NUCLEAR POWER ECONOMICS

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NUCLEAR ENERGY DEVELOPMENT : SEVERAL SUCCESSIVE STEPS

For many technical reasons which have not to be rewieded here, nuclear energy on industrial scale is almost totally produced through electricity generation. This fact will have to be taken into consideration for economic evaluation of nuclear energy.

When analyzing nuclear development, several successive steps can be considered.

In the first step, nuclear energy is used as a substitute of other primary energy sources to generate electricity, the extent of electricity demand being independent of the fact that nuclear units are operated or not within the generation system. Therefore, the economic evaluation of nuclear energy cannot be separated from the more general economic evaluation of electricity generation system considered as a whole, including all kinds of generation facilities : hydro plants, nuclear power plants, fossil-fuelled power plants, gas turbines etc...

Since nuclear units have a lower fuel cost than other thermal units, they will be operated on base load at their first stage of development.

In this simple but current case, an approximate economic evaluation may consist in comparing total generation costs (including capital, operation and fuel costs) between different power plants (nuclear, coal-fired or oil fired) providing a same contribution to the network.

For this purpose, levelized cost comparisons, such as made by the Union Internationale des Producteurs et Distributeurs d'Electricité (UNIPEDE) or by the Nuclear Energy Agency (OECD), may provide valid conclusions on the economic advantage of nuclear power plants compared to fossil-fuelled ones, as described in the following part of this presentation.

A second stage is reached when the total installed nuclear capacity is large enough to cover total base load requirements. Then, any additional nuclear capacity will have to be used in load following, at least during the periods of lower electricity demand [a].

The accurate way of trading with this problem is to determine the optimized structure which allows to minimize the total generation cost for the whole generation system, now and in the future. This rather complex problem is currently solved by using dynamic programming methods.

But levelized cost comparisons can also be used, the cost calculations being made for several reduced annual load factors, in order to determine approximately how far nuclear units have an economic interest for load following, instead of fossil-fuelled units.

It will be noticed that nuclear energy, which is still developing through electricity generation, can induce additional increases of the electricity demand compared to selfgrowing demand. Substitutions electricity/other primary energy sources then appear for specific competitive uses : new industrial process, modification of existing process, transportation, non-industrial fields etc...

Here, the electricity demand (and consequently the electricity consumption growth) may vary substantially according to the amounts of substitutions that become profitable, even if the total energy demand is equal.

When the load following mode is reached, the optimized balance between nuclear and fossil fuelled generation is fully depending on relative values of the different components of the total generation cost for each individual kind of generation unit.

[a] In practice, either only some of the nuclear units or all of them may participate to load following, but in the second case with a lower range of load variation for each unit.

THE WORLD NUCLEAR ENERGY PRODUCTION HAS RISEN AT A LARGE EXTENT DURING THE YEARS 1975-1986 BUT SITUATIONS ARE TYPICALLY DIFFERENT ACCORDING TO COUNTRIES AND AREAS

Table 1 shows the evolution of nuclear capacities and generations from 1975 to 1986 in the countries and areas where nuclear energy is quite significant and for the world.

The total nuclear capacity has risen by more than three times in the world but large differences can be seen between countries and areas with multiplying factors varying from 1.7 (UK) to 15.2 (France).

Figure 1 shows the distribution of different kinds of reactor all over the world.

