serve as an invaluable confidence-building measure for the rest of the world, which otherwise has no way of knowing that these materials will not again be turned into nuclear weapons. The significance of this achievement cannot be overemphasised.

(b) Reduced risk of environmental contamination. By drastically cutting down the duration for which the dangerous materials would be around to a decade or so, the risk of environmental contamination due to leakage etc. would have been reduced to the minimum feasible practically. A most vexatious problem would thus have been tackled successfully.

(c)Energy for developing countries. The programme would yield energy supplies that would be a big boon for the recipient developing countries. Energy, which is one of the most critical inputs for galvanising the economy on to a growth path, is the main constraint limiting economic growth in these countries, the LDCs in particular. This magical injection of power, can therefore be expected to work wonders in the LDCs and other developing countries, with strong multiplier effects in other sectors.

(d)Markets for developed countries. The economic gains would not be confined to the developing world. The programme would provide a boost to the nuclear industry in the developed economies, which in most cases is crippled, as mentioned earlier, because of problems with public opinion. By generating a substantial demand for nuclear reactors and the entire range of related equipment, the proposed programme should help create jobs and stimulate recovery in these economies. The large-scale orders for nuclear reactors and other equipment in a power plant would actually help the suppliers amortise the heavy overhead expenditures already incurred by them in

plant investment etc., which otherwise represent 'sunk' costs for them with little chance of being recouped.

(e) *Reduced GHG* emissions. Most importantly, the programme would work to the advantage of all nations from the environmental point of view. Today, fossil fuels are the mainstay of energy generation all over the world, especially in the developing countries. However the burning of fossil fuels releases CO2 gas, which contributes to the greenhouse effect and global warming. Therefore if new power generating capacity were based on nuclear (rather than fossil) fuel, this would result in abatement of the trend of a rise in GHG emissions worldwide — something that has not been possible to achieve so far.

(f) *Reduced wastes*. Finally, recycling of the Pu in the spent fuel as fuel for reactors would result in a drastic reduction in the amount of hazardous nuclear wastes to be disposed off. Reprocessing of spent fuel is an environmentally sound way of handling the radioactive wastes. Spent nuclear fuel is bulky and highly radioactive (and remains so for tens of thousands of years). Reprocessing minimises the risk of leakage and environmental pollution due to storage, as well as the costs, by sharply reducing the volume of the residual waste and enabling separation of the plutonium in it, which can be used as fuel again in the next round. This would resolve a most intractable problem to which there has so far been no satisfactory answer.

Like the security benefit, the latter two environmental gains are advantages whose significance can again not be overstated for there is no alternative way in which either of these advantages can be enjoyed. Under the Framework Convention on Climate Change (FCCC) concluded at Rio in 1992, GHG concentrations in the atmosphere are to be stabilised at protective levels, with the developed countries (which account for over 70% of the total GHG emissions in the world) being required to take the lead and stabilise their emissions at 1990 levels by 2000 AD. In the absence of any concrete measures to that end having been agreed upon multilaterally, there is not even the ghost of a chance that this target would be met. Nor have nations been able to take any steps to that end domestically. In particular, there has been no basic review of national energy policies in order to effect a shift away from reliance on ($C0_2$ producing) fossil fuels. The main reason for this is the non-availability of viable alternatives, especially for the developing countries which cannot afford to invest in R & D in renewable sources of energy or in energy efficient technologies.

The proposed programme (of recycling of the Pu in the spent fuel into the reactors as fuel) would vastly enhance the chances of a world-wide switch away from fossil fuels, apart from the direct benefit of the substitution of fossil fuels. With the nuclear fuel cycle 'closed' at the aggregate (global) level, the main apprehension about nuclear technology and the main points of criticism that have come in the way of more widespread use of nuclear energy, despite the plus point of its not resulting in GHG emissions - waste disposal and proliferation - would be taken care of. Nuclear energy would thus be able to provide an alternative to fossil fuels right away.

