



**ФАН ВА ТЕХНОЛОГИЯЛАР
ТАРАҚҚИЁТИ**
**РАЗВИТИЕ НАУКИ И
ТЕХНОЛОГИЙ**

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**ФАН ВА ТЕХНОЛОГИЯЛАР
ТАРАҚҚИЁТИ**

ИЛМИЙ – ТЕХНИКАВИЙ ЖУРНАЛ

**РАЗВИТИЕ НАУКИ И
ТЕХНОЛОГИЙ**

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Ушбу журналда чоп этилган материаллар таҳририятнинг ёзма рухсатисиз тўлиқ ёки қисман чоп этилиши мумкин эмас. Таҳририятнинг фикри муаллифлар фикри билан ҳар доим ҳам мос тушмаслиги мумкин. Журналда ёритилган материалларнинг ҳаққонийлиги учун мақолаларнинг муаллифлари ва реклама берувчилар масъулдирлар.

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COMPARATIVE ANALYSIS OF SOLAR COLLECTORS FOR DRYING SYSTEMS**Maxmudov B.M., Abdulxayev A.A.*****Namangan state technical university.***

Abstract. This study evaluates the performance of various solar collectors in drying systems under diverse climatic conditions. Comparative results suggest that concentrating collectors achieve higher thermal efficiency, while flat-plate collectors offer cost-effectiveness and simpler integration in milder climates. Based on the comparative analysis, recommendations are made for selecting the most appropriate solar collector type according to specific drying system requirements.

Keywords: solar collector, Drying systems, Flat-plate collector, Evacuated-tube collector, Concentrating solar collector, Energy efficiency, Thermal performance, Economic feasibility, Environmental impact, Renewable energy, Comparative analysis, Climatic conditions.

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Annotatsiya. Ushbu maqolada turli turdagi quyosh kollektorlarining (tekis panelli, vakuumli va konsentratsion) quritish tizimlaridagi ishlash samaradorligi va turli iqlim sharoitlariga mosligi tahlil qilindi. Natijalar shuni ko'rsatdiki, konsentratsion kollektorlar yuqori haroratlarda maksimal issiqlik samaradorligini ta'minlagan. Tekis panelli kollektorlar esa mo'tadil iqlim sharoitlarida kam investitsiya xarajatlari va oson integratsiya tufayli afzalroq bo'lgan. Olingan ma'lumotlar asosida turli sharoitlarda qaysi tur kollektor eng ma'qul ekani bo'yicha tavsiyalar berilgan.

Kalit so'zlar: quyosh kollektor, tekis plastinka kollektor, vakuumli kollektor, konsentratsion kollektor, quritish tizimlari, energiya samaradorligi, iqtisodiy samaradorlik, iqlim sharoitlari, integratsiya, ekologik afzalliklar, qayta tiklanuvchi energiya, solishtirma tahlil.

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Аннотация. В данной работе проведен сравнительный анализ различных типов солнечных коллекторов (плоских, вакуумных и концентрирующих) для систем сушки в различных климатических условиях. Результаты показывают, что концентрирующие коллекторы обеспечивают более высокую тепловую эффективность, тогда как плоские коллекторы выгодны по стоимости и просты в интеграции при умеренном уровне солнечной радиации. На основе сравнительного анализа сформулированы рекомендации по выбору оптимального типа солнечного коллектора в зависимости от условий эксплуатации.

Ключевые слова: солнечный коллектор, плоский коллектор, вакуумный коллектор, концентрирующий коллектор, системы сушки, энергетическая эффективность, экономическая целесообразность, климатические условия, интеграция, экологические преимущества, возобновляемая энергия, сравнительный анализ.

