Method for calculating and evaluating the total energy capacity of cotton fiber

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Abstract. This paper discusses the need to save material and fuel and energy resources, requires a new approach to their accounting, qualitative and quantitative assessment, and, in particular, to their use. The correctness of planning and forecasting the levels of mining, production and distribution of resources, and, as a consequence, the clear functioning of industrial and household consumers, depends on this. As the first stage of the calculation, an analysis of energy consumption was performed for the following groups of their consumption: field work; production of mineral fertilizers used in cotton growing; water supply for cotton fields (pumping stations, vertical drains); preparation points and cotton processing enterprises. According to consumption groups, energy capacity is: field work 41%, mineral fertilizers 14% and irrigation 45%. The analysis of the obtained results shows that cotton production occupies a rather large place in the total energy consumption in the republic and its savings at each stage of agricultural work and in industrial processing can give significant results in increasing the efficiency of saving the country's fuel and energy resources.

1. Introduction
The Development of the methods for assessing the energy capacity of any production, in particular, in cotton ginning industry, includes (as an integral component) the ways and means of reducing the power-consumption in production process [1-4].

This index, as is well known, is fundamental in solving short-term and long-term forecast problems, designing a new enterprise and evaluating the efficiency of new machines, technologies and processes. The need to save material, fuel and energy resources requires a new approach to their accounting, qualitative and quantitative assessment and, in particular, to their use. It affects the correctness of planning and forecasting the output level, production and distribution of resources, and, as a consequence, the strict functioning of industrial and household consumers [5-9].

In this situation, it is important to assess correctly the energy costs for the production of the main industrial products, including the energy costs for the output and processing of raw materials and semi-finished products used in specific products manufacture, since only this index makes it possible to determine the real need for energy resources when planning a certain industrial product. Energy costs assessment will allow using less energy-consuming materials and raw materials in design and creation of new machines and equipment [9-14].
It is known that the main index that allows solving these problems is the energy capacity of products. However, the form in which this index is presented in departmental materials and reference literature is not complete. The fact is that at present the energy capacity of industrial products is estimated by energy consumption of the enterprise at which the final stage of manufacturing is carried out.

2. Methods
The methodological provisions are based on the results of theoretical and practical research in a broad generalization of practical experience in assessing the total energy intensity of products, scientific investigations of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIIAME), and the Scientific and Technical Center of JSC “Uzbekenergo”. Practical research was carried out using standard and special developed techniques, and the reliability of the results was evaluated by verifying the research results.

The calculation of the total energy capacity is based on a block-differentiated method based on a system approach. It allows assessing the total energy costs of a given specific production (for manufacturing an industrial product) and other enterprises (for the production of raw materials used in technology), as well as the costs of manufacturing auxiliary components of technological process (compressed air, oxygen, water, etc.) [5, 15-18].

3. Results and Discussions
It is quite obvious that the results of calculating the total energy capacity in the ginning industry depends on whether raw cotton is processed at an enterprise with a full production cycle (from harvesting and processing of raw materials to final product) or at a partial processing enterprise. Raw materials are transferred to the first production unit and then, as a semi-finished product, sequentially passes from one processing production to another (Fig. 1, a). For the production output $Z$, raw materials and semi-finished products $G$ are processed in $n$ production unit (enterprises).

The specific energy consumption of the $i$-th production per unit of product of a particular processing stage is determined by the formula:

$$L_i = \frac{W_i}{G_i}$$

(1)

where $W_i$ - is the energy consumption of the $i$-th production.

Figure 1. The formation scheme of total energy capacity of industrial products
The specific consumption of products of the $i$-th production (a semi-finished product) per unit of final product $Z$ is calculated by the expression:

$$ q_i = \frac{G_i}{Z} $$

(2)

Present the magnitude of total energy capacity of the final product as a sum (in terms of energy capacity) of the share values $\alpha$ of each enterprise in the production of final product $Z$:

$$ L_z = \alpha_1 + \alpha_2 + \ldots + \alpha_n $$

(3)

where,

$$ \alpha_i = l_i q_i $$

(4)

$$ \alpha_n = l_n $$

(5)

where $q_i$ is the specific consumption of raw materials or semi-finished products for the calculated final product; $l_i$ is the specific energy consumption for the products of each production.

With account for the measures taken in units to save energy and material resources, we obtain:

$$ \alpha_i = (l_i \pm \Delta l_i)(q_i \pm \Delta q_i) $$

(6)

where

$$ \Delta l_i = \frac{W_i}{G_i} = \frac{W_i - \Delta W_i}{G_i - \Delta G_i} \quad \text{and} \quad \Delta q = \frac{\Delta G_i}{Z} $$

are the saved energy and materials.

