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Nuclear Power in the Restructuring and Modernization of the Romanian Economy

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Introduction

After the collapse, in 1989, of the centralized communist regimes in Central and Eastern Europe, the Romanian economy experienced significant changes. The industrial production decline caused a dramatic drop in the country's electricity consumption. Despite this, the power sector had to cope with many difficulties to cover electricity demand. Under the circumstances of economic restructuring, the problems of the Romanian power sector became acute: most thermal power units are old (older than 20 years), with low efficiency, low performance indicators, high costs, large staff numbers; the dependence on imported fossil fuel is high; the environment protection requirements - emphasized by the European institutions - not met; lack of the capital required for fixing these questions. A peculiar aspect of the transition period occurred: the consumers did not pay timely and entirely the energy bills and the prices for energy established by the state, generally, did not cover the production costs. Consequently, the lack of financial resources at the thermal power plants made the purchase of fuel from import extremely complicated. Also, the maintenance programs at the power plants could not be accomplished. It was very difficult to attract investment funds for rehabilitation work or for the construction of new capacities in the power plants.

In 1989, Cernavoda NPP was under construction, with Unit 1 of the plant 45-50% complete. In 1991, following the IAEA recommendations and specific political agreements, the management of the project was assigned to an international consortium formed by AECL (Canada) and Ansaldo (Italy). The consortium assisted the Romanian authorities to obtain external loans from Canada and Italy, necessary for the completion of the work. Cernavoda NPP Unit 1 started commercial operation in 1996. The unit's reactor type is PHWR-CANDU 6 (electrical capacity 706 MWe), using natural uranium; the nuclear fuel is manufactured in Romania. The process of electricity generation in the nuclear power unit proved to be very clean and the safety and radioprotection standards observed at the plant are very high. The commissioning of this unit and its successful operation by the Romanian personnel of SN "Nuclearelectrica" confirmed nuclear power is a valuable part of the solution to the problems of the country's power sector. Based on such conclusions, the long-term programmes of the Romanian government for economical development foresees the completion of subsequent units on the Cernavoda NPP site.

Meanwhile, in the last three years, a gradual recovery of Romanian industry occurred. Now, it becomes less energy intensive, but the growth of the industrial production and the increasing household electricity demand has induced higher energy consumption. Also, Romania has begun to export electricity. The development of the nuclear power sector enhances these tendencies.

The status of the Romanian electrical power production sector

After 1989, the electricity consumption in Romania dropped to 65% in 1992 and, after some fluctuations, to 60% in 1999, reflecting the degradation of the industrial activity (*Figure 1*). Starting with 2000, on the background of a general tendency of economical recovery, electricity consumption slightly increased; electricity production growth was even larger, due to the power export (mainly from hydro power stations) – see *Table 1*. For the following years, the forecast annual increase of energy demand is 4%.

Table 1. Growth of electricity production/consumption/export after 2000

	2000	2001	2002	2003 (6 months)
Production growth, %	2.43	3.68	2.46	6.11
Internal consumption growth, %	2.73	2.53	-0.41	6.04
Export, GWh (% of production)	694 (1.3%)	1310 (2.4%)	2854 (5.2%)	1399 (4.8%)

At the end of 2002, the installed capacity in the Romanian power plants was:

- ◆ TOTAL: 18 932 MW (100%)
- ◆ units on coal: 7 029 MW (37.1%)
- ◆ units on gas and oil: 5 164 MW (27.3%)
- ◆ hydro power units: 6 032 MW (31.9%)
- ◆ nuclear unit: 707 MW (3.7%)

Figure 2 shows the contribution of each source of primary energy to the electrical energy generation in 2002. If we compare the figures representing the contribution in the energy output and the share in the installed capacity, it is worth observing that:

- The contribution of the sole nuclear unit in energy generation is outstanding (10%, while the installed capacity in nuclear represents 3.7% of total); this is due to the good load factor achieved in NPP operation, as a result of the high availability.
- The units on gas and oil use, mainly, imported fuel (about 70% for oil and 40% for natural gas); the price of the fuel is high, the quantities are limited and, therefore the energy output from these units is low, compared to the installed capacity.