TABLE 1

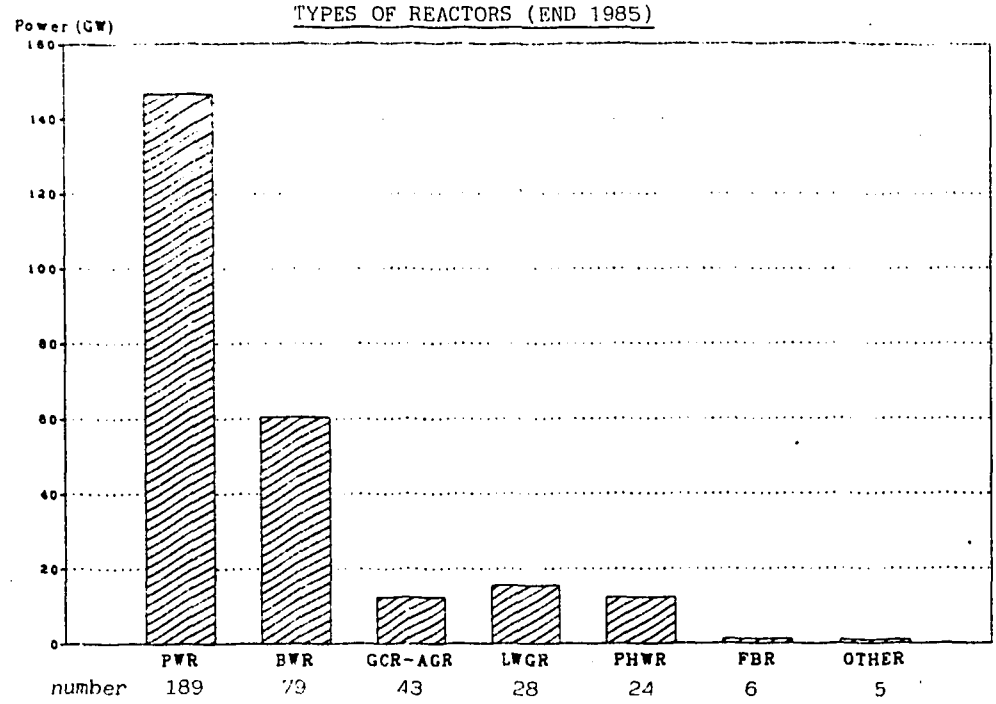
NUCLEAR CAPACITY AND GENERATION (Gross)
1975 - 1986

	1975 (end)			1986 (end)		
	Number of reactors	Capacity GW	Generation TWh	Number of reactors	Capacity GW	Generation TWh
USA	58	40.3	182.0	103	93.0	433.5
FRANCE	10	3.1	18.3	49	47.2	254.2
USSR	23	5.5	n.a.	51*	30.2*	167.0*
JAPAN	12	6.6	21.7	33	24.7	164.8
FRG	9	3.5	21.9	17	18.3	117.4
UK	32	7.7	30.9	38	12.9	59.1
CANADA	7	2.7	13.4	17	11.8	74.5
SWEDEN	5	3.3	12.0	12	9.9	69.9
SPAIN	3	1.1	7.5	8	5.8	37.5
BELGIUM	4	1.8	6.8	7	5.7	38.6
TAIWAN, CHINA				6	5.1	26.9
REP.OF KOREA				6	4.8	26.1
SWITZERLAND	3	1.1	7.7	5	3.1	22.5
.....						
WORLD(TOTAL)	182	81	335	381*	272*	1 479*

* 1985 figures

FIGURE 1

TYPES OF REACTORS (END 1985)



If we consider the nuclear share in the total electricity generation in 1985 (Figure 2), we can separate different groups of countries and areas.

