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# An Investigation for Direct Steam Generation Parabolic Trough vs. Linear Fresnel System Applied in Egyptian Hotels

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**Abstract:** ***Renewable energy is becoming widespread today in various fields, as solar technologies contribute to provide an alternative to fossil fuels. The two technologies discussed in this paper are Parabolic trough and Linear Fresnel Direct Steam Generation. This work is presented on Egypt discussing its energy situation and demands, showing that one of the most consuming energy sectors are hotels and resorts. As Egypt is considered being a tourism attraction including various types of tourism, that means there are huge numbers of hotels and resorts all over the country in various regions that are not enough developed providing all services and depending mainly on fossil fuels. The study was deployed on Aswan in Egypt using the two different technologies. The effect of reflective mirror area is being analyzed, to show which system is more efficient and suitable and how it can be applied for the hotels. The main part of the simulation was done showing how Direct Steam Generation technology can be applied and the amount of steam it can produce during the four seasons of the year. The results show that PTC Direct steam generation is more suitable, as it has a better ability for steam production and water heating, which is the bigger sector of the hotel's consumption and needs.***

**Keywords:** Parabolic trough, Direct Steam Generation, Hotels, Egypt

## 1.Introduction

Today our energy demand is based almost on fossil fuels. The limited natural resources available will not allow supply to continue at current levels. While we use fossil resources, population growth will continue to increase demand. On the other side, the burning of fossil fuels is not less problematic, as emissions have negative effects on our environment and our climate. Throughout the world and in each second nearly 1.2 million kilograms of $CO_2$ are emitted into the atmosphere. The most dangerous is the greenhouse effect causing global warming, but the negative impact on health caused by air pollution constitute a major threat as well [8]. One of the most affecting and consuming sectors worldwide are hotels, as they use substantial amount of energy and are one of the most energy intensive facilities with correspondingly high energy costs [4]. So, there is an inevitable relationship between hotel industry development and environmental and energy efficiency impacts. That's why many countries have set serious and ambitious goals for renewable energy resources. An alternative solution for these problems is solar energy, which is available, in most areas, and represents also a perfect renewable source of thermal energy. By decreasing the fossil fuel resources and increasing the cost of electricity in recent years, the use of renewable energy is going to be a better, more well-known and attractive solution to solve the current problems of energy. Recently, solar energy has received considerable attention, because it is a clean and interminable energy source. Utilization of solar energy has become considerable in many processes due to its advantages, such as: reduction of the greenhouse gas emissions and cost of the electricity, and prevention of the global warming through the reduction of fossil fuel consumption. Solar energy is able to produce thermal energy for house heating and cooling, domestic hot water, industrial heat demand, electricity production in the solar power plants and a lot of other alternatives [8].Solar collectors can be used to produce thermal energy from solar energy. There are various types of solar thermal collectors, which all of them have the common principle of receiving solar radiation, converting it to useful heat and transferring it to a working fluid [12]. In the solar thermal applications, the energy is optically concentrated before being converted into heat. The sunlight is concentrated in the focal plane, with the aim of increasing the energy flux on the absorber surface. Concentrating solar power (CSP) systems work with lenses or mirror tracking systems to focus a large area of sunlight into a small beam. The concentrated heat is then used as a heat source for a conventional thermal plant. A wide Range of concentrating technologies exists and are being developed; the most known are the parabolic trough, the concentrating linear Fresnel reflector, the Sterling dish and the solar power tower. In this paper the simulation was done using parabolic trough collector and compared to the Linear Fresnel collector. The PTC is the most advanced solar thermal technology. Parabolic Troughs are used mainly in two application areas. This classification is based on aperture area of the PTC and the temperature range obtained [5]. The first application area is concentrated solar power where the temperature ranges from 300 °C to 400 °C and a geometrical concentrating ratio between 20 and 30. The second application area needs only temperature between 100 °C and 250 °C and a geometrical concentrating ratio between 15 and 20. These applications are mainly for industrial process heat, as well as domestic hot water, air conditioning and refrigeration, desalination, etc. [5]. Some already existing projects are available and commercially working using solar energy as an alternative, for instance Iberotel Sarigerme park in Turkey, using parabolic trough collectors for steam production and water heating [2]. Also, a solar field configuration of Parabolic trough collectors is installed to supply thermal energy to the heating and air conditioning system of a hotel located in Almería, Spain [3]. The St Regis Aspen Resort. It is one of the first hotels in America to use e-tube solar technology, its solar contractor, Altech Solar, began installing solar e-tubes in December 2008. A year later, it has mounted over 1,300 tubes on the roof, which will utilize the sun as a natural heat source. Another example is Aloft Hotel, where more than 90% of the hot water at Abu Dhabi National Exhibitions Company’s (ADNEC) new Aloft Hotel, operated by Starwood Hotels & Resorts Worldwide, is supplied through energy harnessed from solar panels. Covering an area of 2,300 square meters, 560 solar panels have been installed on the roof of one of the ADNEC car parks. These panels heat water for the hotel's 408 bedrooms, two production kitchens, food and beverage outlets, hotel offices and the swimming pool, saving estimated 870-megawatt hours of electricity every year. Also, Jordan Valley Marriot Resort & Spa was the first hotel in the Middle East to have completed the installation of 275 solar panels to generate the energy needed to heat the property’s water. The Crowne Plaza Hotel in Alice Springs has Australia’s largest rooftop solar system. Due to their geographic location, the hotel conducted a full audit to discover energy-saving possibilities. The results inspired a 305kW system that is made up of 1326 photovoltaic panels and covers a roof area of 1650m2. Since the introduction of solar, the Crowne Plaza Hotel has reduced its CO2 emissions by 420 tons per year. Their photovoltaic installation will also produce up to 80 per cent of the hotel’s power requirements. The 1.6 MW rooftop array at the Grand Palladium Hotel is one of Jamaica’s largest solar installations. 6,336 modules designed for self-consumption on site. Excess energy will be fed to the Jamaica Public Service Company (JPS) utility as part of an ongoing power purchase agreement (PPA).

