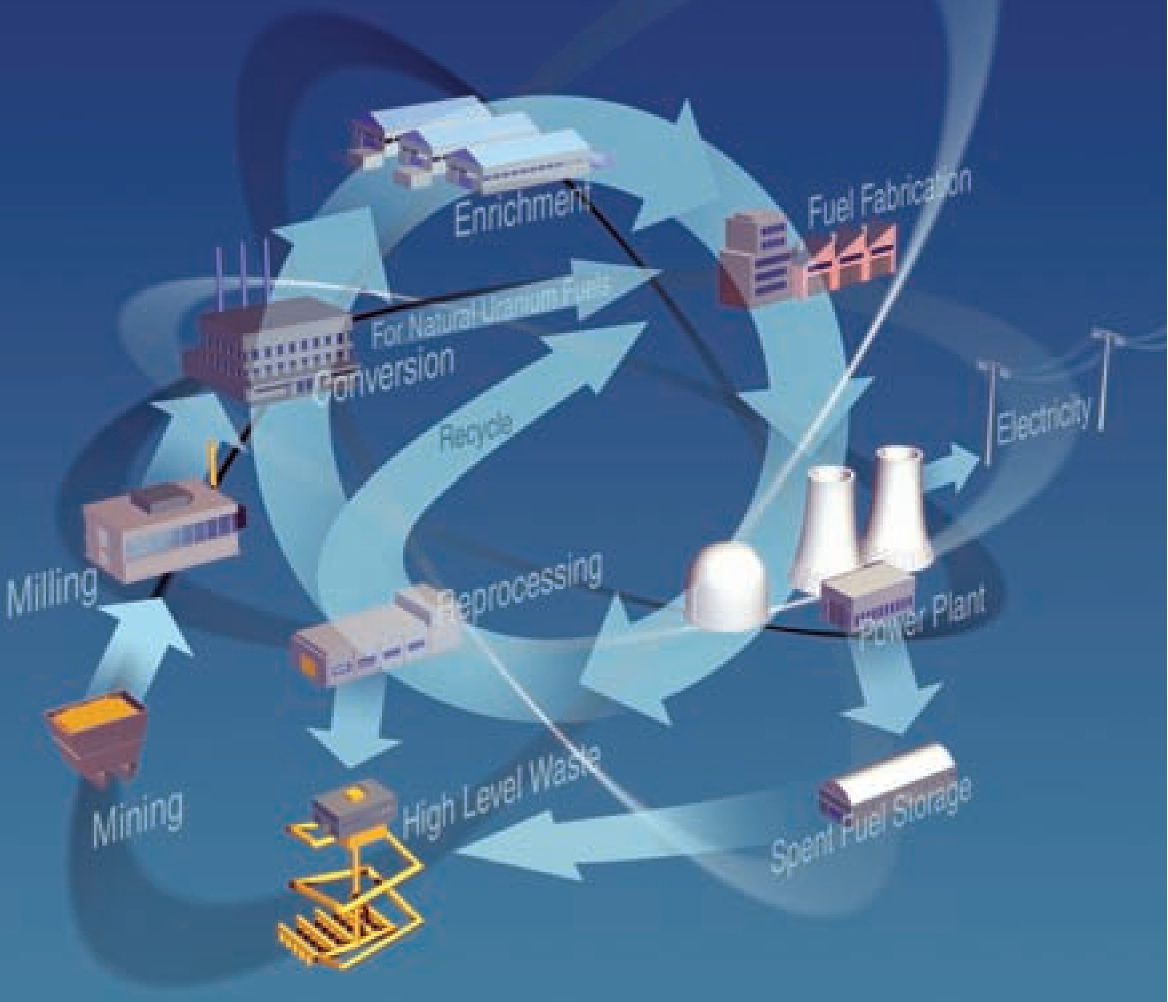
Multilateral Approaches to the Nuclear Fuel Cycle

Expert Group Report to the Director General of the IAEA



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EXPERT GROUP REPORT
TO THE DIRECTOR GENERAL
OF THE INTERNATIONAL ATOMIC ENERGY AGENCY

The report of the Expert Group was officially released on 22 February 2005 as an IAEA Information Circular (INFCIRC/640), and circulated for discussion among IAEA Member States, as well as others. This version of the Expert Group's report has been published by the IAEA for the benefit of a wider audience.

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INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

by Mohamed ElBaradei
Director General

In recent years the nuclear non-proliferation regime has come under increasing strain owing to the growth in both the supply of and demand for proliferation sensitive technology and the production and availability of nuclear materials. As a result, international discussions on this subject have emphasized the urgent need to strengthen the regime.

At the March 2004 meeting of the IAEA Board of Governors, I stated my intention to convene a group of experts to explore options and develop proposals for improved controls, including possible multilateral oversight arrangements of the nuclear fuel cycle. In my view, the work of such a group could be an important contribution in developing practical proposals to minimize the proliferation risks of sensitive portions of the nuclear fuel cycle, thus facilitating the continued use of nuclear energy for peaceful purposes.

In June 2004, I informed the Board of Governors that I had appointed an international expert group, chaired by Mr. Bruno Pellaud, former IAEA Deputy Director General and Head of the Department of Safeguards, to consider options for possible multilateral approaches to the nuclear fuel cycle. The terms of reference for the Expert Group were to:

- Identify and provide an analysis of issues and options relevant to multilateral approaches to the front and back ends of the nuclear fuel cycle;
- Provide an overview of the policy, legal, security, economic and technological incentives and disincentives for cooperation in multilateral arrangements for the front and back ends of the nuclear fuel cycle; and
- Provide a brief review of the historical and current experience in this area, and of the various analyses relating to multilateral fuel cycle arrangements relevant to the work of the Expert Group.

The Expert Group comprised individuals with practical experience in the nuclear field drawn from 26 States. The Group examined the nuclear fuel cycle and multinational approaches at meetings convened over a seven month period. Their report was released on 22 February 2005, and circulated for discussion among the IAEA's Member States, as well as others, as an IAEA Information Circular (INFCIRC/640).

I am pleased to present this report to a wider audience. In particular, I hope that it will increase awareness of this important subject and stimulate a wide ranging discussion of the issues that have been raised leading to practical proposals for the next steps.

EDITORIAL NOTE

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EXECUTIVE SUMMARY

1. The global nuclear non-proliferation regime has been successful in limiting, albeit not entirely preventing, the further spread of nuclear weapons. The vast majority of States have legally pledged to forego the manufacture and acquisition of nuclear weapons and have abided by that commitment. Nonetheless, the past few years have been a tumultuous and difficult period.

2. The decades long nuclear non-proliferation effort is under threat: from regional arms races; from actions by non-nuclear-weapon States (NNWS) that have been found to be in fundamental breach of, or in non-compliance with, their safeguards agreement, and which have not taken full corrective measures; from the incomplete manner in which export controls required by the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) have been applied; from burgeoning and alarmingly well organized nuclear supply networks; and from the increasing risk of acquisition of nuclear or other radioactive materials by terrorist and other non-State entities.

3. A different significant factor is that the civilian nuclear industry appears to be poised for worldwide expansion. Rapidly growing global demand for electricity, the uncertainty of supply and price of natural gas, soaring prices for oil, concerns about air pollution and the immense challenge of lowering greenhouse gas emissions, are all forcing a fresh look at nuclear power. As the technical and organizational foundations of nuclear safety improve, there is increasing confidence in the safety of nuclear power plants. In the light of existing, new and reawakened interest in many regions of the world, the prospect of new nuclear power stations on a large scale is therefore real. A greater number of States will consider developing their own fuel cycle facilities and nuclear know-how, and will seek assurances of supply in materials, services and technologies.

4. In response to the growing emphasis being placed on international cooperation to cope with nuclear non-proliferation and security concerns, the Director General of the IAEA, Mohamed ElBaradei, appointed in June 2004 an international group of experts (participating in their personal capacity) to consider possible multilateral approaches to the civilian nuclear fuel cycle.

The Vienna International Centre, home of the IAEA. The two buildings in the foreground comprise IAEA headquarters (photo courtesy D. Calma, IAEA).

5. The mandate of the Expert Group was threefold:

- To identify and provide an analysis of issues and options relevant to multilateral approaches to the front and back ends of the nuclear fuel cycle;
- To provide an overview of the policy, legal, security, economic, institutional and technological incentives and disincentives for cooperation in multilateral arrangements for the front and back ends of the nuclear fuel cycle; and
- To provide a brief review of the historical and current experiences and analyses relating to multilateral fuel cycle arrangements relevant to the work of the Expert Group.

6. Two primary deciding factors dominate all assessments of **multilateral nuclear approaches (MNAs),** namely **'assurance of non-proliferation'** and **'assurance of supply and services'**. Both are recognized overall objectives for governments and for the NPT community. In practice, each of these objectives can seldom be achieved fully on its own. History has shown that it is even more difficult to find an optimum arrangement that will satisfy both

objectives at the same time. As a matter of fact, multilateral approaches could be a way to satisfy both objectives.

7. The non-proliferation value of a multilateral arrangement is measured by the various proliferation risks associated with a nuclear facility, whether national or multilateral. These risks include the diversion of materials from an MNA (reduced through the presence of a multinational team), the theft of fissile materials, the diffusion of proscribed or sensitive technologies from MNAs to unauthorized entities, the development of clandestine parallel programmes and the breakout scenario. The latter refers to the case of the host country "breaking out", for example, by expelling multinational staff, withdrawing from the NPT (and thereby terminating its safeguards agreement) and operating the multilateral facility without international control.

8. The 'assurance of supply' value of a multilateral arrangement is measured by the associated incentives, such as: the guarantees provided by suppliers, governments and international organizations; the economic benefits that would be gained by countries participating in multilateral arrangements; and the better political and public acceptance of such nuclear projects. One of the most critical steps is to devise effective mechanisms for assurances of supply of material and services, which are commercially competitive, free of monopolies and free of political constraints. Effective assurances of supply would have to include back-up sources of supply in the event that an MNA supplier is unable to provide the required material or services.

OVERVIEW OF OPTIONS

9. Whether for uranium enrichment, spent fuel reprocessing, or spent fuel disposal and storage, *multilateral options* span the entire field between existing market mechanisms and complete co-ownership of fuel cycle facilities. The following pattern reflects this diversity:

- **Type I: Assurances of services not involving ownership of facilities:**

  (a) Suppliers provide additional assurances of supply;
  (b) International consortia of governments broaden the assurances;
  (c) IAEA related arrangements provide even broader assurances.

- **Type II: Conversion of existing national facilities to multinational facilities.**

- **Type III: Construction of new joint facilities.**

10. On the basis of this pattern, the Expert Group has reviewed the pros and cons associated with each type and option. Pros and cons were defined relative to a 'non-MNA choice', namely that of a national facility under current safeguards.

Uranium Enrichment

11. A healthy market exists at the front end of the fuel cycle. In the course of only two years, a nuclear power plant operating in Finland has bought uranium originating from mines in seven different countries. For example, conversion has been carried out in three different countries. Enrichment services have been bought from three different companies. Therefore, the legitimate objective of assurances of supply can be fulfilled to a large extent by the market. Nevertheless, this assessment may not be valid for all countries that have concerns about assurances of supply. Mechanisms or measures, under which existing suppliers or international consortia of governments or IAEA related arrangements provide assurances, may be appropriate in such cases.

12. At first, *suppliers* could provide additional assurances of supply. This would correspond to enrichment plant operators, individually or collectively, guaranteeing to provide enrichment capacity to a State whose government had in turn agreed to forego building its own capacity, but which then found itself denied service by its intended enrichment provider for unspecified reasons. The pros include the avoidance of know-how dissemination, the reliance on a well-functioning market and the ease of implementation. The cons refer, for example, to the cost of maintaining idle capacity on reserve and the lack of perceived diversity on the supplier side.

13. At a second level, international *consortia of governments* could step in, that is they would guarantee access to enrichment services, the suppliers being simply executive agents. The arrangement would be a kind of 'intergovernmental fuel bank', e.g. a contract under which a government would buy guaranteed capacity under specified circumstances. Different States might use different mechanisms. Most of the pros and cons are shared with the preceding case.

14. Then, there are *IAEA related arrangements*, a variation of the preceding option, with the IAEA acting as the anchor of the arrangement. Essentially,

the IAEA would function as a kind of 'guarantor' of supply to States in good standing and that were willing to accept the requisite conditionality (which would need to be defined, but would likely need to include foreswearing a parallel path to enrichment/reprocessing plus acceptance of the Additional Protocol (AP) for NNWS). The IAEA might either hold title to the material to be supplied or, more likely, act as facilitator, with back-up agreements between the IAEA and supplier countries to fulfil commitments made by the IAEA effectively on their behalf. In effect, the IAEA would be establishing a default mechanism, only to be activated in instances where a normal supply contract had broken down for reasons other than commercial reasons. The suggested pros and cons are therefore similar, with the added value of broad international assurances. Several questions can be raised with respect to the IAEA and its special status as an international organization subject to the control of its Member States. Any guarantee provided by the IAEA would in fact require approval by its Board of Governors.

15. Where an MNA would take the form of a joint facility, there are two ready made precedents: the Anglo–Dutch–German company Urenco and the French EURODIF. The experience of Urenco, with its commercial/industrial management on the one hand and the governmental Joint Committee on the other hand, has shown that the multinational concept can be made to work successfully. Under this model, strong oversight of technology and staffing, as well as effective safeguards and proper international division of expertise can reduce the risk of proliferation and even make a unilateral breakout extremely difficult. EURODIF also has a successful multinational record, enriching uranium only in one country, while providing enriched uranium to its co-financing international partners, hence restricting all proliferation risks, diversion, clandestine parallel programmes, breakouts and the spread of technology.

Reprocessing of Spent Nuclear Fuel

16. Taking into account present capacities to reprocess spent fuel for light water reactors and those under construction, there will be sufficient reprocessing capacity globally for all expected demands for plutonium recycled fuel over some two decades. Therefore, the objective of assurances of supply can be fulfilled to a large extent without new reprocessing facilities involving ownerships (i.e. Types II and III).

17. Currently, all reprocessing plants are essentially State owned. By the very nature of the nuclear business worldwide, any guarantee from a

supplier would have the implicit or explicit agreement of the corresponding government. As regards *IAEA brokered arrangements*, these could mean IAEA participation in the supervision of an international consortium for reprocessing services.

18. *Converting a national facility* to international ownership and management would involve the creation of a new international entity that would operate as a new competitor in the reprocessing market. The pros reflect the advantages of bringing together international expertise, while the cons include non-proliferation disadvantages related to the dissemination of know-how and to the return of the separated plutonium. Other cons deal with the fact that, of the existing facilities, all except two Japanese facilities are in nuclear weapon States (NWS) or in non-NPT States. In many of those cases, appropriate safeguards will have to be introduced if they had not been applied before.

19. As noted above, the *construction of new joint facilities* will not be needed for a long time. Therefore, a prerequisite for the construction of new facilities is the demand for additional reprocessing and for recycled plutonium fabrication. In the future, such reprocessing and fabrication would be carried out at the same location.

Spent Fuel Disposal

20. At present there is no international market for spent fuel disposal services, as all undertakings are strictly national. The final disposal of spent fuel is thus a candidate for multilateral approaches. It offers major economic and non-proliferation benefits, although it presents legal, political and public acceptance challenges in many countries. The IAEA should continue its efforts in that direction by working on the underlying factors, and by assuming political leadership to encourage such undertakings.

21. The final disposal of spent fuel (and radioactive waste as well) in shared repositories must be looked at as only one element of a broader strategy of parallel options. National solutions will remain a first priority in many countries. This is the only approach for States with many nuclear power plants in operation or operating in the past. For others with smaller civilian nuclear programmes, a dual track approach is needed in which both national and international solutions are pursued. Small countries should keep options open (national, regional or international), be it only to maintain the minimum national technical competence necessary to act in an international context.

Spent Fuel Storage

22. Storage facilities for spent fuel are in operation and are being built in several countries. There is no international market for services in this area, except for the readiness of the Russian Federation to receive Russian supplied fuel, and with a possible offer to do so for other spent fuel. The storage of spent fuel is also a candidate for multilateral approaches, primarily at the regional level. Storage of special nuclear materials in a few safe and secure facilities would enhance safeguards and physical protection. The IAEA should continue investigations in this field and encourage such undertakings. Various countries with state of the art storage facilities in operation should step forward and accept spent fuel from others for interim storage.

Combined Option: Fuel Leasing/Fuel Take-back

23. In the fuel leasing/fuel take-back model, the leasing State provides the fuel through an arrangement with its own nuclear fuel 'vendors'. At the time the government of the leasing State issues an export license to its fuel 'vendor' corporation to send fresh fuel to a client reactor, that government would also announce its plan for the management of that fuel once discharged. Without a specific spent fuel management scheme by the leasing State, the lease deal will of course not take place. The leased fuel, once removed from the reactor and cooled down, could either be returned to its country of origin which owns title to it, or, through an IAEA brokered deal, could be sent to a third party State or to a multinational or a regional fuel cycle centre located elsewhere for storage and ultimate disposal.

24. The weakness of the arrangement outlined above is the willingness, indeed the political capability, of the leasing State to take back the spent fuel it has provided under the lease contract. It could well be politically difficult for any State to accept spent fuel not coming from its own reactors (that is, reactors producing electricity for the direct benefit of its own citizens). Yet, to make any lease/take-back deal credible, an ironclad guarantee of spent fuel removal from the country where it was used must be provided. Otherwise, the entire arrangement is moot. In this respect, States with suitable disposal sites, and with grave concerns about proliferation risks, ought to be proactive in putting forward solutions. Of course, the commitment of client States to forego enrichment and reprocessing would make such undertakings politically more tolerable.

25. As an alternative, the IAEA could broker the creation of multinational or regional spent fuel storage facilities, where spent fuel owned by leasing States and burned elsewhere could be sent. The IAEA could thus become an active participant in regional spent fuel storage facilities, or third party spent fuel disposal schemes, thereby making lease/take-back fuel supply arrangements more credible propositions.

OVERARCHING ISSUES

26. Apart from the cross-cutting factors related to the implementation of MNAs, such as the technical, legal and safeguards aspects, there are a number of overarching issues, primarily of a broad political nature, which may have a bearing upon perceptions of the feasibility and desirability of MNAs. These issues may be decisive in any future endeavour to develop, assess and implement such approaches at the national and international levels.

Relevant Articles of the NPT

27. The NPT incorporates a political bargain with respect to peaceful uses and nuclear disarmament without which the treaty would neither have been adopted or would have received the widespread adherence it obtained afterwards. The promise by all States Parties to cooperate in the further development of nuclear energy and for the NWS to work towards disarmament provided the basis for NNWS to abstain from acquiring nuclear weapons.

28. Cooperation in the peaceful uses of nuclear energy, which had earlier provided the basis for the foundation of the IAEA, is embodied in Article IV, which stipulates that nothing shall be interpreted as affecting the "inalienable right of all Parties to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II" (that specify the non-proliferation objectives of the treaty). Furthermore, that same article specifies that all Parties to the NPT shall undertake to "facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy", and moreover to "cooperate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes…" Article IV was specifically crafted to preclude any attempt to

reinterpret the NPT so as to inhibit a country's right to nuclear technologies — so long as the technology is used for peaceful purposes.

29. The NNWS have expressed dissatisfaction about what they increasingly view as a growing imbalance in the NPT: that, through the imposition of restrictions on the supply of materials and equipment of the nuclear fuel cycle by the NWS and the advanced industrial NNWS, those States have backed away from their original guarantee to facilitate the fullest possible exchange referred to in Article IV and to assist all NNWS in the development of the applications of nuclear energy. There are also concerns that additional constraints on Article IV might be imposed,

30. Article VI of the Treaty obliges NWS Parties "to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament." Many NNWS deem the implementation of Article VI of the NPT by NWS as unsatisfactory, like the non-entry into force of the CTBT and the stalemate in the negotiations on a verifiable Fissile Material (Cutoff) Treaty (FM(C)T). Such concerns have fostered a conviction among many NNWS that the NPT bargain is being corroded.

Safeguards and Export Controls

31. Some States have argued that, if the objective of MNAs is merely to strengthen the nuclear non-proliferation regime then, rather than focusing on MNAs, it may be better to concentrate instead on the existing elements of the regime itself, for example, by seeking the universality of the Additional Protocol (AP) to IAEA safeguards agreements and by the universalization of safeguards agreements and multilateral export controls.

32. The risks involved in the spread of sensitive nuclear technologies should primarily be addressed by an efficient and cost effective safeguards system. The IAEA and regional safeguards systems have done an outstanding job in these matters. Safeguards, rationally and well applied, have been the most efficient way to detect and deter further proliferation and to provide States Parties with an opportunity to assure others that they are in conformity with their safeguards commitments. Of course, advances in technologies require safeguards to be strengthened and updated, while protecting commercial, technological and industrial secrets. The adoption of an AP, and its judicious implementation based on State level analysis, are essential steps against further nuclear proliferation. The AP has proved successful in providing additional, necessary and effective verification tools,

while protecting legitimate national interests in terms of security and confidentiality. Sustained application of an AP in a State can provide credible assurance of the absence of undeclared materials and activities in that State. Together with a comprehensive safeguards agreement, the AP should become the de facto safeguards standard.

33. The above notwithstanding, the IAEA should endeavour to further strengthen the implementation of safeguards. For example, it should revisit three facets of its verification system:

(a) The technical annexes of the AP, which should be regularly updated to reflect the continuing development of nuclear techniques and technologies.
(b) The implementation of the AP, which requires adequate resources and a firm commitment to apply it decisively. It should be recalled that the Model Additional Protocol commits the IAEA not to apply the Protocol in a mechanistic or systematic way. Therefore, the IAEA should allocate its resources for problematic areas rather than for States using the largest amounts of nuclear material.
(c) The enforcement mechanisms in the case of a fundamental breach of, or non-compliance with, the safeguards agreement. Are these mechanisms progressive enough to act as an effective deterrent? Further consideration should be given by the IAEA to appropriate measures to handle various degrees of violations.

34. Export guidelines and their implementation are an important line of defence in preventing proliferation. Recent events have shown that criminal networks can find ways around existing controls to supply clandestine activities. Yet, one should remember that all States party to the NPT are obliged, pursuant to Article III.2 thereof, to implement export controls. This obligation was reinforced by United Nations Security Council Resolution 1540 (2004), that requires all States to enact and implement export controls to prevent the spread of weapons of mass destruction and related materials to non-State actors. The participation in the development and implementation of export controls should be broadened, and multilaterally agreed export controls should be developed in a transparent manner, engaging all States.

35. In fact, the primary technical barriers against proliferation remain the effective and universal implementation of IAEA safeguards under comprehensive safeguards agreements and additional protocols, and effective export controls. Both must be as strong as possible on their own merits. MNAs will

be complementary mechanisms for strengthening the existing non-proliferation regime.

Voluntary Participation in MNAs Versus a Binding Norm

36. The present legal framework does not oblige countries to participate in MNAs, as the political environment makes it unlikely that such a norm can be established any time soon. Establishing MNAs resting on *voluntary* participation is thus the more promising way to proceed. In a voluntary arrangement covering assurances of supply, recipient countries would, at least for the duration of the respective supply contract, renounce the construction and operation of sensitive fuel cycle facilities and accept safeguards of the highest current standards including comprehensive safeguards and the Additional Protocol. Where the demarcation line between permitted R&D activities and renounced development and construction activities has to be drawn is a matter for further consideration. In voluntary MNAs involving facilities, the participating countries would presumably commit to carry out the related activities solely under the common MNA framework.

37. In reality, countries will enter into such multilateral arrangements according to the economic and political incentives and disincentives offered by these arrangements. A political environment of mutual trust and consensus among the partners — based on full compliance with the agreed nuclear non-proliferation obligations of the partners — will be necessary for the successful negotiation, creation and operation of an MNA.

38. Beyond this, a new *binding* international norm stipulating that sensitive fuel cycle activities are to be conducted exclusively in the context of MNAs and no longer as a national undertaking would amount to a change in the scope of Article IV of the NPT. The wording and negotiating history of this article emphasize the right of each party in good standing to choose its national fuel cycle on the basis of its sovereign consideration. This right is not independent of the faithful abiding by the undertakings under Articles I and II. But if this condition is met, no legal barrier stands in the way of each State Party to pursue all fuel cycle activities on a national basis. Waiving this right would thus change the 'bargain' of the NPT.

39. Such a fundamental change is not impossible if the parties were to agree on it within a broader negotiating framework. For NNWS, such a new bargain can probably only be realized through universal principles applying to all States and after additional steps by the NWS regarding nuclear

disarmament. In addition, a verifiable FM(C)T might also be one of the preconditions for binding multilateral obligations; such a treaty would terminate the right of any participating NWS and non-NPT parties to run reprocessing and enrichment facilities for nuclear explosive purposes and it would bring them to the same level with regard to such activities as NNWS. The new restrictions would apply to all States and facilities related to the technologies involved, without exception. At that time, multilateral arrangements could become a universal, binding principle. The question may also be raised as to what might be the conditions required by NWS and non-NPT States to commit to binding MNAs involving them.

Nuclear Weapon States and non-NPT States

40. Weapons usable material (stocks and flows) and sensitive facilities that are capable of producing such material are located predominantly in the NWS and non-NPT States. The concerns raised previously for MNAs in NNWS do not all apply when an MNA would involve NWS or non-NPT States. Yet, one of the questions here relates to the possibility that the nuclear material produced in an MNA could contribute to such a State's nuclear non-peaceful programme. This shows again the relevance of the FM(C)T.

41. The feasibility of bringing NWS and non-NPT States into MNAs should indeed be considered at an early stage. As long as MNAs remain voluntary, nothing would preclude such States from participating in an MNA. In fact, France (in connection with the EURODIF arrangement) and the United Kingdom (in connection with Urenco) are examples of such participation. In transforming existing civilian facilities into MNAs subject to safeguards and security requirements, such States would demonstrate their support for non-proliferation and for peaceful international nuclear collaboration.

Enforcement

42. Eventually, the success of all efforts to improve the nuclear non-proliferation regime depends upon the effectiveness of compliance and enforcement mechanisms. Enforcement measures in case of non-compliance can be partially improved by the legal provisions of MNAs, which will carefully specify a definition of what constitutes a violation, by whom such violations will be ruled on, and enforcement measures that could be directly applied by the partners in addition to broader political tools.

43. Nevertheless, enhanced safeguards, MNAs, or new undertakings by States will not serve their full purpose if the international community does not respond with determination to serious cases of non-compliance, be it diversion, clandestine activities or breakout. Responses are needed at four levels, depending upon the specific case: the MNA partners of the non-compliant State; the IAEA; the States Parties to the NPT; and the UN Security Council. Where these do not currently exist, appropriate procedures and measures must be available and must be made use of at all four levels to cope with breaches and non-compliance instances in order to unequivocally make clear that States violating treaties and arrangements should not be permitted to do so unimpeded.

MULTILATERAL NUCLEAR APPROACHES: THE FUTURE

44. Past initiatives for multilateral nuclear cooperation did not result in any tangible results. Proliferation concerns were perceived as not being serious enough. Economic incentives were seldom strong enough. Concerns about assurances of supply were paramount. National pride also played a role, alongside expectations about the technological and economic spin-offs to be derived from nuclear activities. Many of those considerations may still be pertinent. However, the result of balancing those considerations today, in the face of a latent multiplication of nuclear facilities over the next decades and the possible increase in proliferation dangers may well produce a political environment more conducive to MNAs in the 21st century.

45. The potential benefits of MNAs for the non-proliferation regime are both symbolic and practical. As a confidence building measure, multilateral approaches can provide enhanced assurance to the partners and to the international community that the most sensitive parts of the civilian nuclear fuel cycle are less vulnerable to misuse for weapon purposes. Joint facilities with multinational staff put all MNA participants under a greater degree of scrutiny from peers and partners and may also constitute an obstacle against a breakout by the host partner. They also reduce the number of sites where sensitive facilities are operated, thereby curbing proliferation risks and diminishing the number of locations subject to the potential theft of sensitive material. Moreover, these approaches can even help in creating better acceptance for the continued use of nuclear power and for nuclear applications, and enhance the prospects for the safe and environmentally sound storage and disposal of spent nuclear fuel and radioactive waste.

46. As far as assurances of supply are concerned, multilateral approaches could also provide the benefits of cost effectiveness and economies of scale for whole regions, for smaller countries or for those with limited resources. Similar benefits have been derived in the context of other technology sectors, such as aviation and aerospace. However, the case to be made in favour of MNAs is not entirely straightforward. States with differing levels of technology, different degrees of institutionalization, economic development and resources and competing political considerations may not all reach the same conclusions as to the benefits, convenience and desirability of MNAs. Some might argue that multilateral approaches point to the loss or limitation of State sovereignty and independent ownership and control of a key technology sector, leaving unfairly the commercial benefits of these technologies to just a few countries. Others might argue that multilateral approaches could lead to further dissemination of, or loss of control over, sensitive nuclear technologies, and result in higher proliferation risks.

47. In summary, the Expert Group on Multilateral Approaches to the Nuclear Fuel Cycle has reviewed the various aspects of the fuel cycle, identified a number of options for MNAs deserving further consideration and noted a number of pros and cons for each of the options. It is hoped that the report of the Expert Group will serve as a building block, or as a milestone. It is not intended to mark the end of the road. MNAs offer a potentially useful contribution to meeting prevailing concerns about assurances of supply and non-proliferation.

48. The Expert Group recommends that steps be taken to strengthen overall controls on the nuclear fuel cycle and the transfer of technology, including safeguards and export controls: the former by promoting universal adherence to APs, the latter through a more stringent implementation of guidelines and universal participation in their development.

49. In order to maintain momentum, the Expert Group recommends that attention be given — by IAEA Member States, by the IAEA itself, by the nuclear industry and by other nuclear organizations — to multilateral nuclear approaches in general and to the five approaches suggested below.

FIVE SUGGESTED APPROACHES

50. The objective of increasing non-proliferation assurances associated with the civilian nuclear fuel cycle, while preserving assurances of supply and services around the world, could be achieved through a set of gradually introduced MNAs:

(1) Reinforcing **existing commercial market mechanisms** on a case by case basis through long term contracts and transparent suppliers' arrangements with government backing. Examples would be fuel leasing and fuel take-back offers, commercial offers to store and dispose of spent fuel, as well as commercial fuel banks.

(2) Developing and implementing **international supply guarantees** with IAEA participation. Different models should be investigated, notably with the **IAEA as a guarantor** of service supplies, e.g. as administrator of a fuel bank.

(3) Promoting voluntary conversion of **existing facilities to MNAs**, and pursuing them as **confidence building measures**, with the participation of NPT NNWS and NWS, and non-NPT States.

(4) Creating, through voluntary agreements and contracts, **multinational, and in particular regional, MNAs for new facilities** based on joint ownership, drawing rights or co-management for front and back end nuclear facilities, such as uranium enrichment, fuel reprocessing, disposal and storage of spent fuel (and combinations thereof). Integrated nuclear power parks would also serve this objective.

(5) The scenario of a further expansion of nuclear energy around the world might call for the development of a **nuclear fuel cycle with stronger multilateral arrangements** — by region or by continent — **and for broader cooperation**, involving the IAEA and the international community.

BLANK

1. PREAMBLE

BACKGROUND

1. In his statement to the IAEA General Conference in September 2003, the Director General observed that international cooperation in the context of the design and operation of the nuclear fuel cycle was an important issue that had been discussed over the years, but which, in his view, now merited serious consideration as part of the global effort to cope with increasing nuclear non-proliferation and security challenges. He stated that such consideration should include an evaluation of the merits of limiting the use of weapon-usable material (HEU and plutonium) in civilian nuclear programmes, by permitting it only under multilateral control and that any exploration of this kind had to be accompanied by appropriate rules of transparency, control and, above all, assurance of supply of nuclear fuel cycle services. He emphasized that strengthened control of weapon-usable material was key to efforts to strengthen nuclear non-proliferation and to enhance international security. These proposals were refined and reiterated in his October 2003 article published in *The Economist*.[1]

2. The Director General also referred to the need to consider the merits of multinational approaches to the management and disposal of spent nuclear fuel and radioactive waste. As he pointed out, not all countries have the appropriate conditions for geological disposal — and, for many countries with small nuclear programmes for electricity generation or for research, the financial and human resource investments required for research, construction and operation of a geological disposal facility were not available. Considerable economic, safety, security and non-proliferation advantages may therefore accrue from international cooperation on the construction and operation of international nuclear spent fuel and waste repositories. In his statement of September 2003, the Director General also indicated that the merits and feasibility of these and other approaches to the design and management of the nuclear fuel cycle should be given in depth consideration.

3. In his statement to the IAEA Board of Governors in March 2004, the Director General referred to the wide dissemination of the most proliferation sensitive parts of the nuclear fuel cycle — the production of new fuel, the

[1] ELBARADEI, M., Towards a safer world, *The Economist* (16 October 2003).

processing of weapon-usable material and the disposal of spent fuel — as the possible "Achilles' heel" of the nuclear non-proliferation regime, and to the importance of tightening control over such operations. He indicated that this could be done by bringing such parts of the nuclear fuel cycle under some form of multilateral control, with appropriate checks and balances to preserve commercial competitiveness, to control the proliferation of sensitive information and to ensure the supply of fuel cycle services for peaceful applications. The Director General informed the Board that he would appoint an independent group of experts to examine the feasibility of moving forward with such measures.

4. In June 2004, the Director General informed the Board of Governors that he had appointed an international expert group, chaired by Bruno Pellaud, former IAEA Deputy Director General and Head of the Department of Safeguards, to consider options for possible multilateral approaches to the front and back ends of the nuclear fuel cycle (i.e. multilateral nuclear approaches, or MNAs).

5. The IAEA serves as the global focal point for nuclear cooperation and is tasked with a dual objective: "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world" and to "ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose."[2]

MANDATE

6. The mandate of the Expert Group was threefold:

- To identify and provide an analysis of issues and options relevant to multilateral approaches to the front and back ends of the nuclear fuel cycle;
- To provide an overview of the policy, legal, security, economic, institutional and technological incentives and disincentives for cooperation in multilateral arrangements for the front and back ends of the nuclear fuel cycle; and

[2] IAEA Statute, Article II, IAEA, Vienna (1989).

- To provide a brief review of the historical and current experiences and analyses relating to multilateral fuel cycle arrangements relevant to the work of the Expert Group.

7. The Director General, in his invitation to the experts, stated that he expected that this work may result in practical proposals which, if implemented, could provide enhanced assurance to the international community that sensitive portions of the nuclear fuel cycle are less vulnerable to misuse for proliferation purposes and thereby facilitate the continued uses of nuclear energy for peaceful purposes.

8. Speaking on the occasion of the first meeting of the Expert Group, the Director General, in elaborating on the Group's mandate, recommended that it address the issue in all of its various facets, and in particular to assess the potential for a positive impact on international security. He requested the Group to take into account the perceptions and expectations of all interested stakeholders and stressed that, to be successful, new approaches must go beyond the outright denial of technology. The Director General noted the importance of examining multilateral options with respect to both the front and back ends of the civilian fuel cycle, noting that any solution must be inclusive and without reference to the status of particular countries under the NPT. He asked the Group not to confine itself to finding "one size fits all approaches" and cautioned that what works in one region may not be the most ideal approach in another. He also agreed that the concept of MNAs could be placed in the broader context of the nuclear non-proliferation regime as a whole, including the NPT, a verifiable FM(C)T and other relevant agreements.

Chairman of the Expert Group, Mr. B. Pellaud (left), with the Director General of the IAEA, Mr. M. ElBaradei (right) (photo courtesy D. Calma, IAEA).

9. The Expert Group held a series of four one-week meetings between August 2004 and February 2005 at IAEA headquarters in Vienna. The Group consisted of individuals, participating in their personal capacity, selected by the Director General to represent a broad spectrum of experience and nationalities, all of whom had been associated with the nuclear field in one capacity or another for many years. A list of the Expert Group members is given in Annex 2 of this report. The Group was assisted in its efforts by Messrs. Lawrence Scheinman and Wilhelm Gmelin as advisors, as well as by a number of current and former staff members of the IAEA and external experts, who are also identified in Annex 2.

10. Although the Expert Group agreed to forward its report to the Director General, it is important to note that the report does not necessarily reflect agreement by all of the experts on the desirability or feasibility of MNAs, or on all of the options. Nor does it reflect a consensus assessment of their respective value. It is intended only to present possible options for MNAs and to reflect on the range of factors that could influence the consideration of those options.

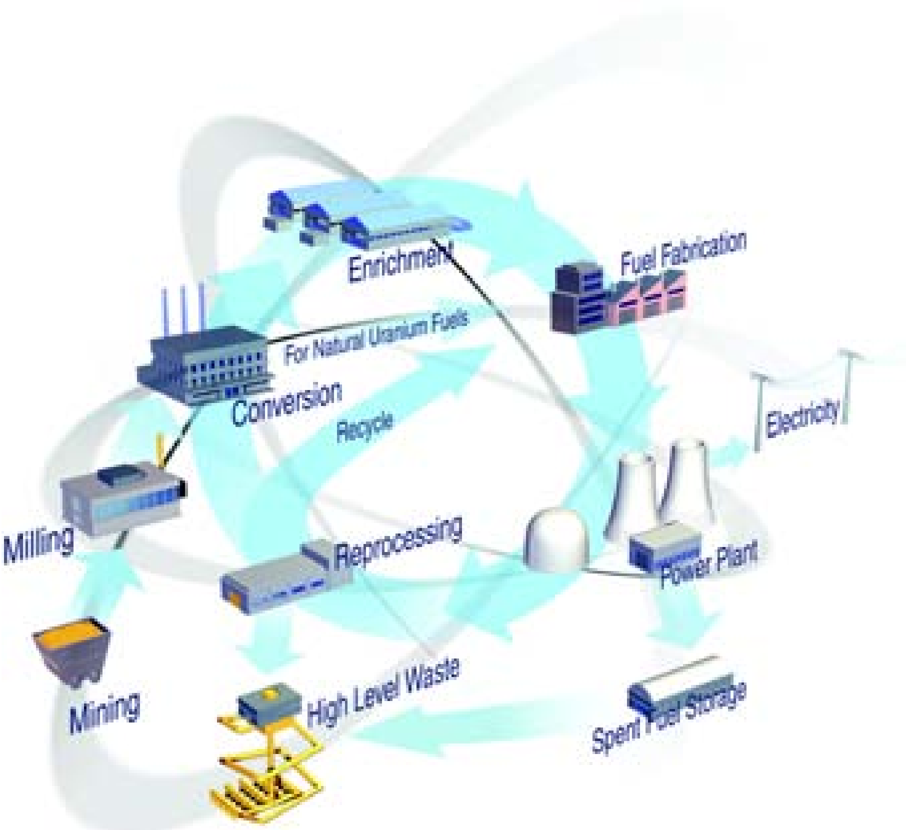
PRELIMINARY CONSIDERATIONS

11. At the outset of its deliberations, the members of the Expert Group expressed the collective expectation that nuclear energy will continue to play a significant role in supplying the world with energy, and that given the dual nature of nuclear technology, reliable and effective existing and new multilateral arrangements are necessary to prevent the further proliferation of nuclear weapons. The Group felt therefore that in fulfilling its mandate, its purpose was to assess MNAs in the framework of a two pronged objective: strengthening the international nuclear non-proliferation regime while securing the peaceful uses of nuclear energy.

