Method for selecting a source of energy supply in agriculture according to the energy-ecological criterion

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Abstract. The choice of a source of electric heat supply in distributed systems is largely determined by the availability or the possibility of delivery of primary fuel and energy resources and economic calculations. Recently, however, more and more attention is paid to environmental protection issues. The aim of the research is to substantiate the methodology for choosing sources of energy supply to agricultural consumers in distributed energy systems. For a comprehensive assessment of the environmental friendliness of energy production, we have proposed an energy environmental friendliness factor. The coefficient simultaneously characterizes the cost of energy production and the amount of generated environmental pollutants. This value turned out to be convenient for comparing a number of production technologies.

1. Introduction
Distributed energy in agriculture is a decentralized electricity and heat supply to remote consumers of small capacity. The prerequisites for the development of this direction in the energy sector are: the dispersal of agricultural facilities, their remoteness from centralized power supply networks, small capacity of energy consumers; availability of local energy resources potential (firewood, wood chips, peat, organic waste for biogas production, sun, wind, etc.); high losses in networks, reduced reliability of power supply and energy quality; many farms are not connected to the centralized power supply at all.

2. Materials and methods
The initial data were obtained from the results of energy surveys of agricultural enterprises in the Leningrad region of Russia, conducted by the Institute since 2011 until now. The data obtained: the consumption of electric energy is 50%, motor fuel 45% of the total consumption of fuel and energy resources. The consumption of other fuels is insignificant. Thermal energy is obtained from electrical energy. Currently, consumers on farms receive electricity mainly centralized. However, the general trend in the development of rural electrification is the transition to distributed energy [1-3]. This means autonomous power supply for a number of consumers from low-power thermal power plants.

In this case, the fuel can be gas, imported types of solid and liquid fuels (coal, fuel oil, etc.), local alternative fuels (firewood, wood chips, pellets, etc.) and renewable energy sources (solar and wind) [4]. Particular attention is paid to obtaining energy from agricultural waste - biogas plants [5]. The consumption of motor fuel is also associated with a decrease in the volume and quality of transportation and can be estimated by the energy intensity of technological processes [6].
In all cases, emissions of pollutants into the atmosphere are possible to varying degrees, which negatively affects the environment [7]. In this regard, the development of a method for assessing technological processes and equipment in agricultural production simultaneously in terms of energy (economic) and environmental indicators is relevant. It is advisable to develop a single rating factor.

Any value involved in technical calculations (calculated parameter, coefficient) can be obtained by a combination of four mathematical operations: addition, subtraction, division and multiplication. Any numbers can be subjected to these actions, if they have no dimension. For dimensional numbers expressing the properties of physical reality, the range of permissible actions is narrowed. Thus, only quantities of one dimension can be added and subtracted. In this case, the operation of division and multiplication is also permissible for quantities with different dimensions. The physical meaning of the ratio of two dimensions is the most transparent - this is the specific value of the first quantity per unit of the second. In engineering applications, different authors often accept different coefficients that characterize the total value through its components.

So, for a comprehensive assessment of the environmental friendliness of energy production, we have proposed a coefficient [7] calculated by formula 1:

\[ K_{ep} = (C_C + C_G) \cdot \sum (Z_V \cdot K_{VV}) \cdot Q \]  

(1)

Where: \( C_C \) - the specific cost of investments, taking into account the number of hours of equipment operation per year, rubles / kW * hour; \( C_G \) - energy cost, rub / kW * hour; \( Z_V \) - specific emission of pollutants, g / kW * hour; \( K_{VV} \) - coefficient of harmful effects; \( Q \) is the amount of generated energy, kW * hour.

The expression in parentheses represents the reduced (taking into account capital) costs for energy generation (RUB / kW * hour).

The expression in curly brackets multiplied by the amount of energy generated is the amount of pollutants, taking into account their harmful effects (g / kWh).

Total, the dimension of the coefficient we proposed is [ruble] × [g] / [kW * hour]. The coefficient simultaneously characterizes the cost of energy production and the amount of generated environmental pollutants. This value turned out to be convenient for comparing a number of production technologies.

The optimal value of this coefficient when choosing a generating source is the smallest.

