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A METHODICAL APPROACH TO THE EVALUATION OF ENERGY EFFICIENCY AT ENTERPRISES

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Energy efficiency has become a top priority at the present stage of economic development for both governments and business. The interdependence of economic processes at all the levels of economy (national, regional and micro level) necessitates a holistic approach to the evaluation of how efficiently energy resources are used. In order to determine the most effective ways to increase energy efficiency, a comprehensive evaluation approach must be applied. It should consider peculiarities of the energy potential through all the levels of the economic system.

A methodical approach to the evaluation of energy efficiency at machine-building enterprises has been presented. In the framework of the proposed methodical approach a comprehensive evaluation is provided, which comprises the following stages: assessing the national economy energy potential availability, and efficiency of energy utilization at industrial enterprises, including machine-building enterprises, and the result of energy utilization through the end product energy efficiency evaluation at machine-building enterprises. Apart from the comprehensive methodical approach to the evaluation of energy efficiency, appropriate analytical instruments for evaluation at each stage have been suggested. On the basis of this methodical approach, the energy efficiency at Ukrainian machine-building enterprises has been evaluated. The evaluation and further analysis have shown that a possible cause of low energy efficiency lies in the lack of organizational conditions for high energy efficiency at the domestic enterprises.

Keywords: energy efficiency evaluation, a methodical approach to the energy efficiency evaluation, energy potential utilization, energy efficiency of products, energy efficiency integral coefficient.

МЕТОДИЧНИЙ ПІДХІД ДО ОЦІНЮВАННЯ ЕНЕРГОЕФЕКТИВНОСТІ НА ПІДПРИЄМСТВАХ

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Енергоефективність стає пріоритетним завданням на сучасному етапі економічного розвитку для держави й підприємств. Взаємозалежність економічних процесів на всіх рівнях економіки (національному, регіональному та мікрорівні) потребує цілісного підходу до оцінювання ефективності використання енергетичних ресурсів. Для визначення найбільш ефективних шляхів підвищення енергоефективності необхідний комплексний підхід до її оцінювання, що буде враховувати особливості енергетичного потенціалу на всіх рівнях економічної системи. Запропоновано методичний підхід до оцінювання ефективності використання енергетичних ресурсів на машинобудівних підприємствах, який передбачає комплексне оцінювання, складене з таких етапів: оцінювання наявності енергетичного потенціалу на рівні національної економіки; ефективність його використання на промислових підприємствах, у тому числі машинобудівних, а також результат його використання шляхом оцінювання енергоефективності виробництва кінцевої продукції машинобудівних підприємств. Було запропоновано не тільки етапи комплексного методичного підходу до оцінювання енергоефективності, а й відповідні аналітичні інструменти для оцінювання на кожному етапі. На основі цього методичного підходу було оцінено енергоефективність на українських машинобудівних підприємствах. Оцінювання й подальший аналіз показали, що можлива причина низької енергоефективності полягає в недостатній наявності організаційних умов забезпечення енергоефективності на вітчизняних підприємствах.

Ключові слова: оцінювання енергоефективності, методичний підхід до оцінювання енергоефективності, використання енергетичного потенціалу, енергоефективність продукції, інтегральний коефіцієнт енергоефективності.

МЕТОДИЧЕСКИЙ ПОДХОД К ОЦЕНКЕ ЭНЕРГОЭФФЕКТИВНОСТИ НА ПРЕДПРИЯТИЯХ

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Энергоэффективность становится приоритетной задачей на современном этапе экономического развития для государства и предприятий. Взаимозависимость экономических процессов на всех уровнях экономики (национальном, региональном и микроуровне) требует целостного подхода к оценке эффективности использования энергетических ресурсов.
Для определения наиболее эффективных путей повышения энергоэффективности необходим комплексный подход к ее оценке, который будет учитывать особенности энергетического