In short, it would be a highly positive-sum game, and one that would be twice blessed. Both the developed and the developing countries would be winners from the point of view of non-proliferation, international security and protection of the environment. In addition, the power generated would be a big donation by the developed countries to the developing world that would, in the long run, rebound to the benefit of the global economy as a whole.

Costs of the programme

The costs of any such internationally sponsored programme for the establishment of nuclear power plants in the developing world would naturally depend on the scale on which it is under taken. Fuel costs being a relatively small proportion of the total cost of a nuclear power plant, the funds required would undoubtedly be far greater than the quantum of the 'peace dividend'. If it is undertaken in numbers adequate for absorbing all the weapons-grade fissile material potentially surplus in a decade or so, i.e. about 100,000 MW in capacity, it would cost approximately USA $ 200 billion (@ $ 2 billion per 1000 MW as a rule of the thumb for the nuclear power plants), and approximately $ 100 billion for the establishment of additional facilities for reprocessing the spent fuel. Some additional amounts may be necessary for expansion of the facilities for fabrication of MOX fuel out of the weapons-grade plutonium stockpiled. (To this must be added the longer-term cost of the establishment of additional fuel-fabrication capacity for meeting the fuel needs of these reactors on an on-going basis. However this would be incurred only after a decade or so, when the nuclear reactors have been commissioned and after the present stockpile of weapons-grade fissile materials has been exhausted.)

These costs are certainly high, but to put them in perspective they have to be seen in the context of some other expenditure that were incurred for far more limited or impractical or even undesirable aims:

(a) Amounts spent ($ 25 billion and more) on fantastic schemes such as ‘Star Wars’ that had a far less realistic basis as compared to the proposed programme.

(b)Resigned acceptance by Governments all over the world of the fact of the drugs trade, whose annual turnover has been estimated by the INTERPOL Chief recently to be of the order of $400 billion, as a fait accompli without raising many eyebrows.

(c) The annual global expenditure on ‘defence’ is over $1000 billion. A 1% cut in, or tax on, these expenditures, on the lines of the ‘Tobin tax’, could release substantial funds for meeting the cost of the programme.

In addition, the cost of the proposed programme has to be set against the vast gap between the targets and goals set in multilateral forums in two important areas of concern, and the actual achievements in both these fields:

(a) As against the long accepted goal of the developed countries of setting aside 0.7% of their GNP for Overseas Development Aid (ODA), the figure realised at present, more than two decades later, is around half that figure only 0.3-0.4%. No more than a quarter of the balance, i.e. 0.1% of their GNP of about $19,000 billion (which would still be less than the target of 0.15% in respect of ODA for the LDCs), or $19 billion per year, would cover the bulk of the cost of the proposed programme.

(b) The Rio Summit Agenda 21 and the Framework Convention on Climate Change agreement on the goal of stabilisation of GHG concentrations in the atmosphere by

2000 AD notwithstanding. There is at present little hope of this target being realised in the absence of any concrete measures to that end having been agreed upon multilaterally. In particular, there has been no basic review of national energy policies in order to effect a shift away from reliance on (CO_2 producing) fossil fuels. This is mainly because of the non-availability of viable alternatives for energy generation.

Who pays?

The big question, of course, is: who would bear these costs? It goes without saying that they would have to be shared by all countries involved in the programme in proportion to the benefits they receive, on the basis of an agreed formula that could be negotiated multilaterally. If the programme is looked upon as a package of measures in the fields of international security, environment protection and pollution control and economic aid, which is really what it is conceptualised to be, it could provide a reasonable basis for arriving at a consensus on the matter.

As with most other major international cooperative ventures, the bulk of the expenses would, realistically speaking, fall to the share of the developed countries. At a time when 'aid fatigue' is only too evident, one may wonder what chance there is for an idea that requires the rich countries to spare additional resources for the developing world. But it would be a mistake to regard this proposal as just another 'aid' project. As mentioned above, it is a comprehensive package, with interlocking and far-reaching advantages in several fields for *all* nations, and is therefore quite unique as far as multilateral cooperation programmes go. There are good reasons why the developed countries should look upon the expenditures involved not as charity but as an investment in the future - their own as well as that of the rest of the world.

