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NUCLEAR INDUSTRIES
IN THE COMMUNITY

Illustrative Nuclear Programme

Under Article 40 of the Euratom Treaty

1984

(Communication by the Commission to the Council)

Com 659

CONTENTS

GENERAL BACKGROUND

1. This Illustrative Nuclear Programme, presented pursuant to Article 40 of the Euratom Treaty,(1) is the third to be published by the Commission. Its predecessor dates back to 1972. Between the two there have been two severe oil crises, each followed by deep uncertainty about the outlook for energy in the Community.

2. Since the nuclear industry was still at an initial stage of development in the early 1970s, emphasis was laid in the last illustrative programme on the need to set up rapidly a nuclear industry infrastructure capable of supporting increasing use of nuclear energy.

3. Today there is a different problem. The European nuclear industry covers all essential aspects of nuclear power-plant construction and fuel-cycle services. Hence the task is now to ensure the full utilisation and further expansion of this industrial capacity with a view to

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(1) Article 40: "In order to stimulate action by persons and undertakings and to facilitate coordinated development of their investment in the nuclear field, the Commission shall periodically publish illustrative programmes indicating in particular nuclear energy production targets and all types of investment required for their attainment.

The Commission shall obtain the opinion of the Economic and Social Committee on such programmes before their publication."

increasing the security of the Community's energy supply under the best possible conditions. The question must, however, be viewed against the background of a changed situation and a new energy outlook. During the decade following the oil shock of 1973, major changes took place in the macroeconomic situation and in the structure of the Community industry, as well as in the pattern of energy demand and the efficiency with which energy is used in the Community.(1) These changes and their implications for the future form a new framework for the development of the nuclear industry in the years to come.

4. During the period since the oil shock, the Commission vigorously promoted the development of nuclear energy as part of the Community's energy strategy. In this connection it suffices to recall, in addition to the extensive R&D programmes decided and implemented, the energy policy objectives for 1985 and 1990, approved in 1975 and 1980 respectively, and the Council Resolutions of 1980 on fast breeder reactors, nuclear waste management and the reprocessing of spent fuel.(2)

5. At the onset of the 1980s, when taking stock of the "nuclear aspects of the energy strategy", the Commission noted that the use of nuclear energy continued to be a fundamental option for the Community. They expressed this point of view to the Council in a communication of February 1982 and, after reviewing all aspects of the nuclear industry, the Commission set out the measures that it intended to take in respect of each of them.

6. In July 1982, the Council expressed its opinion on that communication and stated, in particular(3):

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(1) These changes were analysed in detail by the Commission in two communications to the Council: COM(84) 87 and 88 final of 29 February 1984.

(2) OJ N° C 153, 9.7.1975; OJ N° C 149, 18.6.1980; OJ N° C 51, 29.2.1980.

(3) 8552/F/82 (Presse 109), 13.7.1982.

"The Council agrees with the Commission's analysis of the role of nuclear energy in the Community's overall energy strategy, on the understanding that it is for each Member State to make its own decisions on this matter at national level."

"The Council acknowledges that the development of electricity production from nuclear resources has economic advantages and is aware of the advantages to be gained therefrom by industrial operators through having access to competitive sources of energy."

"The Council notes the Commission's analysis of the respective roles of economic operators and national and Community authorities in the nuclear field. In this connection, it stresses that the realisation of nuclear energy programmes on the necessary industrial scale firstly requires States to make a clear political choice on the objectives and means to be used; the Community provides a framework within which these States can find useful references and a grouping whose solidarity can be an effective instrument."

7. It was in the same communication that the Commission announced its intention to resume publication of the Illustrative Nuclear Programmes.

8. PINC* is a document in which the Commission describes and analyses the situation of the nuclear indsutry and sets out the prospects for its medium- and longer-term development. It is a frame in which to appreciate the cohesive nuclear policy initiatives which have been taken, especially decisions on investments in nuclear installations (particularly those referred to in Article 41 of the Euratom Treaty) and within which the Community's financial instruments can be brought into operation.

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* Acronym derived from "Programme Indicatif Nucléaire pour la Communauté" Illustrative Nuclear Programme for the Community.

PINC is also intended to be a reference and guideline document:

. a reference for those who wish to know and understand the facts about the nuclear industry within the Community;

. a guideline for those who, in the Member States, are more directly involved in the economic development of the nuclear industry and who will find in the document the position of the Commission with regard to that development.

Its periodic publication at appropriate intervals will enable the requisite continuity of action to be ensured in the course of time, account being taken of developments in the overall economic context. Since the frequency of publication depends on the rapidity with which these developments occur, it is conceivable, for example, that a report on the execution of PINC '84 will be published in two years' time, to be followed, two years later, by the publication of a new PINC.

9. The main thrust of PINC hinges on two fundamental aspects of nuclear energy and points to a certain number of implications for the operators and, from a political standpoint, the Member States.

The first aspect is the nuclear objective for 1995 in relation to the perspective of the year 2000. For the Community as a whole, PINC estimates that the contribution of nuclear energy in 1995 will be about 40% of electricity production and, beyond that date, it foresees an appreciable growth in that contribution, reaching 50% around the turn of the century. This energy objective would imply that the Member States will have taken firm decisions by 1987, at the latest, with a view to creating and placing in service a nuclear capacity of at least 25 GWe between 1991 and 1995.

The second aspect relates to the more distant future. According to PINC, long-term security of energy supplies, in particular electricity generation which will be based to a large extent on nuclear power, presupposes that the Community's industry, in twenty years' time, will be able to provide the electricity producers with fast-reactor power-stations capable of economic performances comparable to those of the light-water-reactor power-stations at that time (2005).

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The implications concern:

- the rôle of the public authorities and the electricity producers;
- uranium supplies;
- the nuclear fuel industry; and
- the nuclear power-station construction industry.

These implications are dealt with in the final chapter of PINC.

A. INTRODUCTION

1. It is a basic task of the European Atomic Energy Community (Euratom) to "contribute to the raising of the standard of living in the Member States, ... by creating the conditions necessary for the speedy establishment and growth of nuclear industries" (Article 1 of the Euratom Treaty).

2. The development of nuclear energy, therefore, is aimed at contributing to economic growth and industrial and technological developement. The role of the Community as such, and of the Commission in particular, is to establish and maintain an effective framework for cooperation on nuclear energy matters and to propose new measures where necessary.

3. In the case of nuclear energy, a sophisticated technology, it is extremely important to have available a clear and specific reference framework. A nuclear power-station can take a decade to plan and construct. Once constructed, it must be operated in total safety for 30 years or more. The operator must be confident that fuel and fuel services will be forthcoming during that period and that it will be possible to deal with spent fuel and nuclear wastes satisfactorily.

4. All this requires clear political commitments to provide for continuity of industrial achievement and maximum utilisation of technological skills. The experience acquired in the Community shows that, if these conditions are present, investments in nuclear energy bring returns which make it possible to mobilise the considerable financial resources required.

5. This PINC first of all points out the role of nuclear energy in the economy of the Community. The Annex "Review of and prospects for the development of nuclear energy in the Community" describes the evolution of that sector since 1973. PINC then presents the Commission's views as to the share of nuclear energy in meeting the Community's

electricity requirements up to the end of the century and, finally, proposes specific objectives for 1995, the target date considered by the Commission in defining the Community's new general energy objectives.

6. The Programme also deals with the continuous development and application of advanced nuclear-energy production technologies and, with the aim of preparing in good time for the longer-term future of that sector, defines a specific objective for the purpose of bringing about the economic maturity of fast breeder reactors.

7. The Commission, however, is fully aware of the fact that the development of nuclear energy in the Community also depends, among others, on two factors which determine the public acceptance of the nuclear industry:

   i) the safety and health protection achieved in nuclear installations;

   ii) the existence of safeguards on the use of nuclear materials.

8. The Commission is paying careful attention to both of these factors, which were dealt with in detail in a general communication to the Council on 9 February 1982:

   "An energy strategy for the Community: the nuclear aspects" (COM(82) 36 final).

9. In addition, these factors were subsequently the subject of two specific Commission communications:

   "The Community's role as regards the safety of nuclear installations and the protection of public health" (COM(83) 472 final of 22 July 1983);

   "Report from the Commission to the Council on the implementation of the verification agreements concluded by Euratom and its Member States with the International Atomic Energy Agency" (COM(83) 36 final of 27 January 1983).

The specific case of safe nuclear-fuel transport was dealt with in a communication from the Commission to the European Parliament and the Council:

"The transport of radioactive materials in the European Community" (COM(84) 233 final of 26 April 1984).

Finally, the Community's research and development programmes relating to nuclear fission energy are chiefly concerned with the safety of nuclear installations and health protection and with safeguards on the use of materials.

It is for this reason that these topics are not reviewed further in the PINC.

B. THE ROLE OF NUCLEAR ENERGY IN THE ECONOMY OF THE COMMUNITY

1. Present share of nuclear energy in the energy mix

10. From 1973 to 1984, the nuclear contribution towards meeting the Community's total demand for energy increased from less than 2% to over 10%. Nuclear energy's share of electricity production now exceeds 25%. Furthermore, the Community's nuclear power capacity accounts for about one third of world capacity. These figures speak for themselves and show that nuclear power has become an essential part of the European energy strategy.

11. On the basis of the investment programmes that are being implemented at present (late 1984), it may reasonably be estimated that, in 1990, the capacity of the nuclear power stations in service - close to 100 GWe net - will cover about 35% of electricity production in the Community and meet about 14% of the Community's overall demand for energy. This will make is possible to easily attain the objective set by the Community in 1980, i.e., to have nuclear energy and solid fuels together producing 70 to 75% of the electricity by 1990.

12. This will be a remarkable achievement. Considered against the background of the Community as a whole, this overall capacity does mask, however, a considerable diversity in the national situations. In 1990, some countries will still not be producing any electricity by nuclear means, while in the same year, others will be using nuclear energy as the main source of their electricity. The status of the current nuclear power programmes in the Member States concerned is presented in the following table.

2. The strategic importance of nuclear energy

13. The supply of uranium, the raw material for nuclear energy, has two positive aspects in political terms from the standpoint of the Community, which has to import three-quarters of its nuclear fuel:

   i) the world uranium market is supplied by countries other than those which provide the Community with hydrocarbons (oil and natural gas);

   ii) those countries are not situated in one and the same geographical area nor do they fall within one and the same sphere of political influence.

The share of nuclear energy in the Community's electricity and energy balance: present status and probable increases

1983	B	D	F	It	NL	UK	EUR-10
Installed nuclear power capacity (GWe)	3.5	11.1	27.2	1.3	0.5	8.4	51.9
Share of electricity production (%)	45.7	17.7	48.3	3.2	5.9	17.0	22.4
Share of total energy balance (%)	15.0	6.7	21.6	1.3	1.6	6.8	8.6

1990	B	D	F	It	NL	UK	EUR-10
Installed nuclear power capacity (GWe)	5.4	21.7	54.8	3.3	0.5	12.5	98.2
Share of electricity production (%)	55	31	70	8	6	27	35
Share of total energy balance (%)	18.0	12.7	36.5	3.1	1.6	9.0	14.1

In practical terms, uranium supplies at world level are based on known resources of ore that can be worked at an acceptable cost and are capable of meeting foreseeable requirements for about 20 years. As regards undiscovered resources, it is believed that they will meet the requirements likely to arise during the 20 years that will follow. In order for these resources to be placed on the market, it is still necessary that the appropriate investments that are required for their identification and production be made in good time.

14. The use of uranium, for its part, has two important aspects:

i) Uranium can be stored in large quantities at low cost, without giving rise to practical difficulties, on account of the great energy density of the material. At present, there are stocks in the Community capable of meeting the requirements of present-generation reactor types, e.g. light-water reactors (LWRs) and gas/graphite reactors (Magnox or UNGG and AGRs), for four to five years.⁽¹⁾

ii) When it is used in these types of reactor, the uranium expends only a very small fraction (1 - 2%) of its energy content. The remainder, which can be utilised only in a new reactor type, the fast breeder reactor (FBR) at present being demonstrated, represents a considerable quantity of material, most of which is in the form of spent fuel from reactors of the present generation which has accumulated since the start of commercial operation. This feature makes it possible to consider the nuclear energy produced by fast breeder reactors as virtually renewable energy.

3. The economic benefits of nuclear energy

15. The economic benefits of nuclear energy must be evaluated from the standpoint of three closely-related aspects: competitiveness, balance of payments and macroeconomic impact.

a) The competitiveness of electricity of nuclear origin is constantly being closely studied by the public authorities and the electricity producers, and the Commission is intimately involved in these evaluations. The results of the evaluations are in agreement: when there is an open choice between nuclear fuel, oil and coal as energy sources for the power station to be constructed over the next few years

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(1)
UNGG: French abbreviation for "natural-uranium, gas-graphite" (equivalent to the British Magnox),
AGR: advanced gas-cooled reactor.

and intended for large-scale and continuous electricity production, nuclear energy is advantageous.

