5. ANALYSIS OF ALTERNATIVES

5.1. The Evolution of the Main Macro-Economic and Power Parameters of Romania during 2005 – 2025

The power domain represents the infra-structure of the basic strategy of Romania's economy the whole development of the country is based on (Ref. 5-1, 5-9).

The main elements of Romania's energy strategy are contained in the following official documents:

- the strategy of Energy Efficiency Increase in Romania;
- the Road Map in the energy field for Romania's accession to European Union.

The possible evolution of the electric power demand for Romania for the period until the year 2025 was estimated (Ref. 5-1, 5-2, 5-3) on basis of the consumption required to provide:

- the support of the country's short, medium and long- term development programs;
- the maximum use of the internal available resources on basis of the "priority' principle (i.e the most efficient cost);
- the environment protection according to the requirements of the EC Directives in the field;
- the increase of the energy efficiency , as a target to get closer to the value of the parameter in the EU countries.

In line with the above, the estimation of the energy consumption considered the following criteria, as a basis:

- the support for an accelerated increase of GDP (gross domestic product) by governmental policy , in order to fulfill the strategic objective of reducing the economic discrepancy of Romania versus UE countries. For that purpose, a

GDP average increase of 5.46 % until 2025 (specified in the Road Map) (Ref. 5-1) was considered;

- the reduction of the energy intensity by 30-50 % (Ref. 5-1) until 2025 by a complex process which employs the substitution of the high-energy consumption technologies by re-structuring the economy. The specific power consumption in industry will be reduced to minimum 25-30 % considering both the energy intensity of the industrial sector and the percentage of GDP it represents. Another important task within the energy efficiency increase strategy is represented by the building isolation. The reduction of the energy intensity is also an important instrument in the 8% cutting down of CO2 emissions compared to the 1990 level, correspondingly to Romania's obligations as per Kyoto Protocol.

Romania's energy balance is based on the variety of the employed energy sources, the provision of the power supply by the maximum use of internal resources as per the priority principle, the difference being supplied from imports according to a policy which allows a better promotion of the alternative resources, such as natural gas, and the consideration of the long-term trends on the regional and world energy markets, also making use of the key geographic position of Romania in the route of the resources (natural gas, oil) from the East to the West .

For to provide the energy resources until 2025, the followings have been considered (5-1):

- the availability of internal lignite resources for the next minimum 50-70 years at a production rate of 30-35 million tons/year in surface mines. The strategy regarding mining is providing that the lignite production be concentrated in the most efficient surface mines in point of costs and the non-feasible mines (specially the underground mines) be closed. The lignite production shall be no longer offered subsidies and it will represent a competitive energy source that will not be influenced by the market trend of price increase at other fuels;
- the availability of the bituminous coal resources at a production rate of 3.5 million tons/year;

- the availability of the internal natural gas and oil products (fuel) output with the trend of drastic decrease determined by the limitation of the natural gas resources and the increase of the dependence to imports at a rate of 49-50% in 2015 compared to 39-40% in 2005. It has also been considered that a significant increase of the natural gas imports would happen so that the rate will reach 75.9% of the demand in 2015;
- the exploitation of the hydro power resources so that hydro power may represent 2.5 Twh/year by the installation of 500 –900 MW additional capacities;
- the continuation of the nuclear power program by commissioning Cernavoda NPP-Unit 2 in 2007 and Units 3 and 4 until 2015 (5-4, 5-5) as a joint effort of Romania along the other EU countries for the increase of the safety margin in the supply of power resources simultaneously with the reduction of greenhouse gases. For the latter, on March, 31st,2006, a feasibility study was finalized and now, on basis of the Government Decision, the Ministry of Industry and Trade and S.C Nuclearoelectrica S,A are negotiating with potential investors, electricity buyers, financing groups and other participants in securing the financial scheme for to define and implement the commercial/financial framework of the Project so to allow the start-up of the works earlier, in the year 2008;
- the encouragement and enhance of the renewable resource contribution according to the national program for renewable power sources (biomass, micro-hydro schemes, wind power, geothermal power and others) so that their contribution reach 3-4 % of the total resources, representing thus an important internal source which may help in the reduction of the energy imports and the improvement of power supply safety, also meeting the environment protection requirements. Though the initial investments in the field are big, which represents a restrictive factor in their development, it is foreseen to initiate a simultaneous program which is to include a financial component as well.

Table 5.1 –1 presents the main macro-economic and energy indicators estimated for Romania during 2005 – 2025.

Table 5.1-1. Macro-economic and energy factors estimated for Romania during 2005 - 2025

No.	Indicator	Values of indicators		
		2005	2015	2025
1	GDP(x10^9 \$98)	54.5	93.9	160
2	Population (inhabitants, million)	22.2	22.6	23
3	GDP/inhabitant (\$98/inhab.)	2449	4152	6957
4	Gross electricity output (TWh)	56.3	72.9	90
5	Energy intensity (domestic consumption/ GDP Kg e.p./10^3 \$98) - upper alternative(S) of 50 % cut-down - basic alternative(B) of 40 % cut-down - lower alternative(I) of 30 % cut-down			
		694	427	427 (1)
		742	511	511
		770	595	595

1) According to the Road Map the target to reduce the energy intensity is the year 2025. Moreover, according to Government Decision HG nr.647/2001 the minimal average-term strategic target is the reduction by 3%/year of the energy intensity for a minimum period of 15 years.

In respect of the environment issue, besides signing the Framework Convention on Climate Changes, the Romanian Government has issued a Government Decision nr. 541/2003 regarding the establishment of some measures to limit the release to the atmosphere of some pollutants generated by large burning installations (over 50 MW), a decision which is to provide the implementation of EU Directive 2001/80/EC on releases of solid matter, SO_2 and NO_x. The satisfaction of EU Directive above requirements by the generator units is due in 2012 and it implies a total investment volume of 1.026 billion USD out of which the investments for the rehabilitation of the boilers and electric-precipitates (solid releases) is representing 8 %, the burner rehabilitation 6 % and de-sulphuration 86 %. The results of implementing the program for the power plants within Termoelectrica, will lead to a significant cut-down of the releases as follows:

Table 5.1-2. Plan to cut-down the releases following to the rehabilitation program implementation.

Year / Effluent		1989	2007	2012
SO_2	t/year	645.546	265.649	56.623
	% as compared to 1989	100	41	8,8
NO_x	t/year	112.152	62.125	56.386
	% as compared to 1989	100	55	50
Solid matters	t/year	139.064	16.836	8.836
	% as compared to 1989	100	12	6

The energy development plan for the period 2005 – 2025 is considering the followings:

- planning to shut-off the existing plants until 2015, a plan elaborated according to the efficiency of each production unit as per Table 5.1-3 (Ref. 5-1);
- the selection of the rehabilitation and of the new units on basis of updated production costs;
- the improvement of the existing units with systems to reduce and control the pollutant releases;
- the construction of new units based on lignite and bituminous- coal burning in fluidized layer;
- the construction of new units based on natural gas turbines and recovery of heat by combined cycle with/without co-generation.

Table 5.1-4 illustrates the installed power demand for the period 2006 – 2015 (Ref. 5-1).

