3. ЕКОНОМІКА ПІДПРИЄМСТВА ТА ОРГАНІЗАЦІЯ ВИРОБНИЦТВА

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THE MODEL FOR FORECASTING SALES OF ENERGY SUPPLY SYSTEMS BASED ON RENEWABLE ENERGY SOURCES

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Building an effective model for forecasting sales of products (works, services) allows enterprises to achieve the desired level of competitiveness. It is determined that the most relevant for industrial enterprises, engaged in the sale of energy supply systems based on renewable energy sources, are economic and mathematical methods that take into account the seasonality factor. The purpose of the article is to build a model for forecasting sales of energy supply systems based on renewable energy sources. The main research method is correlation and regression analysis. The article substantiates a model for forecasting the sale of energy supply systems to economic agents by industrial enterprises, which is based on determining the functional relationship between the seasonality factor (seasonal component, harmonic component of the model) and the objective function of ensuring an effective time sequence of management decisions/measures and which, unlike the existing ones, takes into account the duration of the seasonality factor, which increases the efficiency of management decisions by optimizing the time lag between their adoption and implementation. As a conclusion, the elasticity coefficient for energy saving costs in order to ensure the competitiveness of industrial enterprise products reaches 100 times the value.

Keywords: *energy saving, renewable energy sources, forecasting model, seasonality factor, competitiveness.*

JEL Classification: *C39*

Introduction. Strategic management of an enterprise is characterized by a qualitative change in the system of development of social relations, which allows developing relations at a new level of interaction and creating a favourable business environment for the company. The object of strategic management at enterprises is the latest technologies, particularly, energy-saving technologies based on the use of alternative energy sources [1].

Energy supply measures as a part of the energy strategy are the priority condition for the survival of an industrial enterprise in the context of the implementation of alternative energy sources, and the factor in ensuring its competitiveness. The strategy of enterprise development at the current stage of social development is to reduce the external energy dependence of business entities in order to compete in global markets. The plot of solving this priority task is the implementation of technologies using alternative energy sources [2].

Building a model for predicting the sale of energy supply systems based on renewable energy sources to economic agents will ensure the sustainability of industrial enterprises in the face of turbulent changes.

Analysis of recent research and publications. Among the current studies of the methodological platform of the sales forecasting model, it is necessary to distinguish, first of all, the following.

Viedienieiev V. argues that the ARIMA model and linear regression, based on the data of previous periods, failed to predict the fall in the selling price [3]. Whereas the moving average model showed the best result, because there was no clear positive or negative trend in previous periods [3].

Kharchenko Yu. recommends an adaptive model for practical application, as it has the best forecast quality and the minimum sum of squared deviations [4]. Thus, the use of the developed economic and mathematical forecasting

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models will improve the operational planning of the production of certain types of products, as well as (after receiving new statistical data) quickly change production plans [4].

Based on the data on the demand for sales of goods of past periods, the time series of demand was analysed [5]. The analysis was carried out on the basis of forecasting models as a tool for analysing and determining future demand [5]. According to the obtained result, a system was built on the basis of which the size of the reserve warehouse stock is optimized [5].

The authors give the conclusions about the expediency of Microsoft Time Series algorithm application in product sales forecasting [6]. The outcomes of practical Microsoft Time Series algorithm leveraging proved its effectiveness in forecasting sales based on historical data [6].

As the content analysis has shown, there are quite a few tools for building a sales forecasting model. The most relevant for industrial enterprises selling energy supply systems based on renewable energy sources are economic and mathematical methods that take into account the seasonality factor.

Statement of the problem. The purpose of the article is to build a model for forecasting the sale of energy supply systems based on renewable energy sources.

Results of the study. The calculations and results obtained allow to build the model for forecasting product sales and calculating the costs of ensuring the competitiveness of products in the energy saving system on the basis of correlation and regression analysis for the enterprise in Tables 1–2.

If the number of measurements (samples, data) at all levels of each factor is the same, then the analysis of variance is called uniform, otherwise uneven [7; 8]. The results of the analysis of variance are presented in Table 3.

The results of the regression analysis are presented in Table 4.

