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CURRENT TRENDS IN THE USE OF SOLAR ENERGY

Abstract: *Solar energy represents the amount of solar radiation per unit time on unit area. Solar energy is used to obtain thermal energy through solar, and electrical energy through exist for solar energy: passive and active. The utilization of solar energy is essential for the development of human civilization.*

Keywords: *solar drying, solar stills, photovoltaic technology*

1. Introduction

A solar assisted chemical heat pump dryer is a new solar drying system, which have contributed to better cost-effectiveness and better quality dried products as well as saving energy. A solar collector is adapted to provide thermal energy in a reactor so a chemical reaction can take place. This reduces the dependency of the drying technology on fossil energy for heating (Fadhel *et al*., 2011).

The solar still, in many respects, is an ideal source of fresh water for both drinking and agriculture; it is one of the most important and technically viable applications of solar energy. There are many types of solar still; the simplest and most proven is the basin type (Velmurgan and Srithar, 2011).

One of the most promising renewable energy technologies is photovoltaic technology. There are various types of photovoltaic modules based on generation of solar cell and their applications in terms of electrical as well thermal outputs. If photovoltaic technology is used for more than one applications, e.g. thermal heating, drying, day lighting etc. in addition to the power generation, then economics will be in its favour for energy planner. The photovoltaic technology system will be more sustainable for decentralised power generation and harvesting (Tiwari *et al*., 2011).

The object of this study is systematizing and analyzing information and results of various scientific works. Descriptive-analytical method was used in this paper.

2. Solar drying

Sun drying is the common method used to preserve agricultural products in tropical and sub-tropical countries. However, this process has many disadvantages: spoilt products due

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to rain, wind, moisture and dust; loss of produce due to birds and animals; deterioration in the harvested crops due to decomposition, insect attacks and fungi, etc. Further, the process is labour intensive, time consuming and requires a large area for spreading the produce out to dry. Solar-drying technology offers an alternative which can process the vegetables and fruits in clean, hygienic and sanitary conditions to national and international standards with zero energy costs. It saves energy, time, occupies less area, improves product quality, makes the process more efficient and protects the environment (Fadhel *et al*., 2011).

Most solar dryers developed are designed for specific products or class of products. Vegetables such as chilli, cassava, onion, radish, ginger, peas, corn, mushroom, tamarind and coconut, and fruits such as mango, apple, pineapple, banana, grapes, prunes. Selection of a solar dryer for a particular food product is determined by quality requirements, product characteristics and economic factors (Fadhel *et al*., 2011).

Solar-assisted dryers are conventional dryers to which supplementary equipment is added to enable a significant proportion of the thermal energy required for drying to be replaced by solar energy. In these types of dryer, a planned, and generally optimized drying process can be achieved to obtain superior product quality and good economic performance. Any influence of the weather conditions on product quality and on the performance of the dryer can be eliminated by using an independent energy source, if needed, and proper control facilities. The construction of the solar assisted dryers is relatively complex compared to other dryers. They usually consist of a solar collector, a fan, a heat storage system, a burner/heater, and a control system. They can handle large quantities and deliver good product quality (Fadhel *et al*., 2011).

The low temperature thermal requirement of the heat pump makes the system an excellent match for thermal applications for both domestic and industrial use; such as water heating, solar drying, space cooling, and space heating and cooling. Heat pump dryers have been known to be energy efficient when used in conjunction with drying operations. Different types of heat pumps are available on the market for drying applications (Fadhel *et al*., 2011).

A chemical heat pump is proposed as one of the potentially significant technologies for effective energy utilization in drying. Chemical heat pumps are those systems that utilize the reversible chemical reaction to change the temperature level of the thermal energy which stored by chemical substances. The advantages of thermochemical energy storage, such as high storage capacity, long term storage of both reactants and products, lower of heat loss, suggests that chemical heat pump could be an option for energy upgrading of low temperature heat as well as storage (Fadhel *et al*., 2011).

3. Solar stills

Nowadays solar stills are widely used in the solar desalination process. Single basin solar still consists of a black painted basin contains brackish or sea water. This is enclosed in a completely airtight surface formed by a transparent cover. Incident solar irradiance passes through the transparent cover and is absorbed by the black basin plate. Consequently, water contained in the basin heated up and evaporates in the saturated conditions inside the still. Water vapor rises until they come in contact with the inner surface of the cover and condensed into pure water, run down along the cover bottom surface due to gravity and is collected using glass stopper. The construction of this type of still can easily be performed by local people using locally available materials (Velmurgan and Srithar, 2011).