16. The economic advantage of nuclear power over coal(1) varies from one Member State to another with the economic conditions in each country, in particular the specific cost of labour, the scale and type of the nuclear programme implemented and the standardisation effected, the number of units installed on one site and the characteristics of the site, the administrative procedures required for the various installation phases (from construction to power run-up) and the price of the fuel used (domestic coal or imported coal)(2).

On the basis of the study carried out in 1983, using the appropriate assumptions for each country in the calculations, it has been shown that the additional cost of electricity produced from coal in comparison with the cost of electricity of nuclear origin is as follows(3):

Belgium	51%
Federal Republic of Germany	74%
France	88%
Italy	30%
Netherlands	36%
United Kingdom	43%

17. As regards the breakdown of the total kWh production cost, the average for the Community is as follows:

	Nuclear	Coal
Investment	57%	21%
Operation	15%	8%
Fuel (of which uranium accounts for less than 10%)	28%	71%
Total	100%	100%

The slight impact of nuclear fuel costs - particularly uranium - on the cost of the kWh is a factor which stabilises the cost of electricity and

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(1) Electricity produced from petroleum products is more expensive in all countries than that produced from coal.

(2) Irrespective of any effects of environmental protection regulations which may be important with respect to the production of electricity from coal.

(3) For the case of power stations entering into service in 1990.

has a moderating effect on increases in the cost of other energy sources.

18. The production cost of electricity of nuclear origin is characterised by high-fixed investment costs and by low variable operating costs. The main contribution to be made by nuclear power is to "base-load operation", in other words that of production of electricity at maximum possible plant power for the longest possible period of the year. This field represents appreciably more than half of the Community's electricity production.(1) However, the advantage of the cost of nuclear power is now such that the nuclear power stations remain competitive, even with a utilisation factor lower than that adopted for evaluating the production cost of the kWh (approximately 3 000 hours/year instead of 6 500 hours/year). This considerably increases - to over 65% - the share which nuclear power can contribute economically to meeting electricity requirements.(2)

19. b) Energy plays a major role in the <u>balance of payments</u> of countries with indigenous energy resources. This role is independent of the cost of electricity production. The proportion of this cost accounted for by the - presumably imported - primary energy source varies widely according to whether that material is uranium (accounting for less than 10% of production costs), coal (approximately 70%) or oil (approximately 80%). The assumptions concerning the long-term trends in the costs of these materials are certainly open to discussion and

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(1) Even if the fraction is deducted which is covered by so-called "cheap" electricity production (for example hydroelectric, lignite, etc.), the marginal cost of which is low but the available quantities of which are limited.

(2) This is why control systems adapted to rapid load variations will be fitted progressively to the oldest reactors which have already been partly amortised.

it is easily understood that such discussions can become animated if the impact that an error of assessment - always possible in view of the lifetime of a power station - can have on cost estimates for oil - and even coal-fired stations is considered. On the other hand, it cannot be disputed that a given amount of electricity will cost the Community as a whole less - even considerably less - currency if it is generated by nuclear power stations.

20. In addition to the favourable effect on the balance of payments mentioned above, which could be termed a "passive" effect since it results in avoiding excessive expenditure, there is an "active" effect which results from exploiting - to a greater extent than is done at present - the capacity of the European industry to export power stations, equipment and services in the nuclear sector, particularly fuel cycle services.

21. c) The macroeconomic impact of nuclear energy results from the fact that it enables electricity to be produced at a cost that depends very little on fluctuations in the world energy source materials market. The low level and the stability of the cost promote the competitiveness of the electricity consuming industries downstream and, furthermore, naturally constitute an incentive to the wider use of electricity, most particularly for industrial purposes. Finally, the fact that the raw material (uranium) accounts for very little of the cost of electricity of nuclear origin means that a very great part of that cost arises from the value added by European industries.

There is, however, a qualitative impact, also very appreciable, which results from the extremely high value of the technology employed in all phases of nuclear activity: design, workshop and on-site construction, operation and maintenance. This value characterises all branches of engineering: nuclear, civil, mechanical, electrical, chemical and electronic, and also data-processing and software industries, with a spinoff effect for the enormous industrial sectors in the countries concerned.

C. OBJECTIVES OF THE ILLUSTRATIVE PROGRAMME

1. The outlook for 1995-2000

22. In order to serve as a useful reference point in the development of nuclear energy, the illustrative objectives must relate to a date such that, taking into consideration the time required to construct nuclear installations, the corresponding decisions will have to be taken over the next three years: 1985, 1986 and 1987. In this connection, the Commission considers that the target date of 1995 should be retained.

23. The Commission, however, acknowledges that, apart from giving precise quantitative objectives on which decisions are to be taken in the short term, it is necessary to provide the development of nuclear energy a longer term perspective which, in this case, will extend at least to the turn of the century. Without this, the time-scale required to amortise the financial and technological efforts that such development needs, and to make these efforts pay, would be insufficient.

24. If present forecasts made by the Member States prove to be correct, only about one third of the Community's total energy requirements will be met by imported oil in 1990.(1) However, the possibility that the Community's own oil production may start to fall in a few years' time could create a renewed upward trend in oil imports. The Community's vulnerability to oil market disturbances consequently requires further structural changes in the energy supply pattern which promote, in particular, wider use of electricity, the production of which is nuclear energy's essential role.

25. By 1990, this form of energy should account for about 35% of electricity production in the Community, but, on the basis of the considerations set out in the previous Chapter, it should have been possible to attain a much more substantial objective by that time and the nuclear industry would have been in a position to construct the corresponding capacity.

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(1) As compared with 63% in 1973.

without any problems. This development, however, has not occurred, as a result of uncertainties in the demand for energy and owing to difficulties of various origins, particularly the acceptability of nuclear energy to the public and the conflict between the powers of local authorities and national authorities. Moreover, in certain cases, priority was given to using domestic sources of fossil fuels.

26. In view of the existance of such difficulties, care must be taken not to set too optimistic a quantitative objective. It is for this reason that the Commission proposes the adoption of the following lines of development for nuclear energy:

(i) to produce about 40% of Community electricity in 1995, and

(ii) subsequently to increase its share in electricity production considerably after the turn of the century.

27. The analysis of the energy supply and demand picture carried out by the Commission services in the light of new long term energy objectives indicates that electricity consumption in the Community could reach 1 470 TWh(1) by 1990 and 1 650 TWh by 1995, whereas the present level is in the vicinity of 1 230 TWh. It emerges from this that the average annual growth rate up to 1995 will be about 2,3%. This value might subsequently turn out to be a pessimistic one and, if so, the evaluation of the corresponding requirements for investments in electricity production might have to be revised upward.

28. In order to exceed the 40% share of the total electricity production of 1 650 TWh estimated for 1995, the nuclear power stations would have to produce over 660 TWh. This would require that a nuclear capacity of at least 120 GWe(2) be installed by that date. In comparison with the capacity of 98 GWe scheduled to be in service by 1990, this means that

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(1) 1 TWh (Terawatt hour) = 10^{12} Wh = 10^9 kWh = 10^6 MWh = 10^3 GWh.

(2) This estimate is based on the assumption of a modest increase in the average load factor of the Community's nuclear power stations, which will increase from 61% in 1982 to 63% in 1995. There are some indications of a probable improvement in the load factors, particularly the positive results seen in the experience accumulated by the reactor operators and the decrease in the share of new power stations (those most beset by teething problems) compared with the total number of power stations installed. On the other hand, it cannot be expected that all the nuclear power stations will cover only base-load demand; this tends to limit the achieveable load factors.

the net increase in the nuclear power capacity between 1990 and 1995 will have to be greater that 22 GWe. Taking into account a loss of 3 to 4 GWe resulting from the decommissioning of old nuclear power stations which is likely to take place in the first half of the 1990s, it can be seen that:

> The total requirement for additional nuclear power capacity will exceed 25 GWe between 1991 and 1995.

29. It emerged from the Commission's consultations with the sectors concerned that the development of nuclear power production capacities in the individual Member States could be expected to be as follows:

	In service 1990	Decommissioning(1) 1990-1995		New capacity 1990-1995		In service 1995
	GWe	GWe	Reactors	Gwe	Reactors	GWe
B	5.4	0.010	1	1.3	1	6.7
D	21.7	0.016	1	3.3	3	25.0
F	54.8	1.3	3	10.9	8	64.4
I	3.3	0.460	2	8.0	8	10.8
NL	0.5	-	-	1.0	1	1.5
UK	12.5	2.051	12	1.1	1	11.6
Total	98.2	3.8	19	25.6(2)	22	120.0

Should these estimates turn out to be correct, it is evident that the minimum nuclear objective for 1995 will involve an intensity of effort which will vary widely from one Member State to another.

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(1) The estimate is based on an assumed plant lifetime of 30 years. This is only a reference point. The power stations may actually be kept operating longer or be decommissioned earlier.

(2) A 45% nuclear share of electricity production by 1995 would require the installation of additional nuclear capacity amounting to about 40 GWe between 1990 and 1995.

2. The future in the longer term

30. The reactors of the present generation will be progressively improved and will continue to be constructed for several further decades. In parallel, other, "advanced" types of reactor should reach industrial maturity. Thus high-temperature reactors (HTRs), capable of providing industrial heat for advanced technological applications, could eventually be used for the special purposes of coal liquefaction, stimulation of oil flow in highly viscous deposits, reduction of metal oxides, etc. It is, however, the fast breeder reactors, which, in the long term, seem most likely to be foremost in power production.

31. The fast breeder reactors (FBRs) which, in comparison with reactor types of the present generation, are likely to multiply the energy potential of uranium by a factor of over 50, are undergoing technological development in most countries which possess considerable industrial potential (e.g., the USA, the USSR and Japan). Such development, however, is most advanced in the Community, where this reactor concept has reached the demonstration stage with a reactor possessing a capacity close to that of the most modern current reactors (Superphénix, 1 200 MWe).

32. The present situation in the uranium market does not require that FBRs be placed in commercial operation in the short term. Moreover, the economic performance that these reactors could attain in the near future should make them competitive with coal-fired power stations, but not with the reactors at present being constructed in the Community.

33. However, after the target year 2000, it will be very advantageous to possess a reactor type, such as the FBR, which will be capable of reducing the Community's dependence on uranium imports and of setting a reasonable ceiling to any rise in the price of that raw material; in other words, a type that will enable satisfactory uranium supply conditions to be maintained for as long as possible.

34. In all events, in view of the already very advanced stage of development of the FBR type, it would not be judicious to wait until difficulties in the supply of uranium seemed likely to arise before preparing for the commercial introduction of such reactors, especially since that transition can be achieved with limited cost only if the efforts of all the parties concerned in various capacities, Member States, producers, designers and constructors, are properly programmed and coordinated within the Community.

35. In consequence, the Commission proposes that investments in FBRs have the objective of making this type of reactor economically competitive by 2005.

36. By that date (2005), the Community industry should be in a position to offer the electricity producers commercially viable FBR power stations capable of producing power at a cost at least comparable to that of the power produced by power stations equipped with traditional reactors constructed at that time.(1)

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(1) In this event the first competitive FBR power stations would enter into service towards 2015.

37. To this end, the appropriate industrial strategy must be carefully worked out: the entire system which characterises the concept, including the fuel cycle, should be taken into consideration and the installations to be ordered should be defined.

38. The Commission considers that a reasonable scenario would be as follows:

- economic and financial feasibility study of a programme for the construction of a small number of power stations to be constructed consecutively. It would appear that four stations would be most appropriate;
- their design would be progressive and make the most of the experience acquired during the construction and operation of previous power stations, starting with Superphénix which will enter into service in 1985;(1)
- a plant for reprocessing their irradiated fuel elements, with a capacity suitable for establishing with adequate certainty the cost of that reactor type's fuel cycle, would be operational at the appropriate time.

39. In order to possess sufficient operating experience in respect of the five installations covered by the programme sketched out above,

> it would be advisable for the construction of the next FBR power station to be started in 1987 and for the reprocessing plant to be in service before 2000.

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40. The decisions to be taken in the immediate future will have an effect on the energy situation in Europe well beyond the next three decades. There is nothing unusual about this if reference is made to the time constants of energy industries. The particular aspect of the proposed strategy is that it is aimed at bringing about an essential change within one energy sector, the nuclear sector, which achieved industrial maturity and full economic competitiveness only a decade ago. Because of that aspect it is indispensable that the investors benefit from the full support of the authorities, it being understood that the responsibility for the implementation of this strategy, in particular the founding of it, rests with them.