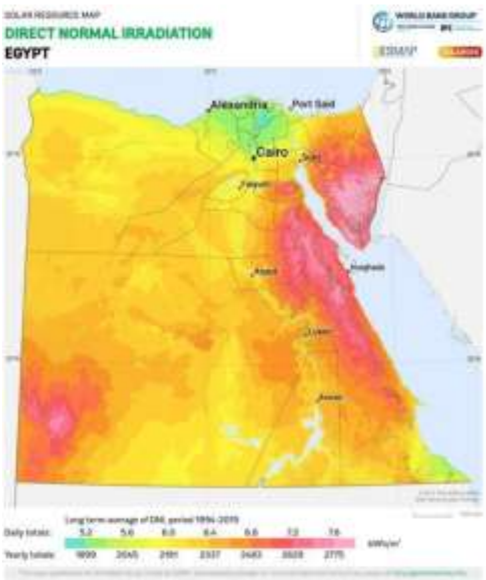


**Figure 1:** shows DNI over Egypt

Mandalay Bay in Las Vegas, USA is one of the largest contiguous rooftop solar photovoltaic arrays in the world generating 6.2 MW of electricity. All these examples and more show how solar energy technologies are being introduced nowadays in the hospitality sector. This paper has been written in the framework of a master thesis under the supervision of Helwan University in Egypt about applying Direct Steam Generation Parabolic Trough in Egyptian hotels. Egypt has an important solar energy potential; the sunshine period is around a 3500 h/year and 290 sunny days per year. It receives an average global solar radiation intensity of 4.3 kWh/m2/day. As mentioned and analyzed by many researchers, the essential factors for the deployment of CSP in a country are the energy situation, the solar resources, the climatic and geographic conditions. These aspects and factors are going to be more detailed discussed throughout this paper. The Egyptian government is making huge plans and progress towards becoming a significant player in the renewable energy industry; it has recognized the need for reforming the electricity sector in order to attract private sector investment in power generation, as it is proven that the private sector will be instrumental to Egypt’s ability to deliver its renewable energy targets. One of the key models that the decision-makers in Egypt are pursuing is the presidential decree of devoting a number of lands for those renewable energy projects, in addition to encourage scientists to work on all tools and facilities that improve those proposed projects. One of the major steps is the presidential decrees (ex. No. 116 for the year 2016) for devoting a number of Egyptian zones (including sub-zones) to be developed and used by the New and Renewable Energy **[15]**.

## 2.Background

### 2.1 Energy considerations in Egypt

The Arab Republic of Egypt is located in North Africa and borders with Libya in the West, Sudan in the South, Palestine Territories and Israel in the East and the Mediterranean Sea in the North. It has an area of approximately 1 million $km^2$. Egypt had a population of around 95 million in 2016. Almost all the population is concentrated along the banks of the Nile (notably Cairo and Alexandria), in the Delta and near the Suez Canal and occupies only 6% of the land, with the remaining 94% of the land as a desert. Most parts of the country have a hot and dry desert climate with extreme heat occurring during summer, as Egypt is considered being a part of the sun belt. An exception is the northern Mediterranean coast which receives more rainfall during winter and has a generally more moderate climate. Egypt’s climate varies greatly depending on the region. There are four climatic regions in the country: mild and humid climate; mild and semi-arid climate, hot and dry climate; hot and humid climate.

Fig. 2. Egypt as part of the solar belt.

**Figure 2:** Egypt as part of the solar belt

The climate in Egypt varies from cold to extremely hot. Along the northern coast of the country the climate is Mediterranean during winter (December through March) – cool, windy and humid, with occasional rains. Summer in Egypt (June through September) is usually very dry with extremely hot temperatures, sometimes breaking 40° C. Many of Egypt's best-preserved sites are in desert regions where it never rains.

## 2.2 Energy situation in Egypt & Renewable Energy plans

Egypt is a resource rich country. According to the US Energy Information Administration, it is the largest non-OPEC oil producer in Africa [1]**]**. Despite this, fossil fuels supplies are being unable to keep up with the energy needs. Egypt's demand for electricity is growing rapidly and the need to develop alternative power resources is becoming more urgent than ever. According to the International Energy Agency IEA , the pattern of energy consumption by end-use in Egypt was 47% for industry, 29% for transport, 20% for buildings, 2% for agriculture and 2% for other sectors. According to the IEA, Egypt's primary energy demand grows by 2.6% [1].It is estimated that demand is increasing at a rate of 1,500 to 2,000MW a year, because of rapid urbanization and economic growth. The shortages have led to frequent electricity blackouts in the country as well as decreasing exports. Once an exporter of oil and gas, Egypt is now struggling to meet its own energy needs. Meanwhile, an increase in Egypt's CO2 emissions is projected at an average annual rate of 2.6%, from 122 Mt in 2003 to 151 Mt in 2010 and 242 Mt in 2039. The main emitter of greenhouse gases (GHG) in Egypt is fuel combustion accounting for 22% in the energy sector, 21% in the industry sector and 18% in the transport sector. The energy sector is expected to remain the major source forGHG emissions in the future and the one to increase its share with the highest growth rate [15]. This presents another compelling reason to monitor and reduce energy consumption in hotels and resorts. Development of the renewable energy industry has become a priority over recent years for the Egyptian government. Egypt's present energy strategy aims at increasing the share of renewable energy, a target expected to be met largely by scaling-up of renewable energy projects. Egypt possesses an abundance of land, sunny weather and high wind speeds, making it a prime location for renewable energy sources. The renewable equipment market is potentially worth billions of dollars. Egypt intends to supply 20 percent of generated electricity from renewable sources by 2022, with wind providing 12 percent, Hydro power 5.8 percent, and Solar 2.2 percent.

