About the Development Strategies of Power Plant in Energy Market

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Abstract: - The paper aims at identifying and assessing the revenues and costs incurred by various modernization and modernization-development strategies for a power plant in order to optimize the electric and thermal energy are produced and to conduct a sensitivity analysis of the main performance indicators.The Romanian energy system and the energy market have gone a long transition way, from the vertically integrated model, the responsibility for the delivery of the electricity comes exclusively to a state monopoly, to a decentralized system, characterized by the decentralization of production and transport, respectively distribution activities. Romania chose the liberal market model where the relations between the actors in the market – producers and suppliers free to make sales and purchase transactions for electrical energy – are mostly governed by contracts, which may be either bilaterally negotiated or are already regulated. Therefore, the importance of understanding the development trend of the Romanian energy market lies in its economic effects upon the solutions which could be adopted for the evolution of the cogeneration power plant in question.

Key-Words: - energy system, energy market, power plant, strategic customer, sensitivity analysis

1 Introduction

The fundamental position of those who decide upon the development of the cogeneration power plant should aim at minimizing the risks, in the case of PPP projects: public – private partnership.

The main risks which the developer of a cogeneration plant may encounter are:

The general risk of a non-regulated market – it is not specific to this type of business. In a non-regulated market the most usual ways to sensibly reduce this risk is to close physical bilateral and hedging contracts.

The risk of non-dispatch – it can take the form of bilateral contracts, concluded especially with internal suppliers or – if possible – export contracts.

The general regulatory risk – it can occur to any producer.

The risk of environmental legislation – it is the most difficult to estimate and manage. The most important thing is the fact that it applies to all the energy producers who use the same type of fuel to the same extent.

The non-credit risk - a sound economical and financial analysis to persuade banks as for the feasibility of the project can substantially lower this risk.

The fuel price risk – this is one of the most visible risks. The easiest, most secure way to manage this type of risk is by closing long-term contracts, if the conditions of the fuel market allow it, [1].

2 Position of the power plant on the energy market

The production of electric and thermal energy of the cogeneration power plant in question is based upon the existence of several important industrial and urban consumers – the National Energy System (NES) is an important customer, requiring around 75% of all deliveries and one of clients is considered so-called "strategic customer", given the level of safety in power supply. The power plant belongs to the country area that is strongly equipped with power generation sources: the steam generators with natural circulation, fuelled by powdered burnt lignite and heavy fuel oil for the support flame, the 50 MW turbo generators and 25 MW turbo generators. The transfer of the produced power is done by means of a 110 kV switching substation to the NES. The transfer of the thermal energy to the industrial and urban consumers within the municipality is done by means of technological and heating networks. The duration curves of primary production and supply are presented in Figures 1 through 3.

