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# Study in industrial applications of solar energy and the range of its utilization in Jordan

O.O. Badran \*

*Al-Balqa Applied University, Amman College for Engineering Technology, Mechanical Engineering  
Department, P.O. Box 330116, Amman 11133, Jordan*

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## Abstract

The objective of this research is to encourage the utilization of industrial solar energy in the Arab world and especially in Jordan, which has a sunny weather for most of the year. From his experiments on the Rankine cycle utilizing solar energy for the period between 1871 and 1884, the scientist John Ericson suggested that international relationships in the future will change to the benefit of those countries having continuous solar energy. Jordan nearly does not have a huge amount of oil, natural gas and uranium fields, but it has a huge amount of solar energy available most of the year. This research is a review of the industrial applications of solar energy and their development, which may be useful for the development of military equipment and for economical purposes. This study also shows that the Jordanian government should encourage research centers to do more serious steps towards the utilization of industrial solar energy. © 2001 Elsevier Science Ltd. All rights reserved.

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## 1. Introduction

It has been realized recently that the world's supply of fossil fuels may be depleted in the foreseeable future. As a result, fuel shortages, rationing and allocation programs, rapidly inflating fuel prices, and economic and political instabilities will occur. In this paper we highlight solar energy, which has to be the number one source in the foreseeable future. The problem is that we have not been forced to find the technological means to convert these natural energies into usable forms

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\* Fax: +962-6-461-3452.

*E-mail address:* o\_badran@yahoo.com (O.O. Badran).

because it has been too easy simply to dig or pump our energy out of the ground. Fisk and Anderson [1] suggested that the problem is not the shortage of energy itself, but the shortage of technology for converting the energy that lies all around us into usable forms. Energy conversion technology is the real issue, and solar energy is one of the brightest and most promising frontiers in energy conversion.

Most Arab countries lack the data for a realistic assessment of the present and future roles of industrial solar energy (ISE) in their economics. The development of ISE will have the most important impact in helping Jordan and some Arab countries (non-oil producing) meet their energy requirements. Sakr [2] suggested that this impact should be measured not only by the quantity of energy produced but also by the contribution made to welfare and development. The Arab countries enjoy some of the highest solar radiation intensities in the world, lying as they do between the equator and the 30° parallel, the sunny belt of the earth. Compared with other regions on the earth, the Arab region receives 70% of the extraterrestrial radiation [3]. Also Jordan has an excellent mean solar radiation on horizontal surfaces of 5.5–6 kWh/m<sup>2</sup>/day compared with that of Europe and most of North America, which amounts to 3.5 kWh/m<sup>2</sup>/day — i.e., about 60% of that falling over a square meter in Jordan. Industrial solar energy (ISE) in Jordan is fairly young and it is not well established to date.

## 2. Industrial solar energy (ISE)

To be put to work, solar energy must be transformed or converted into more useful forms of energy. Solar technology is expanding rapidly into areas other than traditional applications (solar water heating, space heating and to cook and dry food); however, it is important to be aware of this progress. In this section we briefly review some of the recently developed industrial applications (solar thermal power generation) which will be under consideration in Jordan. The generation of electrical power is one of the most important applications of an energy source [4].

Solar thermal power cycles can be classified as low-, medium- or high-temperature cycles. Low-temperature cycles work at maximum temperatures of about 100°C. A diagram of a typical low-temperature system using flat-plate collectors and working on the Rankine cycle is shown in Fig. 1. The working fluids normally used are organic fluids like methyl chloride and toluene, and refrigerants like R11, R113 and

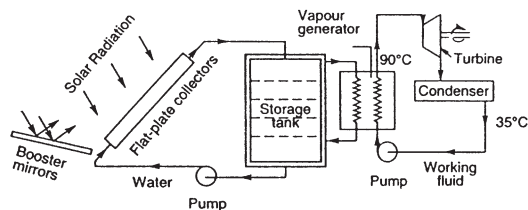


Fig. 1. Low-temperature power generation.

