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Optimization of enterprise production activities aimed at its energy efficiency increase

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Abstract

In the period of crisis in the economy of Russia the changes in the priorities in the solution of the goals of functioning of enterprises has become characteristic for many of them. Among the main goals one can determine the holding of their own positions in the outlets or reorientation of activities in response to changing demands of customers. The solution of the goal of energy efficiency increase which is actual for many enterprises in developed and developing countries have come to the second level. Momentary incomes are now more important than the goals of the increase of utilized resources efficiency that are solved in a planned way every year. Due to this, the main aim of our research is the rationalization of the production program of the enterprise of chemical industry JSC "KazanOrgSyntez" in the way that the maximization of the income, that is so necessary in the current conditions, would be possible under the conditions of the simultaneous growth of its energy efficiency. Methods of economical and mathematical modeling and linear programming were used in the process of the calculations that were carried out. As a result of the optimization of the production activities of an enterprise, aimed at its energy efficiency increase, the decrease of electrical energy consumption comprised 4.7% with regard to real data. The research showed that enterprises even in hard economic conditions are able to combine the solution of current and long-term goals, not depending on external circumstances.

Keywords*:* optimization of production activities, enterprise, production plan, economic-mathematical model.

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1. Introduction

Crisis phenomena, taking place on all levels of economic development, have characterized some recent years in Russia. The weakening rouble led to the appearance of extra expenditures for enterprises when they manufacture and sell their products. The utilization of foreign materials and components in the process of production of various goods increased their product costs, but the correction of price with account for increasing inflation index made the products of the enterprise less demanded on the internal market. In this situation enterprises had to make a choice either to stop working, not being able to overcome the crisis pressure, or to take the crisis challenges as positive signals for their further development. According to a number of researchers, crisis phenomena in the economy should be actively used for the search for further possibilities for the development by Kurbatov (2013), Postaliuk et al. (2013), Sadriev et al. (2015). Reorientation of the current activities, changes in the strategic development priorities, non-standard utilization of enterprise resources, implementation an energy management system by Nepal et al. (2014), Schulze et al. (2016), Sabramanya (2011), can take place at this point.

2. Research objective statement

The large Russian chemical industry enterprise JSC "KazanOrgSyntez", producing mainly granulous polyethylene of different makes, was chosen as an object of studying in this research. The enterprise supplies the Russian and foreign markets, covering 38% of the internal market. The analysis of strong and weak sides of the enterprise made it possible to state that in the current crisis period the most optimal development strategy has been to preserve the same output volume, utilizing the resources in the most efficient way. It should be noted that this development direction was actual for the enterprise in the years preceding the crisis. It is better to say that it was stated in its strategic documents. Actually, the politics of resource conservation suffered from here-and-now profits coming from small non-planned contracts because the equipment was stopped and readjusted for the production of the demanded make of polyethylene. To implement the anti-crisis program the enterprise had to optimize the production program, saving the volume of production of various levels of power intensity, and maximize the gross profit.

3. Research methodology and bench-mark data

The methodological instruments, used to make calculations concerning the optimization of the enterprise activity, are the methods of economic-mathematical modeling and linear programming by Guseva (2014). We should note the works covering the solutions of different tasks directed at the optimization of enterprise activities by Dey et al. (2010), Gumerov et al. (2016), Weijermars et al. (2012),as well as the international patent CN104375477 (dated 25.02.2015) which presents the production method based on integrated optimization of production system and energy system. The research will solve three optimization tasks. The first one presupposes the production optimization considering only the maximization of balance profit. The second task assumes the minimization of energy consumption of the enterprise. Finally, the last task is directed at the production program formation, solving the problem of gross profit maximization minimizing the electrical energy expenditures.

