Possible ways to improve nuclear power systems with fast breeder reactors and conditions for ensuring that such systems are competitive are discussed. Certain questions concerning schematic and structural improvements are examined. The results of a comparative analysis of sodium- and lead-cooled breeder reactors are presented. It is pointed out that for sodium-cooled reactors the corresponding information is due to many years of experience in developing, investigating, and operating experimental, test, and commercial reactors. There is no experience in developing lead-cooled reactors. A comparative analysis does not confirm that there are any advantages with respect to technical or economic performance for lead-cooled breeder reactors.

At the present stage of development of nuclear power not only have the basic water-cooled reactors been determined (VVÉR, RBMK, PWR, and BWR) but the idea of expanded production of nuclear fuel in reactors, i.e., the possibility of organizing a neutron-physical process, where the amount of newly produced fissioning isotopes is much greater than the amount of fissioned isotopes (breeding ratio BR > 1), has been confirmed in practice. Such reactors make it possible to develop a two-component nuclear power structure (breeder and thermal reactors) where the thermal reactors operate on the excess nuclear fuel produced in breeder reactors. In certain countries, experimental sodium-cooled breeder reactors where the fission reaction is maintained predominantly by fast neutrons were developed in the 1950s–1960s. Comprehensive investigations performed on experimental breeder reactors have made it possible to produce prototypes of nuclear power plants with such reactors.

Two prototypes of nuclear power plants with fast reactors, where the reactor systems have different arrangements – BN-350 with a loop structure in Shevchenko and the BN-600 single-unit system in Zarechnoye – have been constructed in the USSR. The nuclear plant with BN-350 operated for five years longer than its design service life (from 1973 to 1998) and has now been decommissioned. The nuclear power plant with BN-600 has been operating successfully since 1980.

Importance of Developing Breeder Reactors. The possibility of developing large-scale nuclear power is determined first and foremost by the existence of accessible fissioning materials. The natural reserves of uranium have been investigated and assessed [1]. Since these reserves are limited and no more than 1% uranium is used in thermal reactors, large-scale development of nuclear power is impossible over the long term. This conclusion does not affect the recycling of fuel from thermal reactors and bringing thorium into the fuel cycle. Breeder reactors are essentially the only way to make complete use of uranium and thorium for producing energy and thereby make possible the long-term development of nuclear power. Consequently, the transition of nuclear power to a closed fuel cycle is inevitable and breeder reactors will play a determining role in the future [1].

It should be noted that breeder reactors can be used efficiently not only for the expanded production of nuclear fuel but also for utilizing weapons plutonium and burning up the long-lived components of spent-fuel wastes prior to disposal.
At the present time, a nuclear power plant with BN-600 is in planned operation only in Russia, and the No. 4 unit in the Beloyarsk nuclear power plant with BN-800, where the main solutions which have proven themselves in BN-600 are utilized and new safety requirements and economic optimization are taken into account, is under construction. This has made it possible to improve substantially the technical-economic performance of the power-generating unit, increase the electric power by 200 MW, and improve safety. The US and Great Britain have ceased operating prototype breeder reactors, and the Phoenix reactor in France is reaching the end of its service life.

The decrease in the volume and intensity of work on such reactors is a reflection of the general slowdown observed after the Three Mile Island and Chernobyl accidents and, consequently, the uranium excess on the international market. The fact that the first breeder reactors are economically uncompetitive is also a factor here.

In this connection, it should be noted that the large increase (~30%) in the capital investment for constructing power-generating units with breeder reactors as compared with VVÉR reactors is largely due to the fact that in building prototype power-generating units with breeder reactors the economic performance is not given a priority. The decisive characteristics at this stage were safety, reliability, fault-free operation, and the breeding ratio. By the time the power-generating units with VVÉR were developed, they already traveled quite a long distance along the road of economic optimization and design-structural improvement and technological fabrication, equipment assembly, and organization of construction work.

There are, undoubtedly, great possibilities in technical-economic optimization of power-generating units with breeder reactors. These possibilities will be used in future designs [2]. For this, future designs must take account of the fundamental significance of the main function of reactors – the expanded production of nuclear fuel should not obscure the need for improving the traditional performance indicators:

- the optimization of methods and technical means for guaranteeing safety;
- the service-life reliability of the equipment;
- the design simplicity;
- the simplicity of reactor systems control;
- the ease of maintenance of equipment and systems;
- the economic competitiveness: capital investments, cost of electricity production, investment payback time, and other factors.

**Economic Improvement of Breeder Reactors.** A determining efficiency indicator of a power-generating unit in a nuclear power plant is the thermodynamic efficiency of the cycle which converts heat into electricity. In power-generating units with such reactors, the thermodynamic efficiency is 40–43%, which is much higher than that of VVÉR units – 32–35%. This is due to the much higher coolant (sodium) temperature at the exit from a fast reactor – 550°C – than for VVÉR units (320–325°C).

The efficiency of fast reactors can be further increased by taking the following measures:

- increasing the temperature at the exit from the intermediate heat exchanger by extending the heat-exchange surface area;
- increasing the heat resistance of the structural materials used in the core (fuel element claddings and fuel assembly jackets) to increase the sodium temperature at the reactor exit; and
- transfer of the steam generator into a transcritical operating regime in terms of steam pressure and temperature.

These measures can increase the thermodynamic efficiency by an additional 2–4%. If high breeding ratios are rejected, eliminating the lateral breeding zone will also decrease the cost and therefore increase the cost-effectiveness of a fast reactor.

The required capital investments can be decreased substantially by decreasing the amount of metal used. Structural designs developed during a search for the optimal variant for improving BN-600 (BN-600M design) showed that by improving the construction of the intermediate loop and equipment in the nuclear-fuel handling systems the amount of metal employed can be decreased by 25%, and an additional 58% decrease can be achieved by replacing modular steam generators by vessel generators; this will also decrease the construction volumes and come close to the overall specific costs of VVÉR and even surpass them.

A comparative technical-economic analysis of power-generating units with BN-800 and VVÉR-1000 (V-392 design) showed that improving the intermediate loop and the transport-technological system of BN-800 and subsequent optimization