An-Najah National University
Faculty of Graduate Studies

Design and Assessment of Parabolic Trough Concentrated Solar System for Palestine: Case Study of Al-Arz Ice Cream Factory

By
Rand Hasan Abd Al-Fatah Khraisheh

Supervisor
Dr. Mohammed Alsayed

This Thesis is Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Clean Energy Engineering and Energy Conservation, Faculty of Graduate Studies, An-Najah National University, Nablus, Palestine.
2021

Design and Assessment of Parabolic Trough Concentrated Solar System for Palestine: Case Study of Al-Arz Ice Cream Factory

By

Rand Hasan Abd Al-Fatah Khraisheh

This Thesis was Defended Successfully on 21/1/2021 and Approved by:

Defense Committee Members	**Signature**
1. Dr. Mohammed Alsayed \ Supervisor	....
2. Dr. Mahmoud Salah Ismail \ External Examiner	....
3. Dr. Abdelrahim Abusafa \ Internal Examiner	....

Dedication

Praise be to Allah, Lord of the worlds

To the Prophet Mohammad Blessings and Peace be upon him

To my father

To my mother

To my brother and sisters

To my precious ones To all friends and colleagues

To my teachers

To everyone working in this field

To all of them

I literally dedicate this work

Acknowledgement

First of all, I would like to express my gratitude to Almighty Allah for giving me the ability and patience to complete this thesis well.

Successfully completion of any type of project requires helps from a number of persons, In particular, I would like to appreciate Dr. Mohammad Al-Sayed, and Dr.Majed Eshtaya who were have a major effort in supporting me to move forward, and helping me to work hard to achieve the success of this thesis.

Many people have given me their blessings and pledges of the heart, they are the people who cannot be forgotten or overlooked.. those who have the favor for all that I have reached today and what I may reach tomorrow, they are my parents, my family, brother and sisters, who I am proud of being their sister.. they have all my Love and thanks for everything and for their presence in every step of my life.

Last but not least, thanks to everyone who contributed to success of this project, directly or indirectly. Apologizing for not mentioning them by name, for fear of forgetting one of them

الاقرار

أنا الموقعة أدناه مقدمة الرسالة التي تحمل العنوان:

Design and Assessment of Parabolic Trough Concentrated Solar System for Palestine: Case Study of Al-Arz Ice Cream Factory

أقر بأن ما اشتملت عليه هذه الرسالة إنما هي نتاج جهدي الخاص ،باستثناء مـــا تمــت الإشارة إليه حيث ما ورد، وإن هذه الرسالة ككل، أو أي جزء منها لم يقدم من قبل لنيــل أيــة درجة عملية أو لقب علميا وبحثي لدى أية مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's name: رزن حسين عبد الفتاح خريشي **:اسم الطالب**

Signature: **:التوقيع**

Date: 21/1/2021 **:التاريخ**

List of Symbols

Symbols	Definition	Unit
A	Area	m^2
a	Aperture length	m
C	Concentration ratio	-
Cp	Specific heat	J/(kg K)
D	Diameter	m
F	View factor	-
f	Focal length	m
G	Irradiation	W/m^2
h_o	Heat transfer coefficient	W/m^2K
h	Concentrator height	m
h_d	Annulus gas conduction heat transfer coefficient	W/m^2K
k_a	thermal conductivity of the annulus gas at standard temperature and pressure	W/m^2
l	Collector length	m
m	Mass	kg
Nu	Nussselt number	-
p_r	Prandtl number	-
p_v	Annulus gas pressure	N/m^2
Q	Energy per unit time	W
R	Reflectance	-
R_e	Reynolds number	-
T	Temperature	K
V	Wind velocity	m/s
x,y	Coordinates	m
Greek		
ρ	concentrator reflectivity	-
α	Absorbance	m
E	Emittance	-
γ	Ratio of specific heats	-
Φ	Insolation rate	-
σ	Stefan Boltzmann constant	W/m^2K^4
T	Transmittance	-
Θ	Free mean path	m

Table of Contents

No.	Content	Page

List of Tables

List of Figure

Design and Assessment of Parabolic Trough Concentrated Solar System for Palestine: Case Study of Al-Arz Ice Cream Factory

By

Rand Hasan Abd Al-Fatah Khraisheh

Supervisor

Dr. Mohammed Alsayed

Abstract

In this thesis, a new solar-based renewable energy system integrated with PTSCs (parabolic trough solar collectors) is proposed, designed and analyzed for an ice-cream factory located in Nablus, Palestine. The Present system includes a PTSC system to cooperate with the heating boiler in the factory to meet the heat energy demand for heating the ice-cream mixture. Comprehensive energy and exergy analysis of the system are carried out for determining the performance characteristics of the actual and the proposed processes. Instead of conventional energy resources, establishment of this kind of energy systems provides better operating conditions energetically, economically, environmentally and hence sustainably. The results show that the actual system produce 487.66 kW, by using input power of 750.25kW, while the energy that could be conserved from using the proposed system is calculated to be 804 kWh per day as it is restricted with a specific area of $250m^2$, on the other hand it works on saving almost $407.9kgCO_2$/day.

It is worth mentioning, that changes have been made to some sensitivity factors, such as the interest rate, life of the project, and the initial investment. As these changes affected the results of the project in general, so that it resulted in making the project economically feasible in certain

circumstances, including the time when the project is 30 years old, the interest value of 8% and the investment value of 2000$/kW, and in another scenario when the project is 25 years old, the interest is 8% and the initial investment for the 2000$/kW project

Chapter One

Introduction

Chapter One
Introduction

1.1 Introduction

Humans need of energy has led to consume resources in a harmful way, which causes several problems to the planet earth and not to mention how costly it is. Among many global challenges, the problem of natural resources depletion is one of the biggest problems facing us today. That is based on the indiscriminate and unintentional exploitation of environmental resources, which generally leads to reducing the value of the resource or disappearing from its role in the ecosystem.

The increase of energy usage is considered as one of the biggest issues that world faces and needs to deal with on a much immense scale. It is important to mention that in the new policy scenario, the rising of income will lead in increase of population, where Population growth and continuous increasing of life style quality are the main reasons of environmental pollution. The Population in the world currently is growing at a rate of around 1.05% per year. And since the population for the year 2020 has reached nearly 7.8 billion, that means the current average population increase is estimated at 81 million people per year. Figure (1) shows the annual global population growth for the last 70 years [(World Population Clock: 7.9 Billion People (2021) - Worldometer, 2021)]. And table (1) below for more clarification.

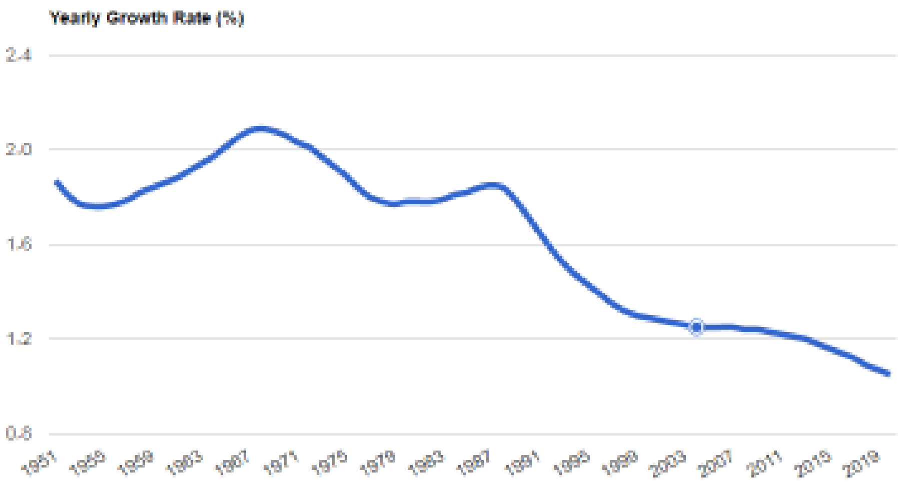


Figure (1): Average annual global population growth rate [(World Population Clock: 7.9 Billion People (2021) - Worldometer, 2021)].

Table (1): World Population growth (1995-2020)(Worldometer, 2021).

Year (July 1)	**Population**	**Yearly % Change**	**Yearly Change**
2020	**7,794,798,739**	1.05%	81,330,639
2019	**7,713,468,100**	1.08%	82,377,060
2018	**7,631,091,040**	1.10%	83,232,115
2017	**7,547,858,925**	1.12%	83,836,876
2016	**7,464,022,049**	1.14%	84,224,910
2015	**7,379,797,139**	1.19%	84,594,707
2010	**6,956,823,603**	1.24%	82,983,315
2005	**6,541,907,027**	1.26%	79,682,641
2000	**6,143,493,823**	1.35%	79,856,169
1995	**5,744,212,979**	1.52%	83,396,384

Moreover the international energy agency in the world energy outlook expects that the population will reach 7.1 billion people most of which will happen in urban areas and emerging economies, and this will increase global energy demand by more than a quarter through 2040 [(World Energy Outlook 2019 – Analysis - IEA, 2021)]. This encourages governments to work on finding different environmentally friendly methods of producing energy. These methods are different from the traditional methods that lead to health and environmental problems such as the fossil fuels as coal, natural gas and oils that supply most of the energy that is used globally. While fossil fuels represent 86% of the world's energy source in 2015, non-fossil fuels are expected to account for half of the growth in energy supply over 20 years

In the coming years, however, the forecasts indicate that oil and gas, in addition to coal, will remain the main source of energy that occupies the global economy, including 75% of the total energy supply in 2035 (Energy Outlook | Energy economics | Home, 2020).

As well as we have to keep in consideration of the limited amount of recourses that are available.

As a direct consequence of population growth and increasing quality of life, natural resources depletion rate will become much higher. Taking into consideration that human beings are still strongly depending on the limited fossil fuels sources, other related economic and political crises will become more significant [(World Population Clock: 7.9 Billion People (2021) - Worldometer, 2021)]. Figure (2) below shows how consumption of liquid fuel is estimated to grow over the next decade (Macmillan, 2019).

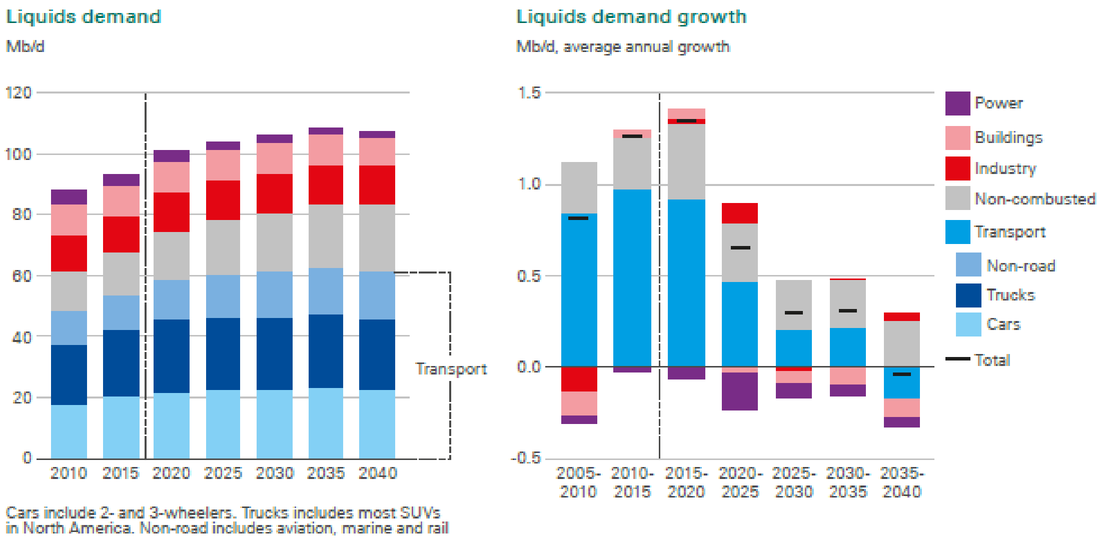


Figure (2): Consumption of liquid fuels grows over the next decade before broadly plateauing in the 2030s

Where the transport demand for liquid fuels increases from 56 Mb/d to 61 Mb/d by 2040, and the industrial demand increases from 70 Mb/d to almost 97 Mb/d (Macmillan, 2019).

In addition, environmental pollution is one of the most controversial environmental problems facing governments. The Global warming, which is an increase in the temperature of the Earth, occurs when carbon dioxide and other polluting gases accumulate in the atmosphere and absorb sunlight and solar radiation that have bounced off the earth's surface. These pollutants, which can last for years to centuries in the atmosphere contribution in making the planet hotter. Each year, scientists learn more about the consequences of global warming, and many agree that environmental, economic, and health consequences are likely to occur more clearly if current trends continue. And will be on a date with melting glaciers, early snowmelt, and severe droughts will cause more dramatic water shortages and increase the risk of wildfires, rising sea levels will lead to coastal flooding. Forests, farms, and cities will face troublesome new pests, heat waves, heavy downpours, and increased flooding. All those factors will damage or destroy agriculture and fisheries, disruption of habitats such as coral reefs and Alpine meadows could drive many plant and animal species to extinction, and Allergies, asthma, and infectious disease outbreaks will become more common due to increased growth of pollen-producing ragweed, higher levels of air pollution, and the spread of conditions favorable to pathogens and mosquitoes [(What is Acid Rain? | US EPA, 2021)].

In addition to, acid rain, which can be defined as precipitation loaded with acidic components, such as sulfuric acid or nitric acid, it may also be known as acid precipitation. It can fall to the ground in various forms, which may be wet or dry. This can include rain, snow, fog, hail, or even acid dust, While a small portion of the SO_2 and NO_X that cause acid rain is from natural sources such as volcanoes, most of it comes from the burning of fossil fuels. The major sources of SO_2 and NO_X in the atmosphere is burning of fossil fuels to generate electricity. Two thirds of SO_2 and one fourth of NO_X in the atmosphere come from electric power generators. acid rain a problem for everyone and not just those who live close to these sources [(What is Acid Rain? | US EPA, 2021)].

Acid rain affects almost everything. Such as plants, soil, trees and buildings and thus on human health. The effect of acid rain is very bad for the soil and trees, where acid deposits are deposited in the breeding, such as calcium, releasing aluminum to it, which makes it difficult for trees and plants to absorb water, and therefore their death, causing damage to forests, especially the high ones (Acid Rain, 2021). Also, these rains can change the formation of water bodies. In fact, for example, acid rain increases the pH of lakes or rivers , therefore it makes it unsuitable for domestic animals and plants (Acid Rain: Causes, Effects and Solutions, 2021).

Climate change, and loss of biodiversity are among the long list of its harmful consequences. Where The main cause of climate change is global warming, It is the long-term alteration of temperature and typical weather patterns in a place. It may cause weather patterns to be less predictable. These unexpected weather patterns can make it difficult to maintain and grow crops in regions that rely on farming because expected temperature and rainfall levels can no longer be relied on. Climate change has also been connected with other damaging weather events such as more frequent and more intense hurricanes, floods, downpours, and winter storms. In polar regions, the warming global temperatures associated with climate change have meant ice sheets and glaciers are melting at an accelerated rate from season to season. This contributes to sea levels rising in different regions of the planet. And together with expanding ocean waters due to rising temperatures, the resulting rise in sea level has begun to damage coastlines as a result of increased flooding and erosion (Society, 2021), And will also led to change in ecosystem and desertification, extreme wither phenomena, massive migration and extinction of species

(What is climate change? | ACCIONA | Business as unusual, 2021). On the other hand the loss of diversity means losing the link between all organisms on earth, binding each into an interdependent ecosystem, in which all species have their role. It is the web of life, simply, reduced biodiversity means millions of people face a future where food supplies are more vulnerable to pests and disease, and where fresh water is in irregular or short supply. And According to IUCN, the World Conservation Union, the monetary value of goods and services provided by ecosystems is estimated to amount to some US$33 trillion per year. It is worth to mention, that The number of harvest plants for traditional and modern medicine worldwide is estimated to range between 50,000 and 70,000. This will greatly affect people's healthy and economic lives (Biodiversity loss has an enormous impact on humans, according to a UN report, 2021).

Therefore depending on fossil fuels mainly coal and oils cause various types of pollution. that affects air quality, water, and soil due to their residues, which are generated during its extraction, transportation, and combustion phases (NREL, 2001).

Without finding sustainable solutions, these problems will grow rapidly, and might exceed irreversibility limits. Sustainable solutions should focus on reducing or slowing down energy consumption growth rate, and finding renewable alternatives. Therefore, it is known that renewable energy is one of the types of energy that is inexhaustible.

Renewable energy uses energy sources that are continually replenished by nature, the sun, the wind, water, the earth's heat, and plants. Renewable energy technologies turn these fuels into usable forms of energy—most often electricity, but also heat, chemicals, or mechanical power, such as hydropower, that can be defined as a method of using water to produce energy, where hydropower plants are convert energy in flowing water to electricity. And the most common form of hydropower is using a dam on a river, to collect water in reservoirs and then this water used to release through turbines to generate power.

It is known that there is no emissions comes out from using hydropower plants to produce energy, but it make huge damage in aquatic life, where the turbines prevent fish from migration, and killed Many marine organisms (Causes, Effects and Solutions for Resource Depletion - E&C, 2019).

Bioenergy is the energy derived from biomass (organic matter), such as plants. If you've ever burned wood in a fireplace or campfire, you've used bioenergy. But we do not get all of our biomass resources directly from trees or other plants. Many industries, such as those involved in construction or the processing of agricultural products, can create large quantities of unused or residual biomass, which can serve as a bioenergy source. Replacing some coal with biomass is a low-cost option to reduce undesirable emissions. Biomass has less sulfur than coal. Therefore, less sulfur dioxide, which contributes to acid rain, is released into the air.

Additionally, using biomass in these boilers reduces nitrous oxide emissions. A process called gasification: the conversion of biomass into gas, which is burned in a gas turbine is another way to generate electricity. The decay of biomass in landfills also produces gas, mostly methane, which can be burned in a boiler to produce steam for electricity generation or industrial processes. Biomass can also be heated in the absence of oxygen to chemically convert it into a type of fuel oil, called pyrolysis oil. Pyrolysis oil can be used for power generation and as a feedstock for fuels and chemical production.

Biofuel is a biomass transfer to liquid, it is favorite to use, due to its possess high energy density, and easy to transfer. ethanol, is the most common biofuel, where it is alcohol made from the fermentation of biomass high in carbohydrates. The current largest source of ethanol is corn. Some cities use ethanol as a gasoline additive to help meet air quality standards (NREL, 2001).

On the other hand there is a geothermal energy, where the Temperature of the core 4000 miles below ground may reach 8680°C, this heat flows outward from the core of the earth, and heat the surrounding space. This heat can be tapped in heating water, producing electricity, and in heating and cooling the buildings by using tanks of hot water and steam. Hence, this energy needs to be used for direct applications, so that the direct use of the water in the well dug inside the underground thermal energy tanks is provided, as this provides a steady flow of hot water.

Sometimes this water passes through the heat exchanger, which keeps the water separate from a working fluid (usually water or a mixture of water and antifreeze), which is heated by the geothermal water. The working fluid then flows through piping, distributing the heat directly for its intended use. The heated water or fluid can be used for example in a building to replace the traditional heat source (NREL, 2001).

Electricity could be produced by piped steam or hot water up to drive steam turbine that power electrical generator, Typically, the water is then returned to the ground to recharge the reservoir and complete the renewable energy cycle. As there is three type of geothermal power plants one draw from steam reservoir such as dry steam plants, but the other two plants: flash steam, draw from reservoir of hot water at temperatures greater than 360°F. And binary cycle, which using hot water reservoir and could be operate at a temperature of about 225° to 360°F (NREL, 2001), there is also GHPs technology which draw the temperature of the shallow ground that is in range of 50°F to 70°F for heating buildings in the winter by extracting heat from the ground and releasing it into the building. Because GHPs actually move heat between homes and the earth, instead of burning fuels, and keeping them cool in the summer Using the principle of the refrigerator, which discharge the heat from inside the building into the ground (NREL, 2001).

Wind energy cannot be forgotten, thousands of years ago people have used windmills to harness the wind’s energy. but now a days, wind turbines are used as they are more effective technology, wind turbine technology may seem simple, however, the turbines are very sophisticated system that capture the wind energy, the wind drives the blades of the turbines that are connected to a central axis, which is connected to a shaft, supplies the generators, to generate electric power. the range capacity of the wind turbines that provide small utility, such as homes, and charging batteries with electricity can be in a range of 50kW to 2MW, and the Large, utility-scale projects can have hundreds of turbines spread over many acres of land (NREL, 2001).

And the most important is solar energy, that takes the greatest interest among the energy sources, in which solar radiation is used to produce electric or thermal energy or other energies that can be used in many fields by using many different applications that have spread widely in the world, basically all these applications consist of three main items: modules that convert sunlight into electricity; inverters that convert that electricity into alternating current so it can be used by most household appliances; and possibly or sometimes batteries that store excess electricity produced by the system (NREL, 2001). And there is a different available technologies for using solar to produce various type of energies including electricity and thermal energy.