12. Beyond long standing issues such as universality, the nuclear non-proliferation debate has been driven by new challenges to the existing non-proliferation regime, inter alia, the discovery of undeclared nuclear material and activities in certain NPT NNWS; the existence of clandestine supply networks for the acquisition of nuclear technology; and the risk of "breakout" from the NPT by States within the regime. Several proposals have been put forward with a view to ensuring that the nuclear non-proliferation regime maintains its authority, effectiveness and credibility in the face of these very real challenges. One of these proposals calls for the denial of sensitive

technology to NNWS not already possessing such facilities. This has been seen by many as inconsistent with the letter and spirit of Article IV of the NPT. There is a consistent opposition by many NNWS to accept additional restrictions on their development of peaceful nuclear technology without equivalent progress on disarmament. Other proposals have focused on the strengthening and effective application of the IAEA's safeguards system. Another proposal is for multilateral approaches to the operation of those parts of the nuclear fuel cycle considered to be of the greatest sensitivity from the point of view of proliferation risk. It is this latter proposal that the Expert Group was asked to consider.

13. First, a word about terminology. In the view of the Expert Group, a distinction should be made between the words 'multilateral' (the broadest and most flexible term, referring simply to the participation of more than two actors), 'multinational' (implying several actors from different States),



Schematic drawing of the nuclear fuel cycle.

'regional' (several actors from neighbouring States) and 'international' (actors from different States and/or international organizations, such as the IAEA). The Group has been asked to address the broadest possible options, and has thus explored all multilateral options, whether multinational, regional or international.

14. In addition, it was necessary to define what the Expert Group considered to be those parts of the nuclear fuel cycle of the greatest sensitivity from the point of view of proliferation risk. As can be seen from the structure of the report, the Group decided to address *uranium enrichment, reprocessing* and *spent fuel disposal and storage*.

15. In fulfilment of its mandate, the Expert Group decided to address three interrelated elements:

(a) **Current and historical experiences with MNAs**: What has already been tried in this regard? How successfully? Sections 2 and 3 provide the background on the mandate of the Expert Group and on the political and historical contexts of MNAs. The Group benefited from accumulated experience with existing successful multilateral solutions, particularly in Europe. The Group took advantage of work previously carried out under the auspices of the IAEA, as well as in other forums. In addition, there is a wealth of practical experience with multilateral approaches not only in the nuclear field, but in other fields of technology, such as aviation and space, to name only two.

(b) **Factors, options, and incentives and disincentives**: Sections 4 and 5 address, collectively and individually: policy, legal, security, economic and technological factors relevant to MNAs in connection with the four sectors of the nuclear fuel cycle identified in paragraph 14. Section 4 discusses cross-cutting factors. Section 5 reflects the Expert Group's analysis of the factors specific to, and possible options associated with, each of those sectors and identifies the corresponding benefits and disadvantages (pros and cons) of the various options.

(c) **Overarching considerations and recommendations**: Section 6 addresses overarching issues, primarily of a broad political nature, that may affect perceptions as to the feasibility and desirability of MNAs. Section 7 reflects on the conclusions of the Expert Group and offers recommendations on possible ways forward with MNAs.

16. Drawing on historical experience with MNAs, borrowing materials and concepts from past and current examples, and aware of the current political

context, the Group hopes to have shed some light on multilateral cooperation and have identified a number of possible options and approaches that could serve the nuclear community in the years to come in the search for a strong nuclear fuel cycle.

2. CURRENT POLITICAL CONTEXT

17. The global nuclear non-proliferation regime has been successful in limiting, albeit not entirely preventing, the further spread of nuclear weapons. The vast majority of States have legally pledged to forego the manufacture and acquisition of nuclear weapons and have abided by that commitment. Nevertheless, the past few years have been a tumultuous and difficult period, during which new challenges to the international non-proliferation system have surfaced.

18. The decades long nuclear non-proliferation effort is under threat: from regional arms races; from fundamental breaches of, or non-compliance with, safeguards agreements, without fully corrective action; from the incomplete manner in which export controls required by the NPT have been applied; from burgeoning and alarmingly well-organised nuclear supply networks; and from the increasing risk of acquisition of nuclear or other radioactive materials by terrorist and other non-State entities.

19. An emerging new concern is that of a possible "breakout" from the NPT, as exemplified by the actions of the Democratic People's Republic of Korea (DPRK). The postulated scenario is that an NNWS acquires sensitive elements of a nuclear fuel cycle — uranium enrichment and/or plutonium separation — ostensibly for peaceful purposes as provided for under the NPT, but then withdraws from the Treaty giving the required three months notice and subsequently is free to utilize its nuclear capability for developing nuclear weapons. The most recent instance of such an unwelcome development is the DPRK — which was determined to be in "further non-compliance" with its NPT safeguards agreement by the IAEA Board of Governors and then announced its withdrawal from the NPT. To date, this announcement has not incurred any action by the UN Security Council. Recently, the DPRK has again claimed that it possesses nuclear weapons. While most of the DPRK's nuclear material and infrastructure was acquired prior to its accession to the NPT and entry into force of its NPT safeguards agreement, the international community: finds the withdrawal unacceptable; in breach of good faith in treaty law; that the DPRK has announced its departure from the NPT: remains in non-compliance with its NPT safeguards agreement: may have been involved in the clandestine nuclear supply networks; and may be developing nuclear weapons. Reversal of this 'DPRK nuclear crisis' and the prevention of any similar scenario remains a high priority for the international community.

Ohi nuclear power plant, Japan (photo courtesy Kansai Electric Power Company).

20. Furthermore, many NNWS have long voiced concerns that the five NPT NWS are not making sufficient progress in fulfilling their nuclear disarmament commitments under the NPT. While some progress has been made, shortfalls continue to draw sharp criticism from many NNWS, which cite them as a major disincentive to support further non-proliferation initiatives that impact upon the NNWS. The same applies to the continuing delay in the initiation of negotiations on a verifiable FM(C)T, and in the entry into force of the CTBT — two measures that have been on the global nuclear non-proliferation and disarmament agenda for decades.

21. As stated by the IAEA Director General in his speech at the Carnegie Conference in June 2004, "any new adjustment to the [nuclear non-proliferation and disarmament] regime must include" the non-NPT States.

22. Despite these challenges, there have been positive developments. Membership in the NPT now stands at 189 countries (including the DPRK). Supplier countries now seek to exercise greater vigilance in their export controls. Meanwhile, in response to the IAEA's uncovering of Iraq's undeclared nuclear-weapon programme in the early 1990s, the international community moved decisively to strengthen the IAEA's safeguards system,

and to adopt the Model Additional Protocol (INFCIRC/540 (Corr.)) as a standard feature of the IAEA safeguards system. The Model Additional Protocol provides the Agency with more information on nuclear activities and future plans, and with more verification tools including, inter alia, extensive physical access to all sites and places where nuclear material is located as well to nuclear activities not involving nuclear material in order to provide credible assurance of the absence of undeclared nuclear material and activities. The IAEA uses more advanced equipment for the verification of nuclear material, including unattended data transmission, and is more sophisticated, alert and responsive in assessing a State's nuclear activities. These new arrangements are already having a positive impact on the level of confidence in IAEA safeguards, and have led to proposals to make the AP a norm under the NPT. Efforts to create additional treaty based nuclear weapon free zones, incorporating IAEA safeguards for verification, are another positive signal.

23. International collaboration between the Russian Federation and the USA in the Megatons to Megawatts programme[3] has resulted in large quantities of HEU released from dismantled Russian warheads being downblended into LEU for civilian use. In addition, a significant portion of US supplied HEU research reactor fuel has now been recovered under US take-back programmes. Similar actions are now also being taken with respect to Russian supplied HEU fuel. United Nations Security Council resolution 1540 (2004) was adopted to prevent access to materials for nuclear and other weapons of mass destruction by terrorist groups and non-State actors, and it has made it mandatory for all States to implement appropriate national control systems to secure such material.

24. A different significant factor is that the civilian nuclear industry appears to be poised for worldwide expansion. Rapidly growing global demand for electricity, the uncertainty of supply and the price of natural gas, soaring prices for oil, concerns about air pollution and the immense challenge of

[3] The Megatons to Megawatts programme is a commercially financed government–industry partnership in which bomb grade uranium from dismantled Russian nuclear warheads is being diluted and recycled into fuel used mainly by American power plants. Begun in 1994, the programme is being implemented by USEC, as executive agent for the US Government, and TENEX, acting for the Russian Government. When it is completed in 2013, the programme is expected to have recycled 500 tonnes of nuclear weapons material (the equivalent of 20 000 warheads) into fuel equivalent to 14% (5.5 million SWU) of the current global enrichment demand.

lowering greenhouse gas emissions, are all driving a fresh look at nuclear power. As the technical and organizational foundations of nuclear safety improve, there is increasing confidence in the safety of nuclear power plants. In the light of existing, new and reawakened interest in many regions of the world, the prospect of new nuclear power stations on a large scale is real. A greater number of States will consider developing their own fuel cycle facilities and nuclear know-how, and will seek assurances of supply in materials, services and technologies.

25. States have sought such capabilities for a variety of reasons: to carry out entirely legitimate, peaceful programmes; to remove doubts about the reliability of fuel supply from foreign sources; to conserve nuclear fuel resources through reprocessing; to achieve the prestige of possessing advanced, sophisticated fuel cycle facilities; to benefit from industrial, technological and scientific spin-offs; to sell enrichment or reprocessing services on the international market; and because the State considers it to be economically justifiable. A few States have also sought such technologies — research reactors and fuel fabrication — for the purpose of developing nuclear weapons or securing the option to do so.

26. Historically, States that wanted nuclear weapons have gone straight for them[4], creating dedicated weapons programmes. Nonetheless, without adequate controls, the civil nuclear fuel cycle has been used to support a weapons programme in a few instances. Despite strengthened IAEA safeguards, clearly it is not desirable from a non-proliferation point of view that every State with nuclear research and/or nuclear energy programmes should necessarily establish its own enrichment and reprocessing facilities (even if such activities would be within the boundaries of Article IV of the NPT).[5]

27. In the 1970s, the search for alternative approaches to complete national fuel cycles, fuelled by growing concerns regarding prospective "plutonium

[4] NEFF, T.L., "The nuclear fuel cycle and the Bush non-proliferation initiative", *World Nuclear Fuel Cycle 2004* (Proc. Int. Conf. Madrid, 2004).

[5] Recent proposals highlighting the need to address the potential proliferation risk of the civilian nuclear fuel cycle include, inter alia, 11 February 2004 speech at the National Defense University by US President George W. Bush; written ministerial statement by UK Foreign Secretary Jack Straw, 25 February 2004; the G-8 statement at their June 2004 summit; further proposals by IAEA Director General Mohamed ElBaradei; the report of the UN Secretary-General's High Level Panel on Threats, Challenges and Change, December 2004.

economies" and the 1974 nuclear explosion by India, led in turn to a number of international initiatives, which are the central elements of the historical perspective provided in the following chapter.

3. HISTORICAL PERSPECTIVE

28. At the very outset of the nuclear age, it was recognized that the atom had both peaceful and military applications. The internationalization of nuclear technology has its origins in the 1946 Baruch Plan, in which the USA proposed that States should transfer ownership and control over civil nuclear activities and materials to an international atomic development agency. Nearly a decade later, in 1953, US President Eisenhower unveiled his "Atoms for Peace" plan. This, in turn, laid the ground not only for the establishment of the IAEA, but also for widespread dissemination of civilian nuclear knowledge and technology. All of this heightened concerns that, with unlimited access to the technologies of nuclear fission and the fuel cycle, someone, somewhere, would light a fuse igniting further nuclear weapons proliferation.

29. The NPT was intended to halt such proliferation by limiting the NWS to those States that had manufactured and detonated a nuclear explosive device prior to 1 January 1967, and committed all parties, under Article VI of the Treaty, "to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament") and, in respect of the NNWS, by requiring that their nuclear activities be for peaceful purposes only and subject to the safeguards system of the IAEA. As has been noted, the NPT has been remarkably successful in limiting the spread of nuclear weapons, in spite of challenges to the regime. Some of these challenges are not new, having loomed particularly large in the 1970s, and led to considerable diplomatic activity and related initiatives — including proposals for multilateral arrangements.

30. One of the most significant events of that time was the 'peaceful nuclear explosion' carried out by India in May 1974. Another was the oil crisis of the mid-to-late 1970s, which gave rise both to plans for, and expectations of, an exponential rise in the number of nuclear facilities in order to meet global energy demands. Essentially, the world was facing the prospect of large scale equipment and material transfers, all bearing on the most sensitive aspects of the nuclear fuel cycle, combined with the dissemination of knowledge of nuclear fission and its various uses, as well as associated training. Particular anxiety was expressed at the time about the prospective escalation in the number of reprocessing facilities (the 'plutonium economy') and the consequent increased risk of horizontal proliferation and subnational theft.

31. The resulting concern about managing this process, while ensuring respect for non-proliferation norms, led to a number of proposals for regional, multilateral and international arrangements. The proposals were intended, on the one hand, to reinforce the NPT objective of discouraging horizontal proliferation and, on the other, not to undermine the right of all States to exploit nuclear energy for peaceful purposes. The IAEA General Conference briefly looked at the issue in 1974, with specific reference to the possibility of establishing internationally approved facilities to handle all spent fuel produced in power reactors. The Final Declaration of the 1975 NPT Review Conference also included a finding that: "regional or multinational nuclear fuel cycle centres may be an advantageous way to satisfy, safely and economically, the needs of many States, in the course of initiating or expanding nuclear power programmes, while at the same time facilitating physical protection and the application of IAEA safeguards and contributing to the goals of the Treaty."

32. Among the more visible efforts to promote MNAs in the 1970s and 1980s were: the IAEA study on Regional Nuclear Fuel Cycle Centres (1975–1977); the International Nuclear Fuel Cycle Evaluation programme (1977–1980); the Expert Group on International Plutonium Storage (1978–1982); and the IAEA Committee on Assurances of Supply (1980–1987)[6]. In a general sense, these studies concluded that most of the proposed arrangements were technically feasible and that, based on the projections of energy demand, economies of scale rendered them economically attractive:

- **Regional Nuclear Fuel Cycle Centres (RFCC) (1975–1977).** The first of the 1970s initiatives, the RFCC study looked into the possibility of pooling the resources of States into regional fuel cycle centres.[7] The focus, as was the case for most of the initiatives at that time, was on the back end of the cycle, specifically reprocessing and plutonium containment. The conclusion of the RFCC study, in brief, was that the proposal was technically valid, but that problems could arise concerning technology transfer, physical protection and the possible risk of host country obstruction.
- **International Nuclear Fuel Cycle Evaluation (INFCE) (1977–1980).** This study, which was prompted by concerns about the widespread use

[6] Selected extracts from some of these studies are reproduced in Annex IV.

[7] *Regional Fuel Cycle Centres*, Report of the IAEA Study Project (Vols I and II), IAEA, Vienna (1977).

of plutonium, also looked into the possibility of regional fuel cycle facilities, as well as other models for multilateral plutonium storage.[8] Again, the technical conclusions were generally positive, but were overtaken by other aspects of the INCFE findings, which tended to focus on whether a technological fix might exist for reducing proliferation risks. At the end of its three years, the work of INFCE arrived at the general conclusion that no single fuel cycle approach was inherently superior to another from the standpoint of non-proliferation and that, while options to increase resistance might be worth pursuing, technical measures alone would not compensate for weaknesses of the international nuclear non-proliferation regime.

- **Expert Group on International Plutonium Storage (IPS) (1978–1982).** This Group explored the mandate of the IAEA under Article XII.A.5 of its Statute, which contemplates IAEA supervised management, storage and release of plutonium.[9] A separate Expert Group on Spent Fuel Storage was also convened. No consensus on either of these initiatives proved possible.
- **IAEA Committee on Assurances of Supply (CAS) (1980–1987).**[10] CAS, which also discussed the concept of multilateral approaches as a central part of its agenda, suffered a similar fate.
- **Conference for the Promotion of International Cooperation on the Peaceful Uses of Nuclear Energy (UNCPICPUNE) (1987).** Another later effort to achieve concrete progress on multilateral approaches, UNCPICPUNE was no more successful. Essentially, UNCPICPUNE, which was seven years in gestation, could not generate specific conclusions owing to a lack of political consensus on the matter.

33. All of these initiatives failed for a variety of political, technical and economic reasons, but mainly because parties could not agree on the non-proliferation commitments and conditions that would entitle States to participate in the multilateral activities. Moreover, differences of views prevailed between those countries and/or regions that did not plan to reprocess or recycle plutonium and those that favoured it (the latter group being concerned, in particular, about the availability of fuel supplies and the possibility of the interruption of supplies by suppliers). In addition, much of the

8 *International Nuclear Fuel Cycle Evaluation*, Summary Volume (INFCE/PC/2/9), IAEA, Vienna (1980).

9 *Expert Group on International Plutonium Storage* — Report to the Director General, IAEA-IPS/EG/140(Rev.2), IAEA, Vienna (1982).

10 Documents and papers issued for CAS (CAS/INF/4), IAEA, Vienna (1985).

momentum collapsed with the slowdown in new civil nuclear programmes in significant parts of the developed world, thereby de facto limiting the spread of reprocessing facilities and temporarily laying to rest fears of a global plutonium economy. As a consequence, efforts to establish multilateral mechanisms had wilted by the end of the 1980s.

34. There things remained until the 1997 IAEA international symposium on the nuclear fuel cycle and reactor strategies, which at the time received little public profile, but which, in retrospect, can be credited with expanding the focus on multilateral approaches from the back end of the cycle (reprocessing) to include the front end (enrichment).[11] One of the most significant conclusions of this symposium was that the previous initiatives had failed because of the difference in priorities motivating governments as opposed to the nuclear industry: for the former, the priorities were political legitimacy and public support; for the latter, technical feasibility and commercial viability. As reflected in the results of the symposium, the great challenge ahead would be to reconcile these different priorities.

35. Then, through a series of IAEA sponsored meetings in 2001 and 2002, the focus on multilateralization of the fuel cycle was broadened beyond reprocessing and enrichment to include repositories for spent fuel and nuclear waste. Once again, the deliberations suggested that, while political and institutional issues were the major obstacles to the establishment of such facilities, technical and economic considerations would favour them. The meetings led to the development of an IAEA publication on developing multinational radioactive waste repositories.[12]

36. Today these concepts have gained renewed salience and prompted the Director General's September 2003 proposal to reconsider such concepts. The nuclear non-proliferation regime faces some old challenges (national versus multinational operation of sensitive facilities; secure fuel supply; concerns over perceived limitations of the NPT); and, as discussed previously, it is confronted by dramatic and immediate new challenges. Some trends suggest that there might be a greater likelihood of success in the development of MNAs. Today, both States and international organizations have more experience with

[11] *Nuclear Fuel Cycle and Reactor Strategies: Adjusting to New Realities* (Proceedings of an International Conference, Vienna, 1997), IAEA, Vienna (1998).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, *Developing Multinational Radioactive Waste Repositories: Infrastructural Framework and Scenarios of Cooperation,* IAEA-TECDOC-1413, IAEA, Vienna (2004).

safeguards; with the commercial operation of sensitive facilities and nuclear fuel markets; with information monitoring and intelligence assessment; and with the identification of pathways to nuclear weapons. Given the challenges to the regime, they may also have greater motivation to look for solutions. The overall challenge to the Expert Group, as noted in paragraph 15 in the Preamble, is to use previous experience and current insights to define promising options for MNAs that would advance both the non-proliferation regime and the effective functioning of peaceful nuclear fuel cycles.

4. CROSS-CUTTING FACTORS

37. Consideration of multilateral approaches to the nuclear fuel cycle tends to involve certain common factors, whether dealing with enrichment, reprocessing storage or disposal. As foreseen in the Director General's mandate to the Expert Group, these cross-cutting factors extend across the spectrum of nuclear technology, economics, assurances of supply, legal and institutional arrangements, and non-proliferation and security issues. These factors are discussed in this section.

ADVANCES IN NUCLEAR TECHNOLOGIES

38. This section deals with a major proliferation factor and its impact on safeguards and verification, namely the degree to which new technologies and other scientific developments interact with each other to lower the threshold of accessibility for sensitive nuclear technologies while permitting more effective and efficient verification by the IAEA.

39. Since the 1970s, nuclear technology has undergone significant developments.

40. *Information technology (IT):* Dramatic changes in IT have taken place since the 1970s, due to the introduction of faster, smaller, more versatile, low cost and more reliable computers and operating systems. For example, complex multi-group codes and hydrodynamic calculations that once took hours on the then-fastest super computers (Cray-1) may now be performed on a €2000 personal computer in the same time or faster, especially when connected with other personal computers in a network.

41. However, the most significant IT development has been the appearance, spread and the usage of the Internet, where, apart from making information widely available and thereby fostering knowledge, a wealth of sensitive nuclear technology designs, methods and techniques can be retrieved worldwide with little difficulty (for example, early generations of production centrifuges for uranium enrichment, reprocessing flow sheets, including detailed descriptions of the radiochemistry involved).

42. *Sensor technology, process engineering and miniaturization:* All kinds of sensors for physical parameters— such as optical (satellites), radiation, pressure and motion sensors — are now available at low cost. These

processes have been both optimized and miniaturized and are now radiation resistant and economical. Developments in this area facilitate the implementation of safeguards though the use of remote monitoring, installed systems and hand-held sensors.

43. *Material technology:* Examples are the use of non-metallic components in enrichment and reprocessing processes. Dual use materials have become ubiquitous in the nuclear realm.

44. *Chemistry:* Basic research has resulted in the development of new techniques for reprocessing, for example with pyrochemical processes with which large separation factors can be routinely achieved in small geometries. Analytical methods have been considerably improved, so that concentrations smaller than one millionth of one millionth are routinely determined.[13] Such developments are particularly important for IAEA verification.

45. Finally, the combination of all of these developments, has led to powerful synergies.[14] For nuclear facilities, the spin-offs of these technical advances are that nuclear safety has been further enhanced, processes streamlined and the economics improved. These advances have also contributed to the development of innovative nuclear systems, purported to be proliferation resistant, safe and economical. Related work performed in the framework of the IAEA INPRO initiative and the multinational Generation IV projects thus have potential implications for non-proliferation, safety and economics of nuclear energy as a whole.

46. Technological developments have made concealment of non-peaceful uses at complex facilities technically less difficult. Conversely, IAEA safeguards verification and other verification systems have benefited as well from most of these developments, in particular, in connection with material accountancy evaluation using IT, particle analysis, destructive and non-destructive measurements (chemistry) and surveillance (sensor technology and IT). In fact, real time verification of most peaceful nuclear processes has

[13] Chemists claim that such low concentrations are equivalent to the concentration of a lump of sugar dissolved in a volume of water as large as the Baltic Sea.

[14] These synergies resulted, for example, in the development and implementation of advanced automatic measurement stations for IAEA safeguards verifications, where motion sensors trigger non-destructive measurements and video films of objects moved through the space of interest and the automatic and encrypted transmission of these data to IAEA Headquarters, via the Internet.

Mühleberg nuclear power plant, Switzerland (photo courtesy Bernese Power Utility).

now become a technical possibility and, indeed, a reality in cases where the IAEA has concluded that it is cost effective and where governments have cooperated in their implementation.

47. An evaluation of the impact of these advances on a variety of aspects of the peaceful uses of nuclear energy, such as proliferation risks, safeguards,

assurance of supply, energy planning security and economics, reveals the following:

(a) Easier accessibility: Proliferation risks have increased markedly in recent decades with the easier accessibility of sensitive nuclear technologies made available through clandestine supply networks that span the globe and by the dissemination of weapons design information.
(b) Safeguards: Technological advances have had a strong and positive influence, leading to increased safeguards effectiveness and efficiency. There is disagreement, however, as to whether this positive factor compensates fully the higher proliferation risks brought about by similar advances in technology, as noted above.
(c) Assurance of supply and energy planning security: Advanced technologies, with their promises of small scale facilities and lower costs, encourage the pursuit of national facilities or regional MNAs may make them more attractive for achieving domestic or regional self-sufficiency in the fuel cycle. For smaller countries, such facilities make the possibility of national independence at a reasonable cost a more achievable goal.
(d) Economics: Technology has made it possible to build smaller facilities, and this trend will likely continue; that is, for a given throughput and a given size, the costs have decreased. Nonetheless, economies of scale continue to apply; a multinational partnership at a higher throughput may provide even better economics than national facilities.

48. On the production side, enrichment to weapon-grade uranium using early generations of ultra-centrifuges seemingly has become less difficult, since documents on design, materials and process control of these early machines are more readily available. However, advanced designs to achieve a steady output at reasonable cost are still not available. Furthermore, the know-how and experience gained from some 20 years of development cannot be re-engineered or reverse engineered in only a few years. With regard to uranium conversion, from uranium oxides to UF_6 and vice versa, the know-how has become readily available.

49. Safeguards verification of the peaceful use of enrichment plants and associated conversion processes has become very effective as a consequence of the advances in chemistry and sensor technology referred to above. Real time verification of an enrichment facility can be achieved at a pro rata cost lower than one thousandth of the cost of producing one “separative work unit” (SWU).

50. Large scale reprocessing installations using wet chemistry are now coming under IAEA inspection. The IAEA has defined the verification approaches and criteria to be applied. Verification of modern reprocessing facilities with complex chemical processes requires a very complex network of advanced sensors. Such verification is therefore costly, with an impact on the IAEA's financial and human resources. The safeguarding of advanced reprocessing techniques, such as those based on pyrochemical processes, will be a challenge. Simpler and cheaper verification might be achieved when integrated plants are constructed with no explicit separation of U, Pu and minor actinides.

51. With respect to fuel cycle facilities at the back end of the fuel cycle (spent fuel and related facilities), there are no major verification problems, since technological advances allow for efficient IAEA safeguards using real time verification for MOX and spent fuel and related facilities. The widespread implementation of the Additional Protocol will further accelerate this development by allowing access to locations beyond the usual "strategic points".

ECONOMICS

52. This section summarizes generic economic considerations relevant for all multinational nuclear fuel cycle facilities. Additional economic considerations specific to different technologies (enrichment, reprocessing, storage and disposal) are addressed in the appropriate sections of the next section.

53. History and logic suggest that the more profitable a proposal, the easier will it be to recruit partners for its implementation. Economies of scale exist for most facilities in the nuclear fuel cycle, and the likelihood that multinational facilities will be larger than national facilities raises the possibility that economies of scale will generate simultaneous non-proliferation and economic benefits. The double incentive should make it easier to establish a multinational facility. Furthermore, hosting an MNA brings many benefits, such as large capital investment and the creation of jobs in the host country.

54. Economies of scale and economic benefits are not sufficient conditions for a multinational facility. Even where they exist, it can be very difficult, for the reasons outlined below, to structure incentives that will be attractive to all necessary partners. Moreover, a country bent on proliferation may not necessarily be dissuaded, even by a very lucrative MNA alternative.

55. As in any other commercial undertaking, the economic attractiveness of an MNA will be vulnerable to economic upsets or major shifts, whether due to markets, politics, accidents, or natural disasters. If so, hedges and insurance arrangements may be needed to enhance its economic appeal in spite of such possibilities. An MNA's attractiveness must also not be overly dependent on the future development of nuclear power, whether in expansion or in contraction, globally or regionally.

56. Different parties sometimes have different motivations and different expectations of the future. A successful MNA must dovetail these differences in ways that attract the participants necessary to deliver the desired economic and non-proliferation benefits. The costs of start-up, operations, liabilities and needed accumulating funds (e.g. for eventual decommissioning) must be allocated efficiently and equitably in the eyes of the participants. Acceptable dispute resolution provisions must be included, and if universal, or very broad, participation is needed, compensation arrangements may be needed to assure that every party judges itself a net winner.

ASSURANCES OF SUPPLY

57. Currently, the commercial market satisfies the demand for fuel services subject to government approval for exports. There is a diversity of commercial enrichment companies; enrichment capacity exceeds demand; and, based on current plans for the substitution of diffusion by centrifugation, capacity is likely to comfortably keep abreast of projected increases in demand in the medium term (e.g. until the end of the USA–Russian Federation agreement on HEU conversion to LEU). For other front end processes (such as conversion and fuel fabrication) the situation is similar. This equilibrium in the uranium market is likely to change only if the demand for nuclear power increases significantly, or in case of sudden disruption in supply.

58. However, there exists the risk that a State with uranium enrichment capacity may cut off supplies to other States to gain leverage for reasons that have nothing to do with non-proliferation concerns. Against that possibility, a country needing LEU for nuclear power plants may have an interest in alternative extra-market measures being in place to provide assurances of supply. Other than for the production of weapons usable nuclear materials, possible motivations for building a domestic enrichment capability might include:

(a) Reducing external dependence on foreign suppliers and achieving greater economic independence, e.g. when faced with a shortage of foreign currency or energy supplies,
(b) Unfavourable experiences in the past and low confidence in existing suppliers,
(c) National prestige and expected spin-offs for industrial and technological development; and
(d) Possible technical advantage, allowing for lower production costs than existing facilities and for a commercial edge.

59. For any country, none, some or all of these motivations might be relevant. Establishing a multinational arrangement may provide inducements for States to join the MNA and forgo their domestic capability. Nevertheless, an international external assurance of supply would address the first two motivations in this list, and further inducements (not necessarily nuclear) would address the third. A State that pursues a domestic capability may not necessarily be doing so to create the option of acquiring nuclear weapons but might be pursuing technological or market gains.

60. As recalled in the previous section, both INFCE and CAS extensively examined the issues surrounding assurance of supply, without coming to any agreed conclusions or agreed mechanisms to provide such assurance. For *customers*, the steps identified included supplier–customer risk sharing arrangements, diversification of suppliers and customers, customised contracts, the early conclusion of commercial contracts, improved information exchange, and the maintenance of a sound market for spot transactions. For *governments,* they included the more uniform, consistent and predictable application of export and import controls; mechanisms to manage changes in non-proliferation policy that would minimise the risk of any resulting disagreements interfering with supplies; and the establishment of a common approach to non-proliferation (which could take the form of common practices, joint declarations, codes of conduct or other instruments) rather than individual prior consent rights.

61. In general, and in particular for MNAs, any prior consent rights should be based *primarily* on non-proliferation considerations, in particular compliance with safeguards agreements, in order to provide a credible assurance of supply. And the opinion of the IAEA should be decisive in this regard. Of course, other legitimate reasons could be invoked for prior consent rights, such as poor safety records, poor physical security and insolvency. Quite evidently from the evidence at hand, individual prior consent rights will not

be readily given up by those holding them, unless the concerns are adequately covered by suitable MNA agreements**.**

62. INFCE discussed two possible multilateral mechanisms for supply emergencies, while emphasising the importance of smoothly functioning competitive markets as the best assurance of supply. The two back-up mechanisms were identified: a 'safety net' network and an international fuel bank.

63. CAS followed up these INFCE discussions and produced periodic forecasts of uranium supply and demand. But CAS was unable to reach a consensus on both the "principles for international nuclear energy cooperation and nuclear non-proliferation" and on "emergency and back-up mechanisms", and went into formal abeyance. A key stumbling block was the inability to reach agreement on broad principles of international cooperation, and the rejection of any piecemeal agreement by many parties without nuclear power programmes.

Fuel Guarantees: Physical and Virtual Fuel Banks and the IAEA as Guarantor

64. Theoretically, a physical fuel bank could store material in any of several post-enrichment forms. Inter alia, some key storage possibilities are: enriched UF_6 as a solid or gas, UO_2 powder, UO_2 pellets or finished fuel assemblies. Some important advantages and disadvantages of each are given below.

65. *Uranium hexafluoride* is the most flexible form of storage and the most desirable for users as it can be easily stored for long periods and transported without difficulty as and when needed. UF_6 is the least proliferation-resistant form of enriched uranium, the chemical form most suitable to boost reactor grade UF_6 to weapon-grade.

66. *UO_2 powder* degrades more quickly than either UF_6 or pellets, making it a less suitable storage form for a fuel bank. But it is more proliferation resistant since a reduction and conversion process would be required prior to clandestine enrichment. A stockpile in a fuel bank containing a variety of enrichments could be considered to augment supply assurance.

67. *UO_2 pellets* are physically and chemically stable, a storage option more suitable for a fuel bank. However, the pellet design depends on the reactor

type. This would be a disadvantage for a fuel bank meant to efficiently provide assurances of supply for a range of different reactors.

68. Storage of a variety of finished fuel assemblies is, in practice, incompatible with the way in which the current nuclear power plants operate since fuel assemblies are effectively tailor-made reflecting the unique operating design and history of a reactor core for which they are intended as well as continuing improvements in fabrication technology, burnup rates and fuel economics.

69. A safety net network, or virtual fuel bank, would be based on commitments by countries and/or firms to make their enriched material available as agreed, either directly or through the IAEA. Commitments from suppliers could be made to the IAEA, and the State receiving the enriched material would receive it from the IAEA. There are precedents for such a role: in the 1960s, in several cases, legal ownership of research reactor fuel was transferred from the USA to the IAEA and subsequently to the recipient country, without physical control of the fuel by the IAEA. The IAEA could maintain 'assurance of supply' arrangements with a number of suppliers and maintain access to funds to allow prompt payment to suppliers before collecting payment from a recipient country.

70. A virtual fuel bank would be closely associated with the existing industrial partners, and would not disturb the market. However, the fuel bank's material would be located in precisely those countries that are trusted least by those seeking assurances of supply. A virtual bank would therefore need a real footing in several trusted locations. Also needed: strong oversight and review through international management and boards, on which supplier States would be represented, and effective and modern IAEA verification to keep close track of all materials.

71. Prima facie evidence suggests that if a prospective fuel bank could improve efficiency, and therefore profits, the industry would have already created it. Economically speaking, a multilateral fuel bank would be more about sharing costs than about profits.

72. Recently, the United Nations High-Level Panel has formulated a recommendation[15] on the involvement of the IAEA. In its report, the Panel urged

[15] *A More Secure World: Our Shared Responsibility*, Report of the Secretary-General's High-Level Panel on Threats, Challenges and Change, United Nations, New York (2004).

"that negotiations be engaged without delay and carried forward to an early conclusion on an arrangement, based on the existing provisions of Articles III and IX of the IAEA Statute, which would enable IAEA to act as a guarantor for the supply of fissile material to civilian nuclear users. Such an arrangement would need to put the Agency in a position to meet, through suppliers it authorized, demands for nuclear fuel supplies of low enriched uranium and for the reprocessing of spent fuel at market rates and to provide a guarantee of uninterrupted supply of these services, as long as there was no breach of safeguard or inspection procedures at the facilities in question".

73. Depending on the specific agreement negotiated, the term "guarantor" could cover a variety of roles to be played by the IAEA: judging whether the conditions for supply are being met, including assessing the non-proliferation status of the recipient; activation of any decision to supply, including requesting governments/companies to fulfil supply obligations; acting as a broker between supplier and recipient; and overall management of the arrangement. In all such "guarantor" functions, the IAEA will need to rely on the cooperation of other actors, i.e. governments and companies.

74. However, the IAEA need not be involved in a multilateral fuel bank, although it would provide a stronger assurance if it were. A fuel bank could instead be nothing more than an agreement between suppliers, with or without government backing. Both alternatives are examined in more detail in the next section.

75. Concerns about assurances of supply have existed since the 1960s and, even in 2005, is a central element of national nuclear policies. The secure availability of nuclear energy rests on assurances of supply of nuclear material, equipment, services and support for those having nuclear plants. Domestic solutions, which are the privilege of a few States, are not available to others. In an age of growing interdependence and globalization, the drive for self-sufficiency is diminishing as an element of national economic policies. In this perspective, MNAs may represent an effective alternative to national solutions, depending upon conditions of the assurances of supply of fuel and/or services that are credible and viewed by the potential clients as dependable, reliable and economical.

76. The fundamental conditions that potential MNA partners may demand are worth restating:

(a) Diversity of suppliers participating in the MNA;

(b) The willingness of a sufficient number of suppliers to grant to the MNA generic consent for the transfer of the respective goods and services assuming of course that basic premises will be fulfilled (non-proliferation credentials, physical security, export controls and safety records);
(c) The availability from such suppliers of significant amounts of fissile material free of 'national flags' and free of prior consent rights from other parties;
(d) Sufficient reserve capacity of the respective fuel and services to cover supply emergencies, in a setup equivalent to the mandatory national oil reserves held by OECD members under the auspices of the International Energy Program of the IEA;
(e) A credible, timely, non-discriminatory and reliable decision making mechanism for the release of replacement supply;
(f) A pricing mechanism for the provision of substitute fuel and services in case of emergency that is deemed fair and that leads to prices not significantly higher than those set by the market; and
(g) A neutral and fair process for determining whether a recipient that has lost its original supplier is in good standing with its non-proliferation commitments.

LEGAL AND INSTITUTIONAL FACTORS

77. The establishment and operation of an MNA needs to be founded on an appropriate legal base. Such a facility could have as its legal basis:

(a) An international agreement alone (as exemplified by Eurochemic);
(b) National legislation (as exemplified by EURODIF);
(c) Any combination of (a) and (b) (as exemplified by Urenco).

78. In practical terms, there is little difference between a legal basis consisting of an international agreement alone and one consisting of an international agreement and national legislation (although the difference between the two will vary depending on the extent to which the requirements of the agreement are expressed in general or specific terms: the more general the terms of the agreement, the greater the difference). This is so because, normally, national legislation is needed to implement the terms of an international agreement. Two exceptions to this general rule are: for a State in which existing legislation is sufficient to enable the implementation of the treaty; for a State in which an international agreement automatically becomes part of national law upon its entry into force for that State. However, even in these

two cases, regulations (which are a form of legislation) may be needed for full and effective implementation.