Table 1 – Initial data for building the model for forecasting product sales (factors X1-X4) and calculating the costs of ensuring product competitiveness in the energy saving system

№ s/n	Period	Sales volume, UAH				
		Current month	1 month later	2 months later	3 months later	4 months later
1	01/2020	498210	326135	364726	491038	409801
2	02/2020	621989	498210	326135	364726	491038
3	03/2020	742467	621989	498210	326135	364726
4	04/2020	810970	742467	621989	498210	326135
5	05/2020	941000	810970	742467	621989	498210
6	06/2020	939168	941000	810970	742467	621989
7	07/2020	1711300	939168	941000	810970	742467
8	08/2020	901613	1711300	939168	941000	810970
9	09/2020	915843	901613	1711300	939168	941000
10	10/2020	883362	915843	901613	1 711300	939168
11	10/2020	745284	883362	915843	901613	1711300
12	12/2020	729727	745284	883362	915843	901613
13	01/2021	949905	729727	745284	883362	915843
Change		Y	X1	X2	X3	X4

Source: author's calculations

Table 2 – Initial data for building the model for forecasting product sales and calculating the costs of ensuring product competitiveness in the energy saving system (factors X5-X9)

№ s/n	Period	Sales volume, UAH (current month)	Expenses to ensure the competitiveness of services, UAH				
			Current month	1 month later	2 months later	3 months later	4 months later
1	01/2020	498210	34875	22829	25531	34373	28686
2	02/2020	621989	43539	34875	22829	25531	34373
3	03/2020	742467	51973	43539	34875	22829	25531
4	04/2020	810970	56768	51973	43539	34875	22829
5	05/2020	941000	65870	56768	51973	43539	34875
6	06/2020	939168	65742	65870	56768	51973	43539
7	07/2020	1711300	119791	65742	65870	56768	51973
8	08/2020	901613	63113	119791	65742	65870	56768
9	09/2020	915843	64109	63113	119791	65742	65870
10	10/2020	883362	61835	64109	63113	119791	65742
11	10/2020	745284	52170	61835	64109	63113	119791
12	12/2020	729727	51081	52170	61835	64109	63113
13	01/2021	949905	66493	66493	52170	61835	64109
Change		Y	X5	X6	X7	X8	X9

Source: author's calculations

A retrospective test of the regression model and the calculation of the average approximation error are presented in Table 5.

Based on the results of testing the regression model and calculating the average approximation error, we can conclude that the average approximation error is 5.69%, which is a high forecast accuracy.

Using the method of correlation and regression analysis, a forecast model of the enterprise's sales volume is built:

$$Y = -10036 - 0,639X_1 - 0,612X_2 - 0,87X_3 - 0,925X_4 + 14,268X_5 + +16,978X_6 + 11,663X_7 + 7,901X_8 + 8,861X_9 \quad (1)$$

where Y is the forecasted sales volume of the company's products, UAH; X_1 ... X_4 is the sales volume of products by months, UAH; X_5 .....X_9 is the cost of ensuring the competitiveness of products, UAH.

This regression model is significant because the coefficient of determination (R square) is 96.22%. This means that the change in the dependent variable (sales in the current month) is described by 96.22% of the variation in the independent variables, and only 3.78%.

When evaluating the parameters of the regression model, it was found that they are statistically significant, since the calculated value of the Student's t-statistic for each parameter does not fall within the critical area of the tabulated value of the t-statistic (-1.1788; +1.1788).

A graphical interpretation of the model for forecasting product sales and calculating competitiveness costs is shown in Figure 1.

It is noteworthy that sales of previous periods, in this model, have a negative impact on product sales: the more we sell, the more we have to spend on ensuring competitiveness in order not to lose the gained positions [8–10].

We present the calculation of the seasonal multiplicative model for the total sales of energy supply systems to economic agents by industrial enterprises based on the use of alternative energy sources (energy-active fencing systems) (Table 6) and the sales forecast (Table 7).

Equations of the mathematical model taking into account the seasonal factor and the general trend (2), where A and B are the parameters of a linear trend.

Table 3 – Results of the analysis of variance

	df	SS	MS	F	The significance of F
Regression	9	5,5881E+11	6,209E+10	8,48348663	0,052670674
Balance	3	2,1957E+10	7318881106		
Total	12	5,8076E+11			

Source: author's calculations

Table 4 – Results of the regression analysis

Regression analysis indicator	Calculated value of the indicator
Multiple correlation coefficient	0,980914611
Multiple coefficient of determination	0,962193474
Normalized correlation coefficient	0,848773896
Standard error	85550,45942
Observations.	13

Source: author's calculations

Table 5 – Retrospective validation of the regression model and calculation of the average approximation error