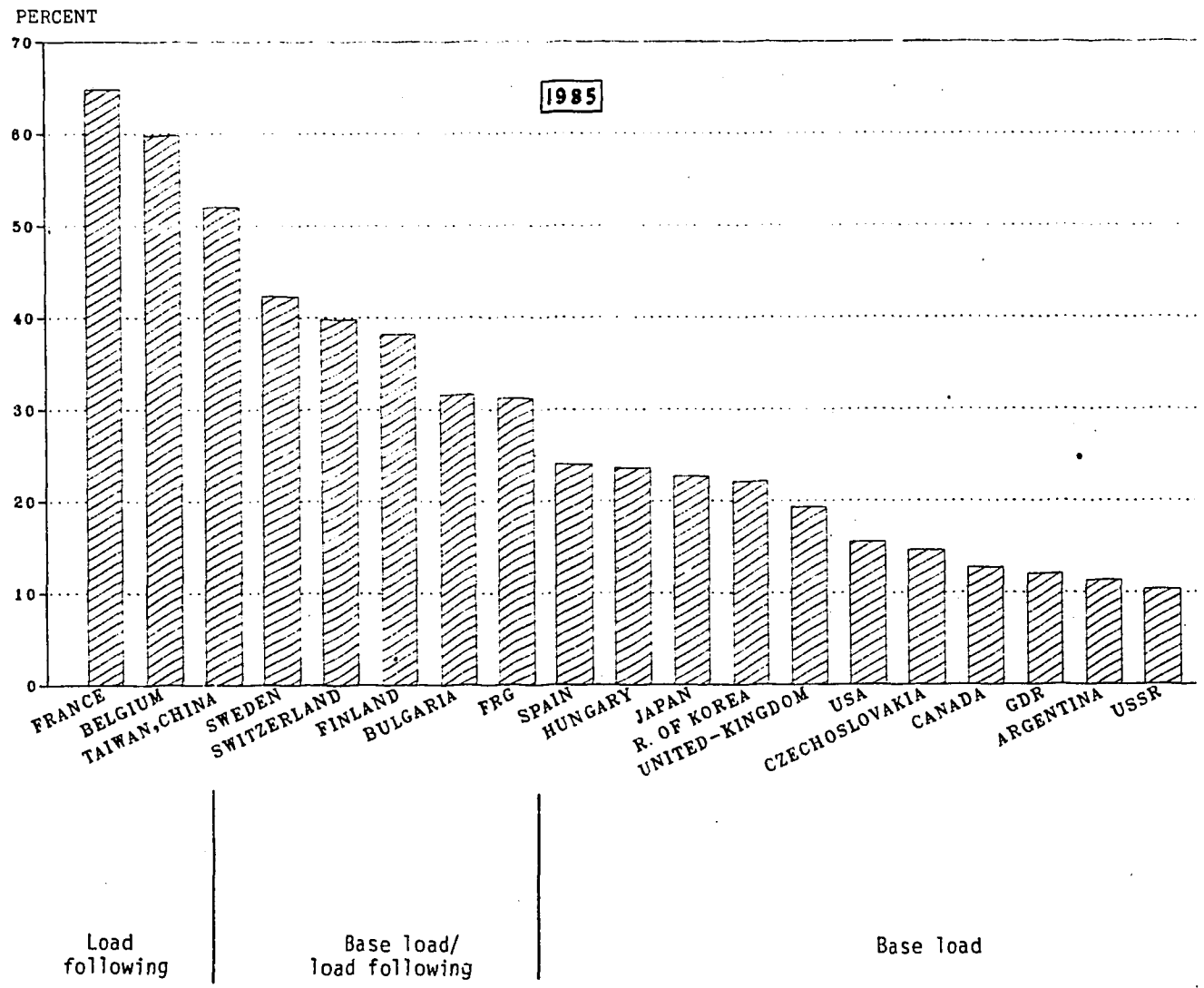
For the two first groups, nuclear generation has already or nearly reached the load following mode (at least during the periods of lower electricity demand).

For the countries and areas belonging to the third group, nuclear units are only operated on base load. For some countries and areas, base load generation is covered by nuclear at a large extent but for many others nuclear generation covers only a small percentage of total.

Those differences in nuclear contribution between countries and areas are not supposed to dwindle in the next ten of fifteen years.

FIGURE 2

NUCLEAR SHARE OF TOTAL ELECTRICITY GENERATION



A CLEAR ECONOMIC ADVANTAGE FOR NUCLEAR POWER PLANTS TO BE COMMITED IN THE MID 1990s

Figures and conclusions below refer to results that were obtained by UNIPEDE and NEA - OECD for projected generating costs of nuclear and coal-fired power plants to be commissioned in 1995, in sixteen various countries and areas.

Levelized generating costs - Ranges of values

This is shown in Table 2, which is based upon a reference case of a 5 % real term discount rate, 25 year life, levelized load factor of 72 %.

The total levelized costs for both nuclear and coal generation varied by over a factor of two from low to high in the studies. The major nuclear cost component, investment cost, showed a variation of over a factor of three, while the major component for coal-fired stations, the fuel cost, varied by over a factor of six.

TABLE 2

RANGE OF LEVELIZED COST DATA
(Jan 1984 US mills/kWh)

	LWRs	Coal-Fired
INVESTMENT	9.5 - 32.0	6.7 - 14.2
OPERATING AND MAINTENANCE	1.6 - 7.7	2.1 - 10.6
FUEL	5.5 - 10.1	6.7 - 41.3
TOTAL	20.3 - 43.6	21.8 - 54.7

Light Water Reactor (LWR) data reported from 13 countries and areas; coal based data from 14 countries and areas.