Table 5.1-3. Evolution of thermal–power unit shut-off during 2006 – 2015

	MW					
	Installed power			Available power		
	Total 2006-2010	Total 2011-2015	Total 2006-20015	Total 2006-2010	Total 2011-2015	Total 2006-2015
Total	**2185**	**0**	**2185**	**1912**	**0**	**1912**
1. lignite	**1835**	**0**	**1835**	**1578**	**0**	**1578**
1.1 condensation	**1835**		**1835**	**1578**		**1578**
- Turceni gr.1.7	2 x 330		660	1 x 284.1 x 280		564
- Rovinari gr.4.6	2 x 330		660	1 x 287.1 x 277		564
- Işalnița gr.8	1 x 315		315	1x290		290
- Doiceşti gr. 7.8	1 x 200		200	1x160		160
1.2 district heating	**0**	**0**	**0**	**0**	**0**	**0**
2. pit coal	**100**	**0**	**100**	**89**	**0**	**89**
2.1 condensation	**0**		**0**	**0**	**0**	**0**
2.2 district heating	**100**		**100**	**89**		**89**
- Paroşeni gr.1.2	2 x 50		100	2 x 44.5		89
3. hydrocarbonates	**250**	**0**	**250**	**245**	**0**	**245**
3.1 condensation	**0**		**0**	**0**	**0**	**0**
3.2 district heating	**250**		**250**	**245**		**245**
- Bucureşti Sud gr. 6	1 x 125		125	1 x 123		123
- Bucureşti Vest gr. 2	1 x 125		125	1 x 122		122

Table 5.1-4. Installed power demand for the period 2006 – 2015 - Basic scenario

		Unit	2006	2007	2008	2009	2010	2015
1.1	Net electricity output-total of system	TWh	55.35	56.22	57.10	57.99	58.90	66.60
1.2	Load factor	hours	6300	6200	6100	6100	6000	6000
1.3	Peak power - total of system	MW	8786	9068	9360	9507	9817	11100
2.1	Net electricity output-domestic consumption	TWh	55.35	56.22	57.10	57.99	58.90	66.60
2.2		hours	6300	6200	6100	6100	6000	6000
2.3	Load factor	MW	8786	9068	9360	9507	9817	11100
	Peak power – domestic consumption							
3.	Evolution of available installed power	MW	13827	12732	12732	11742	11742	11742
4.	Evolution of available net power	MW	10201	9221	9221	8377	8377	8377
5.	Stock of available power							
	- in MW (5 = 4 - 1.3)	MW	1415	153	-139	-1130	-1440	-2723
	- in % of peak net power	%	16.1	1.7	-1.5	-11.9	-14.7	-24.5
6.	Required power stock							
	- in MW	MW	2812	2902	2808	2852	2847	2775
	- in % of peak net power	%	32	32	30	30	29	25
7.	Required net available power (7= 6 + 1.3)	MW	11598	11969	12169	12359	12664	13875
8.	Surplus +/-shortage of net available power (8 = 4 - 7)	MW	-1397	-2748	-2948	-3982	-4287	-5498

5.2. Elaboration of scenarios for the development of the electric and thermal power sector with and without Cernavoda NPP- Unit 3 for the period 2005 –2025

The analysis of the alternatives for the construction of Cernavoda NPP- Unit 3 need to consider three main important aspects (Ref. 5-9):

- the moment Unit 3 is finalized, it will compete on the open energy market both with the domestic energy producers and the foreign ones;
- the standing of the nuclear power on the international market compared to the other options;
- the contribution of the nuclear units in covering the load curve of a country which is always on base load. That implies the consideration of the energy generators that fall in the same coordinates of the load curve only (the production of electricity by combined cycles with natural gas and by classic coal based cycles).

The elaboration of the scenarios for the development of the electric and thermal power sector with and without Cernavoda NPP-Unit 3 starts from the following considerations:

- the existence of a common part for all the proposed scenarios represented by the existing capacities at the present moment and which is to decrease during the period subject to analysis as per the graph in Fig. 5.2 –1 (Ref.5-6);
- the existence of a common part for all the proposed scenarios represented by the power expected to be installed in the analyzed period as per the road map both for the classic fuel based cycles and renewable fuel based cycles;
- the part which differentiates the proposed scenarios between themselves is compatible with the capacity of Cernavoda –Unit 3 in point of power output.

The alternative scenarios are proposing the production of electric power with classic fuel based units (coal and/or natural gas).

5.2.1. Evolution of the Electric Power Demand

In order to estimate the evolution of the electric power demand and implicitly of the installed power at the level of 2025, the hypothesis of a variation as per Road Map was considered. By extrapolation of the Road Map data, the basic alternative for 2015-2025 results that GDP will increase from $54.5 \cdot 10^9$ \$ 98 at the level of 2005 to $160 \cdot 10^9$ \$ 98, at the level of 2025 (average annual increase of 5.46%). In conformity with the same document power intensity will decrease from 1356 KWh/thousand of \$ 98 in 2005 to 560 KWh/thousands of \$ 98 at the level of 2025 (average decrease 4.3% annually). Considering Romania's population of 23 million of inhabitants, an estimated consumption for the year 2025 will be of 90 TWh. This consumption is provided by an installed power of about 23,000 MW.

5.2.2. Provision of Necessary Capacities for Electric Power Demand

The electric power demand will be provided on the one hand by the existing units, considering that both the re-ability program and decommissioning, and on the other hand, of the new capacities projects, of the allowable technologies and fuels. In Figure 5.2-1 the evolution of the installed power in the existing capacity is presented between 2005-2025.

In conformity with "The average term strategy of power regenerable resources evaluation, promoted by Romania's Government in January, 2004, the followings will be provided:

- installation before 2010 of 432 MW in plants co generating biomass operation (190 MW), the wind plants (120 MW), small hydro power plants (120 MW), solar plants (1.5 MW), with an annual production of 1.8 TWh;
- installation between 2010-2025 of 790 MW in plants co generating (biomass operation 380 MW, the wind plants 280 MW, small hydro power plants 120 MW, solar plants 9.5 MW), with an annual production of 3.6 TWh.

Except the renewable sources for meeting the electric power demand the following design types will be considered:

- natural gas groups with gas turbine combined cycle-steam turbine;

- gas turbine with recovery tank with/or without additional combustion;
- combustion groups in fluidized layer at atmospheric pressure with recirculation and lignite operation;
- combustion groups in fluidized layer at atmospheric pressure with recirculation and pit coal operation;
- CAF-s and CAI-s on lignite, pit coal or hydrocarbonates possible to be installed in order to meet the thermic power demand.

Technical, economic and environmental parameters of the new groups considers all necessary equipment, in order to meet EU Directions regarding air release limitation for large combustion installations. Considering that Romania’s integration in EU is possible in 2007, a difference between technical, economic and environmental parameters of the new groups considered before and after the adherence year, meaning that the groups which will be installed up to 2007 will meet the Romanian provisions and those installed after 2007 will meet EU’s norms.