потенциала на всех уровнях экономической системы. Предложен методический подход к оценке энергоэффективности на машиностроительных предприятиях, который предполагает комплексную оценку, состоящую из следующих этапов: оценки наличия энергетического потенциала на уровне национальной экономики; эффективность его использования на промышленных предприятиях, в том числе машиностроительных, а также результат его использования путем оценки энергоэффективности производства конечной продукции машиностроительных предприятий. Были предложены не только этапы комплексного методического подхода к оценке энергоэффективности, но и соответствующие аналитические инструменты для оценки на каждом этапе. На основе этого методического подхода была оценена энергоэффективность на украинских машиностроительных предприятиях. Оценка и последующий анализ показали, что возможная причина низкой энергоэффективности заключается в недостаточном наличии организационных условий обеспечения энергоэффективности на отечественных предприятиях.

Ключевые слова: оценка энергоэффективности, методический подход к оценке энергоэффективности, использование энергетического потенциала, энергоэффективность продукции, интегральный коэффициент энергоэффективности.

Efficient use of energy resources has become a top priority for current economic development. The interdependence of economic processes at various levels of economy necessitates a holistic approach to the evaluation of energy efficiency. To determine the most effective ways to increase energy efficiency, a comprehensive approach to the evaluation of the energy potential peculiarities at all the levels of the economic system is required to include the estimation of the national economy energy potential availability and direct use, and energy utilization efficiency manifested in the energy efficiency of the end product of industrial enterprises. In this connection, the improvement of the methodical approach to the evaluation of energy efficiency is a topical scientific problem.

Numerous Ukrainian and foreign scientists have devoted their studies to the problem of energy efficiency evaluation on various levels of economy, among them the following should be mentioned: V. Kotelenets, L. Melnyk, V. Mikitenko, D. Streimikiene, O. Sukhodolia [1 – 5], and others. Considering the significance of scientific achievements in the field, problems of energy efficiency comprehensive evaluation still require further consideration.

The aim of this article is to improve the methodical approach to energy efficiency evaluation, so as to take into account the complex nature of energy resources consumption and use through all the levels of the economic system.

The energy potential is inherent in the economic system at various levels and has specific manifestations at each of them. To increase the efficiency of energy potential utilization at Ukrainian industrial enterprises, energy potential must be considered comprehensively through all the levels of economy [6]. At each economic level, where energy potential is examined, corresponding measures could be introduced to enhance its utilization efficiency, and thus increase energy efficiency.

The interconnection logic of the energy efficiency evaluation stages at various levels of the economic system
is shown in Fig. 1.

Fig. 1. **The interconnection logic of the energy efficiency evaluation stages**

As shown in Fig. 1, the energy potential of the Ukrainian economy maintains i.a. the operation of industrial enterprises, including mechanical engineering. The end product of enterprises is considered as the result of the energy potential implementation in the industry [7].

Energy efficiency maintenance at Ukrainian industrial enterprises depends on both the quality of the enterprise's own energy potential utilization and common global trends
in the energy sector. This is due to the fact that the amount
of currently proven reserves of fuel and energy resources in Ukraine cannot fully meet the needs of industry, infrastructure and population for energy resources, which makes Ukraine an import-dependent country in the aspect of the energy resources procurement. Therefore, development trends in the global energy system affect the energy efficiency of Ukrainian enterprises.

Three distinctive periods can be seen in the total primary energy supply and final energy consumption in Ukraine. The first period can be referred to as an economic recession of 1991 – 1999, which is notable for rapid decline in GDP (60 % for the period), and a corresponding reduction in energy consumption. The second period, that lasted from 2000 to 2007, is characterized by stabilization of energy consumption with a slight upward trend (0.4 % average annual growth), which was accompanied by a faster growth of GDP (about 7.7 % average annual growth). In the first place, this was due to sectoral shifts and structural changes in the Ukrainian economy that occurred during this period – an outstripping growth rate in the trade sector, service industries and the financial sector, which provided a significant contribution to GDP growth.
In the third period, which began in 2008 and continues to this day, the total primary energy supply and final energy consumption were formed under the influence of the global financial and economic crisis, that has largely determined commodity production of the major export-oriented industries (metallurgical, chemical, mechanical engineering), which in turn affected other industries – electric power and extractive industries (mining ore and coal).