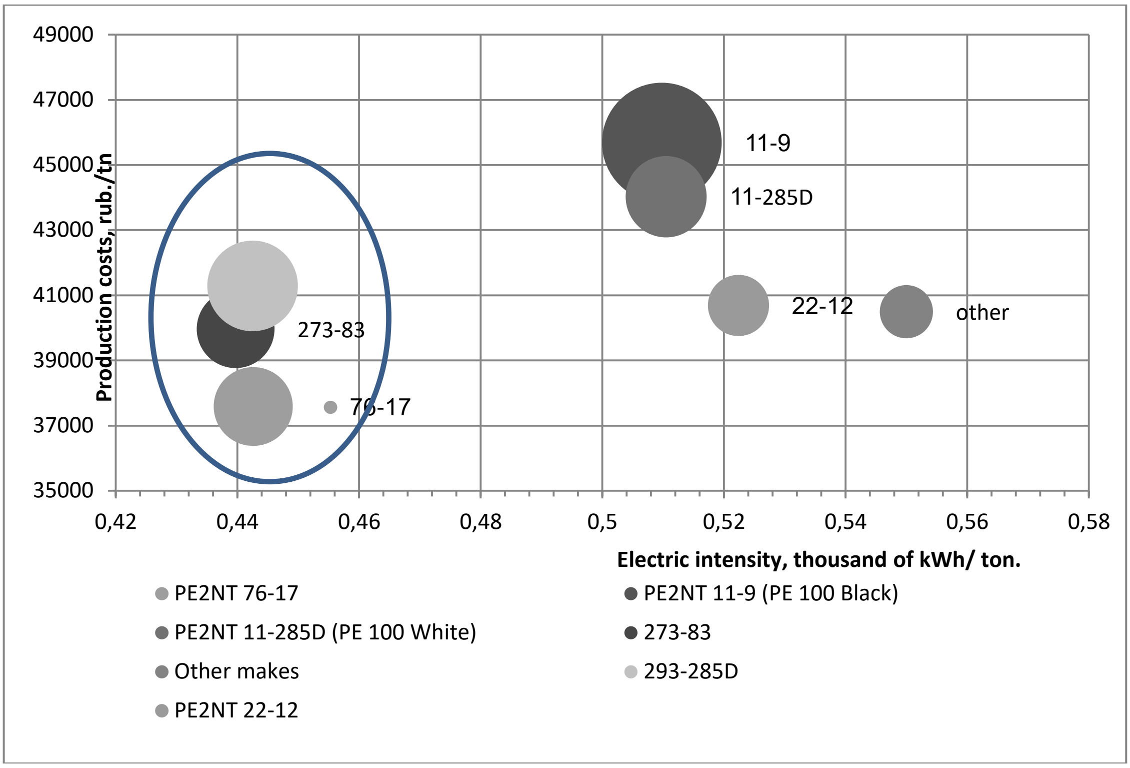

Figure1. Electric intensity and production costs (the diameter of the circle is proportional to the production output of the certain make of polyethylene)

The most electric intensive and, in general, resource consuming kinds of production are such makes of polyethylene as PE2NT 11-9 (PE 100 Black), PE2NT 11-285D (PE 100 White), PE2NT 22-12, and other makes. Such production covers 57,28% of the general volume of all the production.

The original production plan is presented on fig.2.