Solar electricity has been a prime source of power for space vehicles since the inception of the space program. It has also been used to power small electronics and rural and agricultural applications for three decades.

During the last decade, a strong solar electric market has emerged for powering urban grid-connected homes and buildings as a result of advances in solar technology along with global changes in electric industry restructuring.

Photovoltaic (PV) is a technology using to convert sunlight directly into electricity. The PV systems are divided into two types, one of which is connected to the network called "on-grid" in case of available of Any additional electrical energy produced by PV and not being used in homes or facilities can be fed back to the electric grid through a process known as net metering. Which allows electricity customers to pay only for their “net” electricity. The other type which is not connected to the network called "off-grid" the batteries are used to store energy, which usually store electricity for up to three days (NREL, 2001).

And of course in remote areas, solar electricity is often a economic alternative to expensive distribution line extensions incurred by a customer first connecting to the utility grid (NREL, 2001).

Unlike solar-electric systems that convert sunlight directly to electricity, solar thermal electric systems converts sunlight into thermal energy and then to electricity, Concentrated solar technologies (CSP) convert solar energy into thermal energy or electricity by using mirrors to focus sunlight on a component called reservoir that contain heat transfer fluid to heat water to produce steam that passes through the steam turbines connected to the generator to convert heat to electrical energy. There are three type of Concentrating solar technologies (CSP) can be used to generate electricity for a variety of applications, ranging from remote power systems as small as a few kilowatts (kW) or to grid-connected applications of 200 MW or more, and they are: parabolic trough systems, power towers, and the dish Stirling engine systems. A parabolic trough systems using parabolic mirrors to reflect the sunlight to a pipe reserve with the heat transfer fluid at the long of the mirrors to generate electricity. Power towers use a large filed of mirrors to concentrate sunlight onto the top of a tower, where a receiver sits (NREL, 2001). And finally the dish Stirling engine, which gives the lowest capacity between the three technologies, uses a mirrored dish, That dish-shaped surface focuses sun’s heat onto a receiver at the focal point of the dish (above and center of the collectors). The receiver absorbs the sun’s heat and transfers it to a fluid within an engine, where the heat causes the fluid to expand against a piston to produce mechanical power. The mechanical power is then used to run a generator or alternator to produce electricity (NREL, 2001).

And solar water heater, that produce heat energy by heating the water flows pipes in the solar collectors depending in the sunlight. it is also have a storage tank. Additionally it is divided in o two types: first one with a circulating pumps called active: where the pump circulate the household water through the collators and into the home and that is call "direct circulate system", and the "indirect circulate system", which circulate the non- freezing heat transfer fluid through the collectors and then heat exchanger. The other type called Passive Solar Water Heating Systems, which is usually less expensive than active system, but not efficient, it had Integral collector-storage passive systems type, these work best in areas where temperatures rarely fall below freezing. They also work well in households with significant daytime and evening hot-water needs. And thermosiphon systems type, water flows through the system when warm water rises as cooler water sinks. The collector must be installed below the storage tank so that warm water will rise into the tank (Solar Water Heaters, n.d.).

The main and the global aims of making the major dependence in producing energy on natural resources can be shorted in six points:

1. Less global warming: traditional way of producing energy and the human life behavior overloaded the atmosphere with carbon dioxide and other emissions. In contrast, most renewable energy sources produce little to no global warming emissions. The comparison becomes clear when you look at the numbers in figure (3) (Benefits of Renewable Energy Use, 2017).

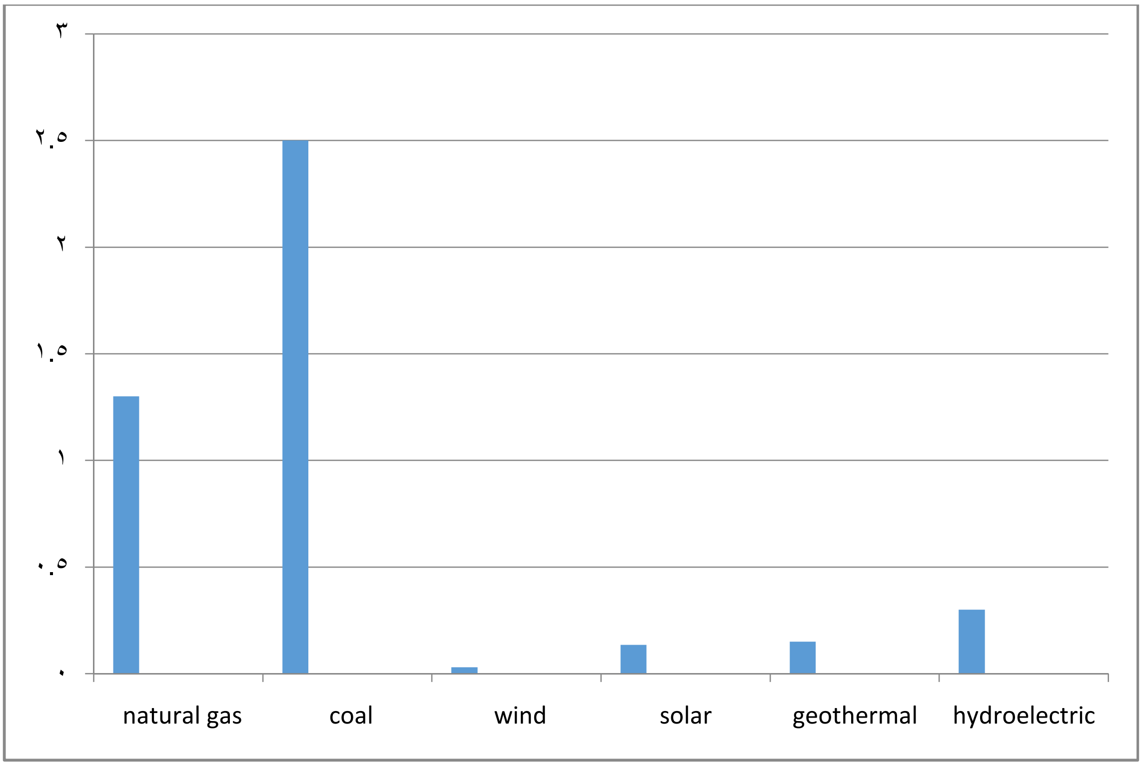


Figure (3): the average amount of carbon dioxide emit by different resources (pound of CO_2/kWh).

2. Improved public health: in a study for Harvard university estimate the life cycle costs and public health effects of coal to be an estimated $74.6 billion every year, which equivalents to 4.36 cents per kilowatt-hour of electricity produced. Overall Wind, solar, and hydroelectric systems generate electricity with no associated air pollution emissions, where breathing problems, neurological damage, heart attacks, cancer, premature death, and a host of other serious problems Most of these negative health impacts come from air and water pollution that clean energy technologies simply don't produce or produce it with a very low amount. but geothermal power plants, like coal- and natural gas-fired power plants, may require water for cooling. Hydroelectric power plants can disrupt river ecosystems both upstream and downstream

from the dam, while esquire essentially no water to operate and thus do not pollute water resources or strain supplies by competing with agriculture, or other important water needs (Benefits of Renewable Energy Use, 2017).

3. Inexhaustible energy: in a report for National Renewable Energy Laboratory (NREL) the dependence of producing energy from renewable resources may reach 80% By 2050.

Winds, sunny skies, abundant plant matter, heat from the earth, and fast-moving water can each provide a vast and constantly replenished supply of energy (Benefits of Renewable Energy Use, 2017).

However, there are many challenges facing renewable energy technologies. The most important of which is their high costs, as building them require significant capital costs, and vary according to the capacity of the plant and the technology required to generate energy. Moreover operating and maintenance cost cannot be forgotten. And the need of these technologies for land and water has become one of the most important reasons that may limit their spread and hinder their use.

Therefore, these sources reduce the known health and environmental problems that results from the production of harmful emissions that are from the consumption of conventional methods of producing energy.

It is worth to mention that saving energy is a way for motivate sustainable development, which is one of the most important issue that governments working on. For this very reason there exists a system of priority in the energy hierarchy, that must be understood to reduce the unnecessary Exhaustion of resources, thus promote conservation of energy, The emerging new global concern on These hierarchies in energy was when realized that energy use became a clear contributor and cause of global extinction if it was not used properly, Therefore here is the hierarchy of energy that should be considered in priority order to ensure a long term success and efficiency in the energy production as shown in figure (4) (Energy Management Hierarchy | Hierarchical energy management system, n.d.).

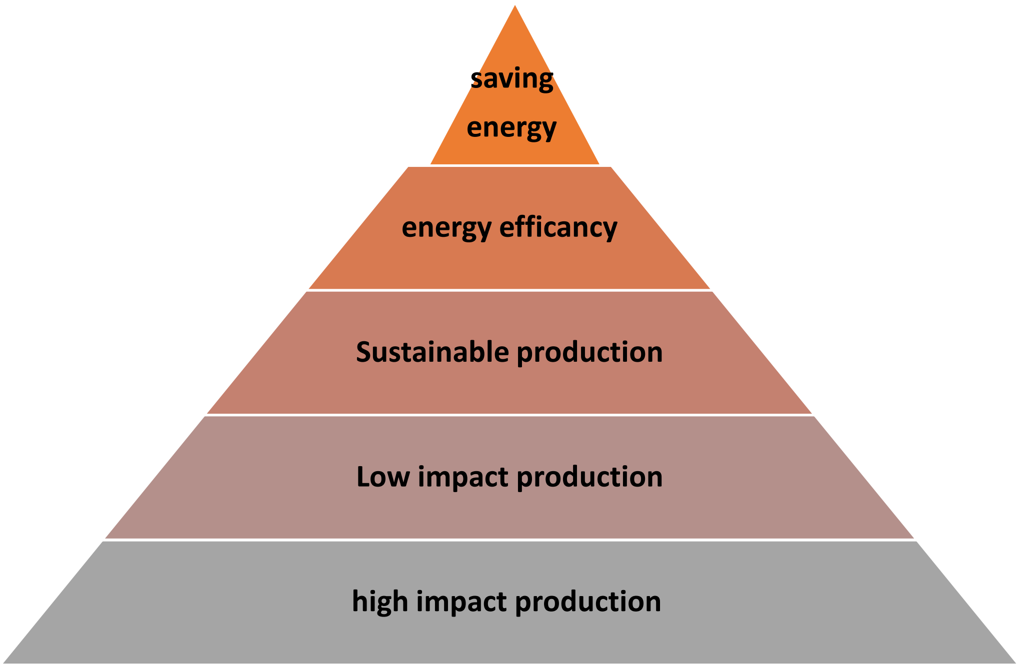


Figure (4) :energy management hierarchy (Energy Management Hierarchy | Hierarchical energy management system, n.d.).

Saving energy is at the top of the hierarchy, by prevent the unimportant utilize for the energy resources, that could be achieved for example by (trying to reduce the uses of heavy machines, close and turning off unused ones, close lamps or televisions in unoccupied rooms in houses, etc..) which must be the top most priority for all corporate buildings and houses (Energy Management Hierarchy | Hierarchical energy management system, n.d.).

To ensure a properly produced and consumed for energy, the principle of energy efficiency should be applied working on using less energy to do the same tasks That will reduce the use of traditional methods of energy production consequently, reducing pollutions, harmful emissions and environmental damage, this is next to saving and has very recently developed as a concept due to the increasing awareness among people and a sudden rise in prices of energy (Energy Management Hierarchy | Hierarchical energy management system, n.d.).

On the other hand, there is sustainable production, which will absolutely depend on the renewable resources that either not exhausted, such as wind, rainwater, waves, earth and the sunlight that could be converted to heat or electricity through several technologies, or the bio energy that is converted through combustion and decay of gasses.

Though these are highly recommended, still there is lack in the proper knowledge to execute such energy productions in the most efficient manners (Energy Management Hierarchy | Hierarchical energy management system, n.d.).

Low impact production is the next option available, which emit the least level of carbon dioxide to the air, and the least damage to the environment in general. Additionally they also have low carbon impact since they are not completely sustainable in nature. despite this, It is not a very effective manner since at high cost there is less production (Energy Management Hierarchy | Hierarchical energy management system, n.d.).

High impact production which has the worst effect on the air and environment, including using unsustainable resources such as fossil fuel and coal, although highly preferred for business purposes due to its cost. Energy utilization of such resources has to be minimized to the least (Energy Management Hierarchy | Hierarchical energy management system, n.d.).

Palestine is almost completely dependent on Israel for its supply of electricity and fuels, as 100% of the fossil fuels and 87.7% of electricity are imported from Israel. The other proportion of electricity is imported from Jordan, Egypt, and the Gaza power plant as shown in Figure (5).

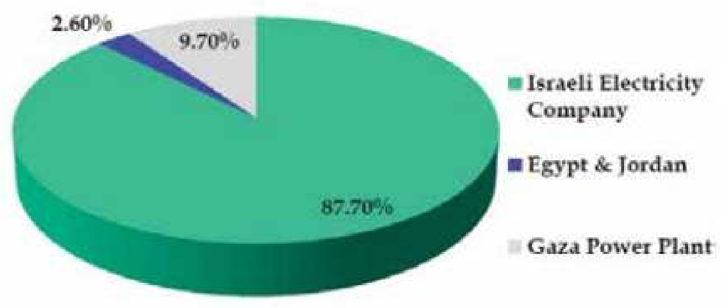


Figure (5): The percentage of electricity supply (Ajlouni & Alsamamra, 2011).

But dependency on Israel for the supply of energy is risky, and politically insecure, as Israel is not supplying enough energy to cover the demand. In fact (Ajlouni & Alsamamra, 2011).

According to the Palestinian Central Bureau of Statistics, it should be noted that purchases of energy is distributed by economic activity are 52% to the industrial sector, 26% to the domestic trading, 8% to services, about 3% to construction and the remaining 11% goes to transportation, storage, and communications sectors (Palestinian Central Bureau of Statistics, 2008).

And since this research deals with the industrial sector, especially the production of thermal energy for the factories, that using a propane gas, therefore, through the research that has been carried out, the industrial sector in Palestine consumed approximately 11,573 tons of LPG in 2019 according to what was published by the Palestinian Statistics Center (Palestinian Statistics Center, 2021).

In addition to the fact that the amount of gas imported to Palestine, specifically the West Bank, excluding the territories occupied in 1976, is 17767 tons during the year 2019 (Palestinian Statistics Center, 2021).

In its national strategy 2017-2022, one of Palestinian Energy and Natural Resources Authority (PENRA) objectives is to achieve energy resources independency. Although this is so ambitious, it is believed that small contributions in achieving energy independency will add up to the whole objective. In such a way, they will help politicians and facilitate their negotiation efforts with the Israeli side. Furthermore, energy fossil fuel based global prices are continually increasing, while renewable energy technologies are decreasing, so, investing in such technologies through pilot projects will accumulate practical necessary experience. In addition to that, Environmental Quality Authority (EQA) concentrated its efforts since 2012 in contributing in CO_2 emissions reduction produced by Palestinian activities, and such projects will help them in achieving their goals.

Sun is one of the best sources of renewable energy. In Palestine, solar energy is one of the most efficient and promising energy solutions that have been put in place to provide the necessary energy in a reasonable price. As the relatively high annual average of solar radiation amounting to 5.4 kWh/m^2/day on a horizontal surface (Juaidi et al., 2016). It is possible to obtain energy utilizing different available technologies such as Photovoltaic systems (PVS), concentrated solar power systems (CSP), and solar water heaters. Which has led us for looking more seriously into using solar water heaters for industrial sectors of food, textiles and chemical at a low temperature process (up to 100 ℃). There is also other solar technology like CSP for the industrial sector of food and chemical at high temperature process (more than 100 ℃).

Regarding other renewables, their applications are limited. Palestine can be considered as a country of moderate wind speeds, where the hilly regions had annual average speed of 4–6 m/s. These values are encouraging to use small wind turbines to electrify sites located far from the grid. In addition, another feasible application for small wind turbines is to use them for water pumping, especially for rural areas, where diesel generators are used for this purpose (Juaidi et al., 2016). For biomass, as Palestine has different types of plant products that can be used as energy sources. Due to evapotranspiration conditions, there are 49 major crops planted in West Bank and Gaza Strip, also waste and the organic portion of municipal waste can be used to produce biofuel from it with negligible additional land requirements or impacts on food and fiber crop production. Recently, studies show that about 1.3% of all electricity consumption in Palestine can be produced by combustion of olive cake, referred to year 2009 (Juaidi et al., 2016). Moreover, there is a geothermal resource, which already has been used in Palestine through various projects done by MENA Geothermal Company which is the first Palestinian Company succeeds in using geothermal energy in the West Bank and Jordan (Juaidi et al., 2016).

Thus, apart from technical limitations due to resources potential, some renewables are able to be applied in Palestine but others are not feasible. Land scarcity is another barrier where areas classified as (C) based on Oslo Accord is under full administrative and security control of Israel. It is worth to mention that 60% of the West Bank land is classified as (C) (Ajlouni & Alsamamra, 2011).

In this context, CST is one of the most promising technologies due to many technical and environmental issues. Although it is still considered as a high investment alternative, many small to medium systems were developed and used commercially and proved it competitiveness from economic point of view. The basic concept behind CST is to utilize solar energy to generate thermal energy by using mirrors to concentrate the sun's energy, transfer it to water then into high-temperature steam (Barlev, Vidu & Stroeve, 2011).

At the end, it can briefly said that the increase in population around the world means increasing in consumption of energy, which makes thoughts tend to save energy, and consume it better as efficiently as possible, therefore we must go to explore alternative ways of guarantees energy continuity, and this can be done by exploiting natural resources such as the sun, wind, water, and land in operating different technologies, air fans, dams, and various solar energy systems, including the CSP system to produce the necessary energy.

Commercial CSP systems can be used to produce electricity, thermal energy, or both. One of its application is power decentralized generation of electricity (distributed generation) and combined heat and power for remote areas with Dish-Stirling engines (Trieb, 2002).

Regarding its benefits, CSP systems are characterized as clean and reliable energy delivery systems that operate at relatively high annual efficiencies. When integrated with thermal storage and/or electric storage systems, on-grid and off-grid configurations become technically viable. It boosts the national economy.

1.2 Problem statement

Industrial thermal load is considered as one of the highest energy loads for almost all factories. Normally, steam is generated, distributed, and utilized in order to transfer heat loads to its demanding points. In all of these stages, heat losses are significant. Thus, generating steam is considered a costly process. In many situations especially where relatively low pressure and temperature steam is required, CSP systems become an attractive alternative to be studied.

In Palestine, diesel or gas fuels are normally used for steam generation. Due to the fact that national fuel prices are among the highest internationally, the generated unit cost is higher than it should be. Adding to that the unfair Israeli competition, high production expenses problem becomes more significant. Palestinian factories should think seriously in adopting energy management programs to reduce production expenses. Where utilizing renewable energy is a key solution in this case.

A comprehensive economic, environmental, and technical evaluation for installing a parabolic trough system had been considered in this research.

As mentioned previously, Al-Arz factory is using LPG boiler in Pasteurization and other heating process to generates (4 bar, 130°C) steam. This costs the factory around 20,937 $/Month, as the boiler works almost 8 months a year .And the cost of one litter of LPG is 0.75$. Running a solar energy-based system with the gas boiler such as parabolic trough CST in the factory aims to reduce the factory's dependence on LPG boiler to produce the heat energy required for work.

1.3 Scope of work

The work on this project is structured on reducing the consumption and dependency of Al-Arz ice-cream factory on the traditional methods of producing energy with a heating process in the factor, which is located in Nabulus, Palestine. This will be done by using a energy 3D software package in simulation, mechanical and financial analysis of using the concentrated solar system (parabolic trough CST system) in the factory with the boiler.

Therefore, in this research, work is done to make the heating system in the factory, operates on the CST systems instead of using boiler. As a result, there will be a significant savings in the fuel used in boiler operation

This will help us to achieve our goal of reducing emissions that are produced from using boiler only in the heating process, along with cost saving in the energy that is used in working of the ice cream factory.

Knowing that work will be done to define some specifications and capacity of the system that can be used based on the available space using energy 3D software. To conclude with determining the economic effectiveness of the project for the factory

1.3.1 CSP systems: Proposed system

With the availability of a 250 m^2 space on the roof of the factory building, work can be done to build a CSP system to work with the LPG boiler in producing thermal energy needed for the factory. The CSP system should be capable to cause saving in the energy consumed by the production process at the factory, especially heating energy due to its high thermal consumption. In this context, energy 3D software was used to carry out the required simulation , analytical calculations and the design .

The analysis included CST system technical constraints, economic visibility and potential environmental benefits.