An alternative comparison is shown in Table 3. It compares the cost distribution as a percentage of the total levelized cost for the reporting countries[b] and areas. There is greater uniformity here since several of the factors which vary between countries and areas affect both coal and nuclear generating costs.

TABLE 3

DISTRIBUTION OF LEVELIZED COSTS (%)

	LWRs	Coal-Fired
INVESTMENT	46 - 73	14 - 42
OPERATING AND MAINTENANCE	11 - 19	5 - 21
FUEL	16 - 35	47 - 76
TOTAL	100 %	100 %

One fact which stands out from this table is that the investment percentage for nuclear is almost identical to the fuel percentage for coal, and vice versa. This means, of course, that once the plants are built the cost of electricity from nuclear plants is much less sensitive to future price variations than that from coal-fired plants. This is the basis for the frequent claim that nuclear generating costs are relatively inflation proof.

Another point that should be made, which is not directly shown on the tables, is that in over a quarter of the countries or regions reporting, the cost of fuelling coal-fired plants exceeded the total nuclear generating costs. In these cases it would appear to be economically justifiable to replace unamortised base load coal-fired plants with new nuclear plants.

[b] Western Canada was left out of this comparison since it has a uniquely low coal cost which gives it a cost distribution well outside the range for other regions.

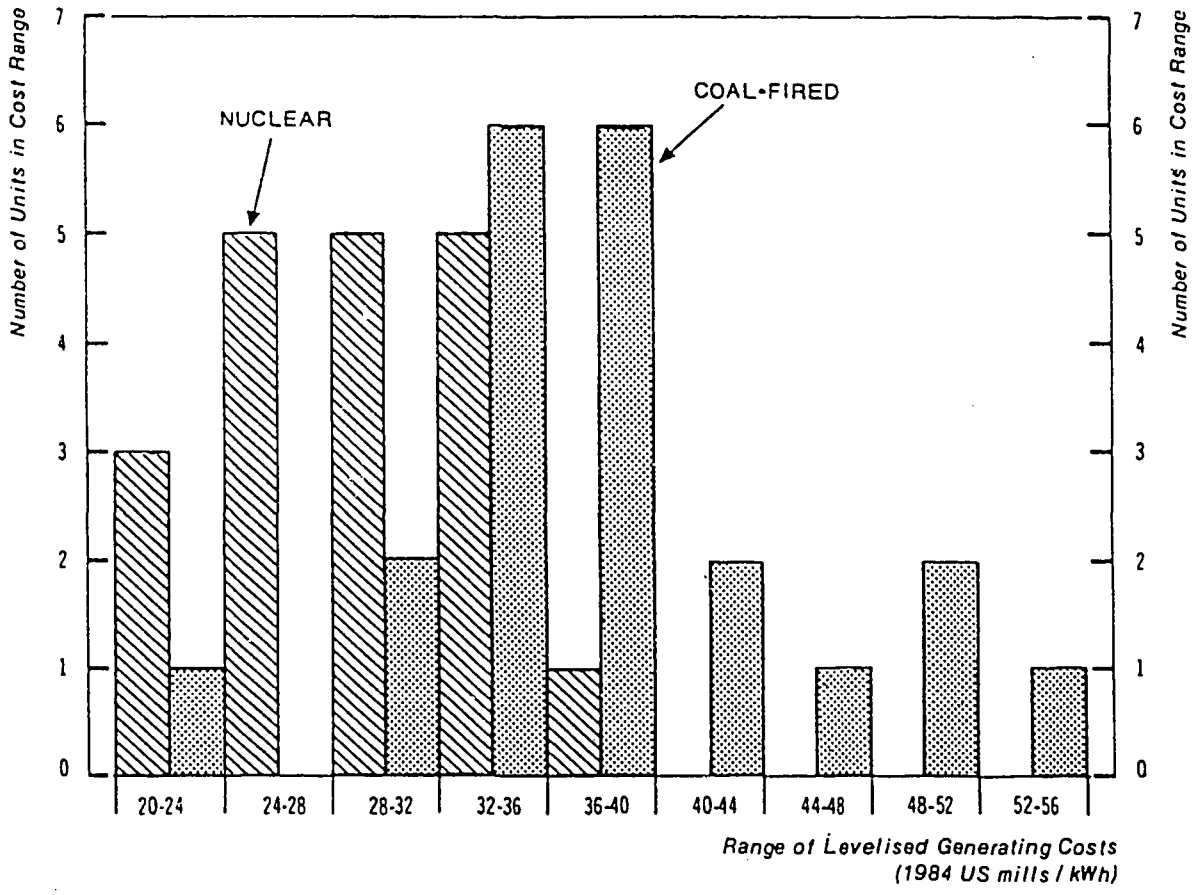
Relative competitiveness of nuclear/coal-fired power plants