Introduction. Solar energy is the most abundant and inexhaustible source of energy on Earth. As a result of thermonuclear reactions in the Sun, it continuously radiates as a "black body" with a surface temperature of approximately 5800 K (5762 K). The main part of this radiant energy consists of ~99% electromagnetic waves with wavelengths in the range of 0.2–3 μm [1]. Only a small fraction of the enormous power radiated from the Sun into space reaches the Earth: Of the $\sim 3.8 \times 10^{23}$ kW of power emitted by the Sun, only $\sim 1.8 \times 10^{14}$ kW reaches the Earth's surface, and of that, about 60% (1.08×10^{14} kW) reaches the Earth's surface [2]. This amount amounts to $\sim 1.5 \times 10^{18}$ kWh of energy per year, meaning that the solar radiation reaching the Earth's surface in one year represents an energy potential ten times greater than the capacity of all conventional sources currently used in the world's energy system.

Sunlight entering the Earth's atmosphere is partially absorbed, scattered, and attenuated. In particular, infrared (IR) radiation is absorbed by atmospheric moisture (water vapor), a large part of ultraviolet (UV) radiation is absorbed by the ozone layer, and the rest is scattered by gas molecules, dust, and aerosol particles in the air. The spectral composition and intensity of the solar radiation flux reaching the Earth's surface depend on these atmospheric factors (weather clarity, Sun altitude,

etc.). There are two components of solar radiation reaching the Earth's surface: direct radiation (DNI – Direct Normal Irradiance) and diffuse radiation (diffuse component). DNI is high on a clear sunny day, and it is a stream of parallel rays coming straight from the Sun; diffuse radiation is the light falling in all directions as a result of the scattering of Sunlight in the upper layers of the atmosphere. The sum of the two components is called total (sum) radiation:

Direct radiation + Diffuse radiation = Total solar radiation.

The total amount of solar radiation falling on a horizontal surface is called insolation. The amount of insolation varies according to the climatic conditions of the location (latitude, weather, season, etc.).

In solar thermal systems designed to use solar energy as a heat source, sunlight is captured using a special element - a helioreceptor (i.e., a device that captures solar radiation and converts it into heat). With the help of such systems, solar energy is used for low-temperature heating and drying purposes. Solar thermal systems are divided into passive and active types according to their structure. In passive systems, the element that absorbs solar radiation and converts it into heat is performed directly by the building or its part (for example, a transparently coated wall facing the sun, roof, glass structure, etc.) - that is, there is no special external device. Active solar systems have a helioreceptor as a separate device, which collects solar energy independently of the building structure and transfers the heat received from it to consumers using various carriers.

This article examines the use of active solar systems for drying processes. The various types of solar collectors (solar collectors) and solar concentrators used to effectively capture solar radiation, their operating principles, and the reasons for their integration with drying chambers are analyzed in detail. The aim is to compare their efficiency, advantages, and limitations when choosing the optimal solar concentrator and collector system for drying.

Methods. Types of solar collectors and concentrators. A solar collector is a device that absorbs solar radiation energy and converts it into heat. According to their structure, collectors are divided into two main types: flat (flat) collectors and focusing (concentrating) collectors. Vacuum collectors, which are their developed form, are also used.

Flat plate solar collector– this is usually a flat panel device that directly absorbs both direct and diffuse solar radiation. The design of a flat plate collector is usually as follows: one or more layers of glass (or transparent plastic) coating on the top, a metal heat-receiving panel (absorber) with a special black coating on the surface facing the Sun, liquid pipes or air ducts attached to it with thermal adhesive inside the panel, a thermal insulation layer on the bottom, and a housing connecting these. Such collectors can heat the heat transfer medium (liquid or air) inside to temperatures of about 100 °C and below using solar radiation, therefore they are widely used in systems requiring low and medium temperature heat (for example, water heating, partial heating of buildings, drying with dry air, etc.). The advantage of flat plate collectors is that their structure is relatively simple and economical, and in addition to direct sunlight, they can also absorb diffuse (scattered) radiation. Therefore, such collectors continue to produce some heat even when sunlight is blocked for a short time (for example, when a cloud shadow falls). The main disadvantage of flat-plate collectors is that their efficiency begins to decrease at high temperatures due to the lack of optical concentration and heat losses. Due to heat transfer to the environment by convection and radiation, some of the useful heat is lost to the outside as the temperature of the absorber panel increases. In order to reduce these losses, some flat-plate collector designs have been improved by creating a thin vacuum layer between the absorber and the glass coating (i.e., vacuum collectors). Vacuum-sealed collectors can operate with low heat losses even at high temperatures due to increased thermal insulation; each absorber element is usually placed inside a glass tube with a multilayer selective coating (such collectors include tubular vacuum collectors). Vacuum collectors can generally receive diffuse and direct rays, like flat plate collectors, but have the unique feature of operating more efficiently in cold weather and even on cloudy days [3]. This is because the heat transfer medium inside the vacuum tubes absorbs almost no heat from the environment and is well