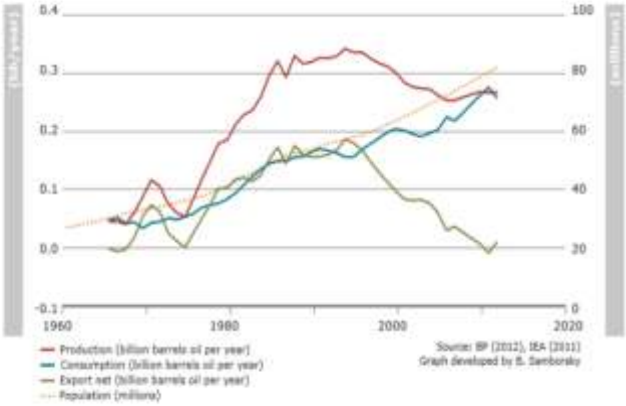


**Figure 3:** Egypt energy supply and demand

The solar energy plan aims to install 3.5 GW by 2027; including 2.8 GW of PV (photovoltaic) and 700 MW of CSP (concentrated solar power). The plan envisions significant private sector involvement, noting that the private sector will take the lead on 67 percent of the plan. Over the next three to five years, the Ministry of Electricity and Renewable Energy plans to add 51.3 GW to current installed capacity [15].

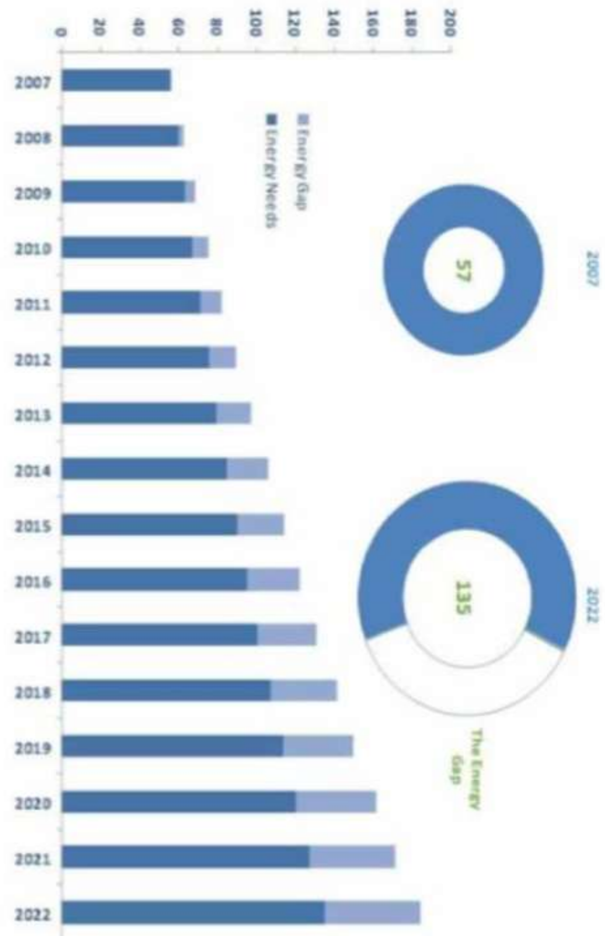


**Figure 4:** Energy consumption in Egypt from 2007-2022

The first Solar Thermal Power Plant at Kuraymat was built in 2011. It has a total installed capacity of 140 MW, with solar share of 20 MW based on parabolic-trough technology integrated with a combined-cycle power plant using natural gas. The power plant is financed from the Global Environmental Facility (GEF) and the Japan Bank for International Development. A 10 MW power plant has been operating in Siwa since March 2015 [15]. Another solar project is the Benban project. Benban project which if successful would be the largest solar PV project in the world, as Benban is widely seen as the Egyptian government's flagship renewable energy project, which will be used to set an example for future initiatives in the sector. Located in the south of the Egyptian territory, the project has an estimated total cost of up to Us$4 billion and will produce 1.8GW of power when operational. The project site consists of a 37 square kilometer plot divided into 39 projects of approximately 50MW each and allocated to special purpose project companies owned by developers and investors. Phase I of the Benban project took place at the end of 2014 [15].

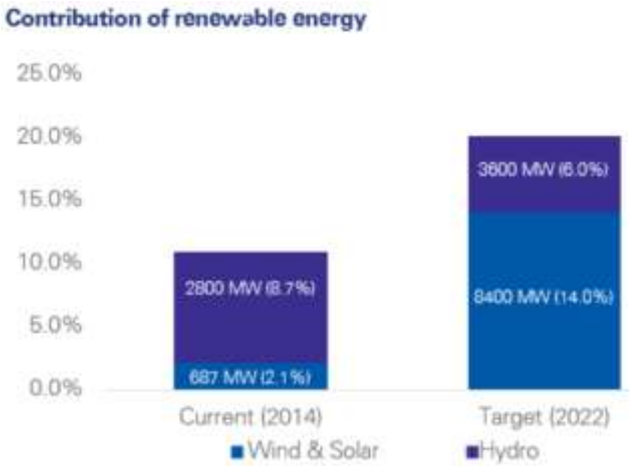


**Figure 5:** Egypt contribution of renewable energy

Finally other two solar energy projects are being discussed, first one Project of solar power station with capacity of 20 megawatts in Hurghada in cooperation with Japanese agency JICA, and second one, project of 20 megawatt solar power plant in Kom Ombo in cooperation with French Agency AFD.

## 3.Energy in Hotels

### 3.1 Energy consumption in Hotels

Hotels use substantial amount of energy and are one of the most energy intensive facilities with correspondingly high energy costs. So, there is an inevitable relationship between hotel industry development and environmental and energy efficiency impacts. Although no collective data is available on global energy consumption in the hotel sector, it is estimated that 97, 5 TWh of energy was used in hotel facilities worldwide in 2007 [12]. Most of this energy is derived from fossil sources, and the hotel sector's contribution to global warming and climate change, is estimated to include annual releases between 160 and 200 kg of CO2 per m2 of room floor area, depending on the fuel mix used to provide energy [12]. The main energy consuming activities in a hotel are: Space conditioning (heating/cooling, ventilation), which is the largest amount of energy in hotels, accounting for approximately half of the total consumption. Also lighting, hot water use, food services, swimming pool, and other activities consume energy [10]. It is thus widely accepted that outdoor weather conditions and floor areas are among the main factors affecting energy use in hotels. The indoor temperature levels also greatly influence the quantity of energy consumed in a building, as it affects the amount of cooling or heating needed. Lighting can fluctuate between a range of 20-24% of a hotel's total energy consumption, depending on the category of the establishment.