People living in remote areas or islands, where fresh water supply by means of transport is expensive, face the problem of water shortage every day. Solar still presents some specific advantages for their use in these areas due to its easier construction using locally available materials, minimum operation and maintenance requirements and friendliness to the environment. It is really very fortunate that, in times of high water demand, solar radiation is also intense. It is therefore beneficial to exploit solar energy directly by installing solar stills. Two major advantages that favour the use of solar stills are: clean and free energy, and friendly to the environment. Their main disadvantage, however, is the lower output of distilled water in comparison with other desalination systems. The system is highly uneconomical. In solar desalination process, the productivity of the solar still is very less compared to other conventional desalination systems (Velmurgan and Srithar, 2011).

The various factors affecting the productivity of solar still are solar intensity, wind velocity, ambient temperature, water-glass temperature difference, free surface area of water, absorber plate area, temperature of inlet water, glass angle and depth of water. By considering the various factors affecting the productivity of the solar still, various modifications are being made to enhance the productivity of the solar still (Velmurgan and Srithar, 2011).

The evaporation rate of the water in the solar still is directly proportional to the exposure area of the water. Thus the productivity of the solar still increases with the free surface area of the water in the basin. To increase the free surface area of the water, sponges are used at the basin water. The yield of a solar still mainly depends on the difference between water and glass cover temperatures. The temperature difference between water and glass are acting as a driving force of the distillation process. Productivity of the solar still increases with increase in absorber area (Velmurgan and Srithar, 2011).

The evaporation rate of saline water increases with the temperature of the saline water. Productivity of the solar still increases with the saturation pressure of the water. Reflectors, condenser, vacuum technology, combined stills, asphalt basin liner and sprinkler and sun tracking systems are used to maximize the yield of the solar still. Also energy storage materials like black rubber, gravel and metallic wiry sponges are used for enhancing the productivity of the solar still (Velmurgan and Srithar, 2011).

4. Photovoltaic technology

A solar cell or photovoltaic cell is a device that converts solar energy into electricity by the photovoltaic effect. A solar cell constitutes the basic unit of a photovoltaic generator which, in turn, is the main component of a solar generator. A photovoltaic generator is the total system consisting of all photovoltaic modules which are connected in series or parallel or combination of both series and parallel with each other. Photovoltaic module is a packaged interconnected assembly of photovoltaic cells (Tiwari *et al*., 2011).

Different photovoltaic modules have demonstrated substantial improvements and transformations over the past 40 years and are expected to undergo developments in the following decades. The drive for more photovoltaic installations is strengthening and this is creating widespread opportunities for business growth and a market with massive job potential. Market and research analysts estimate that in the near future crystalline photovoltaic modules will continue to dominate this market segment due to the fact that in most installation cases, limitations on the available area necessitate the use of modules with high efficiencies (Tiwari *et al*., 2011).

Technologies for the development of photovoltaic modules are rapidly emerging and that there is a diverse portfolio of such technologies which is going to threaten the domination of crystalline silicon in the near future. Crystalline silicon has an ordered crystal structure, with each atom ideally lying in a predetermined position. Monocrystalline photovoltaic modules exhibit predictable and uniform behaviour, are highly efficient but are the most expensive type of silicon because the manufacturing processes are slow, require highly skilled operators and are labour and energy intensive. Until recently the majority of solar cells were made from pure monocrystalline silicon produced for the semiconductor industry, having no impurities or defects in its lattice. This has been a time consuming and expensive manufacturing methodology and produced silicon of a higher purity than required for photovoltaic cells. A number of approaches to reduce costs of crystalline photovoltaic cells and modules have therefore been under development. Techniques for the production of multicrystalline silicon are simpler and therefore cheaper than those required for monocrystalline material. The shortage and high prices of polycrystalline silicon have also been the main reasons for many solar cell manufacturers to seek alternative raw materials such as metallurgical-grade silicon which is successfully entering the photovoltaic arena (Tiwari *et al*., 2011).

The advantages of thin films over crystalline cells have been the important driver to initiate a photovoltaic market in this area. Thin film module production manufacturing processes operate at a much lower temperature than that of crystalline silicon and this reduces the embodied energy per watt-peak. Another manufacturing advantage is the fact that photovoltaic films can be easily deposited on a wide variety of both rigid and flexible substrates including glass, steel and plastics. However, thin film technologies show significant initial performance degradation when deployed outdoors and the most important challenge of thin film technologies remains the production improvement of the technology so as to increase the efficiency of industrially produced cells. Amorphous silicon cells should be cheaper to produce than those made from crystalline silicon and are better light absorbers, facilitating in this way thinner and therefore cheaper cells. However, stabilised amorphous silicon efficiencies of the best commercial modules remain low at 6–7% (Tiwari *et al*., 2011).