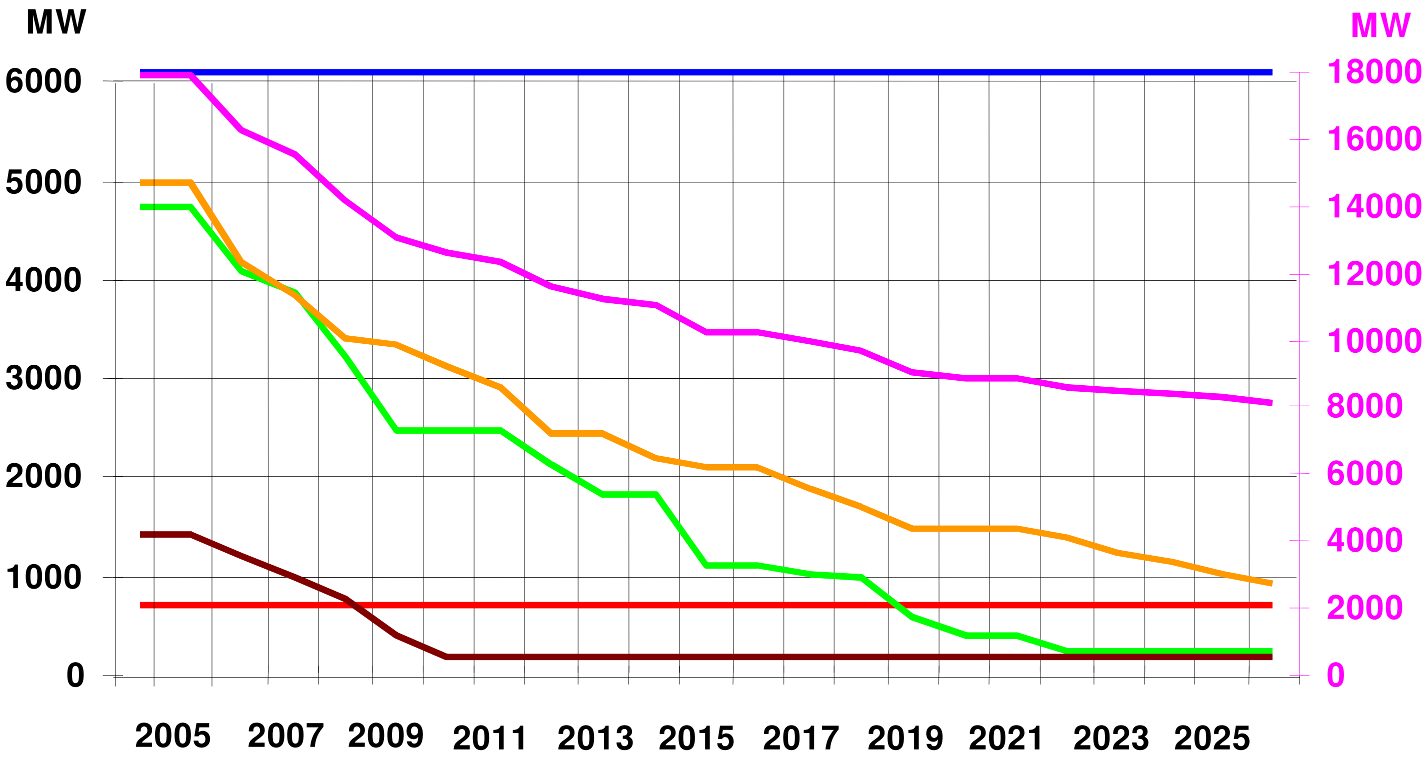
All the scenarios will include, as per RM for period 2005-2015:

- rehabilitation of group 3 of 210 MW from Deva, operating on pit coal;
- rehabilitation of group 5 of 330 MW from Turceni, operating on lignite;
- completion of hydroelectric groups re-ability from “Iron Gates I” for power increase from 175 to 190 MW;
- completion of co-generating group 4 of 150 MW from Paroseni, operating on pit coal;
- completion of Cernavoda Unit 2.

In order to provide local heating power requests, besides CAF-s and CAI-s, for scenarios development, operation of the co-generating groups potential was taken into consideration, by installation of:

- 3000 MW natural gas co-generating groups with combined cycle (gas-turbine and steam turbine) or only gas turbine with recovery tank with or without additional combustion;

- 2x165 MW in co-generating groups with combustion in fluidized layer, at an atmospheric pressure with recirculation and operating on lignite;
- 3x165 MW in co-generating groups with combustion in fluidized layer at atmospheric pressure with recirculation on pit coal.



🟥	Nuclear Plant	🟩	Plant on lignite
▬	Plant on pit coal	🟧	Hydrocarbonate Plant
🟦	Hydroelectrical plants	🟪	**TOTAL**

Figure 5.2-1. The evolution of the installed power in the existing capacities during 2005-2025

5.2.3. Construction of Scenarios for Analysis of Cernavoda Unit 3 Installation Efficiency

The elaboration of the scenarios for the analysis of Cernavoda –Unit 3 finalization efficiency considered the fulfillment of a single basic scenario as per basic case of GDP evolution from RM and of other scenarios in two hypotheses:

- “pessimistic case” (“freezing” the electricity consumption at the value associated to the year 2005). In this case the required installed power would reach about 17900 MW;
- “ minimal case” – an intermediate case of the two cases presented above when the Road Map (RM) targets for the GDP increase , are not fulfilled and the energy intensity gets lower. As per this case the considered GDP increase is 3.5 % (compared to 5.46 % in the RM) and a energy decrease of 3.7 % (compared to 4.3 % in RM). According to this case, the installed power would be 20100 MW.

The proposed constructed scenarios differ among them by the technologies used for meeting the electric power demand.

In the basic case, the following scenarios have been elaborated:

- scenario A – which considers meeting of electric power request, by installation of 13 x 255 MW (3315) in plants with combined cycle gas turbines and steam turbines on natural gas, leading to the level of 2025 year, at a natural gas consumption of $3.46{\cdot}10^9$ m^3;
- scenario B – which considers maintenance up to the year 2025 of an annual quasiconstant consumption of lignite and pit coal at the levels in RM and by installation of 3 x 255 MW (765 MW) in plants with combined cycle gas-turbines – steam turbines on natural gas, a 14 x 165 MW (2310 MW) in combustion groups in fluidized layer at atmospheric pressure with recirculation and operation on lignite and 2 x 165 MW (330 MW respectively of a total of 3405 MW) in combustion groups in fluidized layer at atmospheric pressure with recirculation and operating on pit coal, leading to a consumption at the level of 2025 of 23 million of lignite tons, 1.3 million of pit coal tons and 0.8×10^9 m^3 of natural gas;

- scenario C which, as compared to scenario B, considers Unit 3 from Cernavoda (707 MW) and installation of 14 x 165 MW (2310 MW) in combustion groups in fluidized layer at atmospheric pressure with recirculation and operation on lignite, a 2 x 165 MW (330 MW respectively of a total of 3340 MW) in combustion groups on fluidized layer at atmospheric pressure, with recirculation and operation on black pit, leading to the consumption of 2025 level, of 22 million lignite tons and 1.3 million tons of black pit.

Although the total of the installed capacity in the three scenarios, present small differences determined by the fact that coverage is made in steps and units have no unitary power, the comparative analysis of scenarios is made considering the same total power produced in each scenario.

In table 5.2.3-1 the structure of the electric power generating capacity is presented at the level of 2025 – basic hypothesis.