Chapter Two

Site description

Chapter Two
Site Description

2.1 Case study description: AL-Arz factory.

There are four ice cream factories in Palestine distributed over four governorates, including Ramallah, Bethlehem, Hebron, and Nablus. Al-Arz factory is considered the biggest ice-cream producers in Palestine with a 200 workers and a capacity of 40 Ton/month (Al Assi and Tayeh, 2016).

On the way to the development of the factory, there has been development in the logo over the years, as shown in figure (6)

Figure (6) :Al-Arz Logo changes through the years.

From its' beginning in 1950, it was producing ice in order to cool water and store food. Al-Arz has evolved to be the leader of frozen treats market in Palestine. Since its establishment by the late Mohammad Anabtawi in Nablus, Palestine, Al-Arz grew into a successful producer of high-quality ice cream. In 60's sale was through street vendors, as can see in figures (7-8) (Al Arz| News, 2015).

Figure (7) :The ice cream peddler in the sixties (Bata, 2014).

The process evolved in the 1970s and the products became sold and distributed to the shops using factory cars.

Figure(8) : Al-Arz ice cream factory distribution car in 1978 (Bata, 2014).

In 1982 the production line was developed to be automatic, and in the year 2000, the factory witnessed a qualitative shift, as a new and advanced production line was purchased, which enabled the factory to produce new varieties, and thus produce high quality ice cream.

Whereas, figure (9) shows the automated production line

Figure (9): One of the automated production lines inside the factory old cite

In 2007, Al-Arz started the first step towards exporting its products to different countries including (Jordan and Iraq), where Jordan was the first station, and exports were made to the Gulf states once, but the export did not expand for more than that because of insufficient production due to many marketing and technical concerned (Al Arz| News, 2015).

Two years later, Al-Arz acquired the global food safety certificate Hazard analysis and critical control points (HACCP). It was the first company to acquire this certificate among the ice cream and dairy producers in Palestine and Jordan. With state of the art facilities and equipment along with a production capacity reaching up to 8 million liters of ice cream per month, using only the best ingredients sourced from around the world (Al Arz| News, 2015). Al-Arz factory armies to remain the leading ice cream producer in Palestine with a strong focus on expanding its market internationally (Al Arz| News, 2015).

Accordingly, in 2008, the study began to develop the entire factory on an area of 6000 square meters, it is a sufficient compared to the old factory which was built on an area of only 500 square meters(Anabtawi, 2016). the new factory area took into consideration factory future expansion plans. Figure (10) shows the new factory architectural design.

In 2015 construction began, and in 2016 production began from the new building of the factory, which is now located in the industrial zone eastern area of Nablus (Anabtawi, 2016)

Figure (10): outside complete picture of the building (Al Assi and Tayeh, 2016).

The factory today has seven production lines with an approximate capacity of 56000 pieces hourly. In summer, it produces more than (65) ice cream products, divided into one-share products, family packages and packages for events (Anabtawi, 2016).

Where, an average of 600 tons of ice-cream are produced annually. The main energy consuming sections of the ice-cream production are ice-cream mixture heating and cooling process after mixture preparation. The current system includes heating boiler for steam generation, the ice cream ingredient mixture tank for heating, and cooling and a refrigeration system (as shown in Figure 11). The mixture heating process is considered as a first stage, while the mixture cooling is considered as the second stage of ice-cream preparation. At first stage, water is heated by the LPG boiler to saturated vapor phase at (130°C) and a 4 bar working pressure. Saturated vapor from steam generator then enters to the jacketed pan type heating tank to heat the ice-cream mixture up to 70 °C for 30 minutes, called pasteurizing process. The second stage starts after pumping the mixture to the cooling tank, where the ice-cream mixture is cooled down to 5°C by means of chilled water which is at -6°C. The chilled water is fed from refrigeration system of the factory (Kizilkan, Kabul & Dincer, 2016).

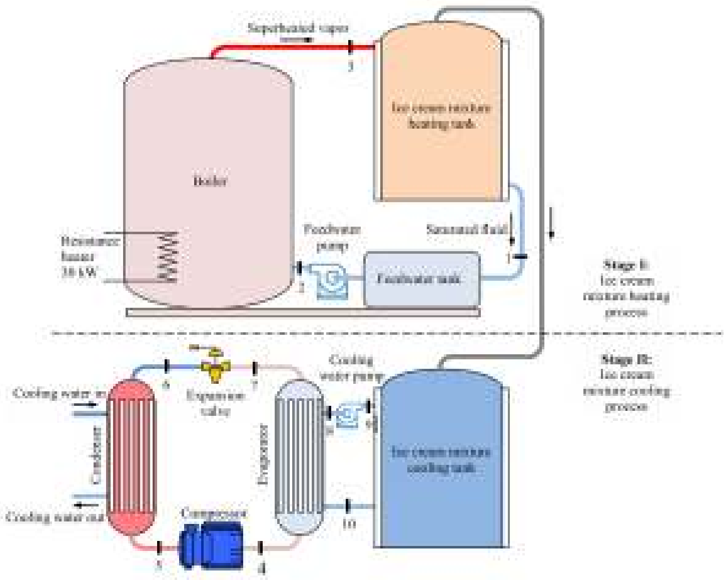


Figure (11): Schematic overview of ice-cream production process (Kizilkan, Kabul & Dincerb, 2016).

The mixture must stay in a temperature between (0-5°C) for 4 hours and under a gentle agitation to allow to the stabilizer to take effect. then the mixture enters the continuous freezer with a frozen air at a temperature between -3°C and -6°C whipped in to the mixture, the ice-cream then leaves with a soft texture and 40% of the water contents of the mixture will be frozen. The last production process stage before packaging is to harden the ice-cream at a temperature of (-20°C) before sending it to the market and local distributors (Al Assi and Tayeh, 2016).

In addition, in 2017 the factory started producing some winter snacks, including Dahbour and wafers (Al Arz| News, 2015). it’s worth to mention that these winter products are not attractively visible for the factory, and so its produced with relativity small quantities. so its energy load will be excluded from this study.

AL-Arz factory main equipment (production station) can be summarized as follows (Al Assi and Tayeh, 2016):-

1. Mix plants continuous HTST pasteurization.
2. Ageing Tanks.
3. Continuous freezing with built in refrigeration.
4. In-line filling machines.
5. Filling machines.

6. Tray Tunnel Extrusion System.

7. Bar Processing Lines.

8. Rotary Bar Processing Lines.

9. Hardening tunnels.

10. Wrapping machines.

2.2 Location and weather data

The proposed parabolic through concentrating solar thermal plant (CST) will be established in Nablus city, just north of West Bank in Palestine. On the roof of the factory building, which has sun exposure on the mirrors of the system most of the time.

As known Palestine is located on the eastern coast of the Mediterranean Sea between latitude 31° 56' 50.46" north and longitudes 35° 13' 37.79" east Greenwich. This has played a major role in influencing its climate and its difference from the tropical climate, desert and semi-desert climate (Palestinian Meteorology, 2019.).

Where the climate of Palestine is moderate compared to the Middle East. It is hot and dry in summer. As well as Palestine is affected by India's seasonal low, which works to raise temperatures in the countries of the Levant greatly as a result of hot and dry winds blowing as it is accompanied by waves of heat prevailing in all of the Levant. Clear and the easterly winds blowing from the altitude toward the above-average depression (Palestinian Meteorology, 2019.). And mild and rainy in winter, noted that before the arrival of the depression, the sky is clear and the east wind is blowing from the elevated air towards the depression above the average. Then the depression advances towards the region and is mostly concentrated in the northeastern Mediterranean basin, and the wind begins to shift into a western and then north wind Western, where the direction of movement changes with the change of movement of the depression, as the air pressure decreases with the advance of the depression and the speed of the wind increases according to this decrease, as it is cool because of its coming from northern and central Europe regions, which leads to a significant decrease in temperatures (Palestinian Meteorology, 2019.).

Therefore, Palestine has sufficient DNI potential in average of 2000 kwh/m^2.y, and 2171 kwh/m^2.y specifically in Nablus, which is located exactly at latitude 32°14'29",and longitude 35°15'26(Global Solar Atlas, 2019.).

Palestine also enjoys more than 300 sunny days a year, which encourages the use of this technology in producing energy.(Palestinian News and Information Agency. 2019)

Chapter Three

Theoretical Background

Chapter Three
Theoretical Background

3.1 Concentrating Solar Power system (CSP)

Concentrating Solar Power system technology utilizes focused sunlight For producing electricity and/or thermal energy, by using mirrors to reflect and concentrate sun light on a central point. The plants consist of two parts: one that collects solar energy by the mirrors and converts it to heat by using a heat transfer fluid in the receivers, and another that converts the heat energy to electricity, this indirect method generates alternating current (AC) which can be easily distributed on the power network.

The mirrors reflect and concentrate sun light onto a large heat exchanger that is called the receiver. Within the receiver the heat transfer fluid flows to the pips that forms the external walls. This fluid absorbs the heat from the concentrated sun light. After passing throw the receiver, the HTF goes to a thermal storage tank where the energy is stored as a high temp molten salt till electricity is needed.

The high temp HTF flows into steam generator as water piped into from the water storage tank to generate the steam, once the hot HTF is use to great steam the cold HTF piped back in to the cold HTF storage tank. Then the HTF will back to the receiver to be reheated. After the steam is used to drive steam turbine it condensed back to water and return to water holding tank, where will flow back to steam generator when is needed.

Concentrated Solar Thermal systems (CSP) concentrate radiation of the sun to heat a liquid substance which is then used to drive a steam generator (heat engine) to generate a steam which can used in the needed facility.

Basically, CSP technology is classified into four main categories as shown in Figure (12). Parabolic trough, power tower, linear fresnel, and dish engine (Barlev, Vidu & Stroeve, 2011).

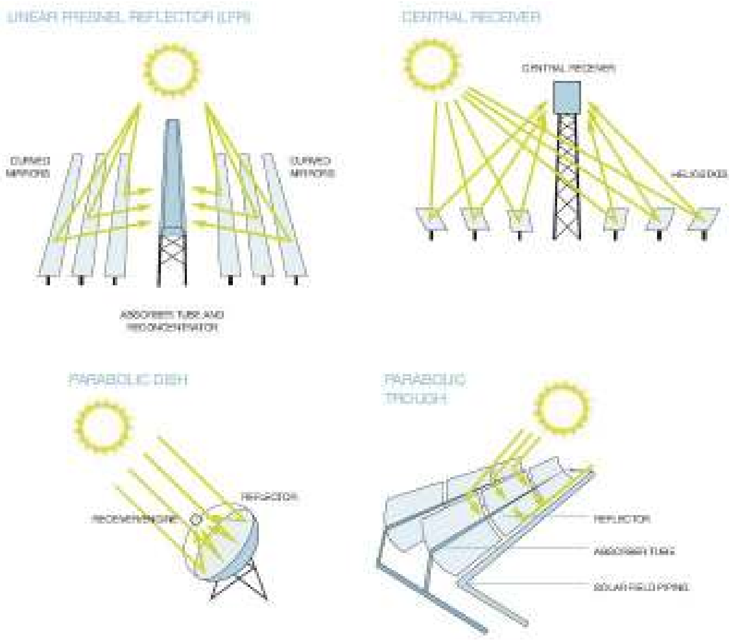
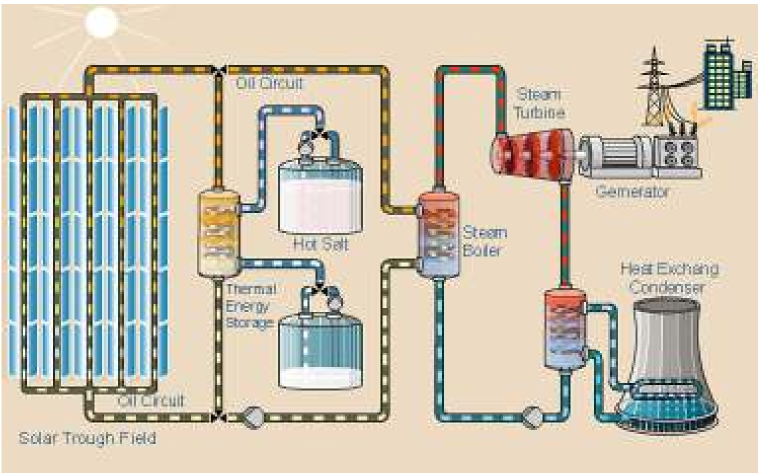


Figure (12): CSP technologies

3.1.1 Parabolic trough collectors (PTC)

The parabolic trough collectors (PTC) consist of solar collectors (mirrors), heat receivers and support structures. The parabolic-shaped mirrors are constructed by forming a sheet of reflective material into a parabolic shape that concentrates incoming sunlight onto a central receiver tube at the focal line of the collector.

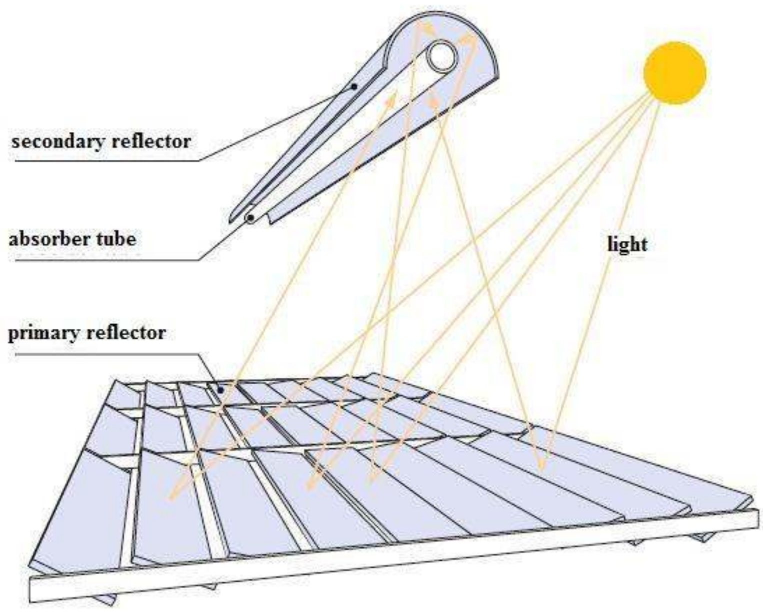
The receiver comprises the absorber tube inside an evacuated glass envelope. The absorber tube is generally a coated stainless steel tube, with a spectrally selective coating that absorbs the solar (short wave) irradiation The receiver comprises the absorber tube (usually metal) inside an evacuated glass envelope. The absorber tube is generally a coated stainless steel tube, with a spectrally selective coating that absorbs the solar irradiation and this receiver contains the heat transfer fluid such as Therminol VP-1, which then used to heat the water and produce the steam which then could use to produce the electricity by the using steam turbine figure (13) shows the mechanism (International Renewable Energy Agency, 2012).



Figure(13): parabolic trough collectors

3.1.2 Linear Fresnel Collector Technology

As figure (14) below shows linear fresnel collectors (LFCs) are similar to parabolic trough collectors, but use a series of long flat, or slightly curved, mirrors placed at different angles to concentrate the sunlight on either side of a fixed receiver (located several meters above the primary mirror field). Each line of mirrors is equipped with a single-axis tracking system and is optimized individually to ensure that sunlight is always concentrated on the fixed receiver. The receiver consists of a long, selectively-coated absorber tube. Unlike parabolic trough collectors, the focal line of fresnel collectors is distorted by astigmatism. This requires a mirror above the tube (a secondary reflector) to refocus the rays missing the tube, or several parallel tubes forming a multi-tube receiver that is wide enough to capture most of the focused sunlight without a secondary reflector. and the optical efficiency of LFC solar fields (referring to direct solar irradiation on the cumulated mirror aperture) is lower than that of PTC solar fields due to the geometric properties of LFCs. The problem is that the receiver is fixed and in the morning and afternoon cosine losses are high compared to PTC (International Renewable Energy Agency, 2012).



Figure(14): LFC Technology

3.1.3 Solar tower technology

Solar tower technologies use a ground-based field of mirrors to focus direct solar irradiation onto a receiver mounted high on a central tower where the light is captured and converted into heat. The heat drives a thermo-dynamic cycle, in most cases a water-steam cycle, to generate electric power. The solar field consists of a large number of computer-controlled mirrors, called heliostats, that track the sun individually in two axes. These mirrors reflect the sunlight onto the central receiver where a fluid is heated up. Solar towers can achieve higher temperatures than parabolic trough and linear Fresnel systems, because more sunlight can be concentrated on a single receiver and the heat losses at that point can be minimized. A plant of the solar tower technology shown in Figure (15) (International Renewable Energy Agency, 2012),(Clean leap2019.).

Solar towers can use synthetic oils or molten salt as the heat transfer fluid and the storage medium for the thermal energy storage. Synthetic oils limit the operating temperature to around 390°C, limiting the efficiency of the steam cycle. Molten salt raises the potential operating temperature to between 550 and 650°C, enough to allow higher efficiency supercritical steam cycles although the higher investment costs for these steam turbines may be a constraint (International Renewable Energy Agency, 2012).

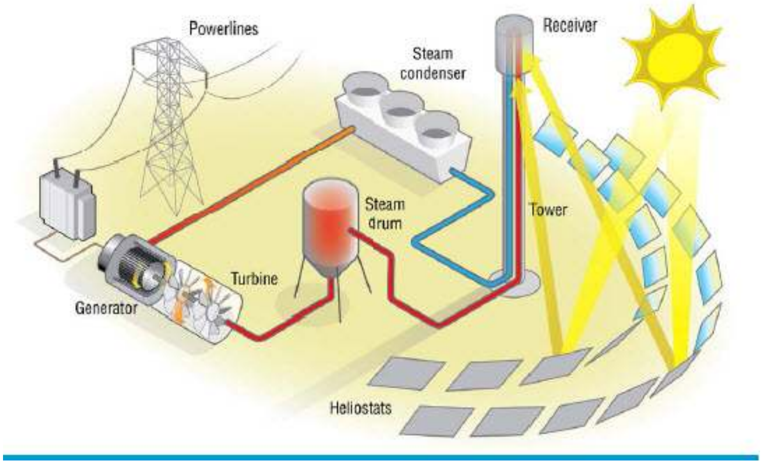


Figure (15): Solar tower plan

3.1.4 Stirling Dish Engine

Dish/engine systems use a parabolic dish of mirrors to direct and concentrate sunlight onto a receiver at the focal point of the dish. The receiver may be a stirling engine (dish/ engine systems) or a micro-turbine that produces electricity. The two major parts of the system are the solar concentrator and the power conversion unit as figure (16) shown (Hafez et al. ,2016)). The location of the generator - typically, in the receiver of each dish - helps reduce heat losses and means that the individual dish-generating capacity is small, extremely modular (typical sizes range from 5 to 50 kW) and are suitable for distributed generation (International Renewable Energy Agency, 2012).

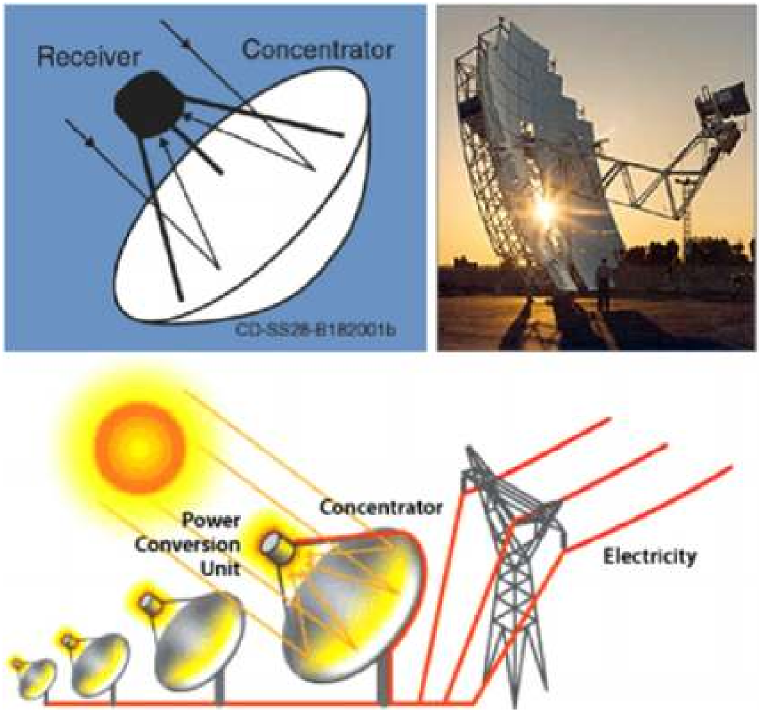


Figure (16) : Solar stiriling engine

That Stirling dish technologies could meet an economically valuable niche in many regions, even though the levelised cost of electricity is likely to be higher than other CSP technologies. Apart from costs, another challenge is that dish systems cannot easily use storage. Stirling dish systems are still at the demonstration stage and the cost of mass-produced systems remains unclear. With their high degree of scalability and small size, Stirling dish systems will be an alternative to solar photovoltaics in arid regions. CSP technologies offer a great opportunity for local manufacturing, which can stimulate local economic development, including job creation.