In urban and suburban areas, photovoltaic arrays are commonly used on rooftops to measure power use. In more rural areas, ground-mounted photovoltaics systems are more common. The systems may also be equipped with a battery backup system to compensate for a potentially unreliable power grid. In agricultural settings, the array may be used to directly power drying pumps, without the need for an inverter. In remote settings such as mountainous areas, islands, or other places where a power grid is unavailable, solar arrays can be used as the sole source of electricity, usually by charging a storage battery. Satellites use solar arrays for their power. Solar photovoltaic panels are frequently applied in satellite power. However, costs of production have been reduced in recent years for more widespread use through production and technological advances. For example, single crystal silicon solar cells have largely been replaced by less expensive multicrystalline silicon solar cells, and thin film silicon solar cells have also been developed recently at lower costs of production. Although they are reduced in energy conversion efficiency from single crystalline silicon wafers, they are also much easier to produce at comparably lower costs. Together with a storage battery, photovoltaics have become commonplace for certain low power applications, such as signal buoys or devices in remote areas or simply where connection to the electricity mains would be impractical (Tiwari *et al*., 2011).

The term “building integrated” refers to photovoltaic systems that constitute part of a building envelope, but has also been used to describe systems that are simply mounted on the rooftop of buildings. For this reason, it is best to describe building integrated photovoltaic systems as systems that are readily integrated with the physical building or with the building's grid connection. The integration of such systems usually requires the advice of professional civil engineers, architects and photovoltaic system designers during the design of the system and the building. In this case a good evaluation of the installation site is required so as to maximise solar coverage and electricity output. Building integrated photovoltaic systems are usually installed on facades, building window systems and as flexible rolls on roofs. Consequently, building integrated photovoltaic systems often have restricted views of the sun, and their orientation must be optimised for the particular circumstances of their installation site. Building integrated photovoltaic systems can achieve significant cost reductions when they are used as part of the building envelope and thereby offset the cost of the building materials they replace (Tiwari *et al*., 2011).

Photovoltaic systems are used effectively worldwide to pump water for livestock, plants or humans. Water pumping appears to be most suitable for solar photovoltaic applications as water demand increases during dry days when plenty of sunshine is available. Photovoltaic is also used to power remote electric fences on farms (Tiwari *et al*., 2011).

Solar photovoltaic street lights can be used as yard lighting, peripheral lighting for industries, street lights in layout, compound lights, etc. The photovoltaic modules charge the batteries during the day time. At dusk an automotive sensor switches on a powerful high efficiency light and at dawn the lamp is switched off automatically (Tiwari *et al*., 2011).

Photovoltaic will play a significant role in meeting the world future energy demand. The so-called "third-generation photovoltaic" will be based on nanostructures. An important advantage for nanostructured solar cells is that they can be used to incorporate new physical mechanisms that allow an efficiency greater than that of a one-junction solar cell. Nanostructured solar cells offer several advantages for solar cells, including: the ability to exceed a ingle junction solar cell efficiency by implementing new concepts; the ability to overcome practical limitations in existing devices, such as tailoring the material properties of existing materials or using nanostructures to overcome constraints related to lattice matching; and the potential for low-cost solar cell structures using self-assembled nanostructures (Razykov *et al*., 2010).

Thin-film silicon solar cells have the following important advantages compared to crystalline cells: the thickness of silicon can be drastically reduced to 50 μm; thin films can be deposited on low-cost substrates; and thin films can be fabricated on module-sized substrates and in integrally interconnected structures. According to some calculations, the thickness of silicon films can be reduced down to 1 μm (Razykov *et al*., 2010).

The superior optical, electric, and chemical properties of nanomaterials offer the chance for solar cells to get higher efficiencies. Competitive costs and performance can be achieved by using quantum wells and quantum dots in crystalline solar cells. The quantum well solar cell is a novel device with the potential to achieve high efficiency in an alternative approach to tandem or cascade solar cells. Quantum dots are nanometer-sized crystallite semiconductors that can be produced by a variety of methods. The advantage of quantum dots is the ability to tune the absorption threshold simply by choosing the dot diameter. Dye-sensitized solar cells have been extensively studied for their reasonable photoelectric conversion efficiency, simple assemble technology, and potential low cost (Razykov *et al*., 2010).

With a theoretical efficiency that is the same as conventional semiconductor devices and a cost structure derived from plastic processing, organic photovoltaic cells offer the long-term potential of achieving the goal of a photovoltaic technology that is economically viable for large-scale power generation. Some key advantages for organic photovoltaic are that organic small-molecule and polymer materials are inherently inexpensive; they can have very high optical absorption coefficients that permit the use of films with thicknesses of only several hundred nanometers; they are compatible with plastic substrates; and they can be fabricated using high-throughput, low-temperature approaches that employ one of a variety of well-established printing techniques in a roll-to-roll process. A key issue faced by the organic electronics community in general is the stability of the organic materials. Device degradation pathways stem largely from changes in morphology, loss of interfacial adhesion, and interdiffusion of components, as opposed to strictly chemical decomposition. Thus, careful design and materials engineering can substantially improve device lifetimes (Razykov *et al*., 2010).