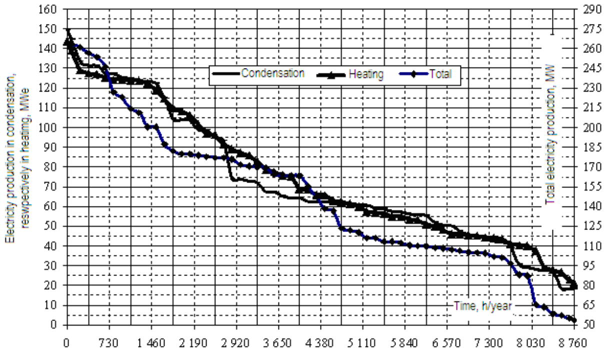

Fig. 1. Duration curves of the ”primary” energy supply

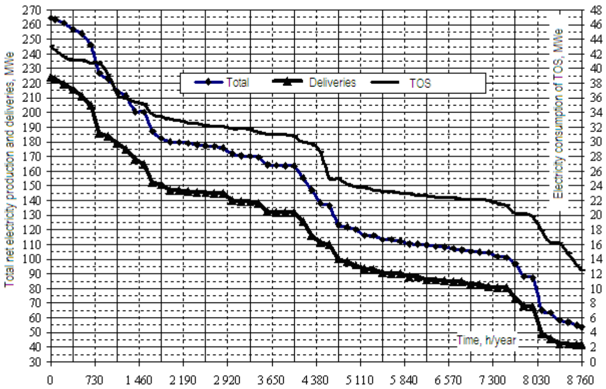

Fig. 2. Duration curves of the technological consumptions and energy supply

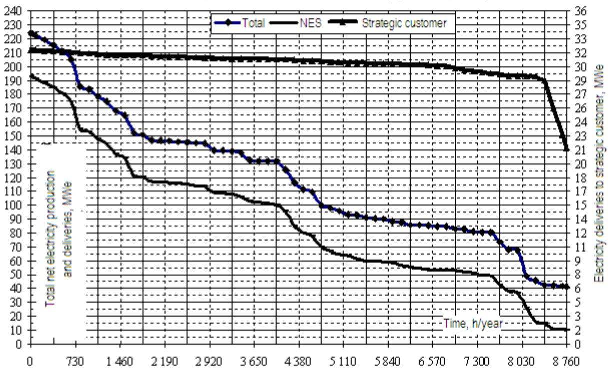

Fig. 3. Duration curves of the electricity supply to strategic customer, respectively to the NES

Tables 1, 2 and 3 present the results of the statistic processing of the average monthly power.

Table 1. The “raw” energy production

Parameter, UM		Condensation	Heat	Total
Maximal peak power, extrapolated, MW_e		144.346	138.914	263.338
Weighted average multiannual power, MW_e		73.032	74.860	147.892
Maximum prediction interval	Med+sigma, MW_e	106.938	107.403	202.239
	Med-sigma, MW_e	39.126	42.318	93.546
Minimum average monthly power, MW_e		18.276	22.907	54.785
Average standard deviation, MWe		33.906	32.543	54.347

Table 2. Technological consumptions and energy supply

Parameter, UM		TOS	Deliveries	Total
Maximal peak power, extrapolated, MW_e		42.557	222.621	263.338
Weighted average multiannual power, MW_e		28.058	119.875	147.892
Maximum prediction interval	Med+sigma, MW_e	35.490	166.939	202.239
	Med-sigma, MW_e	20.625	72.811	93.546
Minimum average monthly power, MW_e		13.208	41.590	54.785
Average standard deviation, MWe		7.432	47.064	54.347

Table 3. Energy supply to strategic customer and to the NES

Parameter, UM		Strategic customer	NES	Deliveries
Maximal peak power, extrapolated, MW_e		31.848	191.711	222.621
Weighted average multiannual power, MW_e		30.331	89.417	119.875
Maximum prediction interval	Med+sigma, MW_e	31.770	136.265	166.939
	Med-sigma, MW_e	28.893	42.568	72.811
Minimum average monthly power, MW_e		22.612	10.485	41.590
Average standard deviation, MWe		1.439	46.848	47.064

It is noted that, unlike the other consumers, the average consumption of the strategic one is close to the maximum and minimum average values, with a strong emphasis on supply continuity. During the power plant operation, it has been emphasized the existence of secondary, less extensive energy exchanges, the consumers connected directly to the power supply – accounting for 0.11 % out of the total amount of energy supply recorded on the power meter of the plant. In the future is also the possibility that some of the eligible consumers may choose other suppliers.

Even though the power plant currently occupies a stable position on the energy market, its evolution may change on the one hand due to the development of the most important economic agent – still considered to be the main energy consumer, the strategies of the neighbouring competitors and on the other hand due to the predictable development of the city. The existence of eligible customers is very important they can conclude contracts at longer intervals – their competitive strength depends on their own development programs and financing schemes. The reasons may be different: the tradition of cooperation with the power plant, the possibility of negotiating some convenient clauses, an advantageous price through the small transport and distribution tariff, price change over time depending on the fuel. In the study, the short term programs are seen as feasible given the normal maintenance costs;

only the medium and long term ones are considered. Live cycle varies between 15 and 30 years for a deeply rehabilitated group, respectively for new group.

The efficiency of a rehabilitated energy group increases by 3-5% with the direct consequence the reducing fuel consumption; were considered investment expenses with desulphurization installations, dense slam, slag, ash deposits.

The development programs of all the potential competitors of the plant are bound to lead to an increase of the production costs, mostly generated by the companies' necessity of return on their significant investments. Although – in each case – performance is improved, the investments put pressure on the market energy price over the next years, given the fact that their purpose is not only to increase efficiency, but also to comply with environmental regulations. Possible external market participation - unfortunately for the power plant, the area is particularly developed in low-cost and direct-to-outdoor energy producers. The most prominent examples are hydroelectric power plants and energy complex, which however have superior energy performance and - implicitly - lower bid prices. Therefore, it is considered that the export can only be a marginal solution for the power plant, up to 1% of the annual energy production.