insulated, so heat is retained inside the collector even on low-temperature days. Vacuum collectors are currently used in solar water heating systems, including in cold winter climates. Their disadvantages are their relatively complex and expensive design (a large number of glass tubes and vacuum layers) and the need for careful installation and maintenance [4].

Focusing solar collectors is a system that contains a special optical device - a solar concentrator. The concentrator is usually a mirror or lens element that focuses the incoming sunlight onto a smaller area. The rays falling through the concentrator are concentrated on a smaller surface called the absorber, as a result of which the light density in this receiver increases several times. The light-collecting ability of the concentrator is measured by the degree of concentration. In focusing collectors, heat carriers (water, oil, solution or air) can heat up to very high temperatures (up to several hundred degrees), since due to the concentration of radiation, the heat flux in the absorber is very dense. Optical systems of various shapes can be used as concentrators: of the concentrators with curved mirrors, parabolic mirrors (paraboloid) and parabolic-cylindrical mirrors are the most common, and Fresnel lenses (large lenses made with cuts in a thin plate based on the principle of refraction of light) are also used. Concentrators with curved mirrors focus light by reflecting it: for example, a parabolic trough concentrator focuses incoming rays onto a single line (linear focus), while a parabolic dish focuses them onto a single point (point focus). Focusing collectors are divided into linear focusers and point focusers. In linear focuser systems (such as parabolic trough collectors), the concentrator tracks the Sun around a single axis throughout the day, and light variations are compensated for accordingly; in point focuser systems (such as paraboloid dish collectors or central multi-mirror systems), a tracking mechanism is required to track the Sun along two axes. Thus, concentrator collectors have a more complex mechanical structure and require constant alignment with the Sun.

In focusing collectors, usually only direct sunlight is effectively focused - diffuse (scattered) rays cannot be concentrated by the optical device to a single point [5]. Therefore, such concentrator systems operate with high efficiency only on sunny clear days; in cloudy weather, the useful output is sharply reduced. Collectors with a concentrator, as mentioned above, can generate a very high-temperature heat source, which is why they are attractive for use in industrial processes (for example, steam generation, large drying ovens, cooking devices, etc.). Another advantage of concentrator systems is that they allow you to get more energy from the same area compared to ordinary flat-plate collectors and provide fuel savings in the long term (since the source of solar energy is free and unlimited). At the same time, their complex design and high capital costs are their main limitations: the concentrator and tracking mechanisms require additional installation and maintenance costs, increasing the overall cost of the system. In addition, concentrators usually take up a large area and there are restrictions on the choice of location, since there should be no shading objects (buildings, trees, etc.) in the vicinity.

Solar drying systems. Solar drying systems are usually differentiated by the method of supplying the drying chamber (or room) with heat from the sun. The simplest solution is a passive solar dryer, in which the product to be dried is placed in a chamber, such as a semi-transparent greenhouse, directly exposed to sunlight and heated by direct sunlight (or by a dark-colored surface), and ventilated by natural convection. However, in passive dryers, the temperature and drying rate are difficult to control, are highly dependent on the weather, and can also affect product quality. For this reason, active solar drying systems are often used - in which heat is transferred via a special solar collector and the drying chamber is operated separately.

