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SALZBURG 77 AND BEYOND: NUCLEAR ENERGY, SAFEGUARDS AND RELATED OPERATIONS

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SALZBURG 77 AND BEYOND: NUCLEAR ENERGY, SAFEGUARDS AND RELATED QUESTIONS

BY

DR. ERIK SOLEM

ORAE MEMORANDUM NO. M92

OPERATIONAL RESEARCH AND ANALYSIS ESTABLISHMENT

DEPARTMENT OF NATIONAL DEFENCE

OTTAWA, CANADA

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ABSTRACT

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Nuclear power will be a necessary and probably irreplaceable source for the future energy supply of the world for a long time to come. Several political, economic and social consequences flow from this. Although the spread of nuclear power contributes to the potential threat of proliferation, the link between nuclear power and nuclear weapons proliferation is not - contrary to what is assumed or stated by media sources - automatic.

The International Atomic Energy Agency (IAEA) must continue to acquire increased sophistication and technical capability to cope with the future introduction of new, large scale fuel cycle facilities. An internationally agreed upon code of conduct as well as a comprehensive, effective, hence reliable international safeguards system must be developed. There is no alternative to such a system if nuclear energy is to be fully utilized on a global basis.

This report examines the main findings, conclusions and recommendations of Salzburg 77 as well as concurrent developments of importance to present and future use of nuclear power.\

RESUME

Le nucléaire sera pendant longtemps une source nécessaire et probablement irremplacable pour assurer les futurs besoins mondiaux en énergie. Il en découle plusieurs conséquences sur le plan politique, économique et social. L'Agence Internationale de l'Energie Atomique (AIEA) doit continuer à développer son champ d'action et à accroître ses capacités techniques, afin de faire face à l'introduction de nouvelles installations à grande échelle, consacrées au cycle du combustible.

Ce rapport examine les principales conclusions et les recommandations de Salzbourg 1977 ainsi que des évènements contemporains qui sont importants pour l'utilisation actuelle et future de l'énergie nucléaire.

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FOREWORD

Salzburg 77, or the "IAEA International Conference on Nuclear Power and Its Fuel Cycle" as it was formally called was a very large, exceptionally timely and rather important gathering of experts from around the globe concerned with problems and possibilities flowing from present and future uses of nuclear energy.

Due to the enormous size and scope of the conference it has been necessary to single out six areas of particular concern. These are: general energy prospects and national programs; integrated planning of the fuel cycle; advanced nuclear systems; safeguards; nuclear power in developing countries; and nuclear power and public opinion.

Critical comments and suggestions are found within these specific sections as well as in the concluding parts on concurrent and future developments.

THE IAEA SALZBURG CONFERENCE ON NUCLEAR POWER AND ITS FUEL CYCLE

THE SCOPE OF THE CONFERENCE

1. The International Conference on Nuclear Power and Its Fuel Cycle, which was organized by the International Atomic Energy Agency (IAEA) took place 2-13 May in Salzburg, Austria. Some 2,000 participants from more than 60 countries attended the conference in the Festspielhaus and the Kongresshaus in Salzburg. The conference was seen as a continuation of the four United Nations conferences on the Peaceful Uses of Atomic Energy, held at Geneva in 1955, 1958, 1964 and 1971.

2. The conference was formally opened by the President of the Federal Republic of Austria, Dr. Rudolf Kirchschläger, and the Director General of the International Atomic Energy Agency, Dr. Sigvard Eklund.

3. At the Salzburg Conference, the overall role to be played by nuclear energy in relation to alternative energy sources with particular reference to the need for an integrated nuclear fuel cycle was discussed and assessed. The integrated approach is considered vital due to the close interconnection of the fuel cycle stages - from uranium exploration to radioactive waste disposal.

4. The conference also dealt with advanced nuclear power systems, focussing on the shorter range problems of proven nuclear power systems and their fuel cycles. Its concentration was on decision-making and policy formation in nuclear power programmes and in supply of fuel cycle materials and services. The conference was directed towards persons responsible for

planning, decision-making and policy formation in the energy sector rather than those engaged primarily in research and development. It was intended to give a global and comprehensive overview of the status and potential of nuclear power with particular emphasis on limitations and constraints of present and future importance. Hence, the IAEA conference did not deal with details of recent research and development work, rather it reviewed such work stressing the main problem areas, while assessing economic and technical aspects of systems under development.

5. The agenda included the following main topics: world energy supply and demand; the role of nuclear power; supply of nuclear fuel and fuel cycle services; radioactivity management, including transport; experience and technical aspects of nuclear safety; nuclear power and public opinion; safeguarding of nuclear materials; and nuclear power prospects and problems in developing countries. For full program, see Annexes A and B.

6. There were 14 plenary sessions, 28 technical sessions and 8 round table discussions. Representatives from 38 states and 11 organizations contributed more than 370 papers (of which 180 had been invited) to the conference.

7. Due to the technical character of the discussions, as well as the proliferation of terms concerning energy measurement, a glossary of terms has been included as Annex C of this report.

GENERAL ENERGY PROSPECTS AND NATIONAL PROGRAMS

8. The first plenary session (1A) which took place in the Festspielhaus on Monday, 2 May dealt with general, i.e., inter- or multi-national prospects of energy. The four papers, their authors, organizational affiliations and subject matter were as follows:

1. U. Lantzke - OECD/IEA - World energy supply and demand and the future of nuclear power.

2. I. Barbur, A. Barchenkov, M. Kreutzburg, L. Molnar, A. Panasenkov, V. Tolpygo, V. Hake, B. Scherbinin - CMEA - Co-operation of the CMEA member countries in the development of different reactor types including certain aspects of their nuclear fuel cycle.

3. V. Baum (USSR) - UN - Energy in the developing countries - prospects and problems.

4. W. Häfele - IIASA - Energy options open to mankind beyond the turn of the century.

9. It is important here to note that the member countries of the Organization for Economic Cooperation and Development had to import a total of 25 million barrels/day (bbl/d) in 1975 from the member countries of the Organization of Petroleum Exporting Countries.

10. The executive director of the International Energy Agency (IEA), Dr. Ulf Lantzke, reported on the prospects of OECD oil imports in detail.

11. The principal findings for the OECD as a whole were based on a moderate growth rate case which was continued with different assumptions on energy policy;

(a) A reference case which implies continuation of current policies, and

(b) An accelerated policy case describing the potential for adopting more vigorous policies.

Throughout the study the IEA/OECD used only one price assumption for the reference Saudi crude, i.e., $11.51 per barrel in 1975 dollars.

12. Dr. Lantzke felt that if the present trends continue OECD hydrocarbon imports would increase substantially by 1985. As for total OECD energy demand, the organization projects it to reach 102 million bbl/d of oil equivalent by 1985 compared to 67 in 1975. It is possible that this projection of OECD energy demand may be on the optimistic side, insofar as it ignores a number of risk factors. First, it is based on a moderate rate of economic growth which is lower than that which occurred in the past. From 1960 to 1974, the average annual growth in OECD GDP was 4.6 per cent; but in their reference or current policy case they assumed to growth of 4.2 per cent per year from 1974 to 1985.

13. Secondly, it represents a considerable effort in reduction of energy use per unit of economic growth through effective implementation of conservation objectives. Hence the estimate for the period 1974-1985 indicates that the ratio between total OECD energy demand and gross domestic product (GDP) will be 0.84 compared to 0.99 over the period 1960-1974. Consequently, should economic growth turn out to be higher than

foreseen or conservation policies less effective than planned, total OECD energy demand could conceivably rise considerably higher.

14. Should the present trends continue, the OECD hydrocarbon imports would increase to 35 million bbl/d in 1985 thereby beginning to exceed potential production capacity ceilings.

15. The IEA thus expects a gap between demand and supply to open up towards the mid-eighties, the severity of which is still very much underrated. Thorough conservation measures are therefore absolutely necessary. Dr. Lantzke stated that the target was to save within OECD 5 million bbl/d oil equivalent by the mid-eighties. Combined with the supply from other energy sources, such as enhanced coal production, the demand for oil could thus possibly be reduced by 10 million bbl/d to 25 million bbl/d, so that no additional imports, as compared with 1975, would be needed. The United States was expected to contribute half of the savings. To realize the above goals strong measures are required and it is by no means evident when such measures can be implemented. But even if they turn out to be feasible, nuclear energy must still be brought in, Lantzke stressed. The facts about demand and supply are therefore straightforward. It is, then, essentially a political issue which must be solved (or settled?) by the politicians. By and large Dr. Lantzke's message was both clear and alarming.

16. The next paper of some interest to us was given by A. Panasenkov, of the Council for Mutual Economic Assistance (CMEA), the rough equivalent of the European Community for the Eastern Countries with centrally planned economies, on behalf of his six colleagues - co-authors. This paper reported on nuclear power production within the CMEA group of countries. Total electricity generation in 1975 progressed with an average

annual growth rate near 7 per cent and with the share of nuclear power steadily increasing. Whereas nuclear generation in the CMEA group of countries went up from 1100 MWh in 1971 to 7500 MWh in 1975, it was expected that the total capacity would reach 30000 MWh in 1980, mostly on the basis of water-water and graphite-water reactors. In addition to nuclear power, the CMEA countries can turn to large gas and coal fields. Mr. Panasenkov anticipated that the 1980 production of natural gas, for example, would reach 15.5 billion m^3 year. This would necessitate long-range transportation over distances of more than 3000 km. High-voltage electricity transmission is being stressed for similar reasons. Regarding R&D, the push for the fast-breeder reactor continues uninterrupted, as does the development of the extended nuclear fuel cycle, including reprocessing.

17. The next paper, entitled Energy in Developing Countries: Prospects and Problems, was by Vladimir Baum, who currently occupies the position as Director of the Centre for Natural Resources, Energy and Transport (CNRET) of the United Nations.

18. The problems of the less developed countries (possibly a more accurate label) are enormous. Very often faced with an insufficient supply base, these countries are forced to use oil in the absence of more meaningful alternatives. The introduction of nuclear power would require large interconnected electrical grids and more than anything else, capital. The most recent UN scenarios for growth in the LDC's, as seen by Leontief estimates a total of $1.5 billion for the period 1975-2000. Consequently, a most prudent use of energy, i.e. conservation and use of local sources, joint ventures and new mechanisms for capital formations and transfers is urgently needed.

19. The most interesting paper of Plenary Session 1A was that of Professor Wolf Häfele, Director of Research of the International Institute for Applied Systems Analysis (IIASA), Schloss Laxenburg, Austria. It was entitled "Energy Options Open to Mankind Beyond the Turn of the Century". As the title indicated, Dr. Häfele looked beyond the year 2000. As an estimate for the long-range future energy he assessed the demand to be in the region of 50 TW.*

20. Renewable resources such as hydro, wind and tidal power each seemed, according to Professor Häfele, to provide energy only in the 1 TW range. Conservation, he thought, would fall in the same category. Therefore, only solar, nuclear and, to a lesser extent, coal can provide a truly large-scale, long-term energy production. Solar energy, while it continues to appear to be extremely expensive, opens up such possibilities in principle. The key problem here is energy storage. This point to a gas or a liquid as a secondary energy carrier and would lead to considerations of distribution problems on a global level. As Dr. Häfele put it, millions of square kilometers would have to be covered by various facilities. Large scale harvesting of solar energy would hence closely resemble a type of global agriculture. Given this perspective, nuclear power should be examined in the same way. Nuclear power should be applied beyond the generation of electricity, which would open up new possibilities for its deployment.

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* The present energy consumption of the world is at 7.5 TW. One TW of thermal power relates to roughly 1 billion tons of coal equivalent (tce) per year. For future use, much depends upon population trends (see Fig 1).

21. Although coal is a large resource, it is not so large when proven resources are taken into consideration. Prof. Häfele meant that 1000 TW years might be a figure of orientation. Hence, coal ought to be used in the sector where it counts, i.e. transportation. Synthetic natural gas (SNG) or methanol based on solar or nuclear process heat could then stretch out the availability of coal past the year 2177.

22. The next two sessions were devoted to national plans. The authors and papers presented were as follows:

A. Rodrigues Barbalho, R. Nazare Alves, C. Syllus, M. Pinto, T.D. de Souza Santos, A. Abrao - Brazil - Planning the nuclear contribution to the Brazilian power programme.

W.J. Schmidt-Kuster - Fed. Rep. Germany - National energy and nuclear power system plans of the Federal Republic of Germany.

M. Boiteux - France - The French nuclear power programme.

A.P. Aleksandrov, V.A. Legasov, V.A. Sidorenko, N.N. Ponomarev-Stepnoy, A.N. Protzenko, V.A. Grebennik. E.S. Glushkov - USSR - The structure of atomic power industry with allowance for energy production other than electricity.

ERDA - USA - National energy projections and plans of the USA.

23. Dr. Rodrigues Barbalho emphasized the high growth rates including those of energy for Brazil by 1985. Total energy consumption would by then reach 190 million tons oil equivalent, with 69 million tons coming from oil and as much as 53 million tons from hydro-power. Despite this, Brazil's energy consumption would never reach 2 KW/capita (roughly world's average). Hence Brazil is aiming at an installed nuclear capacity of 10 GW/year by 1990 and would like to go further.

24. Both the German and French papers made a strong impression. The national plans for these two countries call for a determined substitution of oil by an increased nuclear capacity to safeguard the security of energy supply. This very definitely and explicitly includes the construction of reprocessing plants and fast breeders. Continued installation of LWRs constitutes the basis for this strategy. The combined French-German plea was as strong as possible.

25. It would seem that non-proliferation constitutes the major obstacle to the long-term energy strategies of both countries. This, however, was considered to be primarily a political problem and as such could be solved, or failing that, settled. The statement was made that technological denials were too late and could only be counter-productive.

26. The ERDA programme as presented by Dr. Fri in his paper by contrast made a plea for a reconsideration of the whole approach to civilian nuclear power. The acting ERDA Administrator stated that the construction of LWR ought to proceed and the intent to enlarge enrichment capacity was also mentioned. However, reprocessing would be halted, and essentially also the fast breeders. Therefore, there was a need to consider alternate fuel cycle schemes such as the blending of U_{238} with U_{233}.

27. This very large session of the IAEA Conference continued the following day with a series of additional papers from Italy, UK, USSR, USA, OECD/NEA, and IAEA.

In order of appearance, these were:

A.M. Angelini - Italy - The contribution of nuclear energy to the meeting of Italy's electric power requirements.

S. Catchpole, F.P. Jenkin - UK - UK experience of planning the nuclear contribution to the UK power programme.

A.M. Petrosyants - USSR - Nuclear power in the USSR and its importance as a source of energy.

E.A. Wiggin - USA - The role of nuclear power in meeting future US energy needs.

J. Miida, W. Haussermann, S. Mankin - OECD/NEA - Nuclear power programmes and medium term projections in the OECD area.

J.A. Lane, A.J. Covarrubias, B.J. Csik, G. Woite, A. Fattah - IAEA - Nuclear power in developing countries.

28. Italy has only small fossil fuel reserves, amounting to some 330 million tons available, with renewable resources adding some 11 million tons. The country's oil import amounts to about 70 per cent of primary energy needs. Italy is also facing a slow-down of economic expansion, as well as additional difficulties of a social and political nature. The 5.2 per cent annual growth rate from 1960-65, for the gross domestic product (GDP) has dwindled to approximately 2.1 per cent. Italy's energy growth rate decreased from 9.4 per cent to 2.1 per cent per year, whereas the population has increased by .7 per cent per year.

29. Presently, Italy's nuclear capacity is small. However, its plan for the next 2-3 decades is impressive, insofar as the country hopes to reduce oil imports by 30 million tons by the late 1980s and by some 70 million tons in the early 1990s. An important point arising out of this paper was that co-operation with France and Germany on the fast breeder was stressed. Pumped storage was emphasized as a potential means to reduce the number of necessary nuclear power plants.

30. The situation in the UK whose first commercial nuclear program started as early as 1962 is that 11 Magnox stations continue to operate, the production of each having been in excess of 40 TW. There are 4 advanced gas-cooled reactor (AGR) stations. It seems AGR technology created more problems than expected, but Mr. F. P. Jenkin stated that valuable experiences had been gained, and that electricity production costs from these stations had decreased. Lately the UK energy demand growth rate has come down somewhat. Partly due to North Sea oil and gas, the perceived pressing need for installation of new power stations has largely failed to materialize. However, the need might reappear within the next decade, in which case the prudent development of reactor systems might be called for, such as fast breeders.

31. According to a paper by E. A. Wiggin of Atomic Industrial Forum, the U. S. utilities will continue to make further commitments to nuclear power, since there are nearly no real alternative choices as required substitution for imported oil. The paper, which was otherwise largely a reflection of the US industry view, stressed the problems of uranium supply, stating that projections would continue to be difficult. The combined proven and unproven resources might add up to about one million tons of uranium, enough for 300 GW over a lifetime of some 40 years. Additional resources could possibly add another 340 GW, but major efforts would be required to make

them available. He told us that the present US capacity for uranium enrichment adds up to about 28 million separative work units (swu). An additional 25-30 million swu would be required for US purposes alone by the year 2000 if 500 GW were to be in operation.

32. The OECD's Nuclear Energy Agency (NEA) reported on the nuclear plans of the organization itself. According to Mr. Miida, who presented the NEA paper, a low estimate of 290 GWe is anticipated for 1985, 470 GWe for 1995, and 830 GWe for the year 2000. It is important to note that these estimates are very much lower than the estimates of 1973. Until 2000, nuclear power in the OECD area will be based largely on LWR technology. NEA antidipates significant commercial introduction of fast breeders for the 1990s.

33. The last paper of this very long session on an extremely important topic dealt with LDCs. Mr. J. A. Lane of the IAEA reported on extended IAEA studies which had been undertaken in LDCs. From 26-40 GW installed is foreseen for the LDCs by 1985. The total for 2000 is somewhere between 293 and 437 GW, representing 9 and 20 per cent respectively of IAEA's estimated world total nuclear power for 1985 and 2000.