The portfolio of consumers active on the thermal energy market of the power plant consists mainly of the most important customer - the economic agent to whom industrial steam by pressure 40 bar and 13 bar is delivered as well as the urban consumers to whom they are delivered the hot water.

Figure 4 shows that the absence of consumer... shall be decisive in the structure of the functioning scheme of the cogeneration plant, therefore implicitly influencing the heat supply turnover. A mere analysis of the equivalent year was significant enough to notice the fact that 77% of the heat supply to the strategic customer account for 87% of the turnover in the same equivalent year. As for the thermal energy supply for the city, although amounting to a relatively low 13% figure, it requires an intense supply effort.

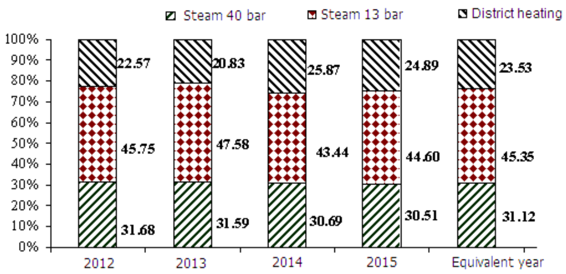

Fig. 4. The share of heat deliveries

The thermal power to meet the current heat demand is approximately: 154 MWt for the maximum winter regime and about 15 MWt for the maximum summer regime. Maintaining the current centralized heating system from a cogeneration source is appropriate due to the absence of a viable technical and economic alternative in the medium term - the city is not connected to the natural gas network. Figures 5 and 6, as well as tables 4 and 5 synthesize the data related to thermal energy production and supply corresponding to various thermal levels and to various types of consumers. The results are the duration curves and the corresponding values.

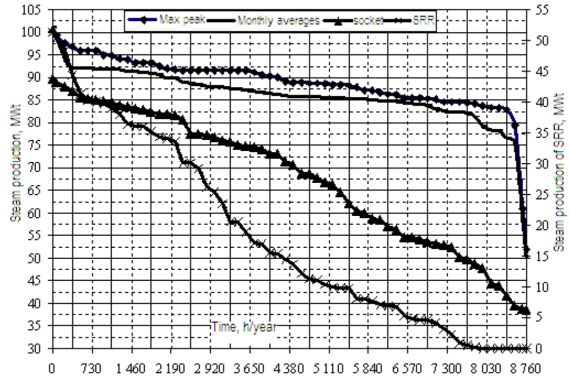

Fig. 5. Duration curves of the IP_{40bar} technological steam supply

Table 4 Values of the IP_{40bar} technological steam supply

Parameter, UM		Max.	Monthly averages	Socket	SRR
Maximal peak power, extrapolated, MW_t		99.42	98.87	89.09	50.33
Weighted average multiannual power, MW_t		88.47	85.58	67.45	20.27
Maximum prediction interval	Med+sigma, MW_t	95.81	92.89	82.21	34.84
	Med-sigma, MW_t	81.13	78.27	52.68	5.71
Minimum average monthly power, MW_t		51.89	49.88	38.48	0.00
Average standard deviation, MW_t		7.34	7.31	14.76	14.57

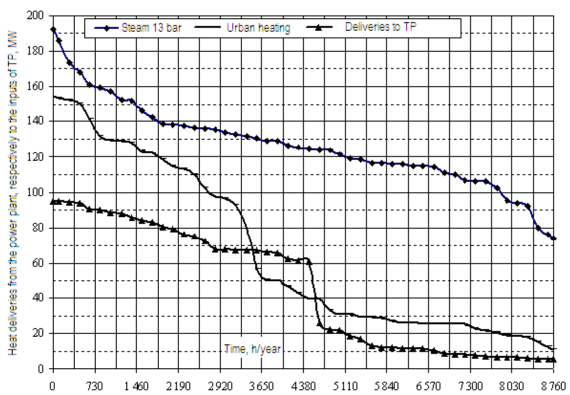

Fig. 6. Duration curves for the 13 bar and hot water heat supply

Table 5. Values of the 13 bar and hot water technological steam supply

Parameter, UM		Steam, 13 bar	District heating	Deliveries to TP
Maximal peak power, extrapolated, MW_t		191.86	154.13	94.65
Weighted average multiannual power, MW_t		126.96	66.40	36.75
Maximum prediction interval	Med+sigma, MW_t	152.37	115.04	71.81
	Med-sigma, MW_t	101.55	17.77	1.69
Minimum average monthly power, MW_t		74.28	11.14	1.06
Average standard deviation, MW_t		25.41	48.63	35.06

