Modeling the Energy and Mass Flows in Evaluating the Energy Efficiency of Industrial Systems

Assoc. Prof. Nadezhda Evstatieva, PhD
Faculty ‘Electrical Engineering, Electronics and Automation’,
Department of Theoretical and Measuring Electrical Engineering,
University of Ruse ‘Angel Kanchev’, Bulgaria
E-mail: nevstatieva@uni-ruse.bg

Prof. Ivan Evstatiev, PhD
Faculty ‘Electrical Engineering, Electronics and Automation’,
Department of Electronics,
University of Ruse ‘Angel Kanchev’, Bulgaria
E-mail: ievstatiev@uni-ruse.bg

Abstract: Key features defining the energy efficiency of industrial systems are energy and mass flows. These are the energy coming from energy sources, ensuring operation of the system - electricity, gas, liquid fuels, water and others. Assessment of energy consumption per unit of output is formed by quantitative estimates of the mass flows, providing the raw material for the production process, flow of finished goods and waste. The relationship between energy and mass flows is complex and depends on many factors. In this paper, modelling the energy and mass flows in order to assess the energy efficiency of industrial systems has been suggested.

Key words: energy efficiency, modeling, industrial system.

JEL Classification: C19
I. Introduction

Implementing measures for energy efficiency in industrial systems is of particular importance for business. Energy efficiency improves the cost structure, provides better competitiveness for the production and sets an example for social responsibility to society. Energy efficiency is one of the main directives in the policy of the EU and the Republic of Bulgaria (Direktiva 2006/32/EO na Evropeiskiya parlament i na saveta, 2006), (Zakon za energiyna efektivnost, 2015), (Naredba № rd-16-346, 2009), (Natsionalen plan za deistvie za energiyna efektivnost 2014-2020, 2014).

Taking into account the importance of energy efficiency, a number of tasks, concerning energy consumption of industrial systems, related to assessment of the state of affairs and identifying of appropriate energy saving measures, whose implementation guarantees a considerable reduction of energy consumption.

The main characteristics related to measures for energy efficiency of industrial systems are as follows (Operativna programa “Inovatsii i konkurentnosposobnost” 2014-2020, 2015):

- annual energy consumption of the company for a year, selected as representative;
- corrected annual energy consumption of the company for a year, selected as representative;
- annual energy savings from the recommended package of measures;
- planned energy savings for the whole company as a result from the implementation of energy efficiency measures;
- the factor of energy savings.

These characteristics present information about the effect from the energy efficiency measures after their introduction. Each of the characteristics is presented as average annual value. They, however, do not provide information about the dynamics of change of energy and mass flows after the measures of energy efficiency in the company have been introduced. This dynamics is definitive for the effect of these measures.
measures. The information is also important for the organisation of production in the company.

The information about the dynamics of change of energy and mass flows after the measures of energy efficiency in the company have been introduced can be obtained through their modelling.

For assessment of the dynamics of the effect from the measures for energy efficiency, it is necessary to take into account the dynamics of change of energy and mass flows, which are fundamental for the economic effect.

The model of studying factors for improving the competitive advantages of regional production clusters on the basis of improving the economic efficiency through implementing technological innovations is well-known (Antonova, 2008). A mathematical model for study of the production function of the industrial companies and increasing their efficiency through technological innovations transfer is also known (Antonova, 2009). These models are based on the economic characteristics of production, when assessing the impact of energy efficiency measures for the production system and do not present the dynamics of energy and mass flows of the industrial systems.

The analytical models find significant application for modelling energy and mass flows in industrial systems (Efremov, A., 2013), (Dorf, R. and R. Bishop, 2008), (Gajic, 2003). They present the development of processes in time through analytical equations. The energy and mass flows in industrial systems have more random character and their development in time depends not only on the technical parameters, but also on a number of economic factors, the dynamics of the finished products market dynamics, the price of the energy sources, etc. This makes the analytical models unsuitable for modelling of energy and mass flows in industrial systems.