79. With respect to the second possible legal basis, that is, national legislation alone, a State could, of course, enact legislation for the establishment and operation of an MNA. However, while a State has jurisdiction to require that the legislation be observed by any person or entity making use of the services provided by the facility, that State has no jurisdiction to enforce the observance of such requirements outside its territory (without the consent of the State in whose territory the person or entity is located, or unless the person or entity has assets against which legal action can be taken in the territory of the legislating State). Further, in the absence of a binding international agreement, a State would be free to repeal or change such legislation.

80. If an international agreement were to form the legal basis, or part thereof, for an MNA, the following issues related to form and procedure would need to be addressed:

(a) Whether all States would be entitled to become parties to the agreement (i.e. a universal agreement) or only those States in a given region (or, for that matter, whether it could be bilateral); and in that context, whether regional agreements could be concluded and brought into force more quickly than a universal agreement.
(b) How the agreement would enter into force: if the agreement were to be multilateral, whether it should enter into force upon adherence to it by the host State and one or more other State(s).
(c) Whether the agreement should refer only to existing facilities of a stated technology (e.g. all existing enrichment facilities in the States party to the MNA), or should refer only to future such facilities, or should refer to other facilities of the fuel cycle.
(d) Whether it would be feasible to have an approach based on an agreement between the States in which the relevant facilities are located, together with separate agreements between that group of States and each State in which persons or entities within the latter's territory are to receive the services of the facility or facilities.

81. The agreement(s) or national legislation would also have to address, among others, the following substantive issues:

(a) What entities may participate in or benefit from the MNA (e.g. governments; governmental entities; private entities).

(b) The conditions for participation in the MNA, may include:

   (i) The application of appropriate IAEA safeguards pursuant to an INFCIRC/66-type agreement or an INFCIRC/153-type agreement, and an additional protocol based on INFCIRC/540 (Corr.)[16] in the territory of all recipients of the output (e.g. services, material) of the facility. Accepting INFCIRC/66-type safeguards as a sufficient condition of supply, however, would imply a fundamental change in the policies of all NPT States Parties involved in the respective MNA.
   (ii) The application of appropriate safety and physical protection measures in the territory of all recipients of the output of the facility.
   (iii) An undertaking by each State to prohibit within its territory activity ‘parallel’ to that of the facility (e.g. any other enrichment activities); and, if agreed by a State or group of States, restricting research and development on such technology to the MNA entity.

(c) The conditions upon withdrawal from the agreement for legitimate reasons must be agreed upon.
(d) The sanctions to be applied with respect to any breach of subparagraphs (b) and (c) above.
(e) How joint decisions are to be taken with respect to the supply of material or services, and agreed circumstances justifying a denial of

[16] INFCIRC/66-type agreements normally apply to particular supplied nuclear facilities, nuclear material, equipment and/or non-nuclear material. They can also apply to transferred technological information. The duration of such agreements is related to the period of actual use of the safeguarded items. The agreements also contain provisions to the effect that, notwithstanding termination of the agreement, safeguards continue to apply to supplied nuclear material and special fissionable material produced, processed or used in or in connection with supplied items until the IAEA has terminated safeguards on such material. Equivalent provisions apply with respect to the continuity of safeguards on supplied items. In cases where a State has in force an INFCIRC/66-type agreement before becoming a party to the NPT (and concluding an INFCIRC/153-type agreement), the INFCIRC/66-type agreement remains in force but provision is made for the application of safeguards under the INFCIRC/66-type agreement to be suspended while the INFCIRC/153-type agreement remains in force. If a State has concluded only an INFCIRC/153-type agreement and a supplier State required that an INFCIRC/66-type agreement also be concluded, there would be no legal impediment. However, whether the IAEA would conclude an INFCIRC/66-type agreement under such circumstances is a matter for decision by the IAEA’s Board of Governors.

supply (e.g. for reasons unrelated to non-proliferation, such as failure to fulfil commercial conditions).

(f) How disputes (commercial or otherwise) are to be settled, including issues of forum and jurisdiction).

(g) Whether the MNA should be treated as an independent international legal entity, and, if so, the nature and extent of any privileges and immunities that are to be accorded to it in the host State and in other participating States.

(h) How and by whom decisions relating to the operation of the MNA are to be taken.

(i) How and by whom the activities of the MNA are to be financed.

(j) What provisions should be made in case of insolvency of the MNA.

82. While many, if not most, of the above substantive issues may also be addressed in commercial contracts, these may not be sufficient since they would be binding only on the commercial parties thereto.

83. With the above in mind, and based on the premise that to be worthy of further consideration an MNA should be designed to lessen proliferation, security and safety concerns while providing assurances of supply of nuclear fuel in return for restraints in the use of sensitive technology, the following three categories of options for multilateral approaches are considered and assessed in the following section:

(a) Options involving assurances of services not involving ownership of facilities:

  (i) Additional assurances of supply by suppliers: These assurances could take different forms, such as longer-term contracts or contracts with more favourable incentives. This might require all supplier States agreeing to amend any national legislation and international commitments which impose prior consent conditions.

  (ii) International consortium of governments: This could take the form of an actual or virtual fuel bank to which governments would ensure the availability of material. Alternatively, supplier governments could physically hold the material, subject to an agreement on how it is to be distributed.

  (iii) IAEA related arrangements: The IAEA could physically hold title and distribute the material. Alternatively, the IAEA could conclude an agreement with a State or States to provide the material or services on instruction from the IAEA. Countries most concerned with assurances of supply would likely prefer a role by the IAEA. For the IAEA to play this role, suppliers would need to relinquish all prior consent rights to material provided to or by the IAEA; for some, this might be a difficult and complicated decision. In addition, the IAEA might decline to provide material in certain circumstances (such as non-compliance in safeguards, poor nuclear safety records, poor physical security or insolvency).

(b) Options involving the conversion of national facilities to multinational facilities:

(i) This would entail the conversion of an existing national facility to one subject to international ownership and management. It could be based on an arrangement in which all partners share the technology or one in which access to the technology is limited to the technology holders.

(c) Options involving the construction of new facilities:

(i) The Urenco model: The original model involved the sharing of technology with all partners involved in the construction of a new facility. More recently, the model has been extended to allow construction of a facility in a third country, without providing this country access to sensitive technology.
(ii) The EURODIF model: Although the partner(s) would all have a financial share in the ownership and production of the facility, the technology holder(s) would not give the other partner(s) access to the technology nor permit them to participate in the operation of the facility.

NON-PROLIFERATION AND SECURITY FACTORS

84. Since nuclear non-proliferation concerns are the driving force behind the present interest in devising multilateral approaches, it is necessary to ensure that any models for such approaches strengthen, not weaken, the non-proliferation regime. The transfer of sensitive technologies should be kept to a minimum and subject to stringent control. Related issues to be resolved from a non-proliferation and security perspective might include: siting of the multilateral facilities or operations; security of materials, facilities and

transport; handling and storage of wastes; take-back of spent nuclear fuel; timely supply of fresh fuel and timely removal of spent fuel; and common legally binding non-proliferation undertakings.

85. As an alternative to multilateral approaches to prevent additional states from developing enrichment and/or reprocessing capabilities, other approaches have been suggested. One proposes that nuclear facilities should be constructed in those States that already possess other such facilities. This idea has led to debate over discriminatory regimes. Some academic literature has suggested that Article IV of the NPT could be amended. However, such an approach is widely considered to be unacceptable. Others argue that economics have meant that there is no need for enrichment and reprocessing MNAs. However, some believe that political assurances will also be needed.

Safeguards Implementation

86. The concerns evoked by clandestine supply networks, the availability of and increasing access to nuclear technology, and the possibility that some countries may be tempted to use such technology for non-peaceful purposes cannot be ignored, particularly given past evidence that a few countries have either been in fundamental breach of, or have not complied with, their NPT safeguards obligations. Hence, the importance of the IAEA's strengthened safeguards system and of an AP. There are primarily two risks, among others, addressed by IAEA safeguards: diversion of fissionable materials from declared facilities and construction of undeclared fuel cycle facilities built with technology transferred from the declared programme. In the latter case, an AP helps to provide credible assurance regarding the absence of undeclared nuclear material and activities.

87. With respect to MNAs, safeguards implementation by the IAEA should take into account the special positive nature of a multinational nuclear facility. Participants, whether private or governmental, would be committed to transparency and openness through the continuous presence of a multinational staff. Flows of materials would be mostly between partners to the MNA. The MNA agreement could even be stronger in this respect. This additional layer of international oversight would be recognized by the IAEA, possibly allowing thereby a reduction of the safeguards verification effort.

88. This situation was anticipated by the drafters of the Model Safeguards Agreement agreed by the Board of Governors in 1971, a model that has been adopted for all NPT safeguards agreements concluded since then. Paragraph

81 of the Model Safeguards Agreement (INFCIRC/153) lists criteria to be used by the IAEA for determining the actual number, intensity, duration, timing and mode of routine inspections of any facility. Its paragraph (d) covers the following criterion: "International interdependence, in particular, the extent to which nuclear material is received from or sent to other States for use or processing; any verification activity by the Agency in connection therewith; and the extent to which a State's nuclear activities are interrelated with those of other States…".

89. In its report to the Director General in May 2004, the Standing Advisory Group on Safeguards Implementation (SAGSI) referred to para. 81 of INFCIRC/153 and noted that a large number of facilities receive nuclear materials from, and send nuclear materials to, other States, and also that many facilities employ multinational staff whose activities are interrelated with those of other States. SAGSI confirmed that the IAEA should give appropriate recognition to international interdependence under the so-called "State level approach", an approach that would include consideration of State-specific factors such as the level of cooperation with the IAEA on safeguards implementation in the State, including consideration of openness and transparency; and the presence of a supportive and effective State System of Accounting for and Control of Nuclear Material (SSAC).

Security and Physical Protection

90. Besides non-proliferation and safeguards factors per se, the physical protection of nuclear materials and related facilities has always been a matter of great importance. This importance has grown, due to the apparent increase in non-State actor interest in acquiring these materials. Nevertheless, no international treaty mandates that States possessing nuclear material enforce physical protection and security measures. The NPT requires safeguards on nuclear material in NNWS Parties and that necessitates the establishment of a SSAC, but physical protection is not an attendant requirement. In practice, SSAC, IAEA inspections and IAEA review of national accounting help to some extent to provide physical security of the nuclear material under safeguards. However, IAEA inspectors are not required explicitly to verify physical protection. When the IAEA system of safeguards for NNWS was established in 1971–1972, physical protection standards were only "recommended", and no agreement was possible among the States to make these standards mandatory.

91. The agreed and recommended standards were published in 1975 as INFCIRC/225, and have been since then regularly upgraded under IAEA auspices. The latest INFCIRC/225 document recommends that each State establish and periodically re-evaluate “design basis threats” for its facilities, as well as conduct exercises to test whether guards, sensors and other protection measures are adequate. The document includes detailed provisions on protecting nuclear power reactors as well as stored nuclear materials from sabotage.

92. The 1980 Convention on the Physical Protection of Nuclear Material (CPPNM) requires physical protection standards but these apply only to nuclear materials for peaceful purposes that are in international transit or in temporary storage as part of international transport. Thus, the CPPNM applies only to civilian nuclear material and contains no verification provisions. The result is that there is a wide variation in physical protection standards from State to State. A process is under way to strengthen the CPPNM to include domestic use, storage and transport of civilian nuclear materials and the protection of nuclear facilities against sabotage. The proposed amendments do not cover nuclear material in military use or related military facilities.

93. From the nuclear security perspective, all multilateral nuclear fuel cycle approaches will face the requirement of being integrated within the existing international nuclear non-proliferation and security arrangements in order to elicit the confidence of participating and other States. The challenge will be to ensure that a multilateral nuclear arrangement can be established with high standards of physical security and of MPC&A (material protection, control and accounting). However, MNAs may provide benefits in this context by encouraging peer group reviews of security issues.

5. MULTILATERAL OPTIONS FOR TECHNOLOGIES

94. As noted in the Preamble, this report will follow a pattern as to the task at hand. The previous section dealt with the broad, *cross-cutting factors* relevant to multilateral nuclear arrangements and independent of any particular step of the nuclear fuel cycle. This section will consider the various steps (enrichment, reprocessing, spent fuel disposal and storage), first to review their *specific factors* and then to tackle the main task of the mandate, namely to define the *specific options* associated with one particular technology of the fuel cycle.

95. Whether for uranium enrichment, spent fuel reprocessing, or spent fuel disposal and storage, the search for MNA options revealed a logical way to catalogue, analyse and assess them. In essence, an MNA can span the whole field between existing market mechanisms and complete co-ownership of fuel cycle facilities. As a result, the following pattern has been adopted:

- **Type I: Assurances of services not involving ownership of facilities:**

  (a) Suppliers provide additional assurances of supply;
  (b) International consortium of governments;
  (c) IAEA related arrangements.

- **Type II: Conversion of existing national facilities to multinational ones.**

- **Type III: Construction of new joint facilities.**

96. Once a pattern has been chosen to catalogue and analyse the various MNA options, a method of assessment remains to be selected. The Expert Group has opted to do so by simply reviewing and listing the pros and cons associated with each option. Pros and cons are defined relative to a national facility under current safeguards. The next step, which is the formulation of criteria allowing some sort of ranking (best, average, poor) according to stated factors such as non-proliferation, economics or assurance of supply, was not systematically attempted in view of the large number of parameters to be considered, including the nature of the fuel cycle and the relative importance of nuclear power to different countries.

97. In articulating the pros and cons, however, it became clear that what might be considered a pro in the context of one factor, such as non-

proliferation, might be perceived as a con when considered in the context of another factor, such as assurances of supply. As a consequence, it was decided to make a short hand reference, in the tables of pros and cons using the labels A to G, to a number of central elements described in the following section.

ELEMENTS OF ASSESSMENT

98. Assessing the options and their pros and cons, implies an underlying choice of relevant elements, which will guide the analysis and the comparison of options. Among the cross-cutting factors considered in the previous section, two stand out as primary deciding factors in the consideration of multilateral approaches, namely 'assurance of non-proliferation' and 'assurance of supply and services'. Both are recognized overall objectives for governments and for the NPT community. In practice, each of these two objectives can seldom be achieved fully on its own. History has shown that it is even more difficult to find an optimum arrangement that will satisfy both objectives at the same time. As a matter of fact, multilateral approaches could be a way to satisfy both objectives.

Key Elements

99. The non-proliferation value (label A) of a multilateral arrangement is measured by the various proliferation risks associated with nuclear facilities, whether national or multilateral. These risks include the following:

(a) *Diversion of materials* from an MNA is primarily related to the level of multilateral involvement in its functioning. Because of the different nationalities and interests that exist in a multinational team, it is reasonable to assume that a deeper involvement of such a team ensures a diminishing risk of diversion — provided that there is no collusion.
(b) *Breakout scenarios and clandestine parallel programmes* are related to the siting of the MNA facility in a country that is not a technology holder. The risk level for the breakout scenario depends upon the effectiveness of contractual enforcement provisions. The risk of a clandestine programme is increased because of the cover provided by the declared facility (i.e. know-how, procurement, R&D and obscuring enriched uranium traces). However, with effective safeguards and an AP in place, these risks could be mitigated.
(c) *Diffusion* of proscribed or sensitive technologies from MNAs to unauthorized entities is predominantly related to the participants degree of

access to these technologies. More extensive access to sensitive technologies increases the risk of their diffusion.

(d) *Security risks* cover the risk of theft of nuclear, and especially of fissile, materials and depend upon the effectiveness of the facility's physical protection system. A well guarded MNA, which replaces a wider dispersion of sensitive fuel cycle facilities, has a clear advantage in that respect.

100. The assurance of supply value (label B) of a multilateral arrangement is measured by the associated incentives. They include the following:

(a) *Guarantees.* The political, commercial, legal and technical credibility of the guarantees provided by suppliers, governments and international organizations.
(b) *Economics.* Economic benefits that would be gained by countries participating in multilateral arrangements. Examples could include competitive fuel service costs resulting from the basic advantages of MNA, such as economies of scale, indirect start-up cost savings, or other economical incentives driven by political considerations.
(c) *Political and public acceptance.* In some instances, MNAs may lead to a wider acceptance of a nuclear project in the host country. In others, e.g. final disposal, the impact could well be negative for the host country, although beneficial for others.
(d) *Security and safety.* To enhance acceptance, any nuclear project, whether national or international, must satisfy proper standards of material security (that is accountability and physical protection), and of nuclear safety for the design and operation of facilities. Here also, the multilateral dimension provides an additional level of confidence, thereby indirectly improving the assurance of supply related to such facilities.

Other Elements

101. While 'assurance of non-proliferation' or 'assurance of supply and services' are the key elements of assessment, other elements — or issues of interest — are important, mainly insofar as they contribute to the two key elements. They include:

102. *Siting* — Choice of host country (label C). There are three basic options for hosting fuel cycle facilities under multilateral arrangements:

(a) Special arrangements — legal structures limiting national jurisdiction on the site of MNA fuel cycle facility ("extraterritorial" status);
(b) States that are already technology holders;
(c) States that are not technology holders.

The nature of safeguards agreements applicable to a location would also be an important factor. Furthermore, the host country will have to be acceptable to partner countries.

103. *Access to technology* (label D). Multilateral options might also vary in the extent of access to technology that they permit:

(a) Full access;
(b) Assembly and maintenance know-how;
(c) Operational know-how;
(d) None.

104. *Multilateral involvement* (label E). Multilateral options may also offer various levels of involvement for the participating States:

(a) Minimum: Supply only arrangement;
(b) Ownership: Sharing ownership of the facility;
(c) Management: Taking part in the management of the facility;
(d) Operation: Participating in the operation of the facility;
(e) Maximum: Joint research and development, design and construction of facilities.

105. *Special safeguards provisions* (label F). Each multilateral option should have safeguards provisions that define the measures to be taken to ensure that no proliferation occurs. Such measures might include:

(a) Expanded facility specific safeguards agreement, covering not only nuclear materials, but also functionally essential components of an MNA facility;
(b) Additional Protocol;
(c) Special safeguards arrangements;
(d) 'Continuity of safeguards' for the facility and the nuclear material and components in connection with the breakout scenario, breach of contract, or a voluntary dissolution of the arrangement.

106. *Non-nuclear inducements* (label G). These may prove vital in securing the willingness of certain States to restrict or forego the possession of indigenous nuclear fuel cycle facilities. Incentives may include:

(a) Trade benefits;
(b) Security arrangements (regional/international);
(c) Security guarantees/assurances;
(d) Assistance in the development of the (non-nuclear) energy sector.

Such incentives would be country specific. An understanding is needed as to what factors are applicable to the partner State and what factors are applicable to the host State, since they would differ for each.

107. Finally, it can be noted that with the help of such elements, multilateral options can be compared among themselves, as well as with purely national arrangements.

URANIUM ENRICHMENT

108. The term 'enrichment' is used in relation to an isotope separation process by which the abundance of a specified isotope in an element is increased, such as the production of enriched uranium from natural uranium or heavy water from plain water.[17] An enrichment facility separates isotopes of uranium to increase the relative abundance, or concentration, of ^{235}U in relation to ^{238}U. The capacity of such a facility is measured in separative work units.

Technologies

109. Uranium must be enriched if it is to be used in certain reactor types and in weapons. This means that the concentration of fissile ^{235}U must be increased before it can be fabricated into fuel. The natural concentration of this isotope is 0.7%, but a concentration of around 3.5% is usual to sustain a chain reaction in the most common commercial nuclear power plants. Some 93% enrichment is customary for weapons and for naval propulsion. Yet, naval propulsion is possible with only 20%, or even less. The enrichment process is not linear, since as much separative work is needed between 0.7%

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, *IAEA Safeguards Glossary,* International Nuclear Verification Series No. 3, IAEA, Vienna (2003)

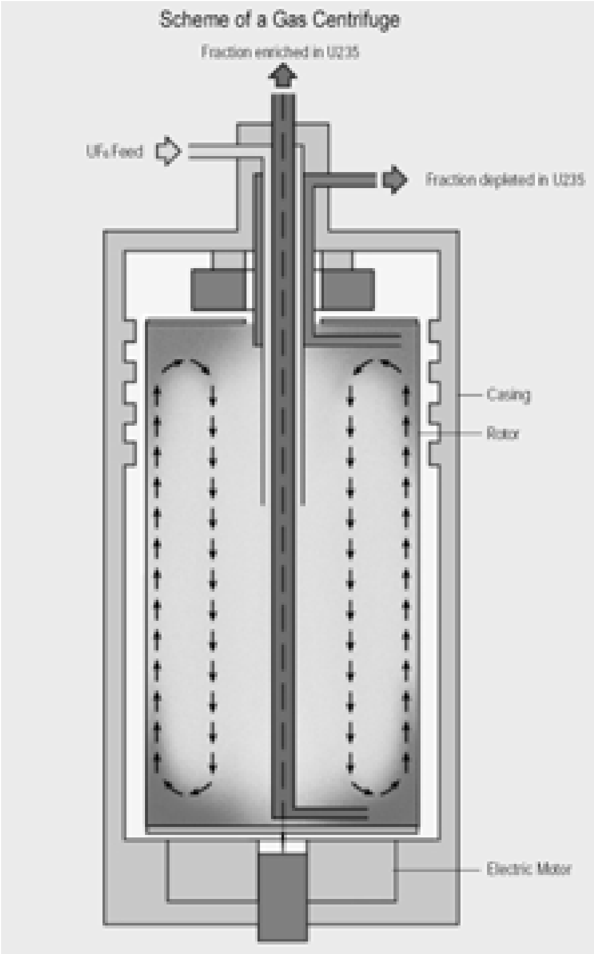
and 2% as between 2 to 93%. This means that the enrichment workup to the weapon level is reduced to less than one half and the amount of uranium feed to less than 20%, when commercial enriched uranium is readily available.

110. Of the techniques for increasing the concentration of ^{235}U, seven are of particular importance.

111. *Gaseous diffusion.* This was the first method of enrichment to be commercially developed. The process relies on a difference in the mobility of different isotopes of uranium when they are converted into gaseous form. In each gas diffusion stage, uranium hexafluoride gas (UF_6) is pumped under pressure through a porous nickel membrane (installed sequentially in a cascade), which causes the lighter gas molecules containing ^{235}U to pass through the porous walls of the tube more rapidly than those containing ^{238}U. This pumping process consumes large amounts of energy. The gas that has passed through the tube is then pumped to the next stage, while the gas remaining in the tube is returned to lower stages for recycling. In each stage, the concentration of $^{235}U/^{238}U$ is increased only slightly. Enrichment to reactor grade requires over a thousand stages.

112. *Gas centrifuge.* In this type of process, uranium hexafluoride gas is forced through a series of rapidly spinning cylinders, or centrifuges. The heavier ^{238}U isotopes tend to move towards the wall of the cylinder more than the lighter molecules containing ^{235}U. The gas nearer the centre is removed and transferred to another centrifuge for further separation. As it moves through a succession of centrifuges, the gas becomes progressively richer in the ^{235}U isotope. Electricity requirements for this process are relatively low compared with gaseous diffusion, and as a consequence this process has been adopted for most new enrichment plants.

113. *Aerodynamic separation.* The so-called Becker technique involves forcing a mixture of hexafluoride gas and either hydrogen or helium through a nozzle at high velocity and then over a curved surface. This creates centrifugal forces that act to separate the ^{235}U isotopes from the ^{238}U. Aerodynamic separation necessitates fewer stages to achieve comparative enrichment levels than gaseous diffusion, but this process still requires large amounts of electricity and is not generally considered economically competitive. In a significantly different aerodynamic process from the Becker process, a mixture of uranium hexafluoride and hydrogen is spun centrifugally in a vortex within a stationary wall centrifuge. Withdrawal of the enriched and depleted streams takes place from both ends of the tubular centrifuge in an



Schematic drawing of a gas centrifuge (drawing courtesy of Urenco Germany).

arrangement somewhat similar to the revolving centrifuge. An industrially sized plant of 250 000 SWU/a capacity for a maximum 5% ^{235}U enrichment operated within South Africa for almost ten years, but also suffered from excessive energy consumption and was closed down in 1995.

114. *Laser enrichment.* The laser enrichment technique involves a three stage process; excitation, ionization and separation. There are two techniques to achieve these effects, the 'atomic approach', and the 'molecular approach'. The atomic approach is to vaporize uranium metal and subject it to a laser beam at a wavelength that excites and ionizes the ^{235}U atoms, but not the ^{238}U atoms. Then, an electric field sweeps the ^{235}U atoms onto a collecting plate.

The molecular approach also relies on differences in the light absorption frequencies of uranium isotopes, and begins by exposing molecules of uranium hexafluoride gas to infrared laser light. ^{235}U atoms absorb this light, thereby causing an increase in their energy state. An ultraviolet laser can then be used to break up these molecules and separate the ^{235}U. This process appears to have the potential to produce very pure ^{235}U and ^{238}U, but overall efficiencies and recombination rates remain to be proven. It should be noted here that the molecular process can only be used to enrich uranium hexafluoride and is not suitable to 'clean' high burnup Pu metal as is possible in principle with the atomic process that can enrich both U and Pu metal. The molecular process is, therefore, marginally more non-proliferation friendly than the atomic laser process.

115. *Electromagnetic isotope separation (EMIS).* The EMIS process of enrichment is based on the fact that an electrically charged atom, travelling through a magnetic field, moves in a circle whose radius is determined by the ion's mass. EMIS is achieved by creating a high current beam of low energy ions and allowing them to pass through a magnetic field created by giant electro magnets. The lighter isotopes are separated from heavier isotopes by their differing circular movements. This is an old technique, used in the early 1940s. Coupled with modern electronics, it can serve for the production of weapon-grade materials, as Iraq attempted to do in the 1980s.

116. *Chemical separation.* This form of enrichment exploits the fact that ions of these isotopes will travel across chemical 'barriers' at different rates because of their different masses. There are two methods to achieve this: the method developed in France of solvent extraction; and the process of ion exchange used in Japan. The French process involves bringing together two immiscible liquids in a column, giving an effect similar to that of shaking a bottle of oil and water. The Japanese ion exchange process requires an aqueous liquid and a finely powdered resin, which slowly filters the liquid.

117. *Plasma separation.* In this process, the principle of ion cyclotron resonance is used to selectively energize the ^{235}U isotope in a plasma containing ^{235}U and ^{238}U ions. The plasma flows through a collector of closely spaced, parallel slats. The large orbit ^{235}U ions are more likely to deposit on the slats, while the remaining plasma, depleted in ^{235}U, accumulates on an end plate of the collector. The only countries known to have had serious plasma experimental programmes are France and the USA. In the USA, development was dropped in 1982. The French project was suspended around 1990, although it is still used for stable isotope separation.

118. Thus far, only gas diffusion and centrifugation have reached commercial maturity. To a different degree, all seven techniques are more or less sensitive in terms of proliferation, since they can be used in a clandestine programme to produce HEU from natural uranium or from LEU regardless of cost. However, the signatures will be different, affecting the likelihood of detection.

Historical Background

119. Multinational arrangements have been somewhat more successful in uranium enrichment than in similar efforts in the field of spent fuel reprocessing. In part, this is because reprocessing technology is much more widely known, and uses more conventional industrial techniques than enrichment, which was originally, and exclusively, based on the very sophisticated, industrially complex and highly classified gaseous diffusion technology. The newer centrifuge enrichment technology is still subject to the kinds of uncertainties that make joint ventures involving cost and risk sharing more appealing.

120. The two uranium enrichment consortia, Urenco and EURODIF, are institutional expressions of the movement towards an indigenous European enrichment capability. In spite of initial difficulties, they came to represent two different economic and industrial models of multinational ownership and operation, neither of which was established for explicitly non-proliferation purposes, but both of which contributed to that end.[18]

121. Urenco is the more complex of the two organizations, embracing enrichment facilities in three countries: Germany, Netherlands and the United Kingdom. Based on the Treaty of Almelo, Urenco owns and operates gas centrifuge enrichment facilities in the three participating States, helps to coordinate research and development (at first jointly, then individually, and then collectively once again), assures equal access to developments in centrifuge technology by any of the members, and executes contracts for the sale of services to third countries with the unanimous agreement of the participants.

122. The main driving force behind the setting up of the Urenco organization in the early 1970s was commercial; it was clear to the British, Dutch and German shareholders that developing the centrifuge technology and

[18] SCHEINMAN, L. The nuclear fuel cycle: A challenge for non-proliferation, *Disarmament Diplomacy* (March/April 2004).

exploiting it solely for their respective national power programmes would bring security of supply, but not at a competitive cost. Clearly, the best way forward was to cooperate and share development and operating costs, firstly to supply their joint national requirements, and subsequently, if the outcome was a more competitive position, to be able to sell enrichment services commercially outside their domestic markets.

123. Nonetheless, for a business and a technology as sensitive as uranium enrichment, there were other political considerations, that helped to drive the decision to set up such an international programme. The three governments believed that the type of international organization that could be established — with multinational organization and management, together with tri-national political oversight and control rights — would prevent the proliferation of technology and materials. It is also worth recalling that, at that time, there were significant political sensitivities to building a plant to enrich uranium in Germany; this was avoided by building the first German owned capacity in Holland, as a joint Dutch/German owned facility, operated by an international team.

124. From the start, EURODIF involved five participating countries — Belgium, France, the Islamic Republic of Iran (Iran), Italy and Spain — but only one enrichment facility, located in France. Unlike Urenco, which is oriented towards an external market, EURODIF was intended to serve the domestic fuel requirements of its members. The level of investment of each member corresponded to its percentage share of the product, and sensitive barrier technology was held by only one member: France. Thus, while excluding the transfer or sharing of sensitive technology, EURODIF did provide European participants with an assurance of supply, and an equity share in a production enterprise utilizing proven advanced technology. Unlike Urenco, EURODIF has never been a manufacturer of enrichment equipment.

125. Neither of the two enrichment consortia have been trouble-free. Urenco has faced difficulties both in terms of technology and investment. It was originally intended that Urenco would develop a single centrifuge technology that would be exploited on a centralized basis. The participants, however, had already made heavy investments in technology development at the time Urenco was established, and they were unwilling to forego this investment in favour of a common technological approach. As a result, they decided in 1974 to permit each of the shareholders to continue developing their own technology, in order to determine which one would best apply for

new common facilities. Insofar as investment was concerned, Urenco plants were to be built with equal ownership and investment by the three partners, regardless of location. By the mid-1970s that formula was revised in favour of a two-thirds national/one-third partners' investment arrangement, in response to differences among the shareholders regarding the timing for new facilities and the appropriate marketing strategy. Subsequently, the formula was revised again to reflect a 90% national ownership in Urenco facilities. Later, all facilities were brought once more under a single ownership with full multinational management and operation.

126. EURODIF's problems have been of a somewhat different nature. Changes in the pace of national nuclear power programmes have affected the timing of requirements for enriched uranium, particularly in Italy, which had taken a 23% share in EURODIF production at the time the organization was created. Unable to absorb its share of the production, yet required to take and pay for it, Italy sought to alter its relationship to the consortium. Iran was faced with the same problem, and received back the major portion of its initial investment. These changes markedly increased the French share, further reducing the multinational character of the enterprise.

127. The EURODIF and Urenco experiences underscore the economic vulnerabilities of multinational arrangements, a lesson for other countries contemplating similar ventures. A multinational fuel cycle strategy, just like a national one, must rest on a solid economic justification in order to be successful.

Current Status

128. Enrichment facilities, under IAEA safeguards, presently exist in: Argentina, Brazil, China, Germany, Iran, Japan, Netherlands and the United Kingdom. Furthermore, enrichment facilities not under safeguards exist in France, India, Pakistan, the Russian Federation and the USA.

129. The next decade will see something very unusual in the nuclear fuel cycle: all of the world's commercial enrichment enterprises will be engaged at the same time in rebuilding and, to a lesser extent, expanding their industrial capacities. Old plants will be decommissioned and new ones will be added as new Parties come into the picture.[19] The annual world demand in 2004 was

[19] RWE NUKEM, *Market Report (*November 2004).

Georges Besse gaseous diffusion enrichment plant, EURODIF, in Tricastin, France (photo courtesy of AREVA).

about 38 million SWU, expected to grow to some 43 million SWU in 2020,[20] with higher projections of up to 52 million SWU.[21] The current production capacity amounts to 50 million SWUs per year.

EURODIF

The Georges Besse gas diffusion plant (GDP), now operated by Areva, has been running in recent years with an output of approximately 8 million SWU/year from a nominal capacity of 10.8 million SWU/year. Investment in new GDPs, however, will not be competitive with the latest generation of centrifuges, which is why the Georges Besse plant will be replaced by centrifuge capacity in the years ahead. The replacement will be based on Urenco technology. A new Quadripartite Agreement, focusing on the protection of the technology, will ensure that the basic Urenco arrangements (the Treaty of Almelo between the British, German and Dutch Governments) are also

[20] AREVA, France communication to the Expert Group.

[21] *The Global Nuclear Fuel Market: Supply and Demand 2003–2025,* World Nuclear Association, London (2003).

Centrifuge enrichment, at Urenco in Gronau, Germany (photo courtesy of Urenco Germany).

respected in the joint venture with Areva in France. The installed capacity of the new French enrichment plant will be some 7.5 million SWU/year as of 2015. In spite of this cooperation, Areva and Urenco will remain competitors in the market of enriched uranium, as explicitly requested by the European Commission.

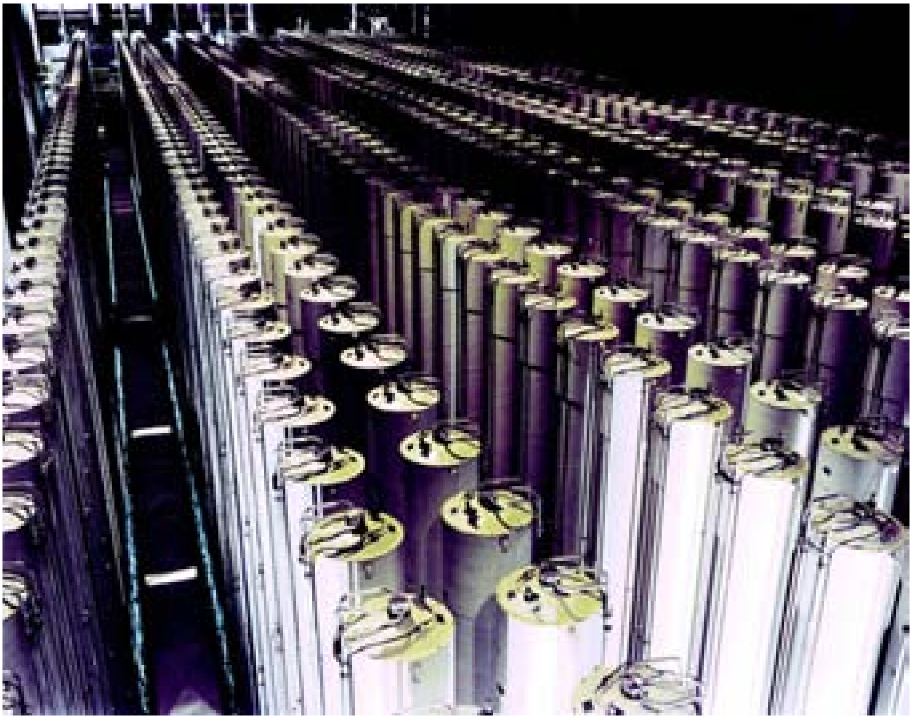
Urenco

The three enrichment plants of Urenco (Gronau in Germany, Almelo in the Netherlands and Capenhurst in the UK) have a total capacity of 6 million SWU/year. The capacity will increase slowly to the level of 8 million SWU/year by the end of 2007.

One of the more closely followed projects in the enrichment world is the current project of Urenco and its American utility partners (Louisiana Enrichment Services, LES) to site and build an enrichment facility in the USA to diversify the national SWU sources of supply. Urenco has estimated (based on its own experience) that a plant can be made operational within about two years of the start of construction. The first enriched uranium from the new US facility is thus expected to roll off the line as early as the last quarter of 2008. Full capacity will be 3 million SWU/year by 2013.

United States Enrichment Corporation (USEC)

USEC is responsible for the marketing of the 500 tonnes of HEU released from the Russian weapons stockpile, and transformed into LEU before shipment to the USA. For the future, unlike Areva and LES, USEC is banking on a new technology that has never operated on a commercial scale. The USEC centrifuge machines will incorporate a number of enhancements that modern industrial techniques and computer technology now make possible. Each of them is said to be about 12 m tall and roughly 50 cm in diameter, far larger than Urenco's latest model. This represents major engineering challenges and makes for a rather technically risky nuclear project. The payoff, according to USEC, is that they will be the most economical centrifuges ever built. The current plan calls for capacity of one million SWU/year in 2010 and 3.5 million SWU/year at "full production" in 2011.



USEC's centrifuge is based on the US Department of Energy's original centrifuges (pictured here), which operated during the 1980s at USEC's Piketon facility (photo courtesy of USEC, Inc.).

Rosatom

The Russian enrichment production runs extremely well using fairly basic 'subcritical' short machines that operate reliably with little maintenance. The Russian current enrichment capacity is about 20 million SWU/year. Freshly mined uranium in the Russian Federation falls short of the annual requirement to fuel Russian type reactors, both domestic and foreign. The shortfall is made up in several ways, including using reprocessed uranium, the return of feed from the Russian–USA deal on HEU, and tails-stripping activities involving both foreign and possibly domestic sources of depleted uranium. The total separative capacity is expected to reach 26 million SWU/year a few of years beyond 2010.

Japan Nuclear Fuel Limited (JNFL)

The Uranium Enrichment Plant is operating with a capacity of 1.05 million SWU/year. A centrifuge with performance of 2.5 to 3 times higher than conventional types is under development. In the future the capacity is planned to be increased by 1.5 million SWU/year, meeting approximately one-third of the enrichment needs of nuclear power plants in Japan.

Economics

130. Little information is available on the economics of enrichment. Most transactions of enrichment services are made through long-term contracts. The spot/secondary market price for a SWU has been moving from a $60–80 range in the late eighties to $90–110 now. With respect to gaseous diffusion, the electricity cost component may be close to $60, since it takes some 3000 MWe to produce 10 million SWU, assuming a cost of 3 cents/kWh. Centrifuge production should offer a comfortable margin, even when taking into account the higher capital costs.

131. Uranium enrichment facilities are extremely capital intensive (centrifugation even more than diffusion). Therefore, from the strict short-term economic perspective, such facilities should serve large reactor fleets or be commercially competitive on the world market to make economic sense.