The period of extensive development in some precedent years was not used fully to implement the structural changes in the economy, where the imbalance and high energy consumption caused increased stagnation in the fuel and energy complex and made it impossible to carry out urgent reforms in it. In turn, within the energy sector itself the imbalances constrained transformation of the energy consumtion structure [1].

Overall macroeconomic analysis of the available energy potential utilization in Ukraine allowed for identification of trends in consumption and production of oil, natural gas, coal, as well as for determination of energy intensity of the gross domestic product. Among these trends, reduction in the absolute consumption and production of energy resources, due to the general downturn in the Ukrainian economy, was observed. Despite the decline in the energy intensity of GDP, which is seen as one of the energy efficiency indicators at the macroeconomic level, the result of the energy potential utilization generalized analysis should be concluded as a need to increase energy efficiency. To determine what areas energy efficiency measures should be developed in, it is necessary to conduct a more detailed analysis of the energy resources production structure and areas of their end use in industrial activities.

The analysis of the fuel and energy resources consumption at industrial enterprises in Ukraine in general, and among them – at mechanical engineering enterprises, allowed identifying overall trends and areas that require improvement. Thus, the largest share of fuel and energy resources, consumed by mechanical engineering enterprises in the production process, falls on electricity and natural gas. Diesel, motor fuel and coal are among the most widely used fuels. The industrial production decline resulted in an increase in the share of energy costs in the cost structure in both physical and value terms. The share of the energy element in the structure of semi-fixed costs is growing, it is used for heating and/or lighting the premises, and for other needs apart from the process of production itself, i.e. these costs do not correlate directly with the value of production output.

The energy intensity of production at Ukrainian mechanical engineering enterprises is considerably higher than in the world's leading mechanical engineering companies, particularly EU companies. This is due to the fact that the industrial infrastructure in Ukraine uses energy-inefficient, highly resource-intensive equipment, which does not meet ecological requirements. Above all, in most cases it is utilized beyond the period of useful life. Ukraine lacks up-to-date industrial technologies, which results in increased fuel consumption per unit of industrial production output. Under present-day conditions imported gas significantly impacts on industrial production, which leads to increased production costs, reduced competitiveness of Ukrainian goods, and internal and external market share loss.

Production output of industrial enterprises can be viewed as the result of implementing energy potential [7].
A comprehensive analysis of energy efficiency at industrial enterprises implies evaluating the energy efficiency of production output, that, within the scope of this research, was carried out for mechanical engineering enterprises, both foreign and Ukrainian. In accordance with the Law of Ukraine "On Energy Saving", energy-efficient products, technology, equipment are a product or a method, a means of production that ensure rational use of energy resources in comparison with other options of use or manufacturing the product of the same consumer level, with the same technical and economic parameters [8].

To perform energy efficiency evaluation of mechanical engineering production output that is based on a range of particular indicators, it is advisable to use the mathematical support such as a methodical approach to the taxonomic index calculation [9].

To conduct a comparative energy efficiency evaluation of production output in the mechanical engineering industry, 15 machine-building enterprises were selected, among which both Ukrainian and foreign international leading manufacturers of wheel general-purpose farm tractors are presented, namely the JSC "Kharkiv Tractor Plant" (Kharkivskyi traktornyi zavod (KhTZ) (Ukraine); the State Enterprise "Production Association Pivdennyi Machine Building Plant named after A. M. Makarov" (SE "PA PMBP") (Ukraine);
the State Enterprise "Production Association Minsk Tractor Plant" (Belarus); Case IH (USA); Claas

(Germany); Deutz-Fahr (Germany); Farmtrac (EU); Fendt (Germany); JCB (United Kingdom); John Deere (USA); Kubota (Japan); Massey Ferguson (Canada); New Holland (France); Terrion (Russia); Valtra (Finland).