When modelling the technological processes, the method of finite differences is applied (Velev, 1984), (Evstatiev, 2009). In this case time and space are divided into
The aim of the study is to model the dynamics of changing the energy and mass flows when assessing the energy efficiency of industrial systems, which leads to improvement of the company management and reduction of energy and financial costs of the production process.

II. Exposition

1. Justification of major approximations and equations used

A few basic approximations are adopted when modelling energy and mass flows in industrial systems with assessment of the energy efficiency of industrial systems. According to (Operativna programa “Inovatsii i konkurentnosposobnost” 2014-2020, 2015), when assessing the current state of energy costs, as well as that of mass flows of finished products, the information used for the energy flows and annual production is claimed to be representative. A number of factors have an impact on the development of energy and mass flows with assessment of the energy efficiency of industrial systems such as:

- market for finished products. For some productions there are periods of greater demand throughout the year, and vice versa, periods when demand is reduced. Thus, for food industry companies there is a
great demand of production during the periods before big holidays. For other companies, it is the seasons that affect this trend. These are companies, whose production is related to products for heating and air-conditioning such as fireplaces, heaters, etc.;
- energy consumption, related to energy costs for air-conditioning of domestic and industrial premises. It is clear that during the cold periods of the year there are significant energy costs for heating, and during the hot summer days there are cooling costs;
- periods, related to the annual leave of personnel. Some companies give the leaves to all their employees at the same time of year, for example, July, August, December or January;
- national holidays. They also affect energy costs and production.

The specific features, determining the dynamics of annual change of energy and mass flows, allow the adoption of the approximation that the dynamics of the annual change of energy and mass flows for future years is analogous to the change in the year, chosen as representative for a certain production.

Information about the dynamics of change in the impact of measures for energy efficiency during the year is contained in the assessment of specific energy consumption. It represents the ratio between energy consumption and the production for specified periods of time. Presented as a function of time, the specific energy consumption shows the dynamics of change of the energy and mass flows in the industrial system.

It is assumed that the reduction of energy costs after implementing energy efficiency measures is calculated on the basis of the technical characteristics of the equipment and machinery suggested in the measures.

2. Methods of modelling energy and mass flows with assessment of the energy efficiency of industrial systems.
The methods involve the following steps:

2.1. Breaking the representative year into equal time intervals. Usually, it is convenient to use the monthly reports for energy resources and production costs.

2.2. Determining the company’s energy costs during the equal time intervals chosen – electricity, natural gas, liquid fuels, etc.

2.3. Align the energy costs to energy consumption in kWh.

2.4. Determining the company’s production for the intervals chosen.

2.5. Determining the specific energy consumption for a unit of output for each interval of time with the equation

\[ e_i = \frac{E_i}{n_i}, \text{ kWh/produktion unit} \]  

where \( E_i \) is energy consumption of all kinds, used by the company, kWh; 
\( n_i \) - quantity of products, production unit.

2.6. Determining the average annual specific energy consumption for a unit of output with the equation

\[ e_{av} = \frac{E_{av}}{n_{av}}, \text{ kWh/produktion unit} \]  

where \( E_{av} \) is the annual energy consumption of all kinds, consumed by the company, kWh; 
\( n_{av} \) - the annual quantity of finished products, production unit.

2.7. Calculating the ratio between specific energy consumption per unit of output for each interval of time and the average annual value of the equation

\[ \Delta e_i = \frac{e_i}{e_{av}} \]  

2.8. Plotting of graphic expression of the specific energy consumption for the representative year.

2.9. A similar treatment (according to 2.1 ÷ 2.8) of the information from other years.

2.10. When there is information available for more than one year, mathematical expectation for each separate item will be
sought for the years under analysis with the equation

$$\Delta e^\text{math.exp.}_i = \frac{1}{m} \sum_{j=1}^{m} \frac{e_{i,j}}{e_{an}}$$  \hspace{1cm} (4)$$

2.11. Calculating the new average annual specific energy consumption per unit of output, based on the specifications of the new equipment and machinery.

$$e_{\text{av.an.}}^{\text{new}} = \frac{E_{\text{an}}^{\text{new}}}{n_{\text{an}}^{\text{new}}} \text{ kWh/ produktion unit}$$  \hspace{1cm} (5)$$

After introducing the measures for energy efficiency, two variants are reviewed – without a change of productivity of the industrial system and with a change of productivity.

