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# Solar Thermal Power Plants: Progress and Prospects in Iran

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**Abstract**

One of the most promising paths towards the sustainable development is utilizing solar energy, especially in oil-dependent economy nations like Iran. Electricity production in Iran is mainly dominated by its fossil fuel resources. High solar insolation and available desert lands in Iran are two main factors to encourage the full development of solar power plants for thermal and electrical energy productions. Herein, the solar thermal power plants have the priorities of consistent power output and the ability to incorporate storage. In the present study, a brief description and working principles of the solar thermal power plants are given. Besides, the paper points out the solar energy potential, the current state of electricity generation and the future of solar thermal power projects in the country. Special attention is drawn to the Iranian government initiatives and support for the use of solar energy. In the end, the future prospects of solar projects development with the worldwide competitive technologies by considering the existing obstacles that should be removed by the Iranian governments and energy planners in the future of energy production are presented.


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*Keywords:* Solar thermal power plant, Solar energy, Electricity, Iran.

## 1. Introduction

The developing country Iran, located in the Middle East, has the area of 1,648,195 km$^2$ and the population of around 77.5 million. More than 90 percent of the land area in Iran is classified as arid and semi-arid with an average annual rainfall of 228 mm [1]. Iran is a rich country in terms of non-renewable energy resources which has the world's second largest natural gas reserves and the OPEC's second largest supply of oil [2]. The renewable energy (RE) resources along with the energy conservation technologies would lead to energy sustainable development [3]. In 2007, the share of the Iran's RE from the total energy production was equal to 0.08 million barrels of crude oil. This is while that the potential of these resources within the country, especially solar and wind energies, is higher than many leading countries in

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this field [4]. In recent years, the electricity demand in the country has been reported as 50,000 MW, which is about 80% of the amount of the fossil fuel consumption (Fig. 1). It has also been projected that Iran's electricity demand will be 200,000 MW in 2030. It is obvious that fossil fuel resources will not cover this percentage in 2030 unless by taking account some new strategies in the case of energy production from alternative energy resources [5].

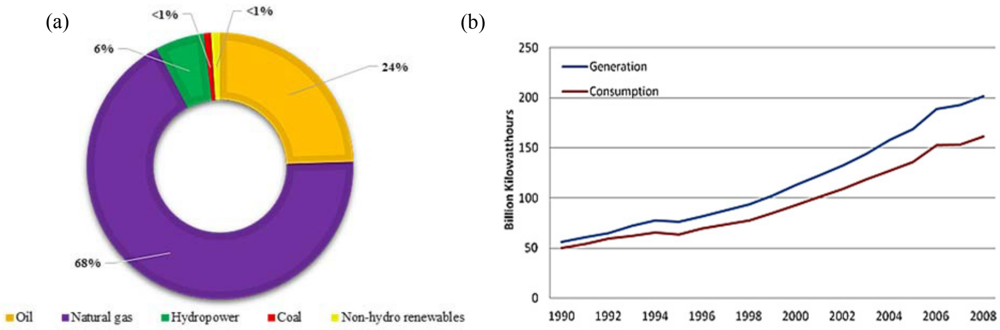


Fig. 1. a) Electricity generation by fuel in Iran, 2012; b) Iranian electricity generation and consumption, 1990-2008 (Source: EIA).

There are plentiful RE resources in the country, but, the share of the generated power from these resources is still very low. In order to achieve the desired goals of the 5th five year economic development plan, implementation of efficient projects relevant to the RE resources is vitally required [2].

At the present time, a part of the Iranian governmental policy is allocated to invest in the RE projects not only to eliminate the environmental effects, but to achieve sustainable development and increase energy security [6]. Among all the RE resources, solar energy appears as the most promising technology to lead the Iran's economic sector towards sustainability since the country enjoys an abundance of solar radiation [7]. About 25% of the country's land are deserts which receive daily solar irradiation of about 5kWh/$m^2$. It would be worth knowing if only 1% of these areas is covered with solar collectors, the obtained energy will be five times more than the annual gross electricity production in Iran [8]. The first PV power plant was established in the central region of Iran in Doorbid village Yazd in 1993. After that, a number of PV projects were begun in Yazd, Semnan, Khorasan, Tehran and Taleghan. In addition, the first concentrating solar power (CSP) plant became operational in Shiraz in 2008. The Yazd integrated solar combined cycle power plant was also put into operation in 2009 [9]. By considering the current solar power generation capacity, a comprehensive plan must be developed to increase the capacity of solar power generation, especially by implementing solar thermal power plants due to their some advantages over photovoltaics.

## 2. Solar thermal power generation technologies

Solar thermal power generation technologies are efficient methods which are more attractive for large-scale electricity production. Heat can be stored during the day and then converted into electricity at night. Solar thermal power plants can improve the economics of solar electricity and make it dispatchable.

### *2.1. Solar tower power plant (STPP)*

A solar tower power plant (STPP) uses a field of sun tracking reflectors called heliostats which reflect and concentrate sun rays onto a central receiver at the top of a fixed tower to produce power in Mega-Watt (MW) (Fig. 2a). Heliostats are composed of several flat or slightly concave mirrors that follow the sun in a two-axis tracking system [10]. In a central receiver, heat is absorbed by a heat transfer fluid, which then is transferred to heat exchangers that power a steam generator. Hence, steam generator of electricity converts mechanical work into electrical energy which is then given to the electric distribution grids [11].