Incentives for the developed countries

First, their contributions would mainly be *in kind* and not in cash - as, for example, nuclear reactors and related equipment from those with an advanced nuclear industry; as fissile materials from the USA and Russia; as services of technical personnel from the CIS countries of the ex-Soviet Union, and so on. The *real* cost to the donor countries would therefore be less than the market value of the reactors, capital equipment, materials, fuel, human resources etc. These items have little alternative use in a situation of spare unutilised capacity in the industry. (Of course, no nuclear supplier would like to admit this publicly and they may well insist on quoting the 'market' price for the orders placed. Nevertheless the point is indisputable, and regardless of the extent to which it is conceded publicly, it cannot be denied that the real costs of the programme, to the donors, would not be as high as would appear from the financial figures.)

Second, when seen against the background of the FCCC, and the obligations of the developed countries under that Convention to take the lead in cutting down on their emissions, this would be a cost-effective way for them to fulfill the targets compared to national options in the donor countries -as, for example, by substituting existing fossil-fuel based energy generation in their countries by renewable or other sources.

Although the amounts in question seem to be very high, especially in comparison to the meager $ 2 billion or so that the Global Environment Fund (GEF) has been able to raise so far, this is in fact not so if consideration is given to the fact that much larger sums would be necessary for taking measures to curb GHG emissions at a later stage, once they have grown to higher levels, no matter where this be - i.e. whether in the developed or developing countries. The proposed programme would be a good example of the concept of 'joint implementation' advocated by some for minimising the trade-off between economic development and protection of the environment. The North and the South would be joining hands to achieve a reduction in the gross GHG emission levels globally on a cooperative basis, in keeping with the principle of common but differentiated responsibility, instead of blaming each other or seeking to shift the responsibility for (not) realising the targets set by the Convention. By paying for energy projects efficient in GHG emissions in the developing countries, the developed countries could perhaps claim to be implementing their commitments for containing GHG emissions under the FCCC. Considering that the developed countries seem to have no other plans to effect the reductions they are required to, this would be a major advance for them; one that may work out to be far cheaper than achieving the same reductions domestically.

The main objection to the idea would, however, be not economic but political — the risk of proliferation. That is the prime reason why promotion of nuclear power has never figured seriously on the international agenda so far, even though that is the stated purpose of the TAEA set up in 1954. Doubts may also be expressed about the capacity of developing countries to cope with the advanced nature of the technology (capacity to handle lethal nuclear wastes with a long life, stringent requirements of reactor safety and modem infra-structural facilities capable of mitigating the severe consequences in case of a radioactive accident etc.). But if the reactors are built, owned and operated by multi-national firms under ‘full-scope IAEA safeguards’ with the spent fuel taken back by them, as proposed, these apprehensions would be taken care of, for there would then be no transfer of technology to the recipient countries and therefore no risk of proliferation. This would also bypass the human resources constraint, of lack of technical expertise that most LDCs suffer from.

Possible objections from the developing countries

On their part, the developing countries might be averse to allowing the multi-national companies of the developed world to build nuclear power plants within their territories because the infrastructure required for the establishment of a nuclear power plant is very extensive and would entail far greater encroachments on their sovereignty than most foreign investment proposals usually do. They would also be apprehensive on account of the risk factor and would need to be assured that rigorous international safety standards would be observed through IAEA inspections and monitoring. Finally, they may not be enthusiastic about it because there would be almost no transfer of technology or buildup of human, technical or institutional capacities under this programme, something that is an obvious desideratum in all aid projects. In view of the very substantial economic gain of free supplies of environmentally clean energy, virtually as Manna from Heaven, however, they may be persuaded to consider the idea favourably.