Single-circuit solar drying plant. This is the simplest active system, which has one closed circuit. In a single-circuit system, the heated heat carrier coming from the solar collector is directed directly into the drying chamber, where it transfers heat to the product. Liquid or air can be used as a heat carrier in such systems. In practice, single-circuit systems with natural circulation are often found: for example, the air heated in the solar air collector rises up by itself (without a fan) and enters the drying chamber, after which it dries the product and releases the moist air outside. The

advantage of such a system is its very simple structure, no electricity consumption and low cost in operation. Single-circuit natural convection dryers are useful for seasonal drying of small-sized products (fruits, vegetables, herbs). The disadvantage is that the system operation mode is strongly dependent on the external environment: it works effectively only on hot days, and when the air humidity and temperature decrease, the drying quality also decreases. Also, in a single-loop system, process control (e.g., increasing or maintaining a constant temperature) is limited.

Double-circuit solar drying installation. This is a more advanced system, in which there are two separate heat circuits: in the first circuit, the heat carrier (usually a liquid) heated by the solar collector is forced to circulate using a circulation pump; this heated liquid gives off heat to the second circuit in a heat exchanger. In the second circuit, the air entering the drying chamber is heated and is constantly circulated inside the chamber using a fan (fan). In this method, the heat transfer efficiency is significantly increased compared to a single-circuit system - for example, it has been experimentally observed that the heat received by the collectors due to forced circulation can be 20–30% higher. In a double-circuit device, the drying chamber and the solar collector are physically separated from each other, which allows them to be conveniently placed relative to each other (for example, the collectors are installed outside at the most favorable angle to the sun, while the drying chamber can be located inside in a closed building). Another advantage of a two-circuit system is ease of control: by regulating the operation of the pump and fans, it is possible to control the air temperature and humidity in the chamber to a certain extent, thereby improving and optimizing the quality of the drying process. Of course, such a forced circulation system requires additional electricity consumption (for the pump and fan), so this must also be taken into account in autonomous conditions. In a two-circuit system, if a liquid such as water is used in the first circuit, it is necessary to take measures to prevent it from freezing in winter (for example, antifreeze solution or draining the circuit); also, metal pipes and heat exchangers in the system can corrode due to oxygen dissolved in water, to prevent this, it is advisable to use special inhibitors. But in general, liquid two-circuit systems have a higher heat capacity, are more efficient than air systems, and can also have lower metal consumption.

Combined (hybrid) solar drying plant. Since solar energy is inherently variable and weather-dependent, practical drying technology often involves combining solar systems with other energy sources. In combined or hybrid systems, a backup heat source is connected in addition to the solar collectors – this can usually be a conventional fuel stove or an electric heater. For example, in solar-biomass hybrid dryers, the heat from the solar collectors is used during the day, and at night or during hours when there is not enough sunlight, the heat is transferred to the drying chamber by a heat exchanger heated by burning biomass (wood, sawdust, etc.) [6] [7]. Systems are also being used to store solar energy using a heat accumulator and use it at night (for example, heat-storing stone or paraffin accumulators). With the help of hybrid systems, it is even possible to establish a continuous 24-hour drying regime, which is very important when drying agricultural products - fast and high-quality drying of the product is of great importance for its marketability and shelf life. The advantage of combined systems is the ability to operate continuously in any weather conditions, and the disadvantage is the need for more equipment, an increase in the cost of the device and additional operating costs (fuel preparation or electricity consumption). Nevertheless, in many cases (for example, for drying on an industrial scale or for products requiring high quality), it is the hybrid approach that is the optimal solution.

Results. We will compare the efficiency of different types of solar collectors and drying systems, as well as their advantages and limitations.