A comparison between the four CSP technologies has been done based on different parameters shows in table (2) below (International Renewable Energy Agency, 2012).(Draidi, 2016).

Table (2): comparison between CSP technologies

	Parabolic Trough	Solar Tower	Linear Fresnel	Dish-Stirling
Typical capacity (MW)	10-300	10-200	10-200	0.01-0.025
Maturity of technology	Commercially proven	Pilot commercial projects	Pilot projects	Demonstration projects
Technology development risk	Low	Medium	Medium	Medium
Operating temperature (oC)	350-550	250-565	390	550-750
Plant peak efficiency (%)	14-20	23-35*	18	30
Annual solar-to-electricity efficiency (net) (%)	11-16	7-20	13	12-25
Annual capacity factor (%)	23-28 (no TES) 29-50 (7h TES)	55 (10h TES)	22-24	25-28
Collector concentration	70-80 suns	>1 000 suns	>60 suns (depends on secondary reflector)	>1 300 suns
Receiver/ absorber	Absorber attached to collector, moves with collector, complex design	External surface or cavity receiver, fixed	Fixed absorber, no evacuation secondary reflector	Absorber attached to collector, moves with collector
Water requirement (m3/MWh)	3 (wet cooling) 0.3 (dry cooling)	2-3(wet cooling) 0.25(dry cooling)	3 (wet cooling) 0.2 (dry cooling)	0.05-0.1 (mirror washing)
Application type	On-grid	On-grid	On-grid	On-grid/Off-grid
Suitability for air Cooling	Low to good	Good	Low	Best
Storage with molten salt	Commercially available	Commercially available	Possible, but not proven	Possible, but not proven

In general, according to table (2), all CSP types can be implemented in Palestine, but based on the maturity and the risk of CSP technology, PTC system is the suitable one (Draidi, 2016).

3.2 Energy improvement

Energy efficiency has huge potential to boost economic growth and avoid greenhouse gas emissions.

Reducing energy consumption through energy efficiency improvements has become an important goal for all countries, to improve economy efficiency, increase energy supply security, and reduce carbon dioxide emissions and other pollutants from power generation. As it is known that energy is the main engine of the economy in the world and will contribute in achieving the development objectives of the countries in industry, trade and agriculture important social services, such as education, health care and is the basis for political development of countries as well (Al Assi, & Tayeh, 2016).

Industrialization has a major impact on the overall energy consumption of the national economy, which increases the pressure on industry. So that, improving energy efficiency in industry is one of the most cost-effective measures to help developing and emerging countries with limited supply constraints to meet their growing energy demand and reduce the link between economic growth and environmental degradation, such as climate change (Al Assi , & Tayeh, 2016).

Due to the occupation policy, Palestine must search for alternative ways to produce the necessary energy, which required the Palestinian Authority to work seriously. On energy efficiency and renewable energy.

In 2007, the Palestinian energy authority worked on setting the master plan for energy efficiency and renewable energy, it aimed to increase the share of renewable energies in the energy balance in Palestine and improve energy efficiency in the consumer sectors, especially industry and construction (Palestinian Energy Authority, 2010).

In 2012, it was agreed to work on a strategy for energy efficiency The National Energy Efficiency Action Plan (NPA) aims to develop a framework for strategic national plans that would assist governments in Arab countries to achieve long-term energy efficiency goals. The initiative mainly aims to spread and promote energy efficiency practices and procedures in the Arab countries by presenting a model plan of action developed specifically for the region.

Consequently, the Energy Efficiency Department of the Palestinian Energy and Environmental Research Center (PEC), within the (PEA), is responsible for plan implementation. It is assumed that achieving this goal means achieving savings in energy consumed by 2020 estimated at 384 GWh per year, it leads to save at least 55 million dollars a year in the cost of energy consumed in Palestine and reducing 285,000 tons annually from carbon dioxide emissions. table (3) below shows the previous and currently assumed average energy consumption in 2020 (Palestinian Energy Authority, 2010).

Table (3): The previous and currently assumed average energy consumption in 2020 (Palestinian Energy Authority, 2010)

Sector	Previous consumption		Expected current consumption of the plant 2020	
	%	GWh	%	GWh
Industrial sector	9	427	11	950
Building sector	70	3324	70	6048
Other sector	1	47	3	259
Loss in the distribution network	20	950	16	1383
Total consumption	100	4748	100	8640

A set of performance monitoring measures has been taken for three main sectors from (2012-2020). As shown in table (4) below (Palestinian Energy Authority, 2010).

Table (4): (NPA) performance monitoring indicators (Palestinian Energy Authority, 2010)

sector	Indicative goal of saving							
	First stage (2012- 2014)		Second stage (2015-2017)		Third stage (2018-2020)		Overall goal 2020	
	%	GWh	%	GWh	%	GWh	%	GWh
Industrial sector	5		6		8		19	
Building sector	38		130		195		363	
Water pumping sector	_		1		1		2	
Total	43		137		204		384	

PEA did many efforts to promote energy efficiency in Palestine. As this reserch focusing on the industrial sector, table (5) shows the achieved saving results based on pea efforts and activities. (Al Assi , & Tayeh, 2016)

Table (5): PEA estimated achived saving in the industrial sector (Al Assi , & Tayeh, 2016)

Capital cost (million/NIS)	134.6
Energy Saving (GWh equivalent /year)	169.3
Gross financial saving (million NIS/ year)	107.1
Cost effectiveness (NIS/kWh equivalent)	0.14
Net Financial savings(million NIS/year)	84.1
Net economic savings(million NIS /year)	94.5

Great challenges can become converted to greater opportunities. Energy is decisive for success – regardless of the industry. The growing need for increased efficiency in the use of resources, rising energy costs, new supply models, and strict environmental regulations make energy-efficient solutions essential. Yet with challenges come opportunities: by designing energy-efficient plants investors can also save significant amounts of money.

3.3 Ice cream processing

3.3.1 Pasteurization

In the first stage of ice cream manufacture, the mixture is heated in a process called pasteurization. Pasteurization is the most important step that is taken in all dairy products, and it is considered a heat treatment process that heats and raises the temperature of each milk molecule or milk product to destroy the microorganisms that cause diseases. In properly designed and managed equipment using one of the methods shown in the table (6) (Al Assi & Tayeh, 2016), (Encyclopedia Britannica. 2015).

Table (6): pasteurization methods (Al Assi & Tayeh, 2016),(Encyclopedia Britannica. 2015)

Pasteurization type	Temperature	Time
Slow continuous pasteurization	63°C	30 minutes
High temperature short time pasteurization	72°C	15 seconds
Higher heat-short time	89 °C	1 second
Higher heat-short time	90°C	0.5 second
Higher heat-short time	94 °C	0.1 second
Higher heat-short time	96 °C	0.05 second
Higher heat-short time	100 °C	0.01 second
Ultra-high-temperature (UHT) pasteurization	138°C to 150°C	(1 or 2) seconds
Ultra-pasteurized	138°C	2 seconds

The original pasteurization process is a slow, continuous pasteurization in which the materials are heated to 63 ° C for 30 minutes. It is the main pasteurization method used in ice cream industry.

The change in temperature and length of time is to determine the appropriate situation in which mycobacterial tuberculosis and other heat-resistant and pathogenic microorganisms are destroyed, in addition to the disposal of microorganisms that causes product damage, pasteurization process increase the time of food storage (Encyclopedia Britannica. 2015).

Ultra-high temperature pasteurization basically for milk or cream Packaged in sterile, hermetically sealed containers, enables milk to be stored without cooling for months. But Ultra-pasteurized products must be refrigerated due to less stringent packaging, so the validity period extends between 60-80 days (Encyclopedia Britannica. 2015).

2.3.2 Boilers

Boilers are pressure vessel designed to heat water or produce steam. Boilers and other fired systems are the most significant energy consumers. They combust fuel with air to release chemical heat energy. The reason for the heat energy might be to raise the temperature of industrial product as part of a manufacturing process, or it might just be to warm a space either in residential or industrial sector (Turner & Doty, 2021).

Boilers can be a category based on fuel type, in to electrical and fossil fuels boilers. Fossil fuels include coal, oil, or natural gas which are most common as heating source due to its' availability, easy to use, and it's typically less expensive than other alternatives (Turner & Doty, 2021).

The boiler can be one of the best methods for heating processes. for its long life and the possibility of working with a high efficiency of up to 95%. But, the costs of operation and maintenance may be somewhat high, especially the costs of fuel used, and if maintenance is not done periodically, repair will be costly (Turner & Doty, 2021).

2.3.2.1 Combustion efficiency

Combustion efficiency is usually utilized for boilers and other terminated frameworks. it can be estimated in the field by analyzing the results of burning the fumes gases.

Normally estimating either carbon dioxide (CO_2) or oxygen (O_2) in the fumes gas can be utilized to determine the combustion efficiency as long as there is excess air. Excess air is characterized as air in abundance of the sum required for stoichiometric conditions. At the end of the day, overabundance air is the measure of air over that which is hypothetically required for complete burning. in reality, it is preposterous to expect to get ideal blend of air and fuel to accomplish total ignition without some measure of abundance air. As overabundance air is decreased toward the fuel rich side, deficient burning starts to happen bringing about the development of carbon monoxide, carbon, smoke, and in outrageous cases, crude unburned fuel. Incomplete combustion is wasteful, costly, and perilous. Along these lines, a measure of abundance air is required to guarantee total and safe combustion (Turner & Doty, 2021).

There are numerous ways to improve performance in a boiler or other fired device. this segment, that are depend on excess air, stack temperature, load balance, and boiler blowdown (International Renewable Energy Agency, 2012).

2.3.2.1.1 Excess-air

In combustion processes, excess air is commonly characterized as air presented over the stoichiometric or hypothetical necessities to impact total and proficient ignition of the fuel.

There is an ideal degree of excess-air activity for each kind of burner or heater plan and fuel type. Just enough air ought to be provided to guarantee total ignition of the fuel, since more than this sum builds the warmth dismissed to the stack, resulting in greater fuel consumption for a given process output.

The measure of excess air (or O_2) in the vent gas, unburned combustibles, and the stack temperature ascend over the inlet air temperature are important in characterizing the effectiveness of the ignition procedure. Overabundance oxygen (O_2) estimated in the fumes stack is the most regular technique for controlling the air-to-fuel proportion. Be that as it may, for increasingly exact control, carbon monoxide (CO) estimations may likewise be utilized to control wind current rates in blend with O_2 checking. Cautious consideration regarding heater activity is required to guarantee an ideal degree of execution. figure (17) can be utilized to decide the ignition proficiency of a heater or other terminated framework consuming petroleum gas in as much as the degree of unburned combustibles is viewed as unimportant (Turner & Doty, 2021).

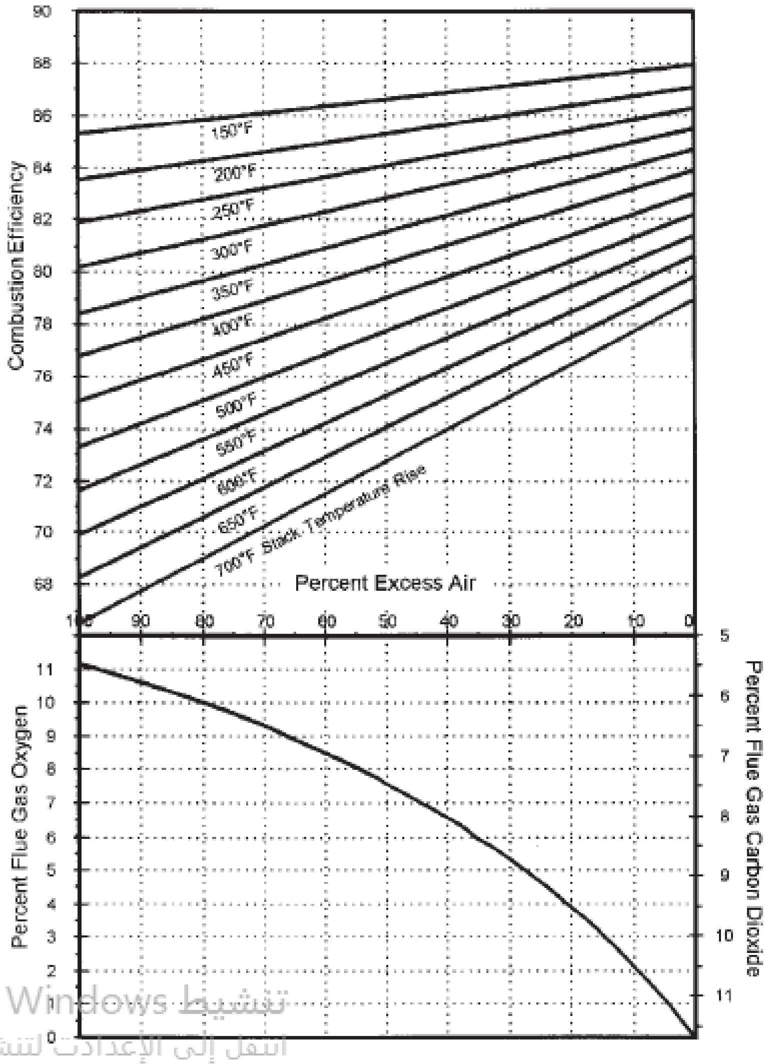


Figure (17) :combustion efficiency chart for natural gas (Turner & Doty, 2021) .

To obtain the maximum benefits of an excess-air, some modifications, additions, checks, or procedures should be considered such as, ensure that the heater limit dividers and pipe work are impenetrable and not a wellspring of air penetration or exfiltration by the recognized leakage problem areas, and tests to locate leakage problems. Also ensure ideal burner performance by ascertain integrity of air volume control, and maintain purchase high-quality gas analyzing systems: calibrate instrument against known flue-gas sample. And establish an upkeep program: Perform periodic support and maintenance as suggested by the maker, and Keep a boiler operator's log and key parameters (Turner & Doty, 2021).

2.3.2.1.2 Exhaust Stack Temperature

Another essential factor influencing unit efficiency and ultimately fuel utilization is the temperature of burning gases dismissed to the stack. Expanded working effectiveness with a relating decrease in fuel input can be accomplished by dismissing stack gases at the most minimal commonsense temperature predictable with fundamental structure standards. As a rule, the utilization of extra warmth recuperation gear can understand this vitality preservation target when the deliberate pipe gas temperature surpasses roughly 250°F. For an increasingly broad inclusion of waste-heat recuperation (Turner & Doty, 2021).

Steam boilers, process fired heaters, and other combustion or heat-transfer furnaces can benefit from a heat recovery program for the wasted heat.

Wasted heat, in the most general sense, is the energy associated with the waste streams of air, exhaust gases, and/or liquids that leave the boundaries of a plant or building and enter the environment. It is implicit that these streams eventually mix with the atmospheric air or the groundwater and that the energy, in these streams, becomes unavailable as useful energy. The absorption of waste energy by the environment is often termed thermal pollution.

Briefly, it is that energy which is rejected from a process at a temperature high enough above the ambient temperature to permit the recovery of some fraction of that energy for useful purposes.

The adaptation of heat-recovery equipment to existing units will be limited to flue gas/liquid and/or flue gas/air preheat exchangers. Specifically, economizers and air preheaters come under this category. Economizers are used to extract heat energy from the flue gas to heat the incoming liquid process feed stream to the furnace. Flue gas/air preheaters lower the flue-gas temperature by exchanging heat to the incoming combustion air stream.

In assessing overall efficiency and potential for heat recovery, the parameters of significant importance are temperature and fuel type/sulfur content. To obtain a meaningful operating flue-gas temperature measurement and a basis for heat-recovery selection, the unit under consideration should be operating at, or very close to, design and optimum excess-air values (Turner & Doty, 2021).

The installation of economizers and/or flue-gas air preheaters on units are not presently equipped with heat recovery devices and those with minimum heat-recovery equipment are practical ways of reducing stack temperature while recouping flue-gas sensible heat normally rejected to the stack.

There are no “firm” exit-temperature guidelines that cover all fuel types and process designs. However certain guiding principles will provide direction to the lowest practical temperature level of heat rejection. The elements that must be considered to make this judgment include fuel type, flue-gas dew-point considerations, heat-transfer criteria, type of heat-recovery surface, and relative economics of heat-recovery equipment (Turner & Doty, 2021).

2.3.2.1.3 Boiler blowdown

In the generation of steam, most water impurities are not vanished with the steam and therefore gather in the boiler water. The grouping of the debasements is normally regulated by adjustment of the constant blowdown valve, which controls the measure of water, and concentrated impurities cleansed from the steam drum.

When the amount of blowdown is not properly established and/or maintained, either of the following may happen:

A. If too little blowdown, sludge deposits and carryover will result.

B. If too much blowdown, excessive hot water is removed, resulting in increased boiler fuel requirements, boiler feed water requirements, and boiler chemical requirements. Significant energy savings may be realized, setting up ideal blowdown levels to keep up satisfactory evaporator water quality and to limit high temp water losses, and the recuperation of heat from the heated water blowdown (Turner & Doty, 2021).

worthy note that, by establishing optimum blowdown levels to maintain acceptable boiler-water quality and to minimize hot-water losses energy savings will be realized, and the recovery of heat from the hot-water blowdown (Turner & Doty, 2021).

The continuous blowdown from any steam-generating equipment has the potential for energy savings whether it is a fired boiler or waste-heat-steam generator. The following items should be carefully considered to maximize savings:

1. Reduce blowdown (BD) by adjustment of the blowdown valve such that the controlling water impurity is held at the maximum allowable level

2. Maintain blowdown continuously at the minimum acceptable level. This may be achieved by frequent manual adjustments or by the installation of automatic blowdown controls. At current fuel costs, automatic blowdown controls often prove to be economic

3. Minimize the amount of blowdown required.

4. Recover heat from the hot blowdown water. This is typically accomplished by flashing the water to a low pressure. This produces low-pressure steam (for utilization in an existing steam header) and hot water which may be used to preheat boiler makeup water (Turner & Doty, 2021).

3.4 Energy 3D software

Energy 3D software is a clean energy management and design software system for energy efficiency, renewable energy and cogeneration project feasibility analysis as well as ongoing energy performance analysis. And figure (18) shows the program working space with the actions that the program go through (Inc. C., 2021).

Empowers professionals and decision-makers to rapidly identify, assess and optimize the technical and financial viability of potential clean energy projects.

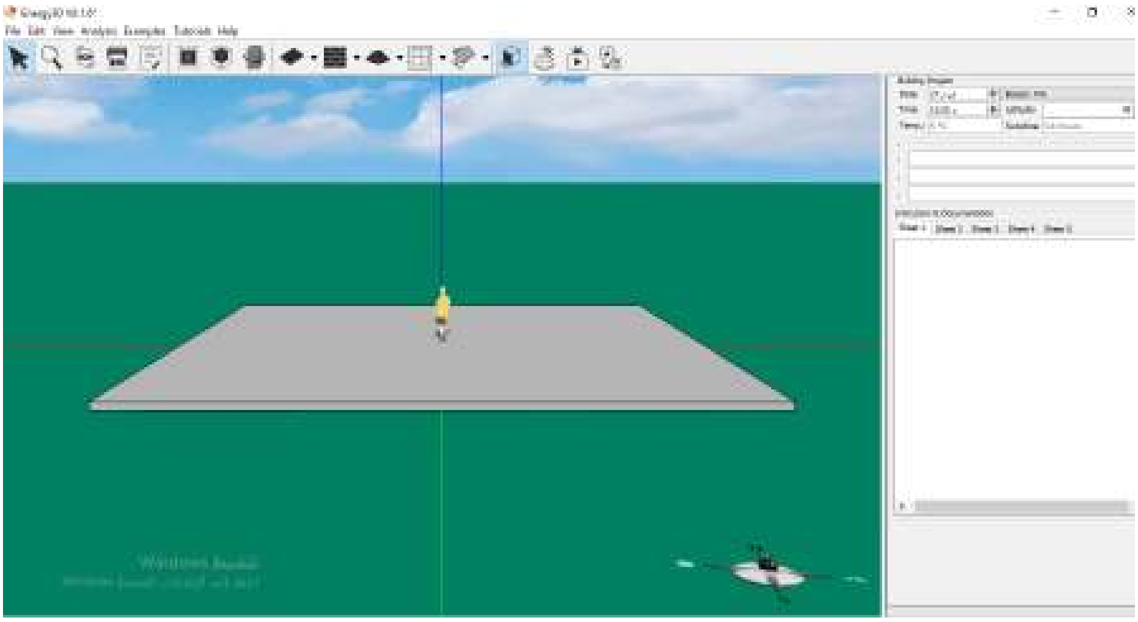


Figure (18): energy 3D software main screen page.