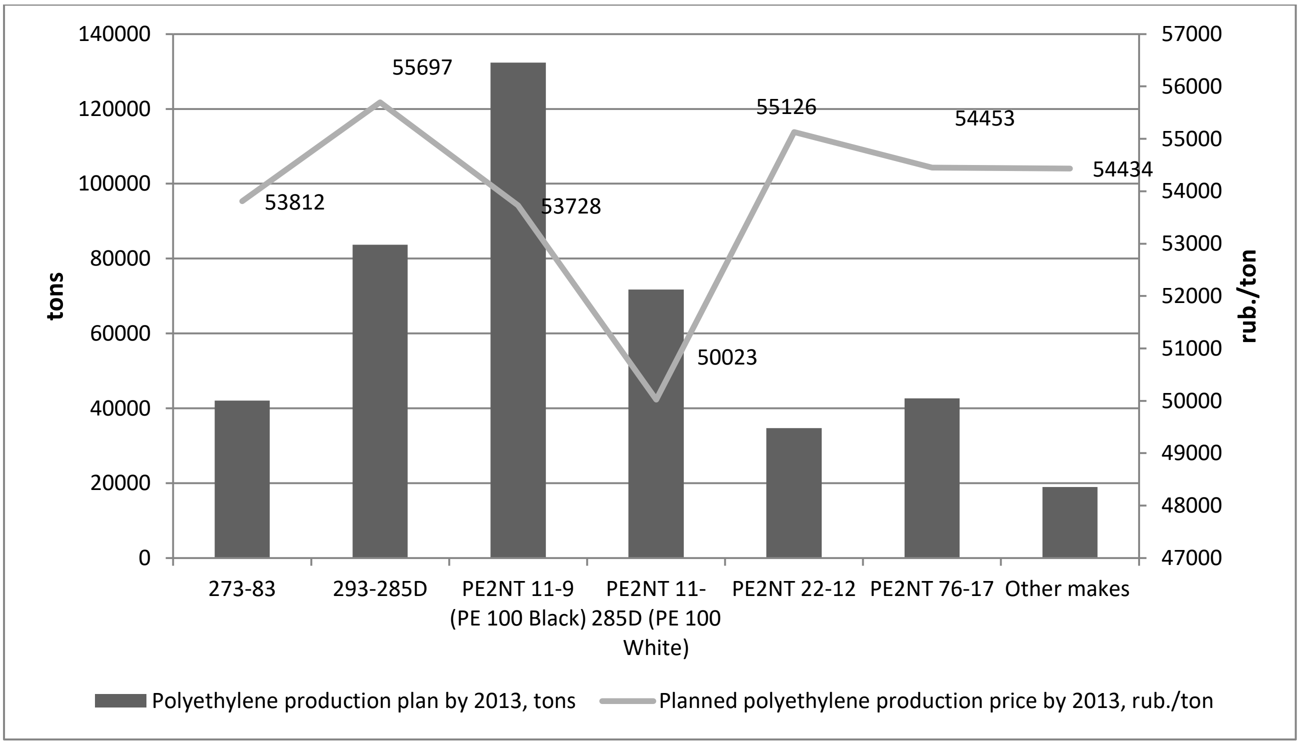

Figure 2. The original polyethylene production plan

4. Optimization task solution

Using the information, concerning the supplied raw materials, their consumption rates, existing limitations, polyethylene production plan, its product costs, electric intensity and planned prices on various makes of polyethylene, we are going to form the first task of production structure optimization from the standpoint of maximization of the enterprise profit under the existing volume of electric energy consumption. In this case, the target function will be the gross profit of the enterprise, which is calculated according to the formula:

$$P = I - E, \tag{1}$$

where 'I' is the income, coming from the sales of goods, rub., 'E' is general expenses, spend on the production of goods, rub.

Having transformed the formula (1) and considering the fact that the product costs can be divided into three components - raw materials costs, energy consumption costs and some other costs, bearing in mind that other costs cover 23,5% of the sum of raw materials costs and energy consumption costs, we get the following target function:

$$\sum_{i=1}^{n}(V_i \cdot \Pr_i) - \sum_{i=1}^{n}(V_i \cdot 1{,}235 \cdot (\Pr_{et} \cdot N_{et_i} + El_i \cdot \Pr_{ee})) \rightarrow \max, \tag{2}$$

where 'n' is the number of the realized polyethylene makes; 'i' is the polyethylene make; V_i – volume of sales of an i-make of polyethylene, tons; $\Pr_i$ – price of an i-make of polyethylene, rub./ton; $\Pr_{et}$ – product costs of a unit of raw materials, rub./ton; N_{et_i} – raw material consumption rates, taken into consideration in the process of production of an i-make of polyethylene; El_i – electric intensity of the production of an i-make of polyethylene , thousand of kWh/ ton; $\Pr_{ee}$ - electric energy charge, rub./ thousand of kWh.

We shall denote the planned volume of polyethylene production via x_i ($i = \overline{1,n}$) and the balance profit of the enterprise, coming from selling of all the production via f*(x_1,..., x_n).* In this case, the production plan will be vector *X = (x_1,...,x_n)*, stating what quantity of the goods of each kind should be produced. Variables x_1,...,x_n are controllable here.

4.1. The solution of the first optimization task

In accordance with the market demands and the manufacturability variables x_1,...,x_n are restricted considering the irreducible and maximum allowable output of goods of each kind. Besides, energy consumption should not exceed this indicator value for the previous year.

$$E(X) \le 214960, \tag{3}$$

where E(X) is the function, measuring electrical energy consumption:

$$E(X) = \sum_{i=1}^{n}(\mathrm{El_i} \cdot x_i). \tag{4}$$

So, we have made an economic-mathematical model of the task of the production plan optimization, which can be solved by using the linear programming method [1, 2]. Using the programming product Mathcad we have defined the following optimization indicators of the elements of the X-vector:

$$\max(f, X) = \begin{pmatrix} 4{,}5 \cdot 10^4 \\ 8{,}8 \cdot 10^4 \\ 1{,}4 \cdot 10^5 \\ 6{,}57 \cdot 10^4 \\ 3{,}6 \cdot 10^4 \\ 4{,}5 \cdot 10^4 \\ 2{,}269 \cdot 10^4 \end{pmatrix}. \tag{5}$$

The calculated indicators are presented on fig.3.

