



# Meva va sabzavotlarni saqlash omborlari uchun quyosh sovutish tizimlarini tahlil qilish

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**Dolzrabligi:** ushbu tadqiqot quyosh termal sovutish texnologiyalarining potentsialini an'anaviy elektr energiyasi bilan ishlaydigan sovutish tizimlariga barqaror alternativ sifatida o'rganadi, bu sovutish uchun global talabning ortishi bilan 2050 yilga kelib uch baravar ko'payadi. Quyosh issiqlik tizimlari, shu jumladan assimilyatsiya, adsorbtsiya va ejektorli sovutish tizimlari, issiqxona gazlari chiqindilarini va energiya sarfini sezilarli darajada kamaytirish uchun qayta tiklanadigan energiya manbalaridan foydalanadi.

**Maqsad:** miqdoriy jihatdan quyosh issiqlik kollektorlari turiga qarab 50-80% gacha samaradorlikka erishadilar, assimilyatsiya tizimlari ishlash koeffitsientini (COP) 0,6-0,8, ejektor tizimlari esa 0,3-0,5 termal COP va adsorbtsiya tizimlarini namoyish etadi.0,2-0,6 dan farq qiladi. Aksincha, fotovoltaiq tizimlar quyosh energiyasini sovutishga o'tkazishda 16-18% samaradorlik bilan cheklangan. Bundan tashqari, quyosh termal sovutish tizimlari yuqori quyosh nurlanish zonalarida yillik sovutish talablarining 30-50 foizini qoplashi mumkin, bu an'anaviy energiya manbalariga bo'lgan ishonchni sezilarli darajada kamaytiradi.

**Usullari:** sifat jihatidan ushbu tizimlar shovqinni kamaytirish, soddalashtirilgan texnik xizmat ko'rsatish va turli xil issiqlik manbalariga moslashish kabi afzalliklarni taklif etadi, bu ularni turar-joy va sanoat dasturlarida iqtisodiy jihatdan foydali qiladi. Boshlang'ich kapital xarajatlarning yuqori bo'lishiga qaramay, ularning operatsion samaradorligini oshirish uchun materiallar va dizayndagi yutuqlar kutilmoqda.

**Natijalar:** umuman olganda, quyosh termal sovutish texnologiyalari global energiya samaradorligi maqsadlariga mos keladigan va qazilma yoqilg'idan olinadigan elektr energiyasiga bog'liqlikni kamaytiradigan barqaror sovutish uchun o'lchovli echimni anglatadi. Kelajakdagi tadqiqotlar issiqlik ko'rsatkichlari va iqtisodiy samaradorlikni oshirish, an'anaviy sovutish texnologiyalari bilan kengroq qabul qilish va raqobatbardoshlikni ta'minlash uchun juda muhimdir.

**Kalit so'zlar:** energiya samaradorligi, meva-sabzavot saqlash omborlari, quyosh sovutish, qayta tiklanadigan energiya, sorbsion sovutish tizimlari.

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## Анализ солнечных систем охлаждения для складов хранения фруктов и овощей

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**Актуальность:** в этом исследовании рассматривается потенциал технологий солнечного теплового охлаждения в качестве устойчивой альтернативы традиционным системам охлаждения, работающим на электричестве, что обусловлено растущим мировым спросом на охлаждение, который, по прогнозам, утроится к 2050 году. Солнечные тепловые системы, включая абсорбционные, адсорбционно-эжекторные системы охлаждения, используют возобновляемые источники энергии для значительного сокращения выбросов парниковых газов и потребления энергии.

**Цель:** количественно солнечные тепловые коллекторы достигают КПД в диапазоне 50-80%, в зависимости от типа, при этом сорбционные системы демонстрируют коэффициент полезного действия (КПД) 0,6-0,8, в то время как эжекторные системы демонстрируют тепловой КПД 0,3-0,5, а адсорбционные системы - в диапазоне 0,2-0,6. Напротив, эффективность фотоэлектрических систем при преобразовании солнечной энергии в охлаждение ограничена 16-18%. Кроме того, солнечные тепловые системы охлаждения могут удовлетворить 30-50% годовых потребностей в охлаждении в зонах с высокой солнечной облученностью, существенно снижая зависимость от традиционных источников энергии.