No. s/n	Period	Sales of services, UAH	Service sales forecast, UAH	Error, %.
1	01/2020	498 210	470878	5,486
2	02/2020	621 989	596361	4,120
3	03/2020	742 467	770659	3,797
4	04/2020	810 970	837932	3,325
5	05/2020	941 000	986509	4,836
6	06/2020	939 168	996308	6,084
7	07/2020	1 711 300	1834713	7,212
8	08/2020	901 613	947878	5,131
9	09/2020	915 843	976369	6,609
10	10/2020	883 362	812038	8,074
11	10/2020	745 284	690164	7,396
12	12/2020	729 727	689434	5,522
13	01/2021	949 905	1010509	6,380
Average approximation error				5,69%

Source: author's calculations

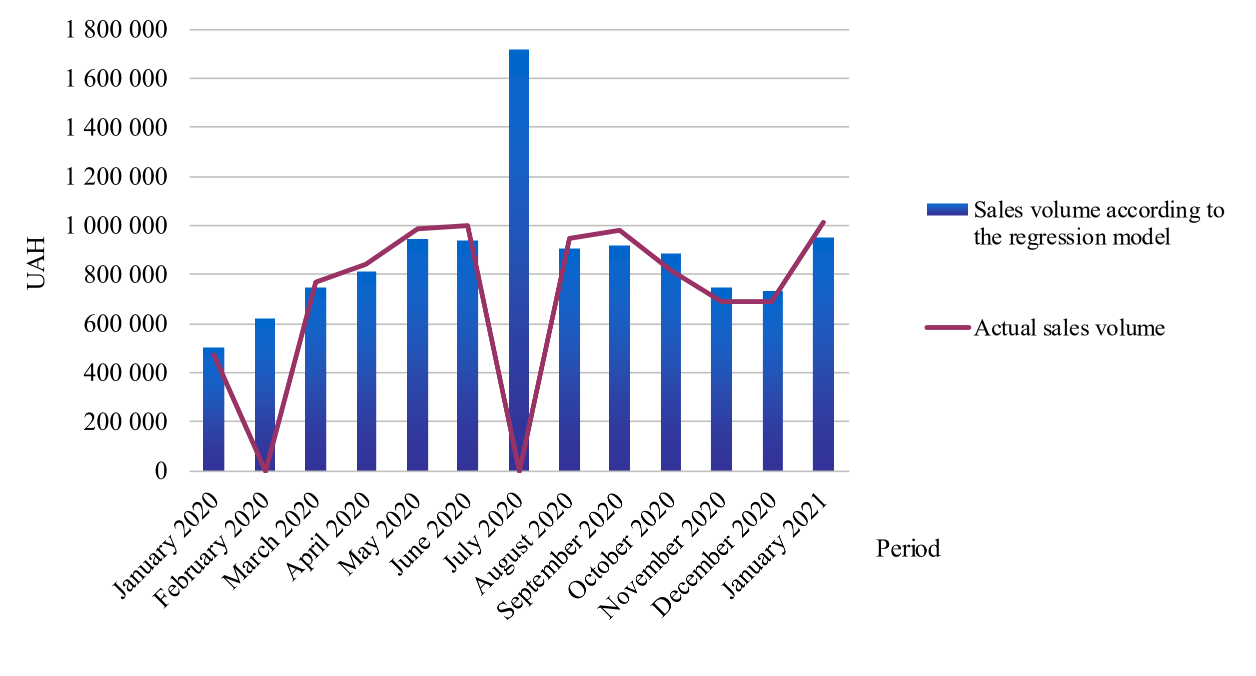

Figure 1 – Model for forecasting product sales and calculating the costs of ensuring the competitiveness of products in the energy saving system

Source: author's calculations

Table 6 – Calculation of the seasonal multiplicative model for the total sales of energy-active fencing systems based on the use of alternative energy sources