R114. Plants of this type of French design having generation capacities up to about 50 kW were installed in many parts of the world, particularly Africa, in the 1970s. Among solar thermal electric power plants, those operating on medium-temperature cycles and using line focusing parabolic collector technology at a temperature of about 400°C have proved to be the most cost-effective and successful so far [4]. A schematic diagram of a typical plant is shown in Fig. 2. The first commercial plant of this type, having a capacity of 340 MW, was set up in 1984 by LUZ International in California.

High-temperature systems use either paraboloidal dish collectors or central receivers located at the top of towers. In the paraboloidal dish concept, the concentrator tracks the sun by rotating about two axes and the sun's rays are brought to a point focus. A fluid flowing through a receiver at the focus is heated and this heat is used to drive a prime mover. Typically stirling engines have been favored as the prime movers and systems having efficiencies of up to 30% and generating power in the range of 8 to 50 kW have been developed.

In central receiver power plants, solar radiation reflected from arrays of huge mirrors (called heliostats) is concentrated on a receiver situated at the top of a supporting tower. A fluid flowing through the receiver absorbs the concentrated radiation and transports it to the ground, where it is used to operate a Rankine power cycle. Fig. 3 shows the main components of a central receiver power plant in which water is converted into steam in the receiver itself [1,4]. Recently the concept of a solar chimney power plant has been suggested. In such plant, a tall central chimney is surrounded at its base by a circular greenhouse consisting of a transparent cover supported a few meters above the ground by a metal frame (Fig. 4). Sunlight passing through the transparent cover causes the air trapped in the greenhouse to heat up. A convection system is set up, in which air is drawn up through the central chimney and turns a turbine located near the base of the chimney. The hot air is continuously replenished by fresh air drawn in at the periphery of the greenhouse. The only solar chimney power plant built so far is a 50 kW pilot plant in Spain.

It can be concluded from this section that solar thermal applications for industrial

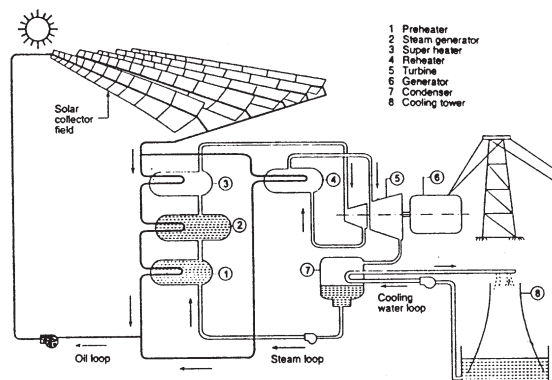


Fig. 2. Medium-temperature power generation.

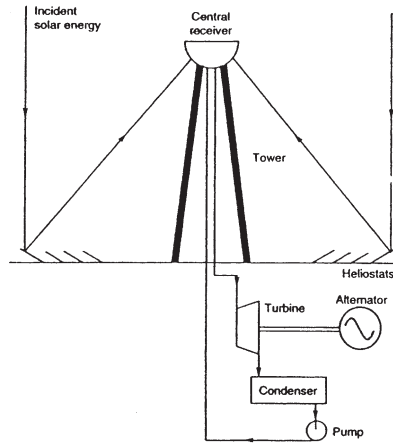


Fig. 3. Central receiver power plant.

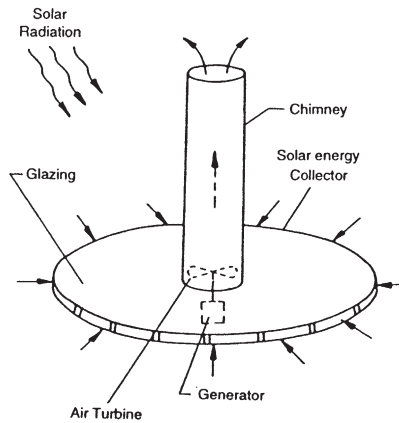


Fig. 4. Solar chimney power plant.

purposes have not yet been utilized in Jordan. This is a little surprising because ISE applications definitely have an important role to play in certain regions in Jordan. A concentrated effort has to be made to make these technologies more cost-effective and reliable, and to disseminate information regarding their use.