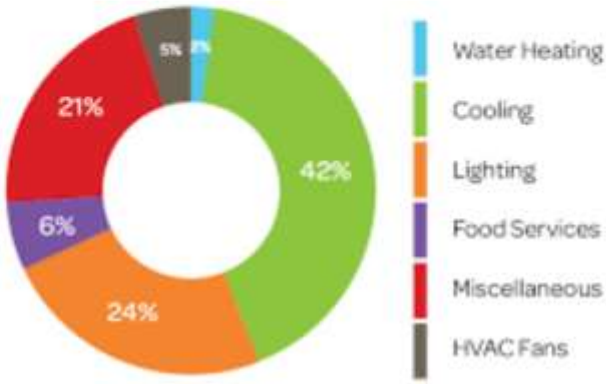


**Figure 6:** Energy consuming activities in hotels

### 3.2 Renewable energy in Hotels

Today there are several solutions for hotels that are ready to think green. Adapting to renewable sources of energy is one of the most beneficial and sensible long-term decisions that any company can take. A large portion of the energy needs in a hotel can be catered to by proven solar technologies [10]. The main intention of the management is to focus its activities in the line of reducing operating costs by introducing new sources of energy that preserve the environment by creating an eco-friendly establishment. Due to the fact that clean and well-preserved environment is one of the main preconditions for high quality service generally in the hospitality-oriented.

**Figure 7:** Grand Palladium Hotel in Jamaica

Most likely, the energy demand will continue growing in the future, so energy planning and use of renewable sources as energy supply alternatives may be a solution for sustainable development. Therefore, various renewable energy technologies which are currently mature and cost effective can be used in hotels. The cost effectiveness of the renewable energy technologies depends on the location and the availability of the energy source. Their use decreases CO2 emissions due to energy use in the hotels and increases their sustainability.

Some successful existing case studies in Europe are:

« Boutique hotel Stadthalle », Vienna (Austria)
« Corfu Mare Boutique Hotel », Corfu (Greece)
« Decoy Country Cottages », Navan (Ireland)
« Hotel Gela », Gela Village Mountains (Bulgaria)
« Hotel a Quinta de Auga» , (Spain)
« Hotel Elda » Lenzumo di Concei-TN (Italy)
« KräggaHerrgard », (Sweden)
« SeehotelWiesler », Titisee (Germany)
« Locada Della Ville Nuova », (Italy)
« AlleGinestre Capri », Anacapri (Italy)
« Arche eco-hotel », (Austria)

### 3.2 Hotels in Egypt

In Egypt, tourism has grown rapidly and almost always constantly over the past 20 years. Recreational tourism domain has increased in particular locations such as Sharm El-Sheikh, Hurghada, Safaga, Taba, Aswan, Siwa, and other places located all over Egypt. Tourism is recognized to be one of the largest contributors to Egypt's economic growth, where most of the sector's new jobs and businesses are being created [11]. According to the Central Bank of Egypt, tourism represents 11.3% of Egypt's GDP (Gross domestic production), 36.4% of the total exported services and accounts for 23% of the country's foreign currency income. According to the statistics in Egypt (2013), the number of hotels is 1193 all over the country [9]. Air conditioning, lighting, water heating and refrigeration represent the main activities demanding electrical energy in hotel business.

| Accommodation Establishment | Energy use per bed night (MJ) | Beds (millions) | Bed nights (millions)[a] | Energy use (PJ) | $CO_2$-emissions (mT)[b] |
|---|---|---|---|---|---|
| Hotels | 130 | 15.98 | 2700.6 | 351.1 | 55.7 |
| Campsites | 50 | 9.05 | 995.5 | 49.8 | 7.9 |
| Pensions | 25 | 4.06 | 686.1 | 17.2 | 2.7 |
| Self-catering | 120 | 3.62 | 611.1 | 73.4 | 11.6 |
| Holiday villages | 90 | 0.75 | 126.8 | 11.4 | 1.8 |
| Vacation homes | 100 | 0.68 | 49.6 | 5.0 | 0.8 |
| Total | – | 34.14 | 5170.4 | 507.9 | 80.5 |

**Figure 8:** Global energy use accommodation (Gössling, 2002)

**a.** A global occupancy rate of 46.4% was assumed here for the categories hotels, pensions, self-catering, and holiday villages (Calculated from data provided by WTO (2001) for 159 countries for the years 1995–1999); for campsites, a lower occupancy rate of 30% was assumed; taking into consideration strong seasonal variations, and for vacation homes, an occupancy rate of 20% was used.
**b.** Based on an emission factor of 43.2 g C/MJ (Schafer and Victor, 1999for the 1990 world electricity generation mix).

The energy consumption per night spent changes a lot, depending on various factors; facilities provided, category of hotel, occupancy, geographical situation, weather conditions, design and control of the installations. Energy benchmarking is an internal management tool designed to provide ongoing, reliable and verifiable tracking on the hotels performance.

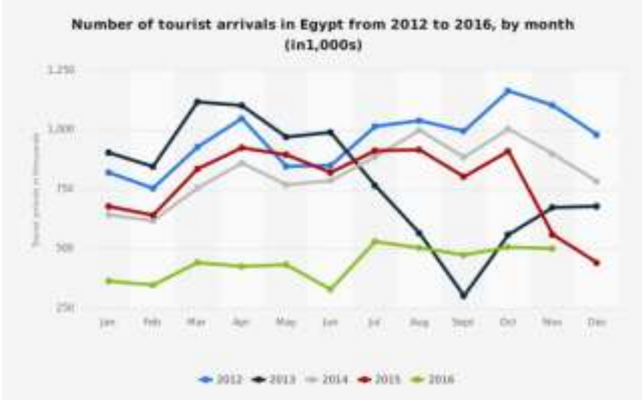


**Figure 9:** Number of tourists from 2012-2016

However, the profitability of the Egyptian hotel sector has been affected negatively after the 2011 revolution and the current political instability in Egypt, with a significant decrease in the number of visitors; this has been affecting the sector income since 2011 [9]. At the same time, the lack of investment on the electrical system in the last years, together with the important growth of the demand side in a country where energy prices are heavily subsidized, have led the system to continuous cuts in the summer season and for a lot of hotels to close during this period, due to the inability of fulfilling the demand and lack of tourists. One of the main strategies of the government is to reduce in the short-medium term the high level of subsidies in natural gas, LPG and electricity; these are the main fuels used by the hotel sector in Egypt.