**Методы:** в качественном отношении эти системы обладают такими преимуществами, как снижение уровня шума, упрощение технического обслуживания и адаптируемость к различным источникам тепла, что делает их экономически выгодными как для жилых помещений, так и для промышленных применений. Несмотря на более высокие первоначальные капитальные затраты, ожидается, что усовершенствования в материалах и дизайне повысят эффективность их эксплуатации.



**Результаты:** в целом, технологии солнечного теплового охлаждения представляют собой масштабируемое решение для устойчивого охлаждения, соответствующее глобальным целям в области энергоэффективности и снижающее зависимость от электроэнергии, получаемой из ископаемого топлива. Будущие исследования имеют решающее значение для улучшения тепловых характеристик и экономической эффективности, способствуя более широкому внедрению и конкурентоспособности традиционных технологий охлаждения.

**Ключевые слова:** энергоэффективность, овощехранилища, солнечное охлаждение, возобновляемые источники энергии, системы сорбционного охлаждения.

## Analysis of solar cooling systems for fruit and vegetable storage warehouses

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**Relevance:** this study investigates the potential of solar thermal cooling technologies as sustainable alternatives to traditional electricity-driven cooling systems, driven by the increasing global demand for cooling, projected to triple by 2050. Solar thermal systems, including absorption, adsorption, and ejector cooling systems, leverage renewable energy sources to reduce greenhouse gas emissions and energy consumption significantly.

**Aim:** quantitatively, solar thermal collectors achieve efficiencies ranging from 50-80%, depending on the type, with absorption systems demonstrating a coefficient of performance (COP) of 0.6-0.8, while ejector systems exhibit a thermal COP of 0.3-0.5 and adsorption systems range from 0.2-0.6. In contrast, photovoltaic systems are limited to an efficiency of 16-18% when converting solar energy to cooling. Furthermore, solar thermal cooling systems can cover 30-50% of annual cooling demands in high solar irradiance zones, substantially decreasing reliance on conventional energy sources.

**Methods:** qualitatively, these systems offer benefits such as reduced noise, simplified maintenance, and adaptability to various thermal sources, making them economically viable in both residential and industrial applications. Despite the higher initial capital costs, advancements in materials and design are anticipated to enhance their operational efficiency.

**Results:** overall, solar thermal cooling technologies represent a scalable solution for sustainable cooling, aligning with global energy efficiency goals and mitigating dependency on fossil fuel-derived electricity. Future research is crucial for improving thermal performance and cost-effectiveness, facilitating broader adoption and competitiveness with conventional cooling technologies.

**Key words:** energy efficiency, vegetable storage, solar cooling, renewable energy sources, sorption cooling systems.

### 1. Introduction

The global demand for cooling is rapidly increasing, driven by rising temperatures and urbanization (figure 1). According to the International Energy Agency (IEA), the energy consumed by air conditioners and electric fans accounts for nearly 20% of total electricity use in buildings worldwide, which is expected to triple by 2050 [1]. Solar thermal energy presents a promising alternative, as it provides a renewable source of energy for cooling, particularly in sunny regions where cooling demands are highest [2]. Solar thermal cooling systems, based on technologies like absorption and adsorption chillers, can achieve significant reductions in greenhouse gas emissions and energy consumption by converting solar heat directly into cooling capacity with minimal reliance on electricity[3].

In technical terms [table 1], solar thermal cooling systems typically use collectors such as flat plate, evacuated tube, or parabolic trough collectors to harvest solar energy. These systems operate with efficiencies between 50-70% for flat plate collectors and up to 75-80% for evacuated tube and parabolic trough collectors [4], achieving collector temperatures ranging from 60°C to over 200°C. These temperature ranges are particularly suited to drive absorption chillers, which can deliver cooling with coefficients of performance (COP) between 0.6-0.8 [5], depending on the collector efficiency and solar irradiance levels. In high solar irradiance zones, solar thermal cooling systems can cover 30-50% of annual cooling demands [6], providing a substantial reduction in conventional energy requirements.