In 2002, the maximum consumption load in Romania was 8410 MW. It represents only 44% of the total installed capacity. But, unfortunately, this does not mean Romania has large reserve and a real excess of capacity; the question is the low availability of the thermal power units (overall utilization factor recorded in 2002: 31.5%). The explanation consists in the advanced age and poor maintenance of these plants. In the last 10 years, a capacity of more than 3500 MW in thermal plants was closed, as aged and obsolete. Today, within “Termoelectrica”, the main operator of thermal power plants, more than 82% of the installed capacity is older than 20 years (see *Figure 3*). An old thermal power unit, inadequately maintained, means: low reliability, high costs, rudimentary control technique, high emissions polluting the environment. The lack of financial resources, during almost two decades, made it impossible to fulfill the program of rehabilitation and upgrading or to build new, modern thermal power units.

On the other side, the output of hydro power plants has large fluctuations (up to 25% of the annual production) depending on hydrological conditions. For example, 2002 was an average year, but 2003 was very drought. The construction of new hydro capacities requires vast resources, because the most accessible hydro potential is already used.

The place of Cernavoda NPP Unit 1 in the Romanian power sector

In the late 1970's, Romania chose CANDU type of reactor for its first nuclear power plant. The main reasons of the choice were the high safety features of this technology and the possibility to manufacture in Romania the nuclear fuel and the heavy water, as well as a part of the equipment for this type of NPP. We remind CANDU reactor is a PHWR, with fuel channels, cooled and moderated with heavy water and using natural uranium. The contracts were signed in 1979 with AECL (Canada) for the “nuclear island” and in 1981 with Ansaldo (Italy) – General Electric (USA) for the “Balance of the Plant”. The history of the construction was long and tormented, including the chaos of the latest years of the communist era. Starting with 1991, when the unit was half completed and the main equipment procured, the management of the construction and commissioning work was transferred to an international consortium formed by AECL and Ansaldo. Subsequently, we succeeded to contract – with the assistance of the consortium - important external loans from Canada and Italy, with the Romanian State guarantee, for the completion of the project.

The commercial operation of Unit 1 of Cernavoda NPP started on 2 December, 1996. Seven months later, the responsibility for the plant's operation was turned-over from the consortium to the Romanian personnel of SN “Nuclearelectrica” company. The training acquired by this personnel was good, as proven by the achieved operation results. A full-scope simulator was commissioned at Cernavoda in 1998, for improving the operating crews training.

Production

For all the years since “in service”, Unit 1 of Cernavoda NPP provided about 10% of the electricity generated in Romania. The unit has a very steady output, delivering almost continuously its maximum power, 700-715 MW, and an annual production of 5200–5400 GWh (gross). *Figure 4* shows the values of the gross capacity factor achieved by the unit in each year of commercial operation. The unit is operated in the base-load mode and the differences in capacity factor values come out mainly from

the different duration of the annual planned outages; the interruptions of power delivery, caused by unplanned outages, are rather infrequent and short.

The performance indicators of Cernavoda NPP are much higher than those recorded at the Romanian thermal power units, while its energy production is notably steadier than hydro plants output. All these confirm the reliability of the nuclear producer in the Romanian power system.

Fuel

Unit 1 of Cernavoda NPP consumes about 105 tonnes of natural uranium per year. The refueling of CANDU reactors is performed on-power, channel by channel. Each year, about 5300 fuel bundles are loaded/unloaded from the reactor. The annual average discharge burnup is 170 MWh/kgU. The fuel manufacturing factory in Pitesti, a subsidiary of SN "Nuclearelectrica", provides all the fuel necessary for the operation of Cernavoda NPP.