Table 5.2.3-1. The structure of installed capacities for electric power generation at the level of 2025 – basic hypothesis

	Scenario A	Scenario B	Scenario C	Total
From the evolution of the existing current capacities	990 MW hydrocarbon groups 707 MW NPP Cernavoda Unit 1 150 MW pit coal groups 200 MW lignite groups 6000 MW hydro groups			8040 MW
Regenerable before 2010	190 MW biomass groups 120 MW wind groups 120 MW small hydro groups 1.5 MW solar groups			432 MW
Regenerable after 2010	380 MW biomass groups 280 MW wind groups 120 MW small hydro groups 9.5 MW solar groups			790 MW
From the Road Map	group 3 of 210 MW from Deva on pit coal (out of service at level of 2025) group 5 of 330 MW from Turceni on lignite (out of service at level of 2025) hydro groups “Iron Gates I” by the increase from 175 MW to 190 MW group 4 of congeneration 150 MW from Paroşeni on pit coal Unit 2 from Cernavoda			947 MW
Demand from FREM analyses	3000 MW cogeneration groups 2 x 165 MW groups on lignite 3 x 165 MW groups on pit coal 22 x 255 combined cycle groups			9435 MW
TOTAL				19644 MW
Elements for scenarios differentiation	3315 MW combined cycles	765 MW combined cycles 2310 MW on lignite 330 MW on pit coal	707 MW Unit 3 Cernavoda 2310 MW on lignite 330 MW on pit coal	
Total system	22959 MW	23049 MW	22941 MW	

Table 5.2.3-2 presents the estimated fuel consumptions for electric power generation at the level of 2025 on the three scenarios in the base hypothesis.

Table 5.2.3-2. Fuel consumptions estimated for electric power generation at the level of 2025 on scenarios considered in the basic hypothesis

	Scenario A	Scenario B	Scenario C
Common parts	7 million tons lignite 3.5 million pit coal 10.34×10^9 m^3 natural gas		
Elements for scenarios differentiation	3.46×10^9 m^3 natural gas	23 million tons lignite 1.3 milion tons pit coal $0.8 \cdot 10^9$ m^3 natural gas	23 million tons lignite 1.3 million tons pit coal (1.8 milion tons equivalent conventional fuel for uranium consumption)
TOTAL power system	13.80×10^9 m^3 natural gas 7 million tons lignite 3.5 million tons pit coal	30 million tons lignite 4.8 million tons pit coal 11.54×10^9 m^3 natural gas	30 million tons lignite 4.8 million tons pit coal 10.34×10^9 m^3 natural gas

The pessimistic case constituting the less favorable scenarios construction case is possible either by proper limiting of consumption increase (from economic considerations, possibly by the dramatic decrease of power intensity) or by provision of foreign sources increase.

In Table 5.2.3-3 the structure of installed capacities for electric power generation at the level of 2025 is presented, while in Table 5.2.3-4 the estimated structure of fuel consumption for electric power generation at the level of 2025 on the three scenarios in the pessimistic case is shown.

Table 5.2.3-3. The structure of the installed capacities for electric power production at level of the year 2025 – pessimistic hypothesis

	Scenario A	Scenario B	Scenario C	Total
Existing capacities evolution	990 MW hidrocarbon groups 707 MW NPP Cernavoda Unit 1 150 MW pit coal groups 200 MW lignite group 6000 MW hydro groups			8040 MW
Regenerable before 2010	190 MW biomass groups 120 MW wind groups 120 MW small hydro groups 1.5 MW solar groups			432 MW
Regenerable after 2010	380 MW biomass groups 280 MW wind groups 120 MW small hydro groups 9.5 MW solar groups			790 MW
From the Road Map	group 3 of 210 MW from Deva on pit coal (out of service at level of 2025) group 5 of 330 MW from Turceni on lignite (out of service at the level of 2025) hydro groups “Iron Gates I” by the increase of power from 175 MW to 190 MW group 4 of cogeneration 150 MW from Paroşeni on pit coal Cernavoda Unit 2			947 MW
Demand from FREM analyses	3000 MW cogenerating groups 2 x 165 MW groups on lignite 3 x 165 MW groups on pit coal 2 x 255 groups combined cycle			4335 MW
TOTAL				14544 MW
Scenarios differentiation elements	3315 MW combined cycle	765 MW combined cycles 2310 MW on lignite 330 MW on pit coal	707 MW Cernavoda Unit 3 2310 MW on lignite 330 MW on pit coal	
TOTAL system	17859 MW	17949 MW	17891 MW	

Table 5.2.3-4. Fuel consumptions estimated for electric power generation at the level of 2025 on the scenarios considered in pessimistic case

	Scenario A	**Scenario B**	**Scenario C**
Common parts	7 million tons lignite 3.5 million pit coal $5.02 \cdot 10^9$ m^3 natural gas		
Scenarios differentiation elements	$3.46 \cdot 10^9$ m^3 natural gas	23 million tons lignite 1.3 million tons pit coal $0.8 \cdot 10^9$ m^3 natural gas	23 million tons lignite 1.3 million tons pit coal (1.8 milion tons equivalent conventional fuel for uranium consumption)
TOTAL power system	$8.48 \cdot 10^9$ m^3 natural gas 7 million tons lignite 3.5 million tons pit coal	$5.82 \cdot 10^9$ m^3 natural gas 30 million tons lignite 4.8 million tons pit coal	$5.02 \cdot 10^9$ m^3 natural gas 30 million tons lignite 4.8 million tons pit coal

In this case it can be noticed that as compared to the evolution as per RM, less than 20 groups of 255 MW will be installed, in the common segment of scenarios.

The minimum case (the target of GPD increase and reduction of power intensity respectively, will not be met) considering a more moderated average annual increase of GPD of 3.5 % compared to 5.46 % in RM, correlated to an annual average reduction of power intensity of 3.7 % as compared to 4.3 % in RM.

In Table 5.2.3-5 the structure of installed capacities for electric power generation, at the level of 2025 year, is presented, while in Table 5.2.3-6 the estimated structure of fuel consumption for electric power production at the level of 2025 on the three scenarios, in case of minimal hypothesis is also presented.

Table 5.2.3-5. The structure of installed capacities for electric power generation at the level of 2025 – minimal case

	Scenario A	Scenario B	Scenario C	Total
From the evolution of the existing capacities	990 MW hydrocarbon groups 707 MW Cernavoda Unit 1 150 MW groups on pit coal 200 MW groups on lignite 6000 MW hydro groups			8040 MW
Regenerable before 2010	190 MW biomass groups 120 MW wind groups 120 MW small hydro groups 1.5 MW solar groups			432 MW
Regenerable after 2010	380 MW biomass groups 280 MW wind groups 120 MW small hydro groups 9.5 MW solar groups			790 MW
From the Road Map	group 3 of 210 MW from Deva on pit coal (out of service at level of 2025) group 5 of 330 MW from Turceni on lignite (out of service at the level of 2025) hydro groups “Iron Gates I” by power increase from 175 MW at 190 MW group 4 of congenerating 150 MW from Paroşeni on pit coal Cernavoda Unit 2			947 MW
Demand from FREM analyses	3000 MW cogenerating groups 2 x 165 MW groups on lignite 3 x 165 MW groups on pit coal 11 x 255 combined cycle groups			6630 MW
TOTAL				16839 MW
Elements for scenarios differentiation	3315 MW combined cycles	765 MW combined cycles 2310 Mw on lignite 330 MW on pit coal	707 MW Cernavoda Unit 3 2310 MW on lignite 330 MW on pit coal	
Total system	20154 MW	20244 MW	20186 MW	

Table 5.2.3-6. Fuel consumptions estimated for electric power generation at the level of 2025 on scenarios considered in the minimal case

	Scenario A	Scenario B	Scenario C
Common parts	7 million tons lignite 3.5 million pit coal $7.41 \cdot 10^9$ m^3 natural gas		
Elements for scenarios differentiation	$3.46 \cdot 10^9$ m^3 natural gas	23 million tons lignite 1.3 million tons pit coal $0.8 \cdot 10^9$ m^3 natural gas	23 million tons lignite 1.3 million tons pit coal (1.8 milion tons equivalent conventional fuel for uranium consumption)
TOTAL power system	$10.87 \cdot 10^9$ m^3 natural gas 7 million tons lignite 3.5 million tons pit coal	$8.21 \cdot 10^9$ m^3 natural gas 30 million tons lignite 4.8 million tons pit coal	$7.41 \cdot 10^9$ m^3 natural gas 30 million tons lignite 4.8 million tons pit coal

In this case, as compared to the basic case, less than 11 groups of 255 MW in the common segment of the scenarios case will be installed.