The programme could be started on an experimental scale at first, at selected favourable sites, and extended gradually if found to be manageable. Hopefully, it could even become the forerunner of a larger international effort to switch to nuclear energy (to conserve fossil fuels for selective uses) in the interregnum until techno-economic breakthroughs in solar or fusion energy are realised.

Conclusion

The expectation that it might thus be possible to kill several birds with one stone leads logically to the idea of an internationally sponsored programme for establishment of nuclear power plants in the developing world. At a time when the intellectual climate the world over is such that the vision thing is at a total discount, in favour of crisp and cut-and-dried proposals that can pass muster at the hands of down-to-earth financial analysts and bankers, this may appear somewhat fanciful. But it is only an attempt to respond rationally to the existential challenges facing the world today, taking advantage of some of the opportunities afforded by the political changes in the world in the post-Cold War period. Indeed it would be ostrich-like not to do so simply because of the vast scale on which corrective action is called for. Leading statesmen, thinkers and economists have repeatedly cautioned against a mind-set that breeds collective indifference or apathy towards global problems in the name of pragmatism. We would do well to heed their advice.

VI
NUCLEAR TECHNOLOGY — SOME

BASIC QUESTIONS

Nuclear technology—image and reality

It is an unfortunate fact that there is a deep fear of nuclear technology entrenched in the mind of the lay-person in most countries of the world. In part this is due to genuine fears regarding the safety of nuclear plants and concerns about the disposal of nuclear wastes. In part it is also a consequence of equating all nuclear technology with nuclear weapons technology. These issues need to be addressed squarely and dispassionately, without any attempt to dismiss or paper over the doubts and dilemmas which haunt lay-persons. It must be admitted that the nuclear establishments in most countries have not been able to do a good job of attending to public fears in this regard, and allowed the anti-nuclear lobby to 'hijack' the issue of the safety of nuclear technology. It is partly a result of this failure that public opinion in many industrialised countries has turned hostile to nuclear energy, despite the tremendous promise it holds for addressing contemporary concerns.

We believe that a 'rejectionist' approach towards nuclear technology is unwarranted. By any objective standards, the situation is not as bad as made out by die-hard opponents of nuclear energy. Many of the fears are unfounded, arising more out of a communication gap, due in part to the complexity of the technical concepts underlying the issues, than any real basis. Others can be traced to the secret, often macabre, experiments conducted on human beings, invariably without their knowledge, in the early years of the Cold War both in the USA and in Russia that came to light subsequently. Nuclear technology as a whole has been tarred with the same brush as nuclear weapons — quite undeservedly.

Here we try to address, very briefly, some of the questions concerning nuclear technology.

Safety

One major fear, since the Three Mile Island and Chernobyl accidents, has been that widespread damage and contamination would be caused in the event of a nuclear accident in any of the power plants. Although it is undoubtedly true that the consequences of a nuclear accident, were there to be one, can spread far and wide, it has also been appreciated that the chances of its occurrence in the first place are extremely low; far, far lower than the risks associated with the use of many other technologies that are commonplace today. As the safe operation of hundreds of reactors the world over testifies, it is perfectly possible to control the operation of reactors sufficiently to run them safely. The accidents mentioned above are not typical of the track-record of the nuclear industry in open societies and systems. In the case of Chernobyl for example, it is well known that the main cause was the flaws in the design of those RBMK reactors, and the accident could easily have been avoided with more careful designing, and by following international safety norms.

By taking proper precautions, pursuing an open policy of public scrutiny and control over regulatory mechanisms and steering clear of irrational fears regarding misuse, it is definitely not beyond human ingenuity, in an age of the managerial revolution, to devise appropriate and effective checks against the risks that go with nuclear technology. That is, in fact, the case with every technology. Repudiating nuclear energy altogether can be no more an answer than giving up on modern transport systems because of the accident rates or pollution levels that afflict them or modern surgery because of the hazards and risks that go along with it.