By integrating solar thermal collectors in cooling applications, buildings and industrial facilities can significantly reduce their cooling-related energy consumption and carbon footprint [7]. This study aims to examine the application of solar thermal collectors in cooling systems, focusing on technical indicators like system efficiency, COP, solar fraction, and collector performance, providing a



quantitative assessment of these systems' potential for sustainable cooling solutions worldwide.

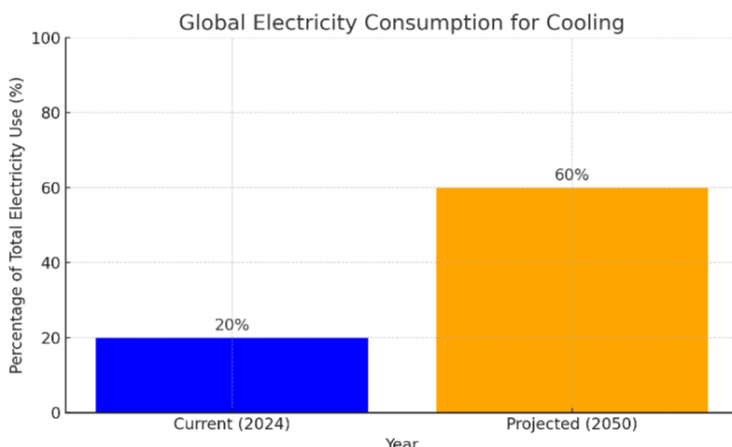


Fig. 1. Global Electricity Consumption for Cooling

Table 1. Comparison of Collector Types and Performance Indicators

№	Collector Type	Efficiency Range	Operating Temperature Range	Suitable for Absorption Chillers
1	Flat Plate Collectors	50-70%	60°C - 90°C	Yes
2	Evacuated Tube Collectors	75-80%	60°C - 200°C	Yes
3	Parabolic Trough Collectors	75-80%	60°C - 200°C	Yes

In the hot, summer season, when insolation is highest, more energy is required for refrigerators. Thus, the highest consumption of frost corresponds to the performance peaks of solar photovoltaic and photothermal modules. By combining solar thermal energy, modern suction and adsorption technologies or heat pumps, heat can be used for cooling in the storage of buildings, products. However, the efficiency of modern commercial photovoltaic panels does not exceed 25%, i.e. the total efficiency of converting solar energy first into electricity and then into heat does not exceed 16-18% [8, 9]. In general, this is not effective enough and requires significant maintenance costs. Photovoltaic refrigerators are therefore considered to be inferior in efficiency to refrigerants that use thermal energy directly.

The generation of cold energy from solar thermal energy is achieved by first making solar energy look like heat or electricity. While solar thermal energy is generated by the use of cooling energy in sorbic and thermomechanical processes, electricity is used in Steam-compressor and thermoelectric cold production processes figure 2 [10].

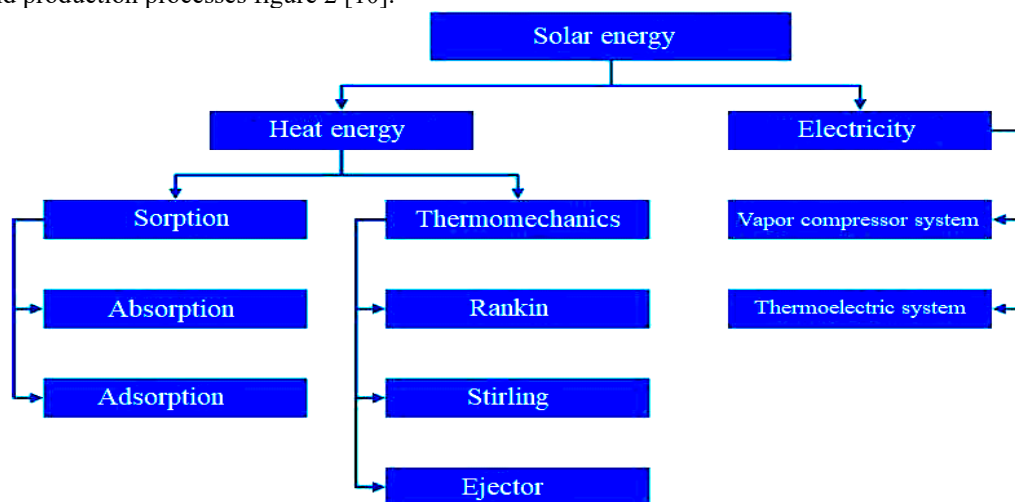


Fig. 2. The production of cold energy from solar thermal energy

## 2. (Methods and materials

Absorbent refrigerant refers to a design in which a heat source is used to provide the energy need-

ed to activate the cooling system. Absorbent refrigerators are a real alternative to compressor refrigerators when they come first:

- power shortage,
- high cost of the system,
- compressor noise,
- excessive heat production.

Open cycle sorption systems.

The open cycle sorption system is basically cooling systems drying. With liquid and solid drying, such cooling periods are known. In an open cycle system, water comes into contact with the coolant and direct air. In a heat-operated cooling cycle, evaporation interacts with the drain in the cooling dryer. Because the refrigerant is removed from the system cycle is called "Open". Common technology, today, uses silica gel or lithium chloride Rotary rotors equipped with sorbent materials [11, 12]. The system is shown in Figure 3.

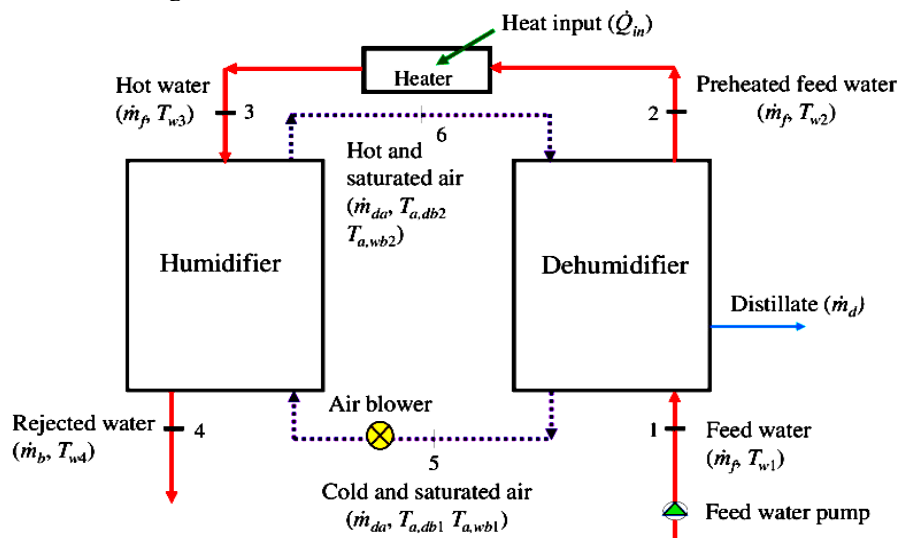


Fig. 3. Open system: cooling system with humidifier through liquid [24]

The drainage cooling system is the most expensive system due to the need for large amounts of processing compared to other sorption air and water systems. Closed-cycle sorption cooling system technologies are the second group of systems. These are in the general case suction, adsorption and cooling systems ejector cooling.

Closed cycle sorption systems. Absorption cooling systems.

The principle of operation of the absorption cycle is similar to the vapor compression cycle, the main differences with the two. The first difference is that unlike electrically powered mechanical compressor refrigerators, cycle absorption is a heat-powered thermal system with little mechanical energy for liquid pumps. The second difference is that the presence of a secondary liquid is known as an absorbent to a working refrigerator. The absorbent solution is used to extract steam from the refrigerator, which makes it cost-effective to increase its pressure using a liquid pump, not a steam pump compressor, which requires more mechanical work. Figure 4 shows the basic cycle of absorption cooling. The components of the main cycle are evaporator, absorber, solution pump, generator, condenser and expansion valves. Similar to the Steam compression cycle, the absorption cycle operates at two pressure levels. The low-level pressure corresponds to the evaporator and absorber, while the capacitor operates at the high-pressure level of the generator. The high pressure level is about ten times higher than the low pressure level, which allows the separation of heat from the refrigerant at the commonly used temperature [13]. These systems are well designed and available on the market. They are more economical than other thermal cooling systems. In addition, absorbent refrigerators are available for a wide range of applications, and they cost lower than other thermally activated cooling systems for such purposes [13, 14].