Figure 5.2.3-1 presents the comparison between the proposed scenarios for analysis in different case.

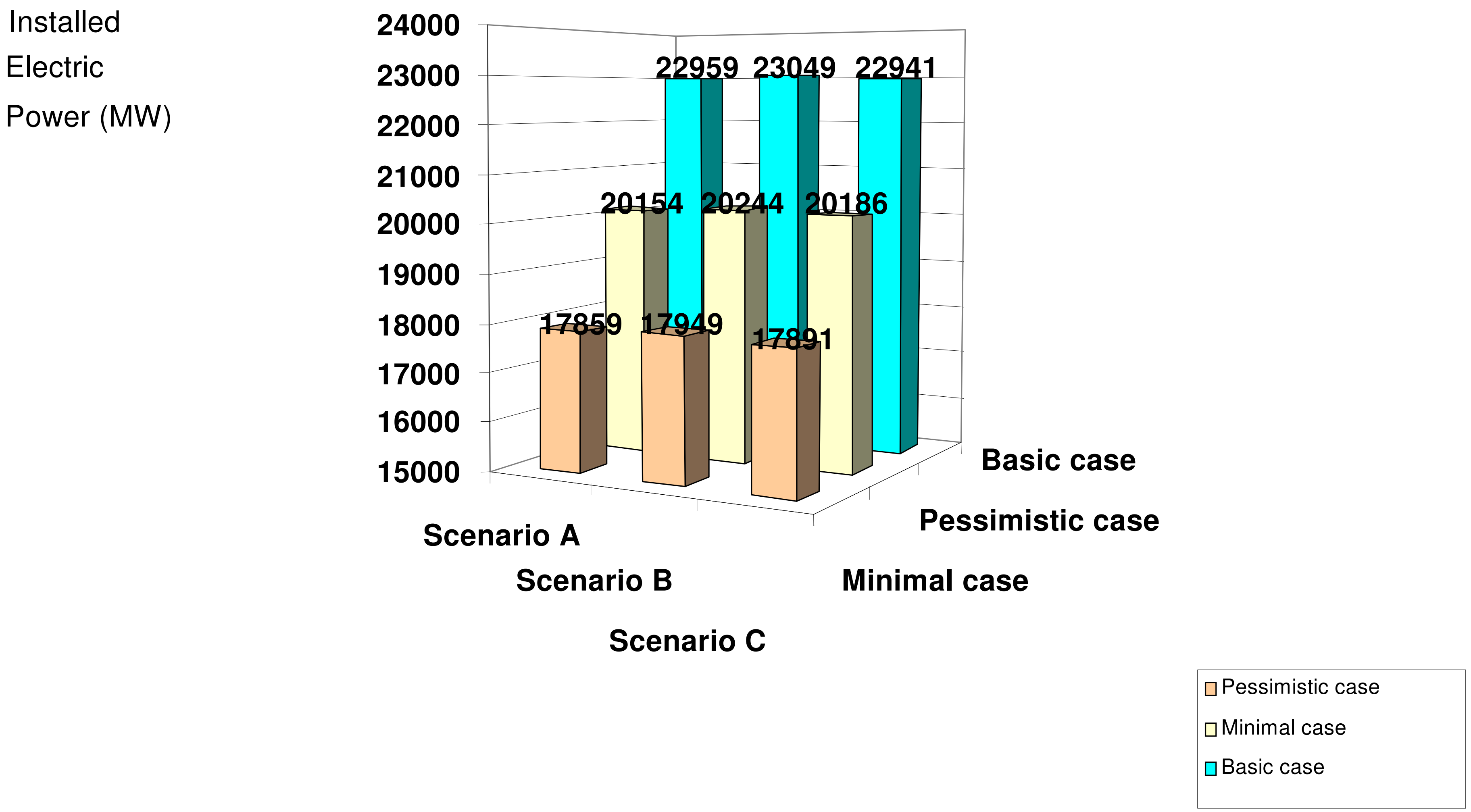


Figure 5.2.3-1. Comparison of the scenarios presented for the 3 considered hypotheses

5.3. Analysis and Comparison of Scenarios for Electric and Thermal Power Sector

As one can see, when structuring the scenarios the aim was to maintain a commonly shared part and one part which is differentiating them. The method to structure the scenarios was selected to allow a comparison among the scenarios only in respect of the part which is differentiating them because only one analysis focused on the installation of Unit 3 may render a relevant comparison. An overall approach at the level of the entire power system could result in a minimization of the effects of one or another of the scenario implementation due to the scale the analysis is developed (Ref. 5.9).

The criteria proposed for the comparison of long-term scenarios are grouped in three categories:

- technical and economic;
- environmental impact;
- social impact.

In order to determine the relative importance of the applied criteria decision-makers in the electric energy field (the ministry, production companies, transport companies in the electric and thermal power field, Polytechnics University in Bucharest, etc) have been interviewed to obtain the qualitative order of the criteria function of their importance. After the qualitative evaluation of the criteria, the most important criterion was assigned four points, followed by the 3 point criterion etc. The order of the scenarios was obtained by summing-up the points resulted for each criterion. To sum–up the points for each criterion, the absolute values were converted in normalized values.

5.3.1. Comparison of the Proposed Scenarios as per the Technical - Economic Criteria

The technical-economic criteria considered in the analysis were:

- total updated costs (CTA);

- the weight of the stationary means that can be re-used in case of the initial investment plan changes;
- the fuel reliable supply.

The comparative analysis of the scenarios upon CTA criterion was conducted starting from the following differences among the scenarios:

- the comparison (that considered the period 2010 –2015) evidenced for scenario A - 5 x 255 MW installed in groups of gas-steam combined cycles while for scenario B - 3 x 255 MW in groups of the same type and 4 x 165 MW in fluidized layer at atmospheric pressure on lignite. With scenario C for the same period, 4 x 165 MW in groups of fluidized layer at atmospheric pressure on lignite and Cernavoda Unit 3 are installed;
- with the time-periods 2016–2020 and 2021-2025, according to scenario A 4x255 MW in gas-steam combined cycle groups and 6 x 165 MW in fluidized layer at atmospheric pressure on coal as per scenario B and scenario C are to be installed;
- at the level of the year 2015 the range of net energy that makes the difference among the scenarios is 9.6 TWh meaning that 1.6 billion m^3 natural gas is substituted by 0.84 billion m^3 natural gas and 6 million tons lignite in scenario B and 6 million tons lignite and 1.8 million tons of nuclear fuel equivalent in scenario C;
- at the level of year 2020 the range of net energy that makes the difference among the scenarios is 16.4TWh meaning that 2.7 billion m^3 natural gas are substituted by 0.84 billion m^3 natural gas and 15 million tons lignite in scenario B and 15 million tons lignite and 1.8 million tons of conventional fuel equivalent for nuclear fuel, in scenario C;
- at the level of year 2025, the energy net range that makes the difference among the scenarios, is 23.1 TWh, meaning that 4.17 billion m^3 natural gas in scenario A are substituted by 0.92 billion m^3 natural gas, 23 million tons lignite and 1.3 million tons pit coal in scenario B and 23 billion ton lignite, 1.3 million tons pit coal and 1.8 million tons of conventional fuel equivalent for nuclear fuel in scenario C.