The wide range of wheel general-purpose farm tractors includes models with capacity varying considerably from 19 kW to 250 kW. Considering the fact that the technical characteristics of the end products within the capacity range vary and are not even by their value, to enhance the estimate reliability of the efficiency evaluation it is advisable to conduct evaluation within the subgroups formed by the nominal power criterion. Thereby, four subgroups were selected (group 1 with a nominal capacity of up to 50 kW; group 2 with a nominal capacity from 50 to 100 kW; group 3 with a nominal capacity from 100 to 150 kW; group 4 with a nominal capacity of more than 150 kW). For the purposes of the research it is assumed that tractor capacity is determined by the nominal engine power. In accordance with the procedure stipulated by the taxonomic index calculation approach the energy efficiency ratings were build separately for four product groups, each of them comprising 30 product models [10], which ensures fairly even and comparable technical and economic characteristics within each group.

Thus the energy efficiency evaluation of production output was conducted in four homogeneous groups by the following parameters:

x_1, maximum engine power, kW;

x_2, nominal engine power, kW;

x_3, specific fuel consumption at maximum power, g/kWh;

x_4, specific fuel consumption at nominal power, g/kWh;

X_5, a unit of weight per unit of production capacity (kg/kW);

x_6, turning radius, m.

Further the results of energy efficiency calculations of the production output are shown for group 3, which comprises the wheel general-purpose farm tractors with a nominal capacity from 100 to 150 kW.

Table 1 illustrates the calculations of the intermediary indicators for the determination of the reference point, namely, the average value of the j-th index (Xmean), standard (root-mean-square) deviation of the j-th index (Sj).

Table 1

Calculation of the intermediary indicators to determine the reference point for group 3 (wheel general-purpose farm tractors with a nominal capacity from 100 to 150 kW)

Estimate	Energy efficiency parameters

indicator	x_1	x_2	x_3	x_4	x_5	x_6	
Average value of the j-th index (Xmean)		129.14	121.18	233.47	254.64	59.68	5.57
Standard (root-mean-square) deviation of the j-th index (Sj)		10.21	9.51	11.41	11.92	5.11	0.89

The results shown in Table 1 were obtained on the basis of technical and economic characteristics of the production output in accordance with already outlined parameters x_1 to x_6. Because these parameters have different units of measurement, standardization of baseline values is required in order to complete the next step in the procedure of energy efficiency integral rating formation that is to define the reference point (Table 2).

Table 2

The matrix of baselines standardized values and defining the reference point for group 3

Tractor model	Standardized values of production output energy efficiency parameters						
	x_1	x_2	x_3	x_4	x_5	x_6	
1. KhTZ -150К-09-25		-0.01	0.01	-1.18	-0.22	1.16	1.27
2. KhTZ -16131		-0.41	-0.38	-0.04	-0.22	1.33	1.71
3. KhTZ -16131-03		0.32	0.40	-1.15	0.28	1.25	1.71
4. KhTZ -16131-05		0.28	0.40	-0.44	0.62	1.25	1.71
5. KhTZ -16331		0.29	0.45	-0.83	-1.65	0.13	1.71
6. KhTZ -17021		0.28	0.40	-1.22	-1.97	0.67	-2.10