The main point of the studies was to examine whether nuclear generation will be competitive with coal-fired generation for plants committed about now. One way of examining that question is shown on Figure 3.

It illustrates the distribution of the levelized cost data supplies on 19 nuclear cases and 21 coal-fired cases. It shows that the coal costs tend to be higher than nuclear costs, though there is some overlap.

FIGURE 3

DISTRIBUTION OF PROJECTED NUCLEAR. AND COAL-FIRED GENERATING COSTS



More important than this overall impression are comparisons of nuclear/coal-fired costs in individual countries or regions which are shown in Figure 4. It should be noted that these figures are not dependent on exchange rates, the cost comparison being made within each country or area.

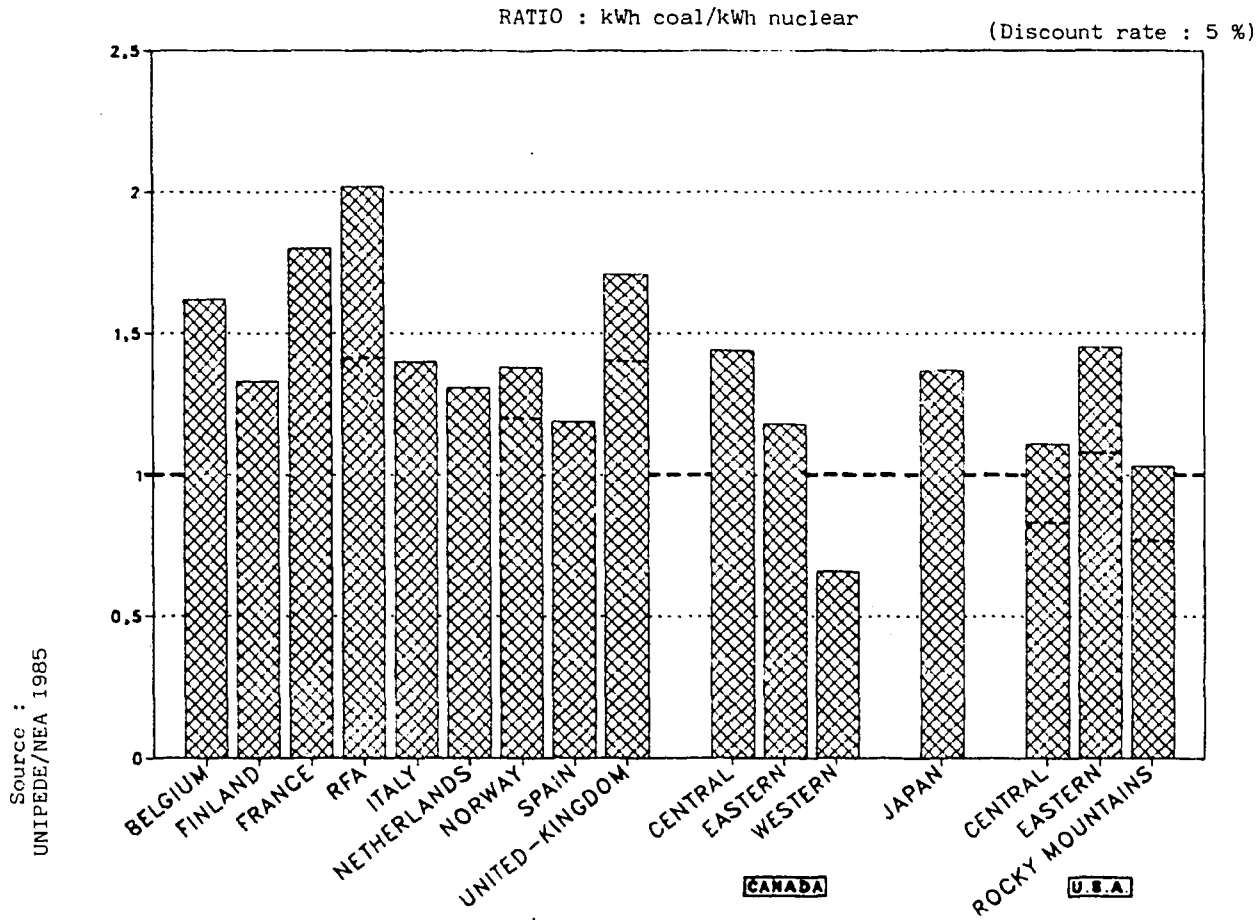
For the Federal Republic of Germany, the range of ratio covers domestic and foreign coal.