In a first stage of the analysis, the tariffs for all fuels were considered constant throughout 2005 –2025 analyzed time-period. The value considered for natural gas was EURO 260/1000 Nm^3, a value corresponding to the estimated level for the 2010-2012 interval when Cernavoda Unit 3 is expected to become operational.

The analyses also considered the new required investments for protection of the environment in Romania till the year 2007, the year of Romania accession to EU upon the Romanian Regulations and of the European laws after the year 2007. Moreover, the analyses considered the implication of the environment protection installations in respect of the operation and maintenance cost increase, reduction of output or net power, the increase of the emergency coefficients.

Updating to the level of January, 1st, 2004 with an annual updating rate of 10% as per the level considered proper for Romanian economy in the system analyses were conducted.

The results of CTA criterion application are presented in the table below.

Table 5.3-1. Results of CTA criterion application for the proposed scenarios in the case of the natural gas tariff of 260 EURO /1000 Nm^3

	Scenario A	**Scenario B**	**Scenario C**
CTA (Mil EURO)	2892	2404	2402

As seen from the table, with the natural gas tariff valid for the year 2010 Scenario C seems recommendable, followed by scenario B and scenario A, the difference between scenario C and scenario B being negligible.

Note that the probability to reach the considered 260 EURO/1000Nm^3 tariff is very high if one has in view Romania accession to EU and the fact that the tariff in force ranges between 200-400 EURO /1000 Nm^3 with the prediction of an increase of the tariff at the level of the year 2010.

It is also worth mentioning that throughout the time-period the analysis is conducted for, the natural gas stocks are getting significantly smaller and consequently the tariff for natural gas in EU countries and worldwide will increase.

In line with the above regarding the probable evolution of natural gas tariff, the variations of CTA criterion with the increase of natural gas tariff were calculated upto the average value of 350 EURO /1000 Nm^3. According to the analysis the tariffs for coal and nuclear fuel were maintained at the same constant level, a case also presented in RM.

Fig. 5.3-1. illustrates the results of the analysis.

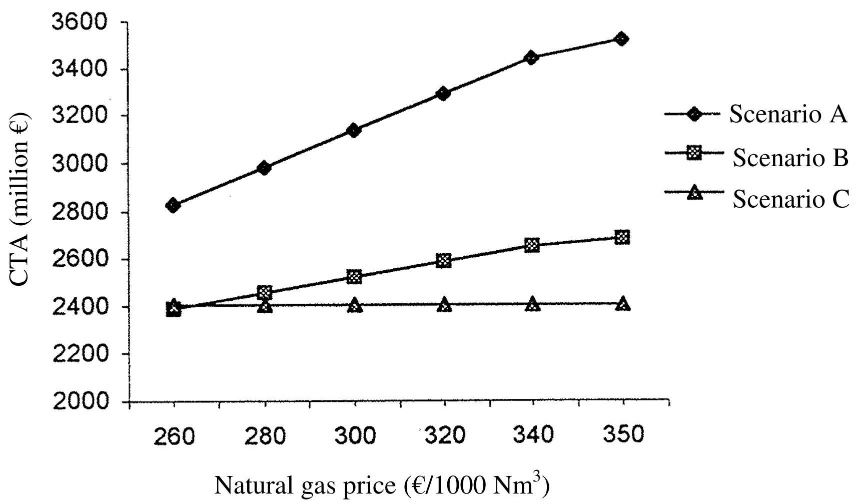


Figure 5.3-1. CTA Variation with the natural gas tariff increase for considered scenarios

As seen, for tariffs higher than 260 EURO /1000Nm^3 for natural gas, Scenario C (the installation of Cernavoda Unit 3 even in association with coal–based units) is undoubtedly differentiated from the other two scenarios. Yet, in the further analysis, the tariff of 260 EURO /1000 Nm^3 will be considered.

The second technical-economic criterion considered in the comparison of scenarios was the criterion regarding the weight of the stationary items that can be re-used in case that the initial investment plan is modified. To quantify the flexibility of the scenarios on the development program modification, first the flexibility of various types of new groups were qualified, flexibilities which were varying from low flexibility – e.g. nuclear groups – and about 70% flexibility in case of combined gas-steam turbine on natural gas. In order to also consider the weight of various groups (e.g. gas turbine, nuclear or fluidized layer coal burning groups), each scenarios was determined the total updated recovering investment for the entire analyzed time-period. Normalized the results, the relative difference among the scenarios was obtained.

According to the above criterion, the favorite scenario is scenario A, followed by scenario B & scenario C.

The 3rd technical-economic criterion applied in the comparison of the scenarios was the one referring to the fuel supply reliability as a component of the power field safety. The number of points in case of this criterion, is increasing due to diversifying the types of fuels at the level of the year 2025 and to the enhanced number of supplying sources for each type of fuel in the applied scenario. It is considered that a reliable supply source can be obtained by an as balanced structure of the fossil fuels as possible.

Starting from the fuel required for producing electric and thermal power at the level of the year 2025 for the selected scenarios, the corresponding degree of variety has been established. The resulted optimum scenario was scenario C followed by scenario B & scenario A (Ref. 5-6).

5.3.2. Comparison of Proposed Scenario as per the Environmental Impact

To compare the proposed scenarios according to the environmental impact criteria, the analysis considered (Ref. 5-6):

- the impact on the surface waters;
- the impact on soil, subsoil and underground waters;
- the impact on public's Health;
- the impact on agriculture & materials.

5.3.2.1. Impact on the Surface Waters under the Considered Scenarios

The energy production domain, be it with conventional basis or nuclear, is using about 60% of the total industrial water consumption.

The production of one electric power unit is requiring 140 l water in case of fossil fuels and 205 l water in case of nuclear. Part of the water is converted into steam but most of it is discharged to the emissary, at a higher temperature.

The impact on the aquatic environment is mainly determined by the entrapping & discharge of the cooled water.

The effects on the aquatic environment may be classified in 3 categories:

- effects due to entrapping into the cooling cycle;
- effects due to impurity and flora & fauna specimen sticking against the retaining systems (grids, screens, etc.);
- thermal effects.

The degree in which the discharged residual water quality and the quality of the receptacle water streams, is depending on some factors such as:

- chemical composition of supply & receptacle water;
- thermal regime of the supply & receptacle water;
- the structure of aquatic systems;
- the contamination due to the substances used for demineralization, lubrication, chlorination, etc.

Since data on the water streams employed as supply source and as receptacle of spent waters, for all the groups provided in the analyzed scenarios, it was assumed that the degree of water stream damage is comparable, the difference being due only in function of the volume of water used for the cooling systems.