The city is a potential city that takes care of its European city. Representatives for the heat energy market are the projects related to the establishment of new institutions, especially in education, as well as the construction of a new modern housing district.

Alternative solutions to this centralized heating system from a cogeneration source are "in antithesis" to the social protection programs for low-purchasing power thermal consumers.

The absence of economic alternative to centralized heating would oblige consumers, in case of a hypothetical "fall" of the current distribution system, to resort to costly solutions, both in terms of initial investment and operating costs.

This is not easy to the buyers with low purchasing power, who will no longer be able to benefit from the heating and hot water service.

Consequently, subvention arises as a result of the cogeneration process, in which allocates the cost share related to electricity generation and that generated by the heat delivery.

3 Technical analysis of modernization and development scenarios

Following examination of the future conditions of operation of the power plant, the following technical and operating restrictions have resulted: cooling capacity of the power plant is sufficient for some scenarios - for others, it is necessary to consider installing a new cooling tower of capacity 10 000 m^3/h; the maximum power produced by the power plant in scenarios without the strategic consumer will be limited to 300 MWe, due to the capacity of the existing transport lines.

In the scoring of scenarios, it was considered that:

"Modernization" solutions will be based on current conversion technology, with steam cycle without intermediate overheating, and a schema with collector bars. The main thermomechanical equipment will be the existing ones, to which will be added a DKAR 22 turbine; base fuel - coal, support fuel - fuel oil or natural gas. These are continuity scenarios for operating with the strategic customer, but they can also be considered when operating without it.

"Modernization – development solutions without changing conversion technology" are only considered in operation without the most important economic agent. The cogeneration part of the plant will be maintained at the strictly necessary capacity to deliver heat to urban consumers; base fuel - coal, support fuel - liquid fuel or natural gas. To increase the production of condensing electricity, new groups based on the steam cycle will be added, in two variants: first, with a new 100 MW pure condensation group without intermediate overheating and, the second, with a new 220 MW pure condensing group with intermediate overheating.

"Modernization – development solutions with changing conversion technology" are only considered in operation without the most important economic agent. To increase the production of condensing electricity, a new unit of about 105 MW of "steam-gas" combined cycle in a single-shaft solution will be added, base fuel - natural gas.

"Development solutions with or without changing conversion technology" – the steam turbines existing are not being used and the new units will have to produce electricity in both cogeneration and condensation; scenarios in operation without the most important economic agent.

The possible solutions, depending on the type of fuel either lignite or coal, are:

- Modernization of existing facilities with existing fuel, "continuity" solution, implemented after the start up of the new turbine, note A_1.
- Modernization of the existing facilities by fuel change – this alternative is based upon the idea of using lignite instead of coal, in view of reducing the fuel/ash flow and the costs incurred by the transportation, handling and storage thereof, A_2.
- Modernization of existing equipments with existing fuel and without the most important customer, A_3.
- Modernization of existing equipments with fuel changing and without the most important customer, A_4. This scenario is similar to A_3 and consists of the change of fuel - from lignite in

coal and is based on the same equipments - boilers and turbines as in the previous case.

