Regional Nuclear Fuel Cycle Centres

by Vinay Meckoni*

A number of countries now have plans to proceed with their nuclear power generation programmes at an accelerated pace. These countries will also have to decide at an early stage of their programmes what should be done with the spent fuel from their power reactors. Should they just store the spent fuel or should they reprocess it?

The decision to follow one or the other strategy at any specific point of time will depend upon a number of factors such as:

- *The type of reactors (whether natural uranium or enriched uranium) that they have accepted for their power generating system.*
- *The price and availability of uranium.*
- *The cost and availability of enrichment service.*
- *The cost of spent fuel reprocessing and availability of such service.*
- *The cost of mixed oxide fuel fabrication and availability of such service.*
- *The price of plutonium and the possibility of its sale to those countries who already have adopted plutonium recycle in their thermal power reactors or who require plutonium for their fast breeder reactors.*
- *The cost of radioactive waste management and the avenues for waste disposal.*
- *The logistics of fuel supply and demand.*

In the final analysis, if the decision is just to store the spent fuel, the problems will be those associated with long term storage of such fuel, which are relatively simpler. However, if the decision is to recycle the fuel, i.e. reprocessing the spent fuel, recovering plutonium and uranium, and fabricating mixed oxide fuel elements as shown in Fig. 1, the problems will be more complex. This will involve assimilation of a number of new technologies, training of local staff, maintaining plant safety, safeguarding of fissile materials, financing of various facilities and other related matters associated with the setting up of the fuel cycle facilities. These are the problems of many of the industrialized countries today.

It appears that the best way to solve this complex of interrelated problems is through international cooperation on a regional basis so as to coordinate effectively the development of all steps of the fuel cycle. Not only would there be economic benefits from large regional centres but also there would be improved manpower utilization, more efficient technological operations, more reliable radioactive waste management and disposal, better security of materials and more effective international safeguards that need to be applied to plutonium separation and storage facilities.

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A 1200 MWe light-water cooled and moderated nuclear reactor needs nearly 200 fuel elements. With ▶ the growing number of nuclear power plants it is essential to develop one or more fuel cycle models that would take into account all new developments in the fuel cycle. Photo: KWU