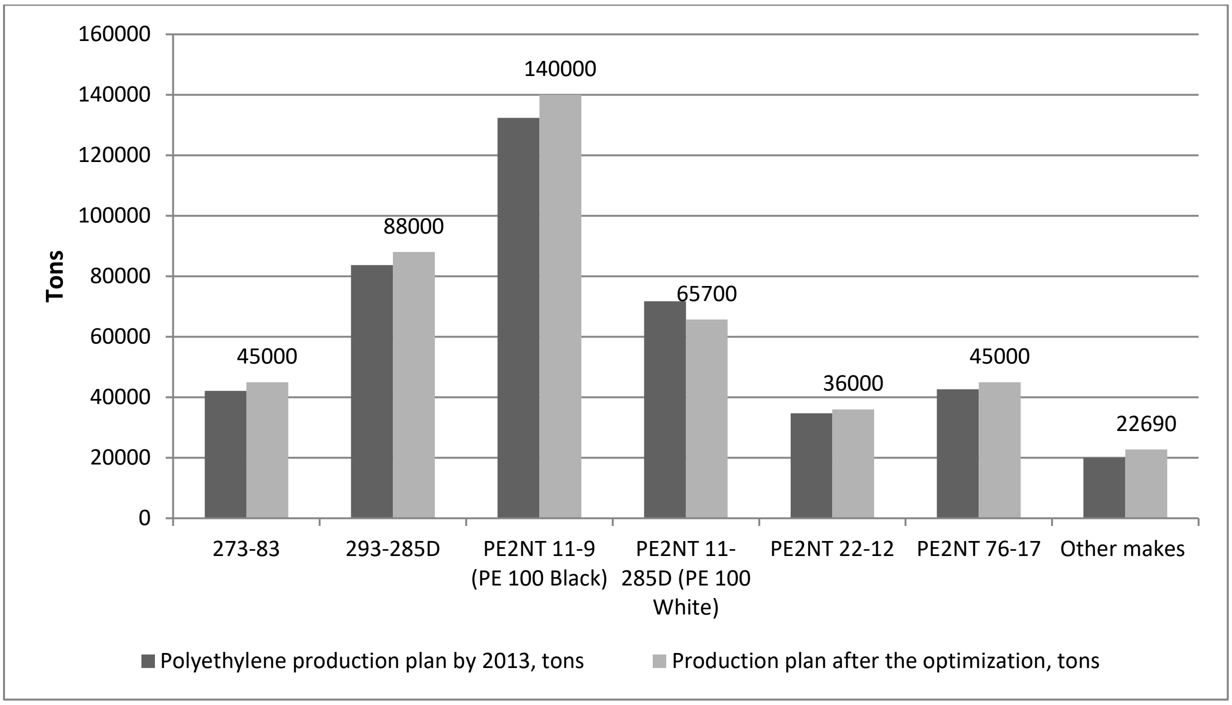

Figure 3. Production plan before and after solving the first optimization task.

4.2. The solution of the second optimization task

Considering the necessity to raise the competitive ability of the manufactured goods, also by decreasing the energy resources costs, we are going to design an economic-mathematical model of the task to determine such a structure of the enterprise that allows to achieve the minimum quantity of electrical energy consumption under the scheduled production volume. In this case, the target function will be the electrical energy consumption:

$$\sum_{i=1}^{n}(\mathrm{El}_i \cdot x_i) \rightarrow \min . \quad (6)$$

Considering the system of limitations, used in the process of solving the previous task, applying the method of linear programming, optimal quantities of the production of separate polyethylene makes were determined:

$$\min(E, X) = \begin{pmatrix} 4,5 \cdot 10^4 \\ 8,8 \cdot 10^4 \\ 1,378 \cdot 10^5 \\ 6,57 \cdot 10^4 \\ 2,568 \cdot 10^4 \\ 4,5 \cdot 10^4 \\ 1,6 \cdot 10^4 \end{pmatrix} . \quad (7)$$

Putting the achieved measurements in the formula (4), the summary consumption of electrical energy is 204700 thousands of kWh, that is 5% less than the real measurement of electrical energy consumption in a certain year.