- Modernization of the existing facilities and development by means of a new 100 MW facility, with no change of the conversion technology - solution consists of connecting a steam generator inside the power plant to a simple cycle steam turbine, thus helping to increase the electricity production capacity of the plant, A_5.
- Modernization of the existing facilities and development by means of a new 100 MW facility, with change of the existing fuel, but not of the conversion technology - this scenario is similar to the one described above. One element is added, however, consisting of changing the solid fuel from lignite to coal, A_6.
- Modernization of the existing facilities and development by means of a new 220 MW facility, with no change of the conversion technology - alternative with an extended efficiency, consisting of turning 2-3 generators for intermediate superheating functioning, to a 2x50% scheme, with a new 220 MW turbine, A_7.
- Modernization of the existing facilities and development by means of a new 200 MW unit, with change of the existing fuel, but not of the conversion technology - this alternative is similar to the one described above. One element is added, however, consisting of changing the solid fuel from lignite to coal and making the necessary investments, A_8.
- Modernization of existing facilities and development with a new unit with conversion technology, 110 MW single shafts, A_9. This alternative keeps some of the existing capacities of the lignite energy conversion technology, introducing in addition a combined gas-steam cycle.
- Modernization of existing facilities and development with a new unit with conversion technology, 110 MW, single shaft with change of the existing fuel, A_{10} - this way is similar to the one described above, in addition changing the solid fuel from lignite to coal with the necessary investments.
- Development by means of a new 225 MW unit, with no change of the conversion technology - implies total replacement of the existing equipment and the installation of a new group, with intermediate superheating and urban connection, solution hereinafter referred to as A_{11}.
- Development by means of a new 225 MW unit, with change of the existing fuel but not of the conversion technology - this alternative is similar to the one described above. One element is added, however, consisting of changing the solid fuel from lignite to coal and making the necessary investments, A_{12}.
- Development with a new unit and conversion technology, 220 MW, triple shaft, A_{13} - the actual equipment is completely removed and a mixed gas-steam cycle is installed.

4 Economic analysis

The purpose of the analysis is to identify and assess the costs and revenues of the various development and/or modernization scenarios in order to optimize the production of electric and thermal energy, to compare costs and revenue for the proposed scenarios and establishing a ranking of the proposed scenarios based on the technical-economic efficiency analyzed using performance indicators. The most important hypothesis that is proposed for the economic analysis is that all the modernization and/or development scenarios will refer to the year when the upgraded or new equipment will be ready to go into operation. The forecast for financial flows was based on direct costs, associated with the production of electricity and heat, and revenues. The solution performance evaluation is based upon the following criteria: the discounted financial flow, DFF; the internal rate of return, IRR; the amended return period, T_a. The discounted financial flow, DFF, is calculated based on the annual financial flow, A_t, which analyzes the investment expenses, the functioning expenses and the achieved income:

$$DFF = \sum_{t=1}^{n} \frac{A_t}{(1+a)^t} \quad (1)$$

where "t" is all period of time and "a" is the actualization rate. The result of reporting the DFF achieved during the implementation of the project to the actualized investment is the R_{DFF} (net profit ratio), expressed in $USD_{DFF}/USD_{investment}$.

$$R_{DFF} = \frac{DFF}{\sum_{t=1}^{PIF} \frac{IE_t}{(1+a)^t}} \quad (2)$$

The internal rate of return is also based upon the actualized cash flow and it represents the "actualization" rate for which the DFF equals zero. The internal rate of return is given by r:

$$\sum_{t=1}^{n} \frac{A_t}{(1+r)^t} = 0 \quad (3)$$

The amended return period (T_a) is superior to DFF. This method is used to actualize the annual net incomes to determine the return period. The acceptability criterion is a return period lower than the regulated duration of use. This period corresponds to the moment when the cumulative net income equals zero:

$$\sum_{t=1}^{T_a} \frac{A_t}{(1+a)^t} = 0 \quad (4)$$

The economic analysis, expressed by means of the calculated criteria of discounted financial flow, internal rate of return and return on values. The estimated order of running solutions without the most important customer (used values obtained for investments with a similar profile) and the results of economic analysis are presented in table 6.

Table 6. Estimates of investment (Euro) and values of the economic criteria

No	Possibility	Investment, mil. euro	DFF, mil. euro	The internal rate of return, %
1	A_1	78	-1.010	0.66
2	A_2	138	-6.110	-
3	A_5	137	-1.915	0.23
4	A_6	210	-9.351	-
5	A_7	201	-1.834	2.69
6	A_8	274	-9.802	-
7	A_9	173	-4.018	-
8	A_{10}	231	-8.349	-
9	A_{11}	154	-902	6.36
10	A_{12}	184	-5.640	-
11	A_{13}	174	-5.552	-

