SOLAR PANELS ON THE ROOF OF GREENHOUSES. RESOURCES OF GREEN ENERGY IN ISRAEL.

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Abstract. Despite the large number of deserts suitable for solar panels, Israel prefers land-saving technologies (even if they are more expensive). Therefore, the double use of space and the search for alternative places for solar panels is a priority. This paper considers the unconventional possibility of arranging solar panels on the roofs of greenhouses.

Key words: Translucent organic solar cells, smart greenhouses, photosynthesis.

INTRODUCTION

Israel has undeniable advantages for solar energy development compared to European countries, since it has much more solar days per year and longer solar days. However, these countries are significantly ahead in the solar energy implementation. According to the current government plan, - Israel is speeding up its gas industry development, and by 2030 should have only 17 percent of electricity from all renewable sources combined. Feeling such a lag, the Minister of Energy Yuval Steinitz promised in September 2019 to bring this goal to 25-30% [1].

Traditionally, solar energy has been associated with using large areas for solar panels. The first solar field in Israel and the entire Middle East was launched on World Environment Day on June 5, 2011. In January 2020 The Israeli Ministry of Finance and Energy, together with the Israeli Utilities Electricity Authority, has opened a tender for the construction and maintenance of a 300-megawatt solar power station. It should become the largest solar energy producer in the country. A 3 square kilometers solar field is located near the city of Dimona in the south of the country. Its construction is planned to be completed by 2023 [1]. It is estimated that to meet all Israel's energy needs - 4 km wide strip along Mediterranean cost (180km) filled with solar panels is required or occupy a 27 by 27 km square (some 6 Jerusalem area).

Israel is a small country with limited resources in many areas, such as drinking water, water for agriculture, the ecological crisis on the Dead Sea. Among other limited resources are: limited resources of the fertile land for agriculture, limited land resources to accommodate the country's growing population. These deficits of resources are connected and reinforce each other. Based on that understanding - deserts are very important potential resources and couldn't be looked as an empty waste land. Therefore, any offerings and proposals of using deserts or other lands, including the "obvious ones", require a comprehensive analysis, and far from all of them are acceptable. For this reason, Israel is and will be in a constant search for new approaches and solutions to overcome its multidimensional resources' limitations. On this basis, many experts have a negative attitude to the generation of green electricity using fields with a large areas occupied by solar panels, even in the desert, considering it irrational. So the Ministry of Environmental Protection, stated in the January 2020 report, that the planned generation of electricity from solar radiation should occur exclusively through the use of solar panels installed on buildings, greenhouses and other infrastructures, without using open areas of urban and agricultural land [2].

DESCRIPTION OF THE NOVEL APPROACH

The Heschel team of scientists led by environmentalist Dr. Shahar Dolev has similar views. In their opinion, energy supply goals should be achieved through a more creative implementation of solar energy: over garages, roofs and walls installations, at military bases, overpasses, industrial parks, reservoirs, public buildings, airports and much more. In this case, the use of open fields with solar panels is excluded while dual-purpose agricultural land with massive pergolas over planted fields with panels is preferred and supported.

One of the land-saving ways to install large green energy facilities and to achieve a multi-goals effect is described in [3] and suggesting placing solar panels above and along the roads, as well as over parking lots.

Another approach is described below. The limited land and water resources in Israel led to the development and wide usage of a greenhouse agriculture, which allowed maximizing land usage efficiency, while reducing water consumption. The total area of greenhouses in Israel exceeds 30 square km.

Modern Israeli greenhouses are high-tech automated systems, managed by specialized computer programs, guaranteeing high yields that are not dependent on adverse environmental factors. Particular attention is paid to maintaining the temperature necessary for optimal climate conditions. Most modern greenhouses are equipped with forced ventilation, special sun shades and heat-saving screens that automatically move depending on the intensity of solar radiation and outside temperature and humidity. Water-saving technologies are used (drip irrigation, water flow control systems, computerized minerals supply systems, necessary for plants submerged in irrigation solution). Specialized plastic coated films for greenhouses are used, for the incident light spectrum correction and stimulation of the plants growth. They filter and convert harmful ultraviolet radiation into infrared, enhancing photosynthesis. Recently developed special nets protect greenhouses from insect during ventilating. This reduces the damage caused by insects, and also cut down the need for chemical treatments. Modern smart greenhouse is designed for comprehensive control of the most technological parameters. The result is a significant increase in production [4] and agricultural land usage efficiency. However, they also consume significantly more energy than conventional farms, partly due to the conditioning of the greenhouse space and the use of pumping systems. One way to mitigate the increased energy consumption is the integration of the solar modules in the design of the greenhouse. Translucent organic solar cells (OSC) are particularly attractive, given that their spectral absorption and light attenuation can be minimized exactly in the part of the spectrum which is critical for the plants' photo synthesis. This provides a significant opportunity to promote environmentally sustainable agriculture [5]. Most necessary bands of the solar spectrum for plants are orange (0.63-0.59 μm) and red (0.77-0.63 μm). These rays supply energy for the photosynthesis. Blue and violet rays (0.49-0.38 μm) are also directly involved in photosynthesis. In addition, their functions include stimulating the formation of proteins and regulating plant growth rates. At the same time, yellow and green spectral bands (0.59-0.49 μm) are not vital for plant development. In fig. 1 shows parts of the solar spectrum absorbed by plants [4].