The factory in Pitesti was upgraded in co-operation with our Canadian partners; now, the factory is certified as a qualified supplier of CANDU fuel. The quality of the fuel bundles manufactured at Pitesti is very good. During each of the last four years, the number of fuel bundles which experienced failure in the reactor (or were suspected of failure) did not exceed 1, see *Figure 5*.

The factory uses UO₂ powder made of indigenous uranium ore; the already prepared concentrate is sufficient to cover the unit's fuel needs, for all its designed lifetime. Having such a fuel source, the security of the energy supply from Cernavoda NPP is very high. At the same time, as the fuel is made from natural uranium, within the power company, the fuel's cost is quite low and highly stable. This is an important advantage of the nuclear, compared with the fossil fuel power units. Due to Cernavoda NPP Unit 1, the country saves the import of 1.4 million tonnes of oil annually.

Costs

The Operation & Maintenance costs (including fuel) at Cernavoda NPP Unit 1 are about US\$12/MWh; for some years these costs were lower, partially because the wholesale energy buyer could not collect entirely the invoiced sums from the final power consumers. As shown in *Figure 6*, the O&M cost represents only a half of the total costs of SN "Nuclearelectrica". The balance covers the capital costs (reimbursement of the loans received for the unit's construction, assets depreciation) and other financial expenses - interest, taxes, etc. When the external loans will be entirely reimbursed, by the end of 2006, it will be possible to reduce significantly the costs. However, at that moment we shall increase the company's contribution to the fund for decommissioning and for radwaste disposal; hence the cost reduction will be less spectacular. It is also the right place to emphasize the small share (~7%) of the nuclear fuel in the total cost of 1 MWh produced at Cernavoda NPP.

SN "Nuclearelectrica" sells the energy produced at Cernavoda NPP at a regulated price, established by the Romanian Electricity Authority - the national regulatory

body for the energy market. The present price is fairly close to the total production costs: US\$23/MWh.

The Authority establishes the prices for the “regulated power sale contracts” of the other Romanian power producers - thermal and hydro power companies. These regulated prices are based not only on the production costs, but also take into account some social and macro-economical issues (e.g. the regulated prices are diminished – by reducing the sums assigned for assets depreciation or keeping low the estimated expenses for the fossil fuel – in order to reduce the effect of high energy prices on the population and industry). Also, most of the environmental protection cost is not included in the regulated price for the thermal power units. The comparison of the regulated prices – as per 1 April 2003 - for hydro, nuclear and thermal power producers is shown in *Figure 7*. Even in the circumstances mentioned above, the price for the electricity produced at Cernavoda NPP is much smaller than the price for the electricity produced today in most of the thermal power units (on average, with 40%). This proves the effective competitiveness of the nuclear power, for the present conditions in Romania.

Nuclear power and environment protection

The electricity production in NPP is proved and recognized as environmentally clean. A nuclear unit does not produce greenhouse gases, sulphur and nitrogen oxides, dust and ashes. Cernavoda NPP, replacing the production of thermal units, contributes to the reduction of CO₂ emission with 4 million tonnes per year.

The radiological effect of Cernavoda NPP on environment and population is insignificant. The radioactive emission to the environment can be described by the equivalent dose to the critical group of population; this dose, measured in Cernavoda area, is 5-8 microSv/year, while the dose received from the natural radioactive background is about 2400 microSv/year.

The issue of radioactive waste is constantly in our attention. Before the end of the seventh year of commercial operation of Unit 1, we already commissioned at Cernavoda NPP the first module of the intermediate dry storage for spent fuel; it is a reinforced concrete monolithic vault, with natural convection air cooling (MACSTOR type, similar to the solution at Gentilly NPP-Canada) where the spent fuel will be stored for about 50 years.

