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NUCLEAR ENERGY CENTERS: ECONOMIC AND ENVIRONMENTAL PROBLEMS

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This paper gives the qualitative and quantitative estimate of factors and problems, that arize with the further building of relatively small nuclear sites and their external fuel cycle facilities. These problems are derived from substantial increase in transportation of nuclear wastes, land and water availability, delay in construction and starting of nuclear plants, increasing cost of labour resourses and other economic and environmental constraints on siting of nuclear plants in the European part of the USSR. The siting of several nuclear reactors and their associated facilities in a small number of concentrated nuclear energy centers is an alternative having many advantages. The centeres should be located in districts with a low density of population, and low cost of land and water resources. The electricity thereafter can be transmitted to the consumers. The comparative estimate of the two ways of further development of nuclear power is also given.

Introduction

The increasing volume of social production leads to the present day necessity in planning further development in accordance our environment /1,2,3/. As energetics is one of the leading branches of social production (from the view point of both the scale its own development, as

well as its in fluence on the development of other branches) and is characterized by the environmental impact, the optimal strategy of its further development becomes an important factor in the successful solution of the problem mentioned.

The present tendency in energetics development planning in near-term perspective is based on the principle of dispersed nuclear sites in densely populated districts.

This principle results from the economically justified tendency to place the sources of energy nearer the consumers. However the dispersion of power plants is accompanied by land interdiction, intensive consumption of cooling water and inevitable contamination of the district by thermal discharges and toxic wastes /4/. So with the exponential increasing power demands (stipulated by the constantly increasing consumption of energy in industry and the improvement of living standards) this principle in the future can lead to the exhaustion of the environmental capacity of these regions.

"Environmental capacity" of a given region in energetics ispresents a permissible (in response to the environmental impact) number of power plants located in this region. Dispite its great range of values it has constraints.

On the one hand, there are specific means of its enlarging, e.g. by organizing supplementary safety measures (filtering of smoke gases, water and other wastes, application of a closed technological cycle, etc); on the other hand these means are limited first by inevitable thermal discharges and industrial wastes, which are present in energetics with all types of filtering, second, by the fact that the additional cost of using more effective safety devices will rize and lower the economic effectiveness of power production out of proportion to the reached effect of a diminished enviromental impact.

Taking into account the above, the achievement of necessary rates of energetics development, preserving the principle of dispersed siting with constantly enlarging capasities in

highly populated regions may lead in the future to a serious economic and environmental problem. The aggravation of this problem is influenced not only by the scale of energetics development, but also by the changes in its structure.

The fuel basis enlargement by the addition of accessory nuclear energy resoures is one of the energetics peculiarites in the 2nd half of the XX-th century. Thus the main tendency in the future structure changes of energetics is to increase the fraction of nuclear sourses in the total energy capacity.

At present nuclear energy sourses are used mainly for generating electicity. Already we are faced with the possibility of applying nuclear reactors to obtain the temperature of a low and average level for central heating and using them in high-temperature technological processes.

The forcasts show that after in the nearest 15-20 years in a number of countries nuclear stations will become a main source of electricity and the necessary rates of energetics development will be provided mainly by the growth of nuclear power.

So in our times the study of the influence of dispersed nuclear sites in densely populated regions on the economic efficiency of nuclear power and the environmental problems of its development in accordance with the environmental capacity restraints in these regions is becoming important for industrially developed countries.

Economic and Environmental Conditions of Nuclear Power Development

It is known that the need in resources and economic effectiveness of nuclear power, in view of the peculiarity of nuclear fuel, is connected with the realization of a closed fuel cycle and the availability of necessary part of power stations with fast neutron reactors in nuclear energetics as a whole /5/.

This speciality in organization and functioning of nuclear energetics influences the economic and environmental conditions of its further development that depends on the siting of facilities, that compound nuclear power industry and are united by a single technological cycle.