t	Month	Y_t	U_t	V_t	V_t '	Y_t '	δ', %
1	01.01.2019	397152	443515	0,895	0,960	425835	7,2%
2	01.02.2019	355256	443013	0,802	0,751	332872	6,3%
3	01.03.2019	383428	442511	0,866	0,858	379800	0,9%
4	01.04.2019	329153	442008	0,745	0,680	300728	8,6%
5	01.05.2019	319019	441506	0,723	0,623	275029	13,8%
6	01.06.2019	383043	441004	0,869	0,844	372413	2,8%
7	01.07.2019	443546	440502	1,007	1,009	444373	0,2%
8	01.08.2019	556415	440000	1,265	1,247	548538	1,4%
9	01.09.2019	573479	439498	1,305	1,325	582196	1,5%
10	01.10.2019	624951	438996	1,424	1,507	661437	5,8%
11	01.11.2019	620238	438494	1,414	1,492	654148	5,5%
12	01.12.2019	937156	437992	2,140	2,433	1065527	13,7%
13	01.01.2020	448343	437490	1,025	0,960	420050	6,3%
14	01.02.2020	306265	436988	0,701	0,751	328345	7,2%
15	01.03.2020	371049	436486	0,850	0,858	374628	1,0%
16	01.04.2020	268592	435983	0,616	0,680	296629	10,4%
17	01.05.2020	227886	435481	0,523	0,623	271276	19,0%
18	01.06.2020	356840	434979	0,820	0,844	367325	2,9%
19	01.07.2020	439111	434477	1,011	1,009	438295	0,2%
20	01.08.2020	533257	433975	1,229	1,247	541 027	1,5%
21	01.09.2020	582813	433473	1,345	1,325	574215	1,5%
22	01.10.2020	688343	432971	1,590	1,507	652359	5,2%
23	01.11.2020	678605	432469	1,569	1,492	645160	4,9%
24	01.12.2020	1177476	431967	2,726	2,433	1050870	10,8%
Average relative mistake	X	X	X	X	X	X	5,8%

Notes: Parameters of the mathematical model: t is the number of the month in the population under consideration; Y_t is the initial value of sales; U_t is the trend or long-term trend of sales growth (decline), the linear component of the model; V_t is the difference between actual sales and the forecast values of the linear component: $V_t = Y_t$ – U_t, necessary for calculating the seasonal component; V'_t – seasonal component, harmonic component of the model, calculated for $V_t = Y_t$ – U_t; - model result, the sum of linear trend and harmonic component forecasts; δ' – relative error of the calculated model: δ'=|Y_t – Y_t '|: Y_t, expressed as a percentage.

$$Y_i = \alpha_1 \cdot \cos(\pi \cdot 1 \cdot t/6) + \alpha_2 \cdot \cos(\pi \cdot 2 \cdot t/6) + \alpha_3 \cdot \cos(\pi \cdot 3 \cdot t/6) + \alpha_4 \cdot \cos(\pi \cdot 4 \cdot t/6) +$$
$$+\alpha_5 \cdot \cos(\pi \cdot 5 \cdot t/6) + \alpha_6 \cdot \cos(\pi \cdot 6 \cdot t/6) + \alpha_7 \cdot \cos(\pi \cdot 7 \cdot t/6) + \alpha_8 \cdot \cos(\pi \cdot 8 \cdot t/6) +$$
$$+\alpha_9 \cdot \cos(\pi \cdot 9 \cdot t/6) + \alpha_{10} \cdot \cos(\pi \cdot 10 \cdot t/6) + \alpha_{11} \cdot \cos(\pi \cdot 11 \cdot t/6) + \alpha_{12} \cdot \cos(\pi \cdot 12 \cdot t/6) +$$
$$+\beta_1 \cdot \sin(\pi \cdot 1 \cdot t/6) + \beta_2 \cdot \sin(\pi \cdot 2 \cdot t/6) + \beta_3 \cdot \sin(\pi \cdot 3 \cdot t/6) + \beta_4 (\pi \cdot 4 \cdot t/6) +$$
$$+\beta_5 \cdot \sin(\pi \cdot 5 \cdot t/6) + \beta_6 \cdot \sin(\pi \cdot 6 \cdot t/6) + \beta_7 \cdot \sin(\pi \cdot 7 \cdot t/6) + \beta_8 \cdot \sin(\pi \cdot 8 \cdot t/6) +$$
$$+\beta_9 \cdot \sin(\pi \cdot 9 \cdot t/6) + \beta_{10} \cdot \sin(\pi \cdot 10 \cdot t/6) + \beta_{11} \cdot \sin(\pi \cdot 11 \cdot t/6) + A \cdot t + B. \quad (2)$$

For the calculated seasonal additive model for the total sales volume of the energy-active fencing system based on the use of alternative energy sources:

A = - 1235, B = 279000. According to the multiplicative model: A = -495, B = 768300.

Let's analyse the spectrum of two variants of sales models for energy-active fencing systems (Table 8).

This makes it possible to increase the efficiency of management measures by optimizing the time lag between their adoption and implementation.

Conclusions. Using the method of correlation and regression analysis, a predictive model of product sales and calculation of costs for ensuring the competitiveness of products in the energy saving system was built on the example of Velta PCF LLC.