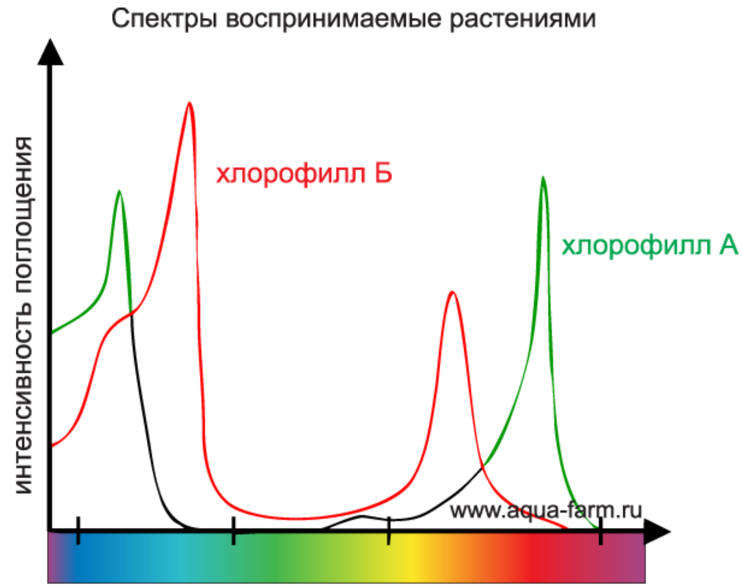

Fig. 1. Bands of the solar spectrum absorbed by plants [4].

Solar radiation transmitted through the Earth's atmosphere has a spectral distribution shown in Fig. 2. [7]. X-ray radiation is absorbed by the ionosphere-nitrogen, oxygen and other atmospheric components. Most ultraviolet radiation is absorbed by ozone. Very small part of the radiation with wavelengths greater than 2.5 microns reaches the earth, due to the low level of extraterrestrial radiation with those wavelengths, as well as the strong CO2 absorption. Thus, for the terrestrial solar energy applications - only 0.29 to 2.5 μm radiation must be taken into account.

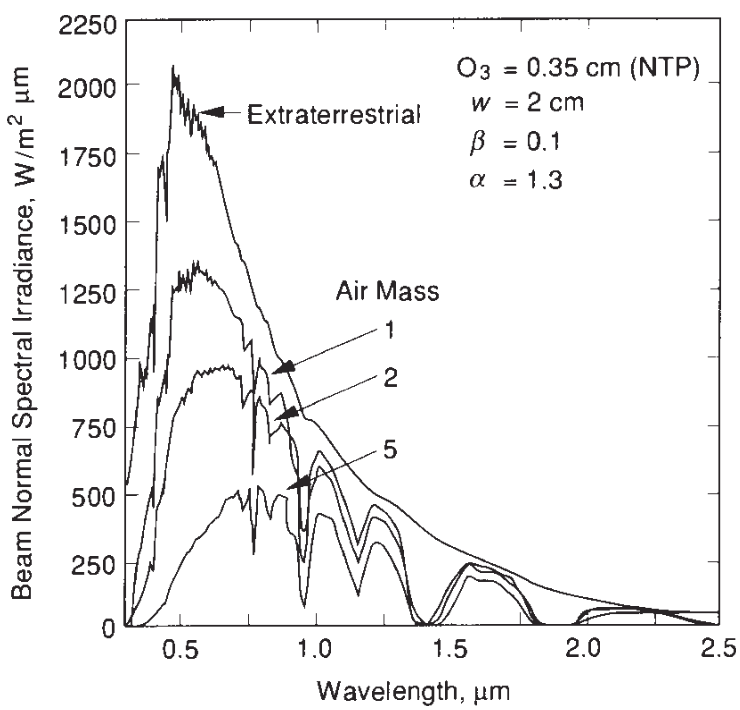

Fig. 2. An example of the spectral distribution of radiation intensity for air masses 0, 1, 2, and 5 [7].

