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SOLAR DRYING OF WOOD

Ana Marija Stamenkoska[1], Goran Zlateski[1], Branko Rabadjiski[1]

[1]Ss. Cyril and Methodius University in Skopje, Republic of North Macedonia,
Faculty of Design and Technologies of Furniture and Interior - Skopje
e-mail: stamenkoska@gmail.com, zlateski@fdtme.ukim.edu.mk,
rabadziski@fdtme.ukim.edu.mk

ABSTRACT

Solar energy represents an alternative source of energy supply, which has also found its application in wood processing technology. In particular, solar energy finds great application in the field of wood drying. Solar energy is defined as the emitted light and heat produced by the sun, which is harnessed with the help of developing technologies such as solar collectors, photovoltaic cells, solar and thermal collectors, various types of solar architecture, plantations and reactors that use molten salts, and technologies of artificial photosynthesis.
The purpose of this paper is to give a brief overview of solar drying technology. A special review is given to solar drying methods. The method of work does not cause experimental research in practice but represents a collection of used literature and individual research.

Key words: solar energy, collector, wood, relative air humidity, wood humidity, heat

1. INTRODUCTION

Solar energy is considered the fuel of the future because the other resources used today and in the past cause more and more damage to the environment. Solar energy is a renewable and sustainable source of energy. This means that endangered natural resources and technologies that are harmful to the environment are not wasted. Solar energy technologies are divided into passive and active, depending on the way the energy is stored and distributed. Active technologies include the use of photovoltaic systems that collect solar energy for use, mostly for the purpose of heating water through solar collectors. Passive technologies are characterized by buildings and objects oriented to the sun, constructed with selected materials with a certain thermal mass or materials with light-dispersing properties. Passive construction solutions also include space for natural air circulation.

Active solar technologies are based on photovoltaic panels or solar and thermal collectors, which use mechanical or electrically powered equipment to convert sunlight into energy that can be further used alternatively. These solar technologies have increased energy production and are considered alternative backup energy sources. Passive solar technologies are based on pointing the panels towards the sun. Materials should have a certain thermal mass or disperse light over their surface. These solar technologies reduce the need for electricity and fossil fuels. Methods that generate electricity through the use of photovoltaic systems are defined as solar energy technology.

Solar collectors store heat by absorbing sunlight. The term "solar collectors" refers to heating hot water with solar heat, but it can also refer to large power generation installations such as solar farms and solar towers or waterless heating devices such as solar air heaters. Solar thermal collectors can be concentrated or non-concentrated.

In non-concentrating collectors, the useful surface (the surface that receives sunlight) is the same as the total surface of the collector. An example of such a surface is metal tiles painted in a dark color in order to maximize the effect of absorbing sunlight. The energy generated by such tiles is further collected by cooling the tile with liquid, water, or glycol, which circulates through pipes attached to the tile. These collectors are mostly used in residential and industrial conditions for space heating.

Concentrated collectors have a much larger, more useful surface than the absorbing surface. The useful surface is usually mirrored. The mirror is aimed at the absorber, the absorbing surface, to which the pipes through which the coolant circulates are attached.

The energy needs of the world have increased interest in using solar energy in various domains of practical application, including in the field of drying solid wood. Ultraviolet (UV) and infrared (IR) rays of solar radiation are converted into thermal, mechanical, electrical, and chemical energy.

These and similar physical properties of solar energy were the inspiration to begin the first experimental tests dating back to 1955 (M.L.Ghal). Three years later, research on the same problem began at the American Forest Products Laboratory (FPRL). The first results were published in mid-1961. The initial tests relate to the drying of 25.0 mm thick oak lumber. At a temperature of 50 °C, the boards are dried to 15.0% humidity, which is 3–4 times faster than natural drying. Drying costs, on average, were the same as the costs of standard drying in blow dryers.

Recent research indicates that using solar energy increases energy efficiency, reduces drying time, and reduces drying errors. European indicators say that by natural means, the lumber is dried from 16.0 to 18.0%, and when using solar energy, from 8.5 to 9.5%.

2. THE USE OF SOLAR ENERGY IN LUMBER DRYING

Solar drying is particularly suitable for sawn lumber, which is used in construction, furniture production, and construction carpentry.

The main equipment of the kiln consists of:

1) heat accumulators,
2) fans for air movement in the chamber with sawn lumber,
3) fans for directing the air in the collectors,
4) solar energy absorption collectors, and
5) pumps for water circulation in the collectors.

The auxiliary equipment of the kiln includes instruments and automatic devices for controlling parameters (temperature, relative air humidity, air circulation speed) and managing the drying process.

According to the method of heating and using the medium for drying the wood, solar energy kilns can be classified as:

1) non-combined kilns, and
2) combined kilns.