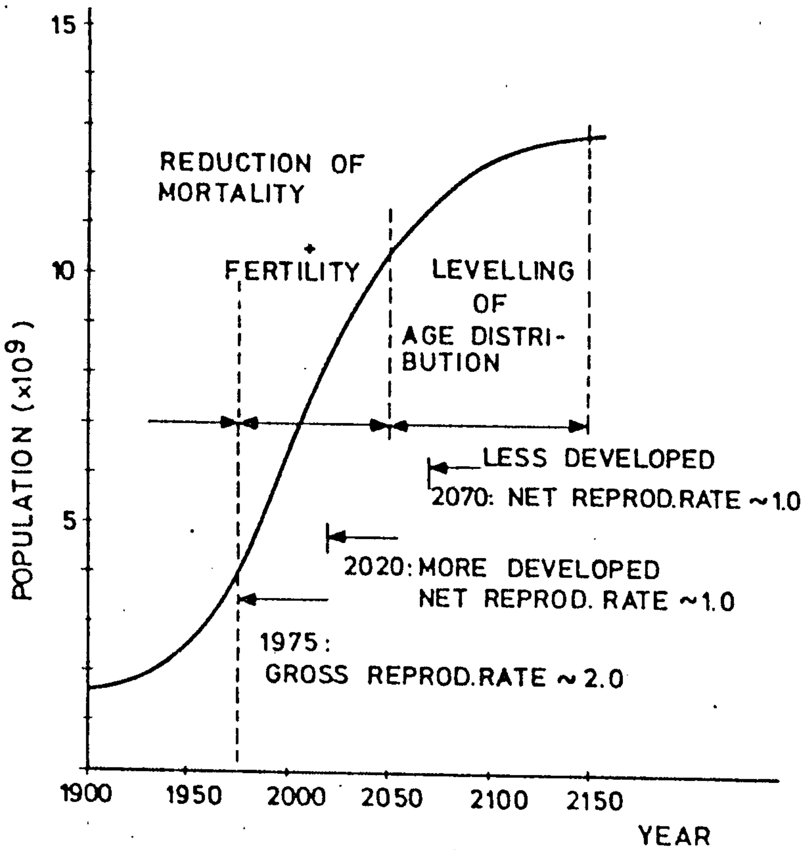
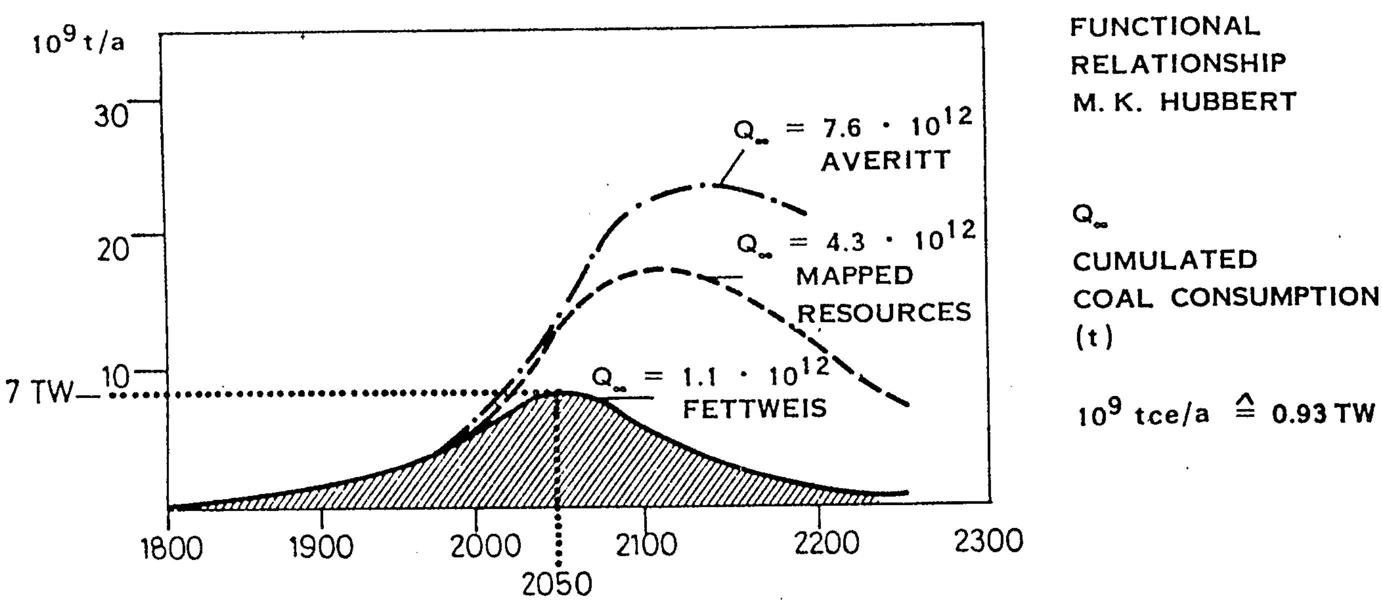


FIGURE 1 - WORLD POPULATION GROWTH ACCORDING TO U.N. WORLD POPULATION CONFERENCE, BUCHAREST 1974, REPORT OF THE SECRETARY GENERAL.

SOURCE: W. Häfele, "Energy Options Open to Mankind Beyond the Turn of the Century", International Institute for Applied Systems Analysis, Laxenburg, Austria, IAEA-CN-36/538.

The importance of different global coal resources, and their utilization is illustrated by the following figures:



GEOL. WORLD COAL RESOURCES, WEC 1974	$10.7 \cdot 10^{12}$ t
REVISED DATA, M. GRENON, IIASA	$8.4 \cdot 10^{12}$ tce
'COAL IN PLACE', G.D. FETTWEIS	$1.7 \cdot 10^{12}$ tce
ULTIM. RECOVERABLE COAL RESERVES, FETTWEIS	$0.85 \cdot 10^{12}$ tce

FIGURE 2 - COAL PRODUCTION AND RESERVES

Source: Ibid., op. cit.

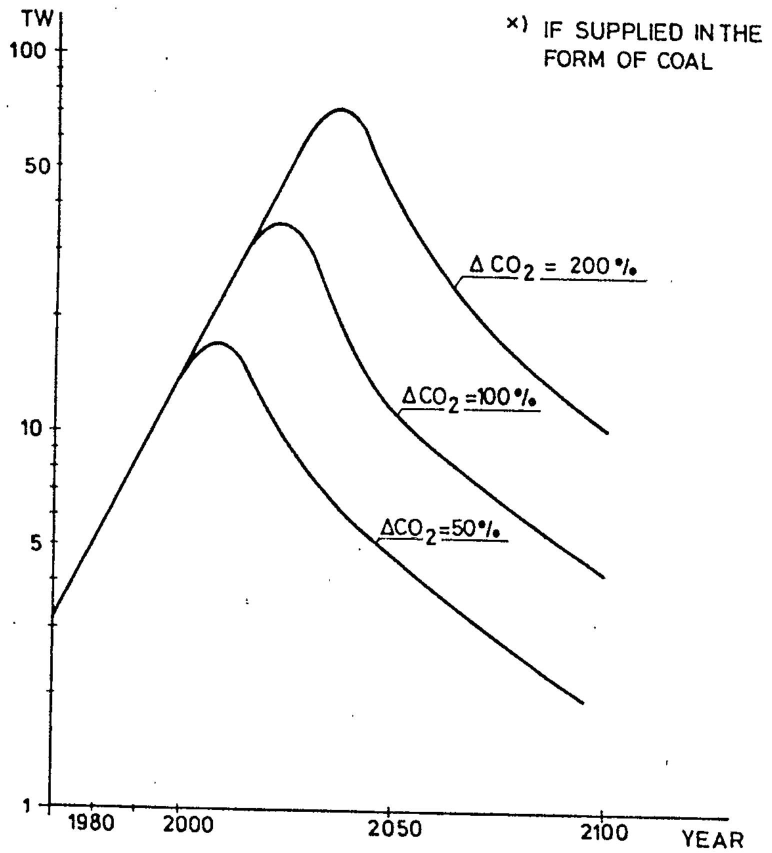


FIGURE 3 - NECESSARY CONTROL OF FOSSIL ENERGY CONSUMPTION, IF SUPPLIED IN THE FORM OF COAL, TO STAY BELOW CERTAIN CO_2 LEVELS IN THE TROPOSPHERE

SOURCE: Ibid., op. cit. W. D. Nordhaus, IIASA

INTEGRATED PLANNING OF THE FUEL CYCLE

34. In the introductory session as well as throughout the Salzburg Conference, several references were made to the need for integrated planning of the fuel cycle. The conclusion of the previous four Geneva Conferences on the Peaceful Uses of Atomic Energy, to which the Salzburg Conference was seen as a natural follow-up, had been that nuclear energy is, at least for the next few decades, the only alternative to fossil fuels available in sufficient quantity, on a competitive and relatively safe basis. The 1973 oil crisis, assessments having been made since then on fossil fuel reserves, availability and price levels, as well as the Salzburg conference itself gave this argument greater strength.

35. Hence, the large development of nuclear energy under way in various countries as well as the even larger development anticipated in the future, closely follows this line of thought. However, there is no guarantee that sufficient nuclear fuel and/or the services of the nuclear fuel cycle will become available to an extent deemed adequate and timely to all the nations currently engaged in a nuclear power programme.

36. Several problems still exist, many of them are of a very serious nature. These problems fall in two main categories, first but perhaps in the long run not most important, the category of public opinion on nuclear energy and public acceptance of its use, and secondly, and possibly of permanent importance, those problems connected with nuclear proliferation. The sociology of public opinion formation aside, the two main problem categories connected with nuclear power and its usage could be described as the problem of safety and the problem of safeguards.

37. Although there was almost total agreement at Salzburg concerning the necessity for preventing proliferation, no unanimity emerged with regard to how best to reach this goal. Substantial disagreement seemed to exist concerning both the role and timing of advanced reactors as, for example, breeders.*

38. This diversity of thinking stems from different energy situations in different countries. Hence, for certain advanced industrialized states such as Japan and some member states of the EC, the earliest possible introduction of the fast breeder reactor was deemed desirable. It was felt by delegates from several states, as well as representatives from such organizations as FORATOM, and perhaps rightly so, that the Western European countries, for example, were experiencing particular constraints which differed in quality as well as quantity from those facing the larger powers with more solid and diversified energy resources to draw on.

39. Throughout the sessions on Integrated Planning of Fuel Cycle some 16 papers were presented on several subjects such as supply and demand for the nuclear fuel cycle, plutonium utilization, reprocessing, thorium cycle, fuel cycle financing and nuclear centres.

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* A 'breeder' may increase the duration of nuclear fuel from a few decades to several centuries.

The papers delivered at the plenary sessions were:

J. van Dievoet, E. Fossoul, E. Jonchheere, E. vanden Bemden	Belgium	The utilization of plutonium: present situation and future prospects
T. Amanuma, K. Uematsu	Japan	The plutonium utilization in thermal and fast reactors in Japan
E. R. Merz	Fed. Rep. Germany,	The thorium fuel cycle
E. Critoph	Canada	The thorium fuel cycle in water-moderated reactor systems
V.V. Fomin, V.B. Shevchenko, V.I. Zemlyanukhin, N.S. Chugreev, V.S. Shmidt, L.N. Lazarev, A.N. Kondrat'ev	USSR	Basic problems of fuel recovery from spent nuclear reactor fuel elements
G.K. Rossney	UK	Status and prospects for reprocessing
W. Haussermann, P. Hogroian, R. Krymm, J. Cameron, O. Pedersen, G. Woite	OECD/NEA IAEA	Supply and demand estimates for the nuclear fuel cycle
J. Kostuik	UK	Industrial and commercial considerations affecting the future supply of uranium
E. Svenke	Sweden	Availability of enrichment services

S. Tamiya R. Kiyose, T. Otomo, T. Meguro	Japan	A review on future trend of LWR fuel cycle costs
R. W. Manderbach	USA	Fuel cycle financing, capital requirements and sources of funds
R. Riverola-Pelayo	FORATOM	Financial aspects of nuclear power programmes from the experience of the FORATOM member countries
A. Giraud	France	The nuclear fuel cycle: encouraging and less encouraging aspects

40. In addition to the plenary sessions on this vast subject, there was a lively round-table discussion (chaired by Mr. K. Davis, USA) dealing directly with Integrated Planning of the Nuclear Fuel Cycle Industry. The topic also came up in different contexts.

41. Now, to the papers. Häussermann, Krymm, et.al. on behalf of the OECD/NEA and the IAEA updated previous analysis carried out by both agencies. The estimates for 1977-2000 have been based on a global power growth* of between 310-415 GW in 1985, 520-740 GW in 1990 and 1000-1900 GW in 2000. It may well be that the lower areas of these ranges are more realistic.

* Excluding centrally-planned economy states.

42. Reasonably assured uranium resources at less than $30/lb (1976 purchasing power) have been evaluated at slightly more than 2 million tons, an increase of 260,000 tons over earlier projections as reported by the NEA/IAEA report of December 1975. Actual reserves could in fact be larger, since prospecting carried out has been of a limited nature. Hence additional prospecting efforts are necessary to maintain sufficient forward reserves throughout the next few decades.

43. The problem does in fact not stop there. It is essential to establish countermeasures to prevent a repetition of the extreme price fluctuations of the past and ensure a more smooth future. This will perhaps not be easily implemented as it will entail long-term contracts, joint ventures by utilities and mining companies, reasonable stock-piling efforts as well as a frank and open exchange of information between producers and consumers. The following table shows the OECD/NEA-IAEA estimates for uranium, separative work and reprocessing requirements.
(See next page)

44. As regards reprocessing plants it seems that the situation is quite well known by everybody. The present capacity is not only insufficient but will likely remain so throughout the next decade. Although the US has postponed reprocessing indefinitely, several other states have so far chosen not to follow this line and are in fact not likely to do so. Their desire to secure energy supplies forces them to go ahead with plans for fuel reprocessing.

TABLE 1 - WORLD REQUIREMENTS FOR URANIUM, SEPARATIVE WORK AND REPROCESSING

(1975-2000)

Uranium Requirements (in 10^3 tons)[1]

Forecast	Recycling	1980 Annual	1980 Cumulative	1990 Annual	1990 Cumulative	2000 Annual	2000 Cumulative
Low	yes[2]	32	141	74	714	110	1650
	no	34	146	94	813	166	2200
High	yes[2]	41	172	126	1022	235	2800
	no	43	175	146	1115	339	3600

Separative Work Requirements (in 10^6 swu)

Forecast	Recycling	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
Low	yes[2]	18	76	47	416	75	1000
	no	19	78	55	456	100	1250
High	yes[2]	23	91	75	580	150	1700
	no	24	93	83	620	200	2050

Reprocessing Requirements (in 10^3 tons)

	Forecast	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
Reprocessing requirement[3]	Low	2.5	7.1	9.3	64	18	210
	High	2.7	7.4	13.0	82	34	316
Reprocessed Fuel	Low	0.9	1.7	8.3	39	18	210
	High	0.9	1.7	8.3	39	40	316
Unreprocessed fuel[4]	Low	1.4	5.4	1.0	25	0	0
	High	1.6	5.7	4.7	43	0	0

1. Excluding centrally planned economies. 2. Uranium and plutonium recycling.
3. Spent fuel is counted as reprocessing requirement one year after discharge.
4. LWR fuel only.

The estimated uranium production capacity obtainable in 1985 exceeds the demand anticipated in that year even in the high growth case, nevertheless, the actual achievement of this output level (100,000 tonnes year) is open to question.

45. The OECD/NEA-IAEA paper also showed that if nuclear power is to play more than a transitional role in the world energy supply system after the next century, fast breeder reactors will have to be developed commercially.

46. Mr. J. Kostiuk of the Uranium Institute of London addressed himself to the problem of uranium supply and demand, seen from the point of view of the producers. His projections were in agreement with those on the OECD/NEA-IAEA paper, and a certain amount of optimism was present in both papers. It was felt that the financing needed on a global scale would not constitute a serious strain on world capital markets.

47. Dr. E. Svenke (Sweden) in his paper entitled "Availability of Enrichment Services", argued strongly for the notion of integrated planning in the fuel cycle. Certain phases of the fuel cycle cannot be looked at only from a conventional commercial standpoint, he argued. The author wanted a type of international co-operative approach to be developed in the fields of enrichment and reprocessing. Dr. Svenke felt that it was the responsibility of governments possessing enrichment facilities to act jointly with the IAEA with a common responsibility for the creation and regulation, in co-operation with all consumer nations - of an adequate worldwide enrichment capacity.

48. The need for plutonium utilization for better resource management in countries which possess the required technology but are poor in fossil and nuclear fuels was pointed out by J. Van Dievoet (Belgium) as well as K. Uematsu and T. Amanuma (Japan). Also, it was argued that plutonium utilization could minimize the potential for proliferation, as the in-reactor inventory is preferable to plutonium storage. On these points there was moderate agreement among delegates present at this session.

49. V. V. Fomin et. al. (USSR) gave a somewhat qualitative and elusive presentation of Soviet activities in the field of reprocessing thermal and fast reactor fuel, fuel shipment and waste disposal. Several requests from the floor failed to bring about definite answers with regard to Soviet plans.

50. The potential advantages of the thorium cycle in the HTR and HWR were discussed by E.R. Merz (Federal Republic of Germany) and E. Critoph (Canada) in their respective papers. A primary advantage is greater conservation of uranium resources. According to E. Critoph, with the present status of the development of the thorium cycle, it would take about two decades before the cycle's competitiveness would be reached. A rather interesting question is if present US policy regarding alternative cycles might lead to a speeding-up of the development and commercialization of the thorium cycle. This would depend, it seems, on the developments of US policy on this matter in the near future.

51. Two informative papers dealt with nuclear power financing. R. Riverola-Pelayo's paper on "Financial Aspects of Nuclear Power Programmes from the Experience of the FORATOM Member Countries", provided extensive information regarding various sources of external finance available both on domestic and international capital markets for Western European nuclear power programmes. The second paper, by R. W. Manderbach (Bank of America) addressed fuel cycle problems, concluding that many of them were relatively minor and would appear manageable. Providing the financing of the fuel cycle represents about 10 percent of the financing needed for nuclear power stations. But since his level of analysis was global, the same may not always hold if one were to examine such problems from a national point of view.

52. According to A. Giraud (France) nuclear power was unavoidable for meeting world energy requirements of the future. In his paper 'The Nuclear Fuel Cycle: Light and Shadow' he strongly advocated this view as well as the need for the development of fast breeder reactors. Neither the objective risks nor the technical uncertainties represent insurmountable obstacles to the development of the fuel cycle. However, in order to overcome such obstacles it would be necessary to co-ordinate planning and win public acceptance by means of a debate which concentrated on 'real' matters, rather than on problems which are incomprehensible to the public. Since the nuclear industry has international implications technically as well as politically, it is only through honest international co-operation that the world will develop fully from nuclear energy. It is through this type of international co-operation that frustration could be avoided, hence the proper organization of the fuel cycle is of paramount importance within this co-operation.

53. Finally, two round table discussions were organized around the general topic of development and integrated planning of the nuclear cycle. The round table chaired by Sir John Hill (UK) which was entitled "Developments and Decisions Needed to Assure the Nuclear Fuel Cycle" proved to be quite lively. This was partly due to the fact that discussion gravitated towards the problem of how to best minimize proliferation. Some technical problems throughout the fuel cycle were hence given second priority in the discussion.

54. The USSR is committed to the development of plutonium FBRs, according to the Soviet panelist. The importance of plutonium utilization in thermal and fast reactors was stressed by panelists from France, Belgium and Japan. The US reply to this (as stated by US-ERDA) was that the great interest from certain

countries in FBR was understandable, however the US was most interested in minimizing the risks of proliferation. Alternatives, such as co-generation, collocation, U-Th cycle, etc., were discussed at some length, including timing and other problems of costs and developments. During the discussion, some doubt was cast on the effectiveness of the U-Th cycle for preventing proliferation.

55. It was stressed by several delegates that efforts ought to be concentrated more effectively on the U-Pu cycle, which it was felt was most suitable for power generation. It was also recommended that such techniques as fuel spiking, low irradiation of fabricated fuels combined with higher international control could minimize risks of proliferation.

56. The second round table, which was chaired by K. Davies (US) dealt with fuel activities which were considered most suited to international co-operation. It was felt, early on in the discussion, and perhaps for good reasons, that these would be activities where the role and influence of governments were strongly felt, i.e.,in the areas of reprocessing and ultimate waste disposal. For the moment, though, it may be too early to attempt a solution of the latter problem internationally. However, international co-operation in the reprocessing field is already under way among certain Western European States.