Nuclear-waste disposal

Likewise, with respect to waste disposal, it is necessary to understand that while the practice regarding the disposal of reactor wastes has generally not been satisfactory so far, this is not because of the technology *per se*. Rather it is the result of a short-sighted *policy* in regard to waste management, followed for political reasons stemming from the antagonism of the Cold War era and from Big Power interests. The option of recycling the spent fuel — the most rational and effective way of dealing with the wastes — was precluded, a priori, on the rather flimsy ground that this would make plutonium too easily accessible to all, and sundry. As mentioned earlier, reprocessing of spent fuel is an environmentally sound way of handling radioactive wastes and, given that there is no other way of getting rid of these hazardous wastes, it was without question a retrograde step to restrict reprocessing of spent fuel. This necessitated its storage in 'temporary' facilities over indefinitely long periods; a practice that has given the technology a frightful image as a major and long term pollutant and threat. That epithet is merited by nuclear weapons and not nuclear technology as such, which has much to offer as an 'environmentally appropriate' advanced technology, if only its potential can be tapped fully. If the disposal of nuclear wastes is problematic, it is precisely, and only, because the obvious answer to this problem was foreclosed for political reasons. Lift this yoke from its neck and you have a first-rate answer to most contemporary dilemmas in the field of energy and environment.

Environmentally acceptable

The unprejudiced observer may well wonder why we do not make greater use of nuclear energy to meet our requirement of electrical power, when there is so much concern about depletion of the Earth's ozone layer and global warming and when renewable sources of energy are yet to prove commercially viable. Alone among the conventional sources of energy generation, nuclear power does not result in greenhouse gas emissions and therefore does not aggravate the greenhouse effect. (Hydel power too does not, but its potential is limited to locations where hydel resources exist. Moreover, it results in ecological damage and loss of biodiversity, except where 'run-of-the-river' schemes are possible, often in remote mountainous areas.) Solar and other renewable sources of energy hold great promise for the future but little prospect of offering economically viable technological alternatives immediately. Nuclear technology produces power for no environmental cost other than generation of radioactive spent fuel as a by-product, which, *if recycled as fuel after reprocessing*, will leave only small quantities of residue for long term disposal.

New and better reactor systems

It is no one's contention that the present generation of reactors are optimally safe and efficient. Improvements are always possible. For example, research is already underway on the design of 'failsafe' reactors in which the fission reaction would be shut down automatically in the event of any accident, and the heat-removal system is independent of operator action. Other ideas include systems which would burn away their waste within the reactor itself, and the increased use of radiation tolerant robotic systems for maintenance, operations and decommissioning of reactors. The suggested internationally sponsored programme would give an impetus to these and other concepts. The transformation in the political climate that a programme on such wide-ranging international cooperation can be expected to bring about should make it possible for national nuclear industries to pool their R&D resources - something that has so far not been possible even after the end of the Cold War. There is need, for instance, for pooling R&D efforts in plutonium recycling and in breeder-reactor technology, in which France, Japan, Germany, India and others have scored notable successes, and which the USA lags behind in. Concentration of R&D efforts under one umbrella should also make it easier to share state of the art technology, as, for example, Russian designs of miniaturised space reactors, safety features of the reactors of western countries etc., with all nations.

Disposal of plutonium

Above all, an internationally sponsored programme can make it possible to freely undertake the extraction of Pu (the main source of worry from the points of view of environmental pollution and proliferation), from nuclear waste for recycling into the reactors as fuel. With this the nuclear fuel cycle can thus be closed at the aggregate global level, and the main point of criticism, and one of the important factors that has come in the way of promotion of nuclear power, would be taken care of.

Is there an alternative?

In any case, one must also ask: is there an alternative? There are no other ideas worth the name for disposing of the highly enriched uranium or the weapons-grade plutonium and spent fuel. The only suggestions that are on the anvil are: shooting it off into space or burying it deep in the ocean floor! And even if it is continued to be stored as dead waste, as at present, the world would not be free of the risk of radioactive contamination for generations to come.