Non-combined solar energy kilns are those in which the heating of the moist air in the collectors is solely by the energy radiated by the sun's rays.

Combined solar energy kilns are those solar energy kilns that, in addition to solar energy, use additional systems (heating elements) to heat the air in the chamber.

A solar kiln with periodic operation and multiple reversible air circulations for sawn lumber is shown in Figure 1.

The construction part of the walls is made of aluminum sheet, filled with mineral wool for thermal insulation. They are structurally placed on a reinforced concrete base. The collector field is formed by five parallel connected collectors placed at a mutual angle of 30° relative to the horizontal plane. The kiln covers an area of about 5.0 m2. The process of guiding and controlling the drying is automated. In a solar kiln, drying is performed using only solar energy through a collector system. This means that energy absorption is done by solar collectors (1), whose surface area is about 20.0 m2. The centrifugal fan (3) enables air circulation in the collector system. Axial fans (4) achieve the necessary speed of air circulation in the chamber with sawn lumber.

Figure 2 shows a solar kiln for drying lumber with a combined air heating method (solar energy - conventional).

The heating is conducted by the use of solar energy, which is absorbed by the collectors placed on the roof of the kiln, and with classic heating elements, which are heated with water vapor or hot water. The air heating system is equipped with a pump and a condensing unit for drying the air. The unit turns on when the relative air humidity rises above 80.0%. The exchange of the saturated air with the atmospheric air is done through the ventilation openings.

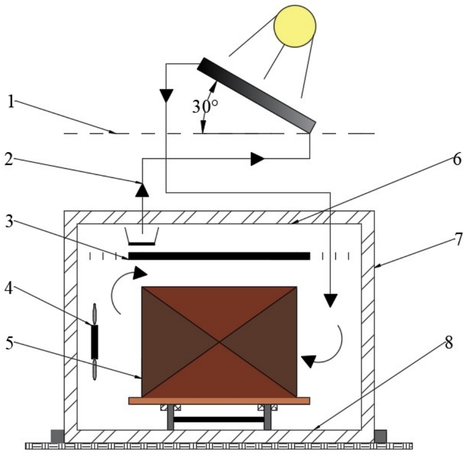

Figure 1: *Uncombined solar kiln*
1) air collector; 2) piping; 3) centrifugal fan;
4) axial fan; 5) lumber chamber; 6) ceiling; 7) wall; 8) floor

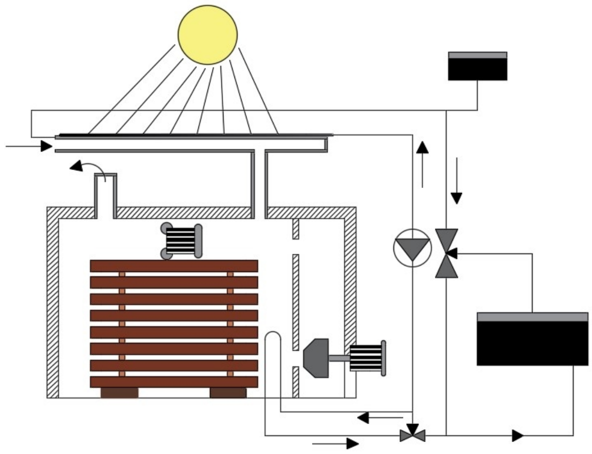

Figure 2:. *Solar energy kiln (solar energy – conventional)*

A solar energy kiln with a combined heating method, that is, solar energy with condensation of moist air, for drying lumber is shown in Figure 3.

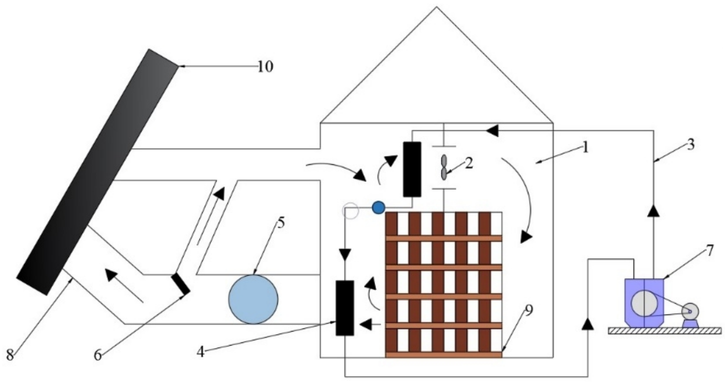

Figure 3: *Solar energy kiln (solar energy – condensation)*
1) chamber; 2) axial fans; 3) condenser (hot air exchanger); 4) centrifugal fan; 5) valve; 6) air cooling and drying system; 7) compressor; 8) cover; 9) whip chamber lumber; 10) collector

According to the applied heating system of the kiln, the drying of the assortments with very little effect is related to the external weather conditions, that is, it depends a little on them. It is significant that the degree of utilization of the solar collector increases.