57. Some illustrations may be useful at this stage. Figure 4, (see following page) shows estimates of nuclear capacities in OECD regions through 2000. Figure 5 shows OECD average, with high and low indications for electricity share on total energy, system load factor, and nuclear share respectively. The figures are from Miida, Hausserman and Mankin.*

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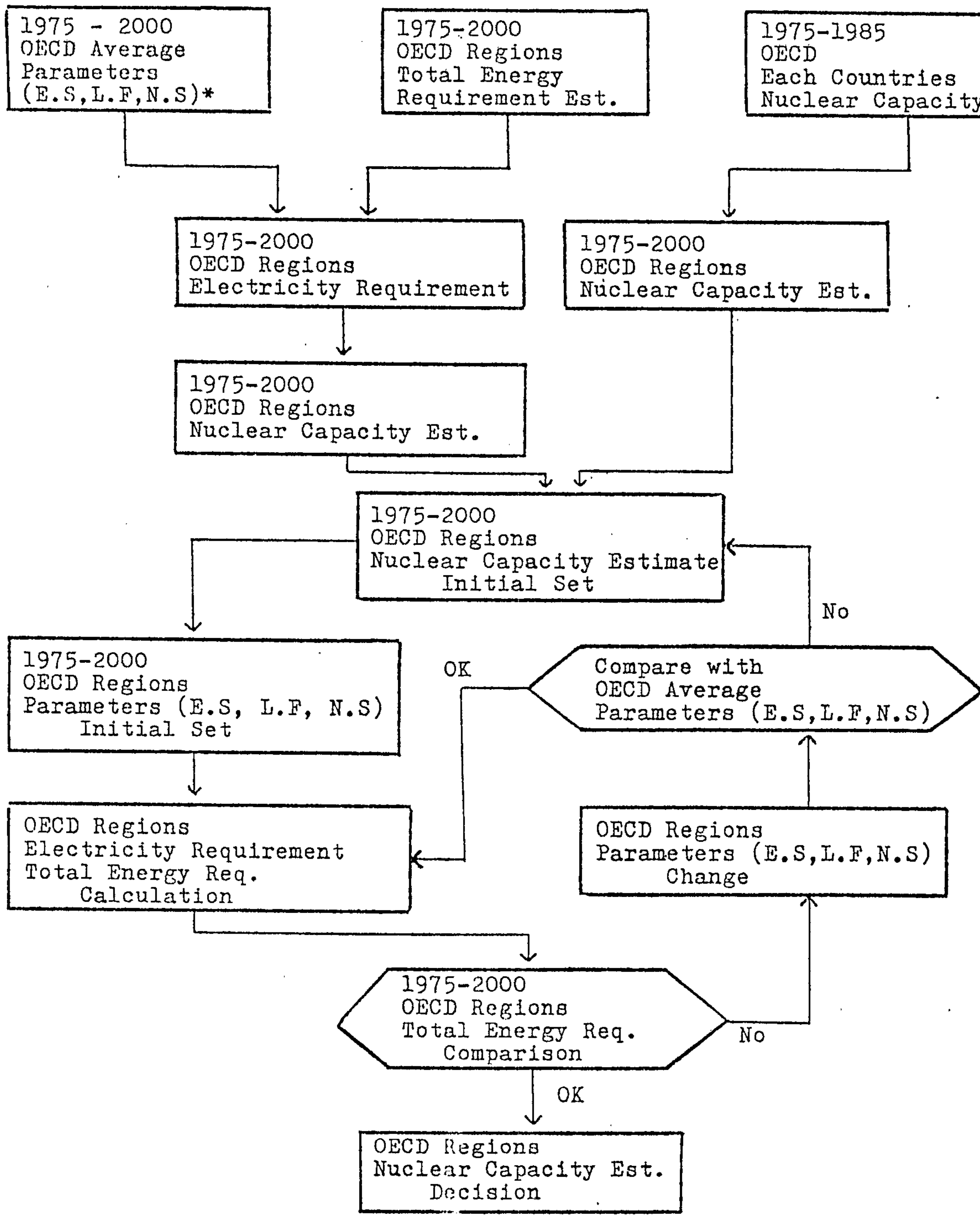
* See J. Miida et al; Nuclear Power Programmes and Medium Term Projection in the OECD Area, IAEA-CN-36/492.

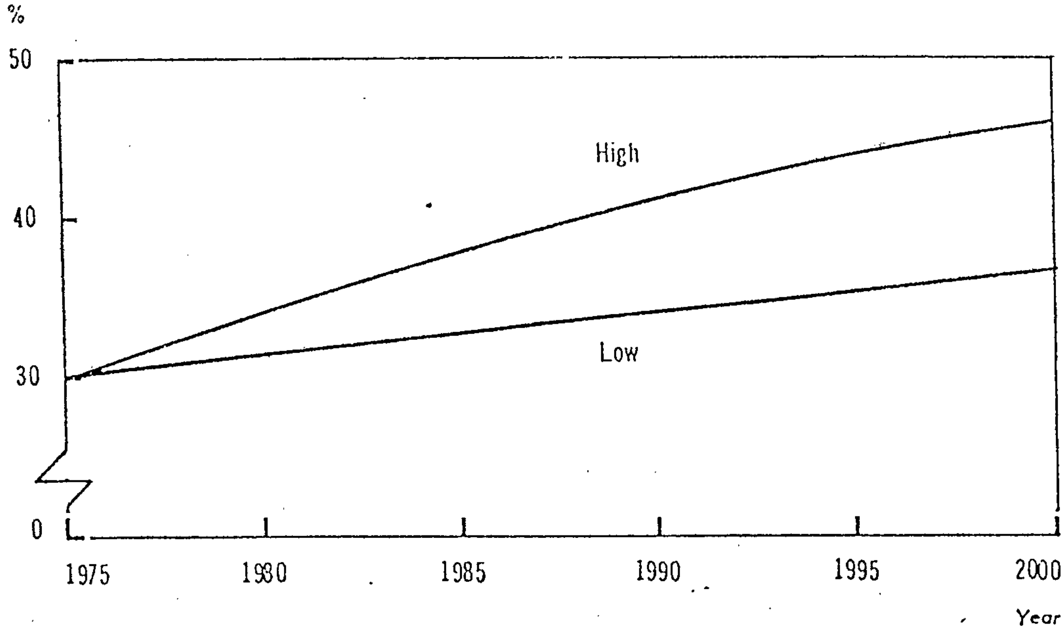
FIGURE 4 - FLOW DIAGRAM TO ESTIMATE NUCLEAR CAPACITIES IN OECD REGIONS THROUGH 2000



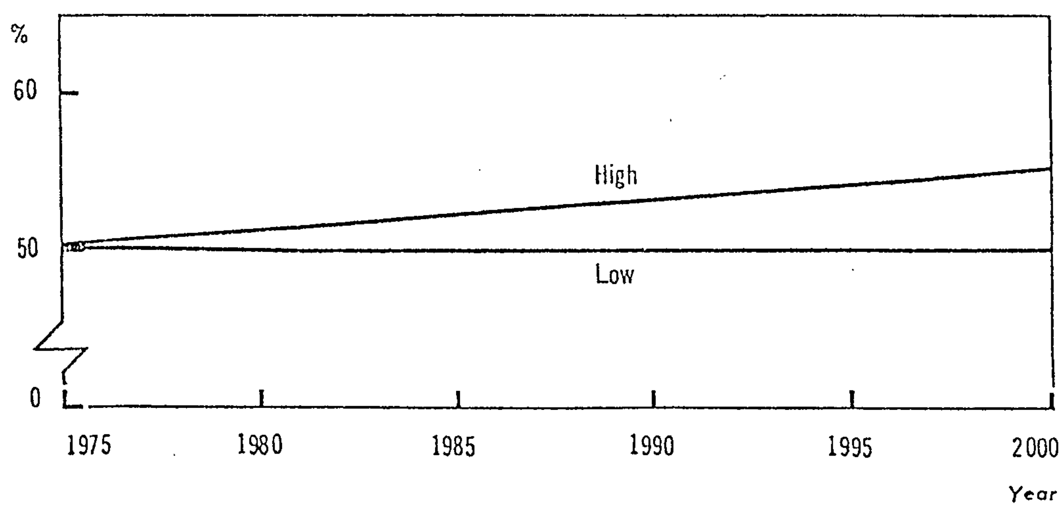
* E.S. Electricity share
L.F. Load factor
N.S. Nuclear share

FIGURE 5 - OECD AVERAGE

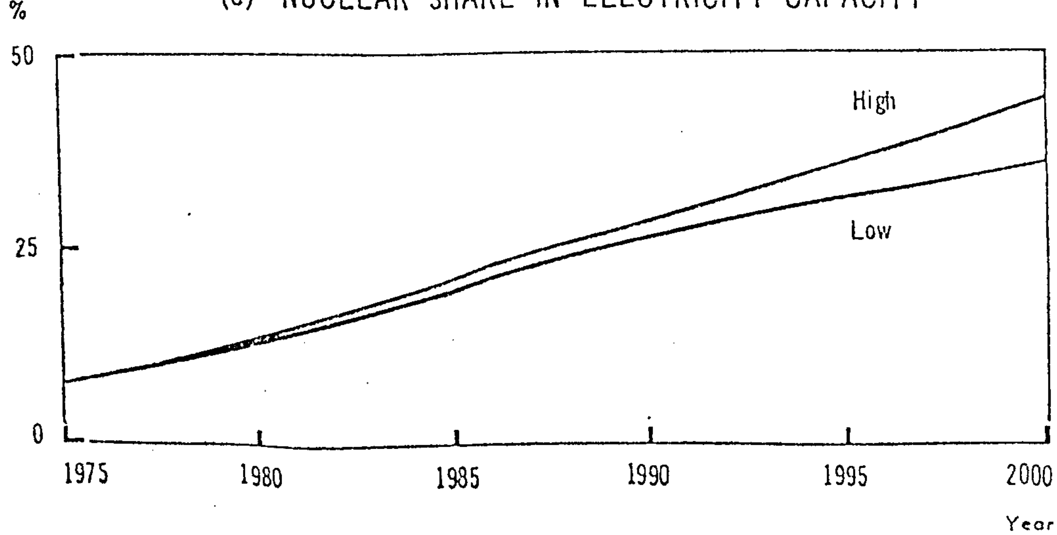
(a) ELECTRICITY SHARE IN TOTAL ENERGY



(b) SYSTEM LOAD FACTOR



(c) NUCLEAR SHARE IN ELECTRICITY CAPACITY



58. Representative nuclear power capacity by 1990 is shown in Table 2. Currently available reactor types are listed in Table 3 and countries with operating and projected commercial nuclear power plants are shown in Table 4. It is important to note that there is no automatic link between nuclear power capacity and nuclear weapons. More about this later.

59. Finally, Table 5 gives an estimate for nuclear power growth until 1985 for the OECD countries.

*See J. Miida et al; Nuclear Power Programmes and Medium Term Projection in the OECD Area, IAEA-CN-36/492.

TABLE 2

REPRESENTATIVE NUCLEAR POWER CAPACITY - 1990

Country	MW	NBR OF PLANTS
Brazil	11,000	15
Iran	16,000	15
Korea	7,000	10
Spain	27,000	35
Taiwan	9,000	10
Yugoslavia	4,000	5
Less Developed Total	100,000	125
World Total	800,000	900

Source: Morris Rosen, "The Critical Issue of Nuclear Power Plant Safety in Developing Countries", IAEA Bulletin, Vol.19, Number 2, April, 1977.

TABLE 3

CURRENTLY AVAILABLE REACTOR TYPES

EXPORTER	REACTOR TYPE
Germany	Pressurized-Water R (PWR)
France	Pressurized-Water R (PWR)
USSR	Pressurized-Water R (PWR)
USA	Pressurized-Water R (PWR)
	Boiling-Water R (BWR)
Sweden	Boiling-Water R (BWR)
Canada	Heavy-Water R (HWR)

EXAMPLES OF REACTOR PURCHASES

PURCHASER	SUPPLIER	REACTOR TYPE
Argentina	FRG, Canada	HWR
Brazil	USA, FRG	PWR
Finland	USSR, Sweden	PWR, BWR
India	USA, Canada, India	BWR, HWR
Iran	FRG, France	PWR
Korea	USA, Canada	PWR, HWR
Spain	USA, FRG, France	PWR, BWR, GCR

Source: Ibid., op.cit.

TABLE 4

COUNTRIES WITH OPERATING AND PROJECTED COMMERCIAL NUCLEAR POWER PLANTS

1975	Argentina	Germany, F.R.	Pakistan
	Belgium	Germany, D.R.	Spain
	Bulgaria	India	Sweden
	Canada	Italy	Switzerland
	Czechoslovakia	Japan	UK
	France	Netherlands	USA
			USSR
1980	(Additional Countries)		
	Austria	Finland	Mexico
	Brazil	Korea, Rep.	Taiwan
			Yugoslavia
1985	(Additional Countries)		
	Hungary	Luxembourg	Poland
	Iran	Philippines	Romania
			South Africa
1990	(Additional Countries)		
	Egypt	Israel	Thailand

Source: Ibid., op.cit.

TABLE 5

NUCLEAR POWER GROWTH ESTIMATE FOR OECD COUNTRIES (GWe)

End of Year	1975	1976	1977		1978		1979		1980		1981		1982		1983		1984		1985	
Country			Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Canada	2.5	3.1	4.0	4.0	4.9	5.0	5.8	6.0	6.7	7.0	7.5	8.0	8.0	8.8	8.5	9.6	9.6	11	11	12
United States	38	43	50	54	56	61	61	70	67	81	80	90	90	105	102	116	114	135	130	160
North American Region	41	46	54	58	61	66	67	76	74	88	88	98	98	114	111	126	124	146	141	172
Australia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Japan	6.6	7.4	10.3	11	12	13	13.2	15	15.2	17	17	24	20	30	22	36	25	41	27	49
New Zealand	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pacific Region	6.6	7.4	10	11	12	13	13	15	15	17	17	24	20	30	22	36	25	41	27	49
Austria	-	-	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1.8	2	1.8	2	1.8	2	2.6	[illegible]
Belgium	1.7	1.7	1.7	1.7	1.7	1.7	1.7	2.6	1.7	3.5	3.5	4.5	4.5	5.5	5.5	6.8	6.8	8.1	8.1	8.1
Denmark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Finland	-	-	0.4	0.4	1.5	1.5	1.5	1.5	1.5	2.2	1.5	2.2	1.5	2.2	1.5	2.2	1.5	2.2	1.5	3.2
France	3.1	3.1	5.6	5.8	7	7.8	12	13	15	18	19	23	23	28	27	33	31	39	35	45
Germany, F.R.	3.5	6.4	8.6	9.5	10.8	11.1	12.4	13.8	12.4	13.8	14	19	16	24	21	29	24	35	28	39
Greece	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	-	0.6
Ireland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-	0.7
Italy	0.6	0.6	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	2.8	3.4	6.4	7.4	10	11.4
Luxembourg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	1.2	1.0	1.2
Netherlands	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.5
Norway	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Portugal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	1.3
Spain	1.1	1.1	2.5	2.5	4.0	4.3	6.2	6.3	7.4	8.2	8.5	11.2	11.5	14.2	13	17.2	14	20.2	14.5	23.2
Sweden	3.2	3.2	4.1	4.2	4.6	4.8	5.3	5.4	6.0	6.0	6	6.7	6	7.4	6	8.0	6	9.0	6	10
Switzerland	1	1	1	1	1	1	1.9	1.9	1.9	1.9	2.5	2.5	2.5	2.5	3.3	3.3	3.3	3.8	3.3	3.8
Turkey	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	0.6
United Kingdom	6.1	6.9	8.3	8.4	9.4	10	9.4	11	9.4	11	10.3	11	11	12	11	12.5	11	13	13	15.7
European Region	21	25	35	36	43	45	53	58	58	67	68	83	80	100	93	118	107	143	125	168
OECD	[illegible]	78	[illegible]	105	116	124	133	149	147	172	173	205	198	244	226	[illegible]	[illegible]	330	[illegible]	[illegible]

Source: Lane, J.A., et al; op. cit.

ADVANCED NUCLEAR SYSTEMS

This plenary session, which took place Saturday, 7 May 1977, consisted of nine papers which were as follows:

G. Vendryes B. Saitcevsky M. Rosenholc G. Besse	France	Status and prospects of the French fast reactor programme
O.D. Kazachkovski A.G. Meshkov F.M. Mitenkov K.T. Vasilenko V.M. Gryazev G.V. Kiselev L.A. Kochetkov V.B. Lytkin V.V. Pahomov N.I. Savin M.F. Troyanov V.I. Shiryaev V.A. Tsikanov D.S. Yurchenko	USSR	The USSR fast reactor development programme and its current state
R.D. Thorne B.J. McKelvain	USA	Status and programme of development of the fast breeder reactor systems in the US
N.L. Franklin Sir John Hill	UK	Status and programme for the fast breeder reactor in the UK
A. Oyama T. Suita	Japan	Programme and current status of fast breeder reactor development in Japan
U. Daeunert G. Kessler	Fed.Rep. Germany	Status and programme of development of the fast breeder reactor systems in the Federal Republic of Germany

E.P. Velikhov	USSR	Prospects of fusion power engineering and fusion fission hybrid reactors
D. Palumbo G. Grieger	EURATOM	The role of fusion in the future of nuclear power. A European point of view
E.E. Kintner	USA	The role of fusion as a future power source

60. It stressed important technical progress having been achieved during recent years with LMFBR technology, largely stemming from operating experience of several demonstration plants (e.g. BN 350, PFR, Phenix) as well as the design of prototype large breeder reactors. It was reported that no major new problems have been encountered in the past few years. Hence it seems that LMFBR technology and its scope are understood, and that engineering development may follow. It was generally agreed by the experts that LMFBR safety matches that of such thermal reactors as LWRs.

61. Countries already committed to the development of LMFBRs include the USSR, Japan, France, the Federal German Republic, UK, Italy and India. These states emphasized that fast breeder reactors seem the most promising solution to meet large-scale energy supplies in the 1990s. It was also pointed out by several speakers that a number of countries have no other way of coping with even conservative assumptions of increased energy consumption.

62. It was also stressed that uranium, if used only in reactors of the first generation (such as LWRs) would not even exceed oil and natural gas as sources of long-term energy supply. Hence LMFBR development is pursued by several states.

Germany, for example, is pursuing the construction of the SNR-300 demonstration plant. Japan is presently involved with the initiation of the experimental reactor Joyo. Italy continues construction of the experimental reactor PEC while India is pursuing the FBTR. As far as the USSR is concerned they have started the design of 1,600 MW large breeder power plants.

63. It seems that major European utilities have committed themselves to the LMFBR. It was reported that EdF, ENEL and SBK have jointly started the construction of the 1,200 MW Super Phenix prototype plant. This is done in accordance with the terms of agreements reached several years ago and through their subsidiary NERSA.

64. How does this fit in with current US policy on fast breeder reactor development? It was felt that the latter could only be construed within the context of recent specific US energy supply developments. The US has, it was felt, left the door open for the LMFBR. This point was substantiated by the US intention to pursue the scheduled completion of the FFTF as well as by the existence of the R&D budget equal to the combined French, Germany and UK efforts.

65. The scientific feasibility of fusion will not be demonstrated until at least late 1990, after which engineering feasibility would have to be proved. Although fusion compares very favourably with fission in terms of energy generation there are nevertheless several environmental and safety problems to be solved prior to any commercial implementation.

66. A closely related session entitled 'Advanced Systems and Applications' presented, inter alia, alternatives to LMFBR technology. This session dealt primarily with nuclear power

reactors and energy systems which are not likely to be of commercial importance until the 1990s or thereafter. A paper from the Netherlands reviewed the status and prospects of thermal breeders utilizing the thorium-U_{232} cycle rather than the uranium-plutonium fast breeder cycle. Very little development effort is currently being devoted to thermal breeders, but they can utilize thorium to good advantage, hence greatly decrease the amounts of natural uranium required to support the world nuclear power industry. This is particularly true of liquid fuel thermal breeders (molten salt and aqueous suspension).