### *2.2. Parabolic through solar power plant (PTSPP)*

A parabolic trough solar power plant (PTSPP) consists of a group of reflectors that are curved in one dimension in a parabolic shape to focus sun rays onto an absorber tube mounted in the focal line (Fig. 2b). The reflectors and the absorber tubes move in tandem with the sun from sunrise to sunset [10]. The absorber tube is composed of a metal tube and a glass envelope, with either air or vacuum between these two to reduce convective heat losses. The metal tube is coated with a selective material that has high solar irradiation absorbance and low thermal emission [12].

### *2.3. Parabolic dish solar power plant (PDSPP)*

Parabolic dish Stirling engine power plants have been developed for commercial applications generate power in kW and are more suitable for power supply in small communities [11]. The parabolic dish tracks the sun in two axes. Hence, the incident sun rays are focused on a point. The receiver absorbs solar radiation and transfers the thermal energy to the Stirling engine (Fig. 2c). Current Stirling absorbers are typically direct illumination, heat pipe and volumetric receivers [10].

### *2.4. Linear Fresnel reflector solar power plant (LFRSPP)*

Linear Fresnel reflectors using long rows of flat or slightly curved mirrors to reflect the sun rays onto a downward facing linear receiver. The receiver is a fixed structure mounted over a tower above and along the linear reflectors which follow the sun on a single or dual axis tracker [13]. The main advantage of LFR systems is the simple design of flexible curved mirrors and fixed receivers which require lower investment costs. LFRSPPs are less efficient than the other technologies in generating electricity. Compact linear Fresnel reflectors, are novel designs, uses two parallel receivers for each row of mirrors and thus needs less land than PTSPP to produce a given output [10].

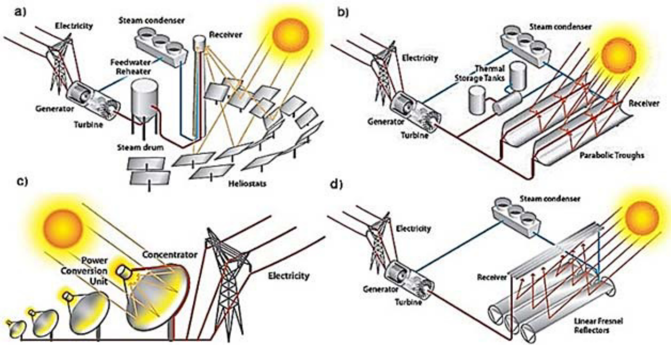


Fig. 2. Concentrating solar thermal power plants. a) STPP, b) PTSPP, c) PDSPP, d) LFRSPP.

### *2.5. Solar chimney power plant (SCPP)*

A solar chimney power plant (SCPP) consists of the three main parts: a collector, a chimney and a power conversion unit which comprises one or more turbine generators (Fig. 3). In this system, the solar radiation heats the air below the transparent collector roof, creating a gradient of temperature. Therefore, the temperature gradient will create the density gradient. The collector slopes from its inlet to its center, hence, buoyancy effects will force air to flow from the inlet of the collector to entry of the chimney where the flowing air will rotate a turbine to produce power [14].

### *2.6. Integrated solar combined cycle power plant (ISCCPP)*

In an ISCCPP, the gas turbine is the same as conventional combined cycle, and the required energy for producing steam can be supplied by both gas turbine exhaust and solar field (Fig. 4). In ISCCPP, higher pressure and temperature steam can be produced because of extra solar energy compared with combined cycle. Steam turbine capacity in the conventional combined cycle is 50% of gas turbine capacity, but in ISCC, the solar field increases steam turbine capacity about 50%. In this system, electricity production drop in summer would not occur because, as ambient temperature increases, solar field absorbs more energy [8].

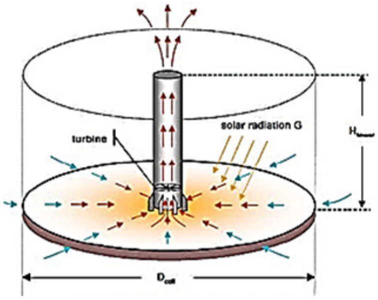


Fig. 3. Solar chimney power plant description.

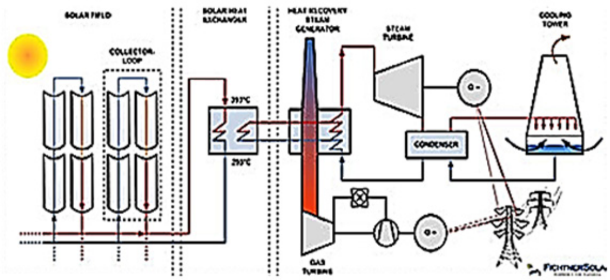


Fig. 4. Integrated solar combined cycle power plant.