#### 3.2.1 Egypt's plan for energy in hotels

Green Star Hotel Initiative

The Green Star Hotel Initiative was jointly developed within the framework of the development program; the Deutsche Gesellschaft fürinternationaleZusammenarbeit (GIZ) implements on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ); between Egyptian and German tourism key players: Orascom Hotels & Development; the Travco Group, TUI AG, the Deutsche Gesellschaft fürInternationale Zusammenarbeit (GIZ) and AGEG Consultants. They all joined forces to establish the Green Star Hotel Initiative (GSHI) in 2007, with the aim of improving the ecological performance and competitiveness of Egypt's hotel industry. The initiative is supported and patronized by the Ministry of Tourism and has been linked and supported by the leading international organizations in tourism from the very beginning [11]. The Green Star Hotel Initiative (GSHI) aims to have a profound impact on further development of the main tourism destinations in Egypt. GSHI is doing this by encouraging and motivating the hotel sector to become active and jointly move towards



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the conservation and protection of natural resources by implementing the Green Star Hotel System into their hotel operations, training their staff and involving their guests accordingly [11].

## 4.Methodology

In the following section, we will present the factors affecting the deployment of PTC and LFC plants in Egypt, mainly the geographic and climatic factors. Therefore, we present the meteorological site of Aswan. The weather data is deployed from "Energyplus" and used to perform modeling and simulation of a solar thermal plant using the "Greenius" software. Greenius (Green energy system analysis) is a software developed at the German Aerospace Center DLR (DeutschesZentrumfürLuft und Raumfahrt-ev). It is a powerful simulation environment for the calculation and analysis of renewable energy projects (solar, wind). It offers a combination of detailed technical and economic calculations necessary for the planning and installation of the electricity and thermal power projects. Additional Greenius interfaces give detailed information that supports to define the project in its entirety. The parameters introduced in the interfaces are preset with realistic values that allow achieving more realistic simulation results. In our modeling and simulations of the solar plant the methodology is divided in this way:

- Analyzing and comparing two well-known solar technologies, PTC and LFC plants according to their reflective mirror area to select the more efficient and suitable plant as a model to exploit its power. Technological and dimensional data in the simulations.
- Collecting data: geographic and meteorological data of Aswan, Egypt.
- Simulation: using Greenius software and adopting the suitable technical Parameters for both Parabolic trough collectors and Linear Fresnel Collector plant. Even the available information relative to Egyptian conditions were introduced.
- Discussing the results: Exploring and analyzing the regime for PTC and LFC plant running as monthly behavior during the four seasons of the year. The steam production was analyzed and compared.

### 4.1 Geographic & Climatic factors

**Table 1:** Characteristics of the site

| Zone | Latitude | Longitude | Altitude | DNI |
|---|---|---|---|---|
| Aswan | 23.97ºN | 32.78ºE | 194 m | 2917kwh/m2 |

In order to get the results of this article, the meteorological data are taken from Aswan with the specific parameters mentioned in Table (1)

In this section, the different weather parameters affecting the PTC performance like DNI, ambient temperature, wind speed, and humidity are being schematic simulated.

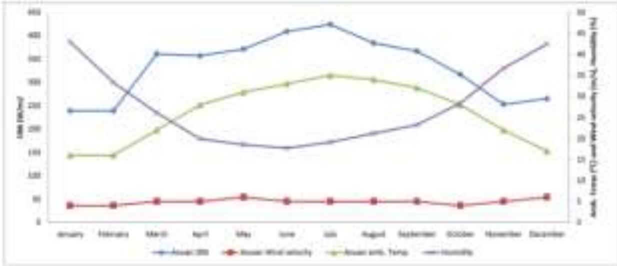

**Figure 10:** Aswan DNI, Amb. Temp. and Wind Velocity, Humidity

### Climate conditions

Aswan has an arid desert climate, with only two main seasons, both of which are dry. The winter months go from November to March, during which the day temperature is warm but during the night can drop to about 12°C and lower in the desert. The annual rainfall is zero; during the winter months, it can rain but just for a few seconds, and every few years a storm takes place, producing floods and power cuts. The summer weather is very hot and dry with low humidity, making high temperatures a lot more bearable. The temperature during the day can be about 40ºC and decreases during the night time to about 20ºC. DNI, ambient temperature and wind velocity have an influence on both PTC performance and LFC performance.

### 4.2 System Description

### 4.2.1 Parabolic trough collector (PTC) description

In this paper, parabolic trough collectors are chosen among the family of solar concentrator to produce thermal energy, as they operate in high temperatures. A parabolic trough solar collector consists of a mirror in the shape of a parabolic cylinder to reflect and concentrate sun radiations towards a receiver tube located at the focus line of the parabolic cylinder. This system is a solar thermal concentrating device, where Direct Normal Insolation (DNI) is reflected and concentrated onto a receiver/absorber where it is converted to heat, then the heat is used to produce steam. By this concept all the solar energy is focused on the tube.