When there is no change of productivity of the industrial system, the energy consumption is reduced as a result of the measures. In this case, the “planned energy savings” (PES) for the whole company are calculated under the formula (Operativna programa “Inovatsii i konkurentnosposobnost” 2014-2020, 2015)

$$\text{PES} = \frac{AS}{AC} \times 100, \%$$  \hspace{1cm} (6)$$

Where $AS$ are the annual energy savings from the recommended package of measures, kWh;

$AC$ - annual energy consumption of the company, kWh.

In this case, for known PES, the new value of annual energy consumption per unit of output is calculated using the equation

$$e_{\text{av.an.}}^{\text{new}} = \frac{E_{\text{an}}^{\text{new}} - (E_{\text{an}} \times \text{PES})/100}{n_{\text{an}}} \text{ kWh/ produktion unit}$$  \hspace{1cm} (7)$$

In the second case, the productivity of the industrial system increases and so does the energy consumption. The new energy consumption is greater, but when it comes to a unit of output, it is smaller. The planned energy savings (PES) for the whole company are calculated under the formula (Operativna programa “Inovatsii i konkurentnosposobnost” 2014-2020, 2015)

$$\Delta e^\text{plan}^{\text{new}}_i = \frac{1}{m} \sum_{j=1}^{m} \frac{e_{i,j}}{e_{\text{cod.}}^{\text{new}}}$$  \hspace{1cm} (4)$$

2.11. Изчисляване на новия средногодишен специфичен разход на енергия за единица продукция, на базата на характеристиките на новото оборудване и машини.

$$e_{\text{пр.год.}}^{\text{нов}} = \frac{E_{\text{год.}}^{\text{нов}}}{n_{\text{год.}}^{\text{нов}}} \text{ kWh.ед. пр.-1}$$  \hspace{1cm} (5)$$

След въвеждането на мерките за енергийна ефективност се разглеждат два варианта – без промяна на производителността на промишлената система и с промяна на производителността. Когато няма изменение на производителността на промишлената система, в резултат на мерките се намалява разходът на енергия. В този случай „планираният енергийни спестявания за цялото предприятие“ (ПЕС) се изчисляват по формулата (Оперативна програма "Иновации и конкурентоспособност" 2014-2020, 2015)

$$\text{ПЕС} = \frac{\Gamma C}{\Pi} \times 100, \%$$  \hspace{1cm} (6)$$

където $\Gamma C$ са годишните спестявания на енергия от преръчване на пакет мерки, kWh;

$\Pi$ - годишното потребление на енергия на предприятието, kWh.

В този случай, при известни ПЕС, новата стойност на средния годишен разход на енергия за единица продукция се изчислява с израза

$$e_{\text{пр.год.}}^{\text{нов}} = \frac{E_{\text{год.}}^{\text{нов}} - (E_{\text{год.}} \times \text{ПЕС}) / 100}{n_{\text{год.}}^{\text{нов}}} \text{ kWh.ед. пр.-1}$$  \hspace{1cm} (7)$$

Във втория случай се увеличава производителността на промишлената система и съответно разходът на енергия. Но- вият разход на енергия е по-голям, но за единица продукция той е по-малък. Планираните енергийни спестявания за цялото предприятие (ПЕС) се изчисляват съгласно зависимостта (Оперативна програма "Иновации и конкурентоспособност" 2014-2020, 2015)
Modeling the Energy and Mass Flows in Evaluating the Energy Efficiency of Industrial Systems

\[ \text{PES} = \frac{\text{AS}}{\text{CAEC}} \times 100, \% \]  \hspace{1cm} (8)

Where \( \text{CAEC} \) - corrected annual energy consumption, kWh.