4.3. The solution of the third optimization task

However, the task of optimization of the structure of polyethylene production, considering the minimization of its electric intensity, should be supplemented with the condition of receiving the maximum gross profit, which will reflect one of the main goals of the functioning of JSC "KazanOrgSyntez". In this case, the target function will be the following equation:

$$\frac{\sum_{i=1}^{n}(x_i \cdot \Pr_i) - \sum_{i=1}^{n}(x_i \cdot 1{,}235 \cdot (\Pr_{et} \cdot N_{et_i} + El_i \cdot \Pr_{ee}))}{\sum_{i=1}^{n}(\mathrm{El_i} \cdot x_i)} \to \max \quad (8)$$

In the target function (8) there is the gross profit, calculated with the help of the formula (2) in the numerator, and there is the energy consumption, calculated with the help of the formula (6) in the denominator. To solve the stated task, the target function (8) should have the maximum measurement, because in this very case the conditions of minimization of electrical intensity of polyethylene production and maximization of balance profit will be fulfilled.

Using the method of fractionally linear programming, we are going to denote the optimal indicators of the volume of production of separate polyethylene makes, considering the system of limitations:

$$\max(f / E, X) = \begin{pmatrix} 4{,}5 \cdot 10^4 \\ 8{,}8 \cdot 10^4 \\ 1{,}274 \cdot 10^5 \\ 6{,}57 \cdot 10^4 \\ 3{,}6 \cdot 10^4 \\ 4{,}5 \cdot 10^4 \end{pmatrix} \quad (9)$$

The received indicators of the volume of production of separate polyethylene makes are presented on fig.4.

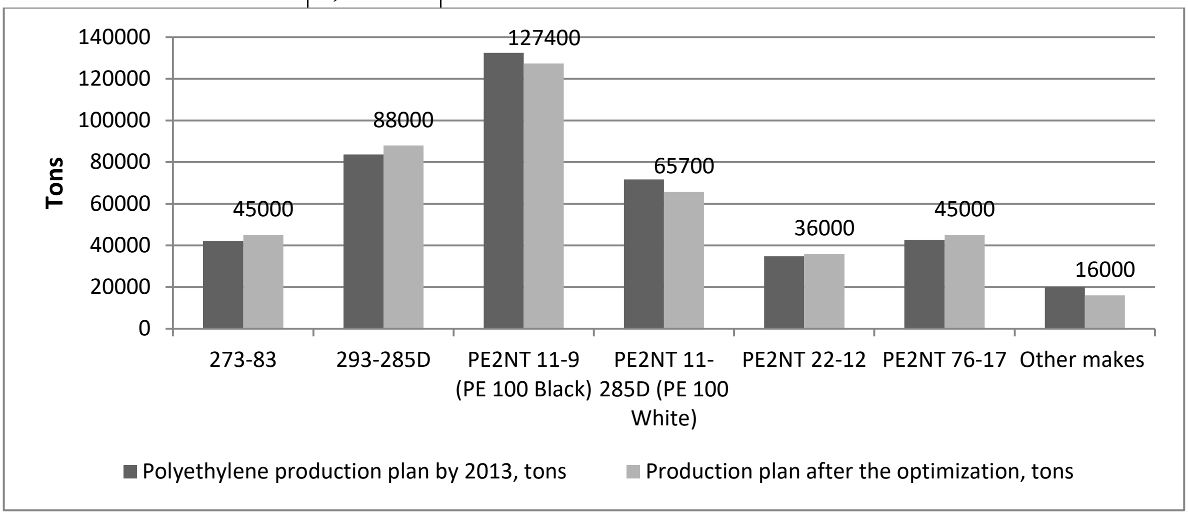

Figure 4. Production plan before and after solving the third optimization task.

5. Conclusion

As a result of the optimization of the production activities of an enterprise, aimed at its energy efficiency increase, the decrease of electrical energy consumption comprised 4.7% with regard to real data. The research showed that enterprises even in hard economic conditions are able to combine the solution of current and long-term goals, not depending on external circumstances.

The tools, suggested in the research, can be successfully applied to solve the tasks of optimization of the enterprise production activities and the production programme, taking into consideration the demands of the market and simultaneous effective utilization of energy resources.

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