Thus, the suction cooler technology is the most promising method for solar thermal cooling and, as expected, will compete with traditional systems in the near future in air conditioners. At the same time, the capital costs for such systems are very large [16, 19]. Therefore, it is necessary to carry out additional studies to assess the energy efficiency, reliability and economic efficiency of this technology in relation to traditional systems such as air conditioning, ventilation and air conditioning.

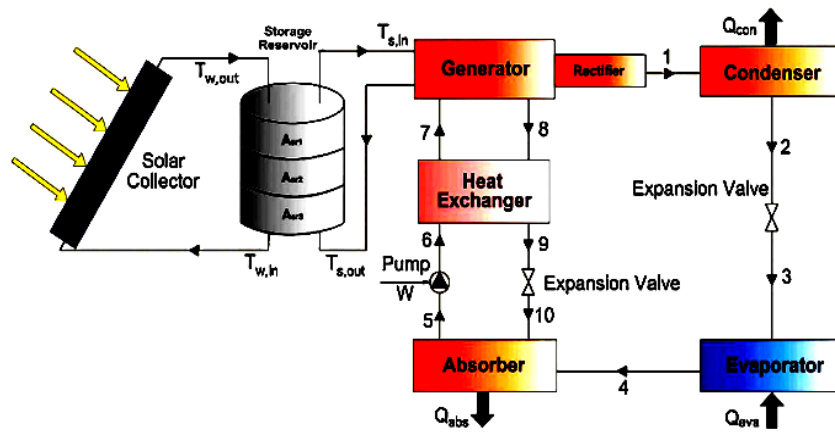


Fig. 4. Basic scheme of the absorption refrigeration cycle [15, 20]

#### Adsorption cooling systems.

The effect of the adsorption cooling cycle between the refrigerant vapors and the solid adsorbent to achieve a refrigerant based on the phenomenon of physical adsorption. When heated, the solid adsorbent disrupts the direction of steam and increases the pressure in the container with steam. It mainly generates heat from a compressor that replaces a simple mechanical compressor. This device is shown in Figure 5 [17, 18].

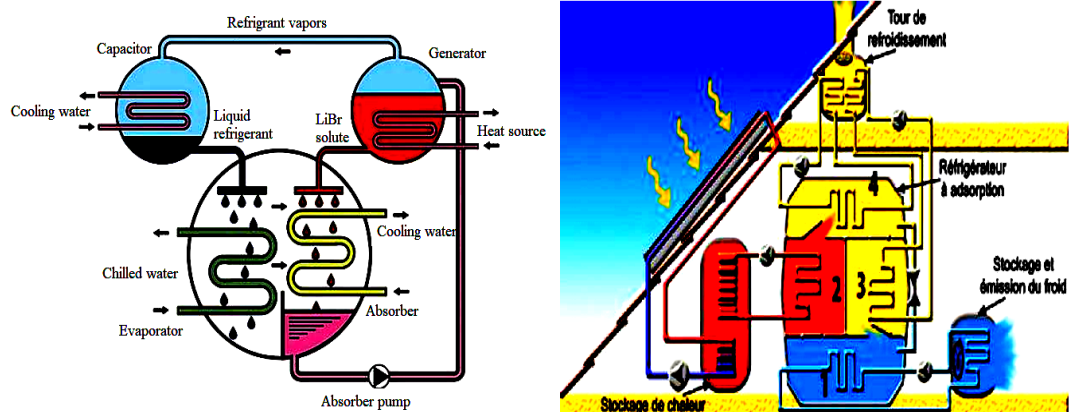


Fig. 5. Schematic diagram of the adsorption cooling system [17, 18]

Although only a limited number of manufacturers have adsorption refrigerators, this technology is capable of working well with dry low-temperature heat source, which is more suitable for working with the cooling tower. However, they are usually heavy, bulky and relatively expensive, especially with high-performance parametric.