67. Assuming that the advanced systems would be introduced after 1995, the following amounts of natural uranium would be required by market economy countries up to the year 2050:

TABLE 6

Reactor Systems	Millions of Tons of Natural Uranium Required	
	low nuclear growth	high nuclear growth
Light Water - No Recycle	38	60
Light Water - Pu Recycle	25	43
Light Water Thorium Breeder	23	44
Thorium Cycle CANDU	17	30
Liquid Fuel Thorium Breeder	9	16
Fast Breeder	10	15
Liquid Fuel-Fast Breeder	5	10

68. A US paper which dealt with the molten salt breeder showed that it has further advantages such as low fuel cycle costs, high thermal efficiency and favourable safety, environmental and safe-guards aspects. Work continues, although the supporting R&D programme was previously cut down. It was estimated that the cost of developing this system through the first 1,000 MW demonstration plant would amount to $3.25 billion.

69. Soviet papers described such advanced reactor types as a 1,500 MW nitrogen tetroxide (gas) cooled fast reactor with a 4-5 year plutonium doubling time and 2,400 MW graphite-water nuclear steam superheating reactors. Experience with superheating channels in the Beloyarsk nuclear power station had shown that this approach was technically feasible and economically justified.

70. Another Soviet paper reviewed MHD generating experience in the USSR, describing how this type of device could be used for converting the heat from an advanced reactor of fusion mechanism into electricity.

71. In a paper dealing with the economics and technology of 1,000 MW to 2,000 MW WWER stations of the Novovoronezh type it was stated that such nuclear plants are presently being constructed at the cost of 200 roubles/kW, having minimum fuel costs of 0.41 kopeks/kWh.

72. There were several papers dealing with the use of nuclear reactors for industrial process heat and district heating. An interesting Swedish paper described a 200 MW (thermal) nuclear steam plant whose safety features would permit urban, underground siting in a city of 60,000 persons. Preliminary design and safety analysis of this concept, called SECURE, are completed.

73. A Polish paper gave a comprehensive review of processes for the production of hydrogen and synthetic fuels using high temperature reactor steam.

74. In a paper from the Federal German Republic a review was given of experiences with nuclear ship propulsion, and describing the design of a nuclear merchant ship.

75. An interesting European paper gave some realistic considerations concerning the LMFBR fuel cycle. Several authors stress the importance of the breeding gain factor for the development of fast breeder power plants. Improvement of in-pile breeding should be consistent with aiming at short out-of-pile time and with a reduction of Materials Unaccounted For (MUF) along the fuel cycle. Hence, efficient management of the breeder fuel cycle is an absolute prerequisite for competitiveness and improvement for rapid breeder reactor penetration into the market.

76. It should perhaps be kept in mind that although alternative ways of breeding are being considered there is still the question of technical feasibility. Once demonstrated it must be followed by industrial and finally, commercial feasibility. Hence, these alternatives, although attractive are unlikely to represent any new energy source much before the year 2000.

SAFEGUARDS

77. There were ten papers presented to the technical session on Safeguarding Nuclear Materials. These were:

C.A. Bennett	USA	Current technical issues in international safeguards
A. Marzochi R. Venchiarutti S. Gatti A. Bertini B. Zaffiro	Italy	Experience on the application of safeguards systems to the Italian nuclear power plants
H. Kurihara Y. Kawashima H. Natsuma M. Hirata T. Haginoya	Japan	The present status and development of Japan's system of safeguards
O.A. Miller N.S. Babaev F.Y. Ovchinnikov L.I. Golubev A.A. Lipovsky P.I. Fedotov S.S. Kovalenko Y.M. Grjasev G.I. Gadjev V.Y. Gabeskizia	USSR	Some technical aspects of the nuclear material accounting and control at nuclear fuel cycle facilities
U. Miranda M. Bresesti P.de Bievre L. Koch	EURATOM	Development and application of safeguards techniques in the nuclear fuel cycle
D. Gupta J. Heil	Fed. Rep. Germany	International safeguards in large-scale nuclear facilities
T. Arnal P. Dumesnil J. C.Edeline M. Ganivet	France	Application of neutronic controls in the plutonium-making and reprocessing installations

M. Krivanek J. Krtil J. Moravec P. Pacak F. Sus	USSR	Destructive and non-destructive methods for controlling nuclear materials for the purpose of safeguards in the USSR
R.M. Smith D.A. Head J. Hodgkinson A. Waligura Y. Konnov	Canada/IAEA	Safeguarding on-power fuelled reactors - instrumentation and techniques
G.R. Keepin	USA	Non-destructive assay technology and automated "real-time" materials control

78. The papers reviewed and summarized technical development and experience in nuclear material accountancy, safeguards procedures applied to typical nuclear facilities and the nuclear fuel cycle. This included the application of safeguards techniques and their in-plant implementation and performance evaluation in different types of fuel cycle facilities. Hence, one of the main issues of this session was the evaluation and analysis of different techniques and their impact on the overall effectiveness of safeguards.

79. Modern safeguards include accountancy as a main verification measure with containment/surveillance as complementary measures. Several of the papers summarized the experience gained in the USSR, EC, France, Italy and other countries in the application of destructive and non-destructive methods of nuclear materials control. The role and possibility of containment/surveillance measures for safeguards purposes of nuclear power reactors and bulk installations were also discussed.

80. Italy, Japan, USSR, EURATOM, Federal Republic of Germany, France, Czechoslovakia, Canada, the US and the IAEA all reported widespread interest in safeguards and experience with various

measurement systems. Several non-destructive assay techniques were discussed. These included passive and active neutron assay methods for various plutonium materials, high-resolution gamma ray spectroscopy for bulk feed and product, scrap and waste assay, as well as various gamma ray correlation instruments for spent fuel burnup and P_u/U fissile material ratio determination.

81. It seems that non-destructive assay (NDA) instruments and techniques may provide assay accuracies in the range of a few percent for several typical process materials. Concerning well-characterized material, e.g., quality-controlled feed and product, NDA accuracy may approach .5 to 1 percent. For poorly characterized materials such as heterogeneous solid wastes the accuracy of measurement may be 20-30 percent, or even larger. This would depend on composition, form and container geometry of the nuclear materials measured.

82. All the speakers at the technical session on safeguards noted the importance of direct physical measurement as the basis for an effective accountability and control system of nuclear materials.

83. A major issue of safeguards is the functioning and effectiveness which national systems will play and their increasing role in international safeguards. Hence,the ability of the systems in analytical and non-destructive measurements, measurement accuracies and material balance closing, development of data processing, and physical inventory taking are of crucial importance with regard to accuracy and control. These will all have a major impact on the effectiveness and viability of international safeguards.

84. Considerable attention was given to recent advances in physical protection technology, including surveillance, seals and containment systems, item-counting instruments, postal

monitoring, personnel identification techniques, secure data links and transport systems. In their joint paper on safeguarding CANDU-type on-line-refueling reactors, the IAEA/AECL stressed the importance of reducing unnecessary redundancy in safeguards, security and surveillance systems.

85. Practically all aspects of modern safeguards techniques and their development were covered in this session. It was evident that the main thrust of in-plant safeguards technology is toward automated material measurement and control systems, and interactive automated data-processing for in-plant materials accountability and accuracy. The US, Japan, German Federal Republic and EURATOM described such systems.

86. Some delegates were concerned with the future availability of advanced materials control system technologies and particular in-plant experience such as the US DYMAC.* Non-destructive assay instruments, interactive computer system technology as well as experience gained with real-time material accountancy would, it was indicated, be made available to the IAEA and member states sharing US non-proliferation objectives.

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* DYMAC DYnamic MAterials Control system being developed and demonstrated at ERDA's Los Alamos Scientific Laboratory.

87. During the Salzburg Conference there was also a round table dedicated to the effectiveness of international safeguards. The presentations were as follows:

304	I.D. Morokhov et al		USSR	International safeguards for non-proliferation of nuclear weapons
414	R.T. Kennedy H.E. Lyon		USA	Assurances of the effectiveness of safeguards in the light of their objectives
157	R.	Imai	Japan	The role of IAEA safeguards in connection with nuclear trade
452	B. R.	Sanders Rainer	IAEA	Safeguards Agreements - their legal and conceptual basis
76	A.	Anderson	UK	Contribution of the "safeguarded" to the development of safeguards
434	H.W. B.W.	Schleicher Sharpe	EURATOM	The EURATOM safeguards system as a regional control system
534	R. G.	Rometsch Hough	IAEA	The position of IAEA safeguards relative to nuclear material control accountancy by States

88. In addition, there was a round-table discussion dealing with the effectiveness of safeguards, the role of the national system of accountancy and control, its relationship to international safeguards and physical protection. The main subject areas of the latter were:

1. Functions of a State's "system of accounting for and control of nuclear material".
2. The technical effectiveness of the State's system and its functional independence of the facility operator.
3. The Agency's independent verification and its inspection effort.
4. The role of physical protection in connection with safeguards.

89. Dr. Rudolf Rometsch, Director of the Department of Safeguards and Inspection of the IAEA defined international safeguards, stressing the fact that the IAEA safeguards system is based upon the national systems of accountancy and materials control. Under the terms of its mandate, the IAEA is charged with independent verification of the effectiveness of the safeguards system of each member state. It is therefore of primary importance that the IAEA continue to acquire increased sophistication and technical capability to cope with the future introduction of new, large-scale fuel cycle facilities.

90. It was indicated that the goal of future safeguards measurement and control is materials control on a "near real time" basis in the order of 1 percent or better. Whereas the older, very general safeguards systems designs were for generic facilities, these are no longer sufficiently useful to meet the needs of diversion detection algorithms and plant simulation models,which may generate detailed quantitative assessments of material balance areas involving specific detection.

91. Not only the "back end" of the fuel cycle (e.g.plutonium recovered from spent fuel) is important. It is equally important to ensure effective safeguards of the "front end" of the fuel cycle, e.g. present and future enrichment facilities. M. Bertrand Goldschmidt from France, for example, saw the front end of the fuel cycle as potentially more dangerous than the back end.

Development of advanced enrichment processes - e.g. centrifuge and laser isotope separation could constitute a greater contribution to nuclear proliferation than reprocessing. (See figure 6).

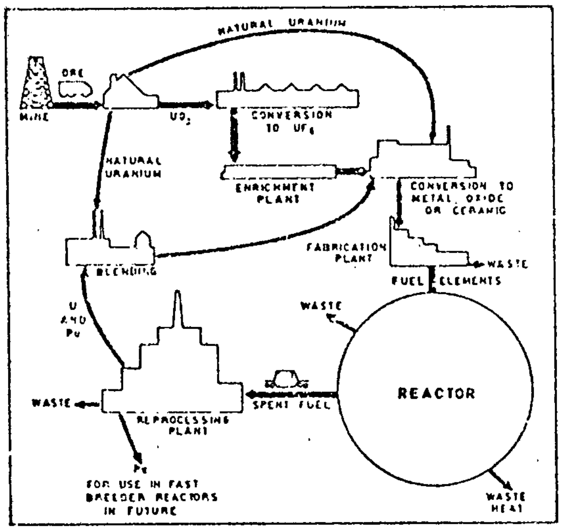

FIGURE 6 - THE NUCLEAR FUEL CYCLE

92. Another French delegate, M. André Diraud made the announcement at Salzburg that France had developed a new uranium enrichment process, based on chemical exchange which would prevent the production of weapon-grade enriched uranium. He revealed no technical details of the process. However, it was stated that France would be interested in discussions with other governments concerning the conditions under which this new enrichment process could be further developed and demonstrated internationally. Some information regarding the French enrichment process is contained in the following sections.

NUCLEAR POWER IN DEVELOPING COUNTRIES

93. The use of nuclear power for electricity production has been steadily expanding into the developing countries. As of March 1977 five developing countries (Argentina, Bulgaria, Czechoslovakia, India and Pakistan) had nuclear plants in operation with a combined net output of approximately 2000 MWe (2 GWe).

94. However, these and eleven other developing countries have nuclear power reactors under construction, ordered or planned for operation by 1985. Assuming that these plants will be constructed on schedule, their combined capacity will reach 30 GWe. This means that electricity equivalent to 300 million barrels (43 million tons) of oil could be provided. However, it constitutes only 9 percent of world nuclear capacity by 1985.

95. The whole question of nuclear power in the developing world received rightful attention during the Salzburg Conference. A plenary session addressing itself directly to this question contained the following presentations:

H. N. Sethna M. R. Srinivasan	India	India's nuclear power programme and constraints encountered in its implementation
J. O. Cosentino	Argentina	Experience acquired at the different stages of the Atucha nuclear power project
G. Szili N. Erdősi Z. Gyimesi M. Ocsai B. Szabó I. Varga	Hungary	Development of the national nuclear programme and preparations for the introduction of nuclear power in Hungary

R. Nazaré Alves C. Syllus M. Pinto C. Marcio M. Dale Jair A. M. Souza J. Spitalnik R. de Araujo	Brazil	Requirements for and development of trained manpower resources
A. de los Santos Lasúrtegui L. Corretjer Palomo	Spain	Legal framework for a nuclear programme

96. In addition, there were two technical sessions dealing with, respectively, Nuclear Programmes in Developing Countries and Experience of Nuclear Power in Developing Countries. The former, which took place on Tuesday 3 May, consisted of the following papers:

C. Syllus M. Pinto R. Nazaré Alves W. Lepecki H. M. Da Costa M. Grinberg M. Grimberg	Brazil	Organization and development of the Brazilian nuclear programme
J. Iljas I. Subki	Indonesia	Nuclear power aspects in an oil and coal producing country
M. Shafique M. Ahmad	Pakistan	Development of a national nuclear power programme, constraints likely to influence timing and introduction.
M. Wa Kalenga	Zaire	The prospects for nuclear power in Central Africa
K.E.A. Effat H. S. Sirry M.E. El-Fouly E. El-Sharkawy A. F. El-Saiedi	Egypt	Projected role of nuclear power in Egypt and problems encountered in implementing the first nuclear plant

M.H.L. Guerrero	Mexico	The fabrication of nuclear fuel elements in Mexico
K.E.A Effat F.H. Hammad A.A. Abdel-Rassoul S. M. Morsy A. A. El-Sayed	Egypt	Future fuel cycle requirements and radio-active waste management plans for Egypt's nuclear power programme
D. Stefanović P. Strugar M. V. Mataušek J. Pop-Jordanov D. Popović M. Copić Z. Gabrovšek	Yugoslavia	On the nuclear fuel cycle for research and power reactors
J. Naigeon A. Kutukcouglu A. Menez B. Milliot S. Sahin A. Valentin	France	The role and functions of a consultant in the selection and construction of a nuclear power station: example of a project in Turkey.
A.B.M. Nurul Islam M. A. Quaiyum K. A. Hasnat	Bangladesh	Problems faced by Bangladesh in introduction of nuclear power programme
M. Nelken Y. Porat M. Namet	Israel	Small system expansion with large nuclear generating units - technical feasibility and economic soundness
J. Marcaillou H. Haond J.P. Py	France	Nuclear power stations for export to developing countries: the problems of adapting a reference power station belonging to the technical level of an industrialized country

97. At the second technical session, the following presentations were made:

K. Kostadinov S. Ruskov	Bulgaria	Experience of NPS construction in the People's Republic of Bulgaria
J.C. Shah T.F. Pardiwala V.V. Kothare M.H.P. Rao K. Nanjundeswaran	India	Experience from the construction and operation of Tarapur and Rajasthan nuclear power stations
J.H. Koll J.E. Kittl C.A. Parera R.C. Coppa E.J. Aguirre	Argentina	Integration of the nuclear fuel cycle in Argentine industry
S.M.N. Kaidi	Pakistan	Experience from construction and operation of Karachi nuclear power plant
S. Challappa G.S.K. Murthy S.K. Mehta A. Kakodkar A. Natarajan	India	Experience in the manufacture of nuclear equipment in India
L.D. Ibe C.R. Aleta	Philippines	Prospects and problems of nuclear power in the Philippines
J.W. Dias S. Krawczynski K. Scharmer	Fed. Rep. Germany	Bilateral cooperation between Germany and Brazil on fuel irradiation
N. Andreescu M. Alecu I. Mirion	Romania	Some aspects concerning the implementation of a fuel technology project
J.C. di Primio	Argentina	Technology transfer and the Argentine-German Co-operation Agreement

H. J. Laue D. Nentwich	Fed. Rep. Germany	Successful transfer of nuclear technology by the aid of scientific and technological co-operation
L. Alvarez de Buergo L. Santoma Juncadella	Spain	The importance of quality control in nuclear power programmes: Spanish experience
T. D. de Souze Santos H. M. Haydt E. F. Gentile F. Ambrozio Filho N. F. Quadros N. Fogaca Filho	Brazil	Review on quality control techniques of UO_2 pellets under pilot-plant conditions at Instituto de Energia Atomica, Sao Paulo, Brazil
J. D. Lafleur R. D. Hauber D. M. Chenier	USA	International exchange of safety and licensing information

98. As can be seen, the ground was covered very well, and the different sessions and subsequent discussions were interesting. There was a round table discussion dealing with Transfer of Nuclear Technology to Developing Countries, the main subject areas of which were:

1. Conditions and constraints of transfer of technology.
2. Requirements for the establishment of capacity to absorb technology transfer.
3. Manpower development.

99. Judging by the numerous papers presented by participants from the Third World, their nuclear programmes now show a relatively high degree of maturity. It seems evident that in establishing their nuclear power programmes, appropriate account has been taken of alternative energy sources available, including in particular, solar energy. The main conclusion to be drawn is that for large-scale electricity production to take place in the

absence of indigenous coal, only imported oil and nuclear power are available as alternatives.

100. The economic recession of 1974 and 1975 with subsequent and related factors may have a negative impact on future energy demand, including electricity and nuclear power. Hence, today's forecasts for nuclear power growth in the developing countries are only 50 percent of the potential market for nuclear plants as estimated in 1974.*

101. The IAEA's own forecast for future nuclear power growth was given in a paper earlier in the conference. J. A. Lane et al** presented the following projections:

TABLE 7
IAEA Nuclear Growth Forecasts

REGION	MARCH 1977 actual	GWe 1980 min.	1980 max.	1985 min.	1985 max.	1990 min.	1990 max.	1995 min.	1995 max.	2000 min.	2000 max.
LATIN AMERICA[1]	0.3	1	2	4	6	15	27	39	66	85	132
MIDDLE EAST, AFRICA[2]				0	2	3	9	10	18	20	34
ASIA, FAR EAST[3]	0.7	4	5	12	15	29	48	60	91	98	139
EASTERN EUROPE[4]	1.0	2	5	10	16	29	41	53	78	84	120
OTHER DEVELOPING COUNTRIES[5]				0	1	2	4	4	6	8	12
SUB TOTAL	2.0	7	13	26	40	78	129	166	259	293	437
INDUSTRIALIZED COUNTRIES[6]	84.0	155	194	279	420	480	780	770	1260	1110	1790
WORLD TOTAL[7]	86.0	162	207	305	460	558	909	936	1519	1403	2227
DEVELOPING COUNTRIES (as % of total)	3	5		9		14		18		20	

[1] Argentina, Brazil, Chile, Colombia, Cuba, Mexico, Peru, Uruguay, Venezuela
[2] Algeria, Egypt, Iraq, Israel, Kuwait, Nigeria, Saudi Arabia
[3] Bangladesh, Hong Kong, India, Indonesia, Iran, Korea, Malaysia, Pakistan, Philippines, Singapore, Taiwan, Thailand
[4] Bulgaria, Czechoslovakia, Hungary, Poland, Romania, Yugoslavia
[5] Greece, Turkey
[6] Includes USSR and German Democratic Republic
[7] Excluding mainland China

* See IAEA 'Market Survey for Nuclear Power in Developing Countries'- 1974 Edition.