The "remote" location of facilities for fuel reprocessing, storage of radioactive wastes with dispersed siting in densely populated regoins leads to the separation of the closed fuel cycle units and to the necessity in transportation of highly active wastes from the plant (in the case when the plant has fast breedes - especially - highly active and containing a substantial amount of plutonium) to fuel recycle facilities.

The necessity in transportation of highly active and plutonium containing nuclear wastes in densely populated regions leads to additional risks of contamination by radioactive fission products. The risks grow with the development of nuclear power and the growing volume of fuel transportation.

Furthermore, the dispersion of closed fuel cycle facilities and technical difficulties in transportation of radioactive fuel, that result from the necessity in its prolonged keeping on the plant after its removal from the core lead to a lengthened external fuel cycle and diminished rates of proliferation of nuclear power plants with reactors on fast neutrons. This in combination with the additional cost of special transport facilities for spent nuclear fuel will lead to a lessened economic efficiency in nuclear power production,

It is also known that the replacement of fossil fuel by nuclear is accomplished by a change in the cost structure of produced energy. The change is brought about by the reduction of fuel expenses and the increase in specific costs for the creation of main funds of power plants, that depend on the capacity of nuclear energy blocks. Thus the necessity in increasing the capacity of power plants arises not only from the rates of putting nuclear plants into commission, which

are determined by the development of energetics, but also from the fact that nuclear plants can compete with other means of producing electricity.

Moreover the necessity in increasing the electric capacity of nuclear plants and a lower thermodynamic efficiency of the energy cycle of a plant with reactors on thermal neutron leads to increasing difficulties in site selection, interdiction of land, intensive usage of water resourses and finally to a faster exhaustion of "environmental capacity" of the regions with dispersed siting.

Thus the present principle of dispersed siting in densely populated regions will in the future play a negative role in the economic and environmental conditions of nuclear power development.

Because of the specific character of nuclear material as a fuel resourse and considering the level of present day projections of technical solutions for nuclear reactors, this principle in nuclear energetics will bear more weight than in fossil energetics in the lessening of economic effectiveness of nuclear power, as in the environmental impact and finally "will lead to faster exaustion of the environmental capacity" of densely populated regions.

Nuclear Energy Centers: The Answer to Economic and Environmental Problems in the Development of Nuclear Energetics

In industrially developed countries usually the density of population is uneven (owing to climatological, historical and other factors), that is with densely populated regions there are also "remote" regions, which are characterized by a lower bioclimatological potential and by more available land and water resources.

Considering the fact that in densely populated regions the "environmental capacity" is limited, and the present tendency of "remote" location of external fuel cycle facilities we see that there are many advantages in clustering

nuclear reactors into nuclear energy centers, located in remote regions.

Economic and environmental problems also arize with the development of fossil fuel energetics. However the specific organization and functioning of the nuclear industry present the idea of nuclear energy centers in a new light. They differ greatly from energy centers working on fossil fuel.

Nuclear energy centers can be industrial sites, withdrawn from densely populated regions connected to the consumers by high-voltage lines and having not only a group of power plants with a combined power capacity of tens of millions of kW, but also external fuel cycle facilities, that is, they can have a full fuel cycle of utilization and reprocessing of nuclear fuel, and perhaps with its storage.

Thus these centers may not only solve the problem of land availability in densely populated regions, but also help in questions of optimization in organization and functioning of nuclear industry as a whole.

The best results from the construction of energy centers can be obtained in the case of the successful development of nuclear power plants with reactors on fast neutrons, which should be included primarily. However even if there is a delay in this program it still is advisable to consider constructing nuclear energy centers, that have only reactors on thermal neutrons. In addition to the mentioned advantages we should get the following benefits:

- industrial development of regions with a low density of population is stimulated and consequently the equalization in dislocation of plants and development of productive forces;
- creation of more favourable conditions for waste management;
- the conditions for a more effective organization of construction and exploitation of nuclear power plants and

their control are provided by combining them into an integral industrial center. We also can have a more effective application of labour resourses;

- the possibility of fast reprocessing of uranium and plutonium for nuclear power plants is provided;

- the reprocessing and refabrication technologies are perfected with a minimum storage time (150-200 days or less);

- the safety risks of storage are lessened by a stricter controll over them and minimizing external transportation;

- a possibility arises of decreasing the nuclear power capacities, planned to be constructed in densely populated regions, and thus lessening the environmental impact without reducing the growth of nuclear energetics. There are compelling arguments for deployment of nuclear energy into such centers but there are many unresolved issues.