Assurance of Services

132. Separative work capacity in the world is expected to exceed demand for the next ten years, and thereafter remain abreast of demand. With suppliers

eager to do business, there is hardly a reason to doubt the ability of the market to provide adequate assurance of enrichment services. Yet, among the suppliers themselves, those with large nuclear power programmes — such as France and the USA — want to maintain a self-sufficient supply capacity. For smaller countries, the MNA route could offer economic and strategic advantages in buttressing regional assurances of supply.

Legal and Institutional Factors

133. Under this heading, the cases of Urenco and EURODIF may again serve to illustrate the related legal and institutional arrangements that need consideration.

134. At Urenco, political responsibilities are kept separate from industrial and commercial operations. The political aspects of the activities of the Urenco Group are controlled by the intergovernmental Joint Committee, which was set up under the agreement of the Treaty of Almelo (signed and ratified by all three governments in 1971). This Joint Committee has jurisdiction over those areas of international concern, including safeguards, classification and security, the suitability of enrichment service customers, the transfer of technical information and technology to third parties, and the siting of major facilities. The Joint Committee governs the way political and security aspects of any technology joint ventures are managed. For example, in the case of the LES partnership venture to build a centrifuge enrichment plant in the USA, the three governments of the Joint Committee reached agreement with the US Government on the Quadripartite Agreement. This agreement sets out the required arrangements under which Urenco classified information and/or technology is to be transferred into the USA, in order to enable the plant to be licensed, constructed and operated, (and the control of any information flowing back to Urenco from the US plant). The commercial viability of any such project is not covered; it is entirely a matter for the Urenco management and its shareholders.

135. Through the late 1970s and 1980s, Urenco operated as three separate national companies working together as a partnership; each country had the ability to design, develop and manufacture centrifuges, and build, commission and operate the plant. Since the restructuring of the Urenco Group in 1993, the organization has been run on an international basis from the Group Headquarters in the UK, with plant design concentrated in the UK, centrifuge manufacture in the Netherlands and centrifuge R&D in Germany.

136. The Almelo Treaty allows for any of the partner countries to formally withdraw from the Treaty, upon one year's notice and after the first ten years of its operation, albeit with some difficult commercial negotiations. If this were to happen, one could then envisage a new, national organization, which could take charge of the national plant. However, although the continued operation of existing enrichment plants would not be compromised, the international division of responsibilities now within the Urenco Group would make this more difficult/expensive to sustain. The most difficult aspect would be the ability to manufacture and assemble centrifuge components for new capacity, and to re-establish R&D capability for future development.

137. Therefore, Urenco represents a good management model for multinational arrangements and demonstrates the viability and utility of separating the political and business decision making authorities, a division of authority that has never disrupted the industrial and operational responsibilities of the organization.

138. In comparison with Urenco, EURODIF is straightforward: management, operations, and technology remain under the national control of the host State. Its potential value as a model for non-proliferation is correspondingly greater. On the other hand, precisely because of the managerial, operational, and technological limitations that this approach imposes on all but the host nation, its appeal may be limited to States which have little interest in the opportunity to participate in management or to have access to advanced technology, but which are content to have access to fuel supply on a timely, predictable, and economically attractive basis.

139. With no transfer or sharing of sensitive technology, EURODIF was able to provide its European partners with irrevocable security of supply. The EURODIF model, however, has one distinct disadvantage whenever a strategic redirection in technology is necessary, as is now the case with EURODIF itself going from diffusion to centrifugation. Although the other shareholders outside the host country may participate in a broad decision to adopt entirely new technology or marginally change the existing technology through upgrading, they have no access to a detailed technical risk assessment of the future new or upgraded technology and they have to rely totally on the host country's own internal and confidential assessment. Partners with a significant investment may perceive this as an unacceptable risk and the Urenco model has a distinct advantage in this regard.

Non-Proliferation and Security

140. Today, if cost is of no concern, small centrifuge facilities can be built in most industrialized countries. In order to produce one significant quantity of HEU (that is the approximate amount required for manufacturing a nuclear explosive device taking into account unavoidable losses), there is no need for plant sizes comparable to the large commercial facilities discussed earlier in this chapter: A good sized office conference room would accommodate the required number of centrifuges. The task is even simpler if enriched uranium is at hand. As noted earlier, at the 3.5% enrichment level, used by nuclear power plants, six-tenths of the separative work needed for weapon-grade uranium has already been carried out. At the 20% enrichment level, used by research reactors, nine-tenths of the separative work needed for weapon-grade uranium has already been carried out. Once an enrichment facility has been established, it is estimated that it could take as little as a few months to produce enough HEU for one SQ (significant quantity), should the operators so desire and without any external restraint.

141. Enrichment facilities represent a particular challenge for international verification, because of the veil of secrecy that enshrouds such facilities. On the one hand, facility owners are often reluctant to let outsiders have a close look at their centrifuges, to protect their legitimate trade secrets. On the other hand, international inspectorates prefer to keep their own inspectors away from proliferation relevant know-how. Verification must sometimes follow indirect routes, the enrichment level in the piping and in the environment being a good indicator of misuse of a facility, so that together with in situ inspections, modern technology — in particular the physico-chemical analyses of trace particles — offers a number of powerful tools capable of detecting anomalies on known nuclear sites.

142. The safeguards approach developed for gas centrifuge uranium enrichment plants subject to safeguards and operating at a stated uranium enrichment of 5% or less involves inspection activities both inside and outside cascade areas. Inspections outside the cascade hall are focused on verifying declared flows and inventories of nuclear material to detect the diversion of declared uranium. Inspections of cascade areas, known as Limited Frequency Unannounced Access[22] (LFUA) are designed to detect the production of uranium at an enrichment level which is higher than that declared, while

22 See the *IAEA Safeguards Glossary.*

protecting the sensitive technical information related to the enrichment process. The LFUA regime, inter alia, secures access with short notice for IAEA inspectors to the cascade area of the plant concerned. Inspection activities to be implemented within the cascade area include visual observation, radiation monitoring and non-destructive assay measurements, environmental sampling, and application and verification of seals. The activities to be performed and the frequency of access to the cascade area depend on the design and operation specifics of the plant.

143. With respect to multinational enrichment facilities, past studies have drawn no specific conclusions as to their possible implications for non-proliferation since, at the time, this technology was of little concern. First, and insofar as safeguards are concerned, the MNA concept implies fewer larger facilities. Having fewer sites to watch means, in turn, that with a given amount of resources — a given safeguards budget — the IAEA is in a position to monitor more carefully. Second, in terms of proliferation risks, a joint facility with multinational staff places all participants under a greater degree of scrutiny from peers and partners, all of which strengthens non-proliferation and security. By their very nature, such MNAs have the potential to deter a breakout by the host partner. A countervailing factor, of course, is the possibility that international cooperation may increase proliferation risks (misuse of know-how, of procurement and of R&D). In this context, it would seem that the Urenco model is quite appropriate for partners having already developed their own individual know-how, while the EURODIF model has the upper hand when most participants/partners have not already done so.

Options for Multilateral Approaches for Enrichment

144. This section suggests pros and cons associated with different approaches to assuring the supply of enrichment services, using the standard typology defined earlier.

Type I: Assurances of services not involving ownership of facilities.

(a) Suppliers provide additional assurances of supply.

145. This would correspond to enrichment plant operators, individually or collectively, guaranteeing to provide enrichment capacity to a State whose government had in turn agreed to forego building its own capacity, but which

then found itself denied service by its intended enrichment provider for unspecified reasons.

Pros	Cons
1. No further dissemination of know-how; hence reduced proliferation risks (A).	1. The cost of maintaining reserve idle capacity (or a fuel bank), if required, needs to be assigned among the suppliers (B).
2. Ease of implementation, few participants, no new ownership arrangements required (B).	2. For some, States with enrichment facilities may not be considered politically diverse enough to provide needed assurance (B).
3. Reliance on a well functioning market (B).	3. Credibility of 'assurance' commitments unclear in the case of private firms (B).
4. No additional safeguards financial burden on the IAEA (B).	4. Maximum dependence on 'prior consent rights' of supplying countries (B).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

By the very nature of the nuclear business worldwide, any guarantee from a supplier would have the implicit or explicit agreement of that supplier's government. However, the governmental agreement would apply only to the supplier under its jurisdiction. This model may be understood as a 'private fuel bank' (see the section on spent fuel processing).

(b) International consortium of governments.

146. In this case, it is a consortium of governments that would guarantee access to enrichment services; the suppliers would simply be executive agents. The arrangement would be a kind of 'intergovernmental fuel bank'. The mechanism might involve legislation establishing a government claim on such capacity under specified circumstances. Alternatively, it might be a contract, under which a government buys guaranteed capacity under specified circumstances. Different States might use different mechanisms. Most pros and cons are shared with the preceding case:

Pros	Cons
1. No further dissemination of know-how; hence reduced proliferation risks (A).	1. Difficult negotiations among many governments and suppliers (B).
2. Cost of reserve keeping can be borne by governments rather than by the suppliers (B).	2. For some, States with enrichment facilities may not be considered politically diverse enough to provide needed assurance (B).
3. Reliance on a well-functioning market (B).	3. Remaining dependence on "prior consent rights" attached by supplier States (B).
4. No additional safeguards financial burden on the IAEA (A).	4. Existing property rights must be taken into account (B, E).
5. Consortium guarantees more reassuring (B).	

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

(c) IAEA related arrangements.

147. This is a variation of the preceding option, with the IAEA acting as the anchor of the arrangement. Essentially, the IAEA would function as the guarantor of supply to States in good standing under the NPT and which are willing to accept the requisite conditionality (which would need to be defined, but which would likely need to include foreswearing a parallel path to enrichment/reprocessing plus acceptance of the AP). The IAEA might either hold title to the material to be supplied or, more likely, act as guarantor, with backup agreements between the IAEA and supplier countries to fulfil commitments made by the IAEA effectively on their behalf. These assurances in turn might need to be supplemented by standby arrangements whereby one nuclear supplier would step into the shoes of another should the first fail to perform. In effect, the IAEA would be establishing a default mechanism, only to be activated in instances where a normal supply contract had broken down for other than commercial reasons, in which case supply would need to be in conformity with the previously agreed criteria.

148. The suggested pros and cons are therefore similar. An additional pro reflects the composition of the IAEA: its membership is broader than that of a commercial consortium. Furthermore, there is the IAEA's track record,

reputation, credibility and relevant experience. The viability of the arrangement might nonetheless require a sufficient number of suppliers to grant prior generic consent for the transfer of the respective materials and services.

Pros	Cons
1. No further dissemination of know-how; hence reduced proliferation risks (A).	1. Difficult negotiations among many governments and suppliers (B).
2. Cost of reserve keeping can be borne by governments rather than by the suppliers (B).	2. For some, States with enrichment facilities may not be considered politically diverse enough to provide needed assurance (B).
3. Reliance on a well-functioning market (B).	3. Remaining dependence on "prior consent rights" attached by supplier States (B).
4. No additional safeguards financial burden on the IAEA (A).	4. Existing property rights must be taken into account (B, E).
5. Consortium guarantees more reassuring (B).	

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

149. Several questions can be raised with respect to the IAEA and its special status as an international organization subject to the control of its Member-States. Any guarantee provided by the IAEA would require approval by its Board of Governors. For a recipient country, this amounts to 35 governments to deal with instead of one or a few. Therefore, what would be legitimate grounds for denial on the part of the IAEA besides safeguards, safety and security? For States seeking a supply guarantee, what would be the real value added of an IAEA guarantee? Questions requiring further clarification also relate to whether procedures for arbitration or legal settlement would be available after a decision by the Board, and whether the IAEA would carry a commercial liability exposure.

Type II: Conversion of existing national facilities to multinational ones.

150. Converting a national facility to international ownership and management would involve the creation of a new international entity, which would operate as a new competitor on the world enrichment market. Thus a number of the suggestions in the table below reflect the pros and cons of an international entity in such a situation, independent of the related technology. Others reflect the fact that most of the existing facilities are in NWS or non-NPT States.

151. The EURODIF model would be the most likely model for the conversion of an existing national facility into a multilateral arrangement. For such a model, the pros and cons are as follows.

Pros	Cons
1. No new construction required. No further dissemination of know-how; hence reduced proliferation risks (A, D).	1. Several facilities would likely be needed in sufficiently politically diverse countries to provide needed assurances (B).
2. When additional safeguards measures are introduced in facilities where they do not now exist, non-proliferation is strengthened (A, F).	2. Existing property rights must be taken into account (B, E).
3. Potential strengthening of proliferation resistance through international management (A, E).	3. Difficulties of international management, especially with the distinctive burden of providing assurances of supply (B).
4. Potential pooling of international expertise and resources (B, D, E).	4. Potential proliferation risks due to diffusion of international know-how (A).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

Type III: Construction of new joint facilities.

152. The two historical precedents for the construction of a new multinational enrichment facility are Urenco and EURODIF. New joint construction was also the focus of the IAEA's 1975–1977 Regional Nuclear Fuel Cycle Centre study, albeit in the context of reprocessing, and is thus of general

relevance here. Most of the suggested pros and cons below stem from this context.

Pros	Cons
1. Strengthening of proliferation resistance through multinational oversight, management and staff, with less opportunity for diversion, theft and loss, and breakout (A, E).	1. Higher proliferation risks due to broader access to know-how (unless the EURODIF model is followed) (A, C, D, E).
2. Pooling of international technical expertise and financial resources (B, D).	2. Uncertain commercial competitiveness in a market where there is no shortage of supply or possible market disturbances by subsidized facilities (B).
3. Economies of scale (B).	3. Difficulties of international management, as experienced by Urenco (E).
4. Fewer larger enrichment centres mean fewer sites to safeguard (A, C).	4. Difficulties with long-term cost sharing, as experienced by EURODIF (E, F).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

153. The planning of a new uranium enrichment facility would be a challenging undertaking, requiring large human and financial resources, in which many considerations would be intertwined. On the non-proliferation side, these considerations are: diversion risks; clandestine parallel programmes; breakout from agreements and from the NPT; and safeguards arrangements. On the business side, such considerations are: siting; economics; political and public acceptance; access to technology; partners' involvement in operation; and non-nuclear commercial and trade agreements. However, in the case of enrichment, there are the existing examples of Urenco and EURODIF to refer to.

SPENT FUEL REPROCESSING

154. Reprocessing facilities dissolve and process spent nuclear fuel to chemically separate uranium and plutonium from fission products. The recovered uranium and plutonium can be recycled in MOX fuel in nuclear power plants

to generate additional energy, thereby making more complete use of uranium resources and reducing enrichment requirements. Reprocessing also facilitates final waste disposal by reducing the volume of high level waste and removing plutonium. Reprocessing is an international business with facilities in France, the Russian Federation and the United Kingdom willing to accept foreign spent fuel for reprocessing. With the exception of Russian reprocessing of Russian origin spent fuel, current laws in these three countries require that all final waste be eventually returned to their countries of origin.

155. The reasons given for civilian reprocessing are: recycling the fissionable components — plutonium (e.g. as MOX) and uranium — and for radioactive waste management. Thus there is a close connection between reprocessing and MOX fuel fabrication: it is important to match these activities to avoid the build-up of separated plutonium. This chapter therefore looks at reprocessing facilities in isolation, and also in connection with their complementary MOX fabrication facilities.

Technologies

156. All operating commercial reprocessing plants, and the one under construction at Rokkashomura, use the PUREX process and 'chop-leaching' technique. After storage for cooling, a fuel assembly's end-fittings are sheared off, the fuel rods are chopped into pieces and dissolved in nitric acid, and cladding hulls and other residue are removed. A multistage solvent extraction process, using TBP as a solvent, is generally used, first, to separate uranium and plutonium from fission products and minor actinides and second, to partition the uranium and plutonium from each other. The end products from the process are uranyl nitrate solution, plutonium nitrate solution and raffinate solution containing fission products and minor actinides.

157. At the Tokai and Rokkashomura plants in Japan, the immediate next steps are denitration to produce uranium oxide powder (UO_3) and co-denitration to produce mixed uranium–plutonium oxide powder (UO_2–PuO_2). Plutonium nitrate solution is immediately mixed with uranyl nitrate solution without separation. These are the forms in which the uranium and plutonium are stored. At the Thorp plant in the UK and the La Hague plants in France, the separated uranium and plutonium are stored as UO_3 and PuO_2. Eventually, the plutonium oxide or mixed oxide powder is shipped to fuel fabrication and then returned to the owner as MOX fuel assemblies. Currently the uranium oxide is largely stored, although Urenco re-enriched

Rokkasho Reprocessing Plant, Rokkasho, Japan (photo courtesy of JNFL).

recycled uranium in the past and some is still sent to Russia for re-enrichment.

158. The RT1 plant in the Russian Federation accepts WWER-440 spent fuel and HEU spent fuel from fast reactors, research reactors and submarine reactors. The principal product is uranium oxide, which is recycled in RBMK fuel. Plutonium oxide is stored.

159. Research to improve existing reprocessing technologies covers advanced PUREX processes and other aqueous processes, the THOREX process for separating ^{233}U in thorium based fuel cycles, non-aqueous processes including volatility processes and reductive extraction processes, and pyrochemical processes.

160. Pyrochemical separation relies on electro-refining techniques, in which spent fuel is dissolved in a molten salt electrolyte, and the useful material is then precipitated onto electrodes. Although they have not yet been developed beyond the laboratory or pilot plant scale, pyrochemical techniques are potentially applicable to most fuel forms. Moreover, because they make it more difficult to completely separate uranium, plutonium and minor actinides from fission products, pyrochemical processes are also considered more proliferation resistant than the PUREX process. Incomplete separation maintains high deterrent radiation levels. However, it also makes the output of pyrochemical processes less suitable for recycle in MOX fuel in thermal reactors, restricting its use largely to fast reactor fuel.

161. Several States are also conducting substantial research on partitioning and transmutation (P&T) as part of processing spent nuclear fuel. P&T, however, has no immediate implications related to non-proliferation.

Historical Background

162. The earliest fuel reprocessing efforts were devoted to recovering plutonium from irradiated fuel for military use. However, the initially rapid expansion of civilian nuclear power and high projections of future growth, coupled with a very conservative understanding of the long term availability of uranium resources, argued strongly for reprocessing spent fuel to recycle fissile plutonium and uranium. The argument was especially strong in countries with limited uranium resources, such as France, India, Japan, UK and to a lesser extent the former Soviet Union.

163. The most efficient way to use reprocessed fuel is in fast reactors. Fast reactors have a long history, with the first nuclear electricity ever produced coming from a fast reactor, EBR-1, in 1951. Additional fast reactors, including some fast breeder reactors, subsequently came on line in the former Soviet Union, UK, USA, France, Germany, India and Japan. New reprocessing plants were planned (and some completed) in Western Europe and North America. However, the early economic incentives for reprocessing and recycling diminished, partly because of the slowdown in nuclear capacity growth starting in the 1970s, partly because uranium resource estimates continually rose and partly because of secondary sources from the release of some military uranium and from the re-enrichment of depleted uranium. The changed economic incentives limited the introduction of fast reactors and of reprocessing.

164. Only one fast reactor, the BN-600 in the Russian Federation, currently operates as a power reactor, and it uses not reprocessed plutonium fuel but fresh HEU fuel. India, however, has just begun construction (October 2004) of a 500 MW(e) prototype fast breeder reactor at Kalpakkam and there is ongoing research in a number of countries.

165. The principal historical example of a multinational arrangement is the European Company for the Chemical Processing of Irradiated Fuels (Eurochemic), created in 1959 by 13 European countries. Eurochemic was initially seen by its member countries as a way to pool financial and intellectual resources, and to gain national expertise in an expensive but promising industry. Its facility at Mol, Belgium, reprocessed civilian power reactor fuel

from 1966 to 1975. At the time of project termination, nuclear growth was slowing, there was overcapacity in the reprocessing business, European enthusiasm for international organizations like Eurochemic had dimmed, national chemical industries in member countries preferred to develop their own experiments with national government aid and Eurochemic's dependence on multiple governments for funding and decision making made it especially difficult to compete in what was anyway a difficult competitive business.

166. A second international reprocessing initiative (which contributed to the demise of Eurochemic) was the United Reprocessors Gesellschaft (UNIREP), created in October 1971 by British, French and German reprocessors. It followed a FORATOM (European Atomic Forum) recommendation to rationalize investment in order to establish a 'viable industry' in Europe given the then prevailing overcapacity. Wolff[23] describes UNIREP as "trilateral commercial cooperation in the form of an oligarchic cartel. Its immediate aim was to divide the European reprocessing market between the British and French plants until their capacity was saturated. At this point, a large German plant would take over." In the end, however, UNIREP never built a plant.

Current Status

167. Growth in reprocessing capacity has been limited. For civilian nuclear power plants, France has two large reprocessing facilities at La Hague owned and operated by Cogema; the UK (BNFL) has two and the Russian Federation (Rosatom) one. Three smaller facilities operate in India (BARC) — as well as one facility for thorium separation — and one in Japan (JNC). Except for the Japanese facility (Tokai), all currently operating plants are in either NWS or non-NPT States. All are owned directly by governments or by companies controlled by governments. The total nominal capacity available for reprocessing civilian spent fuel is approximately 5000 tonnes of heavy metal per year (t HM/a).

[23] WOLFF, J.-M., *Thirty-five Years of International Cooperation in the Field of Nuclear Engineering: The Chemical Processing of Irradiated Fuels and the Management of Radioactive Wastes*, OECD, Paris (1996).

TABLE 1. APPROXIMATE QUANTITIES OF MATERIAL SUBJECT TO IAEA SAFEGUARDS AT THE END OF 2003

Type of Material	Quantity of material (t)		
	Comprehensive safeguards agreements[a]	INFCIRC/66[b]	Nuclear weapon States
Plutonium[c] contained in irradiated fuel	626.54	33.4	95.9
Separated plutonium outside reactor cores	12.7	0.1	72.8
Separated plutonium in fuel elements in reactor cores	14.2	0.3	0
HEU (equal to or greater than 20% U-235)	21.7	0.1	10
LEU (less than 20% U-235)	45 480	3069	4422
Source material[d] (natural or depleted uranium and thorium)	88 130	2124	11 998

[a] Covering safeguards agreements pursuant to NPT and/or the Treaty of Tlatelolco and other comprehensive safeguards agreements.

[b] Excluding installations in NWS; including installations in Taiwan, China.

[c] The quantity includes an estimated 90 t of plutonium in irradiated fuel, which is not yet reported to the IAEA under the reporting procedures agreed to (the non-reported plutonium is contained in irradiated fuel assemblies to which item accountancy and containment/surveillance measures are applied).

[d] This table does not include material within the terms of subparagraphs 34(a) and (b) of INFCIRC/153 (Corrected).

168. About one third of the spent fuel that has been discharged from power reactors has been reprocessed up until today, a significant fraction of which is used for MOX fuel for LWRs. The rest is in interim storage. By the end of 2003, 78 000 tonnes of spent fuel had been reprocessed. The plutonium content of MOX fuel generally ranges from 4 to 40% depending on the capacity and type of reactor. In recent years the world's civilian power reactors generated approximately 89 tonnes of Pu per year in spent nuclear fuel; approximately 19 tonnes of Pu per year were separated out of spent nuclear fuel; approximately 13 tonnes of Pu were fabricated into MOX each year. The approximate amount of plutonium subject to IAEA safeguards at the end of 2003 is included in Table 1, along with other materials subject to IAEA safeguards.

169. The worldwide operational nominal capacity for MOX fuel fabrication is approximately 300 t HM/a. In 2001–2002, MOX fuel requirements for LWRs were approximately 190 t HM/a. MOX fuel was loaded on a commercial basis in 36 LWRs in Europe, and TAPS-1 and -2 in India operated with several MOX fuel assemblies on a trial basis. Although it is possible to use MOX in any

LWR, MOX is currently more expensive than fresh uranium oxide fuel, and no substantial increase in MOX fuel requirements is expected in the near term. Only France plans to license more PWRs for MOX. Japanese plans to load MOX fuel at LWRs have been delayed. In addition to this use in commercial LWRs, MOX fuel was used in Japan at the FUGEN advanced thermal reactor, prior to its being shut down in 2003, and the Joyo fast breeder reactor. It is also used at the Phénix reactor in France and in the experimental BOR-60 fast breeder reactor in the Russian Federation, and a few experimental fuel assemblies with MOX have been used at BN-600.

170. Construction of the new commercial reprocessing facility built at Rokkashomura in Japan started in 1993. Uranium commissioning began in 2004, active commissioning with actual spent fuel will begin in the course of 2005, and commercial operation is scheduled to begin in 2006. The Rokkashomura plant is unique in that the IAEA has been able to monitor and verify all stages of construction, a factor now considered essential for effective safeguards for any new reprocessing plant.[24]

171. Looking to the future, uranium prices have begun to rise in the last few years, and medium term projections of nuclear capacity are regularly revised upwards. Credible long term scenarios for nuclear power still range from a global phase-out in this century to a vast expansion. In fact, a number of countries are seeing a significant expansion of nuclear power, with a concurrent need for reprocessing and the use of MOX and, for countries committed to a high degree of nuclear fuel cycle independence, for fast breeder reactors.

Economics

172. Insights into the economics of multinational reprocessing based on the PUREX process come both from the experience of Eurochemic and UNIREP and from relevant studies. The principal IAEA study, Regional Nuclear Fuel Cycle Centres, focused on the back end of the fuel cycle, and more specifically on reprocessing. Its principal substantive motivation was the anticipated economies of scale in reprocessing facilities, but the study also addressed health, safety, environmental and non-proliferation issues.

[24] *Large Scale Reprocessing Plant Safeguards,* Report of the LASCAR Forum, STI/PUB/922, IAEA, Vienna (1992).

173. The key result was as expected. A regional fuel cycle centre using the PUREX process would be profitable using cost estimates, interest rates, etc., as developed in the study. The calculations showed substantial economies of scale in building and operating reprocessing facilities. The investment in a regional centre could be 40–60% lower than for national facilities in the case of countries with fairly large nuclear power programmes. For States with small nuclear power programmes, the regional cost could be a third or even less of the cost for a national facility. The time necessary to recover capital costs and start turning a profit could be shortened by ten years. The study also concluded that it was possible to evolve to this profitable operation by building the system from the core of existing or planned national installations at the time. The study perceived an incremental practical route from the then current situation to the goal of a regional centre.

174. The study also concluded that regional centres would offer safety, health and environmental advantages. These stemmed from the fact that big regional centres would require fewer sites. Fewer sites would mean fewer environmental impacts and fewer safety risks, and those two things together would mean fewer health impacts and risks, and also smaller cost. There was recognition that fewer, bigger sites would probably mean more shipping and transporting of nuclear material and, other things being equal, more transport would mean more chances for accidents. However, these risks were judged to have been outweighed by the risk reduction attributable to having fewer sites.

175. Despite the study's conclusively positive assessment, no regional fuel cycle centre has ever been built. The principal reason is that the economics changed. The study used a uranium price of \$40 per pound of U_3O_8 (in 1975 dollars), which appeared reasonable at the time, but the study also did a number of sensitivity analyses. Among other things, it concluded that, given the other economic parameter values that were assumed, even the regional reprocessing centre would be uneconomic if uranium prices were to drop as low as \$30 per pound of U_3O_8. In fact, they dropped below \$30 per pound of U_3O_8 (in 1975 dollars) three years after the study was completed and have for almost a quarter of a century been below half that value. The spot price for U_3O_8 as of 10 January 2005 was back up to \$20.70 per pound (or \$7.40 in 1975 dollars).

176. The economics of reprocessing, or more generally the Pu–MOX fuel cycle, have often been debated. France and the United Kingdom now possess significant industrial experience in reprocessing and recycling. They have

demonstrated that the cycle can be more or less competitive, depending on the price of uranium. In the long term, reprocessing makes it possible to recover valuable materials. In the short term, it reduces interim storage requirements, and in the medium term it reduces considerably the quantity and the radiotoxicity of waste to be disposed of. States with a significant nuclear programme and with a policy of energy independence have incentives to keep open the reprocessing and recycling strategy.

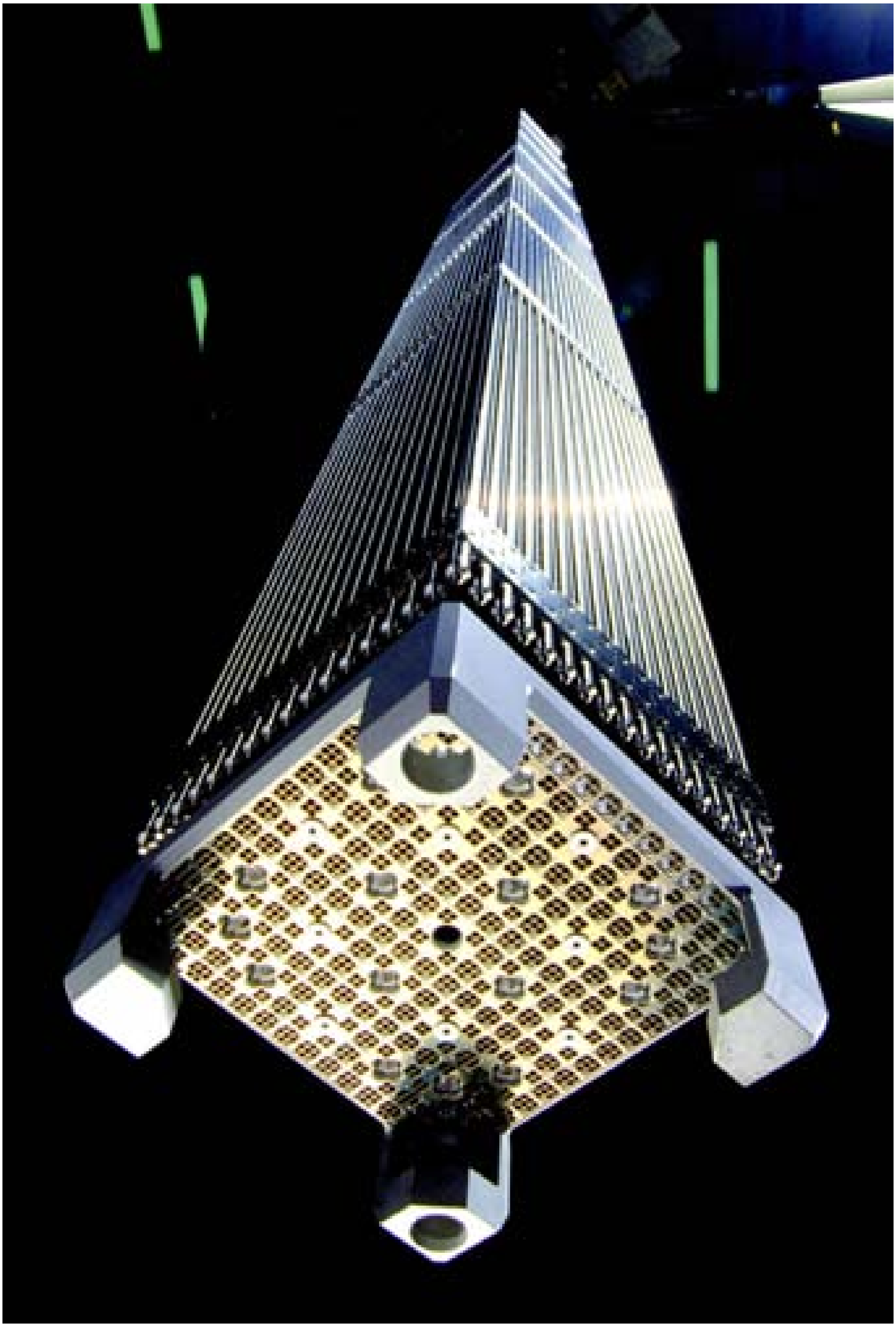
Assurance of Services

177. World capacity to reprocess light water reactor fuel is expected to exceed demand for many decades, until plutonium recycling becomes necessary and more economical. In the meantime, with several suppliers ready to do business, the market stands ready to provide adequate assurance of reprocessing services.

178. A State that agrees to forego building its own reprocessing capability, but wishes to have its spent fuel reprocessed and to use the separated plutonium and/or uranium in MOX fuel, will want some assurance that the reprocessing services will be available as needed. Or the State will want an assurance that a package of reprocessing and MOX fabrication will be available as necessary. These are the scenarios envisioned in the listing below of options and possible pros and cons.

179. Various conditions for the assurance of future reprocessing services should be fulfilled in order for a multilateral facility to live up to non-proliferation premises and to assure services. The following release conditions should be incorporated:

(a) Only MOX fuel and not separated Pu should be delivered or returned;
(b) A reprocessing plant should have a co-located MOX fuel fabrication facility;
(c) Just in time reprocessing, i.e. synchronization of reprocessing and MOX fuel fabrication in order to prevent excess storage of separated plutonium;
(d) Just in time MOX delivery, i.e. the delivery of fresh MOX fuel should be synchronized with the refuelling cycle in order to prevent the customer country from storing this fuel for longer periods of time.



A MOX fuel assembly at the Melox Fuel Fabrication Plant in Bagnols-sur-Cèze, France (photo courtesy of AREVA).

Legal and Institutional Factors

180. In 1978, the IAEA Director General invited States to delegate representatives to an expert group to prepare "proposals for the establishment of schemes for the international management and storage of plutonium in implementation of Article XII.A.5 of the Agency's Statute". The expert group eventually completed its report in November 1982. Three alternatives for the release of Pu were considered, but ultimately no consensus was reached, and International Plutonium Storage (IPS) has never been established. A further study should evaluate release criteria, incorporating and reviewing the conditions mentioned in paragraph 179.

181. Eurochemic, the first multinational nuclear venture, was created in the 1950s under the auspices of the OECD/NEA. Its termination in 1974, in the face of competition from larger national installations in member countries, has frequently been offered as proof of the weakness and improbability of effective multinational arrangements. Such an assessment, however, ignores certain other facts. Eurochemic was established to serve as a training centre in which reprocessing technologies could be acquired, various fuel types and techniques explored, and industrial experience developed. It was not designed as a means of averting the spread of reprocessing technology, or as an alternative to national development, even though some of its members (particularly the smaller States) may have hoped for the eventual emergence of a single European reprocessing consortium, which would provide a partnership of a magnitude beyond their purely national capabilities. In terms of its mandate, Eurochemic was a success. It facilitated and launched the basis for industrial capability in a new technological field.[25]

182. In view of its avowed purpose of technology transfer and the absence of any ban on parallel national technological development, Eurochemic would not be a particularly good model for non-proliferation-oriented multinationalism. On the other hand, ten years of such multinational training and development activity in a high technology area represents an experience and institutional dynamic which may provide important lessons for future ventures, particularly with respect to the scope of the mission; organizational arrangements; allocation of ownership shares and interest; financial obligation; and the degree of restraint imposed on participants regarding parallel

[25] SCHEINMAN, L., The nuclear fuel cycle: A challenge for non-proliferation; *Disarmament Diplomacy* (March/April 2004).

activity. Indeed, Eurochemic's provision for an external control organ of participating State governments to deal with problems of common concern, while avoiding interference in operational activities, has been taken into account by subsequent multinational nuclear industrial ventures.

Non-Proliferation and Security Factors

183. The principal proliferation concern associated with reprocessing plants is the capacity they provide a would-be proliferator to separate plutonium from spent fuel for a weapons programme. The security concern results from the possible presence at reprocessing plants (depending on specific reprocessing cycles) of separated plutonium that could be diverted or misused.

184. Verification of non-diversion at reprocessing plants relies on six major sets of inspection activities: design information verification (DIV); verification of inventory changes; verification of internal material flows; verification of interim inventories for timely detection; the examination of operator records and reports; and annual physical inventory verification. Safeguarding reprocessing plants requires regular measurement and continuous monitoring during routine operations.

185. The effective and efficient safeguarding of a reprocessing facility is essential for assuring non-diversion of fissile material and to detect the misuse of the facility. Safeguarding a reprocessing plant is a costly and resource intensive task. In order to assure the highest level of certainty of non-diversion, the IAEA should be involved in the planning of the plant, as it was in Japan.

186. The additional establishment of regional arrangements could reduce the transportation risk for separated fissile material and enhance security, in comparison to intercontinental shipments, but could increase the transportation risk in comparison to national facilities.

187. In the future, new reprocessing processes may help strengthen proliferation resistance, while maintaining the Pu potential for use as fuel in fast reactors, by less complete separation of uranium, plutonium and minor actinides from fission products, which results in higher deterrent radiation levels. Further improvements, technological and otherwise, in monitoring and safeguards procedures may also strengthen the proliferation resistance of future facilities. Co-location of fuel fabrication plants, and perhaps reactors to burn the recycled fuel, could also help.

188. With respect to potential multinational reprocessing facilities, the IAEA's RFCC study concluded that a regional centre would have important non-proliferation and security advantages. First, given the economies of scale of the PUREX process the concept of regional centres implied fewer bigger centres than reprocessing built on national centres. Having fewer places to watch would mean that with a given amount of resources — a given safeguards budget — it would be possible to watch more carefully. Moreover, there would be fewer opportunities for diversion, theft and loss. Note that for potential future technologies with lower fixed costs, multinational facilities would not necessarily have these benefits. Second, joint operation puts each participant under greater scrutiny from peers and partners, an environment in which people tend to be more careful, attentive and rigorous, all of which strengthens non-proliferation and security.

189. A potentially countervailing factor, not mentioned in the IAEA study, is the possibility that international cooperation facilitates the international diffusion of reprocessing expertise. This would weaken proliferation resistance, given that the wider the expertise necessary to separate and handle weapons usable material is spread, the easier is proliferation.

Options for Multilateral Approaches for Reprocessing

190. This section suggests pros and cons associated with different approaches to assuring the supply of reprocessing and subsequent fuel services, using the same typology as in other sections.

Type I: Assurances of services not involving ownership of facilities.

(a) Suppliers provide additional assurances of supply

191. This corresponds to reprocessing plant operators, individually or collectively, guaranteeing to provide reprocessing capacity and/or MOX fuel to a country that had agreed to forego building its own capacity but then found itself denied service by its intended reprocessor for political reasons.

192. Currently all reprocessing plants are State owned. By the very nature of the nuclear business worldwide, any guarantee from a supplier would have the implicit or explicit agreement of the corresponding government. However, this type of agreement would bind only the supplier party.