**See J.A. Lane, A.J. Covarrubias, B.J. Csik, A. Fattah, G. Woite; International Atomic Energy Agency, Vienna, Austria, Nuclear Power in Developing Countries, IAEA-CN-36/500.

TABLE 8

NUCLEAR AND TOTAL ELECTRIC GROWTH IN DEVELOPING COUNTRIES

	Installed Capacities, GWe		Nuclear % of Total	Avg. Growth Rate* %/yr	
Year	Nuclear**	Total Electric	Electric	Nuclear	Total Electric
1980	7-13	280	3-5		
				24	7.4
1985	25-40	400	6-10		
				26	7.3
1990	80-130	570	14-23		
				15	7.0
1995	170-260	800	21-32		
				11	6.6
2000	290-440	1100	27-40		

* By 5 year periods
** Rounded values from Table II

TABLE 9

CAPACITY DISTRIBUTION IN YEAR 2000 FOR EIGHT COUNTRIES WITH LARGE NUCLEAR PROGRAMMES

Country Ranking	Nuclear (GWe)	Fossil (GWe)	Hydro (GWe)	Total (GWe)
Argentina	10 to 15	17 to 12	10	37
Brazil	35 to 60	35 to 10	84	154
India	15 to 25	52 to 42	33	100
Iran	30 to 40	43 to 33	6	79
Korea	12 to 20	43 to 35	3	58
Mexico	28 to 36	30 to 22	22	80
Taiwan	14 to 18	18 to 14	4	36
Yugoslavia	14 to 20	19 to 13	12	45

102. The projected programmes for the installation and use of nuclear capacity in developing countries as described in the Salzburg papers is ambitious. By the year 2000, according to IAEA compilation, 36 developing countries (including six East European states) could have a total of 290-440 GW of nuclear capacity, which compares with the expected installed nuclear capacity in the industrialized world by 1985. It would seem to be somewhat on the high side, hence, difficult to attain.

103. There are several developing countries which expect to derive 50 percent to 65 percent of their electric power generation from nuclear power plants. The following developing countries are projecting large nuclear power programmes in excess of 10 million KW: Argentina, Brazil, India, Iran, Korea, Mexico, Pakistan, Romania, Taiwan and Yugoslavia. The most ambitious plans come from Brazil, which anticipates having about 75,000 MW nuclear capacity installed by the turn of the century. Iran expects 40,000 MW of installed capacity by the year 2000, while Mexico anticipates more than 30,000 MW.

104. Among the above-mentioned countries only India expects to have early introduction of fast breeder reactors.*

105. Several factors influence nuclear power growth in the developing world, and there are some considerable obstacles to be met. The most serious problem may well be that of financing capital-intensive nuclear plants, requiring more than double the initial investment per KW than conventional thermal units. Developing countries may well be forced to resort to expedient short-term solutions of building lower cost oil-fired stations, while rising fuel costs will worsen their long term energy situation. This is an unattractive but likely scenario. In order to overcome

* 1,000 MW by 1990, 5,000-7,000 MW by 2000.

this problem a special nuclear fund was proposed, with contributions from the industrialized countries as well as the OPEC group of states, allowing for financing viable nuclear power projects in the developing countries on relatively easy terms. This would at least be one way of breaking an otherwise vicious circle. However, similiar suggestions have been made previously with little success.

106. Another major problem to be overcome lies in the lack of industrial and institutional infrastructure within the developing world. Skilled manpower, adequate local industrial and engineering facilities, the need for a free nuclear market, access to advanced technology transfer, the availability of nuclear power plants in the required sizes as well as an ensured supply of nuclear fuels are all requirements which will have to be met.

107. An important component of this problem is the lack of trained manpower. Some of the developing countries are recognizing this problem as well as attempting its solution by means of establishing local training facilities. India, for example,has trained in the excess of 3,000 nuclear engineers and Brazil plans to train more than 6,000 engineers during the next decade. Special courses are offered by the IAEA, to which the U.S., France, the Federal German Republic and other countries have contributed.

108. A wealth of information concerning the nuclear power plans of the developing countries was brought out during the Salzburg Conference, the most important of which were mentioned in the beginning of this section. Going into greater details for a moment, we learned that Brazil plans to expand its nuclear programme to some 10,000 MW in 1990 and to 75,000 MW by the end of the century. If this can be achieved, it means a capacity distribution by the year 2000 of 90 GW Hydro, 75 GW nuclear and 20 GW thermal. The corresponding electricity generation would

be 355 TWh, 460TWh and 50 TWh respectively from these three types of plants.* Several joint Brazilian-Federal German Republic companies have been established for purposes of reactor construction, uranium exploration and the manufacture of fuel.

109. A rapidly growing population, ever increasing energy demand as well as few indigenous energy sources make Egypt one of the developing countries which anticipates meeting future electricity demands from nuclear as well as oil or gas-fired plants. In the period between now and 2000, the electrical growth rate of about 9 percent is expected. In order to meet this demand, Egyptian plans call for the addition of two 600 MW nuclear plants, as well as 2,000 MW of thermal plants by 1985. From then until the end of the century, 5,400 MW nuclear and about 5,000 MW thermal plants may be added.** One step towards the implementation of Egypt's nuclear programme has been taken to purchase from Westinghouse a 600 MW pressurized water reactor, expected to be in operation by 1983.***

110. As far as India is concerned, her strategy of nuclear power development has been based on natural uranium reactors in the first phase, followed by fast-breeder reactors in the second, using plutonium recovered from spent fuel. India has one of the largest resources of thorium and modest resources of uranium. Her estimates are that 5,000-8,000 MW of phase 1 reactors can be sustained by available natural uranium resources. Target figures are 6,000 MW nuclear capacity by 1990 (of which 1,000 MW may be in fast reactors) and 20,000 MW by 2000 (including 5,000-7,000 MW of fast breeder reactors).

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*See also <u>International Atomic Energy Bulletin</u>, Vol. 19, No. 3, June 1977.

**Ibid., op.cit.

***See Effat, K.E.A. et al "Projected Role of Nuclear Power in Egypt and Problems Encountered in Implementing the First Nuclear Plant", IAEA-CN-36/574.

111. Forecast growth figures for Pakistan regarding population, commercial energy consumption and the generation of electricity are 3 percent, 5.2 percent and 10 percent respectively to the year 2000. This means she could have a population of 150 million and an electricity generation of some 120 TWh. All of Pakistan's economically recoverable hydro resources, coal, natural gas and nuclear power must be utilized. The Pakistani plans call for 4,800 MW of nuclear power by 1990, and about 16,000 MW by the end of the century. This cannot be done without enormous strains on financing and manpower resources, as well as industrial and engineering infrastructure.*

112. Even a developing country such as Indonesia, with ample natural resources, is anticipating having to go nuclear to meet future energy demands. Recent studies point to the installation of coal-fired plants as an economic device for the period 1980-1985, but with nuclear power to come into use after 1985. Feasibility studies will determine the exact timing of the first nuclear station.**

113. The grids in LDCs are relatively small and cannot normally absorb large 1,000 MW class standardized nuclear power units. Due to apparent unavailability of smaller units some LDCs: Brazil, Iran and Taiwan among them are constructing plants 900 and 1,200 MW sizes, which could cause initial integration problems.

114. There seems to be a need for developing small and medium power reactors of 100-500 MW size. The IAEA has, through surveys, identified a large potential market for reactors in this range, and various engineering and finance arguments could be advanced in their favour. Studies in both the US and the USSR show how smaller plants can be technically and economically viable in

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*See M. Shafique and M. Ahmad 'Development of a National Nuclear Power Project, Constraints Likely to Influence Timing and Introduction', IAEA-CN-36/546.

**J. Iljas and I. Subki 'Nuclear Power Prospects in an Oil and Coal Producing Country', IAEA-CN-36/175.

situations where transport of conventional fuels is difficult and pollution problems due to burning coal or oil must be avoided. It appears that the main obstacle in the production of small power reactors is a lack of interest among manufacturers. This could change somewhat with the present slack in orders for larger units. What is also required, however, is real incentives among the manufacturers coupled with some assurance of markets, before standardized units at a reasonable cost could be produced. It was felt that the IAEA can play a useful role in bringing together potential suppliers and customers in order to achieve necessary standardization, safety and financial facilitations.

115. A key issue throughout the Salzburg Conference was the transfer of nuclear technology. During the round table discussion it was recognized that nuclear technology transfer imposed serious moral obligations on all countries concerned.* The discussion was less acrimonious than one might have expected, with a seeming desire to avoid confrontation.

116. Embargoes on nuclear technology to needy countries in the less developed world could, by themselves, create serious tensions and energy problems. The secondary effect of this would be a threat to world stability and order. For this reason, a policy of denial symbolizing an attempt by the developed countries to perpetuate a political and technological hegemony (as perceived by 3rd and 4th World Countries) would, by itself be possibly harmful to all concerned. Furthermore, a policy of denial may be counter-productive since basic nuclear know-how has already been widely disseminated during the last 20 years. Hence, embargoes could simply compel these countries to develop their own fuel cycle facilities, which would be more difficult to monitor and control. Thus, restrictions on technological know-how, it was argued, could defeat rather than help the cause of non-proliferation.

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*The interrelating issues being prevention of destructive uses, threats to the security of states, and pollution of the environment.

117. From the point of view of the Salzburg Conference and all the detailed information made available there, it seems an undeniable fact that nuclear energy will play a very important role in allowing the world to come to grips with a deepening energy crisis. Although the spread of nuclear power contributes to the potential threat of proliferation, the link between nuclear power and nuclear weapons**proliferation is not, as is often assumed or stated by media sources, automatic.

118. It may perhaps be useful to emphasize that those parties with a very strong desire to proliferate do not necessarily require nuclear power reactors. One way of contributing towards the elimination of nuclear proliferation may be by creating a climate of trust and confidence by means of a genuine dialogue between suppliers and users of nuclear power technology as well as materials. Of course, what this presupposes would be the creation of an internationally agreed upon code of conduct as well as a comprehensive, effective, hence reliable, international nuclear safeguards system. In one sense there is really no alternative to such a system if nuclear energy is to be fully utilized on a global basis.

**Including SNMs (Strategic Nuclear Materials).

NUCLEAR ENERGY AND PUBLIC OPINION

119. Nuclear energy and public opinion are two important factors which should be taken into account for any evaluation of overall national energy needs and the strategy adopted to meet these needs. As expected, the organizers of the Salzburg Conference had taken this into account. One plenary and two technical sessions dealing directly with the above issues were held. In addition, some of the problems involved came up for consideration in related sessions dealing with, inter alia, nuclear safety in general and reactor management and safety in particular. This permitted what turned out to be an extensive debate in a scholarly fashion. The plenary session contained the following presentations:

H.A. Bethe	Special invitee	The controversy about nuclear power
H. Alfvén	Special invitee	Energy policy and public acceptance
P.R. Abrecht J.M. Francis	World Council of Churches	Public acceptance of nuclear power - some ethical issues
J. Døderlein	Norway	Nuclear power as a public issue: the protection of the public interest
E.E. El-Hinnawi	UNEP	Review of the environmental impact of nuclear energy
L.D. Hamilton A.S. Manne	USA	Health costs of alternative energy sources
H.J. Otway	IAEA/IIASA	A review of research on the identification of factors influencing the social response to technological risks

120. This session, in which two Nobel prize winners, Professors Hans Bethe (Cornell University) and Hannes Alfvén (Sweden) presented their differing views, was chaired by Dr. P. R. Abrecht of the World Council of Churches. Dr. J. M. Francis, also from the World Council of Churches stated some of the basic underlying ethical issues involved, based on the convictions that we can no longer live as though nuclear energy had not been discovered. He also stated that nuclear energy must not be looked upon as an end in itself, but rather as a means to social justice and quality of life.

121. One major preliminary conclusion of this, and the following two technical sessions dedicated to the same problem, was that the nuclear controversy can no longer be resolved by the industry simply giving out accurate scientific and technical data, after which a popular verdict is to be expected. Too much is involved, on both sides, by now, and the stakes are too high. One speaker after another emphasized how disquiet about nuclear power is, by now, only a part of a general and profound disquiet over the probable effects of all advancing technologies on society in general.

122. Put more simply, the debate on nuclear energy and public opinion has by now in part been transferred from the technical and scientific arena into one of social and political activity. Subsequent expert meetings and discussions on this topic have tended to substantiate this thesis.*

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* For an excellent treatment of the problem, see also A. Wyatt, "Opposition to Nuclear Power in Canada", at the CQRI-ICAI Conference on <u>Nuclear Development and Proliferation,</u> La Bastogne, Quebec City, 29 September - 1 October, 1977.

123. This does not mean that accurate scientific data are not required. It simply means that, by themselves, they are not sufficient to meet the attack from opponents of nuclear energy in general. Nuclear energy now acts as a lightning rod for a variety of social dissent and will undoubtedly continue to do so. Part of the problem continues to be a lack of understanding by the average person. As Dr. Francis (World Council of Churches) put it: "Most people are not familiar with probability concepts so that even a one-in-a billion chance of catastrophe makes them uneasy".*

124. An interesting paper was presented by Dr. Jan Døderlein (Norway) who argued for the protection of the public interest, while emphasizing public health and environmental effects of power production. Not only does the public have a right to obtain technically proven correct information, but it must also be protected against the dissemination of myths, including several from the ecologists/non-nuclear proponents. The United Nations Environment Programme (UNEP) presented a review of environmental impacts of nuclear power, whereas L. D. Hamilton and A. S. Manne reviewed the health costs of other energy sources, which included some interesting points of comparison. Finally, Dr. H. S. Otway (IAEA/IIASA) reported on the joint research project of his two organizations, identifying factors influencing social response to technological risks.

125. As was expected, a considerable amount of disagreement existed between the two Nobel laureates, now on opposite sides in the nuclear energy debate. The last has no doubt been heard from neither of them.

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*See paper 36/383.

126. In summary, the following main points emerged from this important session. First, the discussion of critical issues connected with nuclear power programmes must be continued on a broad basis and must, of necessity, include a number of persons concerned with technical, environmental, medical, sociological and political as well as ethical perspectives. Secondly, the public debate about nuclear energy should be seen within the context of the larger problem of meeting world energy needs. This must embrace the question of resources, and a comparison of present and future significance of alternative energy technologies. There was general agreement (including between professors Alfvén and Bethe) on the need and importance of an open debate on these issues, contributing to greater public understanding. Thirdly, it was felt that a more balanced approach to the public information system be devised. A new system of co-operation between governmental and non-governmental information channels could possibly generate and test the objectivity of the approach to those specific problems which have been identified.

127. The first technical session dealing with the problem of Nuclear Power and Public Opinion, which was chaired by Dr. J. M. Døderlein (Norway) contained the following presentations:

M. Popp K. Lang	Fed. Rep. Germany	Nuclear energy information in the Federal Republic of Germany
S. Frigren	Sweden	Public education for energy policy decisions
R.R.Matthews E.F.F.W. Usher	UK	C.E.G.B. experience of public communication
L.B.C. Taccoen	France	Anti-nuclear movements: public and political opinion in France
L.D. Ibe R.A. Savallano	Philippines	Gaining public acceptance for nuclear power: the Philippine approach

G. B. Keyes C. A. Poncelet	USA	Addressing the nuclear controversy on university campuses
T. Yamada H. Ohori	Japan	Public acceptance of nuclear power development in Japan
J. L. Liverman R. D. Thorne	USA	Public acceptance of nuclear power generation in the United States
H. Hirsch	Austria	Preliminary survey on the information campaign on nuclear energy of the Austrian Government

128. This session reviewed public information programmes in eight member countries, i.e., Austria, Federal German Republic, France, Japan, the Philippines, Sweden, the UK and the US. The papers were interesting and covered a wide area of efforts undertaken within different social and political cultures. Some of the main findings were, not unexpectedly, that whereas a large number of individuals have been reached by information material or campaigns, the percentage of well-informed general public remains low. More must be done. National and regional differences in political and social culture necessitates the use of different plans and methods by national as well as international organizations. Finally, preliminary results point, unequivocally, to a strong need for continued and increased efforts to improve communication and understanding among the various parties involved.

129. The second technical session on this topic, chaired by Dr. O. Gunstedt (Sweden) consisted of the following presentations:

C. Zangger	Switzerland	Nuclear energy control and its influence on public acceptance of nuclear energy in Switzerland: aims and implementation

S. D. Jellinek	USA	Public acceptance of nuclear power in the United States: The role of the National Environmental Policy Act
M. J. Feldman	ANS	Public awareness and the professional society
J. E. D. Davies J. K. Dobson R. G. Baril	Canada	Canadian attitudes to nuclear power
F. Oszuszky P. Dierkes	Austria	Public acceptance of nuclear power in Austria
K. G. Vohra	India	A perspective on the radiation protection problem and risk analysis for the nuclear era
J. P. Pagès D. Agrafiotis E. Delarminat G. Morlat	France	Nuclear energy and the public

130. In this session the regulatory processes in some member countries were reviewed, including the role of the National Environment Policy in the US, public awareness in Canada, and the democratic process of decision-making in Switzerland.

131. A useful perspective on radiation protection problems and risk analysis was presented by K. G. Vohra (India). A social analysis of various messages and ecology myths disseminated to the public as well as reactions to them were presented by J. P. Pagès (France).

132. Melvin J. Feldman, past president of the American Nuclear Society (ANS) correctly summed up the need for today's technologist as an individual and through professional societies to become aware of a new dimension, namely a responsibility to communicate

with the public which he has been trained to serve.* Various examples of how this type of communication can be made to work were then offered in some of the papers.