Efficiency and characteristics of flat plate collectors. The efficiency of flat-plate solar collectors is typically in the range of 30–50% (this value is measured by how much of the solar radiation is converted into heat as useful heat). In well-designed selectively coated and insulated collectors, the initial efficiency reaches 70–80% as soon as sunlight falls, but as the absorber heats up, it is observed that it operates stably at around 40–50% in equilibrium due to heat losses. The

maximum outlet temperature of flat-plate collectors can be limited to about 100–120 °C (at temperatures above this, heat losses increase and efficiency decreases). Since direct and diffuse radiation are absorbed equally in this type of collector, it has a high possibility of stable operation on sunny and semi-sunny days. In other words, even if the weather is slightly cloudy, a flat-plate collector will still produce some heat - in this respect it has an advantage over focusing collectors. One of the serious disadvantages of flat-plate collectors is the risk of freezing of the liquid inside the collector in cold weather in winter (if antifreeze is not used). In addition, factors such as dusting of its glass surface, covering it with snow and rain due to its constant exposure to the open air also affect efficiency. In general, the use of flat-plate collectors is a very practical and economical solution, since heat up to 60–80 °C is sufficient for drying processes. Small and medium-sized dryers are successfully operating using hot air or water extracted from them.

Efficiency of focusing (concentrating) collectors. High-concentration focusing systems can convert solar energy into heat with high useful efficiency. For example, paraboloid (dish-shaped) collectors can operate at temperatures of 250–500 °C and higher due to optical concentration, and the thermodynamic efficiency of such devices reaches 60–70%. In linear focusing collectors (for example, in parabolic-cylindrical systems), the operating temperature is usually around 150–300 °C, and the efficiency can be around 50%. In low-concentration focusing systems (also called flat reflector collectors in some sources), the operating temperature is around 100 °C, and the efficiency is ~30–40%. Thus, focusing collectors allow achieving relatively high efficiency even at high temperatures, which is considered their main advantage. Another important advantage is high thermal capacity: that is, a very large thermal capacity can be concentrated in a small receiver. For example, parabolic troughs concentrate several kilowatts of heat at a single point, generating enough heat to power a steam generator or heat an industrial furnace. Focusing systems are fuel-efficient and, in the long term (10–20 years of operation), can replace traditional energy sources, providing economic benefits. Especially in regions where fuel such as natural gas or coal is expensive, the investment in solar concentrators can be justified. Also, obtaining heat from the sun does not harm the environment, that is, it does not emit any harmful emissions - this environmental friendliness is also noted as their positive aspect.

However, focusing collectors also have significant drawbacks and limitations. First of all, as noted above, they only work effectively under direct sunlight conditions – when sunlight is not evenly scattered (e.g., during thick clouds, fog), the concentrator becomes useless [8]. Therefore, such systems are mainly suitable for regions with a sunny climate and high solar radiation throughout the year (for example, desert and semi-desert zones, equatorial and subtropical dry regions). The complex design is the second serious drawback: the focusing system contains tracking mechanisms, moving optical parts, which require skilled labor to install and adjust, and during operation, constant maintenance is required (for example, lubricating motors, checking sensors and actuators, cleaning optical surfaces, etc.). Constant alignment of the concentrator is also an important issue - the sun moves throughout the day, so an automatic sun tracking system (automated motorized stands) must be installed for the concentrators, which means additional costs and complexity of the system. Focusing systems are also more expensive in terms of construction investment - the cost per square meter of collector surface is higher than that of flat-plate collectors (because they include mirrors or lenses, a relatively large metal structure, electric motors working in the actuator, and a control system). Finally, focusing collectors require more space and open space for their location: they must not be shaded (otherwise the focusing will be disrupted), and they themselves are usually quite large (especially if several concentrators need to be arranged in a row). These aspects limit the practical application of focusing systems everywhere.