The annual volume of the solid low and intermediate level radioactive waste at Cernavoda Unit 1 is less than 30 cubic meters – see *Table 2*. For the disposal of this type of waste, the strategy is to construct a near-surface final repository, in the plant’s exclusion zone. The process of the selection and licensing of the site is on-going. Recently, in Romania was created the National Agency for the Radioactive Waste, which will co-ordinate the activity for waste management and decommissioning of the nuclear installations.

Table 2. Cernavoda NPP indicators related to radioprotection and radwastes

Indicators	Recorded value, for year 2002
Station dose (Collective Radiation Exposure)	0.55 person-Sv
Radioactive emission to environment (Equivalent dose to critical group)	8.30 microSv
Solid radioactive waste (except fuel/resin)	29.39m ³

Several international missions - representing IAEA, WANO, WENRA – have assessed the safety and operation issues at Cernavoda NPP and confirmed the plant complies with internationally recognized standards.

Energy market and the nuclear power producer in Romania

For the time being, SN “Nuclearelectrica” sells the electricity produced at Cernavoda Unit 1, to the national utility, “Electrica”, on the basis of a Power Purchase Agreement (PPA) type of contract; it provides all the energy that can be produced is purchased and paid at regulated price. Hence, the unit runs at maximum possible power, in base-load operation. This type of contract for a nuclear company is established by the rules of the Romanian energy market and its aim is to put SN “Nuclearelectrica” in the position allowing it to reimburse - with no market risks - the construction loans, guaranteed by the State, received for Cernavoda Unit 1.

Due to the low price of the electricity produced at Cernavoda, the provisions of the PPA do not cause distortions on the energy market. It is to the benefit of the utility “Electrica” and of the consumers to buy this energy, which is cheaper than the energy from thermal power units and cheaper than the average price of energy on the Romanian wholesale energy market. As a result, the PPA is not anymore a “shelter” for the nuclear producer, as initially intended, but a kind of protection for the captive consumers, preventing a large increase in electricity prices.

The PPA will be valid until the end of 2006, when the loans will be entirely reimbursed. After that date, SN “Nuclearelectrica” will be allowed to sell the energy on the liberalized market, at negotiated prices. We are confident that we’ll make profitable business, because the electricity from the nuclear plant will be competitive, even on the liberalised European energy market; we already received requests for energy supply from many Romanian eligible consumers or from energy traders from abroad. Also, we notice an improvement in the collection rate of the invoiced sums for the purchased electricity, which indicate the mechanisms on the Romanian energy market become effective.

Social dimension of the nuclear sector development

The construction of the nuclear power plant brought many changes to the lives of the people in the area. New social objectives have been built, improving the living standard in Cernavoda: living houses, schools, hospital, roads and bridges, running water and district heating supply grids, etc.

New jobs appeared, with good salaries. It refers not only to SN “Nuclearelectrica”, but also to many other companies, involved in the construction of the nuclear units.

The quality assurance approach and the “safety culture”, specific to nuclear, the tight connections of the plant with the international organizations – IAEA, WANO, etc.- with nuclear power plants from other countries lead to the formation of a new industrial culture, which gradually spreads into other fields of the country’s economy. A new attitude can be already noticed in the construction, equipment manufacturing and service companies, working for the nuclear units.

The level of instruction and of professional qualification required for the nuclear power plant is higher than for other industries. It enhances the development of human personality of the individuals. At the same time, it supports the progress of the educational system, fostering the growth of high schools, colleges, technical universities, with beneficial effects through all the society.

Plans for the future of nuclear power in Romania

The construction work for Unit 2 of Cernavoda NPP is going on. In May 2001, “Nuclearelectrica” signed with the traditional partners - AECL and Ansaldo - the contract for the management of the completion work and commissioning of this unit. The estimated budget of the project is about US\$700 million. External loans, exceeding US\$400 million were obtained from Western banks, with the State guarantee, after difficult, time-consuming process; for this reason, the contract came into force only in March 2003. The balance of the budget will be provided from Romanian resources and will be used mainly for the purchase of the heavy water and of the first fuel load from Romanian suppliers, as well as for payments to Romanian contractors. At the end of June 2003, the unit was ~50% completed and the main technological equipment was already procured. The reference design for Unit 2 is Cernavoda NPP Unit 1, with several operational and safety improvements, implemented at the recently commissioned CANDU units (Wolsung NPP – R. Korea). The first connection to the grid of Cernavoda NPP Unit 2 is scheduled for 2006 and the start of commercial operation for 2007. Units 1 and 2 of Cernavoda NPP will generate, after 2007, more than 18% of the electricity produced in Romania.