133. Type of decision-making needed for implementation of nuclear energy may be illustrated as follows:

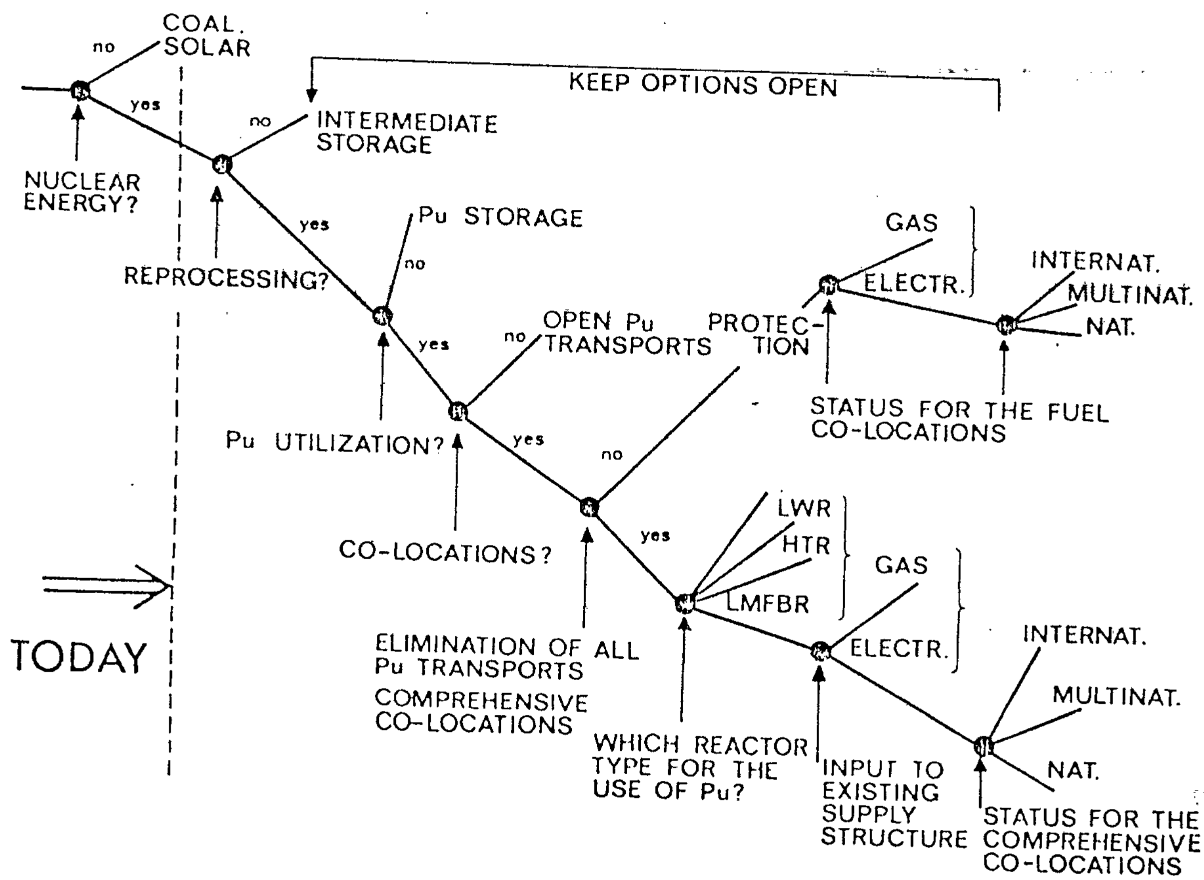

FIGURE 7 - DECISION TREE FOR THE DEPLOYMENT OF PEACEFUL NUCLEAR ENERGY

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* See paper 36/498.

Source: W. Hafele, "Energy Options Open to Mankind Beyond the Turn of the Century", International Institute for Applied Systems Analysis, Laxenburg, Austria.

CONCURRENT DEVELOPMENTS

134. During the period of the Salzburg Conference, and subsequently, a series of expected - and some perhaps less expected - developments took place.

135. Informal meetings, briefings and press conferences were the events of the day. Coverage by newspaper, radio and other news media was extensive, and Austrian TV covered the sessions on a daily basis. A large, peaceful anti-conference took place concurrently, arranged by the "Friends of the Earth" group and followers of Amory Lovins. Its format, apart from seemingly unobtrusive, private lobbying was almost exclusively the publication of a daily newspaper, which was read with some interest by conference delegates. There seem to have been no incidents whatso-ever, or if there were, nothing was heard of them. From this point of view the conference was well-organized, surprise free and pleasantly interesting all around.

136. A few of the major powers, as was perhaps to be expected, may have indulged a little bit in what could have been seen as muscle flexing. However, some of the other states were not afraid to speak out when they felt their sovereignty intruded upon in one way or another with regard to their own ambitions or plans for nuclear energy usage.

137. Joseph S. Nye of the US Department of State gave a well-publicized luncheon talk for heads of major country delegations, followed by a press conference, during which he gave a run down of President Carter's non-proliferation policies. The US will review future applications for the international transfer of spent fuel for reprocessing on a case-by-case basis, he said. Transfers would only be approved in cases of clear need, defined as meaning cases where ability to continue generation is a factor due to spent fuel storage congestion. By implication, Dr. Nye indicated

that this new policy would hurt the proposed Anglo-French 10-year reprocessing contract with Japan, since a case-by-case approach would be inconsistent with a 10-year contract.

138. The possible use of further pressures was indicated by Dr. Nye, this time against EC. The US present co-operation agreement with the Community gives The Americans no control on transfers within the EC. However, Nye suggested, there would be an attempt by his country to renegotiate co-operation agreements with the EC and other countries which do not presently give the US control over the disposition of nuclear materials of US origin.

139. Dr. Nye effectively warned other countries that if they did not go along with President Carter's policies, they might be in trouble with their own electorates over nuclear power. Unless governments were able to show their citizens that the governments were able to work together to maintain the distinction between the peaceful and non-peaceful uses of the atom, Dr. Nye argued, we would find increasing reluctance to accept this energy source.

140. A dramatic support for US non-proliferation policies came in the form of a full-page advertisement in The Guardian (UK) on the eve of President Carter's visit to London for the economic summit meeting. The ad was an open letter to the US President, supported by the names of 1,400 individuals and organizations, asking readers to sign the letter and send it to President Carter at the US Embassy. The text of the letter was as follows: We look to you and the US to continue to take the lead in creating the right climate for world denuclearization. Such an effort offers the best hope for bequeathing to future generations a diverse, sustainable, humane and peaceful world. As individuals we would like to be a part of that effort and we pledge our support."

141. Not all countries agreed. During the London secret meeting of nuclear suppliers, where US officials explained President

Carter's plan, the USSR put forth its own proposals. The Soviet counter-proposals according to observers, constituted a rejection of the whole Carter idea. In a statement handed to the other 14 members of the group, the Soviets called for supplier countries to export nuclear materials, equipment, and technology in the group's trigger list only to countries which accept full fuel cycle safeguards. The Soviet Union supported an outright ban on transfers of installations, equipment and technology for reprocessing and enrichment plants. In order to discourage the build-up in non-nuclear weapon states of SNMs, the plan urged supplier countries of nuclear materials to require that such materials would eventually be retransferred back to supplier countries or to IAEA safeguarded regional nuclear fuel centres.

142. The USSR also expressed concern about the accumulation in laboratories and scientific research centres in non-nuclear weapon states of plutonium and other nuclear materials received for research, medical and other purposes. The proposal urged unspecified stringent measures to prevent or limit such build-up.

143. The USSR expressed strong support for IAEA safeguarded regional fuel centres as well as the internationalization of reprocessing and storage facilities. Its reaction to President Carter's proposals of the previous week was, reportedly, to ignore them. The USSR quoted West Germany, France, Japan and the UK as having expressed very serious doubts (partly true) about the new US policy.

144. The French strategy of persuading non-nuclear weapon states not to acquire uranium enrichment or reprocessing facilities did not lie in the conclusion of a further renunciation treaty but in the creation of an open and liberal market for services from different competitive sources. So argued M. Bertrand Goldschmidt, Director of International Relations, Commissariat à l'Energie Atomique,

both in his IAEA Salzburg paper* and elsewhere. Goldschmidt argued, and the position of France is essentially as expressed by him, that availability of fuel cycle services will not prevent a country which wishes to keep the military option from building its own facilities, but it will stop that country from wanting to do so in order to avoid a not easily tolerated economic and political dependency on a single supplier or group of suppliers.

145. M. Goldschmidt argued that any limitation on reprocessing or enrichment should be compensated for by guaranteed access to corresponding services. He felt that this type of guarantee would assume a choice of suppliers through a free and competitive market where the present distrust would disappear completely. A somewhat Utopian solution to this problem, M. Goldschmidt stated, would be the internationalization of spent fuel storage, enrichment and reprocessing. Any new non-proliferation policy, whether it be based on legal or on technological measures or both, must avoid appearing to prevent - in any way whatsoever - the access of a state to the indispensable source of energy, or to make it dependent on a nation or a group of nations for its energy supplies. As M. Goldschmidt saw it, a real energy shortage could create an even more dangerous world situation than would weapons proliferation.

146. M. Goldschmidt also pointed out, in a different context, that the front end of the fuel cycle is more dangerous than the back end. Development of the centrifuge enrichment process may be a greater contribution to proliferation than the reprocessing which President Carter had temporarily ruled out of the US nuclear programme, the Frenchman said. The remark came in response to a statement by Robert Keepin of the Los Alamos Scientific Laboratory, who pointed out that safeguards discussions emphasizing reprocessing and plutonium use ignore that the diversion risk of

* See Goldschmidt, Bertrand, "The Control of Atomic Energy and the Problem of Non-Proliferation", IAEA Salzburg Conference.

using U_{233} is greater. If the anti-nuclears discover this, Dr. Keepin warned, their next target will be U_{233}. Therefore, he argued, the nuclear industry must stick together to avoid being divided in the future.

147. Sweden was another country with a relatively high profile at Salzburg, mostly through the formal sessions. Mr. E. Svenke of Swedish Nuclear Fuel, for example, stated categorically that enrichment and reprocessing of nuclear materials should be taken out of the commercial arena and provided by what he referred to as a co-operative organization between customers and operators under governmental umbrellas and IAEA safeguards and by a limitation of number and location of enrichment facilities. He felt that it was time to abolish the traditional notion of customer-vendor relationships. His concept might be contradictory to traditional ideas of choice and competition, Mr. Svenke stated, but it would be the only manner in which the nuclear system could stabilize.

148. Meanwhile, back in Sweden a major drive to sell nuclear power to the public was in an advanced stage of planning. Informal discussions for the campaign took place during the annual meeting of the Swedish Power Association of private and municipal utilities. Leaders of the utility industry were, reportedly, afraid that the split over nuclear energy in the 3-party coalition government would lead to the collapse of the government, thus returning to power the Social-Democrats. One of the most applauded points at the meeting came during a speech by the managing director of a Swedish utility company, Mr. Gösta Agrenius who stated that Prime Minister Thorbjörn Fälldin had said that nuclear energy would be nothing more than a parenthesis in the history of Swedish energy. If the government does not get an energy policy soon, Mr. Agrenius said, they too will only be a parenthesis. Mr. Agrenius, himself a Stockholm politician, is a member of the Conservative party. As a

rule industry and utility top management are generally conservative in Sweden. They held back their support of the pro-nuclear Social-Democratic party in its narrow defeat by Mr. Fälldin last year.

149. Among other interesting developments was a statement by John Kostiuk, President of Canada's Denison Mines Ltd.,and Chairman of the Uranium Institute, to the effect that uranium production can be expanded 100 percent in the next three years. This was in reply to a question from the floor on uranium resource availability on a global basis. However, in his formal speech at Salzburg, Mr. Kostiuk stated that uncertainties concerning expanding production to meet demand would come when industry tried to look beyond 1985. Longer term planning in the uranium industry requires reasonably stable prices since both consumers and producers are engaged in the planning activity on time scales measured in decades.

150. Mr. Kostiuk also suggested that the accumulation of stocks by individual customers could conceivably assist price stability. Uranium producers understand the need for electrical utilities to maintain certain minimum stock levels, although they are also conscious of the unfortunate history of mishandled stockpiles in some other countries.

THE FRENCH URANIUM ENRICHMENT PROCESS

151. Few disputed French non-proliferation claims for the chemical separation uranium enrichment process. However, there was considerable skepticism concerning the applicability of those claims, even if accurate, to the problems and issues of the real world. A short run down on the process may be useful.

152. According to Le Monde, it has taken nearly a decade of joint efforts by French scientists under the supervision of Claude Frejacques at the CRA (Commissariat à l'Energie Atomique), based on a technique of chemical exchanges in a liquid medium.*

153. If two uranium compounds, A and B are placed in equilibrium with each other, a constant exchange between the two products takes place. By combining with other atoms or groups of atoms of a different type, each uranium atom can, successively take the form of A or B.

154. First, it looks as though U_{235} and U_{238} have the same chemical properties and may equally well take the form A or the form B. This, however, is not so. Although having the same number of electrons, the electron configurations of uranium's two main isotopes and, more particularly, their energy characteristics differ slightly, due to the fact that their nuclei are not precisely similar; the U_{235} nucleus has three neutrons less than the U_{238} nucleus.

155. Whereas methods such as gaseous diffusion, or aerodynamic techniques are based on the slight difference in weight of the two nuclei, laser enrichment exploits these very properties. The result is that either of the two isotopes may in time contain a certain imbalance in the proportions of isotopes in these compounds. A, for example, could get a little more of the 235 isotope in the beginning, while B gets a little less; hence the separation of the two compounds enables one to obtain in one case slightly enriched uranium (in A) whereas in the other somewhat lightened uranium (in B).**

*See Le Monde, May 7, 1977, "French Scientists Discover New Way of Enriching Uranium", by Xavier Weeger, on which the major part of this argument is based.

**Ibid., op. cit.

156. As Xavier Weeger argues, such dynamic chemical action is relatively slow, which accounts for its non-proliferating features. As a comparison, whereas it would take 1-2 years to obtain strategic uranium through gaseous diffusion, and only a couple of days via high speed centrifugation, it would take about 30 years to obtain 90 percent enriched uranium through dynamic chemical methods.

157. Secondly, unlike the high-speed centrifugal process, it does not make it possible to obtain an enrichment increase in a cascade. Thirdly, concerning the risk of attaining criticality, since the exchange takes place during a liquid phase, the uranium atoms are extremely dense. If the degree of enrichment even with a very small volume is raised too much, the critical mass may be reached suddenly, with the risk of triggering a very dangerous chain reaction.*

158. The French method, in addition to the above-mentioned useful drawbacks, offers further advantages. Its energy consumption, for example, is medium**. Also, since the process relies on relatively conventional chemical engineering, there is little need for the application of highly sophisticated techniques. According to CEA economic surveys, such chemical transfers techniques could make it possible to construct, competitively, relatively small enrichment plants capable of meeting the requirements of a nuclear reactor programme on the order of about 10,000 megawatts.***

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* Ibid., op.cit.

** Approximately 1,000 kilowatt hours per SWU (Separation Work Units) as opposed to 2,500 for high speed centrifugation, 3,500 for the Becker aerodynamic process and 2,500 for gaseous diffusion.

*** Ibid., op. cit.

159. CEA has spent several hundred million francs on this process during the last 9 years. Scientists in the US and Japan have been at work on parallel projects, so far without known success. About 500 persons have been engaged in the French programme, which has been kept a closed secret. In 1970 the decision was taken to build the first pilot plant. Several plants are now in existence.

160. The French announcement at Salzburg took place with the maximum publicity desired. It was stated that the system practically would forbid the production of weapons-grade enriched uranium for several reasons; such as there being no possibility of cascade rearrangements to upgrade the level of enrichment*, that the enriching level is limited to 3-4 per cent due to criticality risks, as well as the time element, previously discussed, which would be around 30 years for highly enriched materials to come through.

161. The major counter argument to this plan is that as long as the economics of the process remain uncertain, if the power requirement is fairly high, and if the system will not be commercially available for one or more decades, it would seem to serve no particular function with respect to either the problem of proliferation or the commercial questions of today. If, by 1990 we have not found any answer to proliferation and related problems of nuclear energy it probably will not matter whether or not a particular enrichment system, should it otherwise work out, discourages proliferation.

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*See previous argument.

THE IAEA INITIATIVE FOR MULTINATIONAL FUEL CYCLE CENTRES

162. In addition to the formal plenary as well as scientific sessions, briefings, and press conferences, arranged during the Salzburg Conference, several round-table discussions were held on a variety of important topics. One such round-table discussion was dedicated to developments and decisions needed to assure the nuclear fuel cycle, by which is meant the continued operation of the nuclear fuel cycle from an economic, financial, administrative and socio-political point of view. The only way to get the idea of multinational fuel centres off the ground would seem to be via an IAEA initiative. This, at any rate, was the conclusion reached by the round-table participants. As summed up by the session chairman, Ken Davis of Bechtel Power, nothing will happen until some basic issues are resolved. How can multinational agreements be credible? Where would manpower originate? Are services only to be available to participants? These were some of the many questions raised and discussed at this round table.

163. Not surprisingly, there were relatively few complete answers to the many questions, although there was considerable agreement on several scores. There was agreement, for example, on the point that uranium mining and milling, exploration, fuel fabrication and conversion could take place in a harmonious international climate, whereas reprocessing and waste management could conceivably keep the fuel cycle centre concept deadlocked for a very long time to come, if not indefinitely.

164. There are three criteria for international waste management. First, the host governments of such centres must guarantee to accept waste. Secondly, the clients must assure the host government that the partners will share risks and liabilities in case of accidents. Thirdly, if additional work of a technical nature is to be done several years into its operation, subsequent costs must be shared.

165. It was pointed out that if the international approach was to be stressed too strongly, private industry could be jeopardized and could eventually be reduced to become solely government contractors or international governing agency contractors. It may well be that a solution for non-proliferation in countries threatening to build their own small (potentially weapons producing) reprocessing facilities could be to guarantee for them a well-managed fuel cycle in exchange for a promise not to construct their own facilities. However, it may well be that this theoretically correct point would not be able to survive today's short-term and somewhat parochial consideration.

166. The Soviets, for whatever it is worth, seemed very interested in the notion of organizing international centres for storage and processing of nuclear waste. They also showed a strong interest in an obligatory international convention on physical protection systems which would strengthen non-proliferation objectives. The IAEA's current role should be reinforced, since it cannot transfer to national nuclear systems the safeguards procedures for which it has responsibility.

THE "PERSEPOLIS CLUB" AND THE THIRD WORLD

167. Support for the Persepolis Club* of third world, non-aligned countries wanting to get on with nuclear power, if necessary without the US would seem to be growing. A senior Argentine nuclear energy official stated during a Salzburg session that it was essential for non-aligned countries to maximize and intensify already existing co-operation, and to create new co-operative agreements in order to combat the influence of the London Suppliers Club.

168. Argentina is already doing this with her agreement to supply Peru with a nuclear research centre. Mr. C. Castro Madero of the Argentine Commission Nacional de Energia Atomica ridiculed the notion of nuclear weapons proliferation in Latin America. Its nations, he felt, lack the manpower, resources and weapons delivery systems to make nuclear weapons feasible or desirable. The developed countries should give reprocessing technology to the South American developing countries, since by the year 2000 there will be so much plutonium around that it must somehow be handled.

169. Castro Madero said that the London Suppliers Club and its attitude towards developing countries was stimulating and strengthening the development of the Persepolis Club.

170. However, an appeal against both seller and buyer clubs came from two officials of Third World countries, namely S. Yiftah of the Israel Atomic Energy Commission and Akbar Etemad, Chairman of the Iran Atomic Energy Commission. According to Mr. Yiftah, both the London Suppliers Club and the Persepolis Club of the Third World ought to be abolished. In lieu of this, according to Mr. Etemad, there should be an open grouping of suppliers and

* So called since the concept was discussed widely at the recent Persepolis, Iran nuclear energy conference.

recipients to be called the Salzburg Club.

171. The notion that the Suppliers Club was a means of foisting industrialized countries' dominance on LDCs was, not unexpectedly, denied by representatives from supplier states. Nelson Sievering of ERDA contended that the London Club had been designed to create order in international commerce by insulating export controls from commercial competitive pressures. The need is to move away from the current atmosphere of polarization.

172. This argument, however, was met head on by delegates from LDCs. Dr. M. A. Khan of the Pakistan Atomic Energy Commission, for example, stated that a deliberate, calculated policy involved in a series of secret meetings would only be interpreted by the LDCs as aimed at maintaining the status quo in energy dependency, and the supremacy of industrialized states over the LDCs. Instead, a good beginning might be to work together by honouring the present agreements instead of unilaterally demanding changes and abrogating contracts and agreements.

OTHER DEVELOPMENTS

173. Major enrichment advances were claimed by South Africa during the Salzburg Conference. Its advanced vortex tube process is now viable at a capacity aprpreciably lower than the 5 million SWUs claimed when that process was unveiled in Paris in April 1975. Several factors account for this, including lower electricity consumption, which was down from 3,600 kwh per SWU to 3,300. The main factor seems to be much greater efficiency.