3.5 CSP Mathematical Modeling

The mathematical modeling of a solar parabolic trough collector is not an easy procedure. Modeling procedure starts from estimating the amount of heat input to the parabolic trough collector can be calculated as equation (1) (Abd-Ennour et al.,2015).

$$q_{in} = C\, I\, \rho\, K \qquad (1)$$

Where C: concentration ratio

I: is the direct solar radiation in [W/m^2]

ρ :concentrator reflectivity, and

K is the thermal conduction W/m^2k.

C is calculated using equation (2).

$$C = \frac{A_a}{Ar} \qquad (2)$$

A_a, A_r are the aperture and the receiver area in [m^2], respectively. Both are calculated using equations (3, 4) (Abd-Ennour et al.,2015):

$$A_a = l\left[\left(\frac{a}{2}\sqrt{\left(\frac{4h}{a}\right)^2 + 1}\right) + 2f\ln\left(\left(\frac{4h}{a}\right)\sqrt{\left(\frac{4h}{a}\right)^2 + 1}\right)\right] \qquad (3)$$

$$A_r = \pi l\, D_b \qquad (4)$$

Where l is the collector length in [m], a: aperture in [m], h:concentrator height in [m], f is the Focal length also in [m], and D_b is the mean diameter of the absorber in [m], and h can be calculated as in equation (5)

$$h = \frac{a^2}{16f} \qquad (5)$$

And these parameters could be described as shown in Figure (19) (Abd-Ennour et al.,2015).

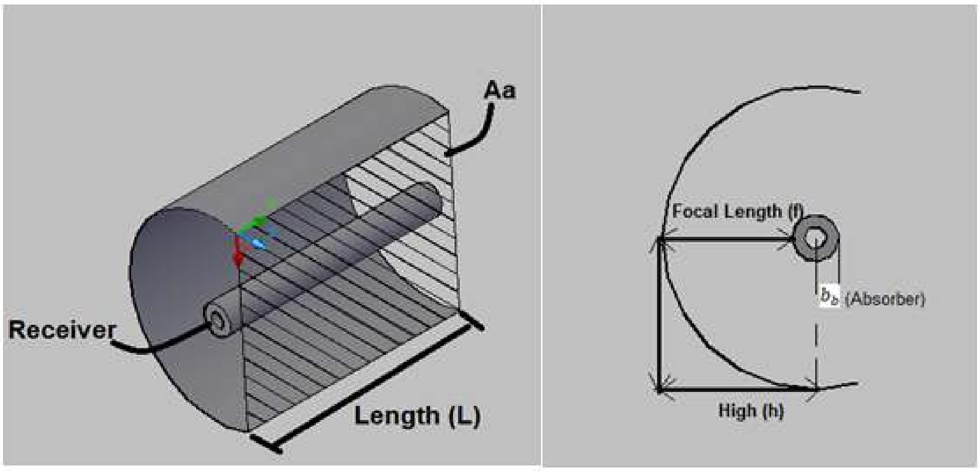


Figure (19): Geometry of parabolic trough solar collector

In dynamic modeling, energy stored in certain levels is considered. These levels are considered as nodes at a uniform temperature. This method is based on subdividing a system into several systems. However before establishing the energy balance of the collector, modeling assumptions must be considered (Abd-Ennour et al.,2015).

In this research, the following simplifying assumptions are considered:

- Due to vacuum, heat transfer between the glass and the absorber is only due to radiation and conduction and therefore convection is negligible.
- The working fluid is incompressible and without phase change.
- The absorbent tube coincides with the focal line.
- The temperature is uniform at each node.

- The glass is considered opaque to infrared radiation.
- Temporal variations along the absorber and the glass thickness are negligible.
- The solar flux at the absorber is uniformly distributed (Abd-Ennour et al.,2015).

In this context, Figure (20) shows the different types of heat transfer involved

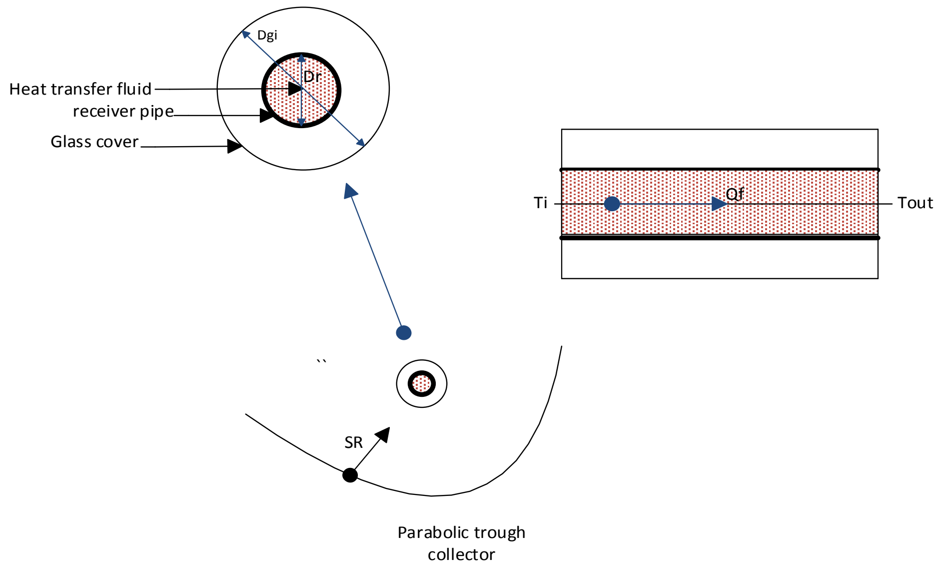


Figure (20): basic components of CSP (Abd-Ennour et al.,2015)].

As a result, the amount of heat exchange between the nodes can be written as in (6) (Abd-Ennour, Bouhelal, Chakib and Saïd, 2015):

$$Q_{ij} = A_{ij}\,\mathrm{ho}_{IJ}\,(T_i - T_J) \tag{6}$$

I $and\ j$ are the two neighboring nodes, A_{ij} and h_{ij} are respectively the surface in $[m^2]$ and heat transfer coefficient in $[W/m^2.K]$ between the two nodes (Abd-Ennour et al.,2015).

Each node stores quantity of heat which depends on the heat capacity of the used material. Temperature change over time is given by equation (7):

$$Q_i = M_i C_i \frac{dT_i}{dt} \quad (7)$$

Heat transfer between reflector and air is given by equation (8), and between glass and reflector expressed by equation (9) (Abd-Ennour, Bouhelal, Chakib and Saïd, 2015) :

$$M_r C_r \frac{dT_r}{dt} = \left[(1-R)G - h_{r-a}(T_r - T_a) - h_{s-r}(T_r - T_s) - h_{r-g}(T_r - T_g)\right] \quad (8)$$

$$M_g C_g \frac{dT_g}{dt} = \alpha_g A_g R G + A_g h_{r-g}(T_r - T_g) - A_{ge}\left(h_{g-a}(T_g - T_a) + h_{s-g}(T_g - T_s)\right) + A_{gi}(h_{b-g} - h_d)(T_b - T_g) \quad (9)$$

Similarly, heat transfer between absorber and glass in equation (10), and between HTF and absorber can be calculated by equation (11):

$$M_b C_b \frac{dT_b}{dt} = \tau_g \alpha_b A_r R G + A_{bi} h_{b-f}(T_b - T_f) - A_{gi}(h_{b-g} - h_d)(T_b - T_g) \quad (10)$$

$$M_f C_f \frac{dT_f}{dt} = A_{bi} h_{b-f}(T_b - T_f) m_f C_f \frac{dT_f}{dt} \quad (11)$$

Where Mi and Ci are the mass and specific heat of the i node material, m_f is the working fluid mass flow. Regarding to heat transfer coefficient between nodes equations (12-30) are used (Abd-Ennour, Bouhelal, Chakib and Saïd, 2015).

$$T_s = 0.0552\, T_a^{\,1.5} \tag{12}$$

$$\mathrm{ho}_{s-r} = \sigma\varepsilon_r (T_s + T_r)\left(T_s^{\,2} + T_r^{\,2}\right) \tag{13}$$

$$\mathrm{ho}_{r-g} = \frac{\sigma\left(T_g^{\,2} + T_r^{\,2}\right)\left(T_g + T_r\right)}{\frac{1-\varepsilon_g}{\varepsilon_g} + \frac{1}{F_{rg}} + \frac{(1+\varepsilon_r)A_r}{\varepsilon_r A_{ge}}} \tag{14}$$

$$F_{rg} = \frac{[(W_1 + W_2) + 4]^{\frac{1}{2}} - [(W_2 - W_1 + 4)]^{\frac{1}{2}}}{2W_1} \tag{15}$$

$$W_1 = \frac{D_{ge}}{f} \tag{16}$$

$$W_2 = \frac{a}{f} \tag{17}$$

$$h_{r-a} = \frac{8.6V^{0.6}}{l^{0.4}} \tag{18}$$

$$h_{s-g} = \sigma\varepsilon_g \left(T_s + T_g\right)\left(T_s^{\,2} + T_g^{\,2}\right) \tag{19}$$

$$h_{g-a} = \frac{4V^{0.58}}{D^{0.42}} \tag{20}$$

$$h_{b-g} = \frac{\sigma\left(T_g^{\,2} + T_b^{\,2}\right)\left(T_g + T_b\right)}{\frac{1-\varepsilon_g}{\varepsilon_g} + \frac{1}{F_{gb}} + \frac{(1+\varepsilon_b)A_{gi}}{\varepsilon_b A_{be}}} \tag{21}$$

$$F_{gb} = \frac{1}{X}\left[\frac{1}{\pi}\left(cos^{-1}\left(\frac{B}{A}\right)\frac{1}{2Y}\left(Ccos^{-1}\left(\frac{B}{XA}\right) + Bcos^{-1}\left(\frac{1}{X}\right) - \frac{\pi}{2}A\right)\right)\right] \tag{22}$$

$$X = \frac{D_{gi}}{D_{be}} \tag{23}$$

$$Y = \frac{2l}{D_{be}} \tag{24}$$

$$A = X^2 + Y^2 - 1 \tag{25}$$

$$B = X^2Y^2 - 1 \tag{26}$$

$$C = \sqrt{(A+2)^2 - (2X)^2} \tag{27}$$

Where T_s is the sky temperature in [K], h_{s-r} is the heat transfer coefficient between Reflector and sky in [W/m^{2}K], h_{r-g} is between Reflector and glass in [W/m^{2}K], F_{rg} is a view factor between reflector and glass, h_{r-a} is between reflector and air in [W/m^{2}K], h_{s-g} is between glass and sky in [W/m^{2}K], h_{g-a} is between glass and air in [W/m^{2}K], h_{b-g} is between glass and absorber in [W/m^{2}K], and F_{gb} is the view factor between glass and absorber.

But the heat transfer coefficient between absorber and fluid is expressed in equation (28) with using equation (29 or 30)

$$\text{With ho} = Nu\frac{k}{D} \tag{28}$$

For turbulent flow, Re $> 10^4$:

$$\text{Nu} = 0.125(0.790 \log(\text{Re}) - 1.64)^{-2}\text{RePr}^{0.34} \tag{29}$$

For laminar flow, Re $< 10^4$:

$$Nu = 3.66 + \frac{0.0668\left(\frac{D_{bi}}{L}\right)RePr}{1+0.04\left[\left(\frac{D_{bi}}{L}\right)RePr\right]^{0.67}} \tag{30}$$

Where Nu is the Nusselt number, k is the thermal conductivity $[W/m^2]$ Pr is the Prandtl number, and D_{bi} is the internal diameter of the absorber (Abd-Ennour et al.,2015), (Yılmaz and Söylemez, 2014).

3.6 Life cycle costing (LCC)

Life-cycle cost analysis (LCCA) takes into consideration all costs associated with the project during its lifespan, LLCA is the most important analysis to make the decision, either accept or reject the technology, which save much time and effort before the implementation process. This is a useful performance measure, as it can be related to the cash flow generated by the energy savings. Other performance measures would include the internal rate of return (IRR), payback period (PBP), life-cycle energy savings and annual energy costs for the project. A LCCA can help inform building owners when considering different alternatives for solar equipment, labor, and balance of systems (Tiwari and Tiwari, 2016).

3.6.1 Cost analysis

Financially; different renewable energy systems, whether CSP systems or solar water heaters are evaluated by taking into account more than one financial valuation method. They will be briefly discussed in this part of the thesis. But there are some terms that must be understood to make things clear and easy to understand.

3.6.1.1 Future Value Factor or Compound-Interest Factor (CIF):

Let P be the initial investment (present value/first cost) of a solar-technology system at zero time (n = 0) at the interest rate of i per year. If the future value of the solar technology at the nth year is S_n, then based on the following cash flow in figure(21) (Tiwari and Tiwari, 2016).

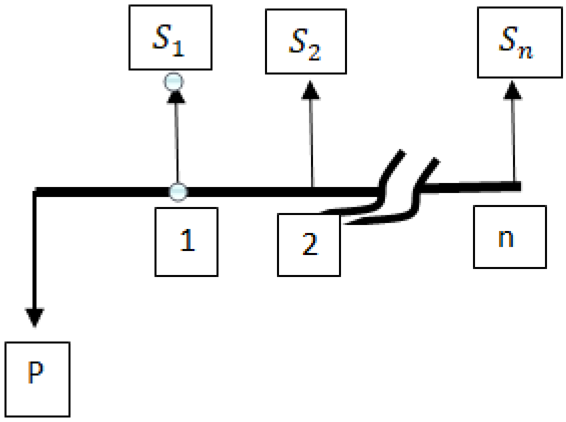


Figure (21): cash flow – future value

Future value (S_n) could be expressed as equation (31):

$$S_n = Presant\ value\ (P) \times Future\ value\ factor\ (F_{PS}) \tag{31}$$

While the Future value ($\boldsymbol{F_{PS}}$) calculate as seen in equation (32) below:

$$F_{PS,i,n} = (1+i)^n \tag{32}$$

3.6.1.2 Present-Value Factor

To convert the future value ($\boldsymbol{S_n}$) to present value $\boldsymbol{p}$, that could be done by using the equation (33) (Tiwari and Tiwari, 2016).

$$Presant\ value\ (P) = future\ value\ (S_n)\ \times present\ value\ factor\ (F_{sp}) \tag{33}$$

This method is known as the "present value" (PV) or "net present value"

(NPV).

Therefore, the present value factor ($\boldsymbol{F_{sp}}$) could be calculated as equation (34) (Tiwari and Tiwari, 2016).

$$F_{sp,i,n} = (1+i)^{-n} \quad (34)$$

Which is always less than unity.

Furthermore, there is a relation between (F_{sp} *and* F_{ps}) can expressed in equation (35) (Tiwari and Tiwari, 2016).

$$F_{sp} = \frac{1}{F_{ps}} \quad (35)$$

3.6.1.3 Uniform Annual Cost (Unacost)

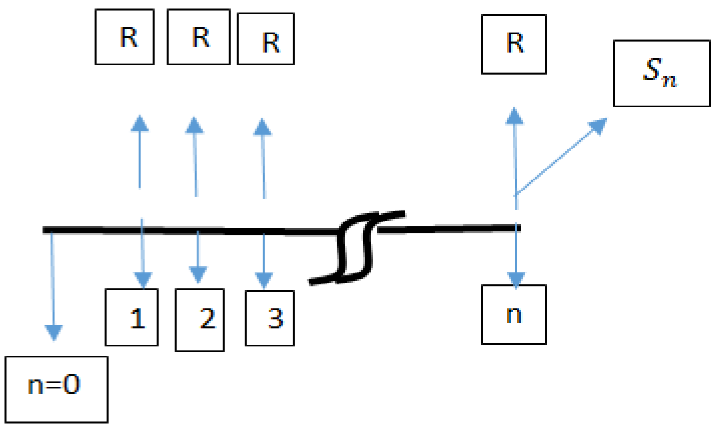


Figure (22): cash flow – uniform annual cost

As shown the cash flow above (R) express the uniform annual cost (uncost) at the end of each year, therefor R could be as (debits) such as operation and maintenance cost of the system shows below the line, or (credit) as the annual energy saving from building the system shows under the line.

Moreover, the present value at (n=0) could be converted to uniform annual series using the following formula in (36) (Tiwari and Tiwari, 2016).

$Annual\ series\ (R) = present\ value\ \times capital\ recovery\ factor$(CRF) (36)

Where, a capital recovery factor (CRF) known by ($F_{PR,i,n}$) as equation (37) (Tiwari and Tiwari, 2016).

$$F_{PR,i,n} = \left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] = \text{CRF} \quad (37)$$

On the other hand, to convert uniform annual cost to the present value, the following expression is used equation (38) (Tiwari and Tiwari, 2016).

$present\ value\ (P) = uniform\ annual\ series\ (R) \times$ annuity present-value factor (APVF) (38)

Where the annuity present-value factor (APVF) measured by equation (39) (Tiwari and Tiwari, 2016).

$$F_{RP,i,n} = \left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \quad (39)$$

So the equation (40) gives the relation between the annuity present-value factor (APVF) and capital recovery factor (CRF) (Tiwari and Tiwari, 2016).

$$F_{RP,i,n} = \frac{1}{F_{PR,i,n}} \quad (40)$$

Based on the above, the assessment of the likelihood of the success of the project and its continuity is through various economic theories, including: -

3.6.1.3.1 Net Present Value (NPV)

In the net present value, a cash flow should be prepared based on the costs and saving of the project as can show in figure (23) (Tiwari and Tiwari, 2016).

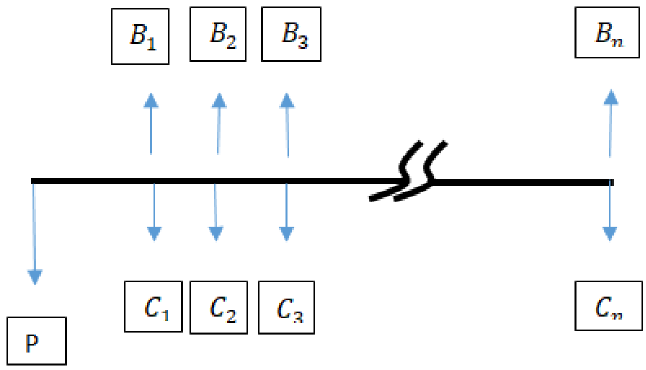


Figure (23): cash flow – Net present value

Depending on the value of the net present value, that could be calculated through equation (41) a project evaluation will done (Tiwari and Tiwari, 2016):

$$NPV = \left(-P + \sum_{j=1}^{n} \frac{B_j - C_j}{(1+i)^j}\right) \quad (41)$$

- ✓ If the (NPV >0): Then the project is accepted.
- ✓ If the (NPV =0): remain indifferent.
- ✓ If the (NPV < 0): The project is rejected.

3.6.1.3.2 Capitalized Cost

Capitalized cost (K) is the present value on an infinite time basis. For a system costing Pn and lasting n years, the present value replacing out to infinity is as follows (42) (Tiwari and Tiwari, 2016).

$$K = P_n \sum_{X=0}^{\infty} \frac{1}{(1+i)^{xn}} = P_n \frac{(1+i)^n}{(1+i)^n - 1} \quad (42)$$

Furthermore, Uniform end-of-year annual amount (R) and capitalized cost (K) are expressed as (43) (Tiwari and Tiwari, 2016).

$$R = iK \quad (43)$$

When using this method to compere between two projects, the project with less K will be more economical than the other one (Tiwari and Tiwari, 2016).

3.6.1.3.3 Benefit Cost Analysis

This method is basically depends on equation (44) as shown:

$$\frac{\mathbf{B}}{\mathbf{C}} = \left(\frac{\mathbf{Benefits - disbenifts}}{\mathbf{Cost}}\right) \quad (44)$$

As **the benefits (B):** are the advantages to the owner. These will be positive in the cash-flow diagram. All benefits, such salvage value, annual C-credit, cost of annual energy savings, etc., should be converted into present (Tiwari and Tiwari, 2016).

Dis-benefits (D): The project involves disadvantages/loss per year to the owner. This should be also converted into present value (Tiwari and Tiwari, 2016).

Costs (C): These are the anticipated expenditures for annual O&M, and should be converted into the present value and then added to the construction cost (P) (Tiwari and Tiwari, 2016).

The value of $\frac{B}{C}$ Ratio is decided the approvability of the project (Tiwari and Tiwari, 2016):-

When $\frac{\mathbf{B}}{\mathbf{C}} > 1$ accept the project

When $\frac{\mathbf{B}}{\mathbf{C}} < 1$ reject the project

3.6.1.3.4 Internal Rate of Return (IRR)

The internal rate of return (IRR) of an investment, P, is the discount rate at which the NPV of costs of the investment equals the NPV of the benefits of the investment. Mathematically

IRR could be calculated as shown in (45)

$$\left[\sum_{j=0}^{n} \frac{B_j - C_j}{(1 + i_{IRR})^j}\right] = 0 \qquad (45)$$

Because at $j = 0, C_0 = P,$ and $B_0 = 0$

Then using the value of i_{IRR} from (45) to find a NPV, if the result calculated is positive, then repeat the calculation until it becomes negative.

