The Role of Nuclear Energy: Within a National Energy Plan An IAEA Training Course for Developing Countries

by J.P. Charpentier

INTRODUCTION

The history of the development of various energy technologies tells us that it very often takes a minimum of 25–30 years for a new technology to pass from the laboratory to the commercial stage. A further 20 years or so is frequently needed before the given technology occupies an important place on the energy market. Most of the non-conventional energy sources are still at the initial stage of development, only a few of them having attained the level of a demonstration prototype. It therefore follows that for quite a few decades to come energy demand can only be satisfied on the basis of proven sources and technologies currently available.

Although it is quite certain that all our efforts should aim at developing all possible energy sources, it is equally true that fossil and nuclear fuels – and to a lesser extent hydroelectric power – are the sole options of importance open to mankind for the rest of this century and perhaps even after that. This does not, of course, preclude the possibility, in highly specific local situations, of resorting to solar energy or using biomass, but it will not be possible, on a global scale, for these energy forms to play a major part in the world's energy balance during this century.

Within the context of each country, whether one that is already highly industrialised or one still developing, the implementation of an energy plan should enable it to gain a better idea of future needs and to determine the technical options that will best meet those requirements, bearing in mind the natural constraints imposed by the country's resources, industrial infrastructure, available manpower and, it goes without saying, financial capacity.

RATIONALE AND AIMS OF THE COURSE

With the idea of assisting developing countries to put energy plans of this kind into effect, the IAEA has organized a training course in collaboration with the French Atomic Energy

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* The exact definition of a developing country is a matter of some difficulty. For the purposes of this section on the nuclear energy situation, the term applies only to those countries with market economies which qualify for technical assistance from the United Nations.

Commission (CEA), the United Nations Centre for Natural Resources, Energy and Transport (UNCNRET), and the World Bank (IBRD). The course aims at enabling energy planning experts to gain a better perspective of the potential of nuclear energy in their national energy plans.

Before describing the structure of the course in detail, it would be worthwhile briefly recalling the way in which nuclear energy is being harnessed in the developing countries.*

By 1 January 1980, there were eight developing countries in the world with nuclear power plants in operation, under construction or firmly on order (see Table 1). The eight reactors now in operation provide a total power output of about 2800 MWe, the 22 reactors under construction represent an output of 15 000 MWe, and the reactor on order in Argentina will have a capacity of 560 MWe.

The table below summarizes the situation.

	Number of countries	Names of countries	Number of power plants	Capacity (MWe)
In operation	5	Argentina, India, Republic of Korea, Pakistan, Taiwan	8	2 844
Under construction	7	Argentina, Brazil, India, Republic of Korea, Mexico, Philippines, Taiwan	22	15 021
On order	1	Argentina	1	560
Total	13		31	18 425

The course on the role of nuclear energy within a national energy plan is obviously not intended purely for the benefit of the eight countries already engaged in using nuclear energy; it is in fact open to all developing countries that are Member States of the Agency (see Table 2). The aim is not a systematic promotion of nuclear energy, but rather to offer each country the chance of making a careful and objective choice among the various energy options open to it. Particular attention is given to the link (too often disregarded) between the choice of the primary energy source and the energy needs of the end consumers.

For each possible form of primary energy (oil, gas, coal, hydroelectricity, nuclear energy, solar energy, geothermal energy, biomass and so forth), a systematic description of the benefits and disadvantages is given in such a way as to increase the participants' awareness of the complementary aspects of the various energy types.

Table 1. Nuclear Power Plants in the Developing Countries (January 1980)

Country	Name of plant	Type	Net electric power	Present status	Year of commissioning
Argentina	Atucha-1	PHWR	345	in operation	1974
	Embalse	PHWR	600	under construction	1981
	Atucha-2	PHWR	560	on order	1987
Brazil	Angra-1	PWR	626	under construction	1980
	Angra-2	PWR	1245	under construction	1985
	Angra-3	PWR	1245	under construction	1986
India	Tarapur-1	BWR	198	in operation	1969
	Tarapur-2	BWR	198	in operation	1969
	Rajasthan-1	PHWR	206	in operation	1973
	Rajasthan-2	PHWR	207	under construction	1980
	Kalpakkam-1	PHWR	220	under construction	1981
	Kalpakkam-2	PHWR	220	under construction	1983
	Narora-1	PHWR	220	under construction	1984
	Narora-2	PHWR	220	under construction	1985
Korea	Kori-1	PWR	564	in operation	1978
	Kori-2	PWR	605	under construction	1983
	Wolsung-1	PHWR	629	under construction	1982
	Korea Nuclear-5	PWR	900	under construction	1984
	Korea Nuclear-6	PWR	900	under construction	1985
	Korea Nuclear-7 and 8	PWR	1539	under construction	1985/86
Mexico	Laguna Verde-1	BWR	654	under construction	1982
	Laguna Verde-2	BWR	654	under construction	1983
Pakistan	Kanupp	PHWR	125	in operation	1972
Philippines	PNPP-1	PWR	621	under construction	1984
Taiwan	Chin-san-1	BWR	604	in operation	1977
	Chin-san-2	BWR	604	in operation	1978
	Kuosheng-1	BWR	951	under construction	1981
	Kuosheng-2	BWR	951	under construction	1982
	Nuclear No.5	PWR	907	under construction	1984
	Nuclear No.6	PWR	907	under construction	1985