174. Mr. Walter L. Grant of the Uranium Enrichment Corporation of South Africa stated, in a formal paper at the Salzburg Conference, that recent improvements and adaptations in separating-element technology as well as cascade techniques mean that a 50,000 SWU/yr module (described in Paris) could now produce 80,000-90,000 SWU/yr depending on the precise operating parameters chosen. South Africa now plans to decide on the size of the plant, scheduled for 1986-87 operation, late next year.

CONCLUSIONS AND FUTURE DEVELOPMENTS

175. The Salzburg Conference took place against a background which assumed that there is a need for a major commitment to nuclear power. Its main objectives had been to discuss and assess the overall role to be played by nuclear energy in relation to other energy sources presently available. Particular reference had been made to the nuclear fuel cycle and the need for integrative measures. In view of some of the doubts and uncertainties which have beset the whole question of nuclear power during the past few years, and which still exist for that matter, it was perhaps somewhat surprising that the great majority of participants left the conference chambers after two weeks of debate with their faith in a commitment to nuclear power not only intact but reaffirmed.

176. The main conclusion which emerged from the debates and deliberations at Salzburg was a general agreement that nuclear power will be a necessary and irreplaceable source of the future energy supply of the world for a long time to come. It was important in this connection that the US confirmed its commitment to nuclear power based on light water reactors.

177. A consensus was reached that world energy needs will rapidly grow over the next decades. Although there may be some question concerning the rates and extent of this growth, it seems certain that the present world consumption of approximately six billion tons of oil equivalent will increase to around two to three times this amount by the end of this century. This is bound to happen even if the maximum efforts of energy conservation are applied by all industrialized countries, as is hoped for, and even if the most efficient methods for conversion and final utilization are found and developed on a global scale. Perhaps it is useful in this context to remember that energy conservation measures, too, have a long lead time and are capital intensive.

178. The LDCs, representing more than one-half of the world's population unanimously insisted that the glaring gap between their own standard of living and that of the developed countries must somehow be reduced. This familiar argument has of course been heard before, and will no doubt continue to be pressed. In this particular context it means that an expansion of energy consumption is required which, by the year 2000 would increase their current level beyond 10 percent of the total.

179. On the basis of the above, agreement was reached on two important points. First, in the short run, nuclear power offers an almost immediate substitute form of energy for the oil and gas used for electrification for those countries deficient in hydrocarbons and coal reserves, and where dependence on foreign import is otherwise essential. Secondly, in the long run nuclear power, it was felt, is a technologically mature solution which may provide the world with a safety net for the future. This is particularly so since we, as yet, do not know what in fact the ultimate potential of solar energy is, and while nuclear fusion still is at the laboratory stage.

180. As for renewable energy sources on a global basis a few calculations exist. An interesting projection is made by Häfele of IIASA (see table following page).

TABLE 10

RENEWABLE ENERGY SOURCES

	Global Technical Potential TW[a]	Technological Maturity	Systems Effects
Hydropower (Greenland)	2.9 (0.1)	Mature Economic potential 1.1 TW Presently utilized 13%	Ecological and safety problems
Wind	1-5	No basic problem	Regional planning, energy storage
Wet Geothermal	0.1	Installed 1350 MW	Salinity of water
Tidal Power	0.04	Installed 240 MW	?
Wave Power	1 per 35,000 km	To be developed	?
Ocean Thermal Gradient	70? 0.35[b]	To be developed	Climatological and ecological effects?

ENERGY CONSERVATION ≈1 TW

[a] 1 TW = 1 TW·a/a

[b] Within 10 km from coastline

Source: W. Häfele, op. cit.

181. Now, the present objectives of several states for nuclear energy development have become lower than they were only a few years back. This is due to the combined and formidable factors of economic recession, pressures from conservationists, ecologists and related protest groups and delays in licensing and constructing power plants, at times due to public opposition in general. Despite these factors, it would seem that the ranges of future nuclear power capacity will be somewhere in the order of 200,000 MW for 1980, 900,000 MW for 1990 and 1,300,000 MW for the year 2000.

182. Hence, the share of nuclear power which today stands at less than 10 percent of electricity and less than 3 percent of primary energy, may grow to about 35 percent of electrical energy and 15 percent of primary energy by the turn of the century.

183. There have been some counter-arguments regarding the use of nuclear energy based on the fact that it only consists of what seems a small proportion of total energy needed on a global basis. These familiar arguments go somewhat like this: Because the numbers are small, nuclear energy usage could be indefinitely deferred, and conventional fuels could take up the slack until all further doubts and uncertainties will be removed.

184. Perhaps too much is demanded of the industry if it is to solve all the problems and remove all uncertainties in advance. The incumbent Director General of the IAEA, Dr. Sigvard Eklund met the counter-arguments head on when he stated, at Salzburg, that they miss some fundamental points.* First,even the present minimum nuclear objective would result in saving 1.5-2 billion tons of oil per year by the year 2000. This is more than half the total world oil consumption today. Furthermore, if/when the demand for oil will become higher than supply, rapid price increases may follow.

* See speech by Dr. Eklund to concluding session of IAEA Salzburg Conference.

185. Secondly, nuclear power - if it is to provide an insurance against general energy shortages of the future - must be based on a solid base of experience, i.e., the operation of a sufficiently large number of proven reactor types.

186. Thirdly, there is the argument of time lag. Experience proves how long it takes for a new power technology to make a significant contribution to the energy market and to build its fuel - and perhaps even more importantly - human infrastructure. To suggest that these could be dismantled for some time, after which they could be rapidly put together again is a very naive, possibly dangerous contention. This, of course does not mean that the argument will not continue to be heard.

187. There is in the world today an extremely varied energy situation with great changes from one country to the next. This point, too, was brought out and widely discussed at the conference. On the one hand, Italy, for example, has a total indigenous fuel resource base which may be sufficient to meet her demands for, say, the next two years. Both the US and the USSR, on the other hand, have vast oil, gas and coal reserves, although the oil import level of the former may be dangerously high. Therefore, the nuclear policies of these different states are bound to differ, and this fact was recognized.

188. The main question, then, would seem to be one of timing. It is necessary to move ahead with the greatest possible speed if the possibility of a world-wide energy crisis is to be avoided which could well be a crisis of inadequacy - before the end of the century. On this point there was almost total agreement.

TIMETABLE OF PROGRAM

ANNEX A
TO ORAE M92
DATED January 1978

MORNINGS 9.00–12.00		
PLENARY SESSIONS FESTSPIELHAUS	TECHNICAL SESSIONS AND ROUND TABLES KONGRESSHAUS	
	EUROPA-SAAL	HUMBOLDT-SAAL
OPENING 9.30 / 1.A. GENERAL ENERGY PROSPECTS		
1.B 2. NATIONAL SYSTEM PLANS (cont.)	2.3. ISOTOPE SEPARATION	
	2.7.(+ 8.) REPROCESSING TECHNOLOGY	7.2. SMALL POWER REACTORS, DESALTING
2.A.1. INTEGRATED PLANNING OF FUEL CYCLE	7.3. EXPERIENCE OF NUCLEAR POWER IN DEVELOPING COUNTRIES	
2.A.2. INTEGRATED PLANNING OF FUEL CYCLE (cont.)	4.2. SAFETY OF FAST BREEDERS AND THEIR FUEL CYCLE	
1.D. ADVANCED NUCLEAR SYSTEMS	2.1. URANIUM EXPLORATION AND EVALUATION. ENERGY ANALYSIS	
5. NUCLEAR POWER AND PUBLIC OPINION	8. SPECIAL SESSION ON ADVANCED SYSTEMS AND APPLICATIONS	6. SAFEGUARDS
6. SAFEGUARDS	5.1. NUCLEAR POWER AND PUBLIC OPINION	4.3. SAFETY OF FUEL CYCLE FACILITIES
4. NUCLEAR SAFETY	6.R.T. EFFECTIVENESS OF SAFEGUARDS. ROLE OF THE NATIONAL SYSTEM AND ITS RELATIONSHIP TO INTERNATIONAL SAFEGUARDS AND PHYSICAL PROTECTION	3.3. + 3.4. TRANSPORT OF RADIOACTIVE MATERIALS DECOMMISSIONING
3.B. OPERATIONAL ASPECTS OF RADIO-ACTIVITY MANAGEMENT	5.2. NUCLEAR POWER AND PUBLIC OPINION	4.1.3. SAFETY REQUIREMENTS AND EXPERIENCE, THERMAL REACTORS (cont.)
2.B. INTERNATIONAL CO-OPERATION IN THE FUEL CYCLE	3.1.R.T. SOLID HIGH-LEVEL AND LONG-LIVED WASTE DISPOSAL OPTIONS AND THEIR AVAILABILITY 3.2 R T RADIATION DOSE IMPLICATIONS OF DIFFERENT RADIOACTIVITY MANAGEMENT PRACTICES	

TIMETABLE, CONT'D

ANNEX A

AFTERNOONS 14.30–17.30		
PLENARY SESSIONS FESTSPIELHAUS	TECHNICAL SESSIONS AND ROUND TABLES KONGRESSHAUS	
	EUROPA-SAAL	HUMBOLDT-SAAL
1.B.1. NATIONAL SYSTEM PLANS	2.2. RAW MATERIALS MINING AND PROCESSING	
	2.4.1. FUEL TECHNOLOGY FOR LWR AND HWR	7.1.1. NUCLEAR PROGRAMMES IN DEVELOPING COUNTRIES
	2.4.2. FUEL TECHNOLOGY FOR LWR AND HWR (cont.) 2.5.1. PLUTONIUM BEARING FUELS	7.1.2. NUCLEAR MANPOWER DEVELOPMENT
7. NUCLEAR POWER IN DEVELOPING COUNTRIES. 14.00	2.5.2. PLUTONIUM BEARING FUELS (cont.)	
1.C. CURRENT NUCLEAR SYSTEMS	7.R.T. TRANSFER OF NUCLEAR TECHNOLOGY TO DEVELOPING COUNTRIES	2.9. FUEL CYCLE CENTRES 2.6. HTR AND OTHER ADVANCED FUELS
	2 1.R.T. DEVELOPMENTS AND DECISIONS NEEDED TO ASSURE THE NUCLEAR FUEL CYCLE 2.2 R T. INTEGRATED PLANNING OF THE NUCLEAR FUEL CYCLE INDUSTRY	3.2.1. RADIOACTIVITY MANAGEMENT PRACTICES
	4.1.2. SAFETY REQUIREMENTS AND EXPERIENCE, THERMAL REACTORS	3.2 2. RADIOACTIVITY MANAGEMENT PRACTICES (cont.)
	4.1.1. SAFETY REQUIREMENTS AND EXPERIENCE, THERMAL REACTORS (cont.)	3.1 CRITERIA FOR RADIOACTIVITY MANAGEMENT
3.A. STANDARDS FOR RADIOACTIVITY MANAGEMENT	4 R.T. USE OF GENERALIZED SAFETY REVIEWS OF MAJOR NUCLEAR FACILITIES IN REGULATORY PRACTICE 1.R.T. ROLE OF NUCLEAR POWER IN FUTURE ENERGY SUPPLY-PROSPECTS AND CONSTRAINTS	
SUMMARY CLOSING		

ROUND TABLES

ANNEX B
TO ORAE M92
DATED January 1978

Round Tables

	Chairman	Participants
Role of Nuclear Power in Future Energy Supply – Prospects and Constraints	W.B. Lewis (Canada)	A.M. Angeli (Italy) R.R. Matthews (UK) I. Morozov (USSR) W.J. Schmidt-Küster (F.R. of Germany) R.D. Thorne (USA)
Developments and Decisions Needed to Assure the Nuclear Fuel Cycle	Sir John Hill (UK)	J.A. Feron (France) H. Murata (Japan) V.S. Shmidt (USSR) R.D. Thorne (USA) J.P.L. van Dievoet (Belgium)
Integrated Planning of the Nuclear Fuel Cycle Industry	K. Davis (USA)	C. Allday (UK) M. Hagen (F.R. of Germany) V. Meckoni (IAEA) M. Pecqueur (France) E. Svenke (Sweden)
Solid High-Level and Long-Lived (Alpha-Contaminated) Radioactive Waste Disposal Options and their Availability	A.M. Platt (USA)	D.W. Clelland (UK) L.N. Lazarev (USSR) N. Rydell (Sweden) Y.S. Sousselier (France) M. Tomlinson (Canada)
Radiation Dose Implications of Different Radioactivity Management Practices	D. Beninson (UNSCEAR)	A.K. Ganguly (India) N.G. Gusev (USSR) H.P. Jammet (France) Sir Edward E. Pochin (UK/ICRP) W. Rossbander (German Democratic Republic)

ROUND TABLES, CONT'D

ANNEX B

	Chairman	Participants
Use of Generalized Safety Reviews of Major Nuclear Facilities in Regulatory Practices	J. Servant (France)	S.A. Alonso (Spain) A. Birkhofer (F.R. of Germany) R. Gausden (UK) J.H.F. Jennekens (Canada) B.C. Rusche (USA) V.A. Sidorenko (USSR)
Effectiveness of Safeguards, Role of the National System of Accountancy and Control, its Relationship to International Safeguards and Physical Protection	C.-M. Zangger (Switzerland)	E.B. Giller (USA) D. Gupta (F.R. of Germany) R. Imai (Japan) V.N. Misharin (USSR) R. Rometsch (IAEA) H.W. Schleicher (EURATOM)
Transfer of Nuclear Technology to Developing Countries	J.C. Shah (India)	R.N. Alves (Brazil) A. Boettcher (F.R. of Germany) A. Etemad (Iran) L.D. Ibe (Philippines) M.A. Khan (Pakistan) N.F. Sievering (USA)

SELECT GLOSSARY OF ENERGY RELATED TERMS*

ATOMIC ENERGY - The energy released by a nuclear reaction or by radioactive decay.

BARREL (bbl) - A liquid measure of oil, usually crude oil, equals to 42 American gallons or about 306 pounds. One barrel equals 5.6 cubic feet or 0.159 cubic meters. For crude oil 1 bbl is about 0.136 metric tons, 0.134 long tons, and 0.150 short tons. The energy values of petroleum products per barrel are: crude petroleum 5.6 million Btu/bbl; residual fuel oil - 6.29; distillate fuel oil - 5.83; gasoline - 5.25; jet fuel (kerosine type)-5.67; jet fuel (naphtha type) - 5.36; kerosine - 5.67; petroleum coke - 6.02; and asphalt - 6.64.

Bbl/d - Barrels per day

Bbls - Barrels

BREEDER RATIO - The ratio of the number of fissionable atoms produced in a breeder reactor to the number of fissionable atoms consumed in the reactor.

BREEDER REACTOR - A nuclear reactor so designed that it converts more uranium-238 or thorium into useful nuclear fuel than the uranium-235 or plutonium which it uses. The new fissionable materials are created by capture in the fertile materials of neutrons from the fission process. There are three types of breeder reactors: the liquid metal, fast breeder (LMFBR); the gas cooled fast breeder (GCBR); and the molten salt breeder (MSBR).

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*Sources: LCol John W. Storr, Dr. Erik Solem, LCol M.V. Cromie, The Impact of Energy on Strategy: A Consolidated Report, ORAE Report No. R64, June, 1977, Annex C, Glossary of Terms, pp. 71-77, Ottawa, Canada;
Energy Facts II, Prepared For the Subcommittee on Energy Research, Development and Demonstration of the Committee on Science and Technology, U.S. House of Representatives Ninety-Fourth Congress, First Session, by the Science Policy Research Division, Congressional Research Service, Library of Congress, Serial H, Washington, D.C.,August 1975;
An Energy Strategy for Canada, Policies for Self-Reliance, Energy, Mines and Resources Canada, Annex IV, Glossary of Terms, pp. 168-170, Ottawa, 1976.

BREEDER RATIO - The number of new fission atoms produced in a breeder reactor per fissionable atom consumed in the reactor.

BTU - British Thermal Unit. The quantity of heat necessary to raise the temperature of one pound of water one degree Fahrenheit. One BTU equals 252 calories, gram (mean), 778 foot-pounds, 1055 joules and 0.293 watt-hours. A BTU is a very small unit of measurement and when one adds up large quantities of energy, one must count in large multiples of the BTU. Thus, energy balance tables are not infrequently expressed in trillions (10^{12}) and quadrillions (10^{15}) of BTU's. The BTU equivalents of common fuels are as follows:

Fuel and Common Measures	BTU's
Crude Oil - Barrel (Bbl).	5,600,000
Natural Gas - Cubic Foot (CF)	1,032
Coal - Ton	13,000,000 to26,000,000
Electricity - Kilowatt Hour(KWH)	3,412

Two trillion BTU's per year are approximately equal to 1,000 barrels per day of crude oil.

BURN UP (NUCLEAR) - A measure of the consumption of nuclear fuel in a nuclear reactor. Fuel burn-up may be expressed in terms of total energy extracted from the fuel during its stay in the reactor, in terms of percentage of the fuel consumed over that period. For the former, the units usually are megawatt-days of heat per metric ton. (MWD/tonne). One percent burn-up is about 9,000 MWD/tonne.

BWR - Boiling Water Reactor. A nuclear reactor in which water, used as both coolant and moderator, is allowed to boil in the reactor core. The resulting steam can be used directly to drive a turbine.

BY-PRODUCT MATERIAL - (NUCLEAR) Any artificial radioactive material obtained during the production or use of source material or fissionable material. It includes fission products and radioisotopes produced in nuclear reactors, but not radioactive materials occurring in nature or those made with accelerators such as cyclotrons.

CANDU - The nuclear reactor system which is derived from CANada, Deuterium and Uranium, signifying that it is a Canadian concept uses deuterium (heavy water) as the moderator and that the fuel is natural uranium.

CHAIN REACTION - A nuclear reaction that stimulates its own repetition. In a fission chain reaction, a fissionable nucleus absorbs a neutron and fissions, releasing additional neutrons. These in turn can be absorbed by other fissionable nuclei, releasing still more neutrons. A fission chain reaction is self-sustaining when the number of neutrons released equals or exceeds the number of neutrons lost by absorption in nonfissionable material or by escape from the system.

COAL GASIFICATION - The conversion of coal (a solid) to a gas which is suitable for use as a fuel. The gas produced may be either a high-Btu or a low-Btu fuel. High-Btu gas is similar to natural gas and will range in energy content from 900 to 1,000 Btu per cubic foot. Low-Btu gas may range as low as 200 Btu per cubic foot.

COAL LIQUEFACTION - (Coal Hydrogenation) The conversion of coal into liquid hydro-carbons and related compounds by hydrogenation.

CONTAINMENT - (NUCLEAR) A gas-tight shell or other enclosure around a nuclear reactor to contain radioactive vapors and gases that might otherwise be released to the atmosphere in a reactor accident.

CONVERSION - The chemical processing of uranium concentrates into uranium hexafluoride gas.

CONVERSION FACTORS - The energy content of most fuels can vary depending on their source and composition. The following energy equivalents are among those commonly used.

Coal:

Anthracite 26.0 million Btu/ton
Bituminous 24.8 million Btu/ton
Sub-bituminous 19.0 million Btu/ton
Lignite 13.4 million Btu/ton

The average heating value of bituminous coal and lignite exported and used in electricity generation and in industry in 1969 in the United States was 24.7 million Btu/ton.