In November 2002, the Romanian government approved “The national strategy for the development of the nuclear sector in Romania”. It provides for the increase of the nuclear share of electricity generation from 10% up to 20-40%, observing the requirements of sustainable development, price competitiveness and nuclear safety. The “Strategy” states that, for the present conditions in Romania, taking into account the cost of the energy from the nuclear plant versus the cost from the fossil fuel power plants, the investment should continue for the next units of Cernavoda NPP. Thus, the completion of Units 3, 4 and 5 is foreseen in the period 2009-2020. Modern types of contract should be promoted, as BOT (Build-Operate-Transfer), implying the

financing by foreign partners, without State guarantees; the Romanian contribution will be based on a public-private partnership. The civil work at these units is mostly completed but, unlike the Unit 2, the equipment is not procured. A large part of the electricity produced at these units will be available for export. At the present time, many political and business contacts are taking place for establishing the framework for continuation of the construction activities at Unit 3 of Cernavoda NPP.

Conclusions

Cernavoda NPP Unit1 is an important, reliable source of relatively low price energy for the country's economy.

In Romania, the nuclear power units can effectively contribute to the security of the energy supply as they use nuclear fuel manufactured in the country, based on natural uranium, preventing an increased dependence of the internal electricity consumption on the imported fossil fuel.

At the same time, the nuclear units have a minimal impact on the environment and population, representing a very clean technology for electricity generation. Equally, the nuclear safety record of Cernavoda NPP Unit 1 is remarkably good. The radioactive wastes are managed properly and the long-term solutions for storage and disposal are being implemented.

The cost of the energy produced at Cernavoda NPP makes it competitive, particularly if compared with the cost of the energy from fossil fuel power plants, most of which in Romania are aged and inefficient. In addition, the cost of the energy from nuclear plant is very stable, due to the stability of the nuclear fuel cost, while the costs of the fossil fuel are greatly volatile.

Apart from the economical and ecological importance of nuclear power, it has a very positive social dimension, especially in a country like Romania, which is on the way of modernization and advance to the Western standards.

The Romanian authorities recognize the role of nuclear power as an important component of a stable and diversified "energy mix", a factor of the sustainable development of the country. The government gives its support for further extension of the nuclear power sector in Romania.