Air circulation in the chamber (1) is made possible by the axial fans (2), which direct the air through the chamber with sawn lumber (9), and from there it passes to the cooling and drying system (6), where the parameters change (low temperature and lower relative humidity). With the help of the centrifugal fan (4), the air is fed into the collector (10) for heating. In the event that the solar radiation is prevented and the relative humidity in the air is elevated, the treated and dried air, with the help of the centrifugal fan, is returned to the chamber. The cover (8) is used to direct the air. As the air passes through the chamber with whipped lumber, it transfers heat and absorbs moisture from the wood. Moisture from the air is removed by condensation in the cooling system using the cold air exchanger (6). Air is heated when passing through the collector (1) or through the condenser with the help of the hot air exchanger (3).

Figure 4 also shows a solar combined kiln for convective drying of solar and electrical energy bundles. In chamber (1) are located: the chamber with whipped lumber (11), the axial fans (2), the humidification system (3), and the ventilation openings (4). Moist air, under the action of axial fans, circulates in a circle. Solar air collectors (5) are placed on the roof of the kiln. The movement of air in them is carried out with the help of a centrifugal fan (6). The heat accumulation system (7) houses the heating elements (6), connected to alternating current, which are additionally connected in order to additionally heat the drying medium. The air in the heat accumulator is supplied by the centrifugal fan (9). The system (10) is used to distribute and direct the moist air to the air collectors or to the heat accumulator.

The solar kiln uses the collector system for heating the air during the daytime solar intervals and the electricity during the night periods of the day and night.

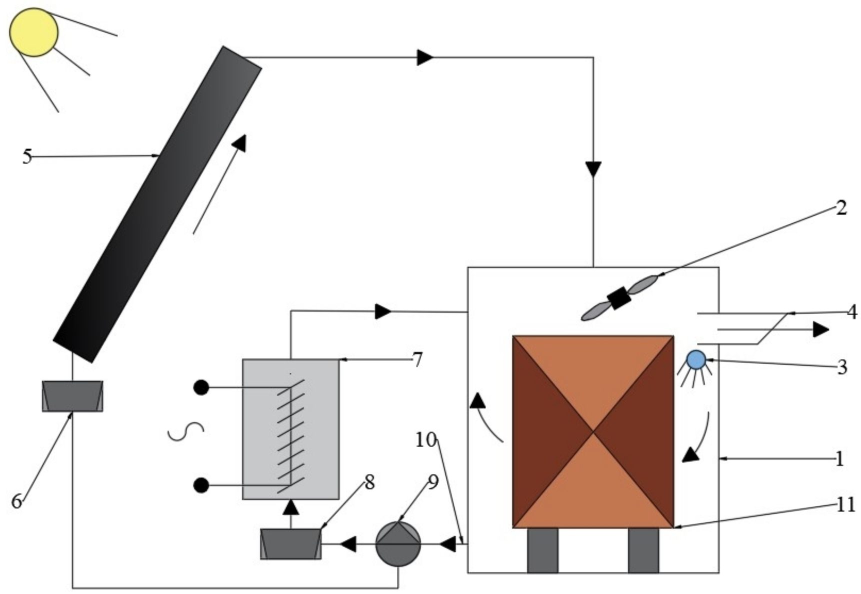

Figure 4: *Combined solar energy kiln with electricity*
1) chamber; 2) axial fans; 3) air humidification; 4) ventilation openings; 5) air collectors; 6) centrifugal fan; 7) heat accumulators; 8) heating elements; 9) centrifugal fan; 10) system for guidance; 11) chamber with whipped timber

3. CONSTRUCTIONAL PARAMETERS OF A SOLAR DRYING KILN

1) The intensity of solar energy

A flat, horizontal surface, on average, can receive from 0.3 to 0.6 kW of solar energy in one day at a latitude of 45° on either side of the equator. This is possible on most of the Earth. In sunny days, the generated solar energy will be higher than average, and in rainy conditions, that energy will be lower than average. Some locations, due to their geographical position, have more rainy and cloudy days during the year and thus generate less sunlight.

2) Orientation of the collectors

A flat surface will generate the most energy if it is directly turned in the direction of the falling rays, directly towards the sun. The surface that generates energy needs to rotate during the day according to the movement of the sun, that is, to be positioned according to the orientation of the sun. The equipment for tracking the movement of the sun is very expensive and is not justified for the construction of kilns with smaller capacities. Such equipment has a precision of 5°.