Likewise, there are not many options for generating energy without aggravating the greenhouse effect. As a result, today most countries have willy-nilly to turn a blind eye to the damage that they cause to the environment in the process of meeting their current energy needs. This is especially true of the developing world, which cannot even dream of stabilising its energy consumption at the current abysmally low levels per capita, by exploring ‘soft energy paths’, the way developed countries can.

Nuclear technology remains the best option, on balance, when all aspects are considered, for tackling the grim energy-environment scenario that the non-oil-rich developing world is faced with. It is undoubtedly a ‘dual-use’ technology par excellence, but this must not be allowed to cloud what it has to offer as an ‘environmentally appropriate’ advanced technology. The end of the Cold War provides favourable circumstances for reviewing some of the earlier constraints of international nuclear policy that had necessitated a restricted regime for the transfer of nuclear technology, and for revisiting the nuclear energy option. With the nuclear power industry in the doldrums in most of the leading industrialised countries, because of lack of demand due to adverse public opinion over the last decade and more, nuclear technology is at a crossroads today. A majority of the present stock of the world’s power reactors will approach the end of their operating life before the first decade of the next century. Viewed globally, it would mean the virtual end of the industry unless a new phase of reactor construction is launched between now and then. This would happen at a time when the world has few other options for generating energy without adding to GHG emissions and causing global warming. Major decisions affecting the future of nuclear energy are thus called for. An international conference on the lines of the earlier United Nations conference on the Promotion of International Cooperation in the Peaceful Uses of Nuclear Energy (UNPICPUNE) organised under the aegis of the UN for undertaking an overall policy review of all aspects of nuclear technology at the global level, would be timely at this juncture.

VII
SUMMARY AND RECOMMENDATIONS

The problem of fissile materials

The weapons-grade fissile materials - HEU and Pu - in the military inventories of the USA and Russia, and those being released as a result of the dismantlement of some of the nuclear weapons of the USA & Russia (and the much larger amounts that would be rendered surplus if the remainder of these weapons can likewise be agreed to be dismantled), provide an unprecedented opportunity for the developed and developing countries to join hands for meeting the twin challenges of global warming and sustainable development to their mutual advantage, with gains for international security in addition. Of course, this will require political will and a readiness to break out of the ideological mind-set of the Cold War era.

Although this HEU and Pu belongs to the USA and Russia, the quantities involved are much too large for the rest of the international community to remain unconcerned with their fate or remain an 'innocent bystander'. The entire amount of HEU under the safeguards system of the IAEA, on which there is much debate and discussion in the IAEA every year, is, in comparison, not even 1% of these stocks in magnitude, and far less sensitive in terms of useability for weapons purposes. Likewise in respect of Pu, where the proportions are a little higher but again highly skewed, with the weapons-grade Pu in these countries being more than the total Pu under safeguards even though the latter Pu is almost all not even separated from the spent fuel (i.e. unreprocessed and therefore not as dangerous).

These materials pose serious dangers to security and safety the world over due to the risks of theft and leakage. All nations therefore have a vital stake in ensuring that they are not continued to be stored in their present form, i.e. as weapons-grade fissile material, but dissipated away by every possible means in the shortest possible time, preferably no more than a decade. In this context we recommend that:

Recommendation 1: A UN-sponsored Conference, on the lines of the earlier UNPICPUNE, should be organised to 'brainstorm' dispassionately on how best to deal with the surplus weapons- grade fissile materials.

We offer the following specific recommendations that could perhaps be taken up at the proposed UN Conference along with other ideas and proposals

Recommendation 2: The HEU should be diluted drastically to fuel-grade (3%) LEU and the plutonium mixed with uranium to form mixed oxide (MOX) fuel immediately.