When choosing an energy source, the selection criterion is taken into account - economy or environmental friendliness. The economic criterion is the cost of kW * hour of energy (table 1). The environmental criterion is the total emission of pollutants when receiving energy (g / kW * h) at various sources of energy supply (table 1).

| Source of electricity-heat supply | Cost of energy rubles / kW * hour | CO₂ equivalent emissions | Total pollutants |
|----------------------------------|----------------------------------|--------------------------|-----------------|
| Diesel boiler room               | 4.6                              | 6.8                      | 19.1            |
| Coal-fired boiler room           | 5.4                              | 9-10                     | 37.4            |
| Fuel oil boiler room             | 4.3                              | 5.4                      | 20.2            |
| Wood-fired boiler room           | 3-4                              | 2.3                      | 2.9             |
| Pellet boiler room               | 7-10                             | 1.9                      | 3.2             |
| Wood chips boiler room           | 2-3                              | 1.3                      | 3.4             |
| Biogas boiler house              | 4-5                              | 3.2                      | 5.6             |
| Natural gas boiler room          | 3.7                              | 1.29                     | 3.6             |
| Solar power plant                | 9-30                             | -                        | -               |
| Solar thermal station            | 10-12                            | -                        | -               |
| Wind power station               | 2.2                              | -                        | -               |
Similarly, the complex rating factor can be used as a criterion for predicting the negative environmental impact of vehicle operation.

3. Results and Discussion

Table 2 shows an example of calculating a single rating factor for energy and environmental indicators. Calculations are given for 8000 hours of work per year.

Table 2. Estimated indicators of a single rating factor for energy and environmental indicators.

| Power generation source                  | Investments, rub./kW * hour | Energy cost, rub./kW * hour | \((\frac{C_c}{T} + C_{G})\) rub./kW * hour | Specific emissions of pollutants, g/kW * hour | \(K_p\) |
|-----------------------------------------|-----------------------------|----------------------------|---------------------------------------------|-----------------------------------------------|--------|
| Coal-fired boiler room                  | 15                          | 5.4                        | 20.4                                        | 37.4                                          | 763    |
| Biomass boiler house                    | 1.7                         | 4.6                        | 6.3                                         | 5.6                                           | 35.3   |
| Solar Power Plant (Photovoltaic)        | 37.5                        | 9.0                        | 46.5                                        | 1                                             | 46.5   |
| Solar thermal station                   | 11.6                        | 9.8                        | 21.4                                        | 1                                             | 21.4   |
| Wood-fired boiler room                  | 4                           | 3                          | 12                                          | 2.9                                           | 34.8   |
| Wood chips boiler room                  | 2.6                         | 2.5                        | 5.1                                         | 3.4                                           | 17.3   |
| Boiler house on liquid fuel (diesel)    | 3.1                         | 4.5                        | 7.6                                         | 19.1                                          | 145.2  |

An example of using the energy efficiency factor when choosing the type of fuel is presented in table 3.

Table 3. Using the energy efficiency factor when choosing the type of fuel.

| Type of fuel | Energy cost, rub./kW * hour | \((\frac{C_c}{T} + C_{G})\) rub./kW * hour | Specific emissions of pollutants, g/kW * hour | \(K_p\) |
|--------------|-----------------------------|---------------------------------------------|-----------------------------------------------|--------|
| Petrol       | 4.0                         | 4.0                                        | 17.5                                          | 70     |
| Diesel fuel  | 3.9                         | 3.9                                        | 19.1                                          | 74.5   |
| Natural gas  | 0.75                        | 0.75                                       | 3.6                                           | 2.7    |
| Biogas       | 0.25                        | 0.25                                       | 5.6                                           | 1.4    |

For example, a diesel generator plant is relatively inexpensive but emits significant pollutants. A solar power plant, on the contrary, does not pollute the environment (not counting the occupation of the areas on which it is located), has a high cost, and in some cases the payback period of solar photovoltaic plants is commensurate with their service life. From the data given in the table, it can be concluded that the most acceptable from the energy-ecological point of view is the energy source biogas. Since the 1990s, the European Union, the United States and other Western countries have adopted a directive on the introduction of renewable energy sources, one of which is biogas. Since 1995, in the EU countries, the number of biogas plants has increased from several dozen pieces to more than 4000 pieces [8]. Moreover, in Germany alone, the number of biogas plants reaches 2000 pieces. At the same time, the EU plans to increase biogas production by 10% annually. In each of the
EU countries there is a plan for the construction of biogas plants, even northern countries such as Finland are planning to increase from 200 units in 2020 to 5,000 units by 2050, thus ensuring full supply of motor fuel for vehicles, in parallel with this, directives on the introduction of vehicles are adopted with gas engines [9]. In addition, the requirements for emissions from vehicles and industries are increasing every year. All these activities are ultimately aimed at reducing greenhouse gas emissions and obtaining "zero" emissions from the use of fuel.

4. Conclusion
The widespread introduction of distributed energy using local and renewable energy sources will significantly reduce emissions of pollutants due to a decrease in energy intensity, match the required load with the capacity of generation sources, use the most energy efficient sources, and widespread introduction of renewable energy sources. In this regard, it is also advisable to forecast negative impacts using the energy-ecological method of the power supply system.

The research result can be used in various branches of agricultural production. The choice of optimal technological processes and the composition of machines in the agricultural sector will allow obtaining an additional economic effect from reducing the cost of fuel and energy resources and ensuring environmental protection.

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