The continuous spectrum has the highest intensity in the wavelength region of 0.43–0.50 microns. About 9% of the solar spectrum energy is in the ultraviolet region with wavelengths from 0.10 to 0.40km. The rest of the energy is divided approximately equally between the visible (0.40–0.76 km) and infrared (0.76–5.00 km) spectral regions.

As we can see, the highest intensity of solar radiation is in the green and yellow areas of the spectrum, which are not vital for the photosynthesis and plants development. The manufacturing technology of translucent organic solar cells (OSC) is capable to adjust the spectral absorption and convert solar energy from these spectral bands into electricity, as well as from the most infrared and ultraviolet radiation. At the same time, region of the spectrum important for the photosynthesis will pass through. Scientists at the University of North Carolina conducted a model study of using transparent solar panels to convert solar energy from an area of the solar spectrum not used for the photosynthesis. This study is reported on the website of the University [8]. Following the thoughts of one of the study co-author - Brendan O'Connor, "Plants use only a few wavelengths of light for photosynthesis, and the idea is to create greenhouses that produce energy from the unused light, while at the same time letting in most of the photosynthetic bands of light. We can do this using organic solar cells because they allow us to adjust the spectrum of light absorbed by the solar cell - so we can focus on using mainly wavelengths of light that are not used by plants. " To evaluate how much energy a greenhouse can generate if translucent organic solar cells are installed on its roof, and whether this energy is sufficient to compensate for the amount of energy the greenhouse needs for efficient operation, the researchers created computational models. Such models were used by them to estimate the energy consumption of the tomatoes growing greenhouses in Arizona, North Carolina and Wisconsin [8]. The modeling process is complicated because there is a complex compromise between the amount of energy that the solar cells generates and the amount of light in the photo-synthetic range that they pass. In fact, the more energy manufacturers are willing to sacrifice for photosynthetic growth, the more electrical energy could be produced. The solar cells used for modeling must also be an effective thermal insulators, because they do not transmit infrared light, converting it into electrical energy. This effect helps to cool the greenhouses in the summer and capture more heat in the winter. According this study - greenhouses in Arizona can become energetically neutral without the need for an external energy source, while blocking only 10% of the photosynthetic band of light. However, if manufacturers agree to block more photosynthetic light, they could generate twice as much energy compare to the greenhouse needs. Most of Israel's territory is located south of Arizona, so the results of a simulation conducted by scientists at the North Carolina University are applicable to Israel and demonstrates that the use of translucent organic solar panels on the roofs of Israeli greenhouses will provide autonomous power supply for greenhouses. In Israel, the annual surface density of the incident flux of solar radiation is about 2000 kW / sq.m [9].

The total fraction of solar radiation in the green, yellow, and infrared regions of the spectrum is 0.546% in the 0.29 to 2.5 μm spectral window [7]. The total area of greenhouses in Israel exceeds 30 square km.

With a 15% efficiency of organic solar panels [10] - the expected average power of an array of solar panels on greenhouses will be up to 563 MW. The energy generated by solar panels can be effectively used in smart greenhouses for control and regulation systems to maintain the temperature, humidity and other necessary and important parameters of the greenhouse environment within a certain homeostasis, which are dynamically adjusted as the plants develop.

For a greenhouse with an area of 10 dunams (1 ha), the average power from solar panels could reach up to 188 kW. The cost of the greenhouse internal energy consumption is combined from the costs for air conditioning and ventilation (up to 50 kW), the costs of drip irrigation (up to 30 kW), the costs of an electric drive, instrumentation and automation (up to 10 kW), the cost of lighting (up to 30 kW). The total energy consumption can be up to about 120 kW. Consequently, about 68 kW of green electricity can be supplied to the Israel electric grid. In the whole country, the production of additional "green" electricity can reach up to 203 MW.

An additional advantage of installing translucent solar panels on the roofs of greenhouses is that they do not interfere with the purpose of the land on which the greenhouses stand. Consequently, with the growth of the greenhouse economy, the production of green electricity will also increase.

The solar panels described in [8] in the future could also be used in pergolas over agricultural fields. The creation of such structures will have triple benefit. In addition to significant electricity production during the daytime, they will create more comfortable working conditions for the farm workers and so increase workers' productivity, at least by reducing the impact of solar radiation and temperature under pergolas.

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