Scenario A – The installation of 13 x 255 MW (3315 MW) in combined gas-steam turbine units with natural gas, is assuming the use of a cooling water volume of 4.066 x 10^9 m^3 yearly.

Scenario B – the installation of a 3405 MW in natural gas & coal units meaning the use of a cooling water volume of 4.175 x 10^9 m^3 yearly.

Scenario C – the installation of 14 x 165 MW in lignite burning units, 2 x 165 MW in bituminous coal units and the finalization of Cernavoda Unit 3 (707 MW) meaning an annual cooling water consumption of 4.494 x 10^9 m^3.

Note that in point of cooling water consumption, the most favorable scenario is scenario A, followed by scenario B & scenario C.

Is necessary to noted that the chemical content of the waste waters at the Cernavoda NPP is insignificant and the temperature of the warm water is in the admissible limits of national regulations in force.

5.3.2.2. Impact on Soil, Subsoil and Underground Waters under the Considered Scenarios

Wastes resulted from fossil fuel burning are in large quantities and user wide surfaces and therefore represent a severe environmental problem. Besides the land surfaces affected by the temporary and final disposal of such wastes, another concern is represented by the chemical composition of such wastes.

Both types of wastes (ashes) – the light ones retained in the gas purification system and the ashes discharged with the slag – are containing some elements, some of them very toxic, such as: Si, Al, Fe, Ca, Mg, Ti, Na, K, As, Hg, Pb, Zn, Cd and Cu. Such toxic elements determine the pollution of soil, subsoil and underground waters.

Besides the above listed elements, both coals and the residue ashes are including some quantities of U and Th. Studies developed by EPA (Environmental Protection Agency) on various types of coals, have confirmed a net contents of 1.3 ppm U and 3.2 ppm Th and during the burning process, the ashes are setting a higher concentration of such elements. It is estimated that 1% of such elements are released to the atmosphere, most of them still being kept in the ashes.

Because the characteristics of the land used for the temporary & final disposal of the ashes are not know, one may assume the degree of soil and underground water contamination. Yet, for the ash and slag disposals and disposals of other materials resulted from technologic processes (chemicals, oil products, etc.). The best technologies for the environment protection are to be applied.

The differentiation in point of soil, subsoil & underground water pollution in the analyzed scenarios, has been conduced by the consideration of the generated waste quantity.

As per Scenario A, solid wastes are not generated. As per Scenario B, 9,752,000 tons lignite ash and 319,800 tons bituminous coal ash, making up a total quantity of 10,071,000 tons ash, is generated. If such a quantity were disposed in a 10 m thick layer, the layer would cover a surface of 1,500 ha yearly.

Scenario C assumes the annual production of 95 tons nuclear spent fuel resulted from Unit 3 operation, in addition to the wastes as per Scenario B; the 95 tons extra nuclear spent fuel is temporarily stored and than finally disposed on an insignificant large surface, if compared with the surface required to dispose the ash and slag. Thus, the total quantity of solid wastes resulted as per Scenario C is 10,071,095 tons.

According to the generated solid waste quantities, the order of scenarios is Scenario A, followed by Scenario B and Scenario C, mentioning that since the difference between Scenario B & Scenario C is small - 0.0009% - they are actually equivalent.

5.3.2.3. Impact on Health under the Considered Scenarios

The most important pollutants of the atmosphere generated by the power industry are: particles (PM), sulphur dioxide and nitrogen oxides.

Studies developed in USA, Europe and other countries, show that PM pollution is inducing death, an increases premature death. The most dangerous fraction is the one called “PM 2.5” represented by particles smaller of 2.5 µm diameter called “light powders” which easily penetrate the filters installed to reduce the effluents (emissions), reaching the breathing system and depositing inside the lungs.

Such a deposit inside the lungs is causing the occurrence of lung and heart diseases and can induce the lung cancer.

The release of some heavy metals, such as: Pb, Hg, As, Be or Cd leads to chromic diseases or cancer. The short-term SO_2 exposure results in the worsening of symptoms and a prolonged SO_2 exposure is generating the increase of lung chromic diseases and death.

Nitrogene oxides are favouring the breathing system diseases and the exposure to high nitrogene oxide concentrations leads to the occurrence of bronchitis, with children, and asthma, with the adults. The epidemiologic studies have demonstrated that an increase by 20 $\mu g/m^3$ of nitrogene oxide concentration for 2 weeks, is leading to a 20% increase of the risk for breathing system diseases occurrence with children.

Recent analyses have shown that there is a linear proportionality relation between PM 10 concentration and the relative death risk and the PM 10 concentration and death caused by heart-breathing diseases. A PM 10 increase by 10 $\mu g/m^3$ leads to a 3.4% increase of death due to lung diseases and to a 1.4% increase of death due to blood system diseases.

The different nature of the environmental effects which occur during the generation of electric power, makes the comparative analysis of various possible scenarios, difficult. The internationally accepted method is the environmental impact equivalent method which means the assessment of losses generated by the environmental impact expressed in money (Ref. 5-6).

The External E software includes the risks/hazard indicators quantified by WHO and the YOLL costs due to premature death related to each scenario, were calculated. The results are presented herein below:

- Scenario A-YOLL: 25,696,330 €;
- Scenario B-YOLL: 329,129,175 €;
- Scenario C-YOLL: 329,889,123 €.

As seen, Scenario C is the most disadvantageous but it must be stated that YOLL evaluation in case of fossil fuel use, was carried-out only in function of the atmospheric pollutions released during the unit operation rather than for the entire fuel cycle from raw material extraction and fuel to the decommissioning of the facilities, inclusively.

It is also worth mentioning the insignificant difference between Scenario B & Scenario C from that viewpoint.

The influence of considering full cycles in respect of the production of greenhouse effect generating gases may be seen in the below table (Ref. 5-7) :

Greenhouse generating gas (CO2) production for various categories of fuels with and without considering the entire cycle (tons/MWh)

	Without considering the full cycle	Considering the full cycle
Coal	0,860	1,290
Natural Gas	0.460	1.230
Nuclear	0,009	0.030

It is obvious that in this case the nuclear represents the advantage against the classic fuel cycle alternatives.

5.3.2.4. Impact on Agriculture & Materials under the Considered Scenarios

Sulphur dioxide is representing a serious threat for forest because a slight sulphur dioxide concentration of only few ppm may produce malfunctions in the photosynthesis process. The most frequent endangered species are the coniferous. The annual increase of SO_2 from 40 to 105 $\mu g/m^3$ led to the disappearance of forests in the so called “black triangle” located between Germany, Poland & Czech Republic.

The NO_2 and SO_2 represent the main cause of acid rains which generate damages upon the vegetation and fish, accelerate corrosion on metals, stones and concrete.

Acidifying the soil is a process which determines the solubility of heavy metal salts which via the trophic chain are reaching the human body.

In worm and sunny days, NO_2 in contact with hydrocarbons is producing the ozone which is very dangerous at the troposphere level. In the stratosphere, the NO_2 is contributing to the destruction of the ozone layer.

The calculations of YOLL for the 3 scenarios led to the following results:

- Scenario A – losses of € 1,493,115;

- Scenario B – losses of € 339,959;
- Scenario C – losses of € 260,473.

The value of the losses was calculated only considering the atmospheric pollution generated by the fossil fuel burning and it did not consider the water, soil, subsoil pollution and the general pollution in the other steps of the life cycle.