Repeat this Process again until one value of $(i = i_1)$ is found at a positive (+) NPV and the next higher value of $(i = i_2)$is found with a negative NPV.

Then Solve for the value of IRR $= i_{IRR}$ by using (46).

$$i_{IRR} = i_1 - NPV_1 \frac{(i_2 - i_1)}{NPV_2 - NPV_1} \tag{46}$$

The IRR is a measure of profitability for the assessment of the project (Tiwari and Tiwari, 2016).

Chapter Four

Literature Review

Chapter Four
Literature Review

Investigating the performance and feasibility of CSP systems requires good knowledge about its mathematical modeling and previous contributions in the field.

4.1 Previous Contributions

There are many researches that have been found talking about the production of thermal energy through using solar energy concentrators systems such as the CST, where,(Naik, Baredar & Kumar, 2017) explain the need and the potential of concentrated solar thermal technologies in a developing country. Typical applications are described with an attempt to explore the extent of their applicability. These include water heating, space heating and cooling, refrigeration and Industrial process heat. The application areas described in this paper show that solar energy concentrators can be used in a wide variety of systems and could provide significant environmental and financial benefits, and should be used whenever and wherever possible.

The paper also helps the reader to identify different barriers to widespread utilization of solar thermal technologies and provide recommendations to the government for promoting its use.

And in other research work has been done in Design and analysis of a medium-temperature, concentrated solar thermal collector for air-conditioning applications, (Li et al., 2017) proposed solar collectors are employed to supply thermal energy to the chiller to offset the building cooling demand or the thermal energy can also be used directly to satisfy the building's heating demand. When sufficient solar energy is not available, the auxiliary heater provides the rest of the heating and cooling demand.

In addition to that, (Blanco & Miller, 2017) introduce Introduction to concentrating solar thermal (CST) technologies, explaining how Concentrating solar thermal (CST) technologies provide promising and diverse opportunities to power the present and future needs of humankind . where, CST technologies collect and concentrate radiation from the sun to transform it into high-temperature thermal energy. This thermal energy can later be used for a plethora of high-temperature thermal applications, such as heating and cooling, process heat, material treatments, electricity production, or chemical processes. This chapter provides a background to the sun as our most valuable energy source, the defining characteristics of CST technologies, and the need and limits associated with the concentration of sunlight.

Furthermore, (Chandra & Dixit. 2018) entitled "Concentrated Solar Thermal Technologies: Recent Trends and Applications" include a reviewed papers, about The sub-topics under concentrated solar technologies and applications included in the book are Solar Field. The domains mentioned topics cover from resource-assessment, collection to conversion of solar energy for applications, like, heating, cooling and electricity. The proceedings also include invited lectures from domain experts. The edited work will be useful for beginners and for the advanced level researchers in the field of concentrated solar thermal technologies and their applications.

Previous Literatures are also rich of researches related to comparing between different CSP types and/or defining CSP systems feasibility. In this context, (Barlev, Vidu & Stroeve, 2011) presented a comparison between different types of collectors used for concentrating solar power system. It was found that the variety of available CSP technologies and the advancements made in each can bring a sense of uncertainty as to which technology works best. This is a complicated issue because of the many factors that need to be considered in selecting a particular CSP design. Every system advantages and disadvantages that must be accounted for in accordance with the size, location, purpose and budget of the plant intended to be build. Many other contributions discussed CSP modeling and simulation. (Tiwari and Tiwari, 2016) discussed the mathematical modeling of a different solar systems including CSP systems and SWH with their types, focusing on the equations used Moreover, (Abd-Ennour et al.,2015) also highlighted a mathematical modeling by which a numerical simulation of the parabolic trough solar collector was performed. The model adequacy was checked on a specific case.

Furthermore, in a Brazilian case study which was published in 2015. (Soria et al., 2015) proposed a low-cost design for CSP systems throw simulating the operation of hybrid CSP plants that use sustainably managed biomass in Brazil's semiarid northeast. Other researches focused on studying the performance and feasibility of already existed CSP plants. (Ashalim (Negev) | Concentrating Solar Power Projects, 2019), (Yiting Wang, 2008), has outlined some of parabolic trough concentrated solar power plants, which include one constructed in Palestine with a capacity of 110-MW in the Negev desert, and another one in Egypt with a capacity of 40-MW steam input for a gas-powered plant with parabolic trough design.

Similarly, (National renewable energy agency , 2012) proposed a case study of establishing a parabolic trough concentrating solar power (CSP) plant in Spain with a nominal capacity of (50 MW) and covers slightly less than 500 acres. It is owned and operated by ACS-Cobra Energy, who invested around €310 million to build the plant.

Regarding CO_2emissions equivalent potential savings, (Trieb, 2002) has claimed that a 1 km² potential of CSP saves 500,000 bbl of oil / year and avoids 200,000 tons CO_2/ year emission.

For investigating the feasibility of CSP technologies in Palestine, (International Renewable Energy Agency, 2012) conducted a cost analysis study for the renewable energy technologies. It covered the analysis of capital investment cost and the cost break down. In addition, it compared between the CSP technologies, but this comparison found that it is difficult to determine the best technology, because it depends on the use and amount of energy need to be produced along with some other factors. As a result, a feasibility study of implementing CSP technology in Palestine has been performed. it Shows that the parabolic trough is the best choice in Palestine as it has a low technology development risk, highly commercial proven feasibility, and its' investment cost is between (4000-7000 $/kW) (Draidi, 2016).

Referring to that, (International Renewable Energy Agency, 2012) dealt with the economic issue, by mentioned some different method to evaluate the project likewise net present value, internal rate of return, and the benefit/cost ratio, on which the project is accepted or rejected.

On the other hand, (Yasen & Dradi, 2016) has discussed the sizing of a solar thermal power in Jericho –Palestine using parabolic trough CSP collector, using a Retscreen program for simulation, it is found that 20 collector loops with 4 parabolic trough collectors per loop are needed to generate 10MW, With a capital cost of 400$/kw and a useful life time of 30 years.

According to the industrial sector, (Kizilkan, Kabul & Dincerb, 2016) had proposed a case study of using the CSP system in an ice cream factory in Isparta, Turkey, instead of the conventional system. Which includes boilers and refrigerators for cooling and heating the ice-cream mixture by this an energy saving of (89%) could be achieved. The energy consumption of the actual system had calculated to be 85.81 kWh per day.

Therefore, (Jin, 2013) presents a thesis that compares between the most efficient technology that converted the sunlight to a useful power, solar photovoltaics (CSPV) and concentrated solar thermal power (CSTP) generation. The comparison shows that the CSTP system is more efficient than CSPV as the CSTP collects the energy in the form of heat which is easy to recollect the waste heat which could be used for other purpose.

Through these studies and reading many papers related to the topic, directly or indirectly, I was able to benefit from them to work on the topic of the thesis.

Chapter Five

Methodology

Chapter Five
Methodology

The followed methodology is describing the stages that the work going through to implement and study the project. The collection of information was considered as the most important stage to be worked on in the beginning; which followed by other stages such as analysis, comparing, and finical evaluation of the project in a right way. As a strategy of search to collect data we used bibliographic research in the international and the national articles along with reading another thesis to put a clear frame work.

Therefore, the first step of work has been by contacting with the Palestinian Energy and Natural Resources Authority - PENRA. As they were working on a projects of parabolic trough CSP system for several places in Palestine, Al-Arz ice cream factory being one of them. However, some data about this project had to be collected through communication with the working team. The energy analysis process was performed for the most LPG consuming devices in the factory, the next sections of this chapter will explain the other steps.

Subsequently, contact with the factory had to be done to take the information needed including technical data, annual consumption of electricity and LPG gas, annual production of ice cream and operation hours of the factory through the day.

After a general study that was worked on in the factory it was found ,that the largest consumption of AL-Arz factory depending on the existing equipment, that is used in the production line is what forms the factory energy bills, and it is important to know that the factory uses two types of energy sources, the first one is natural gas, which uses in producing of thermal energy for the production lines through operation of the steam boiler, and the electrical energy that works to operate the side of lighting, heating and air conditioning in work offices and the administrative building in the factory. as figure (24) below can show the consumption amount of each source per year where the electrical boiler need 743,591kWh of electricity and the steam boiler need 111,666 kg of LPG (Al Assi and, Tayeh, 2016).

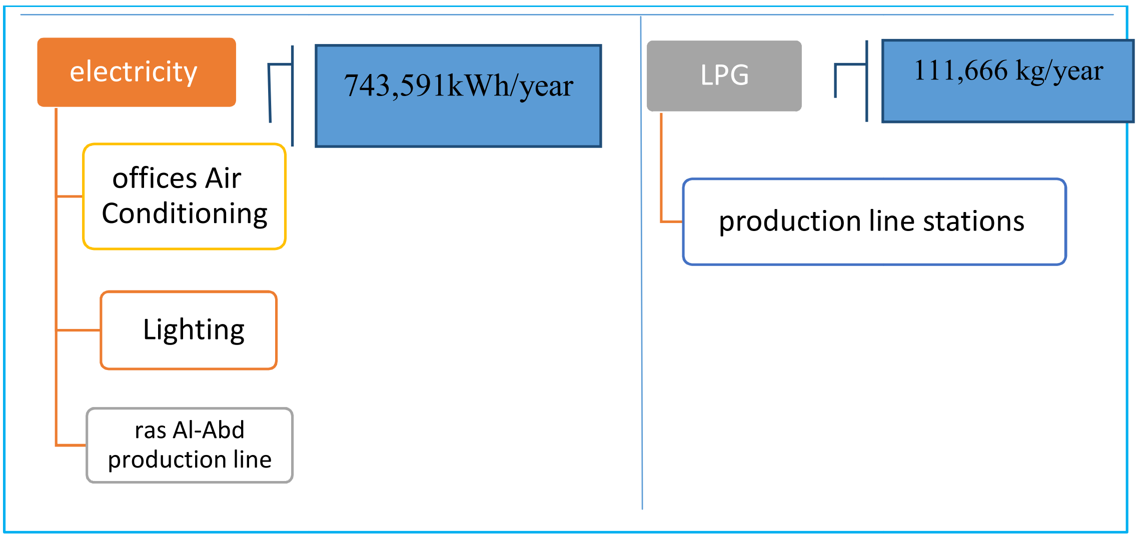


Figure (24): Energy Distribution Diagram

These two boilers supply the factory with all hot water needed, the electrical boiler for space heating and Ras AL-Abed production line with a total power capacity of 72 kW and 4,079 working Hours yearly. The second boiler is powered by propane (LPG) with energy content of (49

MJ/kg) which is used for heating process required for making ice-cream and other products. Ice-cream production line operates continuously for 8 months annually. Al-Arz propane fuel boiler is shown in figure (25) below.

Figure(25):Al-Arz factory LPG boiler (Al Assi and Tayeh, 2016).

The boiler efficiency, excess air, stack and ambient temperatures and other exhaust gases were measured by the combustion analyzer. the data shows Table (7) below.

Table (7): Combustion Analyzer Data.

Fuel: PROPANE	**Value**	**Unit**
Efficiency	65	%
Ambient Temperature	73	F
Stack Temperature	491	F
Oxygen	5.5	%
CO	0	PPM
CO2	10	%
Combustion	0	%
Draft	-0.1	"
Excess Air	33	%
NO	95	PPM
NO2	0	PPM
Nox	95	PPM
SO2	0	PPM
Oxygen Ref	TRUE	

In addition to that, a work has been done to study the operational details of the factory in terms of ice cream manufacturing process, thus taking an overview of schematic diagram of ice-cream production process in the factory, to be able to imagine the way of connecting the parabolic trough CST system at the same way that achieve the needed purpose.

Moreover, a mathematical modeling of the proposed CST system was done through equations (0-30) that were explained and worked on in Chapter 4.

Then analysis of these data have been done to configure the suitable capacity of the system that could be worked on according to the specified available area of the factory.

However, the analysis of the information has been done by using a software, which is (energy 3D software). To find the specifications and characteristics of the CST system, coming up with a preliminary diagram for connecting the system as a source of energy in the production lines in the factory. Also, energy 3D software helped with the location and weather data.

Furthermore, it includes a full economic analysis package that takes into consideration different scenarios based on its built-in available commercial system data economic assumptions and evaluation indicators. The analysis includes gas fuel price fluctuation, thermal load fluctuation, the factory future expansion plan, and different financial and loaning alternative. In addition to that, an environmental study will be performed to assess the environmental benefited of using solar energy instead of gas fuel. For this analysis CO_2 equivalent emissions will be considered as a performance indicator. It is worth to mention that system initial investment will take into consideration actual cost of purchasing available commercial system, its transportations, installation, and all Palestinian authority legislations, laws, and taxis.

On the other hand, this research will generally aim to save energy and reduce the consumed resources by finding other alternative ways to produce the energy needed for the factory. Therefore, special focus placed on the possible savings in natural gas (LPG) used in the production process, and saving in CO_2 emissions.

At the end, results with actual data will be released and discussed according to analysis that have been done of these data. In addition to that, some sensitivity factors has been worked on in the project, whose change will affect the effectiveness and results of this project, this include the internal rate, life time of the project, and the initial investment, with discussion and analysis of these changes.

Finally, conclusions and recommendations were carried on, in order to prepare the final report.

Chapter Six

Results and Discussion

Chapter Six
Results and Discussion

The aim of this research is to find if the other alternative of the LPG boiler in Al-Arz factory is feasible or not. And Based on the previous analysis and researches that were conducted, the following results were reached. The result will be explained in detail in this chapter:

6.1 Technical and cost analysis

By relying on the “energy 3D software ” program in analyzing some data to show the results of solar radiation in relation to the work site of the factory and thus using it to show the design results of the CSP system and the capacity that can be obtained in proportion to the available area in the factory, as mentioned previously.

First of all weather data had been uploaded on energy 3D software , the program does a complete analysis of the location and weather data for Nablus region. Uploaded data is presented on figures (26,27). Figure (26) shows Palestine map and the location of the weather station with uploaded data. Figures (27) (Inc. C., 2021), shows annual environmental temperature Nablus city, and figure (28) shows monthly sunshine hours of the city.

Figure(26): Facility and weather station locations

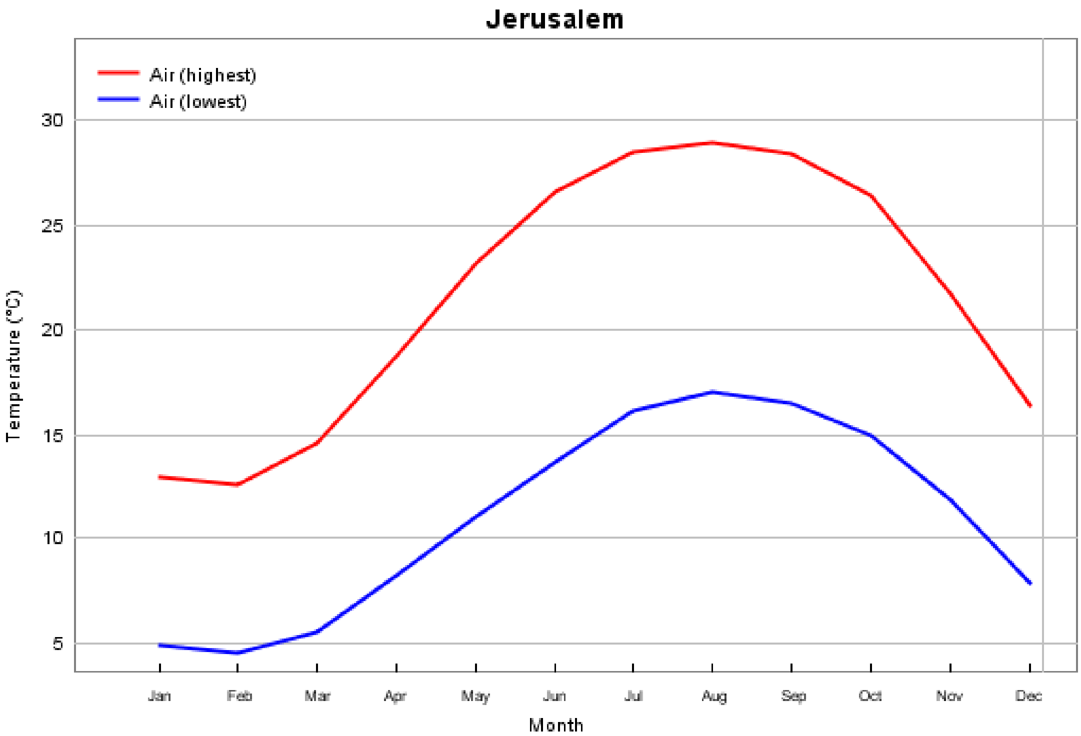


Figure (27): annual environmental temperature of Nablus city (Energy 3D software, 2011).

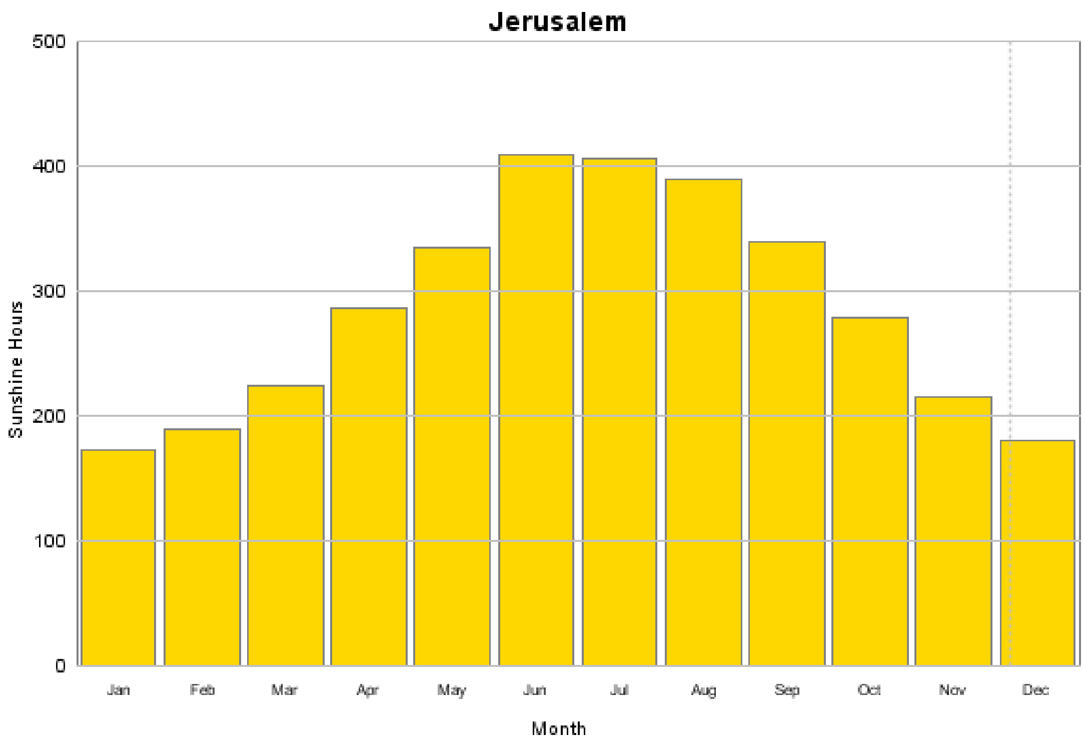


Figure (28) : monthly sunshine hours of the city (Energy 3D software, 2011).

average solar radiation on summer season exceeds 6kWh/m^2/day, Which is considered a sufficient proportion could be used to operate the parabolic trough CST system (PTS) using a solar energy as an alternative source for traditional sources of energy production Thus, it is expected that, the parabolic trough CST system is an effective system, that can provide significant saving from boiler running cost. Parabolic trough CST system (PTSC) thermal efficiency is 76% (Yasen & Dradi, 2016).

6.1.1 Design and sizing of the Parabolic trough CSP system

In cooperation with LPG heating boiler, a solar energy system with PTS is proposed for supporting the current system, Figure (29) propose a schematic diagram for the PTS as sustainable free energy source. The design of a solar field is influenced by technical characteristics of the selected collectors.