\( \text{CAEC} \) is the consumption, which the industrial system would have, in order to produce the increased quantity of products, without the introduction of measures.

When the measures for improving the energy efficiency lead to increase of productivity and we know the value of PES and the increase of productivity (\( k \) times), the annual average energy consumption per unit of output is calculated for the new productivity and the corrected energy consumption. The equation is

\[ e_{an, new} = \frac{E_{an, new}}{k_n} = \frac{\text{CAEC} - (\text{CAEC} \times \text{PES})}{k_n} \times 100, \% \]  \hspace{1cm} (9)

Where \( \text{CAEC} = k \times E_{an} \);

\( k \) - the increase of productivity of the industrial system.

\( k \times n_{an} \) - annual productivity after the introduction of measures, \( \text{produktion unit} \).

2.11. Calculating the new specific energy consumption for the intervals under study using the formula

\[ e_{i, new} = \frac{\Delta e_i \times e_{an, new}}{k \times n} \text{kWh/produktion unit} \]  \hspace{1cm} (10)

2.12. Constructing the dynamics in the time of the graphic equation of the specific energy consumption per unit of output and the graphic equation of the specific energy consumption modelled.

3. Modelling the energy and mass flows with assessment of the energy efficiency of one industrial system in the Republic of Bulgaria, related to woodworking industry

The output data are shown in Table 1, where according to the methods, the division by months of the representative year is adopted (i.2.1 of the methods).

According to i.2.1 ÷ 2.5 of the methods for modelling applied, the energy consumption is represented in Table 1 (electrical – bar 2; diesel – bars 3 and 4; natural gas

\[ \text{PES} = \frac{\text{GC}}{\text{KTP}} \times 100, \% \]  \hspace{1cm} (8)

\( \text{KTP} \) - corrigirano to godishnoto potreblenie na energet, kWh.

\( \text{KTP} \) e tovo potreblenie na energetiya, koto bi izrazhodvala promishlenata sistema, za da se proizvede velychenoto koliqestvo produkci, bez da sa vvedeni merkite.

Kogato merkite za podobrianie na energetiynata efektivnost vozhd do povishavanie na proizvoditelnosti, izvestni sa PES i povishavaneto na proizvoditelnosti (s \( k \) pti), srednii godiшен razhod na energet za jednica produkci se izчисляva pri novata proizvoditelnost i corirencitno energetino potreblenie. Izrazet e

\[ e_{i, razhod} = \frac{\Delta e_i \times e_{an, razhod}}{k \times n_{razhod}} \text{KTP} - (\text{KTP} \times \text{PES}) / k \times n_{razhod} \times 100, \% \]  \hspace{1cm} (9)

\( \text{KTP} = k \times E_{razhod} \); i - увеличенieto na proizvoditelnostta na promishlenata sistemat.

\( k \times n_{razhod} \) - godishna proizvoditelnost sled vvevdaneto na merkite, ed. pr.\(^{-1}\).

2.11. Izчисляване на новите специфични разходи на енергия за разглежданите интервали по формулата

\[ e_{i, razhod} = \Delta e_i \times e_{an, razhod} \times \text{KTP} \times \text{PES} / k \times n_{razhod} \times 100, \% \]  \hspace{1cm} (10)

2.12. Pострояване на динамиката във времето на графичната зависимост на специфичния разход на енергия за единица продукции и на графична зависимост на моделираната специфичен разход на енергия.

3. Моделиране на енергийните и масови потоци при оценка на енергийната ефективност на една промишлена система в Република България, свързана с дървообработващата промишленост

Изходните данни са предстaveni в табл.1, където съгласно методиката се приема разбирането по месяци на представителната година (т. 2.1 от методиката).