This would take care of the risk of their being used for making nuclear weapons as a result of theft by disaffected groups or otherwise. However, these materials should not be stored for long periods of time, even after dilution as above, because of the danger of radioactive contamination of the environment in the event of leakage due to accidents etc. and the high recurring expenditure involved in ensuring their physical security and safety. Therefore:

Recommendation 3: Every possible outlet for consuming the diluted LEU and the MOX as fuel in the existing reactors worldwide should be explored and made use of with a view to dissipating these huge stocks at the earliest.

Burying the fissile materials or the spent fuel in concrete shelters after vitrification or otherwise, as proposed by some, would be a most retrograde step. Apart from entailing considerable expenditure and continued vulnerability to risks of leakage over the very long term, it would mean forgoing the excellent opportunity, inherent in the present situation, of putting these materials, which are nothing but highly concentrated nuclear fuel, to gainful use (for generation of much needed energy).

Recommendation 4: The large quantities of spent fuel accumulated from the nuclear reactors world-wide should be reprocessed to extract Pu for fabrication into MOX fuel — as with the weapons-grade Pu released.

The belief in some quarters that Pu fuel cycles are inherently uneconomic is totally incorrect. Utilisation of the Pu extracted from the world stocks of spent fuel in nuclear reactors (as MOX fuel) would kill two birds with one stone — it would sharply reduce the volume of hazardous nuclear wastes all over the world and, at the same time, harness it for energy generation. In addition, this would also vastly enhance the chances of a world-wide switch away from fossil fuels. With the nuclear fuel cycle 'closed' at the aggregate (global) level, the main apprehension about nuclear technology and the main point of criticism that has come in the way of more widespread use of nuclear energy (despite the plus point of its not resulting in GHG emissions) — waste disposal and the risk of proliferation of nuclear weapons — would be taken care of. Nuclear energy would then be able to provide an alternative to fossil fuels right away, pending a breakthrough in the development of commercially viable renewable sources of energy.

An international programme for new nuclear energy

Recommendation 5: An internationally sponsored programme for the establishment of nuclear power plants in the developing countries (and facilities for reprocessing of spent fuel) on a fairly large scale should be promoted in order to absorb the surplus weapons-grade fissile materials within a reasonable period of time. Such a programme could be taken up by the IAEA, or any other international agency so mandated by the UN, and executed by a consortium of private firms from the advanced nuclear countries on a 'BOO' (Build, Own and Operate) basis, under strict international safeguards, in order to save time and to guarantee non-proliferation.

Since there would be no transfer of technology to the host countries, there would be absolutely no risk of proliferation. The power plants could be established in selected developing countries (those with relatively well developed infra-structure facilities and willing to host nuclear plants), that could then serve as regional centres for the transmission of electrical power to neighbouring, less developed, countries.

A series of logistic, legal and other questions would, of course, need to be resolved before any such programme can see the light of day. However, it should not be difficult to thrash out all such issues at the UN Conference proposed above.

R&D in nuclear technology

Recommendation 6: National R&D efforts should be pooled together to explore the possibility of developing new reactor systems, and finding newer and more efficient applications of nuclear power. The suggested internationally sponsored programme could coordinate and give impetus to these efforts.

The present generation of reactors are considered by none to be optimally safe or efficient. Improvements are always possible, and research is already underway on the design of 'fail-safe-' reactors (in which the fission reaction would be shut down automatically in the event of any accident). There is also the possibility of direct utilisation of the energy generated in the nuclear reactors in the form of heat for large-scale desalination and other energy intensive industrial processes (i.e. without first converting it into electrical energy as in most of the existing nuclear plants in the world). There is also the possibility of developing systems that utilise the HEU directly, without need for dilution, which would allow for a longer life for the fuel and greater safety of operation. Thus there are a number of areas in which research & development in nuclear technology could enhance the scope and efficiency of nuclear power.

Costs and benefits

Recommendation 7: The expenditures be shared by all countries participating in the programme on the basis of an agreed formula, with contributions in kind for the equipment from the developed countries, for the fuel (and technical personnel) from Russia and the CIS and for local expenditures from the host countries.