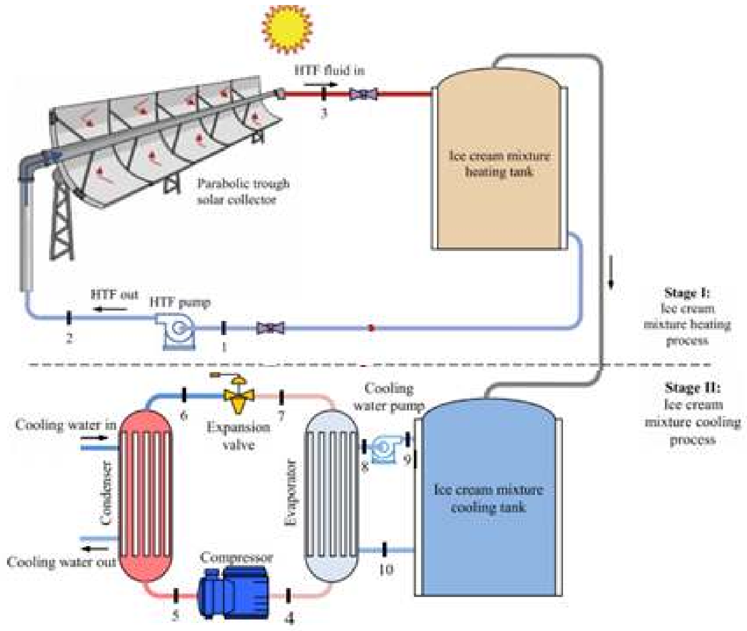


Figure (29): Schematic overview of the proposed system (Kizilkan, Kabul & Dincerb, 2016).

The location of the plant and the climate data. All these parameters are called design-point conditions. The solar collector field consists of several PTS rows. The temperature at the exit of the PTS is about 390 ℃ and at the inlet of the PTS is about 290 ℃. For the operating oil, Thermonil-VP1 is selected for its good heat transfer properties and good temperature control (Kizilkan, Kabul & Dincerb, 2016). Because of its good properties, it is used in many high temperature applications driven by PTS such as power plants. Knowing that determining the appropriate temperature for the heat transfer fluid at the solar field outlet, it must be at least 15 ° C higher than the steam temperature required to be provided to the process to compensate for the thermal loss between the solar field outlet and the steam generator inlet, which is 5-7 degrees Celsius (Kizilkan, Kabul & Dincerb, 2016). So in this thesis, 375 ° C was chosen as the temperature of the superheated steam as the working fluid. Table (8) below summarizes some of the system output specifications based on the 250 m^2 available space from energy 3D software .

Table (8): proposed system technical specifications.

Thermal fluid	Therminol VP-1
Total Aperture area	30 m^2
Number of parabolic trough	5
Number of modules	25
Focal length	1 m
Solar collector area	249.67m^2
Capacity	65.3 kW

The system is going to produce steam for heating process only, the power capacity of the proposed system that have been selected is 65.3 kW, based on the specified area, which is equal to 250 square meters. Figure (30) shows a 3D design for the proposed system.

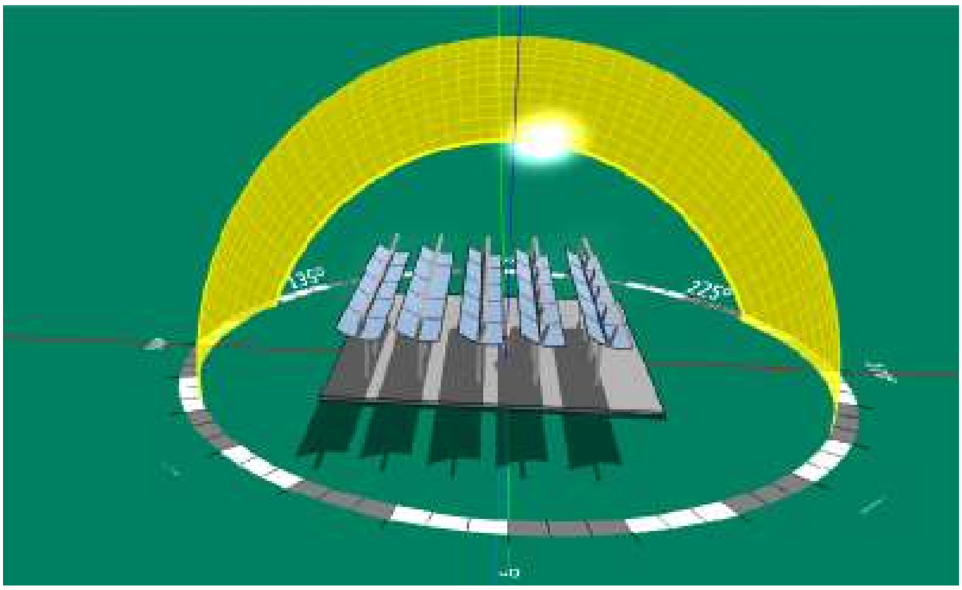


Figure (30) : 3D design for the proposed system

Subsequently, This will help the boiler in meeting the needs of the factory, which usually produces about 3901.33 kWh/d, and considering that the boiler consume 111666 kg LPG/ year, the CLF of it is 12.9 kWh/kg, and the efficiency of the boiler is 65%. This number can be explained by the following calculations, while the boiler works 240 day a year, and 8 hours a day, then:

Input energy = $m_{LPG} \times CLF$

$= 111666\ \text{kg/year} \times \frac{12.9\text{kWh}}{\text{kg}} = 1440491.4\ \text{kWh/year}$

Which equal to 6002.04 kWh/day

Then

Output energy = $\times$ Input energy

$= 1440491.4 \frac{\text{kWh}}{\text{year}} \times 65\% = 936319.41\text{kwh/year}$

Which equal to 3901.3 kWh/day

So that, the output thermal power of the boiler is :

Output power = $\frac{936319.41\text{kWh/year}}{8\ \text{months} \times 240\ \text{days} \times 8\text{hours}} = 487.66\text{kW}$

therefore the proposed CST system will produce 65.3kW .Assuming that the same power that will be produced from the CST system will be produced through the boiler. As can be explained through the calculations and equations below, in order to know the amount of possible savings in energy, fuel, and cost. With using the proposed CST system in producing 65.3 kw of thermal power.

Figure (31):input and output sketch of the boiler

Where the efficiency of the boiler () is equal to 65% and the assumed output energy is equal to 65.3 kW then the input power will be calculated as in equation (47)

$$= \frac{P_{output}}{P_{input}} \qquad (47)$$

Thus, the input power needed to produce 65.3kW will be equal to 100.5 kW as shown in equation (48)

$$P_{input} = \frac{P_{output}}{\ } = \frac{65.3}{65\%} = 100.5kW \qquad (48)$$

Which means that the input power will be needed to produce the 65.3 kW from boiler is equal to 100.5kW, knowing that the LPG boiler in the factory is working 8 hours per day and 240 days per year

Therefor the input energy needed per day can be calculated as in equation (49)

$$= P_{input} \times \text{working hours per day}$$

$$= 100.5kw \times 8\ h = 804kWh/day$$

Which means 192960 kWh/year (49)

Based on that, the saving in the natural gas (LPG) that is using in boiler could be calculated through equation (50)

$$\text{Input energy } = \text{CLF } \times \text{ mass of LPG} \quad (50)$$

Where (CLF) is the calorific value of the LPG gas, which is equal to 12.9kWh/kg, and the mass of LPG is the amount of LPG in (kg),that is needed be used.

Subsequently, this amount of LPG is the same amount that will be saved through using the CSP system that can be calculated as in equation (51)

$$\text{LPG saved} = \frac{\text{E}_{\text{input}}}{\text{CLF}} = \frac{804}{12.9} = 62.3 \text{ KgLPG/day} \quad (51)$$

And since the boiler works about 240 days a year then the saving amount of LPG per year will be equal to the 14952 kg LPG/ year as can be seen in equation (52)

$$\text{LPG } = \text{ 62.3 kg LPG/day } \times \text{ 240days/year } = \text{ 14952 Kg LPG/ year} \quad (52)$$

Taking in consideration the saving amount of money, which means the saving in cost of the LPG gas, where the cost of one liter of LPG is 0.75$, therefore the saving in LPG cost in equation (53) below:

First of all, a kg (LPG) was needed to be transfer to liter (LPG)

Therefore a 14952 kg LPG/ year is equal to 29904 liter as the LPG density is almost 1.89 kg/L

Thus:

$$\text{Cost saving} = \text{LPG} \times \text{cost of 1liter of LPG}$$

$$= 29904 \frac{\text{Liter LPG}}{\text{Year}} \times \frac{0.75\$}{\text{Liter LPG}} = \frac{22428\$}{\text{year}} \quad (53)$$

On the economic side, there are some assumptions that have been taken into consideration to do the economic analysis of the project in order to be able to know whether the project is economically feasible for construction or not, and they were as shown in Table (9). This has been worked on through more than one method to ensure the viability of the project, which can be summarized in the following ways: simple payback period(SPP), net present value (NPV) using equation (41), rate of return (ROR) through using equation (46), and benefit to cost ratio (B/C) by using equation (44)

Table (9): assumptionfor the proposed system

interest rate	12%
Project life	25 years
Debt ratio	0%
inflation factor	4%
Fuel type	Propane
Fuel cost	0.75$/ liter
Fuel consumed in the factory	111666 kg/year
Fuel saving	7476.207 kg/year
Electricity cost	0.17 $/kwh
Initial cost	3000 $/KW
Operation and maintenance costs	43 $/kw.year

In addition, the necessary financial analysis was performed for the project, which resulted, as it is evident from the cash flow diagram in Figure (31) below, that the initial costs required to establish a CSP project with a capacity of 65.3 kW will be $ 195,900. the annual costs, which are presented by the annual operation and maintenance costs, are equals to 2807.9$/year. Moreover, the annual benefits has also been analyzed, and as mentioned previously the annual saving rate by using the proposed system is up to 22428$/year.

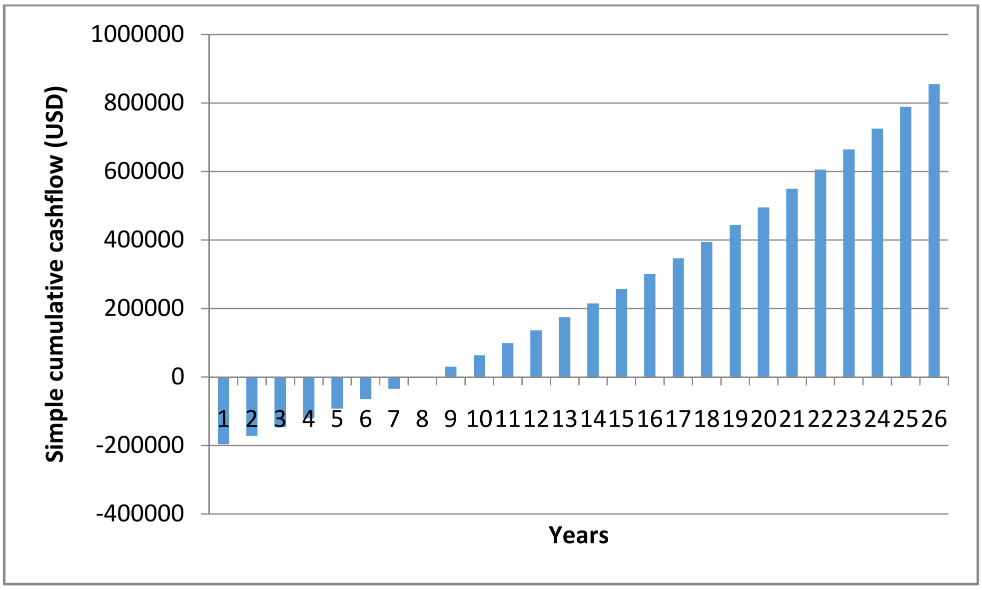


Figure (32):Total cash flow.

Therefore, after making the necessary financial calculations, it became clear as shown in table (10) that the proposed project on the available area is economically feasible for the factory. since the simple payback period is 8.7 years as can be seen in equation (54) below, which calculates how long it will take for the original investment to be paid off. The disadvantage is that this method fails to calculate the time value of money. For this reason, the calculated payback periods for longer investments have a greater likelihood of inaccuracies and the other parameters such as the benefit cost ratio, that equal to (1.0773>1), which means the project's costs are less than the benefits, and Net Present Value (NPV), which gives a positive value equal to 211,060.17 $, where these numbers depend on the equations in chapter 4 means that this project is economically feasible for the factory.

$$SPP=\frac{\text{investment}}{\text{Saving}}=\frac{195900\$}{11214.3\$/\text{year}}=8.7\text{years} \quad (54)$$

Table (10): financial results

SPP	8.7years
(NPV)	211,060.17$
Annual life cycle savings	22428$/year
Benefit-Cost (B-C) ratio	1.077387
ROR	13%

Moreover, the proposed system reduce the greenhouse emissions with average of 48896.64 kgCO2 / year, which means 1222416 kgCO2 in the 25years of the project life.

Therefore the project as a whole is economically acceptable, as the period of repayment of the project's profits are 8.7 years, which is considered a short period, although the payback period is strictly limited to the amount of time required to earn the initial investment costs. The rate of return on investment could see sharp fluctuations. Comparisons using payback periods do not take into account the long-term profitability of alternative investments. However, other economic indicators of the project’s effectiveness indicate that the project is feasible.

Chapter Seven

Sensitivity analysis

Chapter Seven
Sensitivity analysis for active conditions

Sensitivity analysis is a technique used to determine how the different values of an independent variable affect a particular dependent variable within a given set of assumptions by creating a specific set of scenarios and are used within certain limits that depend on one or more input variables. Sensitivity analysis is a method of predicting the outcome of a decision if the situation turns out to be different compared to the main predictors . For this study, as seen in the results shown in tables (8,10), the initial cost of the Parabolic trough proposed system, and the interest rate with two different life time projects, significantly affected the financial feasibility analysis. In this chapter, this input variable “Solar Field Price”, "interest rate ", and "the initial cost of the system "are subjected to several scenarios to note the role of changing these input variables in the financial viability analysis of the selected CSP sites.

First of all, searches have been done to find the price of the CST system in case of producing thermal energy only, so as to obtain the most accurate price possible. Based on that, it has been concluded that the price of the system in this case is equal to $ 2000 per kilowatt (Sebastián González & Flamant, 2014)

As it is known that the CST technology does not exist in Palestine, it is expected that its price will be higher than that, but with the expectations that have been worked on, and by researching on the change in the global price of this technology, As it was observed that there is a continuous change in the initial investment of the CSP system as shown in figure (32) below (IRENA, 2019), whether by a decrease or increase in these costs.

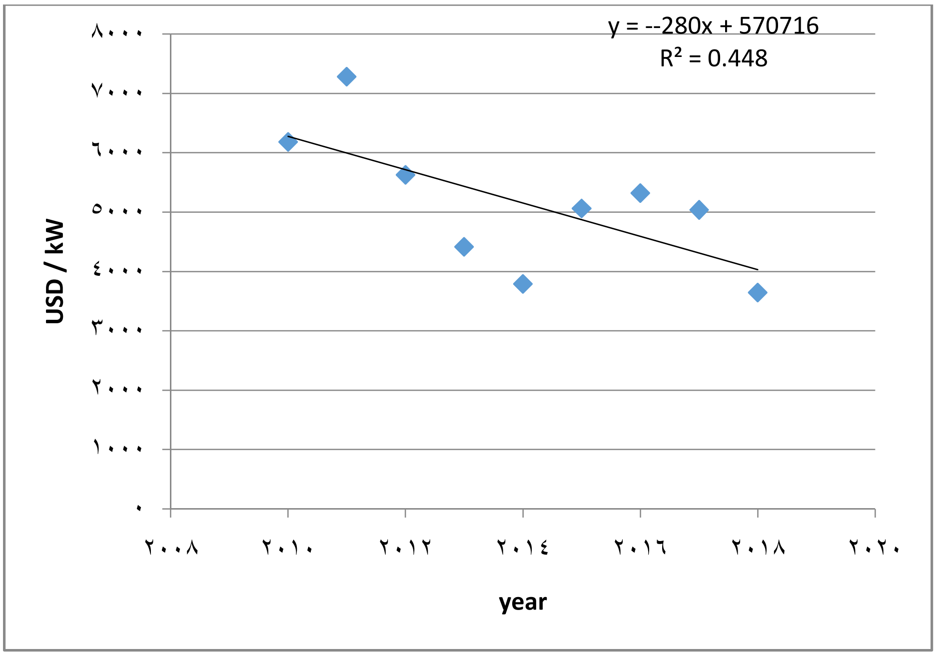


Figure (33): Changes in the average initial costs of the CSP systems (IRENA, 2019).

Therefore it is possible that the price will reach 2000 dollars. In the year 2025, this can be illustrated form the liner equation (53) that was derived from the drawing above as can see in calculation below:

$$y = 570716 + -280.82x \tag{53}$$

Where y is refers to the initial investment in \$/kw and, x refer to the years that the investment will equal to 2000\$/kw

Then, by substitution in equation (53):

$$2000\$/kw = 570716 + -280.82x$$

Then x will equal to 2025, which means that the project initial cost may decline to 2000$/kw by year 2025, where it is not considered as a long period, since it needs only another five years

Accordingly, some sensitive criteria have been dealt with, that give different results and changes in the economic viability of the project, and these criteria can be divided into a main factor, including two sub-factors, Which has important and radical implications for the project.

The change in the project life was considered as a basic factor where the other factors depend on it , the first is the initial investment of the project and the second is the internal rate of return. It is possible to work on these different cases as in the following scenarios, so that they were divided into two main scenarios that depend on a change in the life of the project between 25 and 30 years, where each scenario followed with changes in the interest value and the initial cost of the project

First scenario

Initially, the first scenario will work on the stability of the project life at 25 years, with change in the initial cost of the project between (2000$/kW,2500$/kW, and 3000$/kW), and changes in the interest value, which varies between (8%, 10% and 12%). Therefore, it will be divided into nine different cases to note the changes in the project results.

The First case assumption when the project life time is 25 years, could be summarized as in table (11) below, It is worth noting that the inflation factor is equal to 4%, which was not taken, which takes role in changing the value of saving in the price of LPG as shown in the table.

Table (11): sensitivity parameters

Project life	25 years
interest rate (i)	8%
Initial investment	2000$/kw
Inflation rate	4%

These different values of the internal rate of return and initial investment of the 25 years project life compering to the basic case, makes changes in economic indicators, that effects on the project results as shown in figure (33) that appears the simple cumulative cash flow

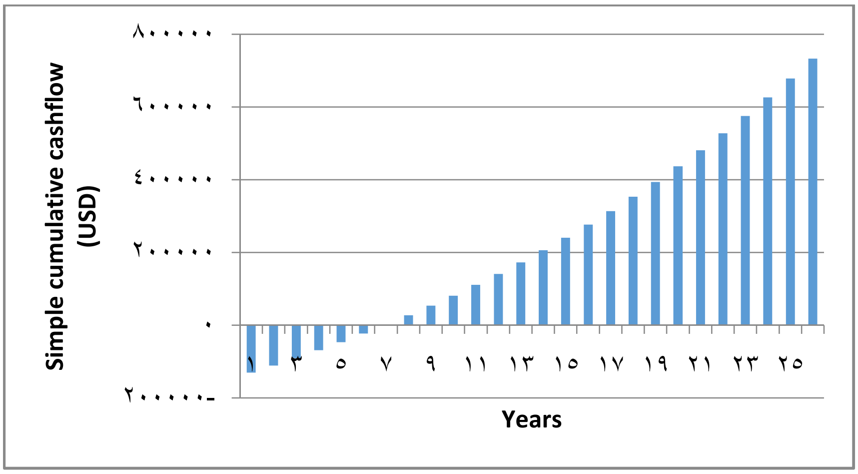


Figure (34) : simple cumulative cash flow first case of the first scenario.

On the other hand, the results of this case can be summarize in table (12) below, where it is possible to see the improvement appeared in the economic indicators of the project, indicating that it has become economically feasible, based on the value of each NPV, that become in a positive value B/C, Which is now greater than 1, SPP and the value of the ROR which become greater than interest rate of the project (i).

Table (12): economic indecator results for the first case

SPP	7 years
NPV	$ 317,075.94
ROR	19%
B/C	2.42784

Second case has the same timeliness, where it is 25 years, same initial investment, but different interest rate, table (13) shows the other factors with the saving in LPG and the inflation rate, that have been relied upon.

Table (13): sensitivity parameters in the second case

Project life	25 years
interest rate (i)	10%
Initial investment	2000$/kw
Inflation rate	4%

This change that occurred in this case depends mainly on the change in the value of interest rate, which in turn affected the value of savings that was made on the price of used gas. However, it is worth noting, that this change did not change in the simple payback, since, the value of the capital investment is still the same, then the initial investment will be returned at year 7 as can be clearly seen in figure (34) below.