#### Ejector cooling systems.

Consider Figure 6 to describe the principle of operation of the ejector cooling system. The system consists of a solar collector, generator, ejector, capacitor and evaporator. The solar collector is connected to the tank storage, circulating pump and regulator. The ejector replaces the compressor in a conventional cooling system and is powered by a low-power energy source supplied by the solar collector subsystem via a generator. Heated water is collected in a storage tank and hot water is circulated between the pump tank and generator. Water enters the generator and exchanges heat with liquid refrigerant pumped from the condenser. The refrigerator evaporates, it overheats and is sent to the ejector as a primary stream. Others the main component is for the manufactured cold consumer who supplies the manufactured product. The produced refrigerant vapor is controlled by a low pressure current in the ejector [22]. This is the secondary flow in the ejector system. Primary and secondary currents are mixed in the mixing zone in the ejector under constant pressure and the mixed current is directed to the diffuser at the exit ejector. Here an increase in pressure is achieved and the total current is directed to the capacitor. After condensation, the liquid coolant is divided into two currents: one of them is pumped through the expansion valve to heat up, and the other to the generator. The solar collector is the main source of energy that provides heat for the generator.





summer, which matches the peak demand for cooling. Solar thermal systems, including those based on absorption and adsorption technologies, are ideal for regions with abundant sunlight. During the hottest months, the solar collectors can generate sufficient thermal energy to drive the cooling system, reducing reliance on conventional electricity sources.

**Compatibility with existing infrastructure:** cooling systems based on solar thermal energy can be combined with existing cooling systems in fruit and vegetable storage warehouses and industries. For example, the suction and adsorption coolers discussed above can be installed alongside traditional HVAC systems, providing a hybrid approach that maximizes energy efficiency while maintaining cooling comfort.

**Storage of Perishable Goods:** Solar thermal cooling is particularly effective in industries related to agriculture, which is a cornerstone of Uzbekistan's economy. By utilizing solar thermal systems for cooling warehouses and storage facilities for fruits and vegetables, significant reductions in energy consumption can be achieved. This would be especially beneficial in hot climates, where conventional cooling methods are less efficient and more costly.

**Technological Advancement:** While solar thermal cooling technology, such as absorption and adsorption chillers, is relatively advanced, it is still emerging in the global market. In Uzbekistan, the adoption of this technology could be seen as an opportunity for technological leapfrogging, allowing businesses to adopt more energy-efficient systems without going through earlier, less efficient stages of cooling technology development.

## 5. Conclusion

This study demonstrates that solar thermal energy-driven cooling technologies—specifically absorption, adsorption, and ejector cooling systems—offer promising alternatives to traditional, electricity-driven cooling systems by leveraging sustainable energy sources and enhancing cooling efficiency in high insolation regions.

Quantitatively, the efficiency of photovoltaic-based cooling systems remains capped around 16-18% after converting solar energy to electricity and subsequently to cooling, whereas thermally driven systems can achieve comparable or higher efficiencies using direct thermal energy. For example, absorption cooling systems operate effectively with low-grade heat sources and achieve efficiencies between 50-70% of comparable vapor-compression systems. Meanwhile, ejector systems, although less efficient overall (around 0.3-0.5 for thermal COP), excel in simplicity and maintenance due to fewer moving parts, making them suitable for regions with high ambient temperatures where waste heat recovery is feasible. Adsorption systems have lower thermal COP (0.2-0.6), but their reliance on solid desiccants like silica gel or zeolite enables operation with lower temperature sources, thus broadening their application range.

Qualitatively, solar thermal cooling systems stand out for their environmental benefits, especially in scenarios with limited electricity access or high costs. They also provide noise reduction, simpler maintenance, and adaptability to a variety of thermal sources, which makes them economically viable alternatives to compressor-based systems in both residential and industrial applications. Despite higher initial capital costs, particularly for absorption and adsorption systems, ongoing improvements in sorption materials and system design are expected to further enhance their economic and operational viability.

Thus, solar thermal cooling technologies represent a scalable solution for sustainable cooling, aligning with global energy efficiency goals and reducing dependency on fossil fuel-derived electricity. Further research is essential to improve the thermal performance and reduce costs, facilitating broader adoption and competitiveness with conventional cooling technologies.

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