The cost of any such programme would naturally depend on the scale on which it is undertaken. In case it is decided to set up nuclear power plants sufficient in number for absorbing all the HEU within a decade or so (which is approximately also the time that will be required for construction of the plants), it would come to roughly $ 200 billion, spread over more than a decade. Establishment of reprocessing facilities adequate for clearing all the inventories of spent fuel in about a decade would cost another $100 billion. For this sum of $ 300 billion raised and spent multilaterally over a decade and more, there would be far-reaching gains, for both developed and developing countries, as follows:

(a) Enhanced international security through dissipation of all surplus fissile material, storage of which is posing a first rate problem from the security, safety (and environmental) points of view, in no more than a decade or so.

(b) Generation of several thousand MW-years of power in the developing countries, with multiplier effects in other sectors of their economies.

(c) Protection of the environment as a result of abatement of the trend of a rise in green-house gas (C02) emissions worldwide (a first ever), to the extent that the newly established nuclear power plants would substitute power generating capacity that would otherwise have, most likely been based on burning of CO2 emitting conventional fuels.

(d) Pollution control through drastic reduction in the amount of radioactive nuclear waste in the world, which is today a major international concern, as a result of extraction of Pu from the spent fuel and its conversion into fuel for the reactors — again a first ever.

(e) Stimulation of the economy of those developed countries where the nuclear industry suffers from over-capacity due to stagnation in demand, with attendant benefits of job creation and economic recovery.

The financial cost of the programme is undoubtedly high but then so are the gains. Not only are there substantial benefits, but at least two of the benefits — moderation of the green-house effect and good riddance to a lot of radioactive rubbish — cannot be had otherwise. Moreover, the cost has to be weighed against the costs of not taking a decision to consciously consume away the surplus fissile materials — the grave risks, for generations to come, of letting the dangerous weapons-grade fissile materials be around. A 'do-nothing' approach is simply not tenable in this situation, especially when the 'clean-up' costs, both sociopolitical as well as financial, in the event of an accident, are uncertain and likely to be prohibitively high.

Conclusion

Those who are fundamentally opposed to nuclear power need to recognise that the situation would be no less vexatious even if the proposed programme for the promotion of nuclear power is not undertaken. If the fissile materials and spent fuel are not consumed away as fuel, they would have to be stored, as at present, indefinitely, and this would be a bigger risk and threat for the environment (especially the Pu). In other words, it is not as if vetoing the suggestion for expansion of nuclear power would solve the problem of disposal of nuclear wastes and weapons- grade fissile materials. The question of what is to be done with the vast amounts of these materials would remain. Recycling alone can consume them away, but that requires a willingness to live with nuclear power on an on-going basis and accept the risks inherent in the operation of nuclear power plants, as is done in case of so many other technologies.

Given its immediate benefits for development as well as far- reaching environmental gains, the internationally sponsored programme would seem to be an appropriate project for being taken up under the 'joint implementation' concept advocated by some for avoiding a conflict or trade-off between the developing and developed countries. It could be viewed as a mechanism for resource transfers to the developing countries in payment of 'economic rent' due to them for use of their share of the atmospheric space by the developed countries, or as compensation under the 'polluter-pays' principle — which is well accepted in cases of local pollution but somehow not yet applied at the global level.

The political implications of such a vast and ambitious programme of international cooperation would be far-reaching, going well beyond the immediate economic or pollution control benefits. A new reality, matching the vision of the founding fathers of the UN of a cooperative world order, would be created by the transformation in the climate of international relations that would result from the demonstration of such wide-ranging cooperation. If it can be agreed upon in 1995, this would be an appropriate commemoration of the 50th anniversary year of the UN. The ‘community’ of nations has at some stage got to move from the existential to a normative world and evolve into a genuinely international, harmonious, community. We would truly, then, have had “atoms for peace”.