Abbreviations: PHWR = Pressurized heavy-water reactor.
PWR = Pressurized light-water reactor
BWR = Boiling light-water reactor.

PARTICIPATION AND COURSE STRUCTURE

That Member States of the Agency have correctly understood the point of the course, is shown by the fact that the list of participants includes a number of countries which have so far manifested no more than a limited interest in the use of nuclear energy (see Tables 3 and 4).*

* Table 3 is an attempt to classify developing countries according to their nuclear intentions. Leaving aside the countries that have never indicated any nuclear interest (stage 0), the remainder can be divided into three categories: Stage 1 applies to countries that have only gone as far as making a few studies, Stage 2 to countries constructing nuclear reactors and stage 3 to countries already having reactors in operation. This classification is based on a more detailed study presented at the Symposium on Manpower Requirements and Development for Nuclear Power Programmes Ref.[1].

Table 2. Developing Member States of the IAEA

Afghanistan
Albania
Algeria
Argentina
Bangladesh
Bolivia
Brazil
Bulgaria
Burma
Chile
Colombia
Costa Rica
Cuba
Cyprus
Czechoslovakia
Democratic Kampuchea
Dominican Republic
Ecuador
Egypt
El Salvador
Ethiopia
Gabon
Ghana
Greece
Guatemala
Haiti
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ivory Coast
Jamaica
Jordan
Kenya
Korea, Republic of
Kuwait
Lebanon
Liberia
Libyan Arab Jamahiriya
Madagascar
Malaysia
Mali
Mauritius
Mexico
Mongolia
Morocco
Nicaragua
Niger
Nigeria
Pakistan
Panama
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Romania
Saudi Arabia
Senegal
Sierra Leone
Singapore
Sri Lanka
Sudan
Syrian Arab Republic
Thailand
Tunisia
Turkey
Uganda
United Arab Emirates
United Republic of Cameroon
United Republic of Tanzania
Uruguay
Venezuela
Viet Nam
Yugoslavia
Zaire
Zambia

Table 3. Classification of developing countries according to nuclear development

Stage 3: Operation	Stage 2: Construction	Stage 1: Studies		Stage 0: Pre-Planning
Argentina	Brazil	Algeria	Lybian Arab Jamahiriya	Other developing countries
India	Mexico	Bangladesh	Malaysia	
Korea, Republic of	Philippines	Chile	Morocco	
Pakistan		Colombia	Panama	
Taiwan		Cuba	Peru	
		Ecuador	Portugal	
		Egypt	Saudi Arabia	
		Greece	Singapore	
		Indonesia	Sri Lanka	
		Iran	Syrian Arab Republic	
		Iraq	Thailand	
		Jamaica	Turkey	
		Jordan	Uruguay	
		Kuwait	Venezuela	
Number of countries 5	3	28		

Up to the present time there have already been two such training courses, both held at the Saclay Nuclear Research Centre. The courses were given in French, with one lasting nine weeks (May-June 1978) and the other seven (May-June 1979). A third course in French has been planned for this year (12 May–27 June 1980) and a fourth course, to be given in English at Karlsruhe Nuclear Research Centre (Federal Republic of Germany), is being considered.

Table 4. Participants to the Training Course by Country

Countries	Number of participants			Stage of nuclear development of the country	
	Session		Total	Stage (cf. Table 3)	Expected year for nuclear power in operation (up to 2000)
	1978	1979			
North Africa					
• Algeria	4	5	9	1	2000
• Morocco	5	2	7	1	–
Middle East					
• Egypt	2		2	1	1990
• Iraq	1		1	1	2000
• Lebanon	1		1	0	–
• Syrian Arab Republic	1		1	1	–
Africa					
• Gabon		1	1	0	–
• Mali		1	1	0	–
Latin America					
• Argentina		1	1	3	operating
• Bolivia		1	1	0	–
• Brazil	1	5	6	2	1985
• Chile	1	1	2	1	1990
• Colombia	2		2	1	2000
• Guatemala		1	1	0	–
• Mexico	2		2	2	1985
Far East Asia					
• Bangladesh	1		1	1	–
• Indonesia	1		1	1	1990
• Korea, Rep. of		3	3	3	operating
• Singapore	1		1	1	–
• Viet Nam		2	2	0	–
Eastern Europe					
• Bulgaria	3	2	5	3	operating
• Czechoslovakia	1	2	3	3	operating
• Hungary		1	1	2	1985
• Poland	1	1	2	1	1990
• Romania	2		2	1	1990
• Yugoslavia	1	1	2	2	1985
Total (26 countries)	31	30	61		