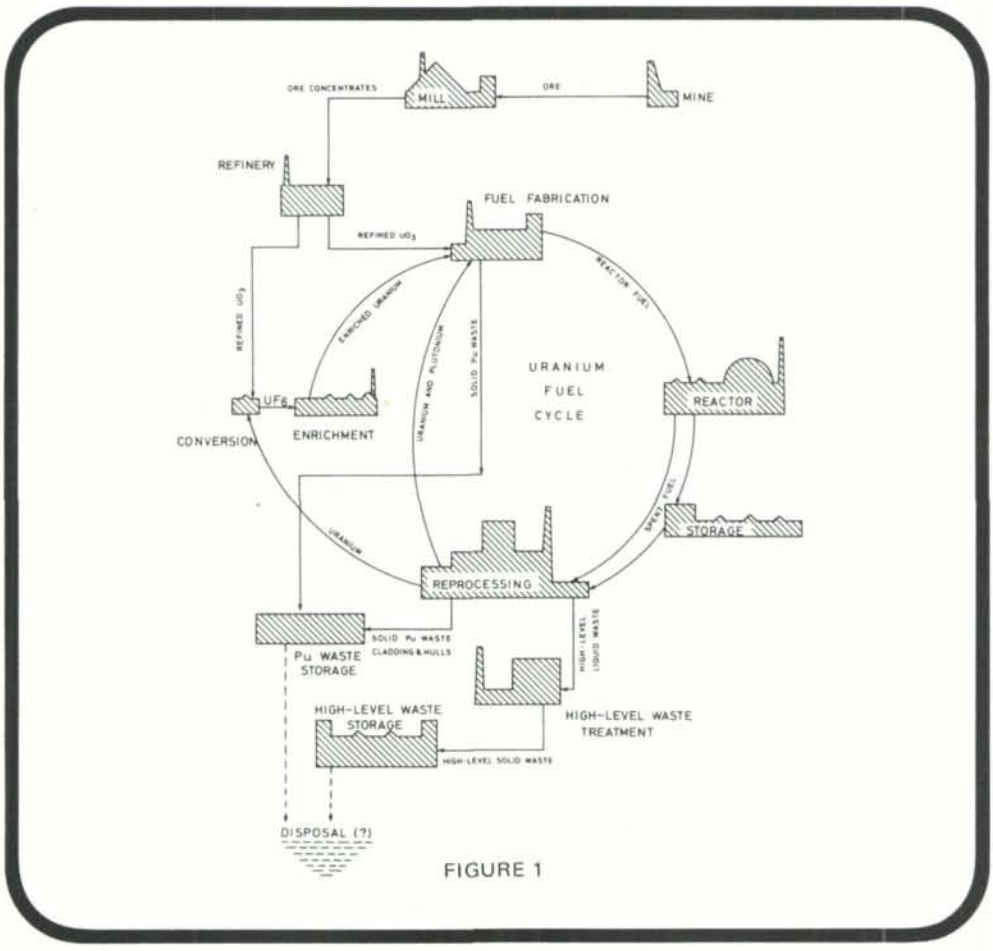

FIGURE 1

Based on the promising results of a preliminary study carried out by the Agency's staff to ascertain if any economic benefits could result from a regional approach to the establishment of nuclear fuel cycle facilities, the IAEA's Scientific Advisory Committee endorsed an in-depth study project, emphasising that the study should encompass fuel cycle centres in a broad context to include fuel fabrication facilities as well as reprocessing and waste management. Accordingly, a project study group was established in the Agency and the relevant development effort initiated.

In the Final Declaration of the Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, the following recommendation was made in the review of Article IV:

"The Conference recognizes 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.

The Conference welcomes the IAEA's studies in this area, and recommends that they be continued as expeditiously as possible. It considers that such studies should include, among other aspects, identification of the complex practical and organizational difficulties which will need to be dealt with in connexion with such projects.

The Conference urges all Parties to the Treaty in a position to do so to co-operate in these studies, particularly by providing to the IAEA where possible economic data concerning construction and operation of facilities such as chemical reprocessing plants, plutonium fuel fabrication plants, waste management installations, and longer-term spent fuel storage, and by assistance to the IAEA to enable it to undertake feasibility studies concerning the establishment of regional nuclear fuel cycle centres in specific geographic regions.

The Conference hopes that, if these studies lead to positive findings, and if the establishment of regional or multinational nuclear fuel cycle centres is undertaken, Parties to the Treaty in a position to do so, will co-operate in, and provide assistance for, the elaboration and realization of such projects."

At the Nineteenth Regular Session of the General Conference held in September last year, the Director General stated that:

"Long-term planning and international co-operation in relation to the nuclear fuel cycle is a logical sequel to the world-wide growth of nuclear power. While most aspects of nuclear power production have now reached the stage of normal commercial and industrial implementation, this is not the case for certain aspects of the nuclear fuel cycle such as fuel reprocessing and radioactive waste management. Hence, it is prudent that the IAEA should examine such potential problem areas. With this aim in mind the Agency has embarked on an extensive study of regional fuel cycle centres."

A number of Member States also endorsed the Agency's study project at the last General Conference.

OBJECTIVES OF THE STUDY PROJECT

The objectives of the Agency's study project are:

– To develop the methodology for assessment of alternative strategies for establishment of integrated regional nuclear fuel cycle centres, so as to evaluate their advantages and disadvantages vis-à-vis dispersed fuel cycle facilities.

– To prepare a report on this methodology, including illustrative examples on approaches and advantages to Member States, for the use of those organizations interested in the implementation of nuclear fuel cycle activities.

– To provide a mechanism for the establishment of a forum where Member States and other interested parties can work out alternative strategies with regard to nuclear fuel cycle activities as well as evolve appropriate frameworks to cover institutional, legal and other aspects related to the establishment of such multinational fuel cycle centres.

SCOPE OF THE STUDY PROJECT

The project will cover the nuclear fuel transport, storage, processing and recycling activities, starting from the time the spent fuel leaves the nuclear power reactor through all subsequent steps until recycled fuel, in the form of fuel elements, is ready for shipment to the reactor.

Production of new uranium fuel and enrichment activities are not included, but the study will include those activities involving management of radioactive wastes generated in the fuel cycle.