Pros	Cons
1. No new plants required (A).	1. Cost of maintaining available idle reserve capacity is unclear (B).
2. Ease of implementation, few participants, no new ownership arrangements required (B, E).	2. For some, States with reprocessing facilities may not be politically diverse enough to provide needed assurance (B).
	3. Issues surrounding return of Pu and/or radioactive waste to customer country (A, B).
	4. Credibility of 'assurance' commitments unclear in the case of private firms (B).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

(b) International consortium of governments

193. In this case a consortium of governments would guarantee access to reprocessing capacity and to the return of MOX fuel. The suppliers would only be executive agents. The mechanism might be legislation establishing a government claim on such capacity under specified circumstances. Alternatively, it might be a contract by which a government buys guaranteed

Pros	Cons
1. No new plants required (A).	1. Cost of maintaining available idle reserve capacity is unclear (B).
2. Consortium commitments may be more reassuring (B).	2. The 'assured' capacity would be in existing facilities, and the countries with facilities may not be politically diverse enough to provide needed assurance (B).
3. Cost can be borne by governments rather than industry (A).	3. Issue of returning Pu and/or radioactive waste to customer country (A, B).
	4. Existing property rights will have to be taken into account (B, E).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

capacity, again under specified circumstances. Different countries might use different mechanisms.

(c) IAEA involved arrangements

194. This is a variation of the preceding option with the IAEA as the key decision making and administrative body of a consortium. The suggested pros and cons are therefore similar. Here, however, an additional pro reflects the composition of the IAEA: its membership is broader than that of a commercial consortium. For the IAEA to play its role, it would seem logical and necessary for the Agency to be freed of any further consent rights, assuming that consent rights could be subsumed into common mechanisms.

195. The mechanism might be legislation establishing an IAEA claim on such capacity under specified circumstances. Or it might be a contract by which the IAEA buys guaranteed capacity, again under specified circumstances.

The comments made previously for this type in the case of enrichment are also valid here.

Pros	Cons
1. No new plants required (A).	1. Cost of maintaining available idle reserve capacity is unclear (B).
2. IAEA commitments may be more reassuring (B).	2. The 'assured' capacity would be in existing facilities, and the countries with facilities may not be politically diverse enough to provide needed assurance (B).
3. Cost of reserve-keeping can be borne by the IAEA rather than by suppliers (B).	3. Diverse interests and priorities of IAEA membership (B).
	4. Issue of returning Pu and/or radioactive waste to customer country (A, B).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

Type II: Conversion of existing national facilities to multinational ones.

196. Converting a national facility to international ownership and management would involve the creation of a new international entity that would operate as a new competitor in the reprocessing market. Thus a number of the suggestions in the table below simply address the pros and cons of an international entity in such a situation, largely independent of reprocessing. Other items deal with the fact that, of the existing facilities, all except the two Japanese facilities are in NWS or non-NPT States. In many of those cases, safeguards will have to be introduced if they had not been applied before.

Pros	Cons
1. No new plants required (A).	1. New safeguards practices would have to be 'back-fitted' to facilities in non-NPT States or NWS (A, B, C, E, F).
2. Strengthening of proliferation resistance through international management and operating teams (A, E).	2. Existing property rights must be taken into account (B, E).
3. Pooling of international expertise and resources (B, D, E).	3. Difficulties of international management as experienced by Eurochemic, especially with the unique burden of providing assurances of supply (B).
	4. Potential proliferation risks due to international diffusion of reprocessing know-how (A, C, D, E).
	5. Several conversions would likely be needed in sufficiently politically diverse countries to provide needed assurances (B).
	6. Issue of returning Pu and/or radioactive waste to customer country (A, B).
	7. Possible increase in transportation requirements (A).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

Type III: Construction of new joint facilities.

197. The one historical precedent for the construction of a new multinational reprocessing facility is Eurochemic. New joint construction was also the focus of the IAEA's 1975–1977 RFCC study. Most of the suggested pros and cons below come from the Eurochemic experience and the RFCC study. The new facility considered here would have the added burden of providing needed assurances of supply while successfully competing against reprocessing facilities without that burden. Therefore, a prerequisite for the construction of new facilities is the demand for additional reprocessing and MOX production.

198. It is presupposed that in the future a reprocessing plant and a MOX fabrication plant would be built next to each other. In such a case, only MOX fuel and not separated Pu will be subject to transportation.

Pros	Cons
1. Fewer bigger reprocessing centres mean fewer sites to safeguard and fewer opportunities for diversion, theft and loss (A, B, F).	1. Several such facilities would likely be needed in sufficiently politically diverse countries to provide needed assurances (B).
2. Strengthening of proliferation resistance through international management and operating teams (A, E, F).	2. Difficulties of international management as experienced by Eurochemic, especially with the unique burden of providing assurances of supply (B, E).
3. Pooling of international expertise and resources (B, E).	3. Potential proliferation risks due to international diffusion of reprocessing know-how (A, C, D).
4. Economies of scale (B).	4. Issue of returning Pu and/or radioactive waste to customer country (A, B).
5. Fewer bigger reprocessing centres mean fewer environmental impacts, safety risks and health risks (A, B, E).	5. Breakout scenario and retention of fissile materials (A, C, D).
	6. Possible increase in transportation requirements (A).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

199. The comments made previously for this type — in the case of enrichment — are also valid here.

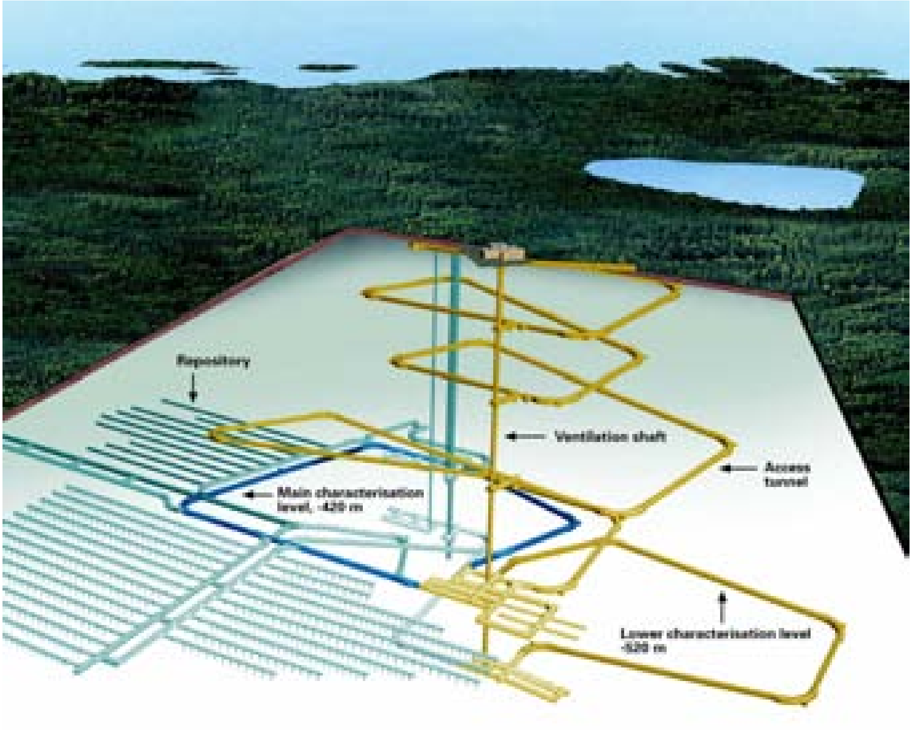
SPENT FUEL REPOSITORIES (FINAL DISPOSAL)

200. Once nuclear fuel has been used in a nuclear power plant to produce electricity, the fuel has been 'spent' and awaits further treatment, either towards a reprocessing facility to recover from the wastes the uranium and plutonium that it contains, or in an intermediate storage building or in a 'final repository' for a terminal solution. Most of the spent fuel around the world is now kept in the nuclear plants themselves, where it comes from. Depending on the route selected, a final repository may thus receive unprocessed fuel assemblies (spent fuel), or plain wastes, or both. Are such special facilities candidates for multilateral approaches? Besides the expected economic benefits of multinational repositories, there is a reason to look at them in terms of non-proliferation in the case of spent fuel, because of the potential risk associated with the contained plutonium, plutonium whose accessibility increases with time due to the radiological decay of the associated fission products.

Technologies

201. A repository is an underground installation for the disposal of nuclear material, such as spent fuel, usually located several hundred metres below ground level in a stable geological formation that ensures long term isolation of radionuclides from the biosphere. In the operating phase, the repository will include a reception area, which may be above or below ground, as well as container handling and emplacement areas underground. After the final closure, the backfilling of all emplacement areas in the repository will have been completed and all surface activities ceased.

202. The technology of spent fuel disposal has been well developed over the years, notably in Scandinavia, where the fuel assemblies are embedded in a solid container (such as copper) before burial. There is thus no concern that multinational final disposal would be less safe or less environmentally acceptable than national solutions.



Underground spent fuel disposal facility at Olkiluoto, Finland (photo courtesy of Posiva Oy).

Historical Background

203. Although international centres concentrating all nuclear fuel cycle activities in a limited number of countries were proposed very early in the development of nuclear power, the first study on 'multinational repositories' for radioactive waste and spent fuel was performed by the OECD/NEA in 1987. No such repository has ever been realized, with the possible 'exception' of the OECD/NEA led disposal in deep oceanic sites of low level wastes in the 1970s. Nevertheless, nuclear materials have been transferred to other countries for disposal and precedents for international disposal exist in the related area of toxic chemical wastes, with the agreed mutual exchange of waste across boundaries for optimal recycling and final disposal.

204. The transboundary movements of such waste are regulated by the Basel Convention, Control of Transboundary Movements of Hazardous Wastes and their Disposal, which entered into force in 1992. The Convention is the

response of 162 countries to the problems caused by the annual worldwide production of 400 million tonnes of wastes, which are hazardous to people or the environment because they are toxic, poisonous, explosive, corrosive, flammable, eco-toxic, or infectious. The common goal is the reduction of special wastes through avoidance and recycling, and the disposal of wastes in conformity with environmented norms in a limited number of locations. This global environmental treaty strictly regulates the transboundary movements of hazardous wastes and places obligations on its Parties to ensure that such wastes are managed and disposed of in an environmentally sound manner. In order to achieve these principles, the convention controls, to some extent, the transboundary movement of hazardous wastes, monitors it, provides assistance for the environmentally sound management of hazardous wastes, promotes cooperation between Parties in this field, and develops technical guidelines for the management of hazardous wastes.

205. Article 11 of the Basel Convention is entitled "Bilateral, Multilateral and Regional Agreements: 1. …Parties may enter into bilateral, multilateral, or regional agreements or arrangements regarding transboundary movement of hazardous wastes or other wastes with Parties or non-Parties, provided that such agreements or arrangements do not derogate from the environmentally sound management of hazardous wastes and other wastes as required by this Convention…"

206. In fact, many countries continue to depend on facilities beyond their own border for recycling certain special wastes (e.g. for metal wastes) and for the disposal of various types of toxic wastes. The export is only permitted if national and international regulations are kept and the environmentally tolerable treatment of the wastes can be assured.

207. The OECD countries and the European Union have gone beyond the obligations of the convention by agreeing to ban export to non-OECD countries of hazardous wastes intended for final disposal. This commitment has helped in securing the support of non-governmental organizations, which were keen to stop the uncontrolled dumping of wastes on the shores of developing countries.

208. Under the convention, transboundary movements are an accepted practice: 5–10% of the total waste is involved, with about 50% going to final disposal. The five largest exporters are Canada, Germany, Netherlands, Switzerland and the USA. The last of these has signed, but not ratified, the Convention. All these States, and others, import waste as well. This results in

a better optimization of final disposal of various kinds of toxic wastes.

209. The Convention on toxic wastes and its implementation is indeed a model for multilateral arrangements, a model that brings maximum benefits in terms of economics and environmental protection.

210. By contrast, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management of 1997 is more cautious on multilateral exchanges, but is still encouraging on this matter through a clause in the Preamble: "xi) Convinced that radioactive waste should, as far as is compatible with the safety of the management of such material, be disposed of in the State in which it was generated, whilst recognising that, in certain circumstances, safe and efficient management of spent fuel and radioactive waste might be fostered through agreements among Contracting Parties to use facilities in one of them for the benefit of the other Parties, particularly where waste originates from joint projects."

Current Status

211. No shared multinational repository exists currently. However, a number of initiatives pursue the idea[26]:

(a) The Arius Association brings together organizations from various countries (Belgium, Bulgaria, Hungary, Italy, Latvia, Netherlands and Slovenia), whose main objective is to explore ways of making provision for shared storage and disposal facilities for smaller users, who may not wish to — or may not have the resources to — develop facilities of their own. The SAPIERR project is a regional feasibility study supported by the European Commission; SAPIERR stands for Support Action: Pilot Initiative on European Regional Repositories and is a project within the sixth EC Framework Programme. The Ljubljana Initiative is a group of seven contiguous countries in Central Europe: Austria, Bulgaria, Croatia, Czech Republic, Hungary, Slovakia and Slovenia. The participants want to assess the potential safety, security and economic advantages of shared solutions.

(b) The Russian Federation has become increasingly serious about spent fuel imports and is the only country publicly supporting this at the govern-

[26] MCCOMBIE, C., et al., Nuclear fuel cycle centres: An old and new idea, Proc. Annual Symp. World Nuclear Association (2004).

ment level. The government is preparing international arrangements for the import and storage of spent fuel. For the time being, the offer does not include the final disposal of spent fuel. In July 2005, the Russian Federation will be holding an international conference in Moscow on multilateral technical and organizational approaches to the nuclear fuel cycle aimed at strengthening the nuclear non-proliferation regime.

(c) The IAEA has continued to work on the topic with dedicated working groups, and published a substantial document on the issue in October 2004 (IAEA-TECDOC-1413; see footnote 11)

212. At the national level, several countries have moved towards the realization of final repositories for high level waste, notably Finland, Sweden and the USA. In many countries, there are both political sensitivities and legal, including in some cases constitutional, barriers associated with the potential import of waste, a concern which would complicate this aspect of MNAs.

213. Yet, the experiences gained in regard to toxic wastes in the OECD/EU countries are reassuring. They address several of the concerns that some within and without the nuclear community have raised against shared nuclear repositories. Specifically, no State Party to the Basel Convention is obliged to accept wastes from others. All exchanges, even for disposal, are voluntary and based on freely entered into bilateral or multilateral agreements subject to international oversight. As noted previously, there is even a joint commitment by OECD/EU countries to keep all wastes for themselves.

Economics

214. Multinational repositories offer numerous economic benefits for both the host and the partner countries with small nuclear programmes. Sharing a facility with a few partners can significantly reduce a host country's expenditures. Of course, since the host country will bear the burden of permanently housing the repository, (and since some partners may be saving the costs of establishing their own centralized facility), the host country must negotiate an equitable contribution from its partners towards the total development costs of the project. Partner countries should agree to pay the host country not only some or all of the costs of development, but also a fee on the operation of the site. Therefore, multinational agreement will spread the full burden of development costs among several partners, thereby significantly reducing these costs for individual members. In most countries, a fee is levied on each nuclear kilowatt-hours (kW·h) produced, prior to construction of disposal facilities.

215. The economics of spent fuel disposal are very difficult to understand. Many figures reflect the decade long delay in coming up with technical and political solutions. The following cost estimates are based on calculations made by the Finnish waste management company Posiva Oy as a basis for financial liability for spent fuel management in Finland. They are based on a favourable socioeconomic framework and with a significant amount of R&D already done at home or elsewhere:

Site and facility specific R&D and design costs:	Around	200 M€
Fixed costs: (construction of the encapsulation facility and the disposal facility, excluding disposal tunnels, decommissioning and closure of the facilities):	About	250 M€
Variable costs (waste canisters, operation of the encapsulation facility, construction of disposal tunnels, operation of the disposal facility), per tonne of uranium (t U):	About	0.24 M€/t U

216. If site and facility specific R&D is included in fixed costs, the following cost formula gives a first order approximation:

Cost = 450 M€ + 0.24 M€ $\times$ spent fuel amount

217. The unit costs for various amounts of spent fuel to be disposed of would be as follows:

Amount of spent fuel (t U)	1000	2000	4000	6000	8000
Unit costs (M€/t U)	0.69	0.47	0.35	0.32	0.30

218. When the total spent fuel amounts approach 10 000 t U, additional investments are probably needed, e.g. parallel encapsulation process units, new access routes to and in the repository. Thus the unit cost will probably not be lower than 0.30 M€/t U. For comparison, the volume of fuel to be disposed of amounts to about 2500 t U in Finland, 10 000 t U in Sweden and 100 000 t U in the USA.

219. As noted, the above cost figures reflect favourable conditions and thus somewhat optimistic scenarios. In countries such as Germany, Sweden,

Switzerland and the USA, the real costs are much higher due to technical difficulties, political controversies, and programmatic delays extending over several decades.

220. Advance cash payments, or cost sharing, over a long time period will be needed, from site selection activities to site construction, operation and post-closure monitoring and maintenance. Long lasting financial arrangements are thus unavoidable, and these can be made in several forms among which could be guarantees as to the amount and time at which certain waste streams would be available, or agreements as to the fees that could be charged for such waste. These could be ultimately paid by the waste generators who would use the multinational repository.

221. Liability is closely related to cost. Several factors can lead to cost increases beyond the estimates, and these have to be properly identified and evaluated (usual contingencies, changing safety requirements, actual experience, advanced state of the art, unforeseen events, etc.) To deal with liability, two typical examples can be envisaged. In the first case, at the time of receiving the waste, the host country may take all responsibilities or liabilities for any possible future remediation. In the second, the host country and partner countries may conclude an agreement by which the partners accept a partly open-ended situation and assume liability for improbable but not impossible future events which might require remediation. Choosing between the two approaches (or any intermediary approach) may depend on institutional factors, half-lives of the predominant radionuclides, practical experience from other international joint ventures, etc.

Assurance of Services

222. 'Assurance of services', in this context refers to 'assurance of final disposal' of one's fuel. A State (for political reasons) and its nuclear plant operators (for operational reasons) must be assured that the spent fuel (or the high level wastes coming back from reprocessing) will indeed be disposed of nationally or internationally, in due time. For a multinational repository or a take-back agreement, this implies a solid, long lasting relationship between the parties and an efficient legal framework in the disposal country.

223. The partners involved would need to agree about the timing of the transfer of waste ownership to the recipient country and on the scope of such property transfer. Transfer could occur at the time when the waste is inspected in the partner's conditioning facilities before transportation, or

when the conditioned wastes enter the host country at the national border, or upon receipt in the repository of the host country. It is conceivable that the transfer could occur at a later stage after which any new and additional costs are extremely unlikely to occur.

224. Transfer of ownership of spent fuel may be complicated, since spent fuel can also be considered as a resource rather than a waste. If spent fuel is held for an interim cooling period of 30 to 50 years, the date of ownership transfer can be delayed.

Legal and Institutional Factors

225. Current and future inventories of all types of waste materials for disposal must be established before serious consideration can be given to establishing a multinational repository. Also, there should be an agreement between the host country and its partners as to waste acceptance criteria, locations of facilities for waste conditioning and interim storage (i.e. at each partner country or at centralized facilities installed on the site of the multinational repository), and quality assurance and control of waste packages to be disposed of. The legal and institutional problems to be resolved are not trivial.

226. States with few nuclear plants would be the most interested in making use of international instruments. Multilateral disposal arrangements imply a willingness to open borders. For States with legislation restricting the export and import of radioactive waste, such legislation will have to be amended, if they wish to join a multinational repository project. The case of Switzerland is of interest here: the new nuclear law that entered into force in February 2005 leaves the door open to both export and import of spent fuel and nuclear waste for final disposal, albeit *both* subject to a right of return to the sender 'in case of necessity'.

227. All considerations about cost sharing, liability, safety regulations, etc., are closely linked to the institutional character of the project, which involves national and multinational relations among regulatory and licensing bodies, as well as with contractual partners. Management of shared repositories could be entrusted to commercial firms, to the host State, or to a consortium of States. At any rate, there should be a clear international framework with agreed guidelines and rules to satisfy the requirements of the partners sending in fuel and IAEA safety standards.

228. A repository is a long term management project. It has a lead time of 20 years or more, an operational period of several decades and a post-closure surveillance and monitoring period that may extend over centuries. Thus, it should be run under an international convention or agreement. This underlines once again the importance of continuity, not only from a political and contractual perspective, but also from a technical and cost sharing point of view. Given the impossibility of predicting how these aspects will evolve over very long time periods, flexibility will be essential.

229. As far as safety regulations for an international repository are concerned, the countries involved should arrive at a common understanding on the licensing and control mechanisms to be applied. There are also legal international instruments that could be used as existing international conventions, e.g. the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, under which they could regulate their partnership.

Non-Proliferation and Security Factors

230. Today more than ever, the security of nuclear materials must remain a high priority at all levels — whether national, regional, or international — at the front end and back end of the fuel cycle. The plutonium contained in spent fuel is indeed a material of interest for the making of nuclear explosive devices, albeit to a different degree, depending on the time spent by the fuel in a reactor.

231. The safeguarding of nuclear materials must be undertaken through the entire nuclear fuel cycle, up to the stage where the materials can be considered to be *practically irrecoverable* (e.g. currently, less than 2.5 kg of plutonium per cubic metre of vitrified high level waste). Otherwise, in particular for spent fuel, where the content is higher than the threshold noted above, safeguards must be continued even after the closure of a repository.

232. Over the last decade, the IAEA's Department of Safeguards has worked towards defining a safeguards policy on nuclear waste and spent fuel. Several advisory group and consultants meetings were held, and an ambitious 'Programme for Development of Safeguards for the Final Disposal of Spent Fuel in Geologic Repositories (SAGOR)' was started in 1994 and finalized in 1998.

233. With respect to nuclear waste, according to SAGOR, the criteria for making determinations of 'practicably irrecoverable' should include waste material type, nuclear material composition, chemical and physical form, and waste quality (e.g. the presence or absence of fission products). The total quantity, facility specific technical parameters and the intended method of eventual disposal should also be considered. The main concern from the waste management standpoint is that any intended safeguards measures should not impair the safety of the waste management system. Another consideration is related to the additional costs associated with the need to implement safeguards measures. The advisory groups and consultants concluded that spent fuel does not qualify as being practically irrecoverable at any point prior to, or following, placement in a geological formation commonly described as a 'permanent repository', and that safeguards on spent fuel should not be terminated.

234. As far as spent fuel is concerned, various safeguards methods and techniques have been proposed for application at a spent fuel conditioning facility. None of the proposed techniques are likely to cause significant problems from the safety point of view. No destructive verification techniques are foreseen.

235. For closed geological repositories, the safeguards approach must provide a credible assurance that an undeclared breaching of the integrity of a repository will be detected. The repository should be safeguarded by a non-intrusive surveillance mechanism that would allow the repository site to be checked periodically, e.g. unannounced inspections, possibly with geophysical equipment, satellite or aerial monitoring and seismic monitoring with remote data transmission.

236. According to the IAEA Department of Safeguards, safeguards approaches for the final disposal of spent fuel repositories will be available in sufficient time to be included in the design for future MNA repositories.

Options for Final Repositories of Spent Fuel

237. Defining options for potential multilateral approaches for the back end of the fuel cycle is relatively complex, since there is a dotted line between storage and disposal. As a first priority, the owners of nuclear plants want to off-load spent fuel as early as possible in order not to congest their own spent fuel storage ponds. 'Assurance of services', in this context, refers to 'getting rid of' the spent fuel. Further down the line, for countries with inadequate

domestic energy resources (such as France, India, Japan, Pakistan and Switzerland), keeping a hand on spent fuel and reprocessed plutonium is important, since this material is seen as an energy resource to be recovered immediately or possibly later after many years of interim storage. For other States not interested in plutonium recovery, storage is only an intermediate step on the way to disposal in geological repositories. There is thus some ambiguity for storage with regard to its duration, its nature and whether it is a precursor of reprocessing or of disposal. This ambiguity even extends to disposal in geological repositories, as indicated by technical specialists references to the oxymoron: 'reversible and retrievable final disposal'.

238. Thus, depending on the State, time period and conditions of the uranium market (which affects the commercial value of plutonium), assurance of service for spent fuel may take different forms: (a) availability of interim storage; (b) availability of reprocessing services in the medium or long term; and (c) outlook for final repositories whether retrievable or not. The first two forms are treated in separate sections of this report. In the present section, the prime interest is on multilateral, shared final repositories for spent fuel, and on the assurance of services for nuclear power plants operators to dispose of the spent fuel produced in their facilities. Three types of multilateral approaches deserve consideration.

Type I: Assurance of services not involving ownership of facilities.

(a) Suppliers provide additional assurances of supply.

239. This option corresponds more or less to the former practice of the Soviet Union under which fresh fuel was supplied to the owners–operators of Soviet designed plants with a full commitment to take back the spent fuel that was thereby returning to Soviet ownership, with an indefinite status for the fuel itself. The Russian Federation is ready to honour this commitment insofar as reprocessing and storage are concerned. There is now a similar arrangement being negotiated between Iran and the Russian Federation. Incidentally, nothing would prevent other nuclear fuel companies to offer on a commercial basis 'fuel leasing–fuel take-back' arrangements. In addition to fuel take-back, one could also envisage just *take*, i.e. the host country for the repository does not have to be the one that supplied the original fuel. At present, while fuel leasing is relatively straightforward, fuel take-back, while more controversial, is more relevant from a non-proliferation standpoint.

Pros	Cons
1. No remaining security risk in client States (A).	1. Concern that recipient State could acquire valuable weapon quality plutonium (A).
2. Ease of implementation, few participants (B).	2. Assurance of service depends on one partner (B).
3. Secured, final solution to waste disposal (B).	3. Issues surrounding long term ownership of Pu (B).
	4. Legal barriers in many States against accepting foreign spent fuel (B).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

240. A form of partial 'fuel leasing–fuel take–back' is also conceivable, under which the donor State would accept to take back an amount of vitrified (or otherwise appropriately conditioned) high level wastes corresponding to the quantity and toxicity of the fission products contained in the spent fuel.

(b) International consortia of governments.

241. This model would be a collective 'fuel leasing–fuel take–back' arrangement involving several nuclear fuel companies together with their governments (fuel take-back would have a political dimension). They would hold the material received, take ownership, store it temporarily or definitively, or even reprocess it. The contractual arrangements would specify, on a case-by-case basis, whether the lessee would be entitled to purchase back the equivalent amount of MOX fuel that it had transferred previously in the form of spent fuel, even when such arrangements would primarily meant to cover final disposal.

242. Partial fuel leasing fuel take back could also work here.

Pros	Cons
1. No security risk in lessee State after return of fuel (A).	1. More difficult implementation, involving several participants (A, B).
2. Rapid to implement after political decision (B).	2. Political will of several recipients needed (B).

Pros	Cons
	3.Changing political conditions over long term could alter commitments (E).
	4. Existing property rights must be taken into account (B, E).
	5. Legal barriers in many States against accepting foreign spent fuel (B).
	6. Issues surrounding long-term ownership of Pu (B).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

(c) IAEA related arrangements.

243. The IAEA has been entrusted with the NPT related obligations to safeguards and thereby to keep track of the spent fuel in final repositories. There is unlikely to be any additional role for the IAEA in any bilateral or multilateral arrangements. While the IAEA could possibly be in a position to 'give' (for example, managing a fresh fuel bank), its Member States would probably be unwilling to allow it to 'receive' spent fuel in specific final disposal facilities, with all the costs and risks that this would imply, except maybe in an oversight function, thereby providing better acceptance.

Type II: Conversion of existing national facilities to multinational ones.

244. In this case, the host country would add imported wastes from partner countries to its national inventory and disposal scope. It could do so after its national facility is seen to be operating safely. The anticipated income would allow the construction of modern repositories with good security and environmental characteristics. Furthermore, one could even envisage regional arrangements involving not only spent fuel and radioactive wastes, but also chemical toxic wastes.

245. Many political and public acceptance issues will arise in connection with the import of nuclear materials to an existing repository. Successful implementation of disposal programmes on the national level, good transparency of the international dimension of the project — broad adherence to international instruments such as the NPT and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management — could significantly contribute to the acceptance of such an

international repository project. The countries sending their nuclear materials will certainly require guarantees of good safety and environmental management through some kind of international oversight, i.e. through the IAEA.

Pros	Cons
1 Reduce proliferation risks (A).	1. Political and public acceptance (B).
2. Energy resource (Pu) secured and available (B).	2. Uncertainty about consent rights as to retrievability and transfer (B).
3. Best economics for all partners (B).	3. Assurance of service depends on only one partner (B).
4. Existing secure and safe facility in host country (A).	4. Possibility of retrieval (A).
	5. Changing political conditions over long term could alter commitments (B, E).
	6. Existing property rights must be taken into account (B, E).
	7. Legal barriers in many States against accepting foreign spent fuel (B).
	8. Increased transportation requirements (A).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

Type III: Construction of new joint facilities.

246. The launching of a project of multinational repository would begin with solid technical evaluations of waste characterization, conditioning and transportation. Analyses would need to be carried out related to the inventories, cost–benefit, safety and legal issues. The identification of suitable repository sites is of paramount importance, since the specific safety, environmental and political aspects associated with the proposed sites will effectively determine the fate of such an international project. No effort should be spared to establish a strong technical and scientific basis for choosing the most suitable location in terms of safety and environmental impact. Among the factors that will play a role in choosing the host State are: political willingness; geological stability; good regulatory infrastructure; political stability; non-proliferation credentials; and agreement on consent rights and by trans-shipment States.

247. Public acceptance is already of crucial importance for setting up national repositories; it will even be of greater importance for multinational repository projects with nuclear waste and spent fuel coming from several countries. Slogans such as 'dumping ground of the world', 'not in my backyard (NIMBY)' would most likely come up as soon as an international project of this kind was mentioned. High safety standards and cost transparency are thus essential for obtaining public acceptance for a multinational repository project.

248. To overcome the so-called NIMBY syndrome on an international scale, there should be more than one international repository, perhaps even more than one per continent. Host countries would certainly prefer not to be the sole site. Several regional repositories would minimize transport, and customer countries would have some degree of flexibility. One could imagine, worldwide, two North American repositories, one in South America, two in Western/Central Europe, one each in the Russian Federation, in Africa, in South Asia, in China and in South-East Asia.

249. The burden would lie first of all on the shoulders of the host country and its government. There are several steps that the host government, the participating countries and the international community could take to help gain the required public acceptance:

(a) The number and nature of the participating countries would play a role in public acceptance in the host country: not too many, not too few. Strong political support of the partner countries is an absolute prerequisite for achieving public acceptance.
(b) While the participation of solid industrial partners would be necessary to ensure the technical viability and economic soundness, the involvement of governments and other public entities is needed to strengthen public acceptance with an assurance of long-term continuity.
(c) For spent fuel disposal, the non-proliferation dimension of the repository can be emphasised in the justification and presentation of an international repository. The host country would thereby provide a safe central shelter for the plutonium contained in the spent fuel, rather than leaving it scattered in numerous facilities around the region.
(d) For 'retrievable spent fuel disposal', the host country would thereby provide temporary storage for a valuable resource — the plutonium — which is a large potential source of energy for future use, should the participants need it in the future. Depending on the ownership

agreement between the participating countries, the host country could thus acquire a potentially exportable commodity.

Pros	Cons
1. Economies of scale (B).	1. Difficult implementation, with several participants (A, B, E).
2. Solution for countries with unsuited geology (B).	2. Difficulty of national public acceptance (B, C).
3. Combining rather than duplicating efforts (A, B, E).	3. Increased transportation requirements (A, B).
4. Solution for countries with political acceptance problems (B).	4. 'Not in my backyard' on international scale (B).
5. Better security in one location (A).	5. Changing political conditions over long term could alter commitments (B, E).
6. Possibility of retrieval for future energy needs (B).	6. Proliferation risks with the possibility of retrieval (A).
7. Energy resource (Pu) secured and available (B).	7. Legal barriers in many States against accepting foreign spent fuel (B).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

SPENT FUEL STORAGE (INTERMEDIATE)

250. The following section discusses spent fuel storage and whether this part of the fuel cycle is a candidate for multilateral arrangements. Without making specific reference to the front end, most of the findings can be applied there mutatis mutandis.

Technologies

251. At the back end of the fuel cycle, spent fuel containing plutonium is frequently stored for long periods of time while awaiting reprocessing or final disposal. At the front end, prior to use in nuclear power plants, fresh fuel isstored on site, be it as plain uranium oxide fuel (UO_2) or as MOX fuel (UO_2 and PuO_2); such fuels represent limited proliferation risks in small quantities inside nuclear plants, more when in longer interim storage as fresh fuel buffer stocks elsewhere.

Intermediate Storage Facility at Würenlingen, Switzerland (photo courtesy of ZWILAG).

252. The technology of nuclear material storage has been fully developed over the last decades, and this experience will be directly applicable to multinational arrangements. The relevant technical issues are: safety; physical protection; safeguards; fuel acceptance criteria; long-term stability; siting; storage technology (wet or dry); licensing; facility operation; transport; and decommissioning.

Historical Background

253. The concept of an extranational trusteeship of special nuclear materials is enshrined in the Statute of the IAEA. Although evaluated at length by an international expert group around 1980 (in parallel with the International Plutonium Storage evaluation referred to in the historical review), the concept of 'International Spent Fuel Storage' never became reality. A study of multinational storage facilities for spent fuel was initiated by the IAEA in 1997.

Current Status

254. Currently, about 165 000 tonnes of heavy metal equivalent (t HM) of irradiated fuel (spent fuel) from nuclear power reactors are stored worldwide. By the year 2015, the mass of stored spent fuel will rise to about 280 000 t HM. More than 62 000 fuel assemblies from research reactors also are stored worldwide.

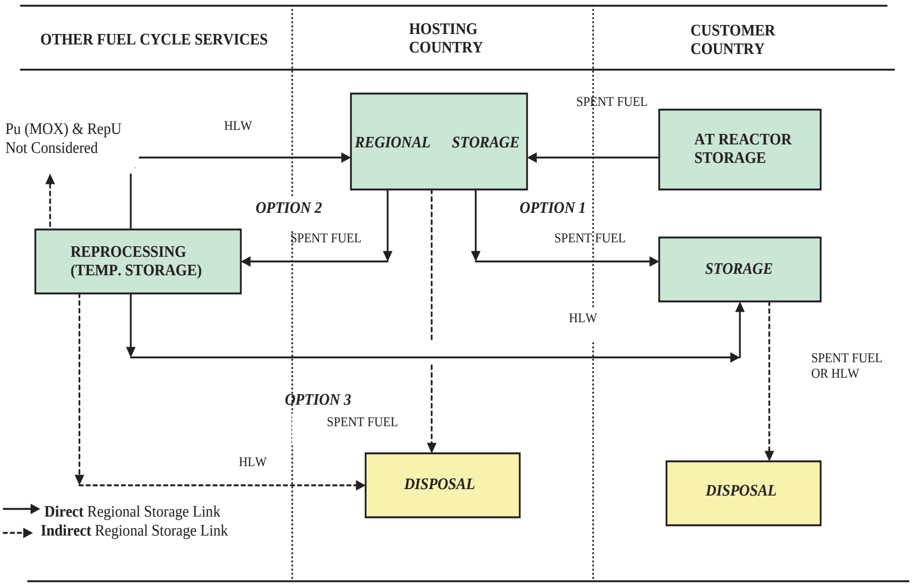
255. No shared multinational storage facilities exist currently. Storage of spent fuel will cover longer periods of time than originally expected, and storage up to 100 years is being discussed now.

256. The IAEA continues to work on the concept for regional spent fuel storage. The objective and scope is similar to that on disposal repositories. The IAEA has presented to the MNA Expert Group preliminary findings of a study it has carried out on technical, economic and institutional aspects of regional spent fuel storage facilities, which will be a very valuable contribution for the assessment of such multinational arrangements.

257. The figure shown on page 110 is from the IAEA study and depicts the possible paths of nuclear materials around a regional store, and the interfaces with disposal and reprocessing.

258. Most countries with power reactors are developing their own national strategy for spent fuel management, including interim storage. However, several countries with small nuclear power programmes, or only research reactors, face the issues of extended interim storage of their spent nuclear fuel. The high cost of interim storage facilities for small amounts of spent fuel accumulated in such countries is obviously not reasonable and therefore, from an economic point of view, access to a regional interim storage facility provided by a third country for their fuel would be an interesting solution.

259. The benefits and challenges of multinational storage are quite comparable to those of multinational disposal. Long term conditions and legal issues applicable to final repositories may not apply in this case or may be of a lesser impact. Greater benefits in the case of storage may favourably impact the acceptability of regional storage projects, i.e. hundreds of storage facilities are in operation worldwide, the time scale for storage is shorter and storage is by definition fully reversible. Hence, political and public acceptance is more likely.



Schematic drawing of a regional spent fuel storage system in the context of the nuclear fuel cycle.

Economics

260. In the future, there may be regional and national bottlenecks, with shortages anticipated in several countries. The costs and the obstacles associated with fuel transportation would preclude a smooth matching of demand and capacity on a worldwide basis.

261. Multinational stores could offer significant economic benefits to both the host and the partner States. Sharing a facility with a few partners can significantly reduce costs in the case of wet storage, less for dry storage, which is more modular in nature.

262. Potential service providers include:

(a) States willing to take advantage of a business opportunity or for other interests (i.e. non-proliferation);
(b) States with advanced nuclear waste management programmes, that are willing to accept additional spent fuel for storage;
(c) States which have existing reprocessing facilities with available or readily expandable reserve storage capacity; and

(d) States with small or extensive nuclear programmes that have favourable sites that could be developed for use by other countries.

263. Potential customers include:

(a) States with small nuclear programmes that cannot realistically develop economically effective comprehensive back end facilities; and
(b) States with large or small nuclear programmes that may see an attractive economic or political advantage in using a regional storage solution.

264. Cost sharing will extend over long time. Long lasting financial arrangements are thus unavoidable, and these can be made in several forms among which could be guarantees as to the storage duration.

Assurance of Services

265. 'Assurance of servicees', in this context, refers to the 'assured storage' of one's fuel. For operational reasons, nuclear plant operators must be assured that the spent fuel discharged from their reactors will have somewhere to go, once the on-site stores have been filled up. Intermediate storage — pending disposal to reprocessing or to a repository — must therefore be prepared either nationally or internationally.

Legal and Institutional Factors

266. A regional approach to the storage of spent fuel would require the involvement of a variety of relevant institutions, including national, multilateral, supranational (i.e. EU) and international entities. On an international level, institutions like the IAEA, OECD/NEA, EURATOM, etc., could be involved. On a national level, governmental and regulatory bodies, local authorities, oversight bodies as well as spent fuel producers and facility operators will take part in the process.

267. Multilateral storage arrangements imply a willingness to work together. Since storage may extend over decades, the facility must be run under an international convention or agreement. The political stability of the host and the partners is again a vital element. This underlines once again the importance of the continuity factor, not only from a political and contractual perspective, but also from a technical and cost sharing point of view. Management of a shared store could be entrusted either to commercial firms, to the

host State, to a consortium of States. At any rate, there should be a clear international framework, with agreed guidelines and rules.