Съгласно т.2.1 ÷ 2.5 от предложената методика за моделиране, в табл.1 са представени енергийните разходи (ел. енергия – стълб 2; дизелово гориво – стълб 3 и 4; природен газ – стълб 5 и 6; общ разход на енергия – стълб 7) и произведена-
- bars 5 and 6; total energy consumption - bar 7) and the finished products (bar 8). After introducing the measures for energy efficiency, the productivity of the industrial system has increased \( k = 2.8 \) times and the planned energy savings for the whole company are \( PES = 40\% \).

To determine the energy equivalent of the diesel in kWh (bar 4) its density at 20\(^\circ\)C has been used, which is 840 kg.m\(^{-3}\) (Stamov, 1990) and the transformation coefficient, which is 11,75 kWh.kg\(^{-1}\) (Naredba za metodikite za opredelyane na natsion-alnite indikativni tseli, 2011).

To determine the energy equivalent of natural gas in kWh (bar 6) its density at 20\(^\circ\)C has been used, which is 0.69578 kg.Nm\(^{-3}\) (http://www.teceko.com/priroden-gaz) and the transformation coefficient, which is 13,10 kWh.kg\(^{-1}\) (Naredba za metodikite za opredelyane na natsionalnite indikativni tseli, 2011).

<table>
<thead>
<tr>
<th>Periods of the year</th>
<th>Electric Energy Consumption</th>
<th>Diesel energy consumption</th>
<th>Natural gas energy consumption</th>
<th>Total energy consumption</th>
<th>Finished products</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kWh</td>
<td>m(^{-3})</td>
<td>kWh</td>
<td>kWh</td>
<td>kWh</td>
</tr>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>38950</td>
<td>3,959</td>
<td>39075</td>
<td>2,423</td>
<td>22085</td>
</tr>
<tr>
<td>February</td>
<td>39095</td>
<td>3,909</td>
<td>38582</td>
<td>1,626</td>
<td>14821</td>
</tr>
<tr>
<td>March</td>
<td>34489</td>
<td>3,949</td>
<td>38977</td>
<td>1,57</td>
<td>14310</td>
</tr>
<tr>
<td>April</td>
<td>49991</td>
<td>4,340</td>
<td>42836</td>
<td>1,359</td>
<td>12387</td>
</tr>
<tr>
<td>May</td>
<td>37907</td>
<td>4,230</td>
<td>41750</td>
<td>0,527</td>
<td>4803</td>
</tr>
<tr>
<td>June</td>
<td>31294</td>
<td>4,390</td>
<td>43329</td>
<td>0,363</td>
<td>3309</td>
</tr>
<tr>
<td>July</td>
<td>37462</td>
<td>4,996</td>
<td>49311</td>
<td>0,205</td>
<td>1869</td>
</tr>
<tr>
<td>August</td>
<td>35774</td>
<td>4,896</td>
<td>48324</td>
<td>0,513</td>
<td>4676</td>
</tr>
<tr>
<td>September</td>
<td>28617</td>
<td>4,886</td>
<td>48225</td>
<td>0,3</td>
<td>2734</td>
</tr>
<tr>
<td>October</td>
<td>27614</td>
<td>4,769</td>
<td>47070</td>
<td>0,323</td>
<td>2944</td>
</tr>
</tbody>
</table>

Table 1. Energy consumption and finished products for the representative year

Таблица 1. Енергийните разходи и произведената продукция за представителната година
Modeling the Energy and Mass Flows in Evaluating the Energy Efficiency of Industrial Systems

In Table 2. The results from the calculation, according to the methods of modeling are presented.

The specific energy consumption for a unit of output (bar 2) is calculated according to equation (1).

The average annual specific energy consumption for a unit of output for the representative year (i.e. 2.6 of the methods) has been calculated according to (2) and is written down in Table 2 bar 3, row “Average” (at the bottom).