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(1) The progressive development which should characterise the design of the four power stations in the series following on from Superphénix could be achieved in two main phases, each involving two power stations of similar design constructed over periods of time that are fairly close together. The positive effects of succession (two design stages between Superphénix and the competitive power stations) and those of series construction (two similar power stations at each stage) would thus be combined, while the opportunities for international cooperation would be multiplied.

41. The agreement on cooperation, signed on 10 January 1984 by five Member States (Belgium, France, Italy, the Federal Republic of Germany and the United Kingdom), reflects that fact and shows that the States concerned are aware of the need for their commitment to that change.

Corollary of the longer-term objective: plutonium management

42. All uranium-fuelled nuclear power stations, whether the uranium is natural or enriched, produce plutonium within the fuel elements. This is the case, in particular, with PWRs and FBRs, on which the development of nuclear power in the Community will henceforth be mainly based.

43. All the Member States - and the Community itself - have chosen the option of reprocessing spent fuel elements which, among other advantages, possesses that of recovering the plutonium by means of which the FBRs can make use of all the uranium's energy content.

44. Although there is a certain measure of interdependence between the implementation of programmes for the construction and operation of nuclear power stations and that of the reprocessing plant, it is not possible to ensure that the flow of available plutonium will correspond exactly to the demand arising from the FBR programme. It is currently estimated that the FBR objective proposed above will absorb only part of the plutonium to be produced by the reprocessing plants between now and the end of the century.

45. Temporary storage of the excess plutonium can be considered, although it gives rise to a technical problem as a result of the radioactive decay characteristics of one of the plutonium isotopes.

46. This characteristic provides an additional reason for seriously considering another use of plutonium, namely, in reactors of the present generation; this is termed "plutonium recycling".

47. This technique, which has reached the stage of industrial application in the Community, is certainly not as efficient as the FBR technique in extracting energy from uranium, but it does enable substantial savings to be made in uranium consumption and in enrichment services.(1)

Finally, only part of the plutonium used in this way is consumed, so that thermal recycling will not compromise subsequent development of the FBR concept.

48. Intensified intra-European cooperation in this field would make it possible to obtain the maximum benefit from all the technological experience acquired by the various Community partners and from already existing investments.

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(1) Amounting to about 10 to 15% of the estimated requirements for uranium and enrichment services up to the year 2000; savings would be of the order of 2 to 5% on the cost of nuclear kWh.

D. WHAT ATTAINMENT OF THE OBJECTIVES INVOLVES: THE COMMISSION'S RECOMMENDATIONS

49. Attainment of the objectives set out in the previous chapter, whether it involves the shorter-term objectives, 1995-2000, or the longer-term objective is within the capacity of the economies of the Community Member States and within the range of their technologies. It does, however, presuppose programming appropriate to the time scale of the problems raised.

1. The role of the public authorities and the electricity producers

50. Firstly, attainment of these objectives clearly involves continuation of the efforts made in the Community by the public authorities to promote the development of nuclear energy. It also involves, more specifically, and with a view to rationalising nuclear policies within the Community, consultations between Member States and between electricity producers with regard to their programme decisions and investments. A realistic price for electricity will be needed to obtain the required level of financial investment.(1)

51. Regarding investment choices, the Commission considers that the acquisition by electricity producers of holdings in nuclear power stations installed in neighbouring countries must be encouraged, since it enables the increase in the nuclear power capacity to be spread over a period of time in accordance with the specific requirements of certain countries or even of certain regions. The examples that already exist are very encouraging and indicate that a certain amount of programmed reciprocity - the principle of "mutual investments" - will give the partners equal benefits.

52. In addition, the cross-frontier acquisition of holdings provides the industries in the partner countries with an effective means of achieving the international cooperation that has long been desired. It also offers the electricity producers the opportunity to obtain greater benefit from the international grid, the capacity of that grid being adapted in good time to handle the expected volume of power transfers.

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(1) See the report by the Commission services on the application in Member States of the principles of energy pricing in the Community (COM 84(490) of 18.9.84.

53. For its part, the Commission undertakes to take every initiative in its power, at the appropriate time and to the extent necessary, to further the application of the strategy set out in the preceding chapter. In particular, the nature and size of the investment needed to attain the objectives could imply a requirement for both Community and national financial instruments.

2. Uranium supplies[1]

54. As regards the general uranium supply situation, although the supply and demand situation is known, it is still difficult to predict how the market will fluctuate.

The Community is heavily dependent on outside sources for its supply of uranium. To mitigate the effects of uncertainties in the market on uranium supplies, it is desirable for these to continue to be obtained under long-term contracts. Such contracts can have a stabilising effect on the market to the benefit of both producers and consumers.

55. As regards more specifically security of supply from the standpoint of resources, although companies in the Community have made considerable financial investment in mining activities throughout the world, the cut-backs in prospecting that can now be observed are likely to make the Community even more dependent on those few countries which possess mines capable of being worked at low cost. It must thus be hoped that the decrease in expenditure on exploration, which, if continued, would limit the necessary diversification of the Community's supply sources, is only a temporary phenomonen.

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[1] An analysis of this subject is presented in the Annex.

56. In view of the foregoing, it is desirable for the Community to implement a supply strategy capable of:

- encouraging the Member States and the companies involved
  - to continue their prospecting activities both within their own territories and outside the Community;
  - to continue these activities, if necessary with Community support, on a scale which is independent of the state of the market at any given moment, bearing in mind the expected requirements of the electricity producers and the considerable lead times required to bring new mines into production;
- encouraging the companies active in this sector to pursue storage policies likely
  - to offset market fluctuations and any interruption of supplies from non-Community supplier countries;
  - to lessen any tensions that exsit between the Community and the supplier countries in respect of supplies, while providing the latter with stable and predictable outlets for their products, thereby assuring them of a reasonable return on their investments and of a regular income.

3. The nuclear fuel industry

a) Enrichment(1)

57. On the basis of existing capacities and of the investment programmes that are being implemented, it is estimated that the world supply of enrichment services will exceed demand until at least the middle of the next decade. In consequence, decisions relating to new investments, with the exception of those concerning the industrial-scale demonstration of advanced technologies that ensure a significant reduction in costs, do not have to be taken before the end of this decade. The need for new investments in existing processes beyond this period cannot, however, be excluded.

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(1) An analysis of this subject is presented in the Annex.

58. In the long term, this sector may see the emergence of new technologies which are more economical and provide greater flexibility in adapting investments to demand. For this reason, it is advisable to continue research and development work in this field on an adequate scale in the Community.

59. In view of the state of the market and of its development prospects, which are likely to compromise the economic viability of the European undertakings in this sector, the Commission proposes that an exchange of views take place at Community level between the parties concerned. In this connection, it wishes to point out that an appropriate structure exists in which such an exchange of views could take place; this is the Standing Committee on Uranium Enrichment (COPENUR) set up by the Council on 22 May 1973.

b) Fuel-element fabrication(1)

60. 1) As regards the fabrication of enriched uranium oxide fuel elements, it is necessary to extend the calls for bids to suppliers other than those who supplied the first cores as part of the order for the reactor.
In addition, there is an advantage in continuing the development of new types of fuel elements which will make it possible to increase uranium burn-up and the duration of the reactor cycles.

2) The development and fabrication of uranium and plutonium mixed-oxide fuel elements should be vigorously pursued, first with a view to promoting commercial recycling in LWRs of the materials resulting from reprocessing (uranium and plutonium) and later with the purpose of optimising the entire FBR fuel cycle. In this connection, close cooperation between designers, fuel manufacturers, reprocessors and electricity producers should be encouraged.

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(1) An analysis of this subject is presented in the Annex.

c) Reprocessing and temporary storage of spent fuel[1]

61. A large part of the demand for reprocessing services from users within the Community and elsewhere is already covered by firm contracts between Community users and service suppliers. However, in spite of the uncertainties inherent in any estimate, the growth prospects are such that a competitive market could eventually arise in this sector, as indicated in the report by the ad-hoc Committee on the Reprocessing of Irradiated Fuel (CORECOM).[2]

62. The Commission's recommendations[2] that accompanied the publication of the CORECOM report are still valid in their entirety. In particular, that:

- decisions be taken and implemented as soon as possible to ensure that programmes for the construction of the capacities required for the storage of irradiated fuel be completed by the appropriate time;

- all possible ways of setting-up reprocessing facilities capable of meeting the needs expressed in several Member States be explored;

- industrial cooperation within the Community be encouraged by adopting as open an attitude as possible to the question of technology transfers and exchanges of experience, particularly in the field of plant safety.

63. Although commercial reprocessing of mixed-oxide (uranium-plutonium) spent fuel from existing reactors can be carried out in plants which reprocess uranium oxide fuel, it is necessary to continue work on developing methods to the stage of industrial maturity for the reprocessing of spent fuel from fast breeder reactors. A demonstration plant, capable of dealing with spent fuel from several FBRs, should be constructed in accordance with the objectives set out above (see paragraph 40).

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(1) An analysis of this subject is presented in the Annex.

(2) Communication from the Commission to the Council, COM(82) 37 final of February 1982.

d) Radioactive wastes[1]

64. The management of radioactive wastes is covered in the PINC because it is one of the industrial operations of the nuclear fuel cycle. The safety aspects have been dealt with in the "Community plan of action for radioactive wastes" approved by the Council on 18 February 1980[2], which covers the period from 1980 to 1992 and which was, in 1983, the subject of a first progress report[3].

It is recalled (see paragraphs 7 to 9) that the safety aspects of nuclear energy, about which public opinion is particularly sensitive, were the subject of a recent communication.

65. The management of low- and medium-activity radioactive waste (excluding alpha-contaminated waste), which accounts for almost 95% of the conditioned waste produced today in the Community, benefits from long industrial experience. However, it is obviously advisable to allow it to continue to benefit from technological progress.

Decisions concerning the selection and opening-up of new sites for the disposal of wastes in this category will have to be taken in good time.

66. Satisfactory results have been obtained with the treatment and conditioning of radioactive waste contaminated by long-lived alpha emitters and of high-activity waste (for example vitrification). It is nonetheless necessary to continue current research and development work in order to optimise these results. As regards the disposal of such wastes, the work conducted at national and Community level by the Commission through multiannual research and development programmes has made it possible to confirm the feasibility of setting-up storage installations in deep geological formations. It is necessary to supplement and further validate these studies, particularly by implementing the development and demonstration of the techniques.

67. A regional approach to the problem of waste disposal, involving several countries, could offer certain advantages insofar as it would prevent costly storage projects from being undertaken prematurely and on an individual basis. Such a solution would seem to be indispensable in the case of countries that have limited nuclear programmes.

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(1) An analysis of this subject is presented in the Annex.

(2) Official Journal of 29.2.1980, C 51.

(3) COM(83) 262 final.

The real problem arising from a regional approach is the fact that, at present, no country is willing to agree to the final storage of waste from another country on its territory.

Since the countries concerned are Community Member States, it would be desirable, in a spirit of mutual assistance, to seek solutions that would enable one country to store waste originating in other countries, while complying with the principle of equitable reciprocity in the long term. The application of this principle would enable storage centres to be set up under the best possible conditions, taking into account the varying requirements of the different Member States' nuclear programmes. In addition, it would enable the most appropriate geological units in the European substratum to be used.

68. Studies underway at Community level, such as the definition of equivalence between different types of waste which is being undertaken with a view to seeting-up specialised storage facilities for certain waste types irrespective of their origin, are an important element in a Community approach to the disposal of radioactive waste along the lines indicated above. The Commission believes that these studies should aim at providing concrete results which would make it possible to set up a waste disposal system of the regional type described above.

4. The transport of nuclear fuel(1)

69. The transport of nuclear fuel in all its forms - from ore to radioactive waste, and including, in particular, uranium hexafluoride, irradiated elements and plutonium - is an essential part of the nuclear supply system.

70. It is hence of vital importance for the Member States to take the requisite measures so that the transport operations, carried out by specialised operators in full compliance with the safety standards, never suffer from administrative obstacles that result in difficulties or delays. This concern certainly applies to cross-frontier operations, but it can also apply to operations within a country.

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(1) A short analysis of this topic is contained in the annex.

5. The construction of nuclear power stations[1]

71. The existing situation within the Community is characterised by the fact that two reactor types, PWR and FBR, have been mainly, but not exclusively, chosen as the basis for the development of nuclear energy in the foreseeable future.

72. Such near-uniformity increases the technological understanding of the designs in question and, as a result, strengthens still further the confidence already placed in them. It should also facilitate intra-Community trade in equipment and the implementation of joint construction projects. Both of these are - in principle at least - permanent objectives of the Community strategy for the development of nuclear energy with, as a corollary, the promotion of exports.

73. It must nonetheless be kept in mind that an essential basis of this strategy is the laying down of common design and construction rules based on data that have already had their validity confirmed in a considerable number of cases.