5.3.2.5. Quantification of Total Environmental Impact under the Considered Scenarios

The previous chapters include a quantification of the environmental effects generated by the electric and thermal power generation for each of the 3 scenarios analyzed on basis of several criteria.

Besides, an additional analysis based on the quantification of the greenhouse effect gases associated to each considered scenario, was conducted. The analysis considered the specific greenhouse effect emissions for each type of fuel in each scenario.

The losses associated to such emissions were expressed by the taxes charged to each greenhouse effect gas source. For the analysis, two levels of taxes, a minimal one of € 19/ton of CO_2 and a maximal one of € 46/ton of CO_2, were employed. The values obtained with the environmental analysis, considered the same updating ratio (10%) like the case of the technical-economic criterion.

The centralized results for the economic-environmental analysis expressed in financial losses, in updated values, are presented in Table 5.3.2-1.

Table 5.3.2-1. Centralized results of the economic-environmental analysis expressed in financial losses, in updated values (mil. €)

Analysis type	Tax level on CO_2 emission	Analyzed scenarios		
		Scenario A	Scenario B	Scenario C
Economic		2 892.0	2 404.0	2 402.0
Environmental	minimal	51.9	128.1	126.9
	maximal	126.1	323.4	320.5
Total economic-environmental	minimal	2 949.0	2 532.0	2 529.0
	maximal	3 018.0	2 727.0	2 722.0

The comparison points out Scenario C as favorite, followed by Scenario B & Scenario A.

5.4. Comparison of Scenarios in Point of Social Impact

Quantification of scenarios in point of the criterion of population acceptance on the type of technology, starts from the energy supplied by the coal-based power plants and nuclear power plants at the level of the year 2025 upon the considered scenarios (Ref. 5.9).

In the Romanian economy, the weight of coal mining is high, involving a large number of employees. An important weight is also represented by coal in the electric & thermal power production. It was assumed that a scenario is likely to be more accepted, the energy supplied by the coal-burning plants is greater and that supplied by the nuclear power plants is smaller.

According to that criterion, Scenario B proved to be optimum, followed by Scenarios C & Scenario A.

It was assumed that today, in Romania, the criterion related to the acceptance of the technology type by the population shows a low importance (10%), by comparison with the importance of the criterion in more developed countries.

5.5. Multi-Criteria Analysis of the Scenarios

To obtain a representative image on the hierarchy of the proposed scenarios it is not enough to have a comparison only on one or another criterion. For that reason, a multi-criteria analysis employing an indicator which quantifies the more or less importance of some criteria as to the others, has been conducted in order to obtain the most objective decision possible by considering all the aspects which differentiate the scenarios (Ref. 5.9).

The way to determine the relative importance of the applied criteria and of the points calculation, was presented in the introduction at Chapter 5.3.

Table 5.5-1 is a synthesis of the results of the multi-criteria analysis that considered the results of the comparison developed as per the individual criteria, assigning importance coefficients to each of the criteria. Note that for the environmental criteria, the case of maximum taxes for CO_2 emissions was considered, a case otherwise justified by the necessary of substantial investments in the construction of systems to entrap and treat the pollutants generated by the power installations.

Table 5.5-1. Centralized results of the multi-criteria analysis comparison of the scenarios

Criterion	Type	Importance	Unit	Scenario		
				A	B	C
CTA+environmental	minim	0.52	mil €	3018	2727	2722
Flexibility of the project to the initial program	maxim	0.08	%	94	84	73
Diversifying the fuel types at the level of year 2025	minim	0.30	%	82	62	55
Public acceptance on the type of technology	maxim	0.10	%	21	40	36
Assigned points (without the importance coefficients)	-	-	points	3.09	3.77	3.67
Assigned points (with the importance coefficients)	-	-	points	0.8	0.96	0.97

As per the table, the favorable scenario is Scenario C which includes the finalization of Cernavoda NPP Unit 3, followed by Scenario B & Scenario A. Through the difference between Scenario C & Scenario B seems to be small, it’s worst mentioning that for natural gas, the € 260/1000 Nm^3 tariff was accepted for all the analyzed time-period (2005-2025) and the expected enhance of the tariff would result in the definite differentiation in favour of Scenario C (Figure 5.3.1) .

5.6. Considerations regarding the alternative to build Cernavoda - Unit 4

Although it has not been available on the date of this document, the analysis study of the alternatives considering Cernavoda - Unit 4 as well, the analysis of the criteria and of the results of the alternatives developed for Unit 3, is obviously pointing out the followings (Ref. 5.9):

1. In point of the updated total costs, the consideration of Cernavoda - U4 will result in the increase of the differences between Scenario B and Scenario C, in favor of Scenario C which supposed the consideration of Cernavoda - U4. The predictable evolution of the cost price for natural gases against the value supposed in the analysis, makes Scenario C get even more favorable, by comparison with the other scenarios.

2. In point of the environmental criterion, irrespective of the considered fee value for the greenhouse gas emissions, taking into account Cernavoda - U4 will result in an increase of the difference between Scenario B and Scenario C, in favor of Scenario C which included Cernavoda - U4 (See Table 5.3.2.1);

3. Finally, bearing in mind both the technical-economic criterion and the environmental one, irrespective of the considered fee value for the greenhouse gas emissions, the difference between Scenario B and Scenario C is getting bigger in favor of Scenario C.

References

5-1. Hotărârea Guvernului Nr. 890/2003 privind aprobarea Foii de parcurs din domeniul energetic din România, MO Partea I, nr. 581şi 581 bis.

5-2. Fundația Română pentru Energie şi Mediu, *Analiza alternativelor la realizarea Unității 3 Cernavodă pentru producerea energiei electrice inclusiv aceea de renunțare la proiect. Etapa I. Evoluția probabilă a necesarului de energie electrică pentru România în contextul energetic european, actual şi viitor,* iunie 2004.

5-3. Scrisoare SITON Nr. 826/19.02.2006.

5-4. Dr. ing. Ioan Rotaru, *"Guvernele şi energia nucleară",* Revista Energia Nucleară Vol.17 Nr. 1-2/2005.

5-5. Th. Chirica, Prezentare la Masa Rotundă "Politica națională de securitate nucleară", Hotel Marriott - Bucureşti 25 aprilie 2006, Revista Energia Nucleară Vol. 18, Nr.1-2/2006.

5-6. Fundația Română pentru Energie şi Mediu, *Analiza alternativelor la realizarea Unității 3 la CNE Cernavodă pentru producerea energiei electrice, inclusiv aceea de renunțare la proiect. Etapa III. Construirea, pentru intervalul 2005-2025 a unor scenarii de dezvoltare a sectorului energiei electrice şi termice cu şi fără Unitatea 3 de la CNE Cernavodă,* septembrie 2004.

5-7. IAEA, Nuclear Power Advantages, *Sustainable Development and Nuclear Power,* Vienna, 1997, pag. 34.

5-8. Fundația România pentru Energie şi Mediu, *Analiza alternativelor la realizarea Unității 3 la CNE Cernavodă pentru producerea energiei electrice inclusiv aceea de renunțare la proiect. Etapa IV. Analiza şi compararea scenariilor de dezvoltare a sectorului energiei electrice şi termice din punct de vedere tehnico-economic, al consumului de resurse necesare şi al impactului asupra mediului şi sănătății populației,* iunie 2004.

5-9. SITON, *Documentație U3/U4 - 08233 - 6023 - STI,* august 2006.