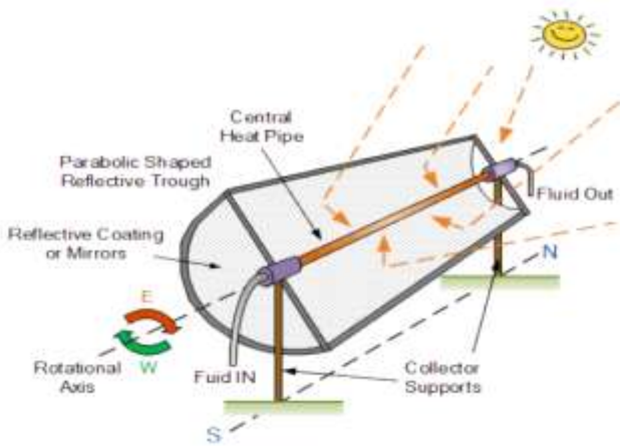


**Figure 11:** PTC schematic diagram

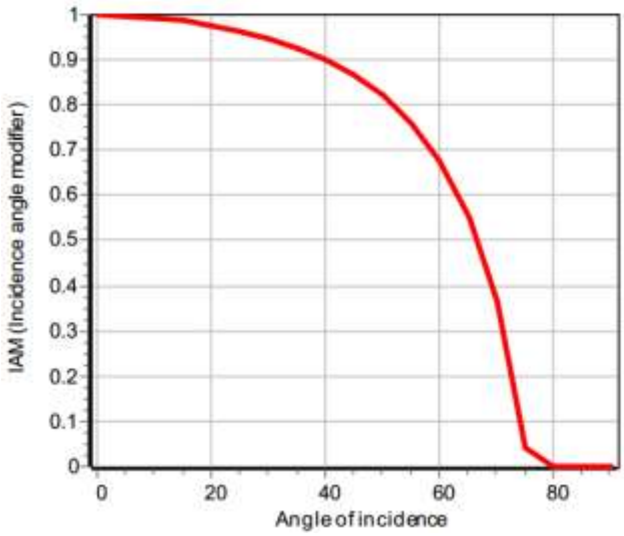


**Figure 12:** IAM Graph for PTC

This is one of the ways to use the PTSCs in solar thermal power plants; it is called Direct Steam Generation (DSG) technology, where the heat transfer fluid (HTF) water inside the absorber pipe is heated to produce steam [6]

### 4.2.2 Linear Fresnel collector (LFC) description

The linear Fresnel reflector technology receives its name from the Fresnel lens, which was developed by the French physicist Augustin-Jean Fresnel for lighthouses in the 18th century. The principle of this lens is the chopping of the continuous surface of a standard lens into a set of surfaces with discontinuities between them. This allows a substantial reduction in thickness (and thus weight and volume) of the lens, at the expense of reducing the imaging quality of the lens [14].

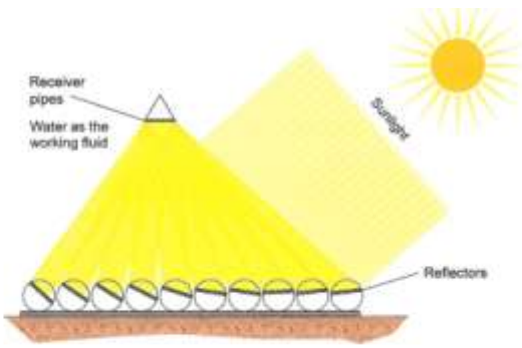


**Figure 13:** LFC schematic diagram

The mirrors in the realized linear Fresnel collectors are made of flat mirror stripes, which receive a small curvature by mechanical bending. Like in parabolic troughs, the reflecting material is silver. In the case of the Novatec Solar plants, the mirrors are glass mirrors with a glass layer of 3mm thickness [14].

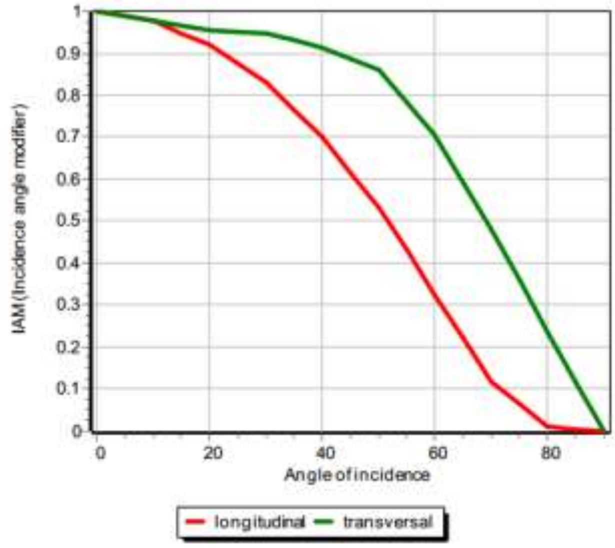


**Figure 14:** IAM Graph for LFC

### 4.2.3 PTC vs. LFC

Fresnel power plants are in a competitive situation with parabolic trough power plants. Roughly, the advantages of Fresnel power plants are the considerably lower investment costs for the solar field (at the same aperture area) and, hence, of the whole power plant (at the same nominal power), the lower operation and maintenance cost and the higher land use efficiency [13]. The disadvantage is that the solar-to-electric efficiency is still lower [7]. The efficiency disadvantage of Fresnel power plants over parabolic power plants is principally caused by optical losses. The Fresnel collector does not follow the Sun, as it is the case with parabolic troughs. What tracks the Sun are the individual mirrors or mirror rows. This implies some optical losses that do not exist (or that do not exist in the same sense) at parabolic troughs.

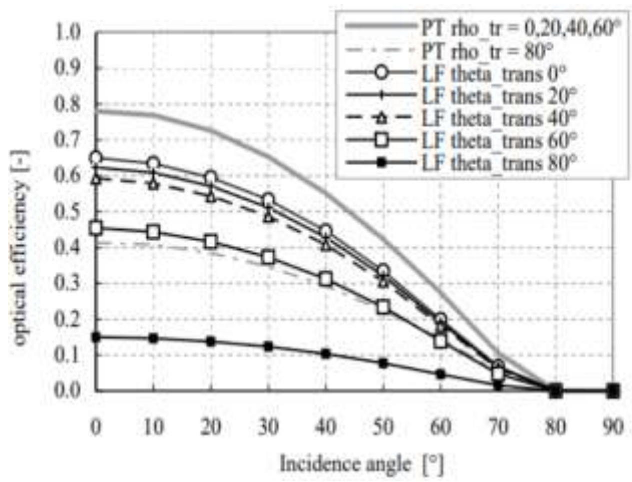


**Figure 15:** Optical efficiency for LFC&PTC

Fresnel collectors do not have only longitudinal cosine losses, but they are affected also by transversal cosine losses. Parabolic troughs, on the contrary, have only longitudinal cosine losses. Transversal losses do not exist because of the tracking of the complete trough. This is the most important additional optical loss factor at Fresnel collectors in comparison to parabolic troughs [13]. The parallel mirror rows shade each other at high transversal incidence angles. They also block parts of the reflected radiation at high transversal incidence angles.