74. The predominance of PWRs and FBRs, together with the option of recycling in the former plutonium that has not been allocated to the latter, occurs at a time when, even in the case of Member States with the most ambitious nuclear programmes, the prospects for the nuclear market are tending to look bleaker rather than brighter. The industry is entering a transitional phase where the size of the market is determined by developments in the overall economy and not by any measures it may take. It must, therefore, progressively diversify its production, in particular to make a suitable place for the FBRs.

It is unfortunate that the adaptation required by this transition has to take place at a time of general excess construction capacity. This excess also affects conventional power stations that could otherwise have provided an emergency outlet for the nuclear construction industry.

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[1] An analysis of this topic is contained in the annex.

75. As regards the FBRs, it seems that the present situation is favourable to the setting-up of an industrial structure, the style and capacities of which would be commensurate with the needs of the European market. As has been the case with the construction of Superphénix, there will be opportunities for those particularly qualified firms in all the countries involved.

76. The industrial rationalisation required does not necessarily have to result in an integrated structure, but neither should it reject such a possibility from the outset.

In any case it should result in the creation of a true common market in FBRs, even though, at present, certain Member States are not seeking to construct reactors of that type on their territories.

77. It is most desirable that the rationalisation in question, the object of which is to provide the industry concerned with the construction of FBRs in the Community with an appropriate structure, should not be restricted to that particular sector. It should also take account of the PWR sector and rationalise it. Difficult though this task may be, it will have to be accomplished sooner or later(1).

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(1) N.B.: Rationalisation of this sort may involve concerted practices likely to come under Community rules on competition: the principle of prohibition laid down in Article 85 (1) of the EEC Treaty implies that the Commission will keep a check on concerted practices. The Commission may, of course, grant an exemption on the basis of Article 85 (3) in certain circumstances in view of the objects and economics of the sector.

NUCLEAR INDUSTRIES
IN THE COMMUNITY

Illustrative Nuclear Programme
under Article 40 of the Euratom Treaty

1984

ANNEX

REVIEW OF AND PROSPECTS FOR
THE DEVELOPMENT OF NUCLEAR ENERGY IN THE COMMUNITY

CONTENTS

REVIEW OF AND PROSPECTS FOR THE DEVELOPMENT OF NUCLEAR ENERGY IN THE COMMUNITY

1. The role of electricity in the economy

1. Electricity is an essential part of the Community's energy infrastructure and plays an increasingly important role in the economic development of the Community.

2. Since 1973, and in particular since 1979, there has been a very appreciable decrease within the Community in the ratio of the demand for energy to the gross domestic product. Since the gross domestic consumption of energy fell by about 56 Mtoe between 1973 and 1983 whereas the gross domestic product increased by 208 000 million ECU (at 1975 value), the rate of energy intensity (the quantity of energy required for the production of one unit of value added) dropped from 0.83 kgoe/ECU (1973) to 0.66 kgoe/ECU (1983).

3. This development is a result of the energy savings achieved in the "residential and tertiary", "transport" and "industry" sectors and of the profound modification of the structure of economic activity: decrease in the share of the activities which are large consumers of energy and increase in the share of the services.

4. As regards electricity consumption, there has been an opposing trend which reflects an increase in the share of electricity in total energy consumption and a greater contribution by electricity to the Community's economy. In 1973, 0.94 kWh was consumed for every ECU of the GNP. In 1983, that figure increased to 0.99 kWh/ECU.

5. Maintenance of the relationship between economic growth and the growth in electricity consumption depends on market factors such as:

- the future opportunities for specific uses of electricity (lighting, power and traction, certain industrial processes, control functions, etc.);

- the rate of electricity savings achievable through the introduction of more efficient equipment;

- the cost of electricity, the trend of relative energy prices and the resulting competitiveness of electricity in applications in which it is capable of replacing other energy sources (for example heating, air conditioning and transport).

The role of electricity will also depend on the choice which certain Member States will make, particularly as regards the development of nuclear energy which can be delivered only through that medium.

2. Nuclear energy production

(a) Progress since 1973

6. At the time of the first oil crisis in 1973-74, the industrial-scale application of nuclear energy was still in its initial stages. With the rapid rise in oil prices, concern about the costs of producing electricity by using oil reinforced existing concern about security of supplies. As a result, ambitious programmes were put in hand to reconvert to coal and to make large-scale use of nuclear energy in the electricity generating industry.

7. Neither the electricity demand prospects on which the nuclear programmes were based nor the nuclear construction programmes have turned out as expected. The downward revision of the estimates of electricity demand and public anxiety resulted in considerable reductions in the nuclear programmes.

8. In spite of these developments, nuclear energy has significantly increased its role over the last ten years. In 1973, only 5% of electricity production in the Community was of nuclear origin, by 1978 that share had doubled to 10% of the total and reached 22.4% in 1983.

9. The increasing importance of nuclear energy has been particularly evident in the Community in comparison with developments in the other main industrialized countries such as the United States and Japan (see Fig. 1). In 1973, the shares of electricity production in the Community and the

United States accounted for by nuclear energy were approximately equal (4% and 5%, respectively). In Japan that share was somewhat less (2%). In 1983, the share of nuclear energy in the Community reached 22.4% as already mentioned, whereas in the United States and Japan it did not exceed 12.6% and 18%, respectively.[1]

10. Total (net) nuclear generating capacity in the Community increased from 10 GWe[2] in 1973 to 52 GWe in 1983. This increase occurred mainly in France (+ 24.3 GWe), but there were also significant capacity additions in the Federal Republic of Germany (+ 8.8 GWe), the United Kingdom (+ 4.1 GWe) and Belgium (+ 3.5 GWe) (see Fig. 2).

11. These developments had a substantial impact on the Community's energy balance. Whereas nuclear energy in 1973 accounted for only 2% of total energy consumption, its contribution had increased to 9% in 1983. Together with energy conservation efforts, the development of North Sea oil production and increased use of natural gas, nuclear energy has helped to reduce the Community's dependence on imported oil from 62% in 1973 to 32% in 1983.

12. This overall progress, however, masks very considerable differences between the Member States (see Fig. 3).

13. Strongly determined to promote the development of nuclear energy, France and Belgium have already carried out large-scale restructuring of their electricity production systems. In 1983, they produced 48% and 46%, respectively, of their electricity from nuclear energy as compared with 8% and 0.2% in 1973.

14. Progress has also been achieved in the Federal Republic of Germany and the United Kingdom, although the programmes in those countries have suffered significant delays. In Germany, the nuclear share of electricity production increased from 4% in 1973 to 18% in 1983, while in the United Kingdom the corresponding increase was from 9% to 17%.

15. Only modest increases in the contribution of nuclear energy have been achieved in Italy and the Netherlands, from 2.2% of the electricity produced in 1973 to 3.2% in 1983 in the case of the former and from 2% in 1973 to 6% in 1983 in the case of the latter.

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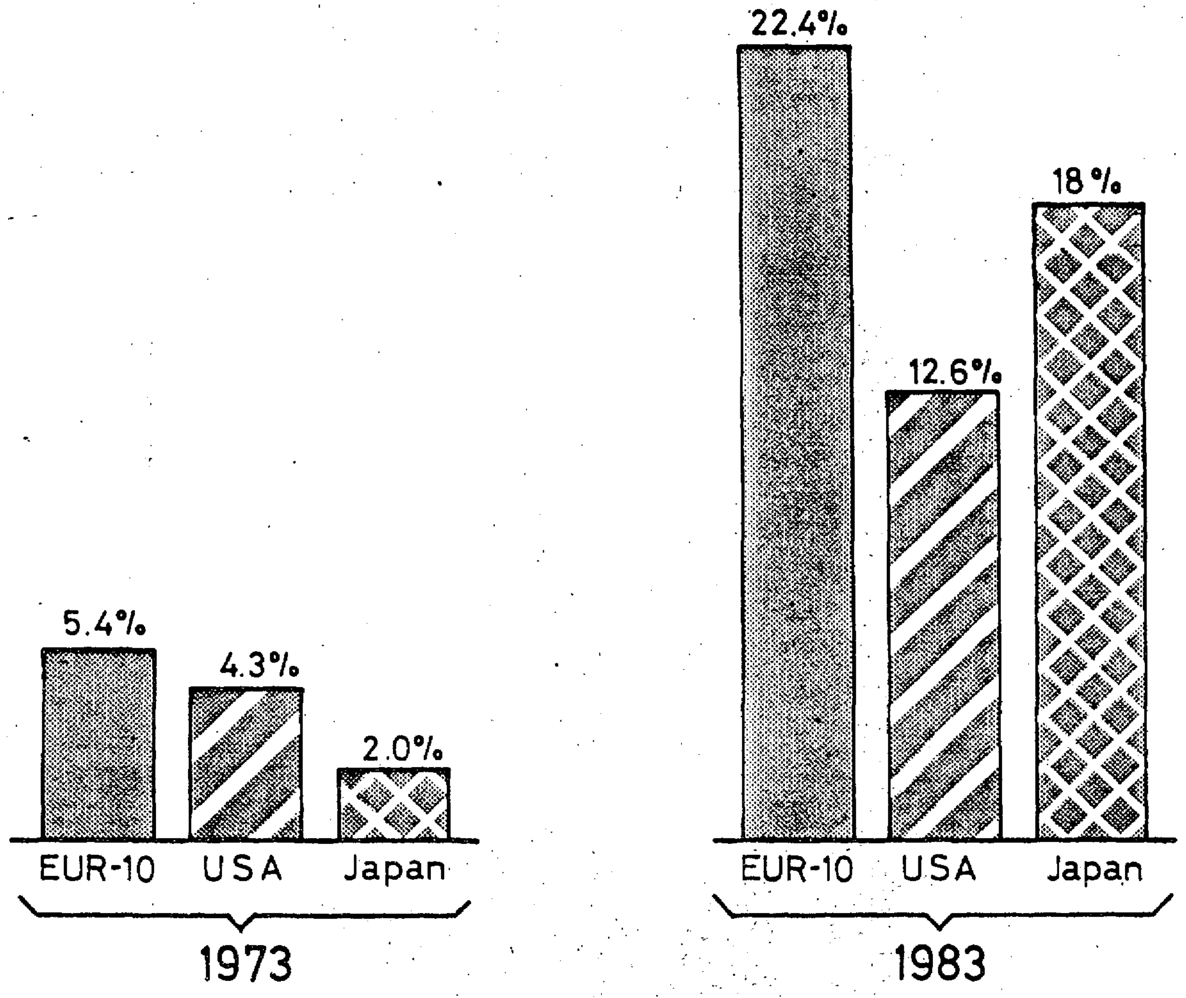
[1] Statistical Office of the European Communities.
[2] GWe: Gigawatt electric = 1 000 MWe.