Figure 1. The Evolution Of Electricity Consumption in Romania

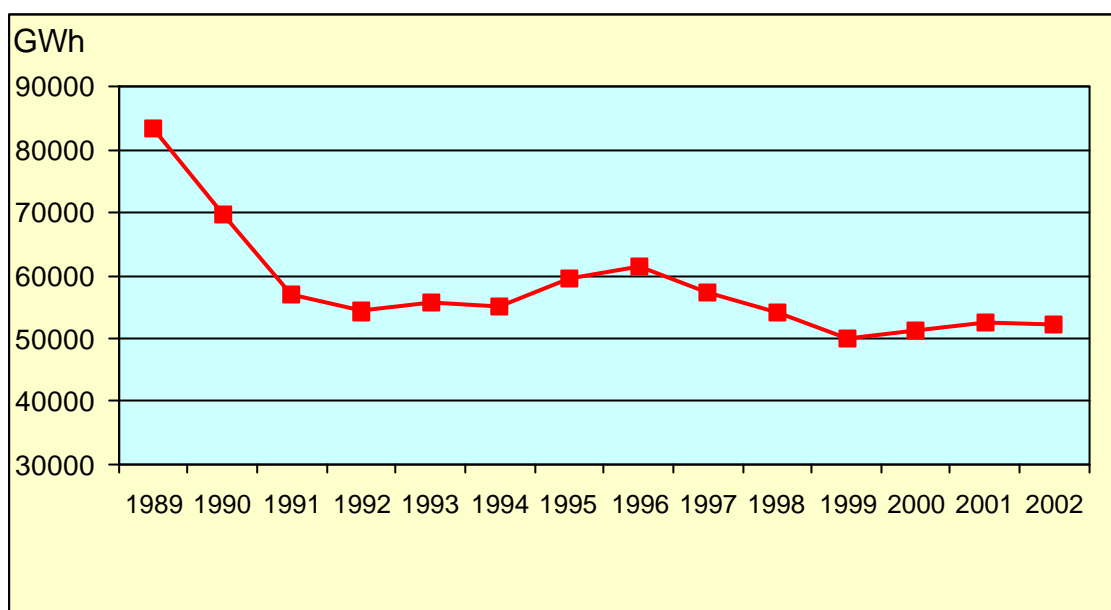


Figure 2. Electrical Energy Generation In Romania – 2002 (total: 55 187 GWh)