A regional nuclear fuel cycle centre would normally be required when there is immediate need for reprocessing the spent fuel being discharged from the nuclear power stations established in the region. However, such a centre, to be economically viable, will have to be of certain minimal or optimum size. On the basis of the earlier studies carried out by a number of countries, it is considered that the optimum capacity of a fuel reprocessing facility to be located in such a centre may lie in the range of 750 to 3,000 tonnes uranium annual throughput. Hence for detailed analysis it is proposed to examine this range initially, and ascertain from the electrical load growth pattern and the nuclear power generation programme as to what would be the earliest period when such a fuel centre would be needed in any region. Later in the study cases could be considered where, under certain special conditions, even a smaller capacity plant could be desirable.

In the first instance it would be essential to develop one or more models that would take into account all the important steps in the fuel cycle. The various facilities could be designed to suit a range of parameters which could vary within specified limits, and the model should be able to reflect the effect that each of these parameters would have on the overall picture. For the purpose of preparing these models, the fuel cycle concept which would be relevant to the present study is presented in Figure 2. Some of the basic criteria and assumptions made for the first phase of the study to keep it relatively simple are given in Table 1.

Taking the fuel cycle concept as set forth in Figure 2, a conceptual economic analysis approach has been developed in the form of fuel cycle programme modules. However, this approach does not take into account all the pertinent considerations and constraints which would also have to be studied in detail. The project would therefore entail four basic types of effort which would be as follows:

– Development of one or more mathematical models and associated computer codes to permit analysis of flow of materials for the nuclear fuel cycle from spent fuel discharge through recycle and fabrication of recycled-fuel elements. The model should enable the evaluation and optimization of various nuclear fuel strategies with respect to reprocessing, storage, transportation and waste management.

– Development of the requisite inputs for the model. This would require the establishment of some form of data bank, as well as the development of empirical data, such as capital and operating costs of various process plants as a function of size, from the best available sources.

– Development of an analytic system for evaluating optimum strategies including identification of further needed inputs and carrying out appropriate sensitivity analyses as a function of variable inputs with the help of the model.

– Development of a number of related studies to evaluate various considerations such as institutional, legal, administrative, financial, environmental, health and safety, etc., that would be essential to implementation of the regional nuclear fuel cycle centre concept.

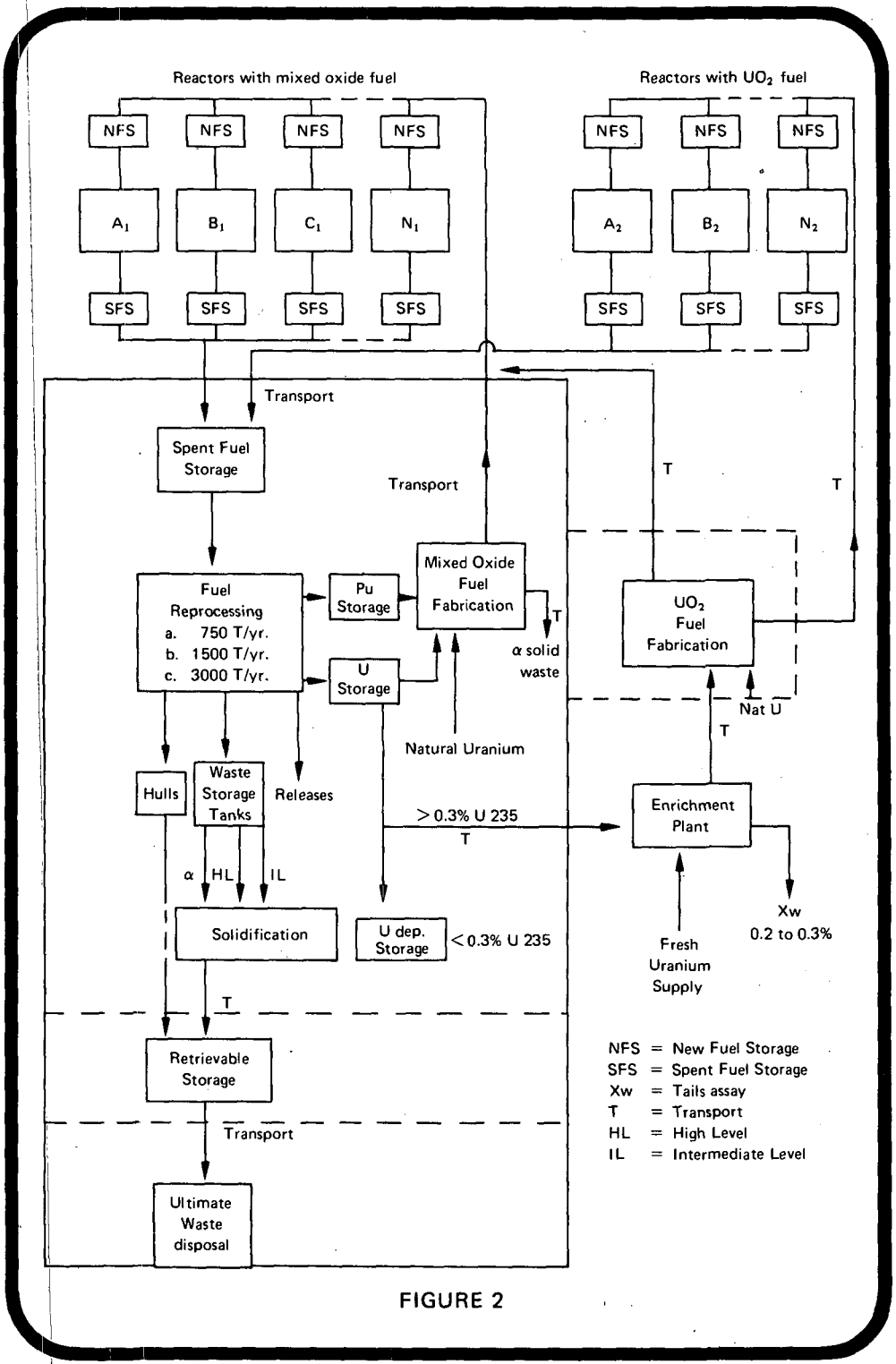
Reactors with mixed oxide fuel
Reactors with UO_2 fuel
NFS
SFS
A_1
B_1
C_1
N_1
A_2
B_2
N_2
Transport
Spent Fuel Storage
Fuel Reprocessing
a. 750 T/yr.
b. 1500 T/yr.
c. 3000 T/yr.
Pu Storage
U Storage
Mixed Oxide Fuel Fabrication
UO_2 Fuel Fabrication
α solid waste
Natural Uranium
Nat U
T
Hulls
Waste Storage Tanks
Releases
α
HL
IL
Solidification
U dep. Storage
< 0.3% U 235
> 0.3% U 235
Enrichment Plant
Xw
0.2 to 0.3%
Fresh Uranium Supply
Retrievable Storage
Ultimate Waste disposal
NFS = New Fuel Storage
SFS = Spent Fuel Storage
Xw = Tails assay
T = Transport
HL = High Level
IL = Intermediate Level