Collectors that are fixed and do not have the ability to rotate are best adjusted according to the geographical latitude of the site to get the best performance throughout the year. Smaller angles are recommended during the winter and larger during the summer, with a difference of ±10° from the latitude.

The critical point of each solar collector represents the surface that is perpendicular to the sun, that is, the surface that falls in the shadow. This critical point is located at the top of the manifold. This surface generates the least energy, so it is necessary to constantly pay attention to its position, that is, its position should not correspond to the highest point of the sun during the day.

3) Construction of the collectors

The top surface of the collector is covered with one or more layers of transparent or relatively transparent material. This coating is called a glaze. A single layer of glaze is quite effective, but adding a second layer will substantially reduce heat loss, with a slight reduction in transparency. Collector performance can be increased by up to 35% if a second layer of glaze is added. A third layer of glaze does not offer a huge improvement in performance and is quite uneconomical, making the use of a third layer not justified.

Under the glaze layer is an absorber, whose task is to absorb almost all solar energy with minimal reflection and transmission. Most often, the absorber is a wooden material or iron coated with black paint and should be ideally flat. Black paint is the primary adsorption factor, so it doesn't matter if the material it's applied to is wood or metal. Immediately after the energy is absorbed, it must be transferred as heat to the surrounding air. For collectors that run on water or liquid, energy is transferred by circulating liquid in pipes.

The space between the glaze and the absorber creates a chamber for air circulation, which circulates and transfers energy in the form of heat.

4) Storage of solar energy

In all construction concepts, the question of storing solar energy is raised for use during the night hours and on cloudy and rainy days. Although, technically, storage is feasible, it should be taken into account that the glaze receives only a finite amount of solar energy, which is immediately used in the drying process. There are two possible solutions to this problem:

- the solar energy passed through the glaze to be used immediately after collection, thus achieving a very high temperature during the middle of the day but resulting in a very low temperature during the night hours.
- the solar energy is to be used evenly throughout the day and night, which is achieved by storage.

To enable the storage of solar energy, the surface area of the collector should be increased to provide enough energy for the ongoing drying process and the energy to be stored. If the surface area of the collector does not increase, neither does the amount of energy compared to the amount of wood to be dried, consequently, all the energy generated is consumed in one drying cycle, and there is no energy left for storage.

5) Air circulation

Air circulation in the kiln chamber is provided to facilitate heat transfer and to ensure uniform, even drying. A typical velocity of airflow through the wood chamber is 46 m/min. When this value is multiplied by the space between the timbers, separated by the slats, the average volume of air required is obtained.

The fans are placed in the hottest parts of the chamber to allow the best heat flow. With this heat positioning, there is a risk of the fins melting as a result of the high temperature if the fans are switched off during

6) Ventilation

The drying rate of the lumber can be directly controlled by varying the relative humidity in the chamber. Low humidity results in faster drying and low final moisture percentages. The humidity in the chamber is controlled through the ventilation system, so that moist and warm air is discharged through the exhaust vents and fresh and cool air is brought in. Subsequently, heating the cold air in the chamber decreases the relative humidity, thereby enabling and initiating the drying process.

At the same time, by releasing the moist air, it is released, that is, part of the energy from the chamber is lost. This is explained by the fact that the used air is hotter than the fresh air supplied, and the energy that initiates the drying is found in the hot air. Ventilation and heat losses must be matched to justify the drying process. Excessive chamber ventilation leads to lower chamber air temperatures and significantly slows drying time.

7) Size of collectors

The amount of energy generated by the kiln controls the amount of water evaporated from the wood. Therefore, in order to control the drying rate and ensure quality drying without the occurrence of defects, it is necessary to ensure the size of the collector corresponds to the capacity of the kiln.

4. CONCLUSION

The world is facing an environmental disaster and a permanent lack of energy. The constant lack requires research on alternative and ecological ways of energy production, which come from nature and do not destroy it. One of the alternative ways of producing energy is by generating it from the sun through electricity. The sun is the largest heating body and a constant source of light and heat. One of the many applications of solar energy is in the drying of wood. The drying of wood with solar energy results from the need to make the drying process more economical and to optimize it. Drying wood with solar energy is a source of constant research and can be said to be a promising method that, with the development of technology, will become dominant in the future.

The drying of wood with solar energy offers justified economic costs for the construction of kilns because it consumes almost no electricity, that is, during operation and maintenance, it does not generate large maintenance costs, which justifies the initial investment.

Solar energy is a renewable and sustainable source of energy. This means that endangered natural resources and technologies that are harmful to the environment are not wasted. Solar energy technologies are divided into passive and active, depending on the way the energy is stored and distributed.

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