Table 2. Calculations of modelling the energy and mass flows with assessment of the energy efficiency of one industrial system

<table>
<thead>
<tr>
<th>Periods of the year</th>
<th>Specific energy consumption</th>
<th>Deviation from the specific energy consumption from the average annual value</th>
<th>Specific energy consumption after introducing the measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$e_i$</td>
<td>$e_i$ - $e^{av}$</td>
<td>$e_i$ - $e^{rev}$</td>
</tr>
<tr>
<td></td>
<td>kWh/number of products</td>
<td>kWh/брай продукция</td>
<td>kWh/брай продукция</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January / Януари</td>
<td>8,7045</td>
<td>1,098</td>
<td>5,224</td>
</tr>
<tr>
<td>February / Февруари</td>
<td>8,0426</td>
<td>1,014</td>
<td>4,824</td>
</tr>
<tr>
<td>March / Март</td>
<td>7,6320</td>
<td>0,963</td>
<td>4,581</td>
</tr>
<tr>
<td>April / Април</td>
<td>9,0189</td>
<td>1,137</td>
<td>5,409</td>
</tr>
<tr>
<td>May / Май</td>
<td>7,2398</td>
<td>0,913</td>
<td>4,344</td>
</tr>
<tr>
<td>June / Юни</td>
<td>6,6803</td>
<td>0,843</td>
<td>4,010</td>
</tr>
<tr>
<td>July / Юли</td>
<td>8,1653</td>
<td>1,03</td>
<td>4,900</td>
</tr>
<tr>
<td>August / Август</td>
<td>8,1774</td>
<td>1,031</td>
<td>4,905</td>
</tr>
<tr>
<td>September / Септември</td>
<td>7,3301</td>
<td>0,924</td>
<td>4,396</td>
</tr>
<tr>
<td>October / Октомври</td>
<td>7,1785</td>
<td>0,905</td>
<td>4,305</td>
</tr>
<tr>
<td>November / Ноември</td>
<td>8,3947</td>
<td>1,059</td>
<td>5,038</td>
</tr>
<tr>
<td>December / Декември</td>
<td>8,6133</td>
<td>1,086</td>
<td>5,167</td>
</tr>
<tr>
<td>Average / Среден</td>
<td>$e^{av}_{in}$ = 7,9290</td>
<td>$e^{cr}_{год}$</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Разчети от моделиране на енергийните и масови потоци при оценка на енергийната ефективност на промишлена система
Calculating the deviation from the specific energy consumption for a unit of output for each interval of time of the average annual value for the representative year (i.e. 2.7 of the methods) is according to (3) and the result is written down in bar 3.

Calculating the new average annual specific energy consumption for a unit of output on the basis of the new equipment and machines (i.e. 2.10 of the methods) is according to equations (6 and 8) and the result is written down in bar 4, row „Average”.

The new specific values of energy consumption for the intervals under study have been calculated using formula (10) and the result is written down in bar 4.

The graph lines of the specific energy consumption results for the representative year and those modelled after introducing the measures, as well as the average specific energy consumption values for the respective years are presented on Fig.1.

**Figure 1.** Graphic presentation of:

1 - dynamics of change of the specific energy consumption results for the representative year; 2 - average specific energy consumption for the representative year; 3 - the modelled specific energy consumption after implementation of the measures; 4 - average specific energy consumption after implementation of the measures.

Фигура 1. Графично изображение на:

1 - динамиката на изменението на специфичните разходи на енергия за представителната година; 2 - среден специфичен разход на енергия за представителната година; 3 - моделираните специфични разходи на енергия след въвеждане на мерките; 4 - среден специфичен разход на енергия след въвеждане на мерките.
4. Analysis of the results obtained

From the graphic representation obtained of the example for modelling of energy and mass flows in an industrial system, after implementing energy efficiency measures, it follows that as a result of these measures, the average annual energy consumption for a unit of output has decreased by 40%.

From the modelled specific energy consumption it can be assumed that the lowest values of this consumption can be obtained for the months of May, June, September and October. This can be explained with the decreased consumption for air conditioning of domestic and industrial premises, costs of heating dryers, etc.