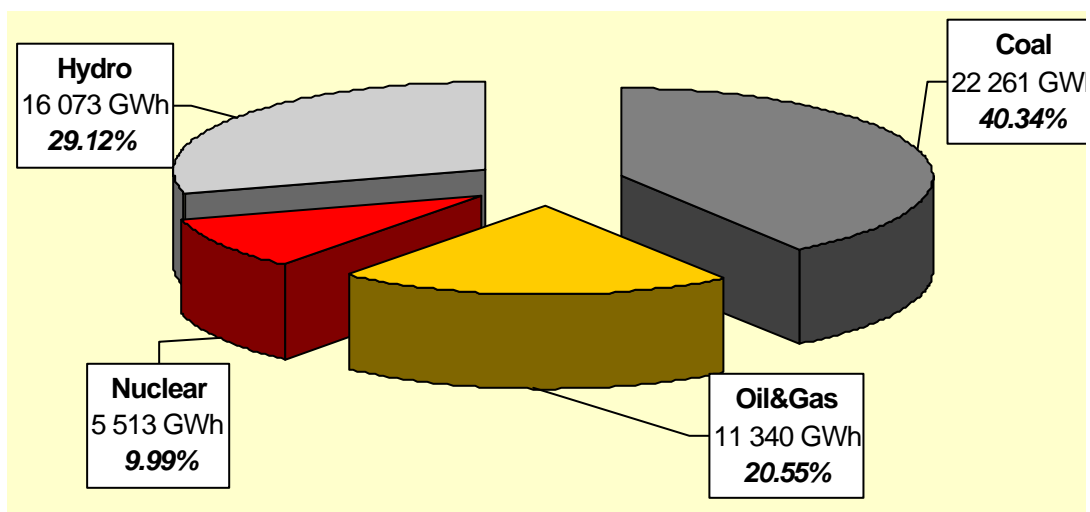


Figure 3. The Age Of The Thermal Power Capacities In “Termoelectrica” Portfolio

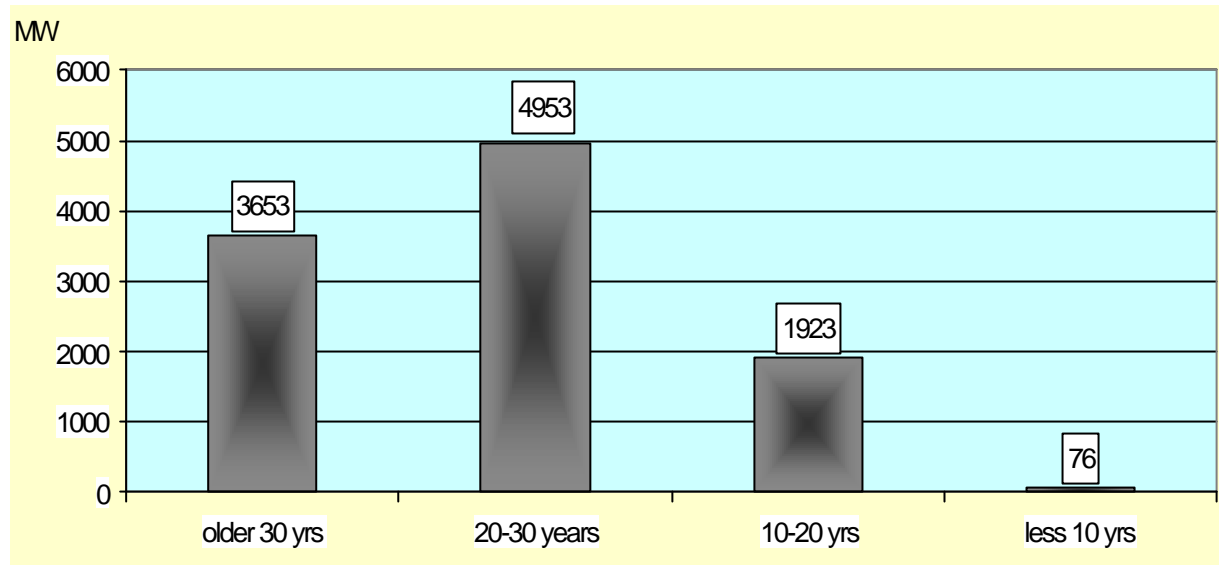


Figure 4. Gross Capacity Factor Achieved In Commercial Operation At Cernavoda NPP