FIGURE 2

TABLE 1

REGIONAL NUCLEAR FUEL CYCLE CENTRE

BASIC CRITERIA – PHASE I STUDY

CONSIDERATION:	SIMPLIFYING ASSUMPTIONS
1. Time Period	1985 to 2000
2. Capacity of Reprocessing Plants	750 to 3000 tonnes/yr
3. Forecast of reactor capacity based on mixed oxide fuel	
Size of reactors	200 MWe to 1200 MWe
No. of reactors	Determined by reprocessing plant capacity, and reactor size
4. Types of Reactors	LWR – 80 to 100% of total installed capacity HWR – 0 to 20% of total installed capacity
5. Fuel cycle characteristics	Pu recycle to be considered. Also deferred fuel reprocessing.
6. No. of Reprocessing Plants	1 to 3 per region initially
7. Fuel Fabrication:	
a. UO_2 fuel	outside of centre as well as at the centre
b. Mixed oxide fuel	only at centre
Manufacturing capacity	Determined by the installed electrical generating capacity
8. Fuel requirements:	
a. Uranium	Annual requirement Integrated total requirement
b. Enrichment plant	Capacity based on a. Pu recycle b. Deferred reprocessing
9. Spent Fuel Storage:	
a. At reactor site	1 to 10 yrs
b. At the centre	1 to 10 yrs. Adequate to satisfy optimal fuel reprocessing plant capacity. Alternatively, when breeder requirement for Pu demands reprocessing of spent fuel, say 1995 (i.e. 10 yrs storage)
10. Pu Storage	Up to 1995 if no Pu recycle occurs. Thereafter additional Pu storage capacity not necessary because of its use in breeders.