The United Kingdom data consider the cost from a first PWR unit and for later similar repetitive units.

But the main conclusion for European countries is a clear advantage of nuclear power plants compared to coal-fired ones.

Canada shows significant regional variations in that the data for Central Canada is based upon Candu medium-sized (880 MWe) multi-unit stations with many common facilities. In Eastern and Western, smaller (635 MWe) single or two unit stations were considered with total levelized costs over 50 % higher than for the Central Canada plants.

FIGURE 4



Canadian coal costs also vary significantly, with Western Canada having the advantage of coal cost less than 30 % of the average for other regions. It is the only region identified within OECD where nuclear is unlikely to be competitive in the time frame considered in the study.

United States numbers warrant some special comments. The nuclear cost data provided by the United States for the reference cases were approximately the same for the three regions considered ; the differences in the margins were due almost entirely to differences in coal costs. However, the capital costs of the nuclear stations were based not on what might reasonably be expected for a new station committed now, but rather on experience with stations which were ordered in the early 1970s and are now coming into operation.

The difficulties and delays experienced in many US plants during this era are well known. It would seem a reasonable assumption that new nuclear units will not be ordered in the United States unless their prospective owners can be confident that similar problems and delays can be avoided.

On reviewing this situation, the United States calculated, for the 1985 study, nuclear costs for a new plant of the same basic design but based on achieving schedule and cost improvements equivalent to the best experience actually achieved in construction of some recent US plants. Although the data were provided for only the Central Region, they can be extrapolated to the other United States regions as well. The results, shown in Figure 4, indicate that new nuclear units could be competitive in all US regions considered, and that in the high-coal-cost Eastern Region, the nuclear cost advantage would be considerable [c].

[c] dash-lined values of the US ratio refer to high capital costs of 1970's committed units with experienced difficulties and delays, as previously said.

Concluding these cost comparisons, the 1985 UNIPEDE/NEA studies have shown that base load nuclear power stations, committed to start operating in the mid 1990s, can be expected to be competitive with contempory coal-fired plants in most countries or regions. The margin of the nuclear advantage is quite substantial, to the point that nuclear plants could be economically operated for load following in many cases.

A question has to be answered. Have the above conclusions to be altered by taking into account the two major events that occured subsequently to the studies : Chernobyl accident - Oil price collapse ?

One year after Chernobyl, most of nuclear power station designers and architect engineers do not believe that conclusions drawn from the accident should have an heavy impact on other power stations with very different design and consequently on costs. In particular, impact on LWR stations generating costs should be almost negligible.

As regards the oil collapse, the World Energy Conference held in France in 1986 has clearly shown that a low level of price is not likely to last for decades, because of progressive exhaust of proven and reasonably expected reserves with very favourable extracting conditions. Therefore oil-fired power stations are not expected to make a come-back in the area of base load or semi base electricity generation.

World coal reserves are known as extremely important. But transportation of coal to electricity consumption areas may increase largely the coal cost at power station sites.

In other respects, burning large quantities of coal in power station will not be performed whithout flue gas desulphurization and probably removal of nitrogen oxides, which means increasing additional costs.

For these various reasons, competitiveness of nuclear power stations compared to fossil fuelled should not be significantly affected by considering the short term context.

Nuclear will still not be the automatic choice for all new generating stations, of course. Studies considering economics along with technical and other factors will continue to have to be made on a case-by-case basis in most countries or areas. However, it appears that nuclear power will have a significant and expanding role to play in providing economic electricity in the coming decades.