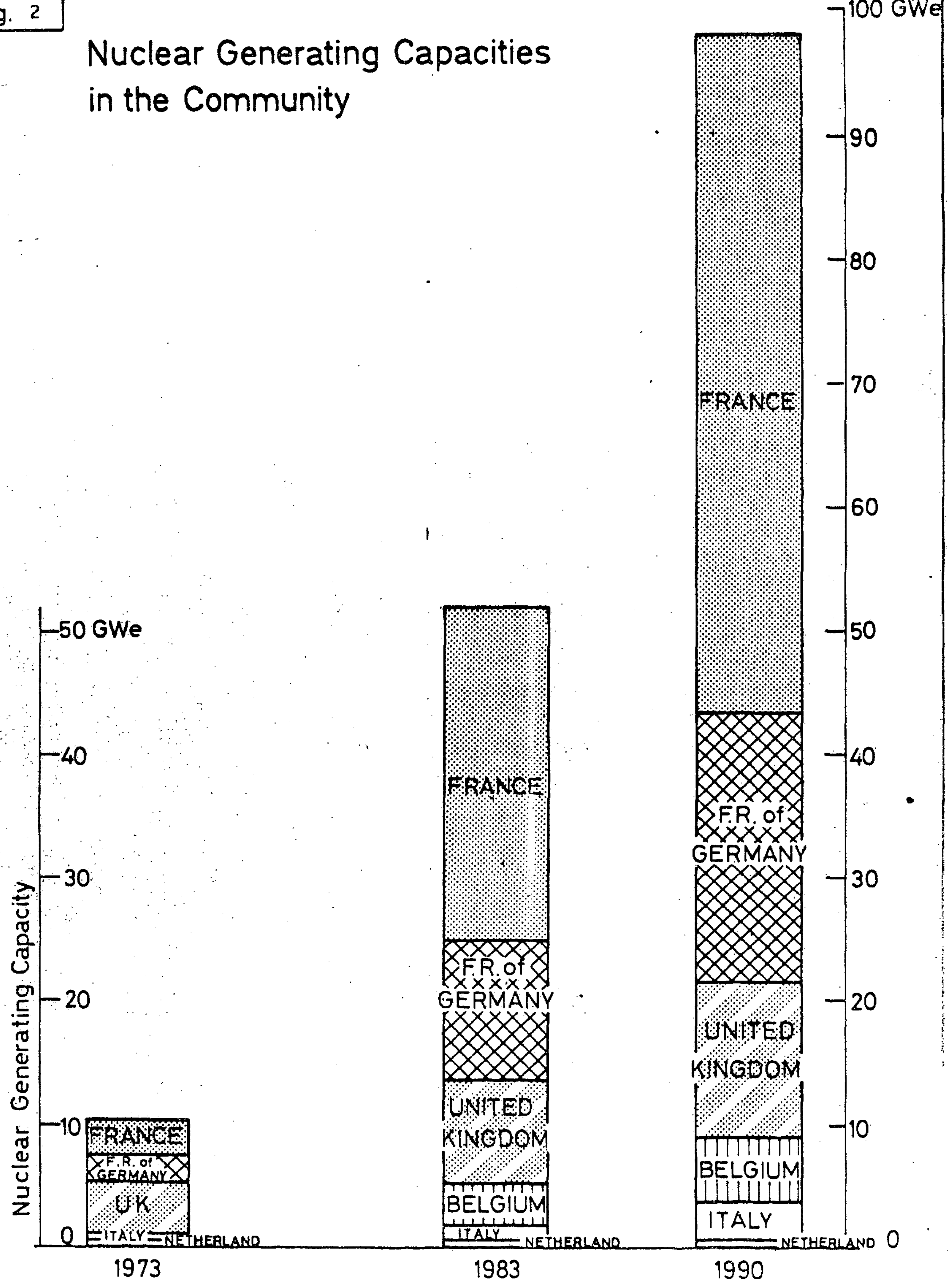
Fig. 1

Nuclear Share in Electricity Production in EUR-10, USA, Japan



Source: Statistical Office of the European Communities

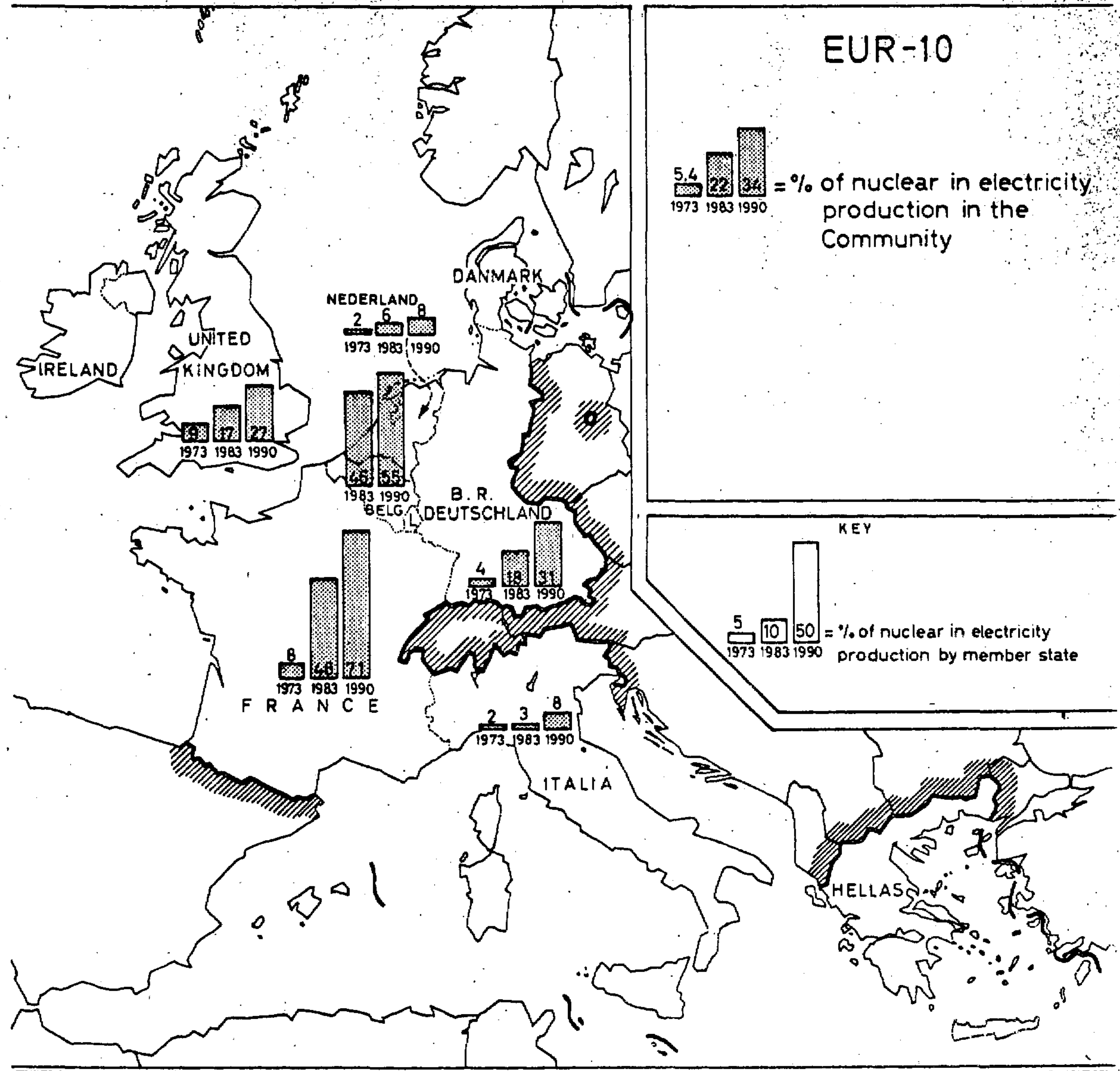
Fig. 2



Source: Statistical Office of the European Communities (years 1973 and 1983)
Commission's estimate (year 1990)

Fig. 3

Nuclear Share in Electricity Production in the Community and in the Member States



Solid fuels[1] share in electricity production in the Community and in the member states (%)

	EUR-10	B	DK	D	F	GR	IRL	I	L	NL	UK
1973 (2)	40.8	22.0	35.7	63.0	19.3	34.7	24.4	3.8	36.6	6.0	63.0
1983 (2)	46	31	95	63.5	20	64	21.5	13.0	35	25	71.5
1990 (3)	41	34	90	54	14.5	80	55	24	63	42	66

(1) Hard coal, Brown coal and derived gases
(2) Source: Statistical Office of the European Communities (1983 data are provisional)
(3) Source: Member States' forecasts

Four Member States, namely Denmark, Ireland, Greece and Luxembourg, have not adopted nuclear energy programmes.

16. There are various explanations for this disparity:

- public opposition of varying intensity to nuclear energy;
- relations between central government and local authorities, which could be better in some cases;
- the use of a fossil source of domestic energy for electricity production in certain Member States, particularly the Netherlands, the Federal Republic of Germany and the United Kingdom.

(b) The outlook for 1990

17. In the context of their joint efforts to reduce the Community's dependence on oil, the Member States have agreed that electricity production should be based mainly on solid fuels and nuclear energy from the 1990s onward.

18. According to the Member States' forecasts for 1990, the switch from oil to nuclear and solid fuels, already well under way in the electricity production sector, will continue throughout the present decade, mainly owing to the increase in nuclear energy production (+ 83%) and, to an appreciably lesser extent, of coal production (+6%) over the present levels (1983). As a result, nuclear energy and coal should be contributing equally to 71% of net electricity production in the Community by the early 1990s.[1]

19. By the end of 1983, there were 95 nuclear reactors in the Community with a total capacity of 52 GWe. By 1990, 128 reactors with a total capacity of 98 GWe should be in operation in the Community. Although the risk of further delays in the nuclear programmes cannot be ignored, there is a good chance that this capacity will actually be available by 1990, as all new reactors planned for entry into service by that date are already under construction.

20. Nuclear energy production should represent 144 million tonnes of oil equivalent (Mtoe) and be sufficient to cover 14% of the total energy requirements in 1990. This means that, within the Community, nuclear energy production would reach the same level in primary energy terms as hard coal production (144 Mtoe) and exceed production both of natural gas (114 Mtoe) and of oil (106 Mtoe). This stresses still further the importance of nuclear power as an energy source for the Community.

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[1] The objective for the Community is that, by 1990, 70-75% of primary energy inputs into electricity generation should be provided by solid fuels and nuclear energy. Measured on this basis, solid fuels and nuclear energy should account for 81% of electricity generation in 1990 according to Member States' forecasts. If this is measured in relation to net electricity production, which is the point of comparison of most interest to the electricity sector and that chosen throughout the illustrative programme, a combined share of 71% is obtained for nuclear energy and coal for the same situation.

21. The upturn in the contribution of nuclear energy will occur exclusively in those Member States which already have a large-scale nuclear energy programme, chiefly France (+27.6 GWe), the Federal Republic of Germany (+10.7 GWe) and the United Kingdom (+4.2 GWe). In this decade, the existing disparities between the Member States as regards the use of nuclear energy will continue to widen. In view of the long lead times involved in nuclear power-plant programming, it will not be possible to reverse this trend before 1990. This should be a primary concern of Member States which, at that time, will still be largely using oil and imported natural gas for electricity production.

22. On the other hand, by the end of this decade, it is likely that the nuclear power production capacity in certain Member States such as France will have increased rapidly until it is in excess of what is needed to meet the base-load demand for electricity up to which point the competitive advantage of nuclear power is at its greatest.[1] In such a case, it would be advantageous to broaden the market for base-load electricity supplies in order to improve the economics of nuclear electricity production.

23. In this context, it is interesting to note that certain States share investments (acquisition of holdings in nuclear power stations) and share the electricity produced. This practice is an advantageous variant of cross-frontier electricity sales, which, in any case, should be encouraged whenever it enables supply conditions to be improved from the two standpoints of price and security.

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[1] It should be noted, however, that progress made in nuclear plant design and operation now permits nuclear power plants to be used also for "load following".

24. Lastly, as regards the prospects for nuclear electricity generating costs, the forecasts made by the Community's electricity producers, in which the Commission was also involved, show that the cost per kWh of nuclear electricity generated by plants to be placed in service in 1990 is less than that of electricity produced with coal and much less than that of electricity produced with petroleum products. These estimates also show that the fuel cost accounts for less than one third (28%) of the total cost of the kWh (see paragraphs 16 and 17 of PINC). The shares of the various components that go to make up the fuel item are as follows:

- Natural uranium : 30%
- Conversion : 2%
- Enrichment : 30%
- Fabrication : 12%
- Reprocessing : 30%[*]
- Materials recovered during reprocessing : - 4%

N.B. The above are average values within quite large ranges because the calculation assumptions varied from one producer to another.

It is apparent from this breakdown that the raw material for nuclear fuel, i.e. natural uranium, accounts for less than 10% of the total cost of the kWh (30% x 28% = 8.4%).

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[*] The reprocessing item includes, among other things, vitrification of fission products and the conditioning, transport, interim storage and final disposal of waste.

3. Uranium supplies

25. Uranium is a strategic material subject to national controls, the only significant use of which is in electricity generation; the uranium market, which came into existence relatively recently, is naturally very sensitive to developments in the field of nuclear energy. Uranium possesses very great energy density and physical and chemical characteristics which make it easy to store. It is thus possible to store much greater quantities of energy than is the case with fossil fuels.

26. The uranium market has been characterized over the three decades of its existence by two periods of intensive growth (1959 and 1978), separated by a sharp depression (1972) and followed by a sudden drop in prices in 1983-84, which was accompanied by a drop in production. In this context, the existence of considerable stocks of uranium is such as to influence the market.

27. Supplies to the Community over the next decade will account for virtually one-third of the uranium requirements in the western world, while those to the United States will account for a further third.[1] The Community meets almost all these requirements by means of long-term contracts. European industry has considerable interests in the major uranium-producing areas and, in the exporting countries, it contributes towards the production of quantities of uranium of the same order of magnitude as all the Community's import requirements.[2] However, this should not be taken to mean that the Community has unlimited access to these potential supplies, since the export of uranium is subject to political conditions.

28. The uranium mining industry is a particularly concentrated industry, with six countries (USA, Canada, South Africa, Australia, Niger and Namibia) holding 80% of the reserves that can be worked at a cost of less than $80/kg U and accounting for 90% of world production. Some 50 companies are involved in uranium production (most of them American), and five companies (Cogema, France; RTZ, United Kingdom; Nufcor, South Africa; Energy Resources of Australia; and Keylake Mining, Canada) control over 60% of the world production capacity.

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[1] Requirements in 1990 can be estimated as 17 500 t/U for the Community, 16 800 t/U for the United States and 16 200 t/U for the rest of the world.