The most important of these are:

- means that can be used to reliably transmit large amounts of electric energy to far away districts;

- the forms of the environmental impact coused by nuclear energy centers, and the means of lessening the impact;

- institutional and organizational arrangements linked with the construction of nuclear energy centers and the infrastructure formed on its base. Considering the above, it is advisable to create nuclear energy centers. This question, in spite of apparent benefits in conditions of nuclear energetics development, is a very difficult one and cannot be answered on the basis of economic estimates only without preliminary study of the said problem.

Also in the first stage the comparative economic estimates of the two tendencies in geographical distribution of nuclear industry units can be of interest in the long--term development of nuclear energetics;

- the dispersed siting of nuclear power plants in densely populated regions, inevitably linked with the geographical disunion of closed fuel cycle branches of nuclear energetics

and the necessity in transportation of large quantities of spent nuclear fuel;

- the siting of nuclear power plants outside the densely populated regions in concentrated nuclear energy centers, that geographically unite closed fuel cycle facilities and transmitting the energy from the centers to the consumers.

Approximate estimate of economic conditions for the creation of nuclear energy centers

In the preliminary stage of making the comparitive estimate of economic efficiency of the above tendencies in geographical distribution of nuclear industry units in long-term planning an approximate estimate of economic conditions for creating a large nuclear energy center was made using the two hypotheses of supplying the consumers with energy from nuclear power sources in the European part of the USSR. In the European part of the USSR the districts located to the west of the Volga- "Volga-Balt" line are characterized by a high density of population and high energy consumption. Becouse these districts have also fossil fuel deficiency we can suppose that in perspective they will be supplied by energy from nuclear plants.

The districts to the north and north-east of the Volga- "Volga-Balt" line have a lower density of population and greater land and water availability and can be considered as plausible locations for nuclear energy centers. From these positions the European part of the USSR is adequate for a comparative examination of the two tendencies in geographical distribution of nuclear industry units /6/.

The existing density of distribution and the capacity of consumption units, the concentration of capacity on one nuclear plant, the level of the construction of high voltage lines and the absence of considerable transport of highly radioactive spent fuel made permissible the principle of dispersed siting of nuclear power plants in densely populated regions of the European part of the country.

However meeting the energy demands in these regions mainly by the construction of nuclear power plants can soon lead to economic and environmental problems in the dispersed siting of nuclear power plants in these districts.

Thus, the estimate of economic conditions for the construction of 1-3 nuclear energy centers in north or north-east districts of the European part of the USSR, with a capacity of 40-50 millin kW each for supplying densely populated districts that are located to the west of the Volga- "Volga-Balt" line with energy and the transmition of electricity to the consumers 1500-3000 km away may be of interest.

The estimate was made with the consideration of the possible cost changes in construction management and of nuclear plants that result from clustering them into nuclear energy centers and the additional expence of energy transmition.

A 30% increase in the cost of construction of nuclear centers in under-developed regions was adopted. High voltage D.C.lines, were also studied which at present are considered to be sufficiently effective for transmiting large quantities of energy.

The summarized results of the made estimate are given in TableI. The cost distribution is given as a percentage of capital investments in nuclear power plants.