**Figure 16:** Radiation losses on LFC surface

The use of flat mirrors allows a cost reduction compared to curved mirrors [13]. The mirror stripes are curved slightly in the collector space frame, but the stripes themselves are flat. Parabolic troughs, on the contrary, need mirrors that are already produced in a curved form. Cleaning is simpler for Fresnel mirrors than for parabolic troughs [7].The alignment of the mirror stripes in one plane has the advantage that wind loads are reduced.

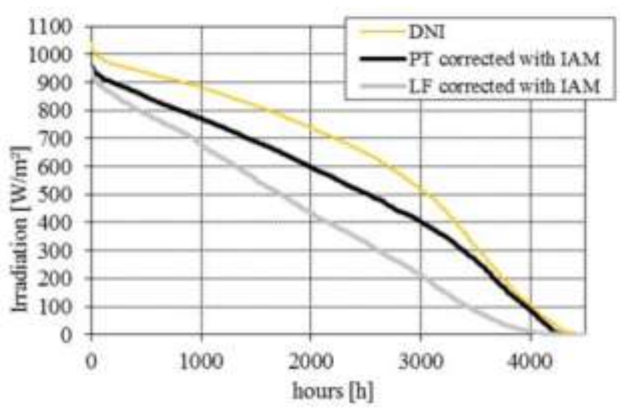


**Figure 17:** Irradiance on LFC&PTC surface

After comparing between the two systems, mentioning some of the advantages and disadvantages, the next section of the paper is going to discuss the more efficient and suitable technology for the hospitality sector due to a simulation that is going to be presented.

## 5.System Simulation

**Parabolic Trough vs. Linear Fresnel**

**Table 2:** PTC Direct Steam Generation Parameters (Euro trough 2 with Schott HCE)

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| Collector length | 148.5 m | Collector width | 5.8 m |
| Optical efficiency | 75% | Focal length | 1.7 m |
| Number of rows | 2 | Effective mirror area | 16350 m2 |
| Number of Collector | 10 | DNI | 1000 W/m2 |

**Table 3:** LFC Direct Steam Generation Parameters (Novatech Fresnel)

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| Collector length | 44.8 m | Collector width | 16.6m |
| Optical efficiency | 67 % | Focal length | 7.4 m |
| Number of rows | 4 | Effective mirror area | 16435 m2 |
| Number of Collector | 8 | DNI | 1000 W/m2 |

### 5.1 Simulation Analysis of the solar thermal plants deployed in Aswan, Egypt

**Exploration of the solar plant simulation results**

The variations of different flows and thermal outputs that come into play during the operation of the simulated solar thermal plant and the monthly performances were discussed. The considered amounts of energy at various stages of the solar plants are:

- **Hdn:** The intensity of direct solar radiation DNI multiplied by the apparent surface of the reflectors. This value can be interpreted as the solar energy available for the solar collectors.
- **Qabs**: Amount of heat absorbed by the vacuum tubes receiver.
- **Qcol**: Amount of heat at the output of the collectors (Qabs- thermal losses in absorbers).
- **Qfield**: Amount of heat at the output of solar concentrator's field (Qcol-heat loss from pipes).
- **Qout**: Amount of heat available for the production of steam.

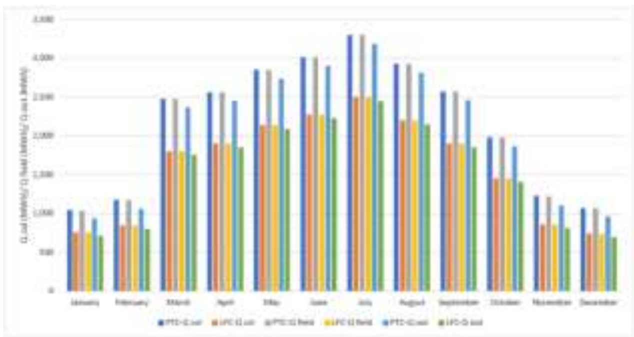

**Figure 18:** Hdn and Q abs for LFC&PTC

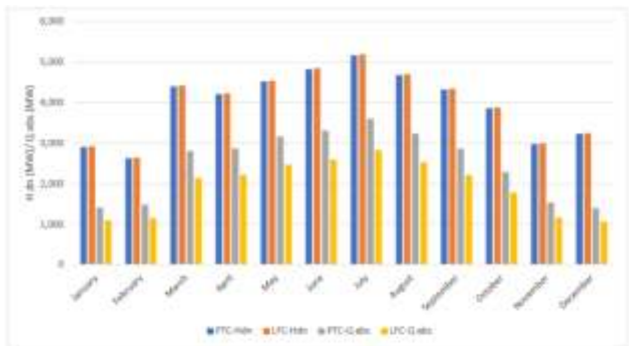

**Figure 19:** Qcol/ Qfield/ Qout for LFC&PTC

This section of the simulation discusses the thermal energy collected and the output produced by both technologies, PTC and LFC by the solar field during the year depending on the installed area of the solar collectors. To be able to compare the CSP and the LFC performance in terms of both energy production and reflective mirror area both plants were sized so that the reflective mirror area for both systems becomes approximately very close in value, as the PTC reflective mirror area was 16350 m2 and the LFC system reflective mirror area was 16435 m2 shown in table (2), and table (3). In this study the chosen compared criteria is mainly the reflective mirror area and the land use of the hotel. It has to be very carefully considered because one of the main aspects of any hotel is to use the whole land area as much as possible to fulfill all the activities and services needed, so it would matter a lot how much land I'm going to use for applying a solar system and on the other hand how much energy I will get in return. The simulation was deployed in Aswan with a DNI value of 2917 kwh/m2. The results show that a LFC system in Aswan will produce a total output of 18766.95 MWh/a. On the other hand, the PTC plant deployed on a same area of land would produce in Aswan an output of 24813.35 MWh/a.