[2] It is estimated that, in 1990, the Community's production capacity, mainly located in France, will be 4 000 t/U; it will cover close to 25% of requirements at that time, the remaining supplies (75%) having to be imported.

29. Most of the commercial transactions in uranium (about 90%, this proportion being greater in the Community) are conducted under long-term contracts. "Spot" transactions account for the remainder. In view of the existing situation, which is characterized by substantial stocks and the closure of unprofitable mines, a "secondary market" has been created which is slowing down the recovery of uranium prices. The drop in prices on the "spot" market, although it may appear beneficial in the short term to the buyers, itself gives rise to risks for the future, since the producers, deprived of financial resources, will sharply decrease their prospecting expenditure. As regards long-term contracts, the prices involved are less subject to sudden change and the general trend which is now emerging is as follows: to avoid, on the one hand, excessive commitments on the part of the buyers which would result in periods of surplus likely to depress the market and, on the other hand, to enable producers' profits to be stabilized in order to ensure regular supplies.

30. As regards the conditions governing uranium supplies, it should first of all be kept in mind that the producer and/or consumer countries can be divided into countries which are solely producers (Australia, Niger, Gabon and Namibia), countries which are producers and low-level consumers (Canada and South Africa), countries which are both producers and consumers (France and the USA) and countries which are solely consumers (other Community Member States).

Among the producing (and exporting) countries, policies for development of the uranium mining industry may be widely influenced by concerns relating to the non-proliferation of nuclear weapons or by the desire to obtain substantial revenue (in the case of developing economies). These factors give rise to a wide diversity of supply conditions affecting countries which import uranium.

31. Although the western world's uranium production capacities in operation, under construction or planned at the end of 1983[1] are sufficient to cover requirements up to the middle of the next decade, the present cut-back in exploration must not be treated lightly in view of the considerable time (about ten years) required to open up a uranium deposit and commence mining operations.

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[1] World uranium output in 1983 amounted to 37 200 t, and the world production capacity by 1990 can be estimated as 50 300 t.

32. The world's resources of low-cost uranium that are known at present[1] are capable of covering the western world's requirements for about 20 years, and half of them are located in Canada, Australia and South Africa. However, the concentration of resources in such a small number of producing countries and the cut-back in prospecting which followed the drop in prices could, if they were to last, run counter to any policy of diversification and thus of security of supply. It is thus a matter of concern for those Member States that are implementing a nuclear power programme and are heavily dependent on outside sources of supplies.

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[1] This does not take account of the conditions imposed by certain producers which are likely to affect the price paid by the consumers (taxation, floor price fixed by the governments, etc.) and to restrict the use of uranium.

4. The nuclear fuel industry (fuel-cycle services)

32 bis. The firms within the Community have developed an industrial potential in respect of all stages of the fuel cycle downstream of uranium production, the latter being mainly carried out outside the Community (see paragraph 27 above):

- uranium conversion;
- uranium enrichment;
- fuel fabrication;
- storage and reprocessing of irradiated fuel;
- management and disposal of radioactive wastes;
- transport of nuclear materials.

(a) Conversion

33. Conversion, which accounts for only a small part of the total fuel-cycle cost (2%), is nonetheless an essential stage in the cycle and possesses its own specific industrial characteristics.

34. Five companies are currently carrying out conversion operations in the western world, two of them within the Community: British Nuclear Fuels Ltd., in the United Kingdom, and Comurhex, in France.[1] In 1982, the average rate of utilization of such installations throughout the world was about 80%.

35. 55% of the capacity available within the Community is enough to cover the Community's own requirements. The rate of utilization of the European installations solely to cover the Community's own internal requirements should increase gradually to 75% by 1990. The conversion industry is also an exporting industry which meets the requirements of European countries outside the EEC and those of non-European countries.

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[1] The European industry also carries out conversion of uranium recovered during reprocessing.

36. It may thus be said that conversion requirements within the Community will be adequately met. Furthermore, the capacities can be increased rapidly, if necessary, by expanding existing plants.

37. However, the European companies in this sector will in future have to cope with keener competition from certain uranium-producing countries which insist, or try to insist, on their uranium being sold in forms that have been processed beyond the ore-concentrate stage.

(b) Enrichment

38. Uranium enrichment is an activity of considerable economic and political importance. This stage is responsible for about 30% of the total cost of the fuel cycle in the case of reactors fuelled with enriched uranium, which account for almost the entire installed nuclear capacity within the Community.

39. Until 1979, the Community was almost completely dependent on outside suppliers for its enriched uranium. The United States dominated the world market until the USSR entered the commercial scene in the early 1970s.

40. This situation has changed fundamentally since the setting-up of two multinational groups for enrichment within the Community: Eurodif and Urenco. The entry into service in 1979 of the Eurodif plant, the capacity of which is 10.8 million separative work units (SWU) per year or 40% of the American capacities, and the current phased implementation of the investment programme decided on by the Urenco group[1] make it possible, not only to meet the Community's requirements, but also to possess capacities sufficient to export this very high value-added service. In consequence, imports of enriched uranium have decreased considerably from the 100% needed to meet requirements in the 1970s to less than 25% in 1983.

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[1] By 1983, these investments had resulted in a capacity of about 1 million SWU.

41. Industrial competition is extremely tough on all the world markets owing to the extent of the existing production capacities. At present, it opposes American and European producers, and it is probable that the Japanese will joint the fray within the next decade. The present enrichment service capacity available on the world market, about 42 million SWU/year, will probably continue to remain in excess of requirements until the middle of the next decade, when those requirements will have increased from about 25 million SWU/year today to over 40 million SWU/year.

42. Furthermore, the conclusion of major long-term enrichment contracts with the USDOE[1] in the 1970s, under conditions fixed by the suppliers which included the obligation to sign long-term contracts at least eight years before first delivery, resulted in the building-up of substantial stocks of enriched uranium by the users, and this has led to the emergence of a secondary market. This market, on which the electricity producers sell their excess quantities, is at present characterized by substantial discounts in comparison with the sole officially published price (that of the American producers).

43. Research under way in the field of enrichment gives grounds to believe that new technologies could make it possible within the next decade to reduce production costs significantly.

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[1] United States Department of Energy.

(c) Fuel-element fabrication

44. This stage comprises the operations which result in the production of complete fuel elements ready to be inserted into reactors and is responsible for about 12% of the cost of the fuel cycle.

45. In the case of light-water reactors, which account for over 75% of the installed capacity, fuel-element fabrication reached industrial maturity several years ago.

46. At present, there is substantial excess capacity in the Community, and a further capacity expansion will not be necessary before 1990. Since the period required for constructing a plant is less than five years, a decision to make new investments in this sector should not have to be taken for some years to come.

47. Although a certain opening of the uranium fuel-element fabrication market has recently been discernible in the Community, the industrial structures are still predominantly national.

48. As regards meeting internal requirements, the European market is virtually self-sufficient, and this situation will continue as long as the European producers possess sufficient industrial and development capacity to maintain their hold on the market in the Community Member States.

49. The industrial expertise in fabrication acquired in the Community should in future enable the manufacturers to obtain a greater share of orders on markets outside the Community. However, it can be seen that there is also worldwide excess production capacity and competition is very keen on all the export markets.

50. The cladding and certain structural components of the LWR fuel element are made of zircalloy, a zirconium alloy. As regards production of zircalloy elements, the plants within the Community have been capable of meeting requirements so far, and it is possible to increase production capacities rapidly as soon as it becomes necessary in order to satisfy requirements up to 1990.

51. The fabrication of plutonium fuel elements requires special installations. The existing plants are low-capacity plants capable of meeting current requirements arising from the operation of pilot and industrial-scale demonstration fast breeder reactors and from plutonium recycling activities in light-water reactors (thermal recycling).

52. The existing plants have made it possible to acquire the technical experience needed in order to be able to construct larger units for the development of a fast breeder programme and of a large-scale programme for the thermal recycling of plutonium.

53. The fabrication of fuel elements for the family of high-temperature reactors at present being developed has reached industrial maturity. The existing plant in the Community possesses a capacity sufficient to meet current requirements. The available technology can be applied to plants with a greater capacity.

(d) Reprocessing

54. Since the early days of nuclear energy, reprocessing has been considered as an essential stage in the nuclear fuel cycle, since it enables the entire energy content of uranium to be exploited by successive recycling of the residual uranium, an operation made possible through the use in fast breeder reactors of the plutonium generated during irradiation of the fuel. Moreover, the recycling in thermal reactors of the uranium and plutonium recovered through reprocessing also has considerable potential, since it allows uranium consumption and the use of enrichment services to be reduced.

Lastly, reprocessing facilitates radioactive waste management, since it enables the fission products contained in the irradiated fuel elements to be separated and treated selectively in accordance with their specific properties.

55. Considerable experience has been acquired in the Community with the industrial-scale reprocessing of metal fuel from natural-uranium-fuelled nuclear power stations. This experience derives from the reprocessing of the approximately 35 000 tonnes[1] of uranium so far dealt with in France and the United Kingdom.

56. The reprocessing of enriched uranium-oxide fuel from modern nuclear power stations has reached a stage at which it can be applied on an industrial scale.

On the one hand, about 1 800 tonnes[2] of fuel of this category from reactors throughout the world have been reprocessed to date, three-quarters of it in the Community, mainly in the French installations at La Hague (920 t), in the German and British installations and at Eurochemic (see the following paragraph).

Furthermore, the continued improvement of technical and economic performance and of the safety of the operating installations shows that reprocessing has now proved itself.

In the Community, this sector has hence been capable of solving the problems arising from the technical, regulatory and financial constraints encountered in the past which often continue to beset reprocessing elsewhere in the world.

57. The experience thus acquired has enabled the French, British and German reprocessors[3] to implement the following projects in the Community:

- two plants with a capacity of 800 tonnes per year each in France, namely the reconstruction and expansion of the existing plant with a concomitant increase in its capacity to 800 tonnes per year (UP 2-800) and the construction of a new unit of the same capacity (UP 3), at present under way at Cap de la Hague;

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[1] The quantities involved in reprocessing are assessed as tonnes of uranium contained in the fuel elements.

[2] The electrical energy produced per tonne of enriched uranium-oxide fuel is about ten times as great as that produced per tonne of natural uranium metal fuel. In other words, to produce the same quantity of electricity, a nuclear plant operating on metal fuel would generate ten times as much spent fuel as one operating on enriched oxide fuel.

[3] These companies are also partners in the company "United Reprocessors", which was set up in 1971 and had its statute approved in 1975 by the Commission pursuant to the rules on competition set out in the EEC Treaty in order to facilitate the harmonious growth of the uranium-oxide fuel reprocessing industry.

- a plant with a capacity of 350 t per year, the construction of which is scheduled to start in 1985 in Germany;

- a plant with a capacity of 1 200 t per year (Thorpe) which is under construction at Sellafield in the United Kingdom.

The projects already under way are financed in advance, through contracts, by customers on a pro rata basis in respect of the services to be provided over a period of ten years of plant operation. To these projects can be added the Belgian plan to modernize, expand and place in service again the Eurochemic plant, which became the property of Belgium in 1978.

On the basis of the start-up schedules put forward for the various projects, it may be expected that about 4 000 tonnes and 12 000 tonnes of oxide fuel will have been reprocessed in the Community by 1990 and 1995, respectively.

58. The plants now available within the Community are used, on the one hand, for the reprocessing of fuel discharged from nuclear power stations in the Community (14 000 tonnes in 1990 and 25 000 tonnes in 1995) and, on the other hand, for the reprocessing of fuel from non-Community countries (about 7 000 tonnes to be delivered between now and 1990).

In view of the way in which reprocessing capacities have been expanding and of the quantities of fuel to be dealt with (those arising in the Community and those from non-Community countries to be reprocessed under contract), it may be estimated that about 17 000 to 20 000 tonnes of irradiated fuel will have to be stored in the Community during the 1990-95 period.

Part of that fuel is already the subject of reprocessing contracts and, in consequence, will be reprocessed after 1995. As regards the remainder of that fuel, any reprocessing thereof will depend on the decisions to be taken by the electricity producers on a case-by-case basis.

59. Thanks to the interim storage facilities, it will be possible to store such quantities of fuel in the Community. At present, the reprocessors have begun to construct, or are planning, large-scale interim-storage capacities on the sites of the reprocessing plants. In addition, many electricity producers have increased the storage capacities of existing spent-fuel ponds at operating power stations, and the most recent plans for new power stations often make provision for storage capacities capable of accommodating fuel discharged over a period of up to ten years or even more of power-station operation. Finally, storage facilities located on sites separate from those of reprocessing plants or of nuclear power stations are already in service or are being constructed in the Community.