CONSIDERATION:	SIMPLIFYING ASSUMPTIONS:
11. Radioactive waste management:	
a. From reprocessing plant	Waste solidification at centre
b. From fuel refabrication plant	Waste solidification at centre
c. From power reactors	Processing at reactor site. Hence not to be considered
12. Waste storage or disposal	Retrievable storage at centre or elsewhere after solidification: for long term
	For short term up to 10 yrs. most economical method
	Ultimate disposal at centre or at remote location
13. Transport:	
a. For spent fuel	In casks according to regulations recommended by IAEA.
	By road, rail and sea
b. For radioactive waste and H.L.	According to regulations recommended by IAEA.
	By road, rail and sea.
14. Discount rate	10%

For this study, a "regional" centre would be a flexible concept so that any group of Member States could interface in a given region on economic, geographic or sociopolitical bases. The project is intended, therefore, to provide Member States with a mechanism for co-ordinating and co-operating with one another in the optimization of nuclear fuel cycle strategies.

IMPLEMENTATION OF THE STUDY PROJECT

From an implementation standpoint, the study would be divided into four phases, as shown in Figure 3. Phase I includes the preparation of the initial model and computer code; Phase II encompasses the initial testing of the model and code; Phase III ends with the preparation of a report detailing the development and application of the regional nuclear fuel cycle centre concept, covering the related model, computer code, input data and illustrative studies. At the end of Phase III, it should be possible to conduct investigative surveys of alternative strategies for regional centres vis-à-vis diverse national centres. However, under Phase IV which would cover the in-depth evaluation of any specific regional centre proposal, engineering feasibility studies using consultant architect-engineering sources would be necessary to obtain local data, cost information and other considerations in order to develop definitive construction and operation costs. This phase would also involve elaboration of more specific institutional frameworks necessary for regional agreements. However, to accomplish this, it would be necessary to initiate early

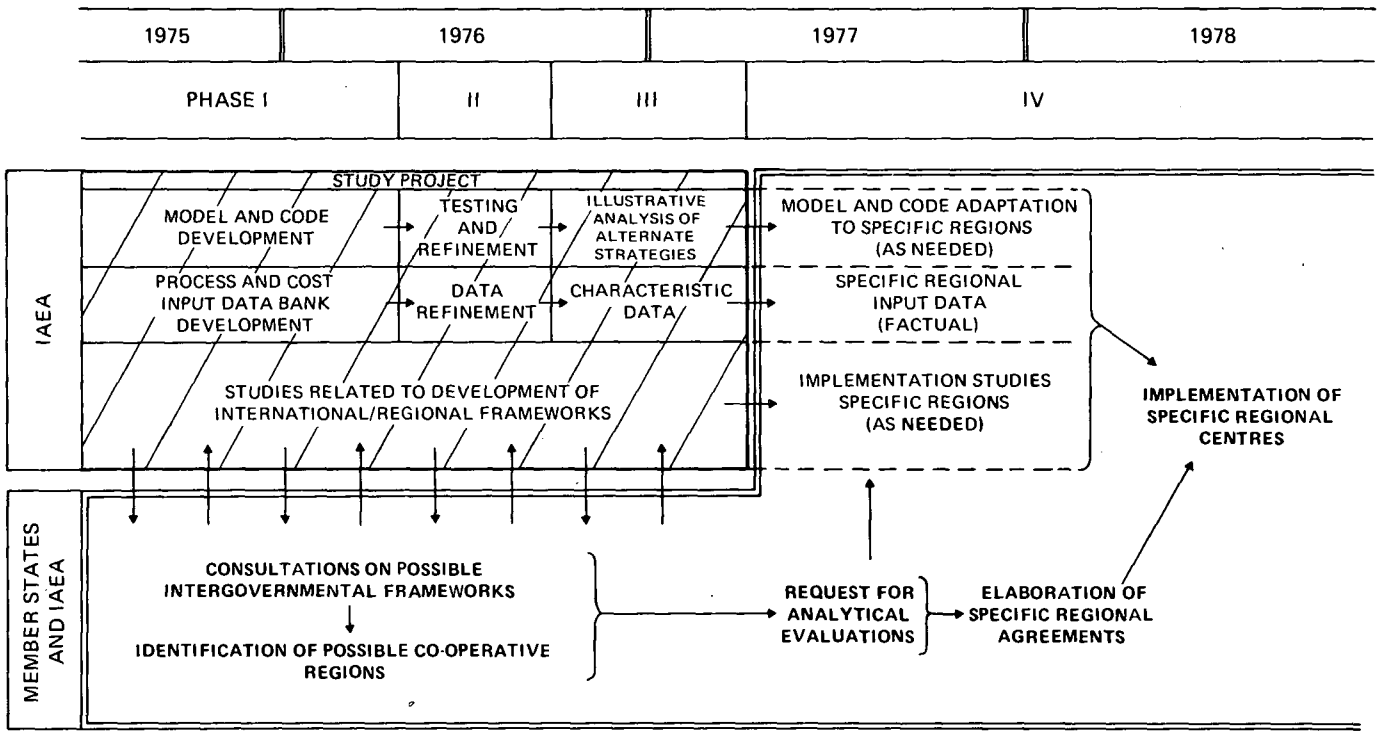
1975
1976
1977
1978
PHASE I
II
III
IV
IAEA
STUDY PROJECT
MODEL AND CODE DEVELOPMENT
TESTING AND REFINEMENT
ILLUSTRATIVE ANALYSIS OF ALTERNATE STRATEGIES
MODEL AND CODE ADAPTATION TO SPECIFIC REGIONS (AS NEEDED)
PROCESS AND COST INPUT DATA BANK DEVELOPMENT
DATA REFINEMENT
CHARACTERISTIC DATA
SPECIFIC REGIONAL INPUT DATA (FACTUAL)
STUDIES RELATED TO DEVELOPMENT OF INTERNATIONAL/REGIONAL FRAMEWORKS
IMPLEMENTATION STUDIES SPECIFIC REGIONS (AS NEEDED)
IMPLEMENTATION OF SPECIFIC REGIONAL CENTRES
MEMBER STATES AND IAEA
CONSULTATIONS ON POSSIBLE INTERGOVERNMENTAL FRAMEWORKS
IDENTIFICATION OF POSSIBLE CO-OPERATIVE REGIONS
REQUEST FOR ANALYTICAL EVALUATIONS
ELABORATION OF SPECIFIC REGIONAL AGREEMENTS