It can be seen from the same graph that the biggest specific energy consumption can be calculated for the months of November, December, January and April. This can be explained with the increased energy costs for heating the premises.

For the summer months, July and August, there is a slight increase of the specific energy consumption. This can be explained with the increased energy consumption for air conditioning of the premises. Another reason can be the increase of waste due to uncomfortable conditions at the work place, created by the high daily temperatures.

Taking into account the decreased specific energy consumption for the months of May, June September and October, it is appropriate to increase the production for these periods when there are industrial and technological capabilities for this.

III. Conclusion

The main characteristics, assessing the effect from the energy efficiency measures of the industrial system are the annual energy consumption of the company for the selected representative year, the corrected annual energy consumption, the annual energy savings due to the measures recommended, the planned energy savings and the factor of energy saving. Taking into consideration these characteristics, which provide average annual assess-

4. Анализ на получения резултат

От получената графична зависимост на разгледания пример за моделиране на енергийните и масови потоци в промишлена система, след прилагане на мерки за енергийна ефективност, следва, че в резултат на мерките средния годишен разход на енергия за единица продукция е намалял с 40%.

От моделирания специфичен разход на енергия може да се направи изводът, че най-малки специфични разходи на енергия може да се получат за месеци май, юни, септември и октомври. Това се обяснява с намалените разходи за климатизация на битови и производствени помещения, разходи за нагряване на сушили и др.

От същата графика се вижда, че най-големи специфични разходи на енергия може да се получат за месеци ноември, декември, януари и април. Това се обяснява с повишаването на енергийните разходи за отопление на помещенията. За летните месеци юли и август също се наблюдава леко увеличение на специфичния разход на енергия. Това може да се обясни с увеличаване на енергията за климатизация на помещенията. Друга причина може да бъде повишаването на брака в резултат на некомфортни условия на работните места, дължащи се на високата дневна температура.

Отчитайки намаления специфичен разход на енергия за месеци май, юни, септември и октомври, е подходящо да се увеличи производството за тези периоди, при наличие на произ водствени и технологични възможности.

III. Заключение

Основни характеристики, оцениващи ефект от мерките за енергийна ефективност на промишлена система са годишното потребление на енергия на предприятието за избраната представителна година, коригираното годишно потребление на енергия, годишните спестявания на енергия от препоръчания пакет мерки, планираните енергийни спестявания и факторът на енергийните спестявания. Отчитайки тези характеристики, даващи средногодишни оценки от ефекта на мерките, е обосновано използване-
The analysis of the dynamics of change in the specific energy consumption, obtained after introducing energy efficiency measures is a prerequisite for obtaining additional effect from the measures. Using this characteristic, it is possible to correct the intensity of production in periods of the year, when the specific energy consumption is smaller, which leads to additional economic effects.

The requirements and the main characteristics, related to measures of energy efficiency of the industrial system, according to the operative programme “Innovations and competitiveness” for energy audit.

The use of the specific energy consumption, as a function of time, for presenting the dynamics of change in the energy and mass flows in an industrial system, has been justified.

Methods for modelling the energy and mass flows in assessment of energy efficiency of the industrial system through the dynamics of change of the specific energy consumption have been developed.

The energy and mass flows in assessment of energy efficiency of one industrial system, in the field of woodworking industry in the Republic of Bulgaria have been modelled according to the methods developed.

The result from the modelling has been analysed. The reasons for obtaining bigger or, respectively, smaller specific energy consumption by months have been analysed as well. The results obtained from the modelling of energy and mass flows are a prerequisite for fulfilling measures, increasing the energy efficiency of the industrial system, which leads to enhancing the economic efficiency of the company.

The use of another characteristic has been justified – the dynamics of change in the specific energy consumption, obtained after introducing energy efficiency measures. This characteristic provides information about the energy and mass flows in the industrial system after introducing the energy efficiency measures.