Petroleum:

Crude Petroleum - 5.60 million Btu/bbl (42 gal)
Residual Fuel Oil - 6.29 million Btu/bbl
Distillate Fuel Oil - 5.83 million Btu/bbl.
Gasoline (including aviation)- 5.25 million Btu/bbl
Jet Fuel (kerosene type) - 5.67 million Btu/bbl
Jet Fuel (naphtha type)- 5.36 million Btu/bbl
Kerosene - 5.67 million Btu/bbl
Asphalt and Road Oil - 6.64 million Btu/bbl

Natural Gas:

Dry - 1031 Btu/cu. ft. at STP
Wet - 1103 Btu/cu. ft. at STP
Liquids (avg) - 4.1 million Btu/bbl

Fissionable Material:

74 million Btu/gm U-235 fissioned

CONVERTER REACTOR - A nuclear reactor that produces some fissionable materials from uranium-238 or thorium, but less than the nuclear material it consumes. Light water reactors and high temperature gas cooled reactors are converters.

COOLANT - A substance circulated through a nuclear reactor to remove or transfer heat. Common coolants include, water, air, carbon dioxide, helium and liquid sodium.

COOLING POND - An artificial pond used to receive and dissipate waste heat, usually from a steam-electric power plant. Approximately an acre of pond surface is needed per megawatt of electric output for a modern steam-electric power plant.

COOLING TOWER (WET) - A unit or structure, usually built of wood, for the cooling of water by evaporation.

COOLING TOWER (DRY) - A unit or structure for cooling water by conduction and convection into the air, much as does the radiator of an automobile.

CORE - The central part of a nuclear reactor which contains the nuclear fuel.

DECAY, RADIOACTIVE - The process whereby atoms of radioactive substances experience transformation into atoms of other elements with attendant emission of penetrating radiations (gamma rays) and some nuclear particles. Each radioactive substance has a unique decay rate which may range from a fraction of a second to hundreds of years or more.

DECAY COOLING - The storage of irradiated fuel elements to allow for radioactive decay of short-lived radioisotopes prior to initiating fuel reprocessing.

DECAY HEAT - The heat produced by radioactive decay of radioactive fission products in a nuclear core.

DECAY PRODUCT - A nuclide resulting from a radioactive disintegration of a radio nuclide, formed either directly or as the result of successive transformation in a radioactive series. A decay product may be either radioactive or stable.

DEPLETED URANIUM - Uranium having less uranium 235 atoms than found in nature, which is 0.71 per cent. Depleted uranium is a by-product of the enrichment process.

DIRECT ENERGY CONVERSION - The generation of electricity from an energy source in a manner that does not involve transference of energy to a working fluid. Direct conversion methods have no moving parts and usually produce direct current. Some methods include thermoelectric conversion, thermionic conversion and magnetohydrodynamic conversion.

DYMAC - DYnamic MAterials Control. System being developed and demonstrated at ERDA's Los Alamos Scientific Laboratory.

EFFICIENCY, THERMAL - Relating to heat, a percentage indicating the available Btu input that is converted to useful purposes. It is applied, generally, to combustion equipment.

$$E \quad \frac{\text{Btu output}}{\text{Btu input}}$$

ENRICHED URANIUM - Uranium in which the amount of uranium-235 present has been artificially increased above the 0.71 percent found in nature. Uranium enriched between 3 and 6 percent is a common fuel for civil nuclear power stations. Uranium enriched to 90 percent or more is used for nuclear propulsion of warships and submarines, and in atomic bombs.

ENRICHMENT - A process by which the proportion of the fissionable uranium isotope (U-235) is increased above the 0.71 per cent contained in natural uranium.

FBR - Fast Breeder Reactor. A fast nuclear reactor that operates with neutrons at the fast speed of their initial emission from the fission process, and that produces more fissionable material than it consumes.

FAST REACTOR - A nuclear reactor in which the fission chain reaction is sustained primarily by fast neutrons. Fast reactors contain no moderator and inherently require enriched fuel. They are of interest because of favourable neutron economy which makes them suitable for breeding.

FEED MATERIALS (NUCLEAR) - Refined uranium or thorium metal or compounds suitable for use in fabricating reactor fuel elements or as feed to uranium enrichment facilities.

FERTILE MATERIAL - A material, not itself fissionable by thermal neutrons, which can be converted into a fissionable material by irradiation in a nuclear reactor. The two basic fertile materials are uranium-238 and thorium-232. When these fertile materials capture neutrons, they become fissionable plutonium-239 and uranium-233, respectively.

FISSION - The splitting of a heavy nucleus into two approximately equal parts (which are radioactive nuclei of lighter elements), accompanied by the release of a relatively large amount of energy and generally one or more neutrons. Fission can occur spontaneously, but usually is caused by nuclear absorption of neutrons or other particles.

FISSION PRODUCTS - The nuclei formed by the fission of heavy elements, plus nuclides formed by the fission fragments' radioactive decay. Fission products are intensely radioactive.

FISSIONABLE MATERIAL - Any material fissionable by slow neutrons. The three basic ones are uranium-235, plutonium-239 and uranium-233.

FUEL - Any substance that can be burned to produce heat. Sometimes includes materials that can be fissioned in a chain reaction to produce heat. The energy content of common fuels are as follows:

1 Barrel (Bbl.) of Crude Oil equals 5,600,000 Btu
1 Cubic Foot (CF) of Natural Gas equals 1,032 Btu
1 Ton of Coal equals 13,000,000 to 26,000,000 Btu

Two trillion Btu's per year are about equal to 1,000 barrels of crude oil per day.

FUEL CELL - A device for combining fuel and oxygen in an electro-chemical reaction to generate electricity; chemical energy is converted diretly into electrical energy without combustion.

FUEL ENERGY CONVERSION-FACTORS - Coal
Anthracite (Penn.) - 26.0 million Btu/ton
Bituminous - 24.8 million Btu/ton
Sub-bituminous - 19.0 million Btu/ton
Lignite - 13.4 million Btu/ton

Petroleum
Crude - 5.6 million Btu/bbl
Residual fuel oil - 6.29 million Btu/bbl
Distillate fuel oil - 5.83 million Btu/bbl
Gasoline - 5.25 million Btu/bbl
Jet Fuel (kerosene-type) - 5.67 Btu/bbl
Kerosene- 5.67 million Btu/bbl
Petroleum Coke - 6.02 million Btu/bbl
Diesel - 5.825 x 10^6 Btu/bbl
Shale - 3.69 million Btu/bbl

FUEL CYCLE - The series of steps involved in supplying fuel for nuclear power reactors. It includes mining, refining of uranium, fabrication of fuel elements, their use in a nuclear reactor, chemical processing to recover remaining fissionable material, re-enrichment of the fuel, refabrication into new fuel elements, and waste storage.

FUEL ELEMENT - A rod, tube, plate or other shape or form into which nuclear fuel is fabricated for use in a reactor.

FUEL FABRICATION - The manufacturing and assembly of reactor fuel elements containing fissionable and fertile nuclear material.

FUEL REPROCESSING - The processing of reactor fuel to recover the unused, residual fissionable materials.

FUSION - The formation of a heavier nucleus from two lighter ones, such as hydrogen isotopes, with the attendant release of energy.

GAS CENTRIFUGE-PROCESS	A method of enrichment in which heavier uranium atoms are partially separated from lighter ones by centrifugal force.
GASEOUS DIFFUSION - PROCESS	A method of enriching uranium based on the tendency of gas atoms or molecules of different masses to diffuse through a porous barrier, or membrane, at different rates.
GCFBR -	Gas Cooled Fast Breeder Reactor. A fast breeder reactor which is cooled by a gas, usually helium, under pressure.
GDP -	Gross Domestic Product.
GEOTHERMAL - GEOTHERMIC	Of or relating to the heat of the earth's interior.
GEOTHERMAL - GRADIENT -	The change in temperature of the earth with depth, expressed either in degrees per unit depth, or in units of depth per degree. The mean rate of increase in temperature with depth in areas that are not adjacent to volcanic regions is about 1 degree F in about 55 feet, corresponding to about 100 degrees F per mile of depth.
GEOTHERMAL STEAM -	Steam drawn from deep within the earth. There are about 90 known places in the continental United States where geothermal steam could be harnessed for power. These are in California, Idaho, Nevada and Oregon.
GNP -	Gross National Product. The total market value of the goods and services produced by the nation before the deduction of depreciation charges and other allowances for capital consumption; a widely used measure of economic activity.
GW/GWe	GIGAWATT. 1,000,000 kilowatts, 1,000 megawatts.
HALF-LIFE - RADIOACTIVE	Time required for a radioactive substance to lose 50% of its activity by decay. Each radionuclide has a unique half-life.
HWR -	Heavy Water Reactor.
HTGCR -	High Temperature Gas Cooled Reactor.

KWe - Kilowatt. 1,000 watts. A unit of power equal to 1,000 watts, or to energy consumption at a rate of 1,000 joules per second. Usually used for electrical power. An electric motor rated at one horsepower uses electric energy at a rate of about 3/4 kilowatt.

KWH - Kilowatt Hour.

LDCs - Less Developed Countries.

LMFBR - Liquid Metal Fast Breeder Reactor. A nuclear breeder reactor cooled by molten sodium in which fission is caused by fast neutrons.

LWR - Light Water Reactor. Nuclear reactor in which water is the primary coolant/moderator with slightly enriched uranium fuel. Two commercially available light water reactor types are the boiling water reactor (BWR) and the pressurized water reactor (PWR).

MHD - Magnetohydrodynamics. A branch of physics that deals with magnetohydrodynamic phenomenon (of or relating to phenomena arising from the motion of electrically conducting fluids in the presence of electric and magnetic fields). In open-cycle MHD generators, the working fluid is exhausted to the atmosphere. In the closed-cycle MHD, the working fluid is continuously recirculated through a closed loop.

MSBR - Molten Salt Breeder Reactor. A breeder reactor in which the fuel would be in the form of a molten salt of plutonium or uranium. It offers several technical advantages, but poses severe, unresolved engineering problems.

MTU - Metric Tons Uranium.

MUF - "Material Unaccounted For". Term used in nuclear safeguards measurements.

MW, Mwh - Megawatts. 1,000 kilowatts, 1 million watts.

NATURAL URANIUM - Uranium as found in nature, containing 0.7% uranium-235, 99.3% of uranium-238 and a trace of uranium-234. It is also called normal.

NDA - Non Destructive Assay Accuracies.

NOL - 'Normal Operating Losses'. Term used in nuclear safeguards.

NUCLEAR POWER PLANT - Any device, machine, or assembly that converts nuclear energy into some form of useful power, such as mechanical or electrical power.

NUCLEAR REACTOR - A device in which a fission chain reaction can be initiated, maintained, and controlled. Its essential component is a core with fissionable fuel. It usually has a moderator, reflector, shielding coolant and control mechanisms. It is the basic machine of nuclear power.

PILOT PLANT - A small-scale industrial process unit operated to test the application of a chemical or other manufacturing process under conditions that will yield information useful in the design and operation of full-scale manufacturing equipment. The pilot unit serves to disclose the special problems to be solved in adapting a successful laboratory method to commercial sized units.

PRESSURIZED WATER REACTOR - A power reactor in which heat is transformed from the core to a heat exchanger by water kept under high pressure to prevent it from boiling. Steam is generated in a secondary circuit.

Pu - Plutonium. A fissionable element that does not occur in nature but is obtained by exposure of U-238 to neutrons in a reactor.

PUMPED STORAGE - An arrangement whereby additional electric power may be generated during peak load periods by hydraulic means using water pumped into a storage reservoir during off-peak periods.

QUADRILLION - 1 million billion; 10^{15}.

Q Unit - One quintillion Btu (1×10^{18} Btu). A very large unit of energy. 1Q represents the energy of 38.46 billion tons of coal, 172.4 billion bbls of oil, 968.9 trillion cu.ft. natural gas.

REPROCESSING - Chemical recovery of unburned uranium and plutonium and certain fission products from spent fuel elements that have produced power in a nuclear reactor.

SNM -	Strategic Nuclear Materials.
SOLAR ENERGY -	The energy transmitted from the sun, which is in the form of electromagnetic radiation. Although the earth receives about one-half of one billionth of the total solar energy output, this amounts to about 420 trillion kilowatt-hours annually.
SOLAR POWER -	Useful power derived from solar energy. Both steam and hot-air engines have been operated from solar energy. Large solar steam engines were built in California, Arizona and Egypt between 1900 and 1914. None of these engines have survived because of competition from the gasoline engine and electric motor.
SOURCE MATERIAL -	As defined in the US Atomic Energy Act of 1954, any material, except special nuclear material, which contains 0.05% or more uranium, thorium, or any combination of the two.
SNG -	Synthetic Gas.
SPECIAL NUCLEAR - MATERIALS	As defined in US Atomic Energy Act of 1954, this term refers to plutonium-239, uranium-238, enriched uranium, or any material artificially enriched in any of these substances.
SWU -	Separative Work Unit. A measure of the effort expended in a uranium enrichment plant to separate a quantity of uranium of a given assay into two components, one having a higher percentage of uranium-235 and one having a lower percentage. Separative work is generally expressed in kilogram units. Therefore, a SWU is a kilogram separative work unit.
TCE -	Tons of Coal Equivalent.
THERMAL EFFICIENCY-	The ratio of the heat used to the total heat units in the fuel consumed.
THERMAL POLLUTION -	An increase in the temperature of water resulting from waste heat released by a thermal electric plant to the cooling water when the effects on other uses of the water are detrimental.
THERMAL POWER - PLANT	Any electric power plant which operates by generating heat and converting the heat to electricity.

THERMAL REACTOR - A nuclear reactor in which the fission process is propagated mainly by thermal neutrons, i.e., by neutrons that have been slowed down until they are in thermal equilibrium with the atoms of the moderator.

THERMIONIC - CONVERSION: A conversion device in which electrical energy is produced directly from heat energy. Theoretical efficiencies range from 15 to 33% with acutal performance of 5 to 16%.

TH - Thorium. A naturally radioactive element with atomic number 90 and, as found in nature, an atomic weight of approximately 232. The fertile thorium-232 isotope is abundant and can be transmuted to fissionable uranium-233 by neutron irradiation. (A naturally radioactive metal. One of its natural isotopes can be converted in nuclear reactors to a nuclear fuel).

THERMONUCLEAR - REACTION: A reaction in which very high temperatures bring about the fusion of two light nuclei to form the nucleus of a heavier atom, releasing a large amount of energy. In a hydrogen bomb, the high temperature to initiate the thermonuclear reaction is produced by a preliminary fission reaction.

TON - A unit of weight equal to 2,000 pounds in the United States, Canada and the Union of South Africa, and to 2,240 pounds in Great Britain. The American ton is often called the short ton, while the British ton is called the long ton. The metric ton, or 1,000 kilograms, equals 2,204.62 pounds. Depending upon specific gravity, a long ton or metric ton will equal from 6.5 to 8.5 barrels of oil.

TRILLION - 1 million million, 10^{12}.

TW - Terawatt. One TW of thermal power relates to roughly 1 billion tons of coal equivalent (TCE) per year.

U - Uranium. A radioactive element with the atomic number 92 and, as found in natural ores, an average atomic weight of approximately 238. The two principal natural isotopes are uranium-235 (0.7 percent of natural uranium) which is fissionable (capable of being split and thereby releasing energy) and uranium-238 (99.3 percent of natural uranium) which is fertile - (having the property of being convertible to a fissionable material.) Natural uranium also includes a minute amount of uranium-234.

U_3O_8 - Uranium Oxide. (Yellowcake). The international standard for the form in which uranium concentrate is marketed.

U-Th - Uranium-Thorium

U-Pu - Uranium-Plutonium

WASTES, RADIOACTIVE - Equipment and materials, from nuclear operations, which are radioactive and for which there is no further use. Wastes are generally classified as high-level (having radioactivity concentrations of hundreds to thousands of curies per gallon or cubic foot), low level (in the range of 1 microcurie per gallon or cubic foot), or intermediate.

WATT - The rate of energy transfer equivalent to one ampere under an electrical pressure of one volt. One watt equals 1/746 horsepower, or one joule per second.

WATT-HOUR - The total amount of energy used in one hour by a device that uses one watt of power for continuous operation. Electrical energy is commonly sold by the kilowatt hour (1,000 watt-hours).

ANNEX D
TO ORAE M92
DATED January 1978

ENERGY ORGANIZATIONS AND ASSOCIATIONS

AEC	US Atomic Energy Commission. Now part of ERDA subsequently in the US Department of Energy.
AECB	Atomic Energy Control Board (Canada)
AECL	Atomic Energy of Canada Limited
CEA	Central Electricity Authority (UK)
CEGB	Central Electricity Generating Board (UK)
CMEA	Council of Mutual Economic Assistance. A rough equivalent of the European Economic Community for the Eastern Communist countries.
CQRI	Centre Québecois de relations internationales
CRA	Commissariat à l'Energie Atomique (France)
EC	European Community. Comprises the European Atomic Energy Community (see EURATOM), the European Coal and Steel Community (see ECSC), and the European Economic Community (see EEC).
ECSC	European Coal and Steel Community
EdF	Electricité de France
EEC	European Economic Community
ENEL	Ente Nazionale per l'Energia Elettrica (Italy)
EURATOM	European Atomic Energy Community
ERDA	Energy Research and Development Agency (US), now part of the US Department of Energy.
FFTF	Fast Flux (or Fuels) Test Facility (Part of US Atomic Energy Commission.)
FORATOM	Forum Atomique Européen
IAEA	International Atomic Energy Agency, part of UN Specialized Agencies, HQ in Vienna, Austria.

ANNEX D

IEA	International Energy Agency, part of OECD, Paris.
ICAI	Institut Canadien des affaires internationales
IIASA	International Institute for Applied Systems Analysis, Schloss Laxenburg, Austria.
NEA	Nuclear Energy Agency, OECD
OAPEC	Organization of Arab Petroleum Exporting Countries. It was founded in 1968 for co-operation in economic and petroleum affairs. Its original members were Saudi Arabia, Kuwait, and Libya. Abu Dhabi, Algeria, Bahrain, Dubai, and Qatar joined in 1970.
OECD	Organization for Economic Co-operation and Development.
OEEC	Organization for European Economic Co-operation. Now collapsed into OECD, which include several non-European members.
OPEC	Organization of Petroleum Exporting Countries, which was founded in 1960 to unify and co-ordinate petroleum policies of the members. The members and the date of membership are: Abu Dhabi (1967); Algeria (1969); Indonesia (1962); Iran (1960); Iraq (1960); Kuwait - (1960); Libya (1962); Nigeria (1971); Qatar (1961); Saudi Arabia (1960); and Venezuela (1960). OPEC headquarters is in Vienna, Austria.

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AUTHOR: Dr. Erik Solem

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13. ABSTRACT

Nuclear power will be a necessary and probably irreplaceable source for the future energy supply of the world for a long time to come. Several political, economic and social consequences flow from this. Although the spread of nuclear power contributes to the potential threat of proliferation, the link between nuclear power and nuclear weapons proliferation is not – contrary to what is assumed or stated by media sources – automatic.

The International Atomic Energy Agency (IAEA) must continue to acquire increased sophistication and technical capability to cope with the future introduction of new, large scale fuel cycle facilities. An internationally agreed upon code of conduct as well as a comprehensive, effective, hence reliable international safeguards system must be developed. There is no alternative to such a system if nuclear energy is to be fully utilized on a global basis.

This report examines the main findings, conclusions and recommendations of Salzburg 77 as well as concurrent developments of importance to present and future use of nuclear power.

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