Thus, another independent method of evaluation has confirmed the rather high efficiency of the costs of ensuring the competitiveness of sales of energy supply systems to economic agents by industrial enterprises. In some cases, the elasticity coefficient for energy saving costs to ensure the competitiveness of industrial enterprise products reaches 100 times the value (i.e., for each additional hryvnia spent to ensure the competitiveness of services, we have more than 100 UAH of additional product sales).

Table 7 – Forecast of sales of energy-active fencing systems

t	Month	Y_t	U_t	V_t '	Y_t '	δ', %
25	01.01.2021	659527	755925	0,960	725791	10,0%
26	01.02.2021	610368	755 430	0,751	567617	7,0%
27	01.03.2021	621942	754 935	0,858	647948	4,2%
28	01.04.2021	503135	754440	0,680	513297	2,0%
29	01.05.2021	513395	753945	0,623	469658	8,5%
30	01.06.2021	636283	753450	0,844	636263	0,0%
31	01.07.2021	814100	752955	1,009	759571	6,7%
32	01.08.2021	986081	752460	1,247	938074	4,9%
33	01.09.2021	871721	751965	1,325	996116	14,3%
34	01.10.2021	922232	751470	1,507	1132242	22,8%
35	01.11.2021	X	750975	1,492	1120310	X
36	01.12.2021	X	750480	2,433	1825735	X
Average relative Error:	X	X	X	X	X	8,0%

Source: author's calculations

Table 8 – Analysis of the spectrum of two variants of sales models for energy-active fencing systems based on the use of alternative energy sources

№ s/n	Period	Additive model			Multiplicative model		
	12 / N	α_i	β_i	$R^2 = \alpha_i^2 + \beta_i^2$	α_i	β_i	$R^2 = \alpha_i^2 + \beta_i^2$
1	1 year (fundamental harmonic)	90036	-78090	14204551820	0,205	-0,172	0,072
2	6 months.	38457	-11700	1615868515	0,087	-0,024	0,008
3	4 months.	46281	-17112	2434767623	0,105	-0,038	0,012
4	3 months.	48776	962	2379996093	0,110	0,003	0,012
5	2.4 months. (72 days)	38451	7 827	1539766758	0,087	0,018	0,008
6	2 months.	43978	0	1934090138	0,100	0,000	0,010

Source: author's calculations

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МОДЕЛЬ ПРОГНОЗУВАННЯ ПРОДАЖУ СИСТЕМ ЕНЕРГОЗАБЕЗПЕЧЕННЯ НА ОСНОВІ ВІДНОВЛЮВАЛЬНИХ ДЖЕРЕЛ ЕНЕРГІЇ

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Побудова ефективної моделі прогнозування продажу продукції (робіт, послуг) дозволяє підприємствам досягти бажаного рівня конкурентоздатності. Виникає потреба в розробленні теоретичних засад і практичних рекомендацій щодо формування концепції управління технологіями енергозбереження з огляду на відповідність концептуальним засадам сталого розвитку, а саме орієнтуючись на безвуглецеві технології отримання енергії. Актуальність теми дослідження зумовлена тим, що вирішення проблеми енергозаощадження та перехід на технології, які надають змогу частково або й цілком відійти від використання газу та іншого викопного органічного палива, є пріоритетними в Україні на сьогодні. Визначено, що найбільш актуальними для промислових підприємств, що займаються продажом систем енергозабезпечення на основі відновлювальних джерел енергії є економіко-математичні методи, які враховують фактор сезонності. Метою статті є побудова моделі прогнозування продажу систем енергозабезпечення на основі відновлювальних джерел енергії. Основним методом дослідження є кореляційно-регресійний аналіз. Обґрунтовано модель прогнозування продажу систем енергозабезпечення економічним агентам промисловими підприємствами, в основу якої покладено визначення функціональної залежності між фактором сезонності (сезонна компонента, гармонійна складова моделі) та цільовою функцією забезпечення ефективної часової послідовності управлінських рішень/заходів і яка, на відміну від існуючих, враховує тривалість фактора сезонності, що підвищує ефективність управлінських рішень завдяки оптимізації часового лагу між їх прийняттям і реалізацією. Як висновок, коефіцієнт еластичності за витратами на енергозбереження з метою забезпечення конкурентоспроможності продукції промислового підприємства досягає 100-кратного значення. Практичне значення одержаних результатів полягає в тому, що теоретичні та положення доведені до рівня практичних рекомендацій щодо обґрунтування управлінських рішень та запровадження технологій енергозбереження на промислових підприємствах.

Ключові слова: *енергозбереження, відновлювальні джерела енергії, модель прогнозування, фактор сезонності, конкурентоздатність.*

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