268. Another challenging issue for multinational facilities has to do with the ownership of spent fuel and transfer of title. Because such projects are long term and the final destination of spent fuel may not have been decided, three options regarding the ownership of spent fuel stored in such a facility need to be considered:

(a) Ownership of fuel remains with the providing customer; after the storage period expires, the fuel (or reprocessing products if appropriate) is returned to the owner;
(b) Transfer of ownership to the host country is delayed and can take place at some later time, depending on contractual arrangements; and
(c) Ownership of fuel is immediately transferred to the host country; no return of fuel (or reprocessing products, if appropriate) is foreseen.

269. In the first option, the agreement to take back the spent fuel in a distant future may be a risk for both sides; on the customer's side, uncertain government policies may prevent the delivery and the payments for spent fuel, while on the host's side the delay in accepting fuel may cause negative economic and political reactions and thereby jeopardize the whole project. Because of the need for an agreement to receive spent fuel, the contract between the host and the customer States requires strong commitments on both sides. An international assurance that the agreements will be respected may be required, with a possible IAEA involvement.

270. The second option includes the possibility of the transfer of title at some future time, depending on possibilities in both the host and the customer countries. The risks associated with this option are similar as for the first one and some international assurance may also be required.

271. The third option avoids the problems of fuel take-back. This option may be the most attractive to the customers' countries. The host country takes the responsibility for storage and the final disposition of the spent fuel. However, some questions may arise when disposal routes are not yet available (after storage), as to the potential commercial value of the spent fuel as an 'energy resource'. These issues should be negotiated very carefully between the parties.

272. Liabilities are associated with the obligation of the spent fuel owner to ensure that the spent fuel is properly managed and finally disposed of in a safe and secure manner. Several factors can lead to cost increases and these have to be properly identified and evaluated, i.e. usual contingencies; changing safety requirements; actual experience; advanced state-of-the-art; unforeseen events, etc. These liabilities are an inherent cost of managing normal operations of a multinational storage facility. In addition, abnormal operations must be addressed through contracts in the context of national laws and applicable international treaties. Future liabilities of the host country of regional spent fuel storage facility are strongly related to the issue of spent fuel ownership.

Non-Proliferation and Security Factors

273. The safeguarding of special nuclear materials is a well established practice with clear criteria. Spent fuel stored in an NNWS, whether in a multinational or national store, will be subject to IAEA safeguards. Customer States may also require that safeguards be applied in a multinational store located in an NWS.

274. If one focuses on security, it is of interest to note that storage facilities located above ground are more vulnerable to external risks than underground disposal facilities.

Options for Multilateral Spent Fuel Storage

275. A complex situation prevails at the back end of the fuel cycle where a dotted line runs between storage and disposal, as already noted at the same location in the chapter on repositories. There is thus an ambiguity for storage as well, regarding its duration, its nature and whether it is a precursor of reprocessing or of disposal.

276. Depending on the State, time period and reprocessing market (whether commercially attractive or not), assurance of service for spent fuel storage may take different forms. Three types of multilateral approaches are also under consideration here:

Type I: Assurances of services not involving ownership of facilities.

(a) Suppliers provide additional assurances of supply.

277. There is a comparison with the front end of the fuel when fresh fuel is stored by the fuel supplier prior to shipment to their clients: the owners–operators of power plants. Such a fresh fuel buffer can be expanded in volume to provide a buffer function. This arrangement could be mirrored at the back end; a commercial entity would commit to take-back and store the spent fuel until its fate is decided between reprocessing and disposal. This could also be seen as a buffer associated with the recyclable plutonium. The Russian Federation has committed to receive spent fuel from Russian supplied reactors for storage. An extension of this proposal to non-Russian-supplied fuel is under consideration.

Pros	Cons
1. Less security risk in client State (A, B).	1. Concern that receiving State could take hold of valuable weapon quality plutonium (A).
2. Ease of implementation, few participants (B).	2. Assurance depends upon one partner only (B).
	3. Concern that fuel would not be taken back (B).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

(b) International consortium of governments.

278. This model — a form of spent fuel bank — would involve additional suppliers and possibly their governments. Suppliers would hold the material received without keeping or taking ownership, and store it temporarily for an indefinite period of time, thereby creating a collective strategic fuel reserve, with some kind of government guarantees.

Pros	Cons
1. Reduced security risk in client State (A, B).	1. Implementation with several participants (E).
2. Assurance of service relies on several partners (B).	2. Multinational, therefore political decisions needed (A, B, E).
	3. Concern that the fuel would not be taken back (A, B).
	4. Existing property rights must be taken into account (B, E).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

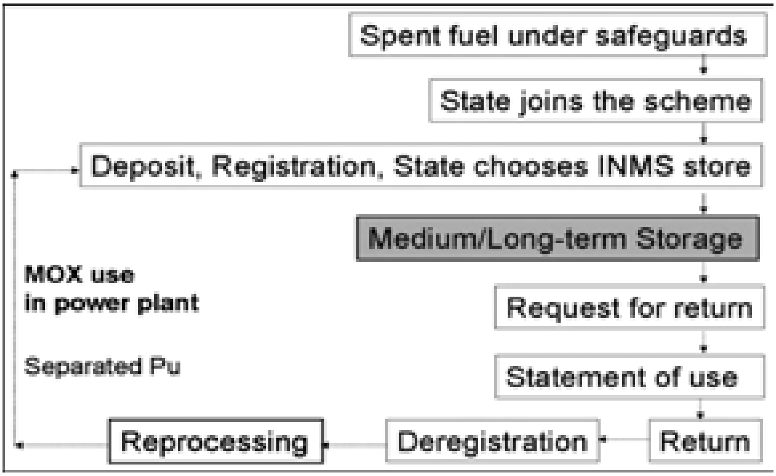
(c) IAEA related arrangements.

279. The attempts to internationalize nuclear material management/storage goes back to Article XII A.5 of the IAEA Statute. From this paragraph came the concept of 'International Plutonium Storage' that provided for the management of special fissionable materials by the Agency:

> "….to require deposit with the Agency of any excess of any special fissionable materials recovered or produced as a by-product over what is needed for the above-stated uses in order to prevent stock-piling of these materials, provided that thereafter at the request of the member or members concerned special fissionable material so deposited with the Agency shall be returned promptly to the member or members concerned for use under the same provisions as stated above".

280. Although evaluated at length by two separate international expert groups between 1978 and 1982, the idea never materialized, for both separated plutonium and for spent fuel. States were not willing to forgo their control of valuable nuclear materials. Furthermore, the original non-proliferation concerns had by that time lost their momentum in comparison to 1957 as a consequence of the advance of safeguards under the NPT since 1970.

281. This idea could be revived under the name of 'International Nuclear Materials Storage (INMS)'. In the case of separated plutonium, the concept would primarily apply to MOX fuel that is returned and stored prior to use in nuclear power plants. In contrast to the reluctance of renouncing national sovereignty over *separated* plutonium, the international storage of *unseparated*



Schematic drawing of the flow of nuclear material in and out of IAEA trusteeship.

plutonium (that is, of spent fuel) could generate more interest. Today, there is the possibility of greater political flexibility in the case of spent fuel, a resource that is less immediately valuable, more difficult to store and also less sensitive than separated plutonium in terms of proliferation.

282. On the basis of a model proposed in 1982, the flow of material in and out of IAEA trusteeship is illustrated in the above diagram.

283. The following arrangements would apply to a participating country, whether an NNWS or not:

(a) *Coverage:* All spent fuel and separated Pu therefrom — from peaceful use;
(b) *Return:* Upon request, authorization to be granted for reprocessing and then peaceful uses, with all material under safeguards and with no stockpiling;
(c) *Use verification:* Material flows to be provided; to be verified (beyond safeguards requirements); and
(d) *Deregistration from the INMS:* When safeguards status is modified, from INMS to owner's facilities.

284. Given the large and growing stockpiles of excess plutonium, some have advocated that the time has come for countries to place such material under the international custody of the IAEA pending subsequent peaceful use or

Pros	Cons
1. Potential economic advantage (B).	1. Lack of political will to involve the IAEA (A, B, E).
2. Good security and non-proliferation framework, under IAEA trusteeship (A).	2. Complex legal and institutional setup (B, E).
3. Strong assurance of service (take back, Pu return) (B).	3. Demanding management task for the IAEA with financial implications (B,E).
4. Reprocessing and disposal options remain possible (B).	4. Risk of breakout remains (A).
	5. Increased transportation requirements (A).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

disposition[27]. Placing the fuel under IAEA custody could facilitate the use of plutonium using fuel cycles, help achieve non-proliferation objectives, avoid discrimination among States and interference with national energy programmes. Separated plutonium and spent fuel would be kept decentralized in a few locations, an arrangement that would minimize fuel transport.

Type II: Conversion of existing national facilities to multinational ones.

285. In this case, the host country adds to its national inventory and storage capacity imported special nuclear materials from partner countries. Again, a similar option already exists (to a limited extent) with the current commercial practice of storing fresh fuel (uranium and mixed oxides) prior to shipment to the owners-operators of power plants. Such fuel buffer could be expanded in volume to provide a strategic reserve function. One can envisage regional arrangements to create strategic reserves of fresh fuel, and joint buffer storage of spent fuel, prior to decisions regarding additional reprocessing capacity or final disposal capacity on a regional basis.

286. Economic incentives, the existence of minimum national storage programmes and good transparency of the international dimension of the project

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[27] BENGELSDORF, H.D., MCGOLDRICK, F., International custody of excess plutonium, *Bulletin of the Atomic Scientists* (March/April 2002).

Pro	Cons
1. Secure and safe facility in host country (A, E).	1. Difficulty of political acceptance in host country (B, E).
2. Energy resource (Pu) secured (B).	2. Uncertainty regarding consent rights (B).
3. Best economics for all partners (B).	3. Assurance of service depends upon only one partner (B).
4. Set up: easy and fast (B).	4. Increased transportation requirements (A).
	5. Existing property rights must be taken into account (B, E).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

would significantly contribute to the acceptance of such international storage projects. There would likely be need for some kind of international oversight (i.e. IAEA).

Type III: Construction of new joint facilities.

287. A new, shared storage facility can be established in a regional or multinational context. Among the factors that will play a role in choosing the host State are: political willingness; siting; good regulatory infrastructure; political stability; non-proliferation credentials; and agreement on consent rights and by trans-shipment States.

288. Political will would depend on understanding at the national level the advantages of joint regional buffer stocks. The combined efforts of participants would indicate a shared conception of assurances of supply and would lead to a better public acceptance of nuclear energy. High safety standards, reliable quality assurance, and fair and transparent cost sharing would also be essential for obtaining political support for a multinational storage project. While the participation of solid industrial partners would be necessary to ensure the technical viability and economic soundness, the involvement of governments and other public entities is needed to strengthen public acceptance with an assurance of long term continuity. For spent fuel storage, the non-proliferation advantages of the regional store should also be emphasized. The host country would thereby provide a safe central shelter for the plutonium contained in the fresh and spent fuel, better than leaving it

Pros	Cons
1. Economies of scale (B).	1. Difficult implementation, with several participants (A, B, E).
2. Solution for countries with unsuited geology (B).	2. National public acceptance (B).
3. Combining rather than duplicating efforts (E).	3. Increased transportation requirements (A, B).
4. Solution for countries with political obstacles (B).	4. "Not in my backyard" on international scale (B).
5. Better security in one location (A).	5. Possibility of fissile material retrieval in case of a breakout (A).
6. Best assurance of service (take back, Pu return) (B).	6. Possible increase in transportation requirements (A).

A: Non-proliferation; B: assurance of supply; C: siting; D: access to technology; E: multilateral involvement; F: special safeguards provision; G: non-nuclear inducements.

scattered in numerous facilities around the region. For spent fuel storage, it can also be mentioned that the host country would thereby provide temporary storage for a valuable resource — the plutonium — which is a large potential source of energy for future use, should the participants need it later on in 30 or more years. Depending on the ownership agreement between the participating countries, the host country would thus acquire a potentially exportable commodity.

OVERVIEW OF OPTIONS

289. An MNA can be an alternative to national fuel cycle facilities, thereby reducing the number of such facilities. In addition to the possible attractive economic aspects discussed, the intergovernmental agreements envisaged for an MNA could enhance controls on the transfer and use of nuclear materials and restricted technologies, would provide for better physical protection in the facilities and could provide for their optimum siting.

290. To the extent that an MNA offers a greater assurance of adequate control over nuclear materials and facilities than would wholly national facilities, it helps to allay concerns about nuclear proliferation. A joint facility with multinational staff puts all participants under a greater degree of scrutiny from peers and partners, a fact that strengthens non-proliferation and

security. This is the fundamental non-proliferation benefit of MNAs. An MNA may also constitute an obstacle to a breakout by the host partner. The multinational dimension of an MNA provides no fool-proof assurance against a breakout, but is better, in this regard, than a simple national facility. Naturally, an MNA would be established with the application of full IAEA safeguards.

291. A countervailing factor is the possibility that international cooperation facilitates the diffusion of enrichment and reprocessing expertise, thereby increasing the proliferation risks outlined in the section on the elements of assessment (page 53). From this perspective, for MNAs in general, it would seem that the Urenco model is only applicable when partners have already developed their own individual know-how, while the EURODIF model is better when most have not done so.

Uranium Enrichment

292. A healthy market exists for all steps in the front end of the nuclear fuel cycle. In the course of only two years, a nuclear power plant operating in Finland has bought uranium originating from mines in seven different countries. Conversion has been done in three different countries. Enrichment services have been bought from three different companies. For fuel manufacturing, there were three qualified factories, each having different fuel design. Therefore, the legitimate objective of assurances of supply can be fulfilled to a large extent by market mechanisms and possibly improved by some governmental guarantees. However, this assessment may not be valid for all countries that have concerns about assurances of supply. Mechanisms or measures under which suppliers or international consortia of governments or IAEA related arrangements provide assurances may, in such cases, be appropriate.

293. Further supply arrangements could involve the IAEA under modalities that are worthwhile exploring. Such IAEA led models need not be elaborate. Indeed, of the options reviewed, one of the most feasible, least likely to be burdened by financial, legal and technical complications, requiring minimum new institutionalisation and likely to be the easiest to implement, could be that of the IAEA standing ready to be the guarantor of substitute fuel supply arrangements in accordance with agreed criteria in the event that a State had its nuclear fuel supply suspended for other than commercial reasons.

294. Where an MNA would take the form of a joint facility, there are two ready-made precedents, Urenco and EURODIF. The experience of Urenco, with its dual layer management under the control of its intergovernmental Joint Committee, has shown that the multinational concept can be made to work successfully. Strong oversight of technology and staffing, as well as effective safeguards and proper international division of expertise can reduce the risk of proliferation and even make a unilateral breakout more difficult. EURODIF has a successful multinational record as well, by enriching uranium only in one country and hence restricting all proliferation risks, diversion, clandestine parallel programme, breakout and the spread of technology.

Reprocessing

295. On the basis of present forecasts regarding nuclear energy, and taking into account present capacities to reprocess spent fuel for light water reactors and those under construction, there will be sufficient reprocessing capacity globally for all expected demands for at least two decades. Therefore, objectives of assurances of MOX supply can be fulfilled to a large extent without MNA involving ownerships.

296. The case of reprocessing is similar to enrichment in terms of the associated proliferation risks. However, there are differences between enrichment and reprocessing facilities:

(a) A lesser sense of urgency to reprocess spent fuel, which will affect the economic feasibility and timing of constructing new reprocessing plants.
(b) Whereas the common practice of returning the reprocessing products to the customer poses a proliferation risk, MNAs will not pose greater risks than the current situation. However, if the reprocessed products will be retained by the host country, the proliferation risks may be higher, depending on the siting of the MNA.
(c) Reprocessing technology is more readily available than enrichment technology, and therefore proliferation risks must also be handled at the previous stage of the fuel cycle — safeguarding spent fuel removed from reactor cores. In this respect, it is worth noting that an MNA, which leases nuclear fuel and takes back the spent fuel, avoids most proliferation risks, but requires the fuel vendor to take care of the spent fuel disposition.

297. In the context of reprocessing, the IAEA could possibly exercise the authority granted in its Statute to require deposit of special fissionable materials in excess of ongoing national needs. For MNAs involving a new joint facility, design features to enhance safeguardability should be incorporated, such as co-location of facilities including storage, features to improve inventory and accounting of materials, features to improve containment and surveillance; and process selection and storage options to make nuclear materials less vulnerable to diversion. Regional facilities would involve transportation of spent fuel over long distance with its associated obstacles. Therefore, in the views of some States, it is desirable to co-locate nuclear power plants, reprocessing plants, MOX fuel (or mixed metal fuel) fabrication plants and fast reactors to use the MOX fuel. Transportation of spent fuel, if any, should be over short distances.

298. What sets reprocessing apart from other steps of the fuel cycle is the separation of fissile material and its reintegration into fresh fuel. One can make the case that MNAs, because of the greater number and better coordination of suppliers and customers in a single organization, might achieve a better match between the separation of plutonium and its consumption in the form of fresh fuel.

Spent Fuel Disposal

299. Many organizations want the disposal of nuclear fuel and waste to be done only domestically. Under the Basel Convention, the OECD has opened the vista by deciding that toxic waste can and must be disposed of within the broader geographical region of the OECD. This eminently reasonable approach does not violate in any way rules of good conduct of an environmental and ethical nature. For nuclear wastes, it would certainly make sense to establish similar regional arrangements in the 'OECD/EU region', as well as elsewhere in the world.

300. At present there is no market for spent fuel disposal services, since there is no urgent need — either from a technical or from an economic point of views for having repositories even at the national level in many countries. From a higher perspective, one may observe that nuclear services are offered internationally by a number of players, from uranium ore to reprocessing. Why not also final disposal in order to achieve best security, safety and economics?

301. The final disposal of spent fuel is a candidate for multilateral approaches. It offers major economic benefits and substantial non-proliferation benefits, although it presents legal, political and public acceptance challenges in many countries. The IAEA should continue its efforts in that direction by working on all the underlying factors, and by assuming political leadership to encourage such undertakings. For example, the IAEA could launch a "Siteless Pilot Project of Spent Fuel Repository" that would elaborate in detail all related technical, economic, legal and institutional aspects. Beyond the IAEA, in spite of current legal constraints on exports and imports, other regional organizations could become active, such as the OECD, the European Union and the North American Free Trade Agreement.

302. To be successful, the final disposal of spent fuel (and radioactive waste as well) in shared repositories must be looked at as only one element of a broader strategy of parallel options. National solutions will remain a first priority in many countries. This is the only approach for States with major nuclear programmes in operation or in past operation. For others with smaller nuclear programmes, a dual-track approach is needed in which both national and international solutions are pursued. Small countries should keep options open (national, regional, international), be it only to maintain a minimum national technical competence necessary to act in an international context.

303. Besides participating countries, it would seem that the international community at large should also play a role in achieving greater public acceptance for international repositories. The IAEA should put forward proposals for a more active role, such as policy statements and resolutions expressing a broad support for international repositories, and possibly for a more active role of the IAEA as an umbrella or a sponsor for such projects.

Fuel Storage

304. Storage facilities are in operation and are being built in several countries. There is no international market for services in this area except for the readiness of the Russian Federation to receive Russian supplied fuel, with a possible offer to do so for other spent fuel. In this connection, the storage of spent fuel is also a candidate for multilateral approaches, primarily at the regional level. Storage of special nuclear materials in a few safe and secure facilities will enhance safeguards and physical protection. The IAEA should continue its related efforts and encourage such undertakings. Various countries with state of the art storage facilities in place could move forward

and accept spent fuel from others for interim storage. The IAEA could facilitate this arrangement by acting as a 'technical inspection agency' assuring the suitability of the facility and applying state-of-the-art safeguards control and inspections.

Combined Option: Fuel Leasing–Fuel Take–back

305. In this model, the leasing State will provide the fuel it promised through an arrangement it will separately enter into with its own nuclear fuel 'vendor'. At the time the government of the leasing State issues an export license to its fuel 'vendor' corporation to send fresh fuel to a client reactor, that government will also announce its plan for the management of that fuel once discharged. Without a specific spent fuel management scheme by the leasing State, the lease deal will of course not take place. The leased fuel once removed from the reactor and cooled down, could either be returned to its country of origin which owns title to it, or, through an IAEA brokered deal could be sent to a third party State or to a multinational or a regional fuel cycle centre located elsewhere for storage and ultimate disposal.

306. The State obtaining the leased fresh fuel may wish to guarantee having adequate fuel supplies by contracting with more than one government and one international vendor corporation for providing portions of its fuel reloading requirements, under multiple lease deals each covering a portion of its fuel supply needs. In this way it has greater assurance that even if one leasing State and its related 'vendor' corporation, for some reason, could not meet all its obligations in a timely manner. In such an event, only a portion of the reload requirements would be affected, and that portion might still be provided by any of its other fresh fuel 'vendors' having some spare 'flywheel' capacity. If the State obtaining leased fuel is in good standing with regards to its safeguards obligations (including the AP), then it could use the good offices of the IAEA to convince various leasing countries to allow their fuel 'vendor' corporations to provide it fuel on lease–take-back arrangements.

307. One weak part in the arrangement outlined above is the willingness, indeed the political capability, of the leasing State to take back the spent fuel it has provided under the lease contract. It may well be politically difficult for any State to accept spent fuel not coming from its own reactors (that is, reactors producing electricity for the direct benefit of its own citizens). Yet, to make any lease–take-back deal credible, an ironclad guarantee of spent fuel removal from the country where it was used must be provided, otherwise the entire arrangement is moot. In this respect, States with suitable disposal sites,

and with grave concerns about proliferation risks, ought to be proactive in putting forward solutions as well as identifying problems and a commitment to forego enrichment and reprocessing in the buyer state should enhance this effort.

308. As an alternative, the IAEA could facilitate the creation of multinational or regional spent fuel storage facilities or of full fledged fuel cycle centres, where spent fuel owned by leasing States and burned elsewhere could be sent. The IAEA could thus become an active participant in regional spent fuel storage facilities, or third party spent fuel disposal schemes, thereby making lease–take-back fuel supply arrangements more credible propositions.

Other Options

309. The concept of 'fuel cycle centres' also deserves consideration. Such centres would combine, in one location, several segments of the fuel cycle, e.g. uranium processing and enrichment, fuel fabrication (including MOX), spent fuel storage and reprocessing. Regional fuel cycle centres offer most of the benefits of other MNAs, in particular with regard to material security and transportation. The further step — the additional co-location of nuclear power plants — would create a genuine 'nuclear power park' — an interesting and more long term concept that deserves further study.

310. In the model of cooperation, one could also foresee the option of companies of different part of the fuel cycle cooperating, and in such a way, supplying a customer with various — or even all — the required services for using nuclear energy.

6. OVERARCHING ISSUES

311. Apart from the cross-cutting factors related to the implementation of MNAs, such as the technical, legal and safeguards factors discussed in Chapter 4 above, there are a number of overarching issues, primarily of a broad political nature, which may have a bearing upon perceptions of the feasibility and desirability of MNAs. These issues may be decisive in any future endeavour to develop, assess and implement such approaches at the national and international level.

RELEVANT ARTICLES OF THE NPT

312. Cooperation in the peaceful uses of nuclear energy, which had earlier provided the basis for the foundation of the IAEA, is an essential element of the NPT.

313. Article IV.1 of the NPT provides that nothing shall be interpreted as affecting the "inalienable right of all Parties to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II" of the NPT. In accordance with Article IV.2, all Parties to the NPT shall undertake to "facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy." That same paragraph requires that Parties to the Treaty in a position to do so to "cooperate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of [NNWS Party to the NPT], with due consideration for the needs of the developing areas of the world."

314. The Treaty thus explicitly confirmed the inherent right of States to use nuclear energy for peaceful purposes. The commitment by all States parties to cooperate in the further development of nuclear energy and for the NWS to work towards nuclear disarmament was the political bargain that provided the basis for NNWS to abstain from acquiring nuclear weapons. Without the inclusion of Articles IV and VI, the Treaty would not have been adopted nor received the widespread adherence it obtained afterwards. Article IV was specifically crafted to preclude any attempt to reinterpret the NPT so as to inhibit a country's right to peaceful nuclear technologies — so long as the technology is not used to produce nuclear weapons.

315. NNWS have expressed dissatisfaction about what they increasingly view as a growing imbalance in the NPT: that, through the imposition of restrictions on the supply of materials and equipment of the nuclear fuel cycle by the NWS and the advanced industrial NNWS, those States have backed away from their original guarantee to facilitate the fullest possible exchange referred to in Article IV.2 and to assist NNWS in the development of the applications of nuclear energy. There are also concerns that additional constraints on Article IV might be imposed.

316. Article VI of the Treaty obliges nuclear weapon States Parties "to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament." Many NNWS also consider the implementation of Article VI of the NPT by NWS as unsatisfactory, as well as the non-entry into force of the CTBT and the stalement in the negotiations on a verifiable FM(C)T. Such concerns have fostered a belief among many NNWS that the NPT bargain is being corroded.

SAFEGUARDS AND EXPORT CONTROLS

317. Some States have argued that, if the objective of MNAs is merely to strengthen the nuclear non-proliferation regime then, rather than focusing on MNAs, it may be better to concentrate instead on the existing elements of the regime itself, for example, by seeking the universality of APs to IAEA safeguards agreements, by the universalization of multilateral export controls, and as stipulated by UN Security Council Resolution 1540 (2004), under which individual States are required to strengthen their export controls in order to prevent the spread of weapons of mass destruction and related materials to non-State actors.

318. The risks involved in the spread of sensitive nuclear technologies should primarily be addressed by an efficient and cost effective safeguards system. The IAEA and regional safeguards systems have done an outstanding job in these matters. Safeguards, well and rationally applied, have been the most efficient way to detect and deter further proliferation and to provide States Parties with an opportunity to assure others that they are in conformity with their safeguards commitments. In a related sense, the IAEA safeguards system represents by itself a multilateral approach to non-proliferation. Of course, advances in technologies require safeguards to be strengthened and updated, while protecting commercial, technological and industrial secrets. Therefore the comprehensive safeguards agreement, in the first place, and

also the adoption of the AP, and its judicious implementation based on State level risk analysis, are essential steps against further nuclear proliferation.[28] The AP has proven to provide additional, necessary and effective verification tools, while protecting legitimate national interests in security and confidentiality. Sustained application of the AP in a State can provide credible assurance of the absence of undeclared materials and activities in that State. Together with a comprehensive safeguards agreement, the AP should become the de facto safeguards standard.

319. The above notwithstanding, the IAEA should endeavour to further strengthen the implementation of safeguards. For example, it should revisit three facets of its verification system:

(a) The technical annexes of the AP should be regularly updated to reflect the continuing development of nuclear techniques and technologies.
(b) The implementation of the AP requires adequate resources and a firm commitment to apply it decisively. It should be recalled that the Model Additional Protocol commits the IAEA not to apply the AP in a mechanistic or systematic way. Therefore, the IAEA should allocate its resources for problematic areas rather than for States using the largest amounts of nuclear material.
(c) The enforcement mechanisms in the case of a fundamental breach of, or in the case of non-compliance with the safeguards agreement. Are these mechanisms progressive enough to act as an effective deterrent? Further consideration should be given by the IAEA to appropriate measures to handle various degrees of violations.

[28] In adopting the Model Additional Protocol, the IAEA Board of Governors requested the Director General:

(a) To use the Model AP as the standard for additional protocols to be concluded by States and other parties to comprehensive safeguards agreements with the IAEA (such protocols to contain all of the measures in the Model Protocol);

(b) To negotiate APs or other legally binding agreements with NWS incorporating those measures provided for in the Model AP that each NWS has identified as being capable of contributing to the non-proliferation and efficiency aims of the AP, when implemented with regard to that NWS, and as consistent with that State's obligations under Article I of the NPT;

(c) To negotiate APs with other States that are prepared to accept measures provided for in the Model AP in pursuance of safeguards effectiveness and efficiency objectives.

320. Export guidelines and their implementation are an important line of defence for preventing proliferation. Recent events have shown that criminal networks can find ways around existing controls to supply clandestine activities. Yet, one should remember that all States party to the NPT are obliged, pursuant to Article III.2 thereof, to implement export controls. This obligation was reiterated by Resolution 1540 of the Security Council for all members of the United Nations. Therefore, the participation in the development and implementation of export controls should be broadened, and multilaterally agreed export controls should be developed in a transparent manner, engaging all States.

321. In fact, the primary technical barriers against proliferation remain the effective and universal implementation of IAEA safeguards under comprehensive safeguards agreements and additional protocols, and the export controls. Both must be as strong as possible on their own merits. MNAs will be complementary mechanisms for strengthening the existing non-proliferation regime.

VOLUNTARY PARTICIPATION IN MNAS VERSUS A BINDING NORM

322. The present legal framework does not oblige countries to participate in MNAs; the political environment makes it unlikely that such a norm can be established any time soon. Establishing MNAs resting on *voluntary* participation is thus the more promising way to proceed. In a voluntary arrangement covering assurances of supply, recipient countries would, for the duration of the respective supply contract, renounce the construction and operation of sensitive fuel cycle facilities and accept safeguards of the highest current standards, including comprehensive safeguards and the AP. Where the demarcation line between permitted R&D activities and renounced development and construction activities has to be drawn is a matter for further consideration. In voluntary MNAs involving facilities, the participating countries would presumably commit to carry out the related activities solely under the common MNA roof.

323. In reality, countries will enter into such multilateral arrangements according to the economic and political incentives and disincentives offered by these arrangements. A political environment of mutual trust and consensus among the partners — based on full compliance with the agreed nuclear non-proliferation obligations of the partners — will be necessary to the successful negotiation, creation and operation of an MNA.

324. Beyond this, a new *binding* international norm stipulating that sensitive fuel cycle activities are to be conducted exclusively in the context of MNAs and no longer as a national undertaking would amount to a change in the scope of Article IV of the NPT. The wording and negotiation history of this article emphasise the right of each party in good standing to choose its national fuel cycle on the basis of its sovereign consideration. This right is not independent of the faithful abiding by the undertakings under Articles I and II. But if this condition is met, no legal barrier stands in the way of each State party to pursue all fuel cycle activities on a national basis. Waiving this right would thus change the 'bargain' of the NPT.

325. Such a fundamental change is not impossible if the parties were to agree on it in a broader negotiating frame. For NNWS, such a new bargain can probably only be realized through universal principles, applying to all States, and with additional steps by NWS regarding nuclear disarmament. In addition, a verifiable FM(C)T might also be one of the preconditions for binding multilateral obligations. As such a treaty would terminate the right of any participating NWS and non-NPT parties to run reprocessing and enrichment facilities for nuclear explosive purposes, it would bring them to the same level — with regard to such activities — as NNWS. The new restrictions would apply to all States and facilities related to the technologies involved, without exception. At that time, multilateral arrangements could become a universal, binding principle. The question may also be raised as to what might be the conditions required by NWS and non-NPT States to commit to binding MNAs involving themselves.

NUCLEAR WEAPON STATES AND NON-NPT STATES

326. Weapons-usable material (stocks and flows) and sensitive facilities that are capable of producing such material are located predominantly in the NWS and non-NPT States. While the issue discussed in previous chapters raised a concern about the construction of such facilities in NNWS in the context of an MNA, the question here is how MNAs for existing or future sensitive facilities should include NWS and non-NPT States, in light of the possibility that the nuclear material produced therefrom could contribute to such a State's nuclear weapons programme. This shows again the relevance of an FM(C)T.

327. The feasibility of bringing NWS and non-NPT States into MNAs should indeed be considered at an early stage. As long as MNAs remain voluntary,

nothing would preclude such States from participating in an MNA. In fact, France (in connection with the EURODIF arrangement) and the United Kingdom (in connection with Urenco) are examples of such participation. In transforming existing civilian facilities into MNAs subject to safeguards and security requirements, such States would demonstrate their support for non-proliferation and for peaceful international nuclear collaboration. If NPT and non-NPT States were both to participate in the same MNA, this would require a change in policy on the part of the participating NPT States Parties.

BREAKOUT AND OTHER RISKS

328. Whether voluntary or compulsory, multilateral facilities share a potential weakness with their national counterparts, namely the risk of the host country 'breaking out': for example, by creating a political emergency, expelling multinational staff, withdrawing from the NPT (and thereby terminating its safeguards agreement), and operating the multilateral facility without international control. For multilateral facilities to be acceptable, this risk would need to be addressed. Nevertheless, MNAs offer a better protection than national facilities if they are run by multinational staff and involving intertwined activities. At a minimum, such a breakout would alienate the other partners in the MNA, possibly lead to some retaliatory measures, raise political temperatures and give the international community (and the IAEA) advance notice that things might be amiss — hopefully within the three months necessary to do something about it. As a further disincentive to breakout, NPT States Parties desiring to host or participate in the MNA, could choose to forego their rights under Article X.1 of the Treaty, or to allow continuation of safeguards and/or to commit to returning equipment and materials obtained through MNA participation.

329. The UN Security Council, as the international organ bearing the main responsibility for the maintenance of international peace and security, should be prepared to respond to such action, insofar as withdrawal from the NPT could be seen as a threat to international peace and security.

330. Breaking out of the NPT would be a clear challenge to the non-proliferation regime and to the security of the international community. However, several other proliferation scenarios more specifically related to the concept of MNA should be included in any agreement setting up an MNA. One is the possibility of withdrawal from the MNA (that is to say, 'going national'), without leaving the NPT. A second would entail the misuse of technology by

non-host parties to the MNA on their own territory using know-how acquired through the MNA.

ENFORCEMENT

331. Eventually, the success of all efforts to improve the nuclear non-proliferation regime depends upon the effectiveness of compliance and enforcement mechanisms. Enforcement measures in case of non-compliance can be partially improved by MNAs' legal provisions, which will carefully specify a definition of what constitutes a violation, by whom such violations will be judged, and possible measures that could be directly applied by the partners in addition to broader political tools.

332. However, enhanced safeguards, MNAs, or new undertakings by States will not serve their full purpose if the international community does not respond with determination to serious cases of non-compliance, be it diversion, clandestine activities or breakout. Responses are needed at four levels, depending upon the specific case: the MNA partners of the non-compliant State; the IAEA; the States Parties to the NPT; and the UN Security Council. Where they do not currently exist, appropriate procedures and measures must be available and must be made use of at all four levels to cope with non-compliance instances, stressing that States violating important treaties and arrangements should not be permitted to do so unimpeded.

7. MULTILATERAL NUCLEAR APPROACHES: THE FUTURE

333. As noted in Section 3, past initiatives for multilateral nuclear cooperation did not result in any tangible results. Proliferation concerns were perceived as not serious enough. Economic incentives were seldom strong enough, and concerns about assurances of supply were paramount. National pride also played a role, alongside expectations about the technological and economic spin-offs to be derived from nuclear activities. Many of those considerations may still be pertinent today. However, the result of balancing those considerations today, in the face of a possible expansion of nuclear facilities over the next decades and the potential for increasing proliferation dangers may well produce a political environment more conducive to MNAs in the 21st century.

334. The potential benefits of MNAs for the non-proliferation regime are both symbolic and practical. As a confidence building measure, multilateral approaches have the potential to provide enhanced assurance to the partners and to the international community that the most sensitive parts of the civilian nuclear fuel cycle are less vulnerable to misuse for weapon purposes. Joint facilities with multinational staff put all MNA participants under a greater degree of scrutiny from peers and partners and may also constitute an obstacle against breakout by the host partner. MNAs will also reduce the number of sites where sensitive facilities are operated, thereby curbing proliferation risks; and they diminish the number of potential points of access for non-state actors to sensitive material. Moreover, these approaches also have the potential to facilitate the continued use of nuclear energy for peaceful purposes and enhance the prospects for the safe and environmentally sound storage and disposal of spent nuclear fuel and radioactive waste.

335. Multilateral approaches could also provide the benefits of cost effectiveness and economies of scale for smaller countries or those with limited resources, while ensuring the benefits of the use of nuclear technology. Similar benefits have been derived in the context of other high technology sector, such as aviation and aerospace.

336. However, the case to be made in favour of MNAs is not entirely straightforward. States with differing levels of technology, different degrees of institutionalisation, economic development and resources and competing political considerations may not all reach the same conclusions as to the benefits, convenience and desirability of MNAs. Some might argue that multilateral approaches point to the loss or limitation of State sovereignty

and independent ownership and control of a key technology sector, leaving unfairly the commercial benefits of these technologies to just a few countries. Others might argue that multilateral approaches could lead to further dissemination of, or loss of control over, sensitive nuclear technologies, and result in higher proliferation risks.

337. One of the most critical steps is to devise effective mechanisms for assurances of supply of material and services, which are commercially competitive, free of monopolies and free of political constraints. Effective assurances of supply will have to include back-up sources of supply in the event that an MNA supplier is unable to provide the required material or services. In this context, the IAEA could play a pivotal role as a kind of guarantor in an international mechanism for emergency supply.

338. Appropriate organizational and institutional arrangements, as well as the relevant legal instruments, would need to be developed, both at the State level and at the commercial level. Arrangements at the State or governmental level would need to specify, for example, the safeguards obligations and the degree of restraint on parallel national nuclear fuel cycle activities in participating States. At the commercial level, such matters as the allocation of ownership, financial obligations and facility operation would need to be articulated.

339. It is also important that international oversight of an MNA be arranged, as needed, to achieve confidence of partners on adequate safety and physical security of the proposed facility.

340. In summary, the Expert Group on Multilateral Approaches to the Nuclear Fuel Cycle has reviewed the various aspects of the fuel cycle, identified a number of options for MNAs deserving of further consideration, and noted a number of pros and cons for each of the options. It is hoped that the report of the Expert Group will serve as a building block, or as a milestone. It is not intended to mark the end of the road. MNAs offer a potentially useful contribution to meeting prevailing concerns about assurances of supply and non-proliferation.

341. In the meantime, the Expert Group recommends that steps be taken to strengthen overall controls on the nuclear fuel cycle and the transfer of technology, including safeguards and export controls: the former by promoting adherence to APs, the latter through a more stringent implementation of guidelines and universal participation in their development.

'Swords into ploughshares' (photo courtesy of D. Calma, IAEA).

342. In order to maintain momentum, the Expert Group recommends that attention be given — by IAEA Member States, by the IAEA itself, by the nuclear industry and by other nuclear organizations — to MNAs in general and to the five approaches given on the next page, in particular.