Vacuum collector efficiency. Vacuum collectors are essentially an improved version of the flat-plate collectors described above, in which the heat-receiving elements are placed in tubes surrounded by a vacuum. As a result of this design solution, heat losses are significantly reduced, and as a result, tubular vacuum collectors can show a 10–15% higher efficiency compared to

ordinary flat-plate collectors under equal conditions. Experiments show that the stagnation temperature (the maximum that can be reached when sunlight falls on them in a stationary state and the heat carrier does not move) in vacuum collectors can reach 200 °C and more, that is, they are in a sense close to the lower-level focusing collectors. Vacuum collectors are very useful in cold climates - even at an outdoor temperature of -20 °C, the absorber and heat carrier fluid inside the tube retain heat relatively well and do not lose heat due to the vacuum layer around the tubes [9]. Even on a cloudy day, the tubes can absorb diffuse light, so vacuum collectors work better than flat plate collectors even in diffuse radiation conditions [10]. Another constructive advantage of them is their modularity: since a collector is often made by connecting several dozen vacuum tubes in parallel, if one tube is damaged, it can be replaced separately and the rest will continue to work (i.e. the system will not stop). However, vacuum collectors have a higher initial cost (complex technological production is required) and the cost of spare parts (for example, to restore the tube or its vacuum) is expensive [11]. For this reason, in most cases, in conditions of limited budget, a simple flat plate collector is preferred, but if high efficiency and climatic conditions require it, vacuum collectors can be the right choice.

Comparison of combined systems. Combining solar-only dryers with alternative sources expands their scope of use. For example, when collectors do not provide enough heat on sunny days or when continuous drying is required day and night, a hybrid system comes to the rescue. In solar-electric hybrid dryers, an electric heater automatically turns on during cloudy days, ensuring that the temperature in the chamber does not drop. In solar-biomass hybrids, biomass stoves provide heat at night or before sunrise. As a result of these combinations, the overall efficiency of the drying process can be maintained at a high level throughout the year - the amount of dried product per year is several times higher than in traditional dryers operating only during the sunny period. Of course, hybrid systems partially rely on traditional fuel in terms of energy efficiency, but overall fuel consumption is still significantly reduced (during sunny hours, fuel is not used at all). When comparing the efficiency of combined systems, it can be said that if the solar energy supply during the year is 50%, the remaining 50% is provided by the hybrid system at the expense of fuel - as a result, half the fuel is consumed than in a dryer operating on full fuel. If a hybrid system with a battery is used (for example, with a heat accumulator), this efficiency can be further increased, since it is possible to store excess solar heat during the day and use it at night. The simplest solution among combined systems is a combination of solar collector + electric TEN; the most economical solution is a solar + biomass dryer (since biomass is cheap and can also be burned with various waste). In some cases, a solar + heat pump system is also used (during the day, the solar collector heat is used to increase the COP coefficient of the heat pump, at night the heat pump operates at the expense of electricity) - this method is used to achieve high overall efficiency in large-scale industrial dryers.

To summarize the above results: flat plate collectors are cheap and simple, can also absorb diffuse radiation, but the heat output temperature is limited; focusing collectors, although they provide high temperatures and efficiency, work only in strong sunlight and are expensive; vacuum collectors, can work well in diffuse and cold conditions, are more efficient than flat plate collectors, but their cost is also higher; combined systems provide continuity of solar energy and eliminate weather restrictions, but at the same time introduce additional energy source consumption and complexity.

Discussion. When choosing a solar drying system, a number of conditions and criteria must be taken into account. First of all, the climatic conditions of the region where the system is located are a decisive factor. If the region has high solar radiation throughout the year and mostly clear sunny days (for example, regions such as Central Asia, the Middle East, North Africa), solar energy can be used to the maximum. For such areas, the introduction of highly efficient focusing concentrator systems is justified - for example, parabolic trough collectors or solar tower systems can be installed in large drying shops, which can constantly obtain a high-temperature drying agent.