7. KhTZ -17221	-0.01	0.01	-1.18	0.37	1.50	1.27
8. KhTZ -17221-09	0.32	0.40	1.59	2.38	1.46	1.27
9. MTZ 1523	-1.48	-1.28	-1.18	-0.39	-1.27	-0.64
10. MTZ 1523.3	-1.29	-1.07	-0.57	-0.39	-1.10	-0.08
11. MTZ 1523.4	0.18	-1.07	2.59	1.29	-1.10	-0.08
12. MTZ 1523.5	-1.28	-0.92	-1.00	0.70	-1.32	-0.08
13. Puma CVX 160	0.08	-0.33	-0.30	-0.14	0.84	-0.14
14. Puma 180	1.26	1.35	-0.04	-0.31	0.27	-1.15
15. Axion 820 C-matic	1.46	1.45	1.54	0.37	1.08	-0.47
16. Arion 650 Cebis	0.57	0.82	0.22	-0.73	0.27	0.03
17. Agrotron M 625	-0.11	-0.12	2.06	1.29	-0.76	-0.50
18. 6180 P	0.18	0.19	-0.30	0.87	-0.40	-0.19
19. Vario 820	1.95	1.98	0.84	-0.14	-1.29	0.03
20. Vario 516	-1.87	-1.91	-0.30	-0.14	0.48	-0.06
21. 6830	-1.68	-1.49	0.31	-0.89	-1.37	-0.42
22. 7530 Premium	1.65	1.56	0.48	-0.89	-0.64	-0.53
23. 6930 Premium	-0.70	-0.76	-0.22	-1.14	-0.74	-0.42
24. M 7.171	-0.54	-0.33	0.13	-0.64	-1.23	-1.48
25. MF 7615 DynaVT	-1.09	-1.18	0.05	0.28	1.36	-0.04
26. T7.210	0.38	-0.02	-1.36	-1.82	-0.72	-0.14
27. T7040	1.26	1.35	0.31	0.20	0.03	0.14
28. N163 Direct	-0.11	-0.12	0.40	0.79	-0.74	-1.20

29. N143 Direct	-0.99	-0.97	0.66	1.62	-0.06	-1.20
30. T182 Versu	1.11	1.18	0.13	0.62	-0.37	0.03
Reference point	1.95	1.98	-1.36	-1.97	-1.37	-2.10

The next step consists in calculating the mean Euclidean distance (D_o mean), the standard deviation of Euclidean distance (S_o), as well as the integral energy efficiency coefficient of the production output (Ki). The results are presented in Table 3.

Table 3

The results of the calculation of the energy efficiency coefficient of the production output for group 3

Tractor model	Energy efficiency parameters of the production output	Sum	Euclidean distance	Ki					
x_1	x_2	x_3	x_4	x_5	x_6				
1	2	3	4	5	6	7	8	9	10
1	3.84	3.87	0.03	3.05	6.43	11.32	28.54	5.34	0.2633
2	5.53	5.55	1.73	3.05	7.33	14.54	37.73	6.14	0.1530
3	2.64	2.49	0.04	5.06	6.90	14.54	31.67	5.63	0.2239
4	2.77	2.49	0.85	6.68	6.90	14.54	34.23	5.85	0.1932
5	2.74	2.33	0.28	0.10	2.27	14.54	22.26	4.72	0.3494
6	2.77	2.49	0.02	0.00	4.19	0.00	9.47	3.08	0.5756
7	3.84	3.87	0.03	5.48	8.27	11.32	32.81	5.73	0.2101
8	2.64	2.49	8.67	18.89	8.05	11.32	52.07	7.22	0.0049