The first two courses were each attended by some 30 participants from a total of 26 developing countries (see Table 4). The calibre of the participants both as regards academic training and professional grade in their respective countries was usually very high. A number of them occupied posts where they were in charge of energy planning either in national commissions or in utilities.

The course itself is divided into two parts, known as "modules", lasting about three weeks each (see detailed programme in Annex). Between the two modules is a week's study tour of various concerns and research centres.

The first part of the course is concerned with a technical analysis of the various energy options. The lecturers first give a survey of renewable and non-renewable energy resources, after which they make a comparative analysis of the various energy chains, i.e. from the mine all the way through to the energy product required by the end consumer; this part of the course then ends with an analysis of the rational use of energy in various economic contexts. Ecological questions and safety-related matters are component parts of this programme. At the end of the first half of the course, two or three participants give an account in outline of the energy situation existing in their own countries, thereby providing an opportunity for general discussion of some specific instances.

The second half deals exclusively with economic questions and with techniques for comparing the various possible energy options. Here, the lectures commence by discussing the relationship between macro-economic growth and energy requirements, after which a number of cases in point are discussed. As far as possible these talks are given by the participants themselves and are open to comment at round-table discussions. Next comes a series of lectures aimed at describing and comparing the econometric techniques and models that can be used for making forecasts in energy planning. This second half of the course ends with an examination of the financial aspects of energy investments in developing countries. The lectures given by representatives of the World Bank and the round-table discussions led by them have been a subject of great interest.

The success of this course to date is largely due to the fact that Member States have always sent high-calibre representatives to attend it and to the co-operation of the other participating organizations: the United Nations Centre for Natural Resources, Energy and Transport (UNCNRET), the World Bank (IBRD), the International Energy Agency (IEA/OECD), the International Institute for Applied Systems Analysis (IIASA) and particularly, the National Institute of Nuclear Science and Technology (INSTN) at Saclay.

Reference

[1] Csik B.J., "Manpower requirements for nuclear power in developing countries", IAEA-SM-238/42 (Proc. Symp., Vienna, 1980), IAEA, Vienna (1980) 11.

ANNEX: PROGRAMME FOR THE COURSE HELD 14 MAY–29 JUNE 1979

PART I: UTILIZATION, MANAGEMENT AND MOBILIZATION OF ENERGY (14 May–1 June)

Description of the course (1 day).
General problems of energy analysis.

A. **Energy sources** (6 days)

1. List of resources

• Non-renewable resources

– List of world non-renewable resources (coal, oil, gas and nuclear fuel); geographical distribution.
– Consumption, utilization of non-renewable resources; present balance and future prospects.
– Resources of regional interest and their size.

•• Renewable resources

– List of renewable resources (hydroelectric power, solar energy and biomass, tidal and wind energy, etc.).
– Comparative prospects for the utilization of these resources; geographical distribution.

••• Round-table discussion: the world's energy resources

2. Introduction to the technical aspects of the use of energy resources

• Nuclear energy

– Working principles of reactors.
– General considerations regarding different types of nuclear power plant and the fuel cycle.
– Films dealing with reactors and uranium.
– Ore extraction, concentration and conversion.
– Uranium enrichment: techniques, production capacity and cost.
– Fuel element fabrication.
– Reprocessing, radioactive waste and effluents.
– Selection of the type and power output of a reactor; adjustment to the existing electricity grid; specific case of combined heat and power plants.
– Economic aspects of nuclear energy: investment, operation and fuel.
– Stages in launching a nuclear power programme.

•• Round-table discussion on nuclear energy and the developing countries

••• Solar energy

– General considerations: present status of solar energy and prospects for its use; different systems and technical problems.
– Solar power plants and technical problems associated with them.
– Economic aspects of solar energy: investment and operating costs for different types of installations.
– A case study: solar energy and the developing countries.

B. Comparative analysis of different usable energy sources (6 days)

1. Technical and economic problems involved in the selection of an energy system: introduction

● Description and relative importance of various technical and economic constraints on the use of coal, oil, nuclear and solar energy, etc.