Unit 1

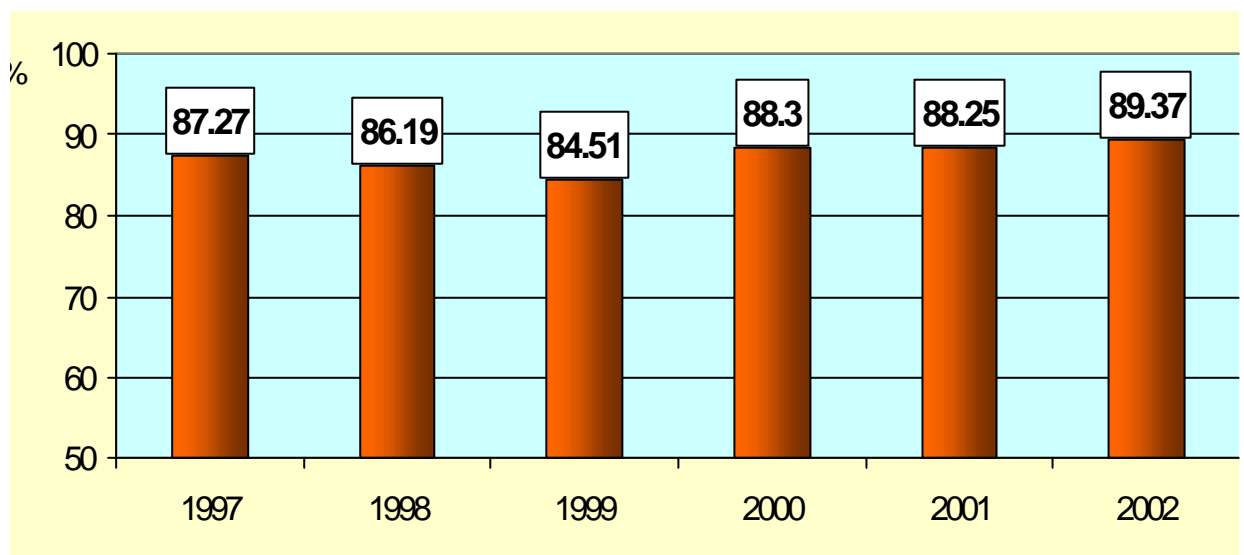


Figure 5. Annual Fuel Failure Rate At Cernavoda NPP Unit 1

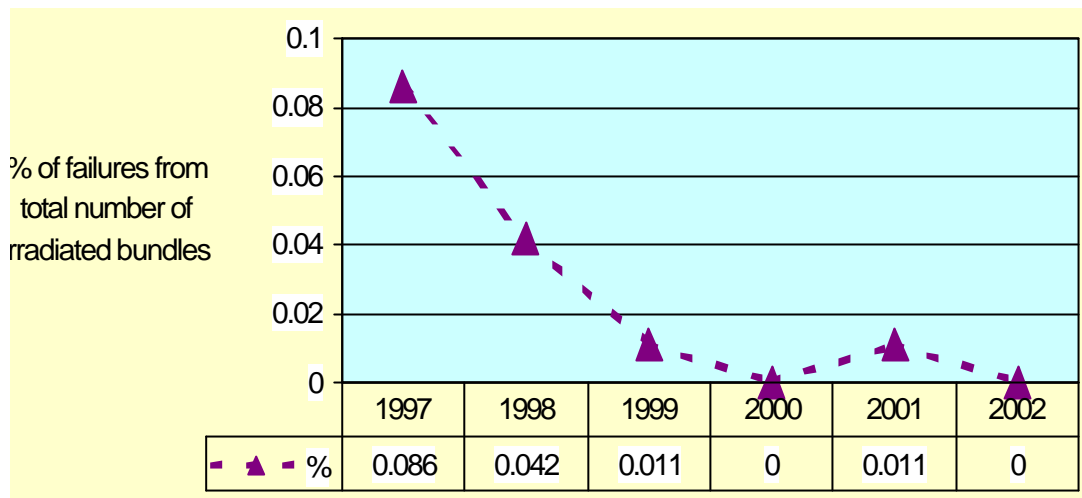


Figure 6. The Cost Structure Of The Energy Delivered By SN “Nuclearelectrica”

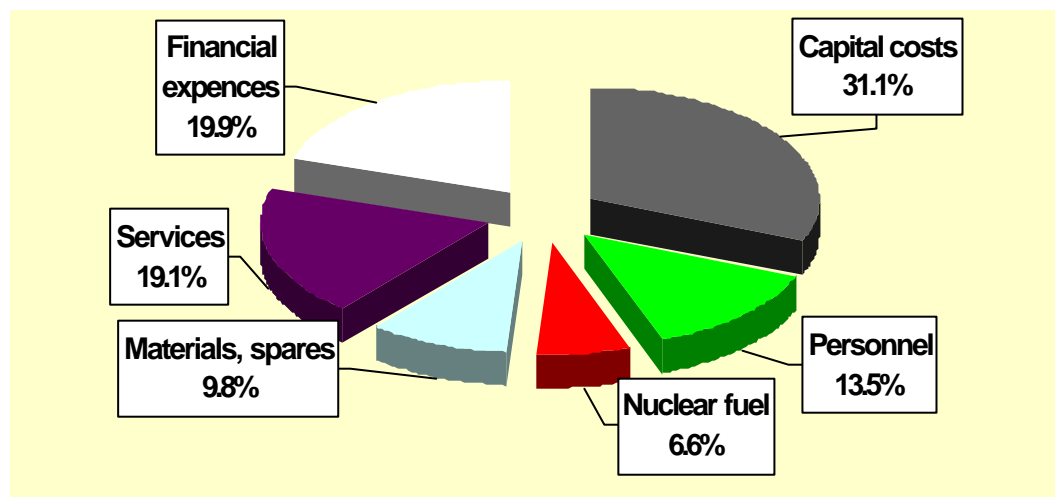


Figure 7. The Range Of The Regulated Prices For Different Power Producers On The Romanian Energy Market – 1 April 2003