9	11.75	10.63	0.03	2.49	0.01	2.13	27.04	5.20	0.2829
10	10.45	9.30	0.62	2.49	0.07	4.08	27.01	5.20	0.2833
11	3.11	9.30	15.55	10.60	0.07	4.08	42.71	6.54	0.0988
12	10.38	8.43	0.12	7.12	0.00	4.08	30.13	5.49	0.2430
13	3.46	5.35	1.11	3.35	4.91	3.85	22.03	4.69	0.3527
14	0.47	0.40	1.73	2.76	2.69	0.91	8.96	2.99	0.5873
15	0.24	0.28	8.36	5.44	6.04	2.65	23.01	4.80	0.3385
16	1.88	1.34	2.49	1.54	2.72	4.54	14.51	3.81	0.4747
17	4.23	4.42	11.68	10.60	0.37	2.57	33.88	5.82	0.1973
18	3.11	3.20	1.11	8.04	0.95	3.64	20.04	4.48	0.3827
19	0.00	0.00	4.80	3.35	0.01	4.54	12.69	3.56	0.5087
20	14.59	15.14	1.11	3.35	3.44	4.17	41.79	6.46	0.1085
21	13.13	12.05	2.77	1.15	0.00	2.83	31.93	5.65	0.2207
22	0.09	0.18	3.39	1.15	0.54	2.47	7.81	2.80	0.6145
23	6.99	7.48	1.30	0.68	0.41	2.83	19.68	4.44	0.3882
24	6.19	5.35	2.22	1.76	0.02	0.38	15.92	3.99	0.4498
25	9.22	9.95	1.97	5.06	7.48	4.26	37.94	6.16	0.1506
26	2.46	3.99	0.00	0.02	0.42	3.85	10.75	3.28	0.5479
27	0.47	0.40	2.77	4.69	1.98	5.03	15.34	3.92	0.4599
28	4.23	4.42	3.07	7.58	0.41	0.81	20.51	4.53	0.3754
29	8.63	8.67	4.06	12.90	1.73	0.81	36.80	6.07	0.1635
30	0.69	0.64	2.22	6.68	1.00	4.54	15.78	3.97	0.4523
D_o mean (mean Euclidean distance)								4.92	

S_o (standard deviation of Euclidean distance)	1.17		
D_o	7.25		

The resulting integral coefficient Ki was used to build the production output energy efficiency rating for mechanical engineering enterprises (Fig. 2).

Fig. 2. **Production output energy efficiency rating for engineering enterprises of group 3**

The production output energy efficiency rating of the mechanical engineering enterprises leads to the following conclusions. As displayed in Fig. 2, the highest level of the production output energy efficiency was demonstrated by such companies as John Deere (USA), Case IH (Germany), JSC "KhTZ" (Ukraine), and New Holland (France). As can be seen, products manufactured by mechanical engineering enterprises of France, Germany and the USA, as well as the tractor model of the Ukrainian mechanical engineering enterprise JSC "KhTZ" took the leading position in Group 3.

As can be seen in Fig. 2, the energy efficiency integrated coefficient of production output amounted to $K_1 = 0.6145$ for the tractor model John Deere 7530 Premium; $K_2 = 0.5873$ for the tractor model Case IH Puma180; $K_3 = 0.5756$ for the tractor model KhTZ-17021; $K_3 = 0.5479$ for the tractor model New Holland T7.210. These indicate the highest level of the production output energy efficiency amongst enterprises in group 3 (with a nominal capacity from 100 to 150 kW).

It is worth pointing out the presence of the Ukrainian machine-building enterprise JSC "KhTZ" among the leaders in the energy efficiency integral rating. Despite the fact that this is definitely a positive outcome for the enterprise, it should be analyzed in more detail. This configuration of the tractor model KhTZ-17021 under analysis is based on the engine model BF 6M 1013E, which is produced by the Deutz AG (Germany). A similar tractor model, but equipped with the engine model YaMZ-236 produced by the JSC "Autodiesel" (Russia), was also evaluated as part of the group and resulted in the overall rating in the 22nd place with an integral energy efficiency coefficient $K_{22} = 0.2101$.

Wheel general-purpose farm tractors manufactured by domestic machine-building enterprises presented in group 3 have the following results. The JSC "KhTZ" resulted with the following value of the integral energy efficiency coefficient:
$K_{14} = 0.349$ (tractor model KhTZ-16331), $K_{18} = 0.263$ (tractor model KhTZ-150K-09-25), $K_{20} = 0.224$ (tractor model KhTZ-16131-03), $K_{22} = 0.210$ (tractor model KhTZ-17221), $K_{24} = 0.193$ (tractor model KhTZ-16131-05), $K_{26} = 0.153$ (tractor model KhTZ-16131). The lowest rate of the integral energy efficiency coefficient of the production output $K_{30} = 0.005$ refers to the tractor model KhTZ-17221-09.

The fact that the integral energy efficiency coefficient of the JSC "KhTZ" production output varies significantly indicates the stochastic nature of high maintenance results for these tractors. This requires further analysis based on the calculation of the average rating for the products of each company.