Thus, the energy capacity of products $Z$ can be determined from the following expression:

$$ L_z = \sum [(l_i \pm \Delta l_i)(q_i \pm q_i)] + (l_n \pm \Delta l_n) $$

(7)

An analysis of formula (7) shows that the value of $l_n$, which, according to existing practice, is the only index of energy capacity of a product, is only a part of it and therefore can be used as a production index of a particular enterprise producing this product.

Raw materials $G$ used in the enterprise that produces the final product are made with certain energy costs at the corresponding specialized enterprises. In this case (Figure 1, b), additional energy costs for the production of these materials, raw materials, semi-finished products, etc. should be added to the energy capacity $Z$ of products. These costs are calculated using the following formulas:

$$ \sigma_n = \beta_1 + \beta_2 + \ldots + \beta_{m-1} + \beta_m $$

(8)

$$ \beta_m = \sigma_m $$

(9)

$$ \sigma_n = \sum_{i=1}^{m-1} (\sigma_i \pm \Delta \sigma_i)(\gamma_i \pm \gamma_i) + (\sigma_m \pm \Delta \sigma_m) $$

(10)

$$ \beta_i = (\sigma_i \pm \Delta \sigma_i)(\gamma_i \pm \Delta \gamma_i) $$

(11)

where $m$ is the number of production units involved in the production of raw materials, materials and semi-finished products;

$\sigma_i, \gamma_i$ are the specific energy consumption per unit of product of the $i$-th enterprise $\Pi_i$ involved in the manufacture of product $\Pi_m$ and the specific consumption of product $\Pi_i$ for the manufacture of product $\Pi_m$, respectively.
In accordance with formulas (7) and (10), the total energy capacity of the product $Z$ is determined by the formula:

$$l'_z = l_z + \frac{\sigma_n \Pi_j}{Z}$$

(12)

If to consider that

$$\delta_n = \frac{\Pi_m}{Z}$$

(13)

we obtain:

$$l'_z = l_z + \delta_n \sigma_n$$

(14)

When using certain types of raw materials, materials and semi-finished products

$$l'_z = l_z + \frac{1}{Z} \sum_{i=1}^{k} \sigma_n \Pi_m$$

(15)

where $k$ is the number of types of materials obtained for the manufacture of product $Z$.

Considering that energy aggregates and plants are the direct energy consumers, the total energy capacity of products should include the corresponding shares of energy losses in the energy supply system, energy consumption for own needs of power plants and for the fuel extraction, processing and transportation at power plants:

$$l'_z = l_z' \frac{1}{\eta_c N} + L$$

(16)

where $\eta_c N$ - are the coefficients that take into account the losses in circuits and electric energy consumption for the auxiliary needs of power plants;

$L$ - is the share of energy consumption for the fuel extraction, processing and transportation at power plants.

One of the largest sectors of national economy of the Republic of Uzbekistan is a cotton growing industry. This industry is a significant consumer of all types of fuel and energy resources (FER); the amount of consumption of each type of these resources and total energy capacity of raw cotton and cotton fiber have not been established.

The development of a method and quantitative assessment of total specific energy consumption of fuel, electric and heat energy for the production of final product - cotton fiber – would allow evaluating the energy capacity of its production [6, 7, 8].

As the first stage of calculation, an analysis of energy consumption was performed for the following groups:

- work in the field;
- production of mineral fertilizers used in cotton growing;
- water supply for cotton fields (pumping stations, vertical drains);
- procurement points and cotton processing enterprises.

The methodological provisions are based on the results of theoretical and practical research, in a broad generalization of practical experience in assessing the total energy intensity of products, scientific works of TIIAME and the Scientific and Technical Center of JSC “Uzbekenergo”. Practical research was carried out using standard and special developed techniques, the reliability of the results was evaluated by verifying the research results.

A calculation of specific consumption of fuel and energy resources for each group is given below in accordance with the formation scheme of total energy capacity of cotton fiber (Figure 2).
Figure 2. Formation scheme of total energy capacity of cotton fiber: a) specific consumption of fuel and energy resources for the production of raw cotton; b) specific consumption of fuel and energy resources for the production of cotton fiber

Calculation is based on regulatory indices adopted in the country.

3.1. FER consumption for the production of raw cotton

The calculation of the share of FER specific consumption for work in the field.

The share of FER specific consumption per ton of raw cotton is determined by the formula:

$$\alpha_1 = \frac{k \sum_i \theta_i q_i}{Z_{x,c}}$$

We obtain the following values from calculation results:

$\Theta = 3.4$ million equivalent fuel tonne - the annual consumption of each type of energy for agricultural needs of the republic;

$n = 6$ is the number of energy resources;

$q_i$ - is the conversion factor of energy resources for fuel equivalent;

$k = 0.6$ - is the share of total energy consumption per cotton gore;

$Z_{x,c} = 4$ million tons - a plan for raw cotton harvesting in the republic.