FIGURE 3

consultations between the Member States and the IAEA. These consultations would endeavour to identify matters of principal concern pertinent to the varying interests of Member States so that a range of possible intergovernmental frameworks could be developed. It is planned to present the material developed in the course of these studies at the Conference on Nuclear Power and its Fuel Cycle of the IAEA to be held at Salzburg/Austria from 2 to 13 May 1977.

With the assistance of the analytic system developed for this study, and the relevant information compiled by the IAEA as part of its activities related to the Market Survey for Nuclear Power in Developing Countries as well as other on-going programmes, it would be feasible to assess the need for storage and reprocessing of spent fuel in the different regions of the world for the period 1975–2000. Some of the relevant information that could be generated and which would be useful for further analysis and for fuel cycle strategy planning purposes would be as follows:

– Forecasting of spent fuel storage and reprocessing, fuel fabrication and waste management requirements, including transport of new and spent fuel and radioactive waste.
– Forecasting of the impact of alternative strategies for spent fuel storage or reprocessing on fuel supply and demand, and the effect of such strategies on radioactive waste management.
– Determination of the optimized economically viable size and distribution of such fuel cycle centres with respect to load growth patterns.
– Comprehensive analysis of the various factors so as to identify a series of options that would be available for the formulation of an appropriate strategy for each region.

Finally the study would also review and analyze the experience of other analogous co-operative international ventures with a view to presenting strategies for developing appropriate frameworks covering the institutional, legal, administrative, financial, environmental and other aspects related to the establishment of such regional centres.

CO-OPERATION OF MEMBER STATES

A fuel cycle centre study of this nature would have its full value only if the relevant input data is developed on a realistic basis. The study must develop and compile relevant process and cost data so that system analysis and sensitivity studies can be conducted as part of the overall fuel cycle strategy evaluation for any specific region. Also in the area of institutional, legal, administrative, financial, environmental and other aspects of this study, information on the results of analogous experiences will have to be generated in order to develop strategies regarding the frameworks that would be well suited to multinational ventures of this type with sufficient flexibility to allow both industrialised as well as developing countries to participate. As part of this study project, the Agency will request Member States to provide specific information and assistance by way of experts who will participate with the Agency in meetings to compile and evaluate the relevant input data.

The Consultants' Meetings have been planned so far for this year in the following areas: Mathematical Models and Computer Codes, Fuel Reprocessing, Mixed Oxide Fuel Fabrication, Waste Management, Fuel Storage, Fuel Transport, Institutional, Legal and Financing Aspects of the Study Project.
Full co-operation and support of Member States is most essential to achieve the maximum benefits from this study project.