Thus, the energy efficiency rating of machine-building enterprises represented in the group with a nominal capacity of 100-150 kW is shown in Fig. 3.

Fig. 3. **Energy efficiency rating of machine-building companies in group 3**

Based on the results of the average energy efficiency rating for the machine-building enterprises in group 3, the production output of such companies as New Holland (France), Case IH (Germany), Kubota (Japan) and Claas (Germany) is characterized by the highest overall level of energy efficiency. Despite the fact that in accordance with the individual production output energy efficiency integral coefficients of the JSC "KhTZ" products were also presented amongst the leaders in this group, the average rating has shown that the production output energy efficiency of domestic enterprises is significantly lower, notably the JSC "KhTZ" (Ukraine) and the State Enterprise "Production Association Minsk Tractor Plant" (Belarus) are in the 9th and 10th place respectively.

Similarly, the production output energy efficiency was evaluated for product groups 1, 2 and 4, mentioned above. As a result, local energy efficiency ratings of machine-building enterprises have been built.

At the final stage of the production output energy efficiency evaluation for mechanical engineering enterprises, the formation of the overall rating of the enterprises producing wheel general-purpose farm tractors was carried out. The results of the local ratings within each of the four groups at nominal capacity were used as the basis for the overall rating (Table 5).

Table 5

Energy efficiency rating of mechanical engineering enterprises producing wheel general-purpose farm tractors

No.	Enterprise	Local rating of the enterprise	Standardized rating of the enterprise		Rating						
		Group 1 (up to 50 kW)	Group 2 (50 – 100 kW)	Group 3 (100 – 150 kW)	Group 4 (from 150 kW)	Group 1 (below 50 kW)	Group 2 (50 – 100 kW)	Group 3 (100 – 150 kW)	Group 4 (from 150 kW)		

1	NewHolland (France)	5	1	1	5	0.50	0.09	0.09	0.45	0.28 /(1)
2	John Deere (USA)	3	2	5	4	0.30	0.18	0.45	0.36	0.33 /(2)
3	Fendt (Germany)	–	3	7	2	0.00	0.27	0.64	0.18	0.36 /(4)
4	Deutz-Fahr (Germany)	1	9	8	8	0.10	0.82	0.73	0.73	0.59 /(9)
5	Claas(Germany)	–	5	4	3	0.00	0.45	0.36	0.27	0.36 /(5)
6	Case IH (Germany)	6	6	2	6	0.60	0.55	0.18	0.55	0.47 /(7)
7	Valtra (Finland)	2	7	6	1	0.20	0.64	0.55	0.09	0.37 /(6)
8	MasseyFerguson (Canada)	4	10	11	9	0.40	0.91	1.00	0.82	0.78 /(12)
9	Kubota (Japan)	4	–	3	–	0.40	0.00	0.27	0.00	0.34 /(3)
10	Farmtrack (EU)	–	11	–	–	0.00	1.00	0.00	0.00	0.50 /(8)
11	SE "PA MTZ" (Belarus)	10	4	10	7	1.00	0.36	0.91	0.64	0.73 /(10)
12	SE "PA PMBP" (Ukraine)	9	–	9	12	0.90	0.00	0.82	1.09	0.94 /(14)
13	JSC "KhTZ" (Ukraine)	8	8	–	–	0.80	0.73	0.00	0.00	0.76 /(11)
14	JCB (Great Britain)	–	–	–	10	0.00	0.00	0.00	0.91	0.91 /(13)
15	Terion (Russia)	–	–	–	11	0.00	0.00	0.00	1.00	1.00 / (15)

To build the overall rating of the enterprises by the level of their production output energy efficiency (wheel farm tractors) the local ratings were used as the basis, i.e. the average places of the enterprise in each local rating that it had received by the energy efficiency evaluation within the individual product groups, as well as the results of the rating standardization procedure if the products of the enterprise were not presented in one or a number of product groups.