– Processing and reprocessing of different fuels.
– Fuel supply network (pipelines and transportation).
– Constraints on the selection of the production site.
– Power transmission grid.
– Investment and operating cost distribution.

●● Example: siting a nuclear installation

2. Factors to be considered in the development and use of different energy sources

● Industrial and human environment; local industry; personnel training
●● Public opinion
●●● Case studies: nuclear, solar, hydroelectric and conventional fossil fuel power plants; investment and operating costs

3. Analysis of various energy systems; primary energy, secondary energy, useful energy

● Coal; oil
●● Solar energy
●●● Nuclear energy
●●●● Round-table discussion of the various energy systems

4. Adverse effects

● Introduction; radiation protection and safety
●● Safety: concepts, principles and methods
●●● Risk comparison for different energy programmes
●●●● Nuclear safety: summary of the present situation and trends; case study: risk evaluation

5. Round-table discussion of the hazards involved in transporting various fuels; oil, coal, nuclear fuel, etc.

C. Rational use of energy (2 days)

1. Meeting various energy needs

● Energy needs: distribution and relative importance
●● Specific role of electrical energy

2. Case studies

● Developing countries which have already had some nuclear experience (e.g. Brazil)
●● Developing countries that import oil (e.g. Israel)
●●● Developing countries using solar energy (e.g. Niger)
●●●● Round-table discussion of PART I of the course

STUDY TOURS (5–8 June)

5 June: Framatome: plant at Creusot; plant at Chalon-sur-Saône.

6 June: Electricité de France: nuclear site at Bugey.

7 June: Morning: Eurodif: uranium enrichment plant under construction at the Tricastin site.
Afternoon: Commissariat à l'Energie Atomique/Electricité de France: nuclear power plant at Marcoule (Phénix fast breeder reactor).

8 June: Commissariat à l'Energie Atomique (Cadarache Nuclear Research Centre): Solar research laboratories; Test facilities of the Water-Cooled Reactor and Fast Neutron Reactor Departments.

PART II: ECONOMICS AND PLANNING OF ENERGY
(11–29 June)

A. The problem of energy and economic development within a worldwide context: general considerations (2 days)

1. The link between energy and economic growth.
2. Recent forecasts for energy: present and future problems.
3. Interdependence of the industrialized and developing countries.
4. The main problems in the economic development of the Third World.
5. Problems involved in the development of nuclear energy in the Third World.

B. The problem of energy in the developing countries (2 days)

1. Energy and developing countries.
2. Problems connected with data and estimates for the developing countries.
3. A specific case: Algeria.
4. A specific case: The Ivory Coast.

C. An account of some of the techniques used for forecasting and planning (5 days)

1. A simple overall model

• An overall model constructed by IIASA
•• Group discussion of the application of this model to a specific case (based on actual data from a country) or an imaginary case

2. Macro-economic considerations

• National accounting systems: aggregates; input-output matrices; application exercises
•• Energy balances in developing countries

3. Can the methods used in the industrialized countries be applied to a developing country?

• A model for demand and a model for supply

– Analysis of energy demand: the MEDEE model.
– The graph linking energy sources and consumption; the utilization of sources: the EFOM model.

●● An account of the French situation

– French energy planning: objectives and methods; discussion by a planning expert; debate between (a) a representative of the state; (b) a representative of an industrial concern; (c) a representative of a trade union.
– Forecast of electricity consumption within the context of overall energy planning: discussion among representatives from a ministry (Electricity Board), a utility (EdF) and the French Energy Convervation Agency.

●●● Discussion of the applicability of different methods to the situation in developing countries

– Further thoughts on planning in developing countries in the light of the discussions in sections (3) (●) and (●●) above.

D. Investment financing (2 days)

1. Methods used as a basis for investment decisions

● The investment decision: general considerations
●● Present value methods and examples of application
●●● Critical comments by a banker
●●●● Round-table discussion on investment financing

2. Economic and financial analyses

● Guidelines for private financing: financial profit and decision-making
●● Financing public investment: economic and financial considerations
●●● Price determination: techniques based on marginal costs compared with those based on average cost

E. Sources of finance for developing countries (1 day)

1. Principles, courses of action and criteria employed by:

● International organizations, e.g. the World Bank (IBRD), and other international development banks
●● Private concerns as represented by a banker

2. Present value and feasibility studies; evaluation techniques

F. A specific example: the development of electricity supply in the Third World (1 day)

1. The role of electricity in a developing country

● Optimization of installed capacity

– simplified method.
– WASP model.

2. Application to a developing country

3. Round-table discussion on the development of electricity supply in the Third World

G. Conclusion (1 day)

1. Geopolitics: feast or famine; development models: energy and productivity; energy and economic policy: the decision to import; consequences; discussion

2. Final discussion: the choices for a developing country.