Providing a microclimate inside the greenhouse through the use of renewable energy sources

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Abstract. The issues of creating and maintaining optimal microclimatic conditions inside the buildings of protected ground due to the energy obtained from renewable energy sources are considered. The analysis of the growing conditions of the most popular crops in the Krasnodar Territory, grown in greenhouses, has been carried out. The graphs of the dependence of the duration of supplementary lighting and heating of the greenhouse depending on the season and type of agricultural crop are shown. Variants of greenhouse energy supply through the use of renewable energy sources are proposed. The calculation of the environmental benefits from the use of renewable energy sources has been carried out.

1. Introduction
The year-round provision of the population with high-quality agricultural products is an important task of the agro-industrial complex of the Krasnodar Territory, which occupies a leading position among the regions of Russia in terms of production per capita, plant products grown in greenhouses, on the solution of which a significant amount of energy is spent, so to ensure the operation of equipment for 1 hectare greenhouses in winter, it is necessary to provide 1 MW of electricity and 2 MW of heat, which for the greenhouse industry of the Krasnodar Territory is more than 160 MW of electricity and 320 MW of heat.

At the same time the technical feature of greenhouses, which complicates the effective use of centralized heat supply and power supply lines. The length of the power lines inside the greenhouse economy can reach several kilometers, not counting the power lines for connecting to a centralized energy source, with such a power lines length, energy losses are high, as well as the cost of connecting new consumers.

To increase the autonomy of greenhouse farms, their energy independence from centralized power lines, increase the economic efficiency of farms, as well as reduce the environmental load, it is possible to use renewable energy sources (RES). The greenhouse energy supply system using RES can significantly reduce the consumption of traditional resources and, thereby, increase the economic efficiency and environmental friendliness of the process of growing crops.

2. Conditions for growing crops in a greenhouse
Vegetable and berry crops optimal for growing in a greenhouse are dynamically changing environmental conditions that simulate the changing seasons of the year. Consider the most common greenhouse vegetables, such as cucumbers and tomatoes, as well as garden strawberries that are gaining popularity in Russia and occupying a leading position among berry crops in the Krasnodar Territory.
For cucumbers and tomatoes, the duration of lighting should vary from 18 hours, during the period from planting seedlings in the greenhouse to the appearance of flowers, up to 20 hours a day, during the period from the beginning of flowering to the end of fruiting, with illumination of 10,000-15,000 Lx, air temperature 23-25 °C [1,2].

Garden strawberries have a more complex regime, so to accelerate the growing season, the duration should vary from 8-10 to 16-18 hours per day (figure 1), with illumination of 6000-10000 Lx, temperature from +15 °C to +25 - +27 °C (figure 2), while the relative air humidity decreases from 85-80% to 70-65% [3].

![Figure 1. Duration of supplementary lighting, in hours per day, for growing garden strawberries.](image)

![Figure 2. Change in air temperature for growing garden strawberries.](image)

In this case, the internal parameter of the heat and humidity regime should not depend on seasonal and short-term changes in climatic conditions outside the greenhouse.
3. Installation for maintaining the microclimate

The creation and maintenance of dynamically changing parameters of temperature, humidity and illumination inside buildings of protected ground is carried out through the use of a system for creating an artificial microclimate, which is a complex of climatic equipment for achieving and maintaining the specified thermal and humidity parameters of air and soil, temperature of feed water, as well as illumination and spectral the composition of light shown in figure 3.

![Figure 3. System for creating an artificial microclimate: 1 - Forced ventilation, 2 - heating installation, 3 - lighting installation, 4 - irrigation installation, 5 - heating pipes.](image)

To control the presented power supply system of the greenhouse, automation means should be used that allow, according to a given program, to change the supply of heat, light and water, as well as to control the supply of feed necessary to accelerate plant growth.

The main functions of the automatic control system are as follows:

- automatic regulation of air temperature;
- automatic heating control;
- automatic control of lighting installations;
- automatic control of air circulation.

4. The use of renewable energy sources for power supply of greenhouses

To create and maintain microclimatic parameters, a large amount of energy is required, therefore, to increase the autonomy of greenhouses, their energy independence from centralized networks, increase the economic efficiency of farms and reduce the cost of finished products, as well as reduce the environmental burden on the environment, it is possible to use renewable energy sources (RES) [4].

The greenhouse energy supply system using renewable energy sources (figure 4) can significantly reduce the consumption of traditional resources and, thereby, increase economic efficiency and environmental friendliness.

To supply power to the greenhouse using renewable energy sources, a hydroponic plant was developed (figure 5) [5].
Figure 4. System for creating an artificial microclimate: 1 - solar collectors, 2 - forced ventilation, 3 - wind generator, 4 - heating installation, 5 - geothermal heat supply pipes, 6 - lighting installation, 7 - irrigation installation, 8 - heating pipes.

Figure 5. Hydroponic plant. 1 - control unit, 2 - cultivation vessel, 3 - water level sensor, 4 - ozonizer, 5 - well, 6 - heat pump, 7 - concentrator of solar radiation, 8 - outlet pipeline, 9 - supply pipeline, 11 - air pipeline.
The work of a hydroponic plant is as follows. Water is taken from the well, which is enriched with ozone in a concentration required for a given plant, ranging from 2-15 mg / m³ through an air duct to which an ozonizer is connected. Further, the enriched water through the supply pipeline enters the solar collector, which heats the water, then the heated water through the heat pump enters the cultivation vessel, in which the water level sensor connected to the control unit regulates the level of the supplied water, the waste water and its surplus by return pipeline through the heat pump 6 back to the well. Also, an installation was developed that combines RES and traditional power plants, which is shown in figure 6 [5].

Figure 6. Power system of a hydroponic greenhouse: 1 - boiler room / thermal power generator, 2 - chimney, 3 - blower fan, 4 - downpipe gas pipe, 5 - airlift, 6 - water-gas mixture outlet, 7 - plants, 8 - hydroponic installation chute, 9 - solar collectors, 10 - ground heat exchanger.

The exhaust gases of the heat-electric generator are filtered from soot and impurities, then the blower is directed into the well, where they are mixed with groundwater and in the form of a water-gas mixture they enter the airlift. The airlift feed pipe delivers the water-gas mixture to the trays of the hydroponic greenhouse. Carbon dioxide from the water-gas mixture nourishes the plants and increases their productivity, and warm water contributes to uniform heating of the greenhouse plant. For additional heating of the feed water, solar collectors are installed on the roof of the greenhouse, which heats the coolant, which flows through pipes to heat exchangers located in the ground, which also allows accumulating thermal energy for seasonal heating of the greenhouse.

5. Conclusion
Thus, the most effective way to create artificial microclimatic conditions for growing garden strawberries in the Krasnodar Territory is a combined system using renewable energy sources, such as solar radiation, wind energy, geothermal energy, as well as low-potential heat of air and soil. In this case, the dependence of changes in microclimatic conditions on the phase of growth and development of the plant should be taken into account.

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