60. The cost of the commercial reprocessing of oxide fuel accounts for about 30% of the cost of the fuel cycle, allowance being made for the conditioning of the wastes and any credit from the recovered fissile materials.

61. As regards the fast breeder reactors, a modern pilot plant for the reprocessing of irradiated fuel from reactors of that type is under construction at Marcoule (TOR). This plant was preceded by pilot installations which, for several years, ensured that the Dounray reactor in the United Kingdom and the Phénix reactor in France could operate with a virtually closed cycle.

(e) Radioactive waste

62. All industrial activities, including the use of nuclear energy, give rise to residues, some of which can be recovered and recycled, while others are considered as wastes. The radioactive wastes arising from the use of nuclear energy are considered here.

63. To facilitate understanding, radioactive wastes are here divided into two main categories:

- high-activity wastes, arising from the reprocessing of spent fuel[1] and containing about 99% of the radioactivity produced during uranium fission in reactors;
- low- and medium-activity wastes, arising during the operation of nuclear power plants and other fuel-cycle installations.

The low- and medium-activity wastes can be further subdivided according to whether or not they contain a significant quantity of long-lived alpha emitters.

64. The processing and conditioning of low- and medium-activity waste (with the exception of alpha-contaminated waste), which account for almost 95% of the volume of the conditioned waste produced today in the Community, benefit from experience acquired over 30 years. Several processes for reducing the volume of such wastes, adapting their chemical composition and incorporating them into solid structures (matrices) are commercially available.

65. Certain Community Member States have already acquired considerable experience with the disposal of these wastes,[2] while others only store them pending subsequent disposal. No major problem should be experienced in this field.

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[1] If irradiated fuel is not reprocessed, it is considered to be high-activity waste. Disposal of such waste gives rise to problems which differ from those encountered in the management of high-activity waste that has been reprocessed. Only limited experience with the processing, conditioning and disposal of irradiated fuel has so far been acquired anywhere in the world.

[2] Sub-surface land disposal and sea disposal undertaken in the context of the multilateral consultation and surveillance mechanism established by the OECD. The latter form of disposal is at present the subject of a de facto moratorium.

(N.B.: these wastes are of low and medium activity).

66. Technologies are available for the processing and conditioning of waste contaminated by long-lived alpha emitters and for high-activity waste, and some of these technologies have arrived at the industrial-application stage.

This is the case, for example, with the vitrification of waste separated during the reprocessing of irradiated fuel.

67. There has been no disposal of such wastes as yet. The first installations for the disposal of alpha-contaminated wastes at intermediate depth in geological formations will enter into service in some Member States at the beginning of the 1990s. Various options for the diposal of high-activity waste are being studied by the Member States and the Community, particularly disposal in deep-lying continental geological formations such as salt, clay and crystalline rocks, which are sufficiently abundant throughout the Community.[1] The results obtained from research and experiments in this field confirm that disposal in these types of formations is feasible.

At present, waste of this type, some of it already conditioned, is stored temporarily in special facilities. The need to allow high-activity waste to cool down for periods that can be as long as several decades in order to obtain optimum conditions for final storage would seem to rule out the need for industrial-scale application of final-disposal methods before the end of this century.

68. The costs of processing and conditioning, including, where necessary, the cost of interim storage on the site where the waste was produced, are known accurately enough and are accounted for at the stages in the fuel cycle where they arise.

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[1] It should be noted that certain Member States without nuclear power programmes are also interested in this subject. In particular, Denmark has studied the feasibility of waste disposal in salt domes situated within that country.

As regards the cost of waste disposal, particularly that arising from the disposal of high-activity waste in deep-lying geological formations, the converging conclusions of economic studies carried out in several countries indicate that it will not exceed 3% of the production cost of the nuclear kWh.[1]

69. In accordance with the Council resolution of 18 February 1980[2] approving a plan of action, the Commission is administering, in the radioactive waste sector, a major Community programme - including, in particular, research work - which has been coordinated with the activities of the Member States; it is also associated through specialized agreements with certain non-Community countries.

As part of this plan of action, the Commission also has to analyse continuously the situation in this sector. The first exhaustive analysis of the present situation and prospects was recently forwarded to the Community institutions.[3]

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[1] This is not an estimate of the cost of disposal, but an upper limit which that cost will not exceed under any circumstances; such an assessment does not take account of cost discounting, which reduces the relative extent of the costs.

[2] OJ C 51, 29.2.1980.

[3] COM(83) 262 final.

(f) The transport of nuclear fuel

70. The nuclear-fuel transport sector in the Community will expand considerably in the years ahead because of the rapid expansion of national nuclear power programmes. The diversity of products transported, the means of transport used and the geographical locations concerned are three essential - but not necessarily interdependent - aspects of this type of transport.

The sector covers a very wide range of activities: the transport of uranium in all its forms (ore concentrate, natural and enriched uranium hexafluoride, uranium and plutonium oxide, new and irradiated fuel elements) in specific packagings adapted to the physical and chemical characteristics of these materials and the nature of the risks they represent.

71. The cost of transporting nuclear material (ore, processed uranium, fuel, etc.) is included in that of the various services associated with the fuel cycle and accounts for a very small proportion of the overall cost of the full range of such services.

By way of illustration, the unit cost of transporting irradiated fuel - which is the most expensive transport operation - amounts to a few percent of the cost of reprocessing.

72. In view of the foreseeable trend in power-plant siting, the number of journeys for the purpose of transporting new fuel is likely to increase appreciably. This trend is not so pronounced in the case of irradiated fuel, as large-capacity transport casks will be developed over the next few years.

73. The need for a new type of heavy cask has recently become evident in the Community. The type concerned is a dual-purpose cask for the transport and extended interim storage of irradiated fuel pending reprocessing. As the practice of extended interim storage becomes more widespread, there could well be a considerable increase in the demand for casks with which the industry seems capable of coping.

74. Programmes for the transport of irradiated fuel discharged from nuclear power stations call for meticulous planning on the part of the transporters, the electricity producers, the reprocessors and the competent national authorities.

Provision is made for a reserve transport-cask capacity of approximately 30% in order to allow for maintenance requirements and other contingencies.

75. The scale of such operations will increase in future to keep abreast of the requirements arising from the greater number of power stations in operation.

The future prospects for this sector point to the use of large - and to some extent standardized - casks, which will make it possible to provide a more efficient service.

5. Nuclear reactors: design and construction

(a) Reactor types

(i) The types already developed

76. Power reactors of several types - or concepts - are in operation in the Community, since their design depends on the technological and political considerations, infrastructure, etc., specific to each client.

77. The oldest type is the Magnox (British designation) or UNGG (French designation meaning natural uranium, gas, graphite) which was adopted in the United Kingdom and France and exported by the former to Italy and Japan and by the latter to Spain (a single reactor in each case). This type of reactor was designed at a time when:

- only the USA had the capacity to provide industrial-scale supplies of enriched uranium;
- the production cost of nuclear graphite was lower than that of an equivalent quantity of heavy water (it was also possible to use natural uranium in heavy-water reactors).

At a later date, in the United Kingdom, France, Germany, Italy and at Euratom, attempts were made to improve the neutron economy of the systems in order to increase the quantity of energy that the uranium could yield by developing heavy-water reactors. Except in Germany, where it was developed exclusively for export,[1] this design never advanced beyond the prototype stage, since other designs, which did not require the quite specific and very considerable investments in heavy-water production, had become available in Europe where uranium-enrichment technologies had been acquired in the meantime. The unanimous European decision to abandon

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[1] Argentina purchased two heavy-water reactors from Germany with a capacity of 319 and 692 MWe, respectively, while in Germany itself there was the 52-MWe prototype, shut down in May 1984. European industry developed this reactor type up to a total capacity of 1 267 MWe, while in Canada, where the heavy-water reactor was adopted as the standard national type, a total capacity of 15 499 MWe has been attained.

the heavy-water design has aroused regret, which is perfectly understandable in view of the satisfactory performance of the system. However, that decision was motivated by the desire to avoid commitment to overly specialized investments at a time when alternatives based on less specific technologies were available, as was enriched uranium.

78. The design of the British Advanced Gas-Cooled Reactor (AGR) was derived from that of the Magnox and was intended to reduce the production cost of the kWh by increasing:
- the power density, and
- the thermodynamic efficiency.

In order to attain that objective, it was necessary to make use of higher temperatures, which required that the cladding be made of refractory metals and consequently that enriched uranium be used as the fuel. Because of this, the neutron economy of a graphite reactor became quite comparable to that of a light-water reactor.

The AGR reactors developed in the United Kingdom (and even in the USA, where work on them was discontinued at an early stage) had so far not obtained commercial success on the export market, since the cost of the power they produced was not competitive with that of the power generated by LWRs (light-water reactors). This was due to the fact that the good neutron economy achieved by the use of graphite was adversely affected by the cladding materials, while the high level of thermodynamic efficiency resulting from high temperatures was offset by the high construction cost. As regards the latter aspect, it is regrettable that comparison with the LWR cannot take place under equal conditions (in other words, after the same number of reactors have been placed in service).

79. The other European countries chose light-water reactors, mainly in the form of pressurized water reactors (PWRs), since:
- enriched uranium had become available from several sources;[1]
- they provided an opportunity to draw on American experience.

For a certain period, the PWR had to compete with the BWR (boiling-water reactor), but the Community Member States later showed preference for the former. It is possible that the BWR will return to favour as a result of the experience acquired in the construction and use of that type of reactor.

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[1] It should be noted that there is no reactor concept which enables natural uranium to be used in conjunction with light water; at the beginning of the nuclear era, this was a serious disadvantage for the development of light-water reactors in Europe.

(ii) The concepts of the future

80. It can be expected that new reactor designs that may be developed in future will possess one or more of the features listed below in increasing order of importance and priority:

- suitability for low- and medium-temperature applications;[1]
- suitability for use in power stations of lower electrical capacity than those of today;
- suitability for high-temperature applications;[2]
- capacity to recycle the plutonium produced by any type of reactor in which uranium (natural or enriched) is used, either in reactors of already established design or, preferably, in specially designed reactors (fast breeder reactors);
- capacity to utilize almost all the energy contained in natural uranium, that is to say, to multiply by a factor of about 60 the amount of energy utilized so far.

However, it is unlikely that the diversity of the features referred to above will give rise to a proliferation of advanced concepts, if for no other reason than that the level of the development costs, known to be necessary from the experience acquired with existing reactor types, will be high.

81. As regards district heating, it may be considered that such a development will take place only very slowly and that steam for that purpose will first be supplied by existing power stations, priority being given to conventional plants, although nuclear power stations were chosen in Switzerland. District heating could eventually be based on specialized reactors that generate heat alone (as was done in the USSR) or have a dual role, generating both power and heat.

82. Furthermore, the AGR reactors and the Magnox reactors could provide industrial steam (the uses of which are very widespread but vary from place to place),[3] but it is improbable that this highly fragmented potential market would be compatible, in the short or long term, with the economic dimensions of today's reactors.

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[1] The low-temperature applications chiefly concern collective (district) heating (temperatures below 200°C); medium-temperature applications concern uses of industrial steam (temperatures below 570°C).

[2] High-temperature applications (at about 800°C) require the use of permanent gases (difficult to liquefy), for example, the liquefaction of coal, the stimulation of deposits of very viscous petroleum, the reduction of metal oxides, the production of hydrogen, etc.

[3] Fast breeder reactors (FBRs), which are dealt with later on, would also be suitable for that purpose.

83. Low-power reactors are of interest either as replacements for decommissioned conventional or nuclear units or for export to countries possessing low-capacity power transport grids. The problem is neither technical (since the known concepts were developed with low-power units) nor one of credibility (since the German industry successfully sold two PHWR units to Argentina without first having placed units of comparable power in service in the Federal Republic), but an economic one. It is necessary to be certain that the cost of the installed kWe, which is higher in the case of smaller units, is low enough for such units to be competetive; moreover, the extent of the small power-reactor market is uncertain, which makes it difficult to access with accuracy the series effect when it is superimposed on the scale effect influencing the construction cost of these units.

84. Where high-temperature applications are concerned, they presuppose the industrial-scale development of a specific design, that of high-temperature reactors (HTRs), which have already proved their worth as experimental reactors in the United Kingdom, Germany and the USA, mainly with a view to electricity generation. All these reactors have the quality required for these types of technological application. In addition, they can also clearly be used for electricity production, and it is even likely that, in order to reach the level of profitability indicated above, this reactor type would have to make its initial penetration into the electricity sector. However, it will inevitably meet with competition from the existing commercial types.

85. The cost of developing and promoting this reactor type has so far prevented it from being more widely used, but the associated technology is well known (that of helium, graphite and carbides), its thermodynamic efficiency and neutron economy are excellent and its adaptability to small or medium-sized units has been demonstrated. A further advantage of the HTRs is their capacity to utilize thorium (more abundant than uranium, but not directly fissile in a reactor) to produce fissile uranium-233, which can be recovered as an energy source material by reprocessing the irradiated fuel elements.