5. Solar air conditioning systems

The main reasons for the increasing energy demand for summer air conditioning are the increased thermal loads, increased living standards and comfort demands in conjunction with architectural characteristics and trends. In the current practice, air conditioning is exclusively based on the use of electric energy, while solar energy is used mainly for water heating and in limited applications for space heating and cooling. As a result of the extensive use of electricity for cooling there is a big impact in the greenhouse gas emissions due to the fact that electricity is production is based on lignite combustion. Also the leakage of cooling fluids have an impact on the greenhouse effect, intensifying the cycle of climate change. The latter is of great significance, especially in the case of public buildings (Koroneos *et al.*, 2010).

Solar cooling systems have the advantage of using harmless working fluids such as water or solutions of certain salts. They are energy efficient and environmentally safe. They can be used either as stand-alone systems or with conventional air conditioning to improve the thermal comfort of all types of buildings. The main goal is to utilize “zero emission” technologies to reduce energy consumption and CO_2 emissions (Koroneos *et al.*, 2010).

The continuous increase in the cost of energy, associated with renewable energy support instruments set up by the majority of governments, has made it possible for a significant solar thermal sector growth. Although a precise statement on the economic situation of a solar assisted air conditioning system depends on the individual system, the annual cost of a solar assisted air conditioning system in general, including capital, operation and maintenance cost, are currently above the annual cost of a conventional system (Koroneos *et al.*, 2010).

Solar air conditioning refers to any air conditioning system that uses solar power. This can be done through passive solar, photovoltaic conversion or solar thermal energy conversion. Specifically, solar cooling technologies use solar thermal energy provided through solar collectors to power thermally driven cooling machines. A solar cooling installation consists of a typical solar thermal system made up of solar collectors, storage tank, control unit, pipes and pumps and a thermally driven cooling machine (Koroneos *et al.*, 2010).

The basic principle in using solar heat for cooling is based on the evaporation technique. The big advantage of solar cooling is that as the intensity of solar heat increases the cooling generation will be increased. This is a very important advantage since the cooling needs of buildings in the summer are synchronized with the intensity of solar radiation (Koroneos *et al.*, 2010).

The greatest exploitation of solar cooling potential is achieved in buildings with high thermal gains during the day and consequently high cooling load. The efficiency of the solar air conditioning installation depends on the type of the used solar collectors, the size of solar field, the cooling load as well as the used cooling and air conditioning technique. Most collectors used in solar cooling systems are the high efficiency collectors available in the market today. In order that energy savings are achieved, solar cooling installations should be able to cover a minimum of about 20% of the load in absorption and open air cycle cooling based on absorption, and about 30% in absorption cooling (Koroneos *et al.*, 2010).

Solar air conditioning systems have as main objective the replacement of fossil fuel based systems so as to attain a primary energy saving, in terms of economic vitality. In this context, the resource to solar energy for air conditioning represents a suitable choice not only to reduce the final energy consumption but also to significantly reduce greenhouse gases. Especially in the case of Mediterranean climates, which are characterized by high cooling demand during the summer, solar air conditioning can play a crucial role in the promotion of sustainability. For this reason the solar air conditioning system under study is evaluated not only economically but also environmentally both for the winter and summer period (Koroneos *et al.*, 2010).

The use of conventional cooling equipment has introduced several drawbacks such as frequent peak electric loads, increase of electrical energy consumption and environmental problems resulting from the use of refrigerants and the increase of installed electric power generation. As the rate of air-conditioned demand is expected to grow, the exploitation of solar energy seems to be a valuable option to mitigate the consumption of conventional fuels due to the cooling requirements. Solar air conditioning systems can be a reasonable alternative to conventional air conditioning systems. No long-term intermediate storage is necessary. The sun can provide a substantial part of the energy needed for air conditioning. This can help to reduce primary energy consumption. The most common technology of solar thermal cooling is absorption chiller (Koroneos *et al.*, 2010).

The economic viability of such an innovative cooling method is of great importance; nevertheless the technical effort in the implementation of a solar thermal air conditioning system is higher compared to the implementation of a conventional system. Additionally, some of the components costs are still high. In general, the annual cost, i.e., the cost including investment, operation and maintenance costs of a solar thermal system are currently above the annual cost of a conventional system using an electric vapour compression chiller (Koroneos *et al.*, 2010).

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