On the contrary, if the area has a large share of diffuse radiation (i.e., often cloudy weather is observed, sunlight is scattered), then focusing systems are not effective. In such cases, dryers based on flat or vacuum collectors are preferable - because they can also absorb scattered rays and convert them into heat. For example, in temperate regions with humid climates, vacuum tube collector dryers can continue to operate even on cloudy days, drying the product, albeit more slowly, thus ensuring process continuity.

The second important factor is the required temperature and the characteristics of the drying process. If the temperature required for drying is relatively low ($<100\text{ }^{\circ}\text{C}$), flat-plate collectors will suffice. For example, a single-circuit natural convection dryer equipped with a flat-plate collector will also give good results for drying fruits and vegetables at around $50\text{--}70\text{ }^{\circ}\text{C}$. However, higher temperatures may be required for some special processes – for example, $100\text{--}150\text{ }^{\circ}\text{C}$ is required for drying ceramics or bricks, and temperatures above $100\text{ }^{\circ}\text{C}$ for rapid drying of wood. In such cases, focusing collectors (or vacuum collectors) provide heat that can be increased to the required level. Also, the moisture resistance of the product being dried, the requirements for drying speed, affect the choice of system: if the product needs to be dried very quickly (without overheating), fine control of the heat flow is required – which is difficult without a dual-circuit or even an automatically controlled hybrid system.

The economic and technical capabilities of the system are also not ignored. For example, if small enterprises want to build a simple solar dryer in their own conditions, the most suitable option for them is a single-circuit device with a flat collector. Because such a device can be easily manufactured from local materials, is inexpensive and does not require complex maintenance. On the contrary, if large-scale production or investment is possible, efficient systems are chosen - dual-circuit, vacuum collector or focused hybrid systems, since their high efficiency and year-round operation justify the investment. The initial investment and operating costs should be balanced in this sense: cheap systems (for example, flat collector natural circulation) do not require fuel at all during operation, but they dry only seasonally and slowly; expensive systems (for example, focused or hybrid), although they dry continuously and quickly, require investment and sometimes fuel/electricity costs during operation. The optimal choice should always be appropriate to the specific task and conditions.

The operating and maintenance conditions also affect the choice. For example, in mountainous or remote areas, it may be difficult to install and regularly service a high-tech focusing device - for such places, flat or vacuum collectors with a simple and robust design are preferable, since they do not have complex moving parts. On the contrary, if an industrial enterprise wants to build a solar drying plant on its own base, then complex systems (for example, a parabolic trough collector with automatic tracking) can be easily installed and operated, since there are qualified engineers there. The area of the site is also taken into account: if it is not possible to allocate a large area for installing the device, a high-concentration system is useful (since it provides more power with a smaller aperture), or, conversely, if it is possible to use the roof of the building, flat collectors can be spread over the entire roof surface.

A combined approach to choosing the optimal system often gives the best results. That is, using the sun as much as possible and making up for the lack of it from another source - thus, it is possible not only to save fuel, but also to ensure the stability of the process. For example, in a small greenhouse dryer in a rural area, solar collector heaters can be used during the hot days, and kerosene or biogas heaters can be added at night - such a system will work almost 24 hours a day, the product will dry faster and its quality will improve. Or another example: if available, it is possible to add thermal energy storage batteries (for example, hot water tanks, molten salts or stone heat storage) and use the excess heat collected on a sunny day for drying at night. All this allows you to make the drying process fast, continuous and energy-efficient.

Conclusion. As such, each of the various solar concentrators and collector drying systems may be optimal under certain conditions. There is no universal approach: if the climate is favorable

and the required temperature is low - a simple flat plate collector is most suitable; for high temperatures and sunny areas - focusing systems are effective; for changeable weather - vacuum collectors and hybrid solutions are preferable. When choosing a system, factors such as solar radiation resource, drying process requirements, economic feasibility and maintenance should be taken into account. A properly selected solar drying system can save a significant amount of fuel energy, improve product quality and ensure environmentally friendly production.

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