Whatever the intrinsic qualities of high-temperature reactors may be, it will not be possible to make use of them in any new projects unless major decisions on that reactor type are taken from an industrial standpoint with regard to a possible project and the way it is to be implemented: national framework or European cooperation. In Germany, a consensus has been reached by the potential users, the research bodies and the construction industries, who may shortly adopt an investment programme involving both the construction of a certain number of reactors and the infrastructures for the production, on an appropriate scale, of graphite and graphite- and carbon-coated uranium-oxide particles.

86. As regards the use (recycling) of plutonium in non-specialized reactors, technical solutions are available and industrial-scale plutonium-recycling operations are now being conducted by several electricity producers.[1] Decisions in this connection depend on detailed economic assessments which take account, in particular, of the following specific problems: the handling of plutonium fuel elements; accumulation of the uranium-236 isotope, which limits the re-enrichment of spent uranium; accumulation of non-fissile plutonium isotopes, which limits the number of times plutonium can be recycled; and the internal structures of reactors fuelled with enriched uranium (in which recycling is carried out), which limit the volume of the reactor capable of accommodating plutonium fuel.

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[1] It may be possible to achieve an approximately 15% reduction in the uranium requirements of the total number of light-water reactors.

87. Finally, fast breeder reactors (FBRs) are capable of extracting 60 times as much energy from uranium as are light-water reactors, either PWRs or BWRs, and, at the same time, of recycling plutonium, whatever its origin, with greater efficiency.

This capability derives from the fact that FBRs use depleted uranium, which is a by-product of the enrichment of natural uranium,[1] in combination with plutonium, which is created during the operation of any reactor fuelled with uranium (natural, enriched or depleted) and is later separated from that uranium during the reprocessing of irradiated fuel.[2]

88. Community industry has already acquired considerable knowledge of and experience with FBRs, and this is reflected, in particular, in the construction of 3 prototypes within the 200- to 300-MWe range[3] and of one demonstration unit

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[1] Depleted uranium can also be derived from the reprocessing of fuel from reactors in which natural uranium is used, such as the Magnox (UK), UNGG (France) or CANDU (Canada) types.

[2] The FBR is not only the most effective system for exploiting the energy potential of plutonium, it is also the system which most reduces the out-of-pile plutonium inventory that has accumulated to date:

(a) it can always contain much greater quantities of plutonium than a thermal reactor, even when it is used for recycling purposes;
(b) furthermore, it is virtually unaffected by the isotopic composition of the plutonium, which it consumes almost fully (high burnup).

It is also interesting to note that FBRs do not necessarily generate plutonium - and still less breed it; if properly adjusted, they are capable, while generating electricity, of "burning" plutonium without producing any.

[3] One of which has been in operation for over 10 years, the third being scheduled to enter into service shortly.

with a capacity of 1 200 MWe, bringing the total capacity up to 1 959 MWe.[1]

89. Studies, experiments and operating demonstrations have shown that, particularly in Europe, the FBR concept has come to the fore as a fundamental component of a long-term nuclear strategy. Dividing nuclear power production between FBRs and PWRs would give the strategy under consideration a considerable measure of flexibility in the total utilization of uranium and would enable the consumption of that material to be appreciably reduced. However, this development must be preceded by a demonstration of the economic viability of the reactor concept.

90. Except in the case of the Magnox and UNGG reactors, which were developed mainly on the basis of a political decision, it can be seen that, where real alternatives were available (for example, heavy water/light water; graphite/light water; helium/carbon-dioxide gas; helium/sodium), the solution that turned out to be the most economic one was always that which enabled industry to minimize its specific expenditure. In particular, if the technologies required by the two most promising reactor types, the PWRs and the FBRs, are considered in detail, it is evident that a plant designed to produce PWRs which was subsequently forced to lie idle could manufacture other heavy mechanical components (with, of course, investment in excess of that required in the case of less exacting conventional work). For its part, the FBR industry is characterized by greater mobility, since, under normal conditions of site accessibility, it has to make use of on-site applications[2] of high-quality stainless-steel technology which can be used for a wide variety of purposes.[3] However, it is conceivable that, with a view to improving the economic performance of FBRs, greater use will be made of workshop fabrication in the development of that reactor type, which would make FBR technology more conventional to some extent.

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[1] With modern technology, FBRs are cooled by means of molten sodium (LMFBRs) in order to ensure that operating pressure will be low and that there will be a truely efficient inherent - and passive - emergency cooling system. In the quite distant future, a gas-cooled variant of the FBR (GCFBR) may be developed. This is one of the types to be considered in respect of the technological applications of heat previously mentioned. The difficulties arising from very high pressure and temperatures in the case of this variant can be overcome only by means of very specific and exclusive techniques. As a result, industry is not giving much priority to the development of the GCFBR variant, since it wishes to cut back on investments that are too specific and, in any case, such development would follow that of the LMFBR and HTR reactor types.

[2] Because its large components are too bulky to be transported.

[3] The fact that the stainless-steel industry makes use of well-known and tried techniques explains the success of certain industries in their participation in Superphénix, although they have not previously had an opportunity to acquire that technology in the FBR field.

(b) General outlook for the industry

91. The Community's nuclear construction industry has a production capacity which greatly exceeds domestic and export market requirements.

92. Although the nuclear industry is characterized more by the extent of its technical expertise, its creative ability and its capacity for coordination (parameters which separate countries that have attained industrial maturity from the others) than by its investment in manufacturing, it is nevertheless the latter factor which, on account of its social impact, determines the potential development of that industrial sector as a whole.

93. The existing excess capacity in the nuclear power-station construction sector affects a flexible and highly ramified industry possessing wide-ranging skills that are very difficult to acquire and can be put to use for other ends. Nuclear component manufacturers are well equipped for conventional boiler-making and for manufacturing conventional turbines, distillation towers, equipment for the iron and steel industry, concrete furnaces, heavy or sophisticated equipment for major earth-moving and civil-engineering work and for the mining or oil-extraction industries, machine tools, etc. This flexibility is still greater in the field of design and industrial architecture, since the capital there is almost entirely human and the skills extremely comprehensive.

94. Furthermore, many non-Community countries wish to make use of nuclear energy, so that interesting export opportunities would be created. This would continue a long-standing tradition of the European heavy electrical engineering industry and would bring to fruition the extensive experience acquired on the domestic market. Nevertheless, such exports would not suffice to absorb the excess capacities of the nuclear industries in view of the general economic crisis, particularly in countries of the Third World.

95. The pressure of external competition, which is already considerable in traditional markets, will increase in the nuclear market, mainly in countries of the Far East and particularly in Japan. In that country, operators have the advantage of being able to construct, service and operate nuclear power plants within their own market, which is closed to the European industry. They are also the favourite partners of the Americans in reactor-system development (an example of such cooperation is the Westinghouse-Mitsubishi agreement on the marketing of the APWR,[1] "A" meaning "advanced").[2] For their part, the Americans possess all the requisite skills, but in the past lacked the motivation which would have enabled them to be more agressive in exporting their equipment and are also hindered by their internal nuclear policy.

96. One of the most serious weaknesses of the European nuclear industry is the absence of a coherent tradition of cooperation between the major industries participating in the nuclear sector, whereas there are cases of fruitful cooperation between partners of different sizes.

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[1] And the agreement between General Electric and Hitachi-Toshiba on the marketing of the ABWR (advanced boiling-water reactor).

[2] In addition to the American operations in Japan, the presence of the Germans (KWU), which is a European alternative, should be mentioned.

However, some examples of cooperation on advanced technology projects do exist. Studies on uranium enrichment, thermonuclear fusion and the fast breeder reactor show that fuller and more balanced cooperation is certainly possible.

97. Thermonuclear fusion is dealt with in paragraphs 105 and 106. In the fast-reactor field, mention should be made of the SNR 300[1] and Superphénix reactors.

98. Superphénix, which is nearing completion at Creys-Malville, France, and will enter into service in 1985, is being built jointly by France, Italy and the Federal Republic of Germany;[2] it is the largest FBR constructed so far and is closer to a standardized industrial product than any other fast breeder. It will have been built with a cost overrun and minor delays that can be envied by those responsible for many projects involving less-advanced reactors. From this it may be concluded that, fortified by this experience, the industries will be able to improve their international cooperation still further. It should be stressed in addition that this achievement demonstrates that the cost estimates for the FBR are as reliable as those usually made for light-water reactors and can also provide a sound basis for planning.

99. It can be seen that the national markets for light-water reactors and AGRs are to a great extent walled-off.[3] This partitioning of the European market, while not the cause of the current excess industrial capacity, is nevertheless holding back any efforts to reduce it. This excess capacity is the result of the extent and duration of the economic recession, which has made obsolete the projections on the basis of which the investments were made.

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[1] Project implemented by the Federal Republic of Germany and the Benelux countries and accorded the status of Joint Untertaking within the meaning of the Euratom Treaty. Luxembourg has in the meantime withdrawn from the project.

[2] Holdings were subsequently acquired by Belgium and the Netherlands.

[3] In practice, a national market is closed whenever a country wishes to be self-sufficient in a particular product.

100. This situation, which is compatible with the Community Directives on the opening-up of public contracts to competitive bidding, is the result of policies of the Member States most concerned and cannot change until those countries consider that rationalizing the sector at Community level is more beneficial than conserving jobs which are not always viable and maintaining a surplus on the balance of payments at the cost of greater internal expenditure. The Community has already had sectoral industrial difficulties arising either from problems of excess capacity or from problems relating to the opening-up of contracts. With the assistance of the Community institutions, it has been possible to find solutions.

(c) Maintenance of nuclear power stations

101. In the short term, the industry has found a susbstantial market in the maintenance of nuclear power stations. It is estimated that the sum of almost 500 million ECU per year is budgeted for maintenance in the Community alone. Furthermore, a certain proportion of services is being exported to the United States, mainly because of the number of reactors in operation and of the compulsory backfitting system in force in the United States.

102. In Europe, service activities are being developed mainly towards specialized maintenance with specially designed tools, the use of appropriate software and optimization of the fuel cycle, these being sectors in which it is clear that the original designers are in an advantageous situation from a technological standpoint in comparison with the installation operators.

(d) Decommissioning and the industry

103. The dismantling of nuclear power stations[1] must be considered from two standpoints:

- its economic importance, that is to say, the extent of the dismantling market;
- the associated technology, that is to say, the development of methods most suitable for the different materials.

The extent of the market, in terms of the volume of business, is at present equivalent to 1% of the construction market. Hence it does not provide a significant additional outlet for the industry.

It would be astonishing were the situation otherwise; demolition obeys the same law of growth as the construction sector, but after an interval of close to 30 years. Since the nuclear sector is of recent origin, demolition is an activity for the distant future.

As regards the technological aspect, small reactors are more than sufficient to allow dismantling techniques to be developed. The problems of a qualitative nature to which they give rise are the same as those in the case of larger reactors, and their demolition will provide valuable experience which can be extrapolated to the subsequent demolition of larger reactors in the same way as the construction of smaller reactors provided a basis for the construction of larger ones.

104. Despite the scarcity of opportunities on the present dismantling market, it is likely that the construction industry will find it sufficiently advantageous to become active in the field, if only because there are points of similarity between dismantling and power-station maintenance. The former can, in fact, be regarded as the final phase of the latter, both activities requiring of industry the same skills and the same precautions, since they are carried out in the same environment.

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[1] The decommissioning of nuclear-fuel fabrication facilities is not considered here, since it has an even smaller economic impact. The equipment, in fact, is exposed only to surface contamination and not to activation in depth, due to the lack of a neutron flux.

The example of General Electric in the United States, in acting as main contractor for the demolition of Shippingport (the first PWR nuclear power station) is most revealing of this trend on the part of constructors to undertake demolition work, especially because it shows their willingness to dismantle reactors which are not part of their range of products.

6. Thermonuclear fusion

105. The Illustrative Nuclear Programme, although deliberately focused upon aspects of the use of nuclear energy which are of economic significance, cannot disregard thermonuclear fusion, since it represents for mankind a new energy source of considerable potential which could be inexhaustable. However, before that potential can be exploited, appropriate practical means must be available, and a considerable period will inevitably elapse before they are.

106. Research conducted to this end is concentrated on the toroidal geometry reactor, which has met with a large measure of approval in the scientific world. The Joint European Undertaking JET (Joint European Torus) is operating the most advanced model of this type, which was constructed on time and within the budget provided.

The main importance of JET derives from the opportunity it offers to prepare, with full knowledge of the facts, the specifications for future research investment in the field of fusion, namely for NET (New European Torus) with which it may be possible to achieve a major advance in fusion technology.