The requirements and the main characteristics, related to measures of energy efficiency of the industrial system, according to the operative programme “Innovations and competitiveness” for energy audit.

The use of the specific energy consumption, as a function of time, for presenting the dynamics of change in the energy and mass flows in an industrial system, has been justified.

Methods for modelling the energy and mass flows in assessment of energy efficiency of the industrial system through the dynamics of change of the specific energy consumption have been developed.

The energy and mass flows in assessment of energy efficiency of one industrial system, in the field of woodworking industry in the Republic of Bulgaria have been modelled according to the methods developed.

The result from the modelling has been analysed. The reasons for obtaining bigger or, respectively, smaller specific energy consumption by months have been analysed as well. The results obtained from the modelling of energy and mass flows are a prerequisite for fulfilling measures, increasing the energy efficiency of the industrial system, which leads to enhancing the economic efficiency of the company.

Method of the effect of measures, the use of another characteristic has been justified – the dynamics of change in the specific energy consumption, obtained after introducing energy efficiency measures. This characteristic provides information about the energy and mass flows in the industrial system after introducing the energy efficiency measures.

The analysis of the dynamics of change in the specific energy consumption, obtained after introducing energy efficiency measures is a prerequisite for obtaining additional effect from the measures. Using this characteristic, it is possible to correct the intensity of production in periods of the year, when the specific energy consumption is smaller, which leads to additional economic effects.

The requirements and the main characteristics, related to measures of energy efficiency of the industrial system, according to the operative programme “Innovations and competitiveness” for energy audit.

The use of the specific energy consumption, as a function of time, for presenting the dynamics of change in the energy and mass flows in an industrial system, has been justified.

Methods for modelling the energy and mass flows in assessment of energy efficiency of the industrial system through the dynamics of change of the specific energy consumption have been developed.

The energy and mass flows in assessment of energy efficiency of one industrial system, in the field of woodworking industry in the Republic of Bulgaria have been modelled according to the methods developed.

The result from the modelling has been analysed. The reasons for obtaining bigger or, respectively, smaller specific energy consumption by months have been analysed as well. The results obtained from the modelling of energy and mass flows are a prerequisite for fulfilling measures, increasing the energy efficiency of the industrial system, which leads to enhancing the economic efficiency of the company.

Analysis of the effect of measures, the use of another characteristic has been justified – the dynamics of change in the specific energy consumption, obtained after introducing energy efficiency measures. This characteristic provides information about the energy and mass flows in the industrial system after introducing the energy efficiency measures.

The analysis of the dynamics of change in the specific energy consumption, obtained after introducing energy efficiency measures is a prerequisite for obtaining additional effect from the measures. Using this characteristic, it is possible to correct the intensity of production in periods of the year, when the specific energy consumption is smaller, which leads to additional economic effects.

The requirements and the main characteristics, related to measures of energy efficiency of the industrial system, according to the operative programme “Innovations and competitiveness” for energy audit.

The use of the specific energy consumption, as a function of time, for presenting the dynamics of change in the energy and mass flows in an industrial system, has been justified.

Methods for modelling the energy and mass flows in assessment of energy efficiency of the industrial system through the dynamics of change of the specific energy consumption have been developed.

The energy and mass flows in assessment of energy efficiency of one industrial system, in the field of woodworking industry in the Republic of Bulgaria have been modelled according to the methods developed.

The result from the modelling has been analysed. The reasons for obtaining bigger or, respectively, smaller specific energy consumption by months have been analysed as well. The results obtained from the modelling of energy and mass flows are a prerequisite for fulfilling measures, increasing the energy efficiency of the industrial system, which leads to enhancing the economic efficiency of the company.
Reference/Литература


For contacts:
Nadezhda Evstatieva, Assoc. Professor, PhD, University of Ruse, Bulgaria, e-mail: nevstatieva@uni-ruse.bg
Ivan Evstatiev, Professor, PhD, University of Ruse, Bulgaria, e-mail: ievstatiev@uni-ruse.bg