### 3. Solar energy applications in Jordan

A brief description is now given of the main projects and applications of various solar energy technologies in Jordan performed by the Solar Energy Research Center (SERC). Since its establishment in 1972, the Mechanical Engineering Department at the Royal Scientific Society (RSS) has been placing emphasis on applied research

in the field of solar energy [5,6]. The RSS upgraded this by establishing the Solar Energy Research Center in November 1983 which was renamed the Renewable Energy Research Center (RERC) in 1989. The RERC's main fields of expertise are solar thermal, wind and photovoltaic applications. To date, the RERC has implemented research and development work on the following: (1) solar desalination using (i) the solar still method and (ii) solar heat; (2) solar water heating pipes for domestic and industrial applications; (3) solar space heating and cooling; (4) water pumping utilizing photovoltaics; (5) delivery of electric power for a remote village utilizing a photovoltaic system; and (6) supplying power to radio communication systems and other electrical loads required in isolated villages by photovoltaic generators. In addition, the RERC has conducted several studies concerning determination of the application potential of solar and wind energy in Jordan, investigation of the socio-economic impacts of renewable energy systems in remote areas, and technoeconomic feasibility studies. The RERC contributes significantly to the compilation of Jordanian and Arab standards. These include Jordanian Standard No. 394 (Identification plate), Standard No. 421 (Flat plate collectors: Part 2 – terms definitions, units and symbols), Standard No. 434 (Part 3 – construction requirement) and Standard No. 435 (Testing methods performance). In the area of flat-plate collectors (which was one of the first activities carried out by RSS), the RSS worked on the development of flat-plate collectors for domestic solar water heaters. The RSS designed and produced prototype collectors in its workshops and signed three agreements with local manufacturers for mass production for the local market and for export. The number of houses utilizing solar water heaters in Jordan by the end of 1992 was estimated to be 158,669 (more than 20% of the total number of houses in Jordan) [5].

Energy required for space heating and hot water purposes is estimated to be 12% of the total energy consumed in Jordan [7]. Many photovoltaic-pumping systems were installed in different places in Jordan and especially in remote areas, to supply the Bedouins with daily water. Also, photovoltaic systems have been used for emergency telephone, educational television and refrigeration with an anticipated energy saving contribution of 851 kWh/day. These projects were supported by the Ministry of Water and Irrigation/Water Authority of Jordan (WAJ), designed and executed by the RSS/RERC. A new Renewable Energy Research Center has recently been established at Applied Science University to make it possible for both staff members and students to conduct experiments and research projects in this field. The center sets itself the task of estimating environmental parameters, such as temperature, sun radiation intensity, etc. Through the technical equipment developed, experiments on solar desalination, water heating systems and electric generation by photovoltaics can be conducted in the center [8]. It is concluded from this section that solar energy utilization in Jordan has made reasonable progress in the traditional application of solar energy only (i.e., solar water and space heating, solar desalination), due to the activities in research institutions such as the RSS and some universities. But their efforts have resulted in activities that are usually uncoordinated, not only among different Arab countries, but also between different departments within the same country.

#### **4. Conclusion**

It is concluded that industrial solar energy applications should be encouraged by the authorities concerned on pan-Arab levels, to act quickly and promptly to establish strong research centers specialized in the ISE fields (i.e., power generation and refrigeration). Also, the exchange of information among Arab scientists should be encouraged through official channels such as the Arab Union of Scientific Research Centers. The present study of various solar thermal applications shows that solar water and space heating, photovoltaic-pumping systems and solar desalination have already made a small and encouraging impact on the Jordanian energy scene. Other applications using heat directly, like power generation and refrigeration, have not been utilized yet. Solar industrial applications have an important role to play in meeting the needs of thousands of small communities across the country where electricity is scarce. Also, we can conclude that research and development projects in the field of ISE are of utmost importance to Jordan knowing that Jordan does not have any source of conventional energy.

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