## 3. Iran's solar thermal power plants

Located on the world's Sun Belt, Iran is one of the countries with the highest incoming solar radiation. The average global radiation for the country is about 19.23 MJ/m$^2$/day, which is even higher in the central regions with more than 2,800 hours per year [15]. By considering the area of the country, the total amount of radiation is about 3.3 million TWh per year, which is thirteen times higher than the total energy consumption in Iran [16]. In general, the regions with the minimum annual direct solar insolation of 1,800 KWh/m$^2$ are considered as the most desirable sites to install solar power plants [17].

### *3.1. Parabolic through solar power plant in Shiraz*

Shiraz, the capital of Fars Province is located in the southern part of Iran. It is the most favourable site for solar thermal power plant installations as enjoys 3,354 hours of sunshine annually with average daily solar radiation of 20 MJ/m$^2$ [18]. Iran's Deputy of Energy supported and installed the first pilot parabolic trough solar power plant in Shiraz which became operational in 2008. The plant is designed to generate 250kW of electricity (is being upgraded to 500 kW) during the sunny days with the process diagram shown in Fig. 5. The plant consists of a field of 8 parallel loops of 6 solar parabolic trough collectors, a Rankine steam cycle, an oil cycle and a heat storage system (Fig. 6).

### *3.2. Integrated solar combined cycle power station in Yazd*

Yazd province located in the central part of Iran is the driest major city in Iran, with blazing sunshine and no humidity. Yazd is an ideal location for solar energy utilization as the daily average of solar insolation is between 4.5 and 5.5 kWh/m$^2$ with 3200 sunshine hours in a year [19]. Therefore, the biggest solar energy project in Iran and even in the Middle East is devoted to Yazd by the Ministry of Energy. The project was 467MW Integrated Solar Combined Power Station. It consists of two 159 MW gas turbines, a 132 MW steam power plant and a 17 MW solar steam generation unit (Fig. 7). The captured energy from the solar unit is due to be utilized in the preheater of the Heat Recovery Steam Generator (HRSG) [20].

### *3.3. Solar chimney power plant in Kerman*

Kerman Province is located in southeast of Iran. The average solar radiation intensity in Kerman is about 2000 kWh/m$^2$ with 2800 h sunshine hours in a year. In order to evaluate the feasibility of a SCPP in Kerman, a pilot power plant based on the initial evaluations in this area was built (Fig. 8). The pilot power plant, has a chimney with a height and diameter of 60 m and 3 m respectively. The radius of its single glazed solar collector is 20 m [21]. The total power generation of the proposed solar chimney power plant to be built in Kerman is 410 MWh [22].

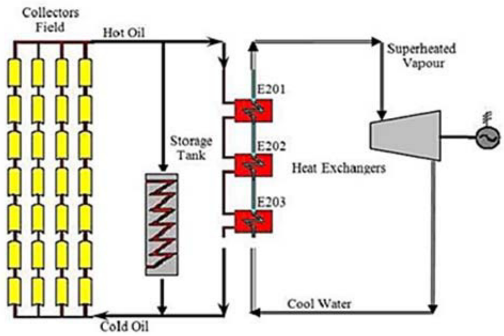


Fig. 5. Schematic of oil and steam cycle of the PTSPP [23].

Fig. 6. Photo of a PTSPP in Shiraz, Iran [23].

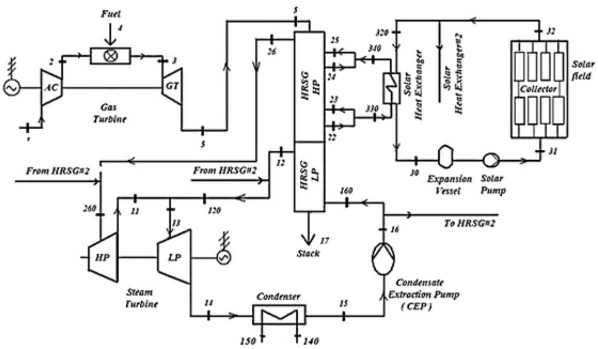


Fig. 7. Schematic diagram of ISCCS in Yazd, Iran [24].

Fig. 8. Solar chimney pilot plant in Kerman, Iran [21].

## 4. Conclusions and future prospects

The Iranian economy is heavily dependent on the oil and gas sector. Drop in oil prices, due to the international sanctions, will weaken the Iranian government's ability to stimulate the economy and slow the investment in the oil and gas in the next few years. In order to overcome crippling Western sanctions, the Iran's economy must rely less on crude oil exports. The country's superiority in terms of solar potential, encourages the full development of solar power plants for the thermal and electrical production of energy. Studies show that Iran can become the major supplier of the Mediterranean solar power generation chain in 2050 to provide the electrical power demand of Europe. However, some obstacles such as lack of required financial supports, contractors and competent observers, highly time consuming for develop of technical and scientific potentials, lessen the process of starting new projects. Besides, the Iranian government should support the private sectors to invest in solar installations. Apart from private investments, the Iranian government should also invest in extension of solar energy by launching an expert agency or contracting firms. A "Quality Control Manager" should be defined to monitor all the factors and processes as well.

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## Biography

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