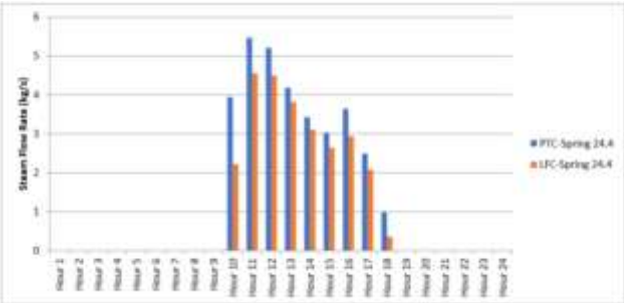

**Figure 20:** Steam flow rate during Spring

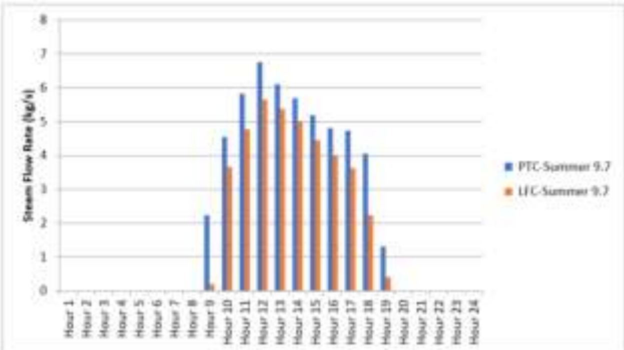


**Figure 21:** Steam flow rate during Summer

In this part of the simulation, the PTC and LFC Direct steam Generation is being obtained for the city Aswan during the 4 different seasons of the year. After searching and analyzing, it has been proven that the main need of a hotel is steam, as it is being consumed in various sections for most services. That's the main reason for applying this simulation for steam production mainly, showing the results and ratios of steam flow rate as shown in Figure (20), (21), (22), and (23). Discussing the results of this simulation and the comparative simulation between the PTC and LFC is going to be presented in the next section of the paper.

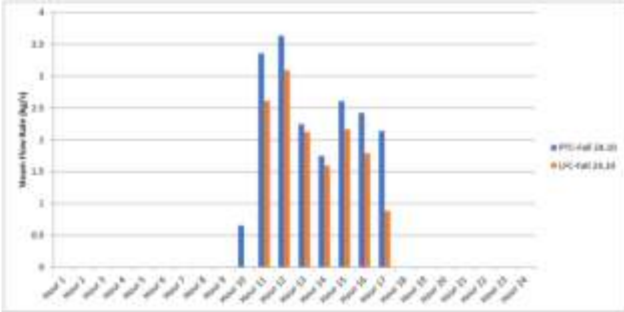

**Figure 22:** Steam flow rate during Fall

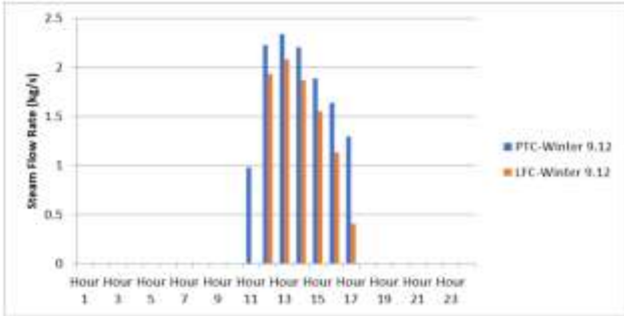


**Figure 23:** Steam flow rate during Winter

## 6.Results & Discussion

In order to compare the PTC with the LFC technology in terms of their amount of output, it was assumed to size approximately the same reflective mirror area for both technologies to see what amount of output can be produced under the same circumstances of both PTC and LFC. Simulation had shown that under the same climatic and geographic features and under deploying both systems with an approximately equal reflective mirror area the LFC output in Aswan reached an amount of 18766.95 MWh/a. On the other hand the PTC plant deployed on a same reflective mirror area would produce an output of 24813.35 MWh/a. Despite the differences between both technologies, it is being only compared in terms of reflective mirror area not any technical aspects because the main interest of any hotel and investment is land and how it is being used providing all the services needed with reducing cost and getting the best service. According to the simulation presented and mentioned with its results, it is very obvious that the current state of solar heat production with Linear Fresnel collectors, will be extended by Parabolic Trough collectors into higher temperature sectors for the process steam production and this is the suitable technology for applying on a hotel. These systems offer a wide range of opportunities to reduce costs of the energy supply. The high thermal output from parabolic trough collectors can be used for producing process steam for powering double absorption chillers for air conditioning as well as for steam consumers as laundry and food preparation, especially in high load periods. So, every kind of thermal energy request in hotels can be supplied by solar energy. After deploying the PTC and LFC Direct steam Generation in Aswan the steam flow rate presented in Figure (20), (21), (22) and (23), shows that the ratio for Aswan during the 4 seasons varies from 2 – 7 kg/s steam for the PTC and the amount lies for the LFC between 1 – 5 kg/s of steam. This amount calculated on a monthly basis for instance, would make a huge economic and environmental difference for any hotel, as it is going to fulfill the energy saving demand which will lead automatically to reducing energy and electricity costs. Finally, this simulation can be applied to any hotel or resort with different parameters and inputs depending on the hotel's needs, consumption, location, area, and other criteria, and it's going to fulfill all the needs required and even can make a hotel achieve being a zero-energy building. That means less energy costs, more income, safer building, and greener environment.

## 7.Conclusion

The Hospitality sector worldwide nowadays is increasing and developing rapidly, using more technology and providing more services, which automatically leads to a higher energy demand and higher costs. Egypt's energy consumption is increasing day by day and fulfilling then demand for the other sectors is already struggling. Tourism in Egypt is represented on a huge scale that is growing that's why it is necessary to find other alternatives to fulfill at least this sector with green energy sources. Parabolic trough collectors are able to deliver high temperature heat, which is a basic condition for the efficient utilization of great amounts of solar heat in hotels. These systems offer a wide range of opportunities to reduce costs of the energy supply. If applied in a suitable way for the hospitality sector it can ensure a sustainable future with less struggles and shortages, this field is getting more spotted throughout a lot of researches and experiments, to reach the perfect alternative for the future.

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