FIVE SUGGESTED APPROACHES

343. The objective of increasing non-proliferation assurances concerning civilian nuclear fuel cycles, while preserving assurances of supply and services around the world could be achieved through a set of gradually introduced MNAs:

(1) Reinforcing **existing commercial market mechanisms** on a case by case basis through long term contracts and transparent suppliers' arrangements with government backing. Examples would be: fuel leasing and fuel take-back, commercial offers to store and dispose of spent fuel and commercial fuel banks.

(2) Developing and implementing **international supply guarantees** with IAEA participation. Different models should be investigated, notably with the **IAEA as guarantor** of service supplies, e.g. as administrator of a fuel bank.

(3) Promoting voluntary conversion of **existing facilities to MNAs**, and pursuing them as **confidence building measures**, with the participation of NPT NNWS and NWS, and non-NPT States.

(4) Creating, through voluntary agreements and contracts, **multinational, and in particular regional, MNAs for new facilities** based on joint ownership, drawing rights or co-management for front end and back end nuclear facilities, such as: uranium enrichment; fuel reprocessing; and disposal and storage of spent fuel (and combinations thereof). Integrated nuclear power parks would also serve this objective.

(5) The scenario of a further expansion of nuclear energy around the world might call for the development of a **nuclear fuel cycle with stronger multilateral arrangements** — by region or by continent — **and broader cooperation**, involving the IAEA and the international community.

Annex I
LETTER FROM THE DIRECTOR GENERAL

11 June 2004

Dear Mr. ….

As an expert on nuclear fuel cycle and non-proliferation matters, you will have followed the recent international discussions about the need to further strengthen the nuclear non-proliferation regime. Some of the proposals and initiatives in this regard focus on the non-proliferation benefits of more effective controls over the most proliferation sensitive technologies involved in the nuclear fuel cycle — such as enrichment and reprocessing.

During the March 2004 meeting of the Agency's Board of Governors, I signaled my intention to convene a group of experts to explore options and develop proposals for improved controls, including possible multilateral oversight arrangements, for the front- and the back-ends of the nuclear fuel cycle. In my view, the work of such a group will be an important contribution to the ongoing debate on this issue. Moreover, I expect that this work may result in practical proposals, which, if implemented, could provide enhanced assurance to the international community that sensitive portions of the nuclear fuel cycle are less vulnerable to misuse for proliferation purposes and thereby facilitate the continued uses of nuclear energy for peaceful purposes.

Following consultations, and in recognition of your knowledge and expertise, I am pleased to invite you to participate in a personal capacity in the work of the International Expert Group which I am setting up with the task of preparing an initial study on the above issues by Spring 2005. I trust you will be able to accept this invitation and will also be able to arrange for the necessary funding of your participation.

I have invited Mr. Bruno Pellaud, former Deputy Director General of the Agency for safeguards and verification, to be the Chairman of the Expert Group. Based on discussions with him, I suggest that the first meeting of the group be held from 30 August to 3 September 2004 in Vienna at the Agency's Headquarters. It is anticipated that the Group will have up to four meetings in Vienna in order to complete its work.

The Terms of Reference for the Group are attached. I have asked Mr. Pellaud to contact you with more details and information relating to the arrangements for the meetings of the Group.

Yours sincerely,

Mohamed ElBaradei (*signed*)

Terms of Reference

a. Identify and provide an analysis of issues and options relevant to multilateral approaches to the front-end and back-end of the nuclear fuel cycle;

b. Provide an overview of the policy, legal, security, economic and technological incentives and disincentives for cooperation in multilateral arrangements for the front and back ends of the nuclear nuclear fuel cycle; and

c. Provide a brief review of the historical and current experiences and analyses relating to multilateral fuel cycle arrangements relevant to the work of the Expert Group.

Annex II
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IAEA Support

The Scientific Secretary of the Expert Group was Tariq Rauf of the IAEA. In addition, the following IAEA current and former staff members made contributions to the Group's work (in alphabetical order): Elena Bergo (administrative support); Jill Cooley, Matthias Gohl (intern); Eckhard Haas; Vladimir Kagramanian; Alan McDonald; Jan-Marie Potier; John Rames; Laura Rockwood; Mazhar Saied; and Fiona Simpson.

External Support

The Group drew on the expertise and presentations of the following external individuals (in alphabetical order): Alexy Grigoriev (TVEL); Caroline Jorant (AREVA), Jean-Louis Lemarchand (AREVA); Charles McCombie (Arius Association); Sergey Ruchkin (TENEX); Philip Sewell (USEC); Pat Upson (Urenco); Charles Yulish (USEC).

Annex III
ACRONYMS

^{235}U	Uranium 235
^{238}U	Uranium 238
AP	Additional Protocol (IAEA INFCIRC/540(Corr.))
BNFL	British Nuclear Fuels Limited
CAS	Committee on Assurances of Supply (1980–1987)
CTBT	Comprehensive Nuclear-Test-Ban Treaty
EC	European Commission
EMIS	Electromagnetic isotope separation
EU	European Union
EURATOM	European Atomic Energy Community
EURODIF	Usine EUROpéenne d'enrichissement par DIFfusion gazeuse (European Gaseous Diffusion Uranium Enrichment Consortium)
FM(C)T	Fissile Material (Cut-Off) Treaty
FORATOM	European Atomic Forum
HEU	High enriched uranium ($^{235}U \geqslant 20\%$)
HLW	High level waste
IEA	International Energy Agency (of the OECD)
INFCE	International Nuclear Fuel Cycle Evaluation (1977–1980)
INFCIRC	Information Circular (IAEA)
INMS	International Nuclear Material Storage
INPRO	International Project on Innovative Nuclear Reactors and Fuel Cycles (IAEA)
IPS	(Expert Group on) International Plutonium Storage (1978–1982)
JNC	Japan Nuclear Cycle Development Institute
kW·h	Kilowatt-hours
LES	Louisiana Enrichment Services

LEU	Low enriched uranium ($^{235}U < 20\%$)
LFUA	Limited Frequency Unannounced Access
LWR	Light water reactor
MNA	Multilateral nuclear approach
MOX	Mixed oxide (mixture of the oxides of uranium and plutonium used as reactor fuel)
MW(e)	Megawatt electric
NEA	Nuclear Energy Agency (specialized agency within the OECD)
NNWS	Non-nuclear-weapon State(s) (under the NPT)
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
NSG	Nuclear Suppliers' Group
NWS	Nuclear-weapon State(s) (under the NPT)
OECD	Organisation for Economic Cooperation and Development
Pu	Plutonium
PuO_2	Plutonium dioxide
PUREX	Plutonium and Uranium Recovery by Extraction
PWR	Pressurized water reactor
REU	Recycled uranium
RFCC	Regional Nuclear Fuel Cycle Centres (1975–1977)
SAGOR	Programme for Development of Safeguards for the Final Disposal of Spent Fuel in Geologic Repositories (1994–1998)
SAPIERR	Support Action: Pilot Initiative on European Regional Repositories
SQ	Significant quantity (of nuclear material for safeguards purposes)
SSAC	State System of Accounting for and Control of Nuclear Material
SWU	Separative work unit (measure for the capacity of an enrichment plant)
TBP	Tributyl phosphate

TENEX	Techsnabexport
THOREX	Thorium recovery by extraction
U	Uranium
U_3O_8	Tri-uranium oxide
UF_6	Uranium hexafluoride
UNCPICPUNE	United Nations Conference for the Promotion of International Cooperation in the Peaceful Uses of Nuclear Energy (1987)
UNIREP	United Reprocessors Gesellschaft
UO_2	Uranium dioxide
UO_3	Uranium trioxide
Urenco	Uranium Enrichment Company
WWER	Water cooled, water moderated power reactor

For further information see the *IAEA Safeguards Glossary.*

Annex IV
REGIONAL NUCLEAR FUEL CYCLE CENTRES

1977 Report of the IAEA Study Project
International Atomic Energy Agency, Vienna, 1977 *

Vol. I
Summary

3. ALTERNATIVE APPROACHES

As pointed out earlier, the establishment of fuel reprocessing capacity did not take place as planned in some States. At the same time, there was also a growing realization in a number of States that specific arrangements should be made for appropriate disposition of the spent fuel generated in the power reactors. Some States are considering new alternatives to reprocessing based on non-proliferation considerations. Some have considered reprocessing to be necessary to recover the energy and economic values remaining in the spent fuel. Others have considered the reprocessing of spent fuel as an essential step in the management of radioactive wastes, i.e. it is desirable to separate the highly radioactive wastes from the spent fuel and to convert them into solidified form, which would be more amenable to long-term storage or ultimate disposal, rather than leave these wastes in the spent fuel.

Economic as well as safeguards and physical-protection considerations favour the use of plutonium as fuel in thermal reactors rather than its storage for an indefinite period awaiting the introduction of commercial fast breeders. Because of the high initial inventory requirement of plutonium for each fast breeder power reactor, the demand for plutonium would rise very rapidly once the fast breeders were fully developed on a commercial scale, and at that stage recycle of plutonium in thermal reactors could be expected to decrease.

It is clear that, under the circumstances explained above, the nuclear fuel cycle situation will be different for each State. Some States would have a commercial interest in providing reprocessing and recycle services, while others

* An extract from the RFCC study is reproduced here in unedited form.

may see reprocessing and recycle as a necessary step for waste management, extending fuel resources or supporting fast breeder programmes.

As regards the need for fuel cycle services, even though there are only five countries at present which have spent fuel generation rates exceeding 50 t/a, there will be about 25 countries in this category by 1990, as shown in Table 3-I. Many of these countries, will find it difficult to arrange for suitable disposition of their spent fuel; in fact, some are even seriously concerned about the possibility of licensing difficulties for their new power stations in the absence of any definite plans for the disposition of their spent fuel.

TABLE 3-I. NUMBER OF COUNTRIES[a] THAT MAY REQUIRE FUEL REPROCESSING SERVICES IN THE WORLD (excluding Centrally Planned Economies) — for LWR and HWR oxide fuel

Annual quantity of spent fuel (t/a)	1976	1980	1985	1990
>500	1	1	5	6
50–500	4	10	14	19
<50	10	8	11	21
Total	15	19	30	46

Under the circumstances therefore, a number of these countries will have to consider seriously preparing plans for establishing the essential fuel cycle services on a national basis unless some other approach appears possible. The RFCC concept would meet the fuel cycle needs of States on an economical and assured basis through multinational cooperation and participation in a joint project. When individual countries perceive incentives to join such an RFCC, they then have less incentive for establishing their own national facilities, which would thereby reduce the problem of spread of reprocessing capability around the world.

These problems could be dealt with by pursuing any one of several approaches. No one of these may have the same appeal for each State.

(a) States could continue to look to the nuclear supplier States to provide the full range of fuel cycle services on a timely basis. These suppliers, however, may be unable to provide such services at the time required in view of the problems noted earlier. On the other hand, existing fuel cycle service suppliers could not be expected to expand existing facilities, or establish new ones, until they were reasonably certain that there would be a substantial and steady demand for the expanded services.

(b) States may consider, based on the considerations in (a) above, development of an indigenous national fuel cycle capability. Several States have headed in this direction. While there are not many full-fledged national reprocessing facilities in operation or under way at present, a number of States with nuclear programmes of various sizes have some level of effort for developing the indigenous scientific and technical base needed for a modest-scale reprocessing capability. A widespread movement in this direction magnifies proliferation problems and concerns. It could also lead to a multiplicity of approaches to long-term waste management problems, a consideration which in itself might increase international concerns about the adequacy of individual national waste disposal programmes.

(c) States may choose to establish bilateral international cooperative approach through which an advanced nuclear supplier assists a State in the establishment of its national facilities but with constraints designed to assure that the considerations in (a) and (b) above are taken into account — the technical and economic interests of the State which is developing its power programme and the non-proliferation and environmental interests of all States.

(d) States may consider a multinational cooperation approach, which offers economies of scale and at the same time diminishes the problems and concerns regarding proliferation and safety which would be inherent in a multiplicity of facilities. Multinational facilities could be established under various forms of common ownership, and even common management, thereby giving the participants more opportunity for an active role in the development of mutually satisfactory solutions to the basic problems discussed above.

Each of these alternative approaches could offer specific advantages under a certain set of conditions. However, in order to assess the full potential of the multinational cooperative approach given under (d) above, a detailed study of the Regional Nuclear Fuel Cycle Centres concept was carried out by the Agency.

4. NON-PROLIFERATION AND SAFEGUARDS CONSIDERATIONS

A paradox of our time is that nuclear technology, which promises so much for peaceful purposes in meeting the present and future energy needs of the world, remains also a major contributor to programmes of a military nature. Indeed, with this in mind, the IAEA was established with the objectives as stated in its Statute that it ".... *seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world" and that it ensure to the extent possible that assistance provided through its auspices "... is not used in such a way as to further any military purpose". Further, the Agency is charged, in carrying out its functions, to* "... conduct its activities in accordance with the purposes and principles of the United Nations to promote peace and international cooperation, and in conformity with the policies of the United Nations furthering the establishment of safeguarded world-wide disarmament and in conformity with any international agreements entered into pursuant to such policies" (IAEA Statute).

Broadly speaking, the objectives of non-proliferation include:

(a) Deterring initiation of nuclear weapons or other nuclear explosives programmes.
(b) Deterring the conversion of peaceful nuclear energy programmes and facilities to further any military purpose.
(c) Deterring the stockpiling of special fissionable materials over that which is needed for peaceful purposes.
(d) Complete ban on nuclear testing in all environments.
(e) Reduction of nuclear weapons capabilities leading ultimately to complete nuclear disarmament.

Present methods which have been used to further non-proliferation objectives include the Non-Proliferation Treaty and other treaties; the application of Agency safeguards; controls on the transfer or use of nuclear materials imposed by national, bilateral, multilateral and other requirements; similar controls on the transfer and use of certain sensitive technologies; arrangements of an industrial or commercial nature applying to nuclear research and development activities; and the application of requirements for the physical protection of nuclear materials and facilities.

These methods basically involve the use of commitments, controls and sanctions, and the exposure of actions to the world community.

Despite this formidable array of non-proliferation methodology there is a growing concern that gaps exist now or may develop in the immediate future and that such gaps are no longer amenable to purely unilateral action but will require harmonization of actions at the multinational or international level for their solution. This situation has arisen mainly owing to the anticipated large-scale use of nuclear power in many nations by the end of this century, and the expectation of widespread possession of large quantities of nuclear material and an increasing number of commercial nuclear fuel cycle facilities which might at some future time be diverted to non-peaceful activities, if control measures are inadequate.

In particular, concern is addressed to the reprocessing of spent fuel from nuclear power plants and to the separated plutonium from this fuel. Both fuel reprocessing facilities and recovered plutonium may be diverted from peaceful uses, and this has led some to suggest that the fuel needs of nuclear power be met with newly-mined uranium and that spent reactor fuel not be reprocessed but placed in storage. However, this raises several problems; the spent fuel must be stored safely until final disposal; also the plutonium contained in spent fuel that is in storage may be of some concern, since small reprocessing plants can be constructed and operated with data available in the open literature. Thus, the solution to this proliferation problem cannot be attained merely by discouraging reprocessing or the spread of national reprocessing facilities. A constructive solution must be sought whereby legitimate interests in obtaining a well-managed nuclear fuel cycle programme can be reconciled with concerns about proliferation. There are a number of ways of meeting these interests, including the utilization of commercial services offered by nuclear supply states, the taking of equity shares in national facilities, or the establishment of multinational fuel cycle centres. While none of these provide a complete solution, they do, in varying degrees, resolve some of the concerns about present non-proliferation measures applicable to nuclear energy programmes for peaceful purposes.

The Regional Nuclear Fuel Cycle Centre concept offers a number of advantages in meeting non-proliferation objectives, when compared to the alternative of a further expansion of national capabilities in the back-end of the fuel cycle. The most important of these advantages is that states are offered an incentive to engage in multinational alternatives to national reprocessing and thereby to reduce the number of national facilities constructed. In addition to the possible attractive economic, waste disposal and environmental aspects discussed elsewhere, the inter-governmental agreements envisaged for the RFCC (a) would enhance controls on the transfer and use of nuclear materials and restricted technologies, and provide for physical protection requirements for the facilities; (b) would provide for the adequate siting of reprocessing and fuel fabrication facilities; and (c) could define limitations on the other programmes of the participants that might otherwise be detrimental to the non-proliferation objectives of the RFCC.

Further, the RFCC concept offers States the opportunity to meet their needs for spent fuel storage and reprocessing in a timely manner. To the extent that the RFCC conveys to the public a greater assurance of adequate control over nuclear materials and facilities than would wholly national facilities, it helps to allay concern in some countries about proliferation. Nevertheless, these advantages depend to a degree on the adoption and implementation of suitable controls and guarantees, which would be required for the establishment of the RFCC.

An RFCC should be established with the application of full IAEA safeguards to its activities. Significant interest has developed in the possibility of the IAEA exercising authority granted in its Statute to require deposit of special fissionable materials, in excess of on-going national needs, and some have suggested this authority might also extend to spent fuel storage. A determination in this regard is yet to be made. Such activities might be implemented in connection with the RFCC.

It may also be beneficial if the IAEA were to be given an advisory role on the inter governmental body of the RFCC. This not only could be useful to that body but also would serve to keep the activities more open and hence more acceptable internationally. Further, the IAEA may be helpful in arranging for general guidance on criteria for the release of nuclear material from the RFCC and other technical assistance as appropriate.

If the RFCC should involve a new facility, design features to enhance safeguardability should be incorporated, such as co-location of facilities including storage, features to improve inventory and accounting of materials, features to improve containment and surveillance and process selection and storage options to make nuclear materials less vulnerable to diversion.

IMPLEMENTATION OF THE RFCC CONCEPT AND POSSIBLE ROLES OF THE IAEA

In the course of this study, the IAEA has acquired additional capability to assist Member States in analysing how potential groupings of RFCC participants might select the most suitable strategies and organizational framework to meet their mutual interests and needs regarding the back-end of the nuclear fuel cycle. Any discussion of RFCC implementation would involve consideration of the possible roles of the IAEA.

The IAEA could provide in the organizational stage a forum for initial discussions among potential participants, could give guidance to Member States on economic evaluation of, different fuel cycle strategies and on detailed study and evaluation of specific RFCC proposals prior to an implementation decision, and could assist Member States in negotiations prior to establishing institutional and legal arrangements for an RFCC. This is a logical role, insofar as the necessary experts and Secretariat infrastructure for assistance and evaluation are already available.

In the initial phase of negotiation, there would be no need for potential RFCC participants to set up a separate legal entity for this purpose. Thus, the RFCC Study Project could most profitably be extended in the direction of more concrete analyses, based on expressed interest of a group of Member States in exploring the potential applicability and implementation of the RFCC concept.

No firm commitment to establish an RFCC would be necessary at this stage, although it would probably be advisable to have participation based on something in the nature of a statement of intent. Potential participants might find it a positive step if all participants would refrain, during this concrete case study or evaluation phase, from taking actions towards establishing potentially competing national facilities. Such a group could, in effect, begin to apply somewhat empirically the results of the RFCC Study Project to a particular situation. They might even find it useful to proceed with an informally structured operation such as an analysis and planning board or council. This step would follow the completely unstructured study effort approach and lead to the formation of an interim legal entity discussed below.

The final phase would see the effort proceeding on a more formal and definitive basis, perhaps within the framework of an international entity such as a "study syndicate" i.e. a joint venture or other legal entity formed to study possible arrangements that might be suitable for an RFCC. In such a case it would be possible to plan, if desired, on continuing close and extensive interaction and cooperation with the Agency.

At this stage, the group would consist of those willing to be committed to strategies and arrangements appropriate for the group membership. The potential participants should be prepared to give general, though tentative, commitments on such items as siting, extent of use of RFCC services and investment level. The final phase would merge into formal intergovernmental and industrial negotiations.

Following the completion of the organizational stage by intergovernmental agreement, an intergovernmental body would be formed and, subordinate to this, a project group, which would manage and coordinate the design and construction of the RFCC. This project group would later be expanded or modified into the management core for the commercial and technical operations of the facility.

In general, this part of the study has discussed the establishment of an RFCC from its very beginning phases by a group of participants. Another possibility, however, is that a State may agree to internationalize a reprocessing facility which is already in operation or in the process of being built as part of a purely national programme. In this case, the IAEA could play a valuable role in providing the forum for negotiations with other potential participants in establishment of an RFCC on such a basis.

RFCC implementation studies could involve, upon request, the Agency's assistance in:

(a) Analysis and evaluation of detailed alternative fuel cycle strategies; both in the technological and economic aspects, using methodology and information developed by this Study. For actual implementation studies, a more extensive and concrete financial analysis of possible modes of funding and costs of an RFCC could be made. Possible inclusion of facilities related to the front-end of the fuel cycle could also be studied.

(b) Developing possible forms of institutional-legal arrangements: defining the legal status of an RFCC; possible issues of extra-territoriality; agreements among sponsoring governments to establish an RFCC; agreements of the RFCC with the host State; agreements among participants, sponsoring States including the host State, and other affected States concerning physical protection.

(c) Developing design guides, including requirements for safety and safeguards, and supplying technical assistance needed in the design and construction stage of the RFCC.

Because of the IAEA's safeguarding functions as visualized by the IAEA Statute and as required by NPT, the IAEA would be involved in multinational or international activities related to the back-end of the fuel cycle. Possible other roles of the IAEA must inevitably depend on what the Member States decide would be the most effective and feasible solution to the problems now associated with the back-end of the fuel cycle, including the best way in which the goals of non-proliferation and safeguards can be met.

With this in mind, a number of possible roles for the IAEA can be envisaged. Some of these are:

(a) Assisting in establishment of general guidelines for nuclear material release.

(b) Providing for IAEA laboratories on-site for safeguards analyses and other technical support, depending on the size of the RFCC.

(c) Providing technical assistance to support on-going RFCC activities. This could involve application of established technology and development of improved fuel cycle technology.

(d) Advisor on the RFCC intergovernmental body overseeing RFCC policy and operation.

(e) If the Agency, in accordance with its Statute, were to decide to require deposit of an excess special fissionable materials recovered or produced as a by-product over what is needed for peaceful purposes, facilities for such materials could be established in connection with an RFCC, and the IAEA would assume a custody or an overseeing role over this special fissionable material.

Decisions regarding problems associated with the back-end of the fuel cycle cannot be taken in isolation, and are inevitably related. In this regard, the Agency would most appropriatetely be involved in a role that enhances the credibility and effectiveness of safeguards and of NPT.

To achieve confidence and acceptance, measures and controls must not only be effective and equitable, but must be perceived to be so. In this regard, the RFCC concept, combining technological and control activities on an equitable basis, offers the world community a ration framework well-suited to attaining the objectives of non-proliferation and safeguards, while developing solutions to problems associated with reprocessing and recycling of fissile fuel materials. It also offers all States the opportunity to work together towards optimized nuclear fuel cycle strategies to meet their needs on a timely and economic basis.

Annex V
INTERNATIONAL NUCLEAR FUEL CYCLE EVALUATION

INFCE SUMMARY VOLUME*

Printed by the IAEA in Austria, January 1980

IV. MAKING NUCLEAR ENERGY WIDELY AVAILABLE TO MEET THE WORLD'S ENERGY REQUIREMENTS

Working groups, within their terms of reference, had to consider matters bearing on the availability of nuclear fuel, heavy water, fuel cycle services, technology and trained manpower to meet the requirements of national nuclear energy programmes as determined by national authorities. The major responsibility in this area, however, devolved on Working Group 3, which was assigned the task of investigating assurances of long-term supply of technology, fuel and heavy water and services in the interest of national needs consistent with non-proliferation.

Two aspects of the problem were considered separately: (1) the assurances provided by commercial markets, particularly with respect to uranium and enrichment services; and (2) government intervention in the operation of such markets on the basis of considerations of national interest and policy.

IV-A. Commercial markets

While the uranium market has been subject to considerable confusion in the past, in recent years a better balance between supply and demand has emerged which, if maintained, will have a beneficial effect on assurances of supply. As regards assurance of supply in the nuclear market, generally the contractual system is considered to be well adapted to meeting the needs of suppliers and consumers and it seems likely that it will continue to be so. In the cases of uranium and enrichment services, consumers have been able to protect against short-term interruptions of supply by the accumulation of stocks (as a result both of normal inventory policies and of slowdowns in planned reactor deployment) or by means of ad hoc commercial swapping or

* An extract from the INFCE study is reproduced here in unedited form.

loan arrangements. But it was also agreed that the functioning of these markets could be improved in a number of ways. Central importance is attached by many countries to long-term commercial contracts as an effective means to achieve the assurance of supply and demand which is essential to the continued development of nuclear electricity. In addition, the existence of a sound market for spot transactions could help consumers and suppliers to cope with short-term fluctuations in supply and demand. Moreover, like all commercial markets, those in nuclear materials would be improved by free exchanges of information at all levels.

Until recently, sources of uranium and enrichment services were few in number, thus preventing consumers from protecting against interruption by diversifying sources of supply. However, Working Group 1 notes that there is potential for additional sources of uranium supply in the future. Working Group 2 has identified several new suppliers of enrichment services likely to enter the market at the beginning of the 1980s and beyond. These additional sources will provide considerable possibility for consumers to protect themselves by diversification if a sufficient variety of commercial terms and conditions is available.

The overall goal in achieving the long-term assurance of commercial contracts should be to ensure that, through international cooperation, a political, economic, technical and commercial climate evolves that is conducive to the development of a healthy nuclear industry and the efficient functioning of market forces. Any factors that could diminish the assurance of commercial contracts should be removed or mitigated to the extent possible in the light of prevailing governmental policies through the efforts of the industries concerned and, as appropriate, through cooperation between governments in both supplier and consumer countries. It was recognized that the long duration of such contracts makes it desirable to preserve a certain flexibility in key terms to permit adjustment and appropriate sharing of burdens and risks of market fluctuations between supplier and consumer, through direct consultation or negotiation between the parties concerned.

In the context of non-proliferation policies, the growing interest in certain nuclear fuel cycle facilities and materials and the risk of political change in and among countries have increased the perception in most countries of the proliferation risks that might follow from certain nuclear fuel cycle activities. This has caused great concern. Achieving greater non-proliferation assurance regarding nuclear supply has therefore become an important objective for exporting countries, which regard such assurance as an essential component of common approaches to solve supply assurance problems and some of which consider effective non-proliferation assurances as necessary to maintain their continued ability to participate in the nuclear market. The significance of non-proliferation objectives for assurance of supplies is that supplier governments generally place great importance on their achievement and are not willing to supply, or continue to supply, nuclear materials, services and related equipment and technology in circumstances that do not adequately respect their non-proliferation objectives. In this connection, certain major supplier countries, noting changes that have taken place or may take place in the nuclear field, have decided to strengthen their non-proliferation policies concerning the terms on which nuclear exports will be permitted in the future. In pursuance of their national policies, they have also applied or given notice of their intention to apply these new conditions to existing supply contracts and have deferred or given notice of their intention to defer deliveries in an event of prolonged delays in the negotiations of new conditions with consumers. Some consumers contend strongly that these new conditions, even though associated with non-proliferation, should not be applied unilaterally to existing contracts with countries not in breach of previously agreed conditions and in particular not to materials delivered prior to changes of conditions. Consumer countries emphasize that actions of this kind inhibit the performance of contracts made in good faith and that mutual governmental agreement should be sought before new conditions are implemented. They also emphasize that unilateral action of this kind implies the right of consumers to take similar action, leading to the disruption in the flow of trade. In addition, consumer states stress the necessity to reach a clear interpretation of the duties and of the rights provided by the various non-proliferation instruments.

In the case of the development of new sources of uranium supply or new enrichment or reprocessing facilities, a greater financial participation or assistance by consumers on the supply side may contribute to an increased availability of capital for the development of production and service facilities and to a greater correlation between supply availability and demand forecasts. Participation or financial assistance may take various forms, as for instance capital participation (by acquiring equity right), management participation (by engaging in joint ventures), loans or advance payments. Foreign investment controls are applied by both supplier and consumer governments to the nulear energy sector for a variety of domestic, political, economic and social reasons. A supplier government's policies regarding foreign investment and ownership, taxation, royalties and pricing may, in certain circumstances, act as a disincentive to consumer participation in the financial risk on the supply side. Should the degree of disincentive be such that the development of supply facilities sufficient to meet the forecast demand is imperilled, there may be an adverse effect on long-term assurance of supply. There may consequently be a need to introduce greater flexibility in the implementation of such policies and to introduce positive incentives for greater consumer participation through capital investment, management participation, advance payments and loans in return for assured supply, and through other means.

Although the market has, in the past, operated in general to permit successful response and adjustment to minor interruptions in supply, it was recognized that more formal back-up arrangements, possibly including governmental participation, would be helpful in this regard, particularly for countries with smaller nuclear programmes having limited capacity for diversification or internal stockpiling. It was emphasized that these arrangements should not be designed to substitute for the market, but to operate as a last resort in case of market failure. Working Group 3 examined two forms of such short- or medium-term back-up arrangements, recognizing that other forms might be devised and that the two were not necessarily exclusive.

The first was designated a Uranium Emergency Safety Network. It could build on existing ad hoc arrangements among utilities, primarily in Europe and the USA, for swapping or loans of fuel for a limited period of time out of existing inventories. It was considered that a more institutionalized form with some governmental involvement could be envisaged on the basis of this experience. Participating members (utilities and/or states) would commit an agreed portion of their existing stockpiles to a pool to be drawn on in case of failure of supply, in accordance with agreed terms and procedures. Although this could probably begin on a limited scale, the experience gained in Western Europe and the USA suggests that there might be virtue in developing more systematic back-up arrangements, beginning at the utility level and gradually evolving into regional or even worldwide arrangements capable of meeting not only minor but substantial supply interruptions. In the case of such a development there could be a network of pools, involving consumers and/or consumer countries, producers and/or producing countries and various combinations thereof.

An alternative considered by Working Group 3 is an International Nuclear Fuel Bank. This bank would be made up of supplier and consumer states and would itself hold a stockpile of natural and low-enriched uranium or claims to such uranium. These assets could be made available to a consumer state whose supplies were interrupted by a contract default that was not the result of a breach of its non-proliferation undertakings.

It was, however, obvious that non-proliferation aspects will be relevant to criteria for membership and/or access to the emergency schemes. It was also generally recognized that to be able to work in a prompt, unbureaucratic, open, economic and reliable manner, the proposed mechanisms should be based on an agreed set of predetermined emergency criteria which when met would automatically trigger fuel supplies. In this respect, it will be indispensable for every back-up arrangement, irrespective of its form, to exempt the material to be transferred to meet an emergency from approvals of transfer, use or disposal, or at least to facilitate such transfer approvals considerably. It must be ensured by all means that the material will be transferred promptly and automatically. On the other hand, the non-proliferation concerns of supplier countries would need to be taken fully into account. In this respect the participation of supplier governments in back-up arrangements would be helpful.

In each case, a variety of important institutional matters would have to be worked out, including membership, distribution of decision-making power, financing, terms of access (particularly non-proliferation undertakings) and dispute settlement. These matters are highly political in content, and would in any case be very sensitive to the needs and desires of participants in the particular arrangement. In consequence, these matters were considered outside the scope of INFCE and were not pursued further by the Working Group.

IV-B. Government intervention

The main concerns with respect to assurance of supply have arisen not from commercial defaults or market failure but as a result of government intervention in pursuit of national policies and objectives. These have usually been associated with non-proliferation goals, but sometimes with other defined national policies as well. Government action may take the form of export controls on nuclear materials or facilities (as by right of prior consent) or import controls. However, to date few actual interruptions of supply have occurred, and where they have, they have caused delay and expense rather than damage to power production. On the other hand, if uncertainties about the possibility of supply interruptions were to continue, it would affect the orderly development of nuclear power programmes, and this has caused great concern.

If suppliers are better assured that nuclear power programmes in consumer countries will proceed in accordance with plans, they will find it easier to gear their production to meet demands. By the same token, consumers will be better able to carry out their nuclear power programmes with greater confidence if they can expect supply capacity to continue to be maintained. Foreign governmental economic or non-proliferation policies or market interventions have not been the only, or in some countries even the major, factor creating difficulties for the development of the nuclear power of nuclear supplying industries. Public concern in both producer and consumer countries over the environmental, health and safety aspects of the nuclear industry have also had an impact on its development. It is therefore clearly desirable that continuing steps be taken to respond to these concerns.

It was recognized that governments are not likely to give up the possibility of intervening in supply arrangements when they perceive it to be necessary from the point of view of their national or international interests. Nevertheless, consumer countries have been acutely concerned by these interventions, especially when, as has sometimes been the case, they reflect unilateral changes in agreed conditions of supply, and even more so when the action has had a retrospective aspect. Supplier governments, however, generally place great importance on the achievement of non-proliferation objectives and are not willing to supply, or continue to supply, nuclear materials in circumstances that do not adequately respect those objectives.

It was generally accepted that more uniform, consistent and predictable application of national export and import controls by each supplier and consumer country, in accordance with more concrete criteria, would go a long way to mitigate uncertainties and thus strengthen assurances of supply. It was considered desirable that governments develop mechanisms for the management of changes in non-proliferation policy designed to reduce to a minimum the risk that such changes, when they give rise to disagreement between supplier and consumer countries, would lead to interference with supplies.

Another important problem relates to the right of prior consent, which certain supplier countries wish to retain in respect of the retransfer to third countries and/or reprocessing of fuel supplied by them to consumer countries, and which may, if exercised arbitrarily, have a negative impact upon assurance of fuel supply and a consequent adverse effect upon their nuclear programmes. The potential for such arbitrary exercise of prior consent causes concern to consumer countries. Where a supplier country has a right of prior consent to retransfer or reprocessing, the criteria for its exercise should be established, to the extent possible, before long-term fuel supply contracts are concluded or, for short-term contracts, before fuel is committed to nuclear reactors. It is generally agreed that pending the development of common approaches to the exercise of the right of prior consent — as a first step towards broader international consensus — supplier countries should exercise that right in a manner that takes account of the national policies and particular circumstances of consumer countries, with the objective of avoiding, wherever possible, problems in the planning of nuclear power programmes. Subject to relevant circumstances not having changed, the right of prior consent should be exercised in a manner that is predictable and that conforms to any understanding that may have been reached between the parties when the right of prior consent was established.

A number of possible mechanisms have been suggested for updating non-proliferation undertakings and conditions when necessary:

(a) Provision in intergovernmental agreements for, or a joint declaration of intent to conduct informal consultations among the parties to determine if changes are necessary, on the basis of which specific amendments might be contemplated.
(b) Provision in intergovernmental agreements for periodic review by the parties involved, possibly followed, if necessary, by amendment of non-proliferation undertakings and conditions in such agreements.
(c) Provision in intergovernmental agreements for the adoption of non-proliferation undertakings and conditions agreed on by multilateral review, to the extent that all governments party to the agreements have subscribed to them.
(d) The inclusion in intergovernmental agreements of contingency provisions under which further non-proliferation requirements would be introduced or existing requirements modified in response to particular developments.

Assurances of supply could be enhanced if the adoption of such mechanisms were to be complemented by guarantees regarding continuity of supply during the re-negotiation process. Suggestions that were discussed included:

(a) Undertakings by the parties to an agreement not to refuse export or import licences under the terms of established contracts if the other party guarantees to accept amendments to non-proliferation conditions identified from time to time, in accordance with the mechanism agreed by the parties either bilaterally or within a broader international framework.

(b) Undertakings by the parties that any proposal for the extension or the amendment of non-proliferation requirements would not affect the issue of export and import approvals before the amendment mechanism has led to a consensus of the parties to the agreement.

(c) Undertakings that the parties will not interfere with deliveries under existing contracts for some reasonable period following a proposal for the extension or amendment of non-proliferation conditions, for example until it was clear that negotiations had reached an impasse.

It was also agreed that, to meet the concerns of some consumer countries about differences in some of the non-proliferation conditions of bilateral agreements, common approaches would have to be sought against the background of the need to make nuclear power available to all nations which wish to use it for peaceful purposes and the need to achieve this in a way that avoids proliferation while respecting the sovereignty of nations and the national needs of technological development.

The following are illustrations of fundamental matters the relevance, importance and acceptability of which should be considered in such common approaches, it being noted that some of these matters are the subject of divergent attitudes among exporting as well as importing states:

(a) Undertakings on the peaceful uses of nuclear materials, equipment and technology and verification of these.

(b) Undertakings not to develop or acquire nuclear weapons or nuclear explosive devices.

(c) Undertakings not to acquire, manufacture or store nuclear weapons or to help any country to do so.

(d) Undertakings with respect to the application of IAEA safeguards, including the requirements for nuclear materials accountancy and control and the implementation of any eventual IAEA system for storage of excess plutonium.

(e) Adequate levels of physical protection.

(f) Conditions governing the establishment and operation of certain stages of the nuclear fuel cycle and the management of their associated materials, including those stages based on international or multinational institutions or on national enterprises that fulfil a set of internationally or multilaterally agreed obligations.

(g) Duration of non-proliferation undertakings and controls.

(h) Sanctions and other measures to be applied in the case of a breach of non-proliferation arrangements.
(i) Undertakings regarding transfer and retransfer of supplied materials, equipment and technology, and their multilabelling and safeguards contamination implications.

These common approaches, which could be expressed initially through practices of states and bilateral agreements, might eventually take the form of joint declarations, codes of practice or other multilateral or international instruments that might eventually result in more formal measures, directed to ensuring secure access to nuclear materials, services and related equipment and technology, and especially to certain services and technologies, under internationally accepted, effective non-proliferation conditions. Such an evolutionary process — building on existing instruments, institutions, standards and practice — might be both practicable and conducive to measured progress towards a more certain regime in which national export and import policies related to non-proliferation might be implemented in a manner acceptable to both supplier and consumer countries.

VI. INSTITUTIONAL ARRANGEMENTS

The terms of reference directed working groups to examine institutional arrangements relevant to their portion of the study. A broad meaning has been given to the term `institutional arrangements', including a range of undertakings by either governments or private entities to facilitate the efficient and secure functioning of the nuclear fuel cycle, and encompassing commercial contracts, intergovernmental agreements, technical assistance programmes, international studies, non-proliferation agreements, supply assurances and international and multinational institutions. The purpose of institutional arrangements is to support and strengthen the existing mechanisms of cooperation in the peaceful utilization of atomic energy and the nuclear weapons non-proliferation regime. They are also directly or indirectly in support of the IAEA as the important international organ in this field.