The overall rating is calculated as the average of the normalized ratings for every single enterprise. Thus, this makes it possible to use all the results received from the local rating calculation procedures, even if certain enterprises were not presented in every group under analysis. This could be mostly explained by objective reasons, such as the absence of a relevant portfolio of technical and economic parameters of the production model.

The first places in the energy efficiency rating belong to the following enterprises: New Holland (France), John Deere (USA), Kubota (Japan), Fendt (Germany), Claas (Germany), Valtra (Finland), Case IH (Germany). Considering these, the overall rating provides an evaluation of the production output energy efficiency for each enterprise as a whole, integrating the results of individual evaluations. It should be noted that despite the high energy efficiency standards for the processes and production output, certain companies that were recognized industry leaders in the market of agricultural equipment did not take high places in the ratings, neither local nor general. This could be explained by the power ranges, which have been selected for the groups created. Since the evaluation was conducted to assess the production output energy efficiency of domestic machine-building enterprises in the first place, the product groups were selected based on their peculiarities. The end products of domestic machine-building enterprises the JSC "Kharkiv Tractor Plant" and the State Enterprise "Production Association Pivdennyi Machine-Building Plant named after A.M. Makarov" resulted in the 11th and 14th places in the overall energy efficiency rating. Despite the fact that in certain product groups domestic mechanical engineering enterprises received high comparative energy efficiency assessments, their overall ratings are quite low.

Thus, the energy efficiency evaluation with the use of the given methodical approach allows estimating similar products manufactured by various enterprises based on the energy efficiency parameter. The results of the energy efficiency evaluation may be used to develop measures to improve energy efficiency of individual enterprises, among which the implementation of the organizational conditions of energy efficiency maintenance similar to those implemented at the enterprises that took the leading positions in the ratings are of high importance. One of the essential components of organizational conditions of energy efficiency maintenance at such enterprises is the introduction and use of energy management standards.

At the same time, domestic machine-building enterprises, which by the results of the energy efficiency evaluation were rated low, are mostly characterized by the absence of obligatory implementation of these standards. This is one of the causes of low results. Improving organizational conditions for energy efficiency maintenance at the expense of adopting best management practices used at the enterprises that are leaders of the rating, namely the introduction of energy management standards, will contribute to an increase in energy efficiency of the production output. The implementation of procedures and regulations provided by such standards improves the efficiency of the production process, and accordingly, the energy efficiency of the production output, as the end result of the production process, reduces the loss of energy resources, increases correspondence between the actual results of the manufacturing process and the technical requirements, that regulate the processes and depend on the equipment and technology development level in the industry.

Applying the methodical approach to integrated energy efficiency evaluation has proved that the low level of energy efficiency of domestic machine-building enterprises significantly depends on the imperfect utilization of the energy potential at the macroeconomic level, causing a low level of energy efficiency of the end product manufactured by these enterprises. It was determined that an important aspect that ensures a high level of energy efficiency is the introduction of the organizational conditions for energy efficiency maintenance, that are an essential part of the management practices for the leading enterprises.

Thus, the article has presented a methodical approach to the evaluation of energy efficiency at machine-building enterprises. In the framework of the proposed methodical approach a comprehensive evaluation has been provided, which comprises the following stages: assessing the national economy energy potential availability, the efficiency of its utilization at industrial enterprises including machine-building enterprises, and, finally, the result of its utilization through the production output energy efficiency evaluation of machine-building enterprises. The correlation between the level of the energy potential utilization and the production output energy efficiency has been substantiated. Apart from the comprehensive methodical approach to the evaluation of energy efficiency, appropriate analytical instruments for the evaluation at each stage have been suggested. On the basis of this methodical approach the energy efficiency at Ukrainian machine-building enterprises has been evaluated. The evaluation and further analysis have shown that a possible cause of low energy efficiency lies in the lack of organizational conditions for the energy efficiency maintenance at the domestic enterprises. Further scientific research will be focused on the formation of a mechanism for energy efficiency at industrial enterprises.

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