The estimate shows that from the economic point of view the conditions for the creation of large nuclear energy centers in the north and north-east districts of the European part of the USSR, which are to meet the energy needs of densely populated regions to the west of the Volga- "Volga-Balt" line are identical to the conditions for the construction of the same number of dispersed nuclear power plants even taking a 30% increase in the cost of construction of the plants in nuclear energy centers. It is explained by the fact that we make up for additional transmition cost by cost savings which are connected with the construction and

Table I-

Approximate Estimate of Construction and Management of Nuclear Power stations for the Two Tendencies of their disposition

Cost distribution	Value of costs from capital investments in nuclear power plants, %	
	dispersed siting	nuclear energy centers
1) Storage of spent fuel	1-2	0.1
2) Containers and transport facilities for transportation of spent nuclear fuel	4-6	0.5-1
3) Compensation for the cost of land interdiction	5-10	0.1
4) Technical water supply	10-15	3-5
5) All stational and auxiliary focilities	15-20	1-2
6) Housing	10-15	5-10
7) Hosses becouse of the duration of the construction	10-15	1-2
8) Transmition of energy (high voltage lines and substation)	-	50
Total:	50-80	60-70

management of nuclear plants, e.g., economic benefits from the cocentration of capacity, better land and water management, the establishment of a minimum number of radioactive sites, faster construction of nuclear power plants etc.

Thus, there are many economic advantages to the construction of nuclear energy centers.

It is evident that in a number of countries technical, economic, organizational, social and other problems will be resolved in accordance with the specific features of that country. Later a more exact economic and environmental study based on these results can be made and the questions of expediency, specific location, and terms of construction of nuclear centers can be answered.

A more Important Role to be Played by Nuclear Energy Centers in the Future

Previously we delt with nuclear energy centers as a means of intensive increasing of electric capacity. We supposed that with the construction of nuclear energy centers in under-developed districts the despersed siting of nuclear power plants in densely populated regions would still continue but on a lower scale.

The questions of using nuclear plants for covering the alternating part of grid's load and of the necessity in using nuclear reactors in other spheres such as central communal and industrial heating, or in high temperature technological processes already stand. So nuclear energy sources, that are to be located in densely populated regions with a developed infra-structure probably, in the future can perform these functions.

Furthermore, electricity takes up only a relatively small part of the whole volume of fuel consumption (25-30%), the main part is taken up by industry and heating. In the whole volume produced electricity the part of basis electric loads is about 60% and has a tendency to decrease in time.

The nuclear energy centers will also play a more important role if in the future they given additional functions. The participation of nuclear energy centers in covering the alternating part of grid's load is possible but is linked first with increasing the construction of high voltage lines so as to transmit greater amounts of energy, and second with the solution of serious technical problems, linked with the organising and providing the reliability of further transmition of alternating electric load. The possibility of participation of nuclear energy centers in covering thermal loads is guestionable. Maybe it will arize after mastering a way of transmitting energy in a chemically linked state and using the closed cycle of reversible chemical reactions. The participation of nuclear energy centers in industrial technology, particularly in resolving the problem of large scale production of hydrogen which is considered one of the main problems, is essentially possible. It can be done first, by electrolysis of water for example, in combination with an alternating load for supplying the consumers with energy, second, by working out the means of abtaining hydrogen on the basis of high temperature reactors, and thermochemical water dissimilation processes. Possibly, it is advizable to distribute the thermochemical industries, that use highly toxic intermediate reagents in nuclear centers, located in under-developed districts.

Conclusions

Meeting the necessary energy demands while conserving the principle of dispersed siting in densely populated regions with a developed infrastructure, considering the environmental capacity of these regions can lead to a serious economic and environmental problem.

Nuclear power industry, which will be the main source of electricity, will be greatly influenced by the dispersed siting of nuclear power plants, which in turn will lead to the geographical disunion of the closed fuel cycle facilities.

Nuclear energy centers, large industrial sites, withdrawn from densely populated regions, connected to the consumers by high-voltage lines and having not only a group of power plants with a combined power capacity of tens of millions of kW but also external fuel cycle facilities can substantially simplify the economic and environmental problem of the future nuclear power development and help to raize its economic efficiency.

Many new and important problems have to be resolved, in connection with the nuclear energy centers.

If we come to the decision of building nuclear energy centers, it probably will be unadvizable to constrain their functions to the production of electricity while at base load. The possibility of using them to cover the variable part of the electric loads, thermal loads, and in high temperature industrial processes, such as large scale production of hydrogen, should be considered.

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