Institutional arrangements were seen as contributing importantly both to minimizing proliferation risks and to assurance of supply. Indeed, Working Group 3 asserted as a general principle that assurance of supply and assurance of non-proliferation are complementary. Not only do effective non-proliferation assurances facilitate supply assurance but the non-proliferation commitments of any country may be considered stronger to the extent that such a country relies on international markets for a part of its nuclear supplies. Moreover, greater assurance of supply can also contribute to non-proliferation objectives by reducing the pressures for a world-wide spread of enrichment and reprocessing facilities. However, it should be recognized that national needs of technological development and of energy independence may ultimately require the installation of such fuel cycle facilities in a manner consistent with non-proliferation. Examples of measures which were suggested in Working Group 3 were an emergency safety network, an international nuclear fuel bank and financial participation by customers in uranium, enrichment and reprocessing ventures.

Situations were also identified in which such institutional arrangements would have other important values, such as achieving economies of scale, sharing financial risks, or maximizing favourable environmental situations.

As already noted, Working Group 1 found (though primarily from the perspective of market stability) that a pattern of cross-investment by consumers in production activities is already apparent, and most countries believe that this is to be encouraged.

Working Group 2 listed among the 'means to minimize the proliferation risks of enrichment' multinational or national institutional arrangements with supervision by governments in controlling plant technology and nuclear material produced. Measures such as classification and export control of sensitive equipment and technology, as well as the establishment of facilities under multinational auspices, which could reduce the number of facilities, are available, and to some extent have been effective in reducing the risks that would not be covered by international safeguards, though the selection of these institutional means depends on a variety of additional factors. It was noted that multinational facilities would have a generally more complicated management system than national facilities. It was also noted that limitation of the number of plants and development of additional enrichment capacity only in response to market forces are desirable from the perspective of non-proliferation. Subject to the need for a competitive market, economies of scale associated with enrichment might support limitations on the number of plants. Only a few states in the world are in a position to develop commercial-size enrichment capabilities on a national level, because such facilities require a large capital investment, highly developed basic technology and a well-developed industrial infrastructure. Of those few states capable of developing national facilities, those having substantial commercial or industrial incentives to do so would include countries having a large domestic nuclear power programme or large indigenous natural uranium resources.

Working Group 4 noted that the development of institutional arrangements must be viewed as a process of gradual evolution. Initially it seems likely that, if reprocessing is carried out, the economic incentive to build large-scale plants may mean that it is not necessary for all countries to establish the technology simultaneously, but those countries which do build large national reprocessing plants could offer reprocessing services to countries which are at an earlier stage of nuclear development. As their nuclear programmes and experience build up, these latter countries in their turn could also be expected to progress to a stage where reprocessing within their own countries could be justified by their nuclear programmes. They may then wish to consider the construction of their own plants and, in turn, be in a position to provide services to other countries. It seems desirable that the evolution of institutional arrangements should be towards multinational ventures and could eventually result in the development of regional nuclear fuel cycle centres. However, the practical difficulties in establishing and operating such ventures should not be underestimated. The nature of an International Nuclear Fuel Authority (INFA), which was also among the various institutional models discussed, was found to be not yet clear, and its formation and operation would require a major international initiative; there is little indication at present of any demand for the services of such an authority.

Working Group 4 also considered the specific question of the possibilities for international control of separated plutonium and reported on arrangements for international storage of plutonium. The IAEA Statute, Art.XII A(5), provides a possible basis for such an arrangement with respect to excess plutonium. A group of experts under IAEA auspices is at work on this problem and Working Group 4 had the benefit of their initial deliberations. Its conclusion was that a scheme for international storage of plutonium could have important non-proliferation and assurance of supply advantages. Whether or not most countries decide to reprocess their spent fuel, the scheme would be relevant, since separated plutonium already exists in the world and some countries have definite plans to continue to introduce reprocessing.

Working Group 5 considered the Fuel Cycle Centre as one of the institutional arrangements proposed to strengthen the proliferation resistance of the fuel cycle. It took as a starting point the IAEA study on LWR regional fuel cycle centres. It concluded that, from the viewpoint of non-proliferation, a multinational or international facility could form an attractive institution, for example by providing easier safeguards implementation and by making unauthorized operations more difficult. A preliminary comparison between the multinational and international solutions seems to show that multinational schemes offer slightly fewer difficulties with regard to ownership and have relatively fewer problems. Negative effects of multinational or international arrangements would be the increased risk of transfer of sensitive technologies and the difficulties of co-ordinating physical protection and safety measures with those of the host country. Taking into account the significant technical problems associated with co-location, when reactors are included within the centre, on issues such as safety and environmental impacts, public acceptance, and land and water requirements, the group put forward as a general conclusion that the co-location of only reprocessing and fabrication plants could be a more acceptable way of improving diversion resistance. However, in view of the complexity of the problems, careful evaluation would be required before any implementation. Studies of co-location should refer to specific sites for which a proper evaluation of the environmental impact and the implications for local communities can be made and public acceptance verified.

With regard to the choice of spent fuel management concepts, institutions providing services such as reprocessing or AFR storage necessary for the implementation of some of these management concepts either do not exist or are inadequate to meet the needs of some countries. Countries with large nuclear programmes will most probably use their own national facilities or institutions for spent fuel management. However, there are countries that do not have, and do not plan to have, within their national borders all the steps of the back-end of the fuel cycle. Thus they depend on foreign nuclear industries and services. Therefore, adequate interim storage capability must be provided in support of the spent fuel management concepts of these countries. There are also countries that have not taken any decision at present to develop all the steps of the back-end of the fuel cycle but have decided to build national AFR facilities. The evaluation identified situations where ways of resolving spent fuel management problems need to be considered. The main sources of concern are restrictions upon the choice available to states regarding their spent fuel management concepts. The required solutions involve both the legal framework and institutional practices and they should also take into account the fact that the magnitude of the problem varies widely from country to country. Lack of assurance of long-term supply has already in some cases motivated countries to adopt policies of fuel cycle self-sufficiency earlier than would be required by their optimum economic and technical development schedule. The feasibility of an international mechanism for providing assurances to participating states for access to and management of their spent fuel consistent with non-proliferation objectives should be investigated. Consideration should be given to international cooperation in developing spent fuel storage and management options. In this regard Working Group 6 has identified requirements which international or multinational institutions should ideally fulfil. Since the negotiation and implementation of multinational or international enterprises generally take time, it seems that for the near future national facilities will be the most realistic solution to avoid a deficiency in spent fuel storage. Moreover, the fundamental question remains: to what extent would individual countries be willing to offer sites and accept the agreed international conditions? However, consideration should be given to whether international spent fuel management schemes might improve prospects for storing spent fuel and thereby assist certain countries in the economic and management aspects of spent fuel storage. In this regard it would be useful to define the role that the IAEA and other international organizations might play.

Finally, the Working Group 7 report included the following recommendation. Multinational and international repositories could offer advantages as concerns non-proliferation as well as economical aspects. Proposals for the legal and institutional solutions for establishing multinational and international repositories should be elaborated. Centralized facilities for the disposal of spent fuel and/or vitrified high-level waste would alleviate the concerns of countries with small nuclear power programmes or in which suitable sites may not exist. These facilities, whether international, multinational or national with access by foreign countries, would benefit from the economies of size discussed in section 7 of the Working Group 7 Summary. They could also reduce the diversion risk, since obviously a larger number of spent fuel repositories would enhance this risk. Furthermore, because the collective dose commitments would be small compared with annual exposure from the background radiation, a central repository would not present a health impact of any consequence in the country of its location. However, it was noted that international repositories may require considerable negotiating time and be more difficult to administer than national or multinational facilities.

In connection with all international or multinational arrangements, it was recognized that decisions would be required on such sensitive questions as membership, financing, voting arrangements, conditions of access, dispute settlement, status of the host government and the like. It was noted that a solution would have to be found for avoiding possible interference by the host government. It was also recognized that in addition to the multinational and international non-proliferation undertakings some supplier governments require the conclusion of bilateral agreements or evidence that, when exported, the material or equipment will fall under another recognized bilateral agreement. Some of the working groups examined possible alternative solutions on these matters in the main body of their reports. But it was recognized that final solutions could be developed only by the potential participants themselves, acting at the political level. Conclusions on these matters, therefore, were outside the INFCE terms of reference.

Although primary attention was placed on formal institutional arrangements, several groups discussed the growing importance of international cooperation through the development of recommendations, guidelines and codes of practice to standardize procedures and harmonize practices in this field. For example, several working groups noted that there was a need for international cooperation in international transport, particularly in cask licensing and harmonization of regulations.

Finally, many of the working groups acknowledged the value of continuing consultations on a bilateral and multilateral basis for smooth adjustment of problems arising from diverging national interests and policies in connection with nuclear fuel cycles. These consultations could possibly lead to common approaches, which might eventually result in more formal measures, as already mentioned in the last paragraph of Chapter IV.

Annex VI
INTERNATIONAL PLUTONIUM STORAGE

International Atomic Energy Agency

IAEA-IPS/EG/ 140
(Rev. 2)

EXPERT GROUP ON INTERNATIONAL PLUTONIUM STORAGE

EXPERT GROUP ON INTERNATIONAL PLUTONIUM STORAGE*

1 November 1982

4. BACKGROUND

4.1 Most of the procedures for the implementation of Article XII.A.5 have been carried out by the Working Group on IPS and Safeguards, the report of which is in Annex A. The Working Group was charged in its terms of reference to consider the relationship between an IPS concept and existing safeguards.

4.2 Three approaches to the implementation of Article XII.A.5 have emerged. The evolution of these concepts in the Expert Group and its subgroups is described in the meeting reports. From a procedural and operational point of view the three alternatives have certain elements in common and all three could be operated in close association with current IAEA safeguards. The differences between the alternatives are more of a conceptual nature, arising from different views on the precise relationship between States and the Agency in the implementation of Article XII.A.5. The main features of the three approaches are apparent from the summaries which follow and from the fuller descriptions given in Annex A.

5. SUMMARY OF PROPOSED PROCEDURES — ALTERNATIVE A

5.1 Registration of all separated plutonium owned by the State and under IAEA Safeguards. An initial inventory, established when a State accepted IPS

* An extract from the IPS study is reproduced here in unedited form.

obligations, would be updated through notifications which would also be required under either an INFCIRC/66 (Rev.2) or INFCIRC/153 (Corrected) safeguards agreement, but with the addition of details of ownership. The procedure would enable a State to take plutonium into use directly after separation and registration, by making a Statement of Use to the Agency prior to, or during, separation or in connection with registration (Flows 1 and 2 in the figure opposite). For plutonium not taken directly into use (Flow 3 opposite), the next stages would be 5.2, 5.3 and 5.4 below:

5.2 Deposit and

5.3 Storage in an International Plutonium Store.

5.4 Return of deposited plutonium promptly, at the request of the owner State and on the basis of a Statement of Use similar to that referred to in 5.1 above.

5.5 Verification of Use: i.e. verification that plutonium is used in accordance with the Statement of Use referred to in 5.1 or 5.4 above, up to its deregistration, and therefore that stockpiling is not taking place. Verification of use would apply whether plutonium was taken into use directly after registration or returned after deposit and storage in an IPS store.

5.6 Deregistration, when plutonium fabricated into fuel is loaded into a reactor; or, where appropriate, when plutonium residues or scrap are dissolved in a reprocessing plant; or when safeguards are terminated in accordance with the relevant safeguards agreement.

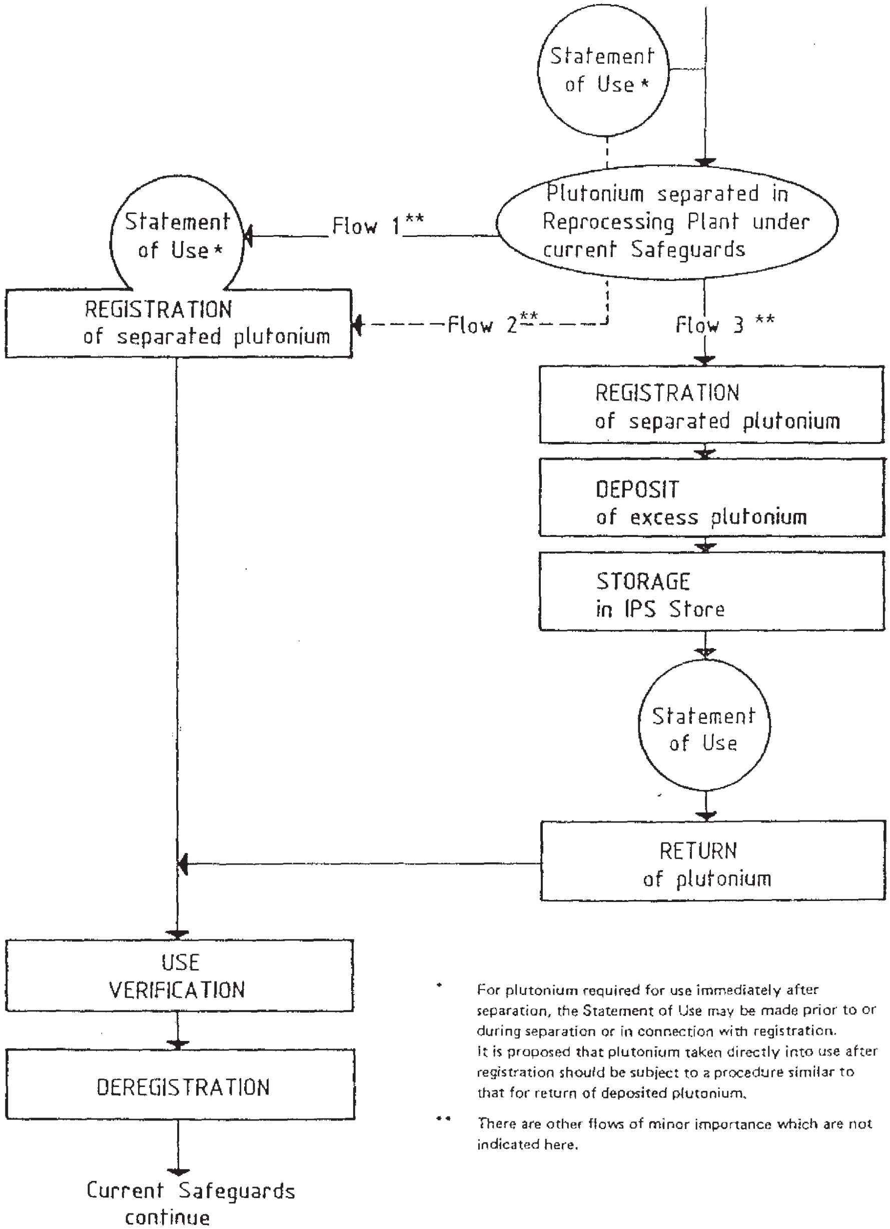
5.7 Current safeguards apply to the plutonium at all stages and are used as a basis for performing 5.1–5.6 above.

6. SUMMARY OF PROPOSED PROCEDURES — ALTERNATIVE B

6.1 Article XII.A.5 of the Statute will provide the basis for International Plutonium Storage which will be a purely voluntary arrangement applicable to separated plutonium under IAEA safeguards. A State accepting IPS obligations on a voluntary basis will decide how much of its separated plutonium is needed for its use, and what is excess.

6.2 Deposit

ALTERNATIVE A - PROPOSED PROCEDURES



* For plutonium required for use immediately after separation, the Statement of Use may be made prior to or during separation or in connection with registration.
It is proposed that plutonium taken directly into use after registration should be subject to a procedure similar to that for return of deposited plutonium.

** There are other flows of minor importance which are not indicated here.

6.3 Storage in an International Plutonium Store of owner State's choice.

6.4 Return: When the owner State requires the deposited plutonium for its use, it will make a request to the Agency giving details of the quantity and form of plutonium, timing of dispatch and location of use and the Agency will return the plutonium promptly.

6.5 The provisions and the undertakings in the safeguards agreement and the facility attachments/subsidiary arrangements will ensure that the plutonium will be in peaceful use under continuing Agency safeguards.

6.6 The information available from current safeguards practices on the location, quantity, form and flow of plutonium will enable the Agency to know that the plutonium is in peaceful use.

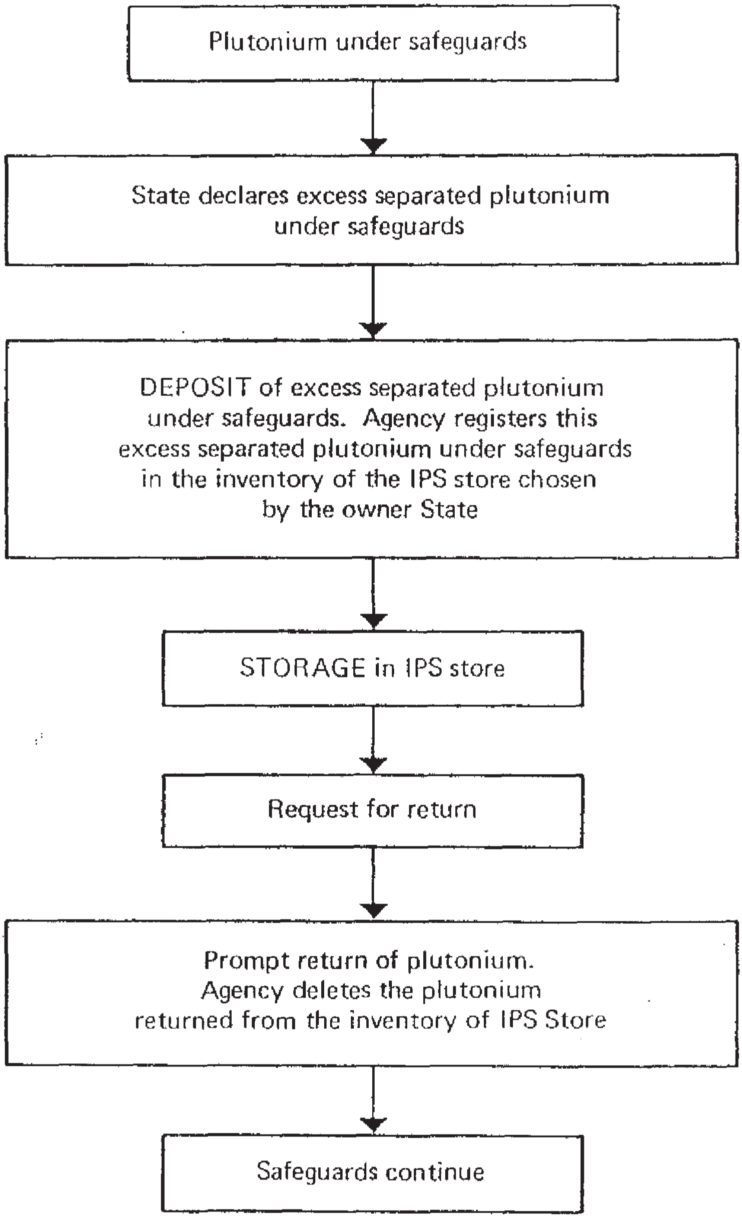
6.7 Prevention of stockpiling: The provision that plutonium will not be stockpiled will be satisfied by the undertaking that the limits on buffer stocks at Fuel Fabrication Plants as determined by the owner State and notified to the Agency will not be exceeded. These limits may be changed by mutual agreement between the owner State and the Agency in the light of experience. In case plutonium in quantities larger than a minimum quantity lies idle in any facility for an unusually long time, due to unforeseen delays or operational problems, the owner State will consider the necessity of taking action in consultation with the Agency.

7. SUMMARY OF PROPOSED PROCEDURES — ALTERNATIVE C

7.1 General: All plutonium for peaceful purposes would be continuously covered by the scheme. The use of plutonium must be for specified peaceful purposes which excludes any explosive use. The requirements of the Statute that plutonium be used for specified peaceful purposes, and not be stockpiled, would be satisfied by prior assessment by the Agency of a Statement of Use and subsequent verification of the stated use.

7.2 Registration: All plutonium for peaceful purposes in, or owned by, participating States will be registered. An initial inventory of separated plutonium, established when a State accepted IPS obligations, would be updated through notifications. These notifications would additionally contain information on ownership and isotopic composition. The procedure would enable a State to take plutonium into use directly after separation and

ALTERNATIVE B – PROPOSED PROCEDURES



registration, by making a Statement of Use to the Agency prior to, or during, separation or at the time of registration (Flows 1 and 2 opposite). Following registration, the Agency would have the right to request clarification of details of registration and/or use, examine their technical consistency and compare the information provided with information available to it through the safeguards system. For separated plutonium not taken directly into use (Flow 3 opposite), the next stages would be 7.3, 7.4 and 7.5 below:

7.3 Deposit and

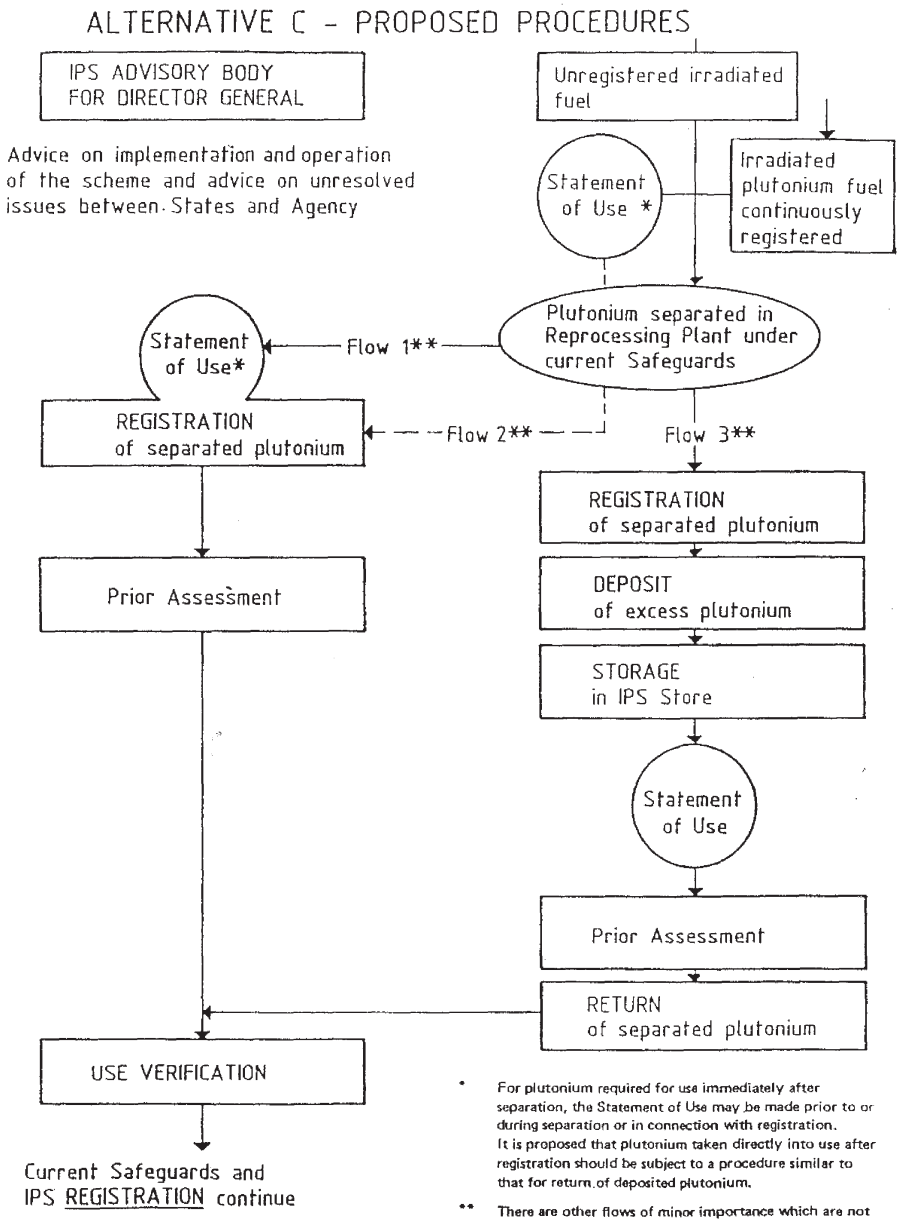
7.4 Storage in an International Plutonium Store.

7.5 Return of deposited plutonium at the request of the State and after prior assessment by the Agency of an accepted Statement of Use similar to that referred to in 7.2 above. If at any stage information required by the Agency to authorise return is not provided, consideration of the request for return would not proceed.

7.6 Verification of Use: i.e. verification of the information in the Statement of Use; and verification that plutonium is used for peaceful purposes and that stockpiling is not taking place. Verification of use would apply whether plutonium was taken into use directly after registration or returned after deposit and storage in an IPS store.

7.7 Current safeguards are used as a basis for performing 7.2–7.6 above. When use verification is completed, i.e. when the plutonium has been mixed with fission products, current safeguards and IPS registration continue to apply.

7.8 An IPS Advisory Body, drawn from participating States, would provide advice to the Director General on the implementation and operation of the Scheme. The Director General could refer any unresolved issues between the Agency and any participating State to the Advisory Body for advice on the matter.



* For plutonium required for use immediately after separation, the Statement of Use may be made prior to or during separation or in connection with registration.
It is proposed that plutonium taken directly into use after registration should be subject to a procedure similar to that for return of deposited plutonium.

** There are other flows of minor importance which are not indicated here.

PART III — CONCLUSIONS

General Considerations

8.1 The Expert Group met at the invitation of the Director General of the IAEA "to begin the preparation of proposals for the establishment of schemes for the international management and storage of plutonium in implementation of Article XII.A.5 of the Statute". In the course of the discussions it was concluded that, to be generally acceptable, proposals for the implementation of Article XII.A.5 should be such as:

- to facilitate the development of plutonium-using fuel cycles;
- to facilitate the achievement of international non-proliferation objectives;
- not to discriminate between States; and
- not to interfere with national energy programmes.

Operational aspects

8.2 The detailed conclusions of the Group on the operational aspects of implementing Article XII.A.5 are set out in Part II, with supporting material in the Annexes. The key points can be
summarized as follows:

(1) IPS should be seen as a part of the IAEA safeguards system — and not as a new or separate system. Accordingly, the emphasis has been on developing proposals for the implementation of Article XII.A.5 of the Statute as an extension of current safeguards,

(2) Proposals for IPS should utilize established safeguards reporting and inspection procedures to the fullest extent possible. The conclusions of the Working Group on IPS and Safeguards suggest that this is a realistic objective, which could be accomplished with no great difficulty.

(3) Since it would be impracticable and unnecessarily costly for the Agency to build its own plutonium stores, excess separated plutonium under safeguards, deposited with the Agency, should be stored in facilities designated as international plutonium stores. An instrument between the responsible State and the Agency would provide for appropriate custody and supervision of deposited plutonium by the Agency, which would, in particular, supervise movements of plutonium in and out of the store.

(4) IPS stores would be located at places where plutonium would normally be stored in any event, such as reprocessing plants or mixed oxide (MOX) fuel fabrication plants.
(5) Transport of plutonium should be kept to a minimum in view of the physical protection requirements and costs associated with plutonium transport.

Institutional aspects

8.3 In the absence of identity of views amongst the experts on the conceptual basis of IPS, no final conclusions on institutional and legal questions have been reached. However, there appeared to be a general tendency in favour of definition of the rights and obligations of Member States and the Agency in bilateral instruments. This was without prejudice to a final decision on the possibility of a multilateral approach. It was also understood that there would be equivalent rights and obligations between participating States.

Open Questions

8.4 The Expert Group has examined the technical and operational possibilities but the task of preparing proposals for the implementation of Article XII.A.5 is not yet completed. The following questions remain open;

(a) Harmonization of the conceptual approaches described in this report;
(b) Following (a), to draft elements for the conclusion of implementing instruments between member States and the Agency;
(c) To draft elements for the conclusion of instruments between Member States and the Agency for the designation and operation of international plutonium stores;
(d) To consider how the procedures laid down in instruments concluded in accordance with (b) and (c) should be applied (e.g. in subsidiary arrangements).

8.5 Different States are at different stages of fuel cycle development and for some States the need to solve the above open questions is a pressing matter in order to resolve problems which already exist. However the Expert Group recognizes that consideration of suitable mechanisms for tackling these questions is a matter for the decision-making organs of the Agency. In this spirit the Expert Group submits this final report to the Director General.

Alternative A	Alternative B	Alternative C
Registration 1. All safeguarded separated Pu in the State to be registered, (together with that owned by the State outside its territory at the time). 2. Information on ownership to be included in data base, (together with information on Pu isotopic composition). 3. All newly separated Pu to be registered on leaving the end-product MBA of the reprocessing plant.	**Registration** 1. Safeguarded separated Pu declared as excess by the Owner State will be registered by the Agency in the inventory of the IPS store. 2. Data base will include information on facility/ location.	**Registration** 1. All separated Pu for peaceful purposes in, or owned by, participating States will be registered. 2. Data base will include information on ownership and Pu isotopic composition. 3. Pu will be registered on separation or acquisition.
Deposit 1. 'Excess' Pu to be deposited with the IAEA and placed in stores designated for this purpose. 2. Each state can hold a limited quantity of un-deposited excess Pu, [the quantity would be dependent on the number of Pu facilities]. 3. Owner States to be responsible for deposit.	**Deposit** 1. Safeguarded separated Pu declared as excess by the Owner State will be deposited in an IPS store chosen by the Owner State. 2. Each State can hold a limited quantity of excess separated Pu without depositing in an IPS store. This quantity should be related to each Pu handling facility. 3. Owner State is responsible for deposit.	**Deposit** 1. Excess Pu, i.e., that not covered by a Statement of Use, would be deposited in an IPS store. 2. Each State would be able to hold a limited quantity of undeposited excess Pu. This would be kept under special seal and could be used on completion of the return procedure. 3. As Alternative A.
Return 1. Pu will be returned to the Owner State, if the specified use is: (i) peaceful; (ii) safeguarded; and (iii) will not lead to stockpiling. 2. The Owner State will provide a Statement of Use for all non-excess Pu specifying the use and quantities required. 3. The Pu will be returned promptly if the Agency is satisfied that criteria (i), (ii) and (iii) will be met. Criterion (iii) will be satisfied by the State undertaking to ensure that agreed Buffer Stock Limits at fuel fabrication plants will not be exceeded, or, if as a result of the return the quantity of Pu at the named facilities would not exceed a threshold amount, or if the return would not result in the inventory of the facilities exceeding the figures stated in their design information. The Buffer Stock Limits would be agreed between the operator and the Agency. 4. Statements of Use can be submitted for the use of declared excess Pu or for Pu which is to go directly into use before deposit. 5. It is assumed that Pu will only be returned for use in States where IPS procedures apply.	**Return** 1. The Owner State will request return of the deposited Pu in storage giving details of the quantity and form of Pu, timing of despatch and location of use. 2. The Pu will be returned promptly upon request. The provisions and the undertakings in the safeguards agreement and the facility attachments, subsidiary arrangements will ensure that the Pu will be in peaceful use under continuing Agency safeguards. 3. The provision that Pu will not be stockpiled will be satisfied by the undertaking that the limits on buffer stocks at fuel fabrication plants as determined by the Owner State and notified to the Agency will not be exceeded. These Limits may be changed by mutual agreement between the Owner State and the Agency in the light of experience.	**Return** 1. As Alternative A, but, in addition specified use shall be: (iv) non-explosive. 2. As Alternative A. 3. Pu will be returned promptly, provided that the Agency makes a prior assessment that the criteria (i) — (iv) will be met. Provision is made for unresolved issues to be submitted by the Director General to an IPS Advisory Board. Buffer Stock limits would be set in a similar method to Alternative A. The methodology of establishing the limits and the limits themselves would be reviewed by the Advisory Board. 4. As Alternative A. 5. As Alternative A.

Alternative A	Alternative B	Alternative C
Use Verification 1. The use of returned Pu will be verified to establish that no stockpiling takes place, by confirming that the Pu is used in the way specified in the Statement of Use.	**Use Verification** 1. Information available from current safeguards practices on the location, quantity, form and flow of Pu will enable the Agency to know that the Pu is in peaceful use, No additional use verification is, therefore, necessary. 2. In case Pu in quantities larger than a minimum quantity lies idle in a facility for an unusually long time, the Owner State will consider the necessity of taking action in consultation with the Agency.	Use Verification 1. Use verification would be similar to Alternative A. In addition, the Agency would review stocks of "residues awaiting recovery" to ensure that they did not constitute stockpiling.
Deregistration 1. Pu will be deregistered: (i) when it is loaded into a reactor core. (ii) when unirradiated Pu enters the head-end of a reprocessing plant. (iii) when safeguards are terminated in accordance with relevant Safeguards Agreements.	**Deregistration** 1. As soon as Pu is returned for use, this quantity of Pu will be deleted from the IPS inventory.	**Deregistration** 1. Pu will be deregistered only when safeguards are terminated in accordance with relevant safeguards agreements

Annex VII
Committee on Assurances of Supply: Draft Synthesis of Principles

International Atomic Energy Agency

COMMITTEE ON ASSURANCES OF SUPPLY (CAS)

DRAFT SYNTHESIS OF PRINCIPLES*

Note by the Secretariat — 23 May 1985

The circulation of this working paper was authorized by the Committee at its sixteenth session in order that it might serve as a basis for further discussions by the Committee at its next session. It is recalled that, at its first session, the Committee agreed that the status of working papers would be informal. The Committee noted that, although significant progress is reflected in the working paper, some delegations have reservations about parts of it.

INTRODUCTORY STATEMENT

The Committee was established (document GOV/1997 of 20 June 1980) to consider and advise the Board of Governors on — inter alia — ways and means in which supplies of nuclear material, equipment and technology and fuel cycle services can be assured on a more predictable and long-term basis in accordance with mutually acceptable considerations of non-proliferation. Pursuant to its mandate the members of the Committee have formulated a number of principles.

All members of the Committee agree, in understanding the term "non-proliferation", that their common basic objective, as stated in paragraph 65 of the Final Document of the tenth UNGA Special Session on Disarmament (1978),

* An extract from the CAS study is reproduced here in unedited form.

is preventing the proliferation of nuclear weapons. The majority of them who have obligations arising from their commitments to treaties such as the Treaty for the Prohibition of Nuclear Weapons in Latin America or the Treaty on the Non-Proliferation of Nuclear Weapons understand the term "non-proliferation" in accordance with those treaties.

It is in these circumstances that the members of the Committee, in accordance with its mandate, have agreed on the following principles which, in the field of nuclear supply, concern the role of governments and describe the role and responsibilities of the IAEA rather than the activities of commercial entities.

I. PRINCIPLES ON WHICH SUPPLIES OF NUCLEAR MATERIAL, EQUIPMENT AND TECHNOLOGY AND FUEL CYCLE SERVICES CAN BE ASSURED ON A MORE PREDICTABLE AND LONG-TERM BASIS

(1) In order to promote their economic and social development, all States have the sovereign and inalienable right, on a non-discriminatory basis, to develop, acquire and use nuclear energy for peaceful purposes, including the right to choose a fuel cycle, in conformity with their national priorities, interests and needs.

(2) All States have the sovereign and inalienable right to choose their own role in international nuclear trade.

(3) Nuclear supplies -- i.e. supplies of nuclear material, equipment and technology and fuel cycle services -- and international nuclear trade in general should be assured on a long-term, international basis that is widely acceptable and in a non-discriminatory, predictable, consistent and ultimately uniform manner.

(4) Effective measures should be taken to meet the specific needs of States whose nuclear programmes are still in an early stage of development, including their needs in the fields of manpower training, domestic participating industry development and research cooperation.

(5) In accordance with international law and applicable treaty obligations, States should fulfil their obligations under agreements in the nuclear field and any modification of such agreements, if required, should be made only by mutual consent of the parties, through revision mechanisms previously agreed by the parties. Revision mechanisms should be further developed on an international basis.

(6) When trading partners have agreed to apply prior consent clauses to nuclear supply transactions, such clauses should be implemented as

previously agreed upon by the parties and in an established and predictable manner.

(7) The retransfer of nuclear materials, materials and equipment should be possible when these are subject, in the recipient State, to the same commitments as those accepted by the retransferring State in relation to the original transfer.

(8) The availability of international mechanisms to ensure assistance in cases of supply emergencies should be an important element of backing up assurances of supplies.

II. PRINCIPLES FOR ASSURANCES OF SUPPLY IN ACCORDANCE WITH MUTUALLY ACCEPTABLE CONSIDERATIONS OF NON-PROLIFERATION

(9) Assurances of supply and assurances of non-proliferation are complementary, interdependent and essential for international cooperation in the peaceful utilization of nuclear energy.

(10) The interests of all States in stable international nuclear trade and cooperation will be enhanced by the fulfilment of a common basic objective of non-proliferation. The development, acquisition and use of nuclear energy for peaceful purposes and international nuclear trade should be conducted accordingly.

(11) The implementation of non-proliferation assurances should be compatible with the right of every State to develop, acquire and use nuclear energy for peaceful purposes.

(12) Non-proliferation assurances for nuclear supply assurances should be based on a national commitment that is internationally binding together with the application of Agency safeguards. Each State has the sovereign right to decide how to make such a commitment. Many States, being parties to treaties such as the Treaty for the Prohibition of Nuclear Weapons in Latin America or the Treaty on the Non-Proliferation of Nuclear Weapons, have made such a commitment under the terms of those treaties. Other States have made commitments of an international character by means of declarations of national non-proliferation policy.

DESCRIPTION OF THE AGENCY'S ROLE AND RESPONSIBILITIES

(1) The Agency continues to serve as the primary multilateral forum for the development of international cooperation in the field of nuclear energy, including the strengthening of assurances of nuclear supply.

(2) Agency safeguards have a basic role in facilitating international cooperation and trade. Adaptations of safeguards procedures and techniques with a view to increasing their effectiveness and efficiency serve to further strengthen assurances of nuclear supply.

(3) The Agency keeps the nuclear supply situation under permanent review. To assist the Agency in performing this function, States may inform the Agency of abnormal situations of direct concern to them regarding the fulfilment of supply assurances so that the Agency may prepare itself to take timely action if required, and to report thereon whenever it deems it necessary.

(4) The Agency, to the extent requested by a State, shall provide summary statements on the results of the implementation of safeguards in the requesting State which should constitute, in consultations on nuclear cooperation between that State and other States, an important element of confirmation of that State's compliance with its non-proliferation commitments as verified by Agency safeguards.

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In response to the growing emphasis on international cooperation to cope with nuclear non-proliferation concerns, the Director General of the IAEA appointed an international group of experts (participating in their personal capacity) to consider possible multilateral approaches to the civilian nuclear fuel cycle. The mandate of the Expert Group was to: analyse the issues and options relevant to multilateral approaches to the nuclear fuel cycle; review the policy, legal, security, economic, institutional and technological incentives and disincentives for cooperation in such multilateral arrangements; and evaluate the historical and current experience with multilateral fuel cycle arrangements. This publication presents the report of the Expert Group, which was officially released in February 2005 and circulated for discussion among the IAEA's Member States.

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