Thus, the shift from the operation on lignite to the coal entails very high costs that produce discrepancies between solutions of the same type in terms of investment. The most expensive solution turns out to be the A_8, and the cheapest is maintaining the current profile with the introduction of desulphurisation facilities. As shown in the table, the comparatively more efficient variants from an economic point of view are: A_{11} presents the best value for economic efficiency indicators; A_1 is ranked second and A_7 is ranked third, following the economic analysis. It is however noticed the fact that, in neither of the suggested solutions has DFF got a positive value, under the circumstances of reference prices. From these, result a group of solutions that are more efficient, in relative values, than the rest of the other proposed. Solutions that involve operation on coal can not be an option for power plant development due of the significant investment that the changing of steam generators requires. Also, the solutions that propose operation on the natural gas do not provide special economic performance, mainly due to the high price of this fuel. Solutions selected to be the subject of financial analysis are those that occupy the top four positions of the rankings, namely: A_{11}, A_1, A_7, A_5.

From these results, it can be concluded that the power plant must continue to operate on lignite.

The installation of new groups, in parallel or not with the modernization of existing ones, will be decided by the price of the electricity to be produced. The purpose of the sensitivity analysis is to determine the variation of economic indicators values when changing certain parameters on which they depend. It is also aims to check the ranking obtained from the economic analysis for various scenarios of variation of the most important calculation data.

The most important parameter for checking the sensitivity of economic indicators is the slope of the electricity price increase. In the reference version, this increase was considered to be 10% per year.

Shall be studied the sensitivity of economic efficiency, by DFF variation, to changing this growth slope from 5% to 15%. The resulting values, for the four suggested technical alternatives, are presented in table 7.

Table 7. DFF sensitivity at change the slope of increase of electricity price

Possibility	Slope variation of increase of electricity price		
	5%	10% (ref)	15%
A_{11}	-2.020	-901	240
A_1	-1.991	-1.016	-42
A_7	-3.602	-1.840	-77
A_5	-3.444	-1.921	-399

We can see the tendency of variation of the operational cost of energy, electrical and thermal, for the four scenarios, compared to the continuity one characterized by the keeping of the most important customer, figure 7.

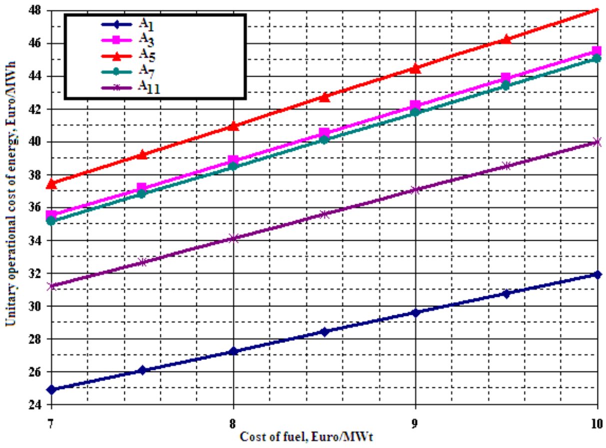

Fig. 7. Variation of the specific energy cost according the lignite price

It can be noticed that the lowest cost is given by the actual equipment in the context of the operation with the economical agent; the next scenario is the development one with a 200 MW group, the other three scenarios are closer and are characterized by higher energy costs.

From this sensitivity analysis follows the conclusions: the efficiency of the project is extremely sensitive to the change in the price of energy - any change in the upward slope of this value in the future may even change the order in the ranking of the proposed scenarios; if there is not an annual increase of at least 10% in the price of energy, the continuity solution with the modernization of the existing equipment is the only eligible one.

The conclusion is logical because, in the absence of industrial heat consumption and a favourable evolution of price of energy, it is not efficient to make new investments. Also, at an increase in the slope of variation of the energy recovery tariff of up to 15%/year, the A_7 solution becomes the most efficient proposal as this is the project that offers the highest annual electricity available for sale. In addition, the solution becomes economically efficient, with a positive value for DFF.

5 Conclusion

Lignite-based scenarios are the only viable alternative for continued operation of power plant. The choice of one or another of the existing solutions will be based solely on the analysis of the evolution of the price of energy.

If this parameter has an annual growth slope of more than 10%, projects involving the increase of installed power, A_{11} type, are favoured and should be taken into account.

However, if, in the coming years, there is a slower increase in the price of electricity used, caution is advised in making a decision on new investments in the increase of installed power.

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