As a result of calculation, the share of FER specific consumption for raw cotton per work in the cotton field is:

$\alpha_1 = 0.5$ equivalent fuel tonne/t

Calculation of the share of FER specific consumption used for the production of mineral fertilizers applied per hectare

The share of FER specific consumption for the nitrogen fertilizers introduced into soil is determined as:
\[ \alpha_2 = \frac{q_i (R_y \cdot \gamma_a \cdot e_a + \theta_2)}{Z_{x.e}} \]  

(18)

where:

- \( R_y = 880 \) thousand hectare – is the total area of fertilized land;
- \( e_a = 830 \) kVh/t is the total specific energy consumption for the production of nitrogen fertilizers;
- \( \gamma_a = 230 \) kg/ha specific consumption of nitrogen fertilizers;
- \( \theta_2 = 520 \) thousand equivalent fuel tonne is the annual gas consumption for the production of nitrogen fertilizers.

The share of FER specific consumption for nitrogen fertilizers introduced into soil is:

\[ a_2 = 0.14 \text{equivalent fuel tonne/t} \]

The share of FER specific consumption for phosphorus fertilizers introduced into soil is determined similarly to formula (2).

Here: \( e_p = 2480 \) kVh/t, \( \gamma_p = 120 \) kg/ha, \( \theta_2 = 54 \) thousand equivalent fuel tonne

and

\[ a_3 = 0.03 \text{equivalent fuel tonne/t} \]

The calculation of the share of specific consumption of fuel and energy resources per ton of raw cotton for irrigation of cotton fields

This share is determined by the following formula:

\[ \alpha_4 = \frac{W_{op} q_i}{Z_{x.e}} \]  

(19)

where: \( W_{op} = 6.7 \text{- billion kWh} \) is the total annual energy consumption for cotton field irrigation, and

\[ a_4 = 0.54 \text{ equivalent fuel tonne/t} \]

Thus, the energy capacity of one ton of raw cotton is:

\[ \sum_{i=1}^{n} \alpha_i = 0.5 + 0.14 + 0.03 + 0.54 = 1.2 \text{ equivalent fuel tonne/t} \]

Including electric power:

\( j_{e,c} = 2280 \text{ kWh/t} \)

Energy consumption by consumption groups is: work in the field 41%, mineral fertilizers 14% and irrigation 45%.

3.2. Calculation of the share of FER specific consumption for the production of cotton fiber

Consider the given factor for procurement points and ginneries.

The share of FER specific consumption at procurement points.

The share of specific fuel and energy consumption per ton of cotton fiber is determined as:

\[ \beta = \frac{\sum_{i=1}^{n} \theta_i \cdot q_i}{Z_{x.a}} \]  

(20)
where: $\theta_i = 29.3$ thousand equivalent fuel tonne - is the total annual energy consumption at procurement points; $Z_{x,a} = 1200$ -thousand t is the plan for the cotton fiber production in the republic. The share of specific fuel and energy consumption at procurement points is:

$$\beta_i = 0.02 \text{ equivalent fuel tonne/t}$$

**The specific consumption of fuel and energy resources in ginneries.**

The share of specific energy consumption per ton of cotton fiber is determined from the expression:

$$\beta_2 = \frac{\sum_{i=1}^{n} W_i \cdot q_i}{Z_{x,a}}$$

(21)

where: $W_i = 446390$ - equivalent fuel tonne – is the total annual energy consumption for the cotton fiber production.

$$\beta_2 = 0.37 \text{ equivalent fuel tonne/t}$$

The total specific consumption of fuel and energy resources per ton of cotton fiber is:

$$\sum_{i=1}^{n} = 0.02 + 0.37 = 0.39 \text{ equivalent fuel tonne/t}$$

and specific electric power consumption is:

$$j = 650 \text{ kVh/t}$$

Thus, the total energy capacity of raw cotton is:

$$l_{x,c} = 1.3 \text{ equivalent fuel tonne/t}$$

specific power consumption is:

$$l_{x,c} = 2500 \text{ kVh/t}$$

The total energy capacity of cotton fiber is:

$$l_{x,a} = 4.2 \text{ equivalent fuel tonne/t}$$

specific power consumption is:

$$l_{x,a} = 7800 \text{ kVh/t}$$

**4. Conclusions**

From the above considerations for assessing the total energy capacity of cotton ginning production, it is obvious that the calculation results of total energy capacity in the ginning industry depends on the total consideration of energy costs for raw cotton processing at a plant with a full production cycle (from raw material harvesting and processing to final product manufacture) or at a partial processing enterprise.

The calculations were carried out without accounting for the energy consumption during their production (mining, oil and gas production, power plants), as well as the energy loss for the transportation (railway, pipeline, electric supply network), the value of which is in the range of 20-30%.

The analysis of the results obtained shows that the cotton production plays a rather high role in total energy consumption in the republic and its savings at each stage of agricultural work and in industrial processing can give tangible results in increasing the efficiency of saving the country's fuel and energy resources.
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