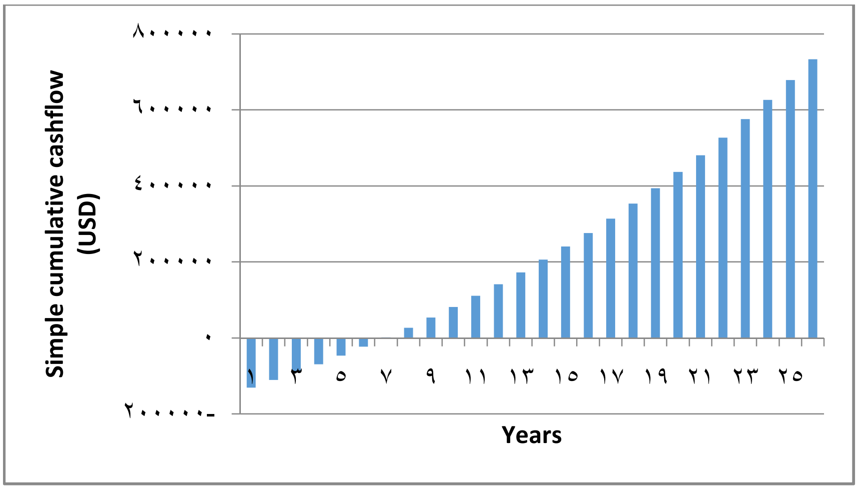


Figure (35): cash flow for the second case changes of the first scenario.

this affect the other economic indicator in a good way, which led to make the project with this interest rate equals to 10% economically unacceptable, as rate of return is more than the interest rate, and the value of the net present value is still in the positive side more than 0, which make the benefit cost ratio also more than 1, means the project is still feasible, table (14) below shows the specific value of the indicators.

Table (14): economic indicator results for the second case

SPP	7 years
NPV	$ 256,207.27
ROR	19%
B/C	1.961771

Moreover the third case the project has also the same life time, and the same initial investment, with the different of the interest rate to become 12%, the table (15) below shows the value of the parameters, including the saving amount of the LPG, that could be save according to the changes in this case

Table (15): sensitivity parameters in the thirdcase

Project life	25 years
interest rate (i)	12%
Initial investment	2000$/kw
Inflation rate	4%

the result of this case show in table (16), where the net present value, rate of return, b/c ratio and simple payback period presented again with numbers to be able to figure out if the project with this conditions will be feasible or not. and figure (35) shows the cash flow diagram of this case which the SPP can clearly see in year 7

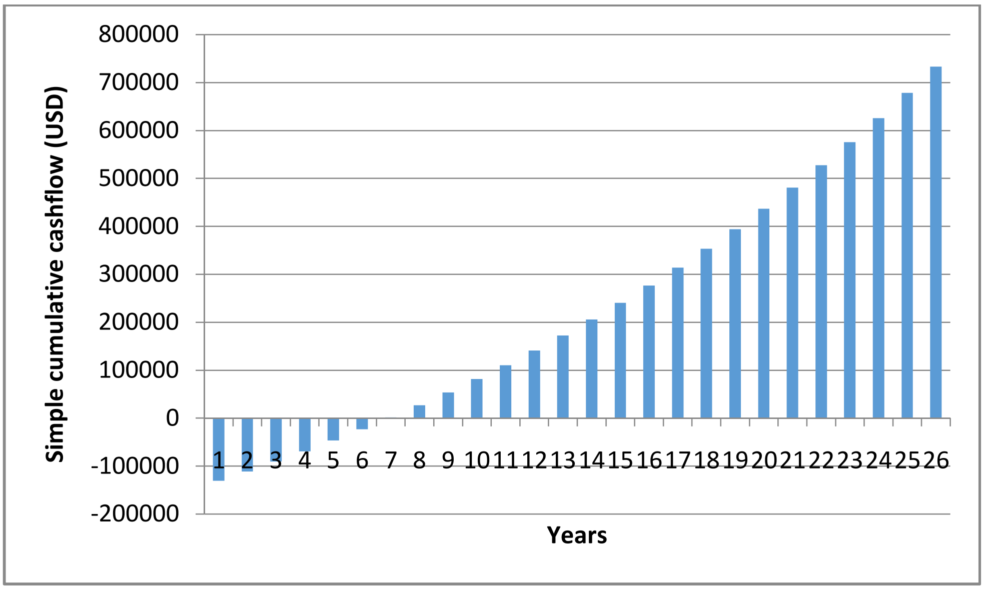


Figure (36) : cash flow for the third case changes of the first scenario.

Table (16):economic indicator results for the third case

SPP	7 years
NPV	$ 211,060.17
ROR	19%
B/C	1.616081

As shown in the table, the change in the economic indicators still taking a positive side, as the value of the internal rate of return (19%) is more than the suggested interest value, which is 12%, Furthermore the B/c ratio is more than one, and the NPV also more than zero, these results confirm the effectiveness of the project for implementation

With the onset of the fourth case the different will appear in the initial cost of the project, which will become 2500$/Kw, and the interest rate will keep to change starting with 8%, and project life of 25 years. table (17) below shows the value of the parameters at this stage

Table (17): sensitivity parameters in the fourth case

Project life	25 years
interest rate (i)	8%
Initial investment	2500$/kw
Inflation rate	4%

In this case, the impact of the increase in the investment price of the project on the time period for restoring the capital cost, which decreased by about a year, as can clearly show in figure (36) below, that shows the simple cumulative cash flow.

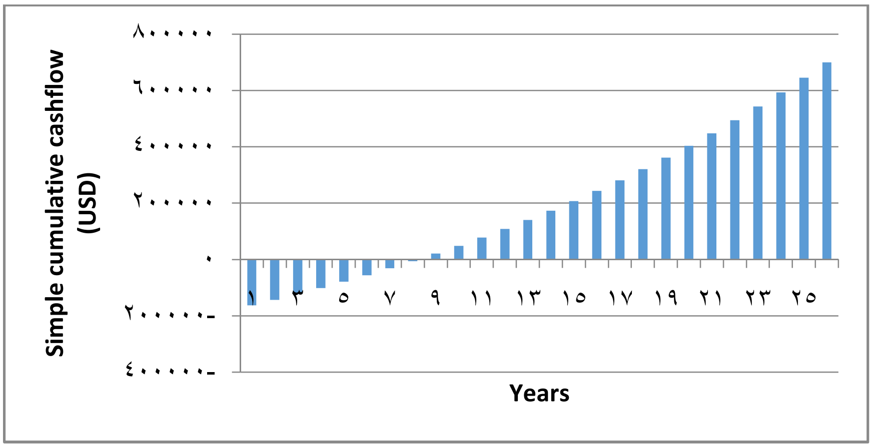


Figure (37) : cash flow for the fourth case changes of the first scenario.

Where the pay pack period become at year 7, and other changes in the economic indicators, such as NPV, B/C ratio, and rate of return appear. Table (18) below shows the value of these indicators

Table (18): economic indicator results for the fourth case

SPP	8years
NPV	$ 317,075.94
ROR	15%
B/C	1.942272

Through the values in the previous table from the changes that took place in this case, it appears that these changes still had good impact on the project, the value of net present value still positive, in addition to the value of B/C ratio is more than 1, and the value of the rate of return is more than the value of the proposed interest for the project. Which mean that the project is not economically feasible. Consequently, these changes, which were shown by the aforementioned results, can be adopted in this project.

In the fifth case, which also depends on the capital investment of 2500$/kW, but its difference in interest rate, whose value is 10%, with 25 years project life. Table (19) below summarize these parameters

Table (19): sensitivity parameters in the fifeth case

Project life	25 years
interest rate (i)	10%
Initial investment	2500$/kw
Inflation rate	4%

This change in relation to the fourth case did not change the project payback period, as the cash flow in figure (37) can show.

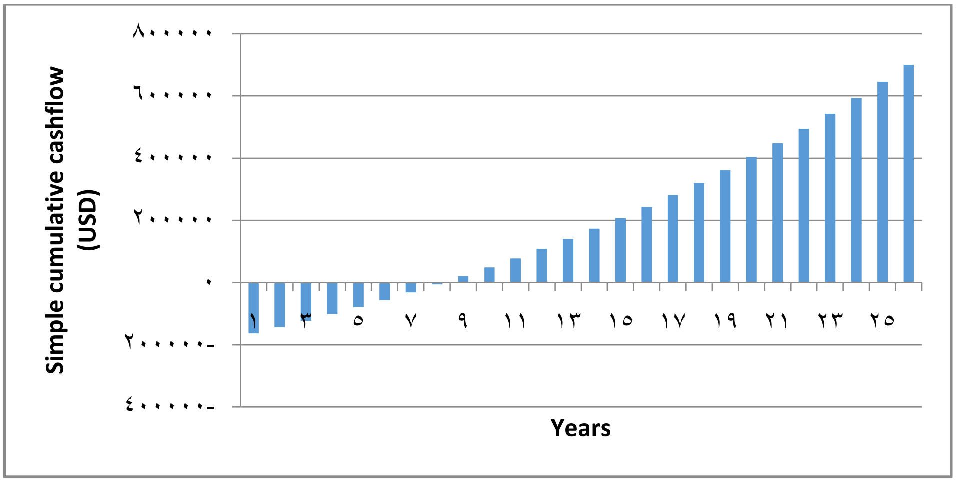


Figure (38) : cash flow for the fifth case of the first scenario.

the economic indicators of the project in this case can show in table (20) below

Table (20):economic indicator results for the fifth case

SPP	8 years
NPV	$ 256,207.27
ROR	15%
B/C	1.56

Where these values are less than the values in the previous case which the net present value is equal to 256,207.27 $, and the b/c ratio is more than 1 equal to (1.56),which is less than B/C ratio in the fourth case. but these circumstances are still acceptable . and still making the project economically feasible.

In the sixth case of this scenario, the investment price remains 2,500 and the project is last for 25 years, but the interest value changes to becomes 12%, where the value of the saving in LPG cost change as can see in table (21).

Table (21): sensitivity parameters in the sixth case

Project life	25 years
interest rate (i)	12%
Initial investment	2500$/kw
Inflation rate	4%

On the other hand, figure (38) show the cash flow of this case, Whereas, the project will recover the capital investment at year 7 and start getting profits at year 8 as can see

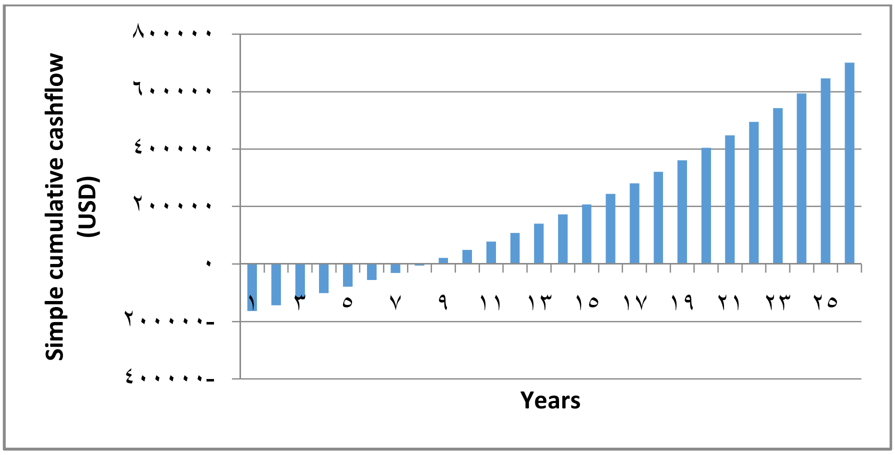


Figure (39) : cash flow for the sixth case of the first scenario.

Based on this, the project is accounted as a feasible project, where the payback period will take 7 years, and other economic indicators whose value did match the conditions of economic effectiveness of the project**,** table (22) summarize the values

Table (22): economic indicator results for the sixth case

SPP	8 years
NPV	$ 211,060
ROR	15%
B/C	1.292865

Since the value of the net present value is positive, the B/C ratio more than 1 and the rate of return is more than the interest rate of the project, then the project is clearly still economically feasible.

With the beginning of the seventh case and the end of the ninth case, the investment cost remains 300$/kW with the life of the project 25 years, and the interest value changes between (8%, 10% and 12%).

Therefore table (23) shows the value of sensitivity parameters in case seven

Table (23): sensitivity parameters in the seventh case

Project life	25 years
interest rate (i)	8%
Initial investment	3000$/kw
Inflation rate	4%

As previous cases these changes will affect the cash flow diagram and the economic indicators of the project as can see in figure (39) for cash flow and table (24) for the net present value, rate of return, B/C ratio and the simple payback period.

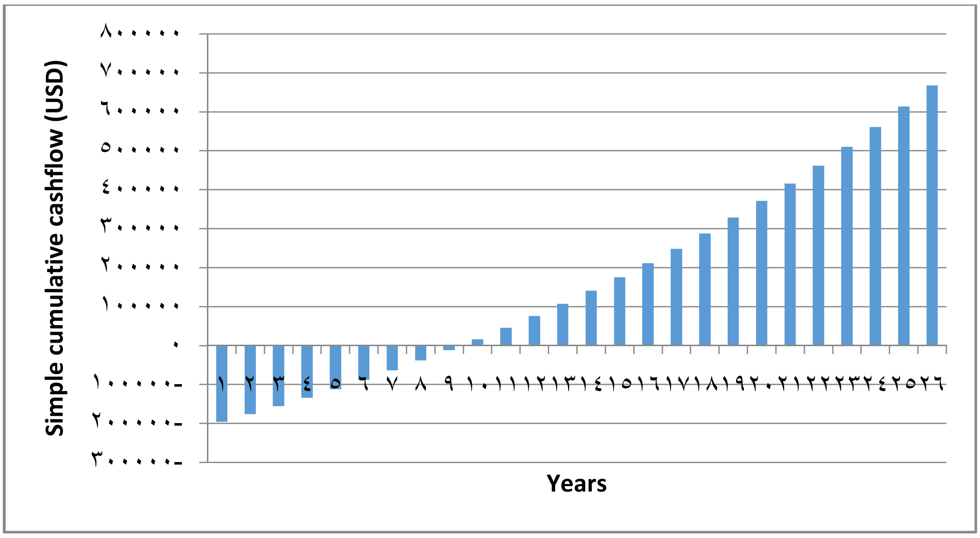


Figure (40) : cash flow for the seventh case of the first scenario.

It is clearly shows from the drawing that the period of capital recovery increased, based on increasing in the investment cost, which reached to year 9 of the project's life, means that the project will get the investment cost back at year 9, where it is considered satisfactory duration of recovery, Table (24) is summarizing the economic indicators.

Table (24): economic indicator results for the seventh case

SPP	9 years
NPV	$ 317,075
ROR	13%
B/C	1.61856

Net present value has a positive value, the b/c ratio is again more than 1, and the rate of return reach the more than 8% v. Thus, this case is grouped with other cases where the project is economically viable based on these conditions.

In addition to, The eighth case will take into account a change in interest rate to 10% with remaining the rest of the indicators the same, but the difference in interest works on a difference in the savings of LPG cost. As can see in table (25)

Table (25): sensitivity parameters in the eighth case

Project life	25 years
interest rate (i)	10%
Initial investment	3000$/kw
Inflation rate	4%

The cumulative cash flow of this case can be seen in the figure (40) below, which shows the year in which the capital for the project is recovered, and it still at year 9 as the previous case, according to having the same investment cost of 3000 $/kW.

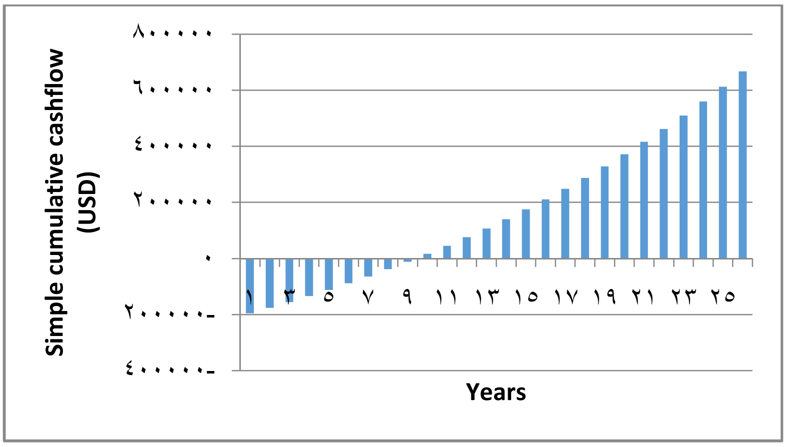


Figure (41) : cash flow diagram of the eighth case of the first scenario.

However, will also return to touching upon the economic indicators that have been adopted, which table (26) illustrates

Table (26): economic indicator results for the eighth case

SPP	9 years
NPV	$ 256,207
ROR	13%
B/C	1.30784

Which shows that the project in this case is still feasible, as the net present value is positive, B/C ratio is more than one and the rate of return is more than the interest rate

The last case of this scenario is the ninth case, which is have the same project life, the same initial investment, and different interest rate, as can see in table (27) below

Table (27): sensitivity parameters in the ninth case

Project life	25 years
interest rate (i)	12%
Initial investment	3000$/kw
Inflation rate	4%

Figure (41) below shows the cash flow of this case, where the payback period is still at year 16

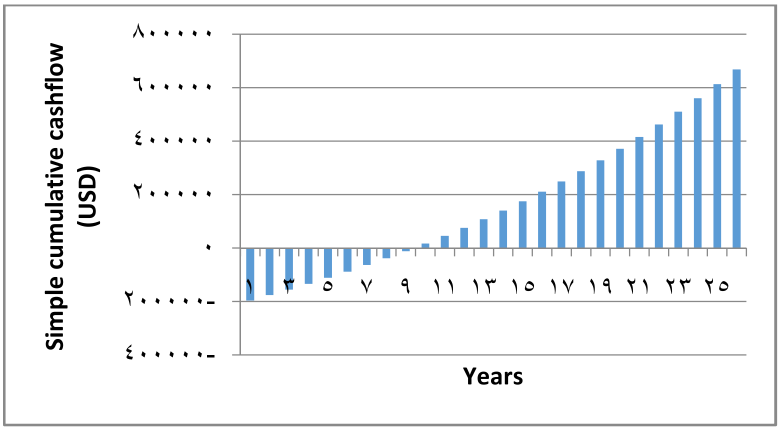


Figure (42): cash flow diagram of the nine case of the first scenario.

The cash flow has not actually changed significantly according to these changes, but the change appear in the economic indicators that are clarified in table (28)

Table (28): economic indicator results for the nine case

SPP	9 years
NPV	$ 211,060
ROR	13%
B/C	1.07

The impact of these changes on the project is also positive, this can be noticed through the net present value, where it is positive, means that the present value of the costs do not exceeds the present value of the revenues at the assumed discount rate. Rate of return is more than the assumed interest rate of the project, and the B/C ratio is more than 1, not mentioning the simple payback period, which is in year 9. Therefore the project at this case is also economically feasible.

Second scenario

At this part, works will be done on the stability of the project life at 30 years and other parameter will be change, but the initial cost of the project will change every three cases according to the change in the interest rate value, which varies between (8%, 10% and 11%). Therefore, it will be divided into three different stages to note the changes in the project results.

The first case will take the assumption accrued in table (29) below, as the project life will be 30 years, the initial investment will be 2000$/kW and this will applied for the first three cases, anyways the interest rate will start with 8%.

Table (29): sensitivity parameters in the first case

Project life	30 years
interest rate (i)	8%
Initial investment	2000$/kw
Inflation rate	4%
(PW)	175,914.38 $

The cash flow diagram in figure (42) below shows the year at which the investment of the project will be recovered. Where it is appeared at year 12

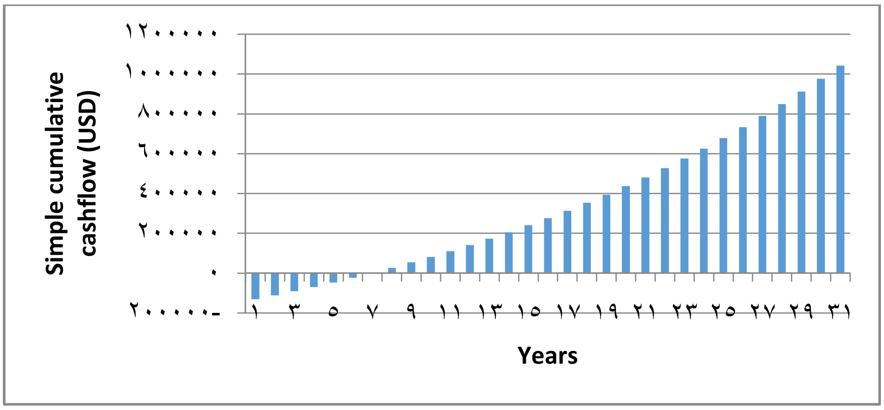


Figure (43) : cash flow diagram for the first case of the second scenario.

Table (30) shows the values of the economic indicators where the change in the project life positively affected on the project as can see

Table (30): economic indicator results for the first case of the second scenario

SPP	7 years
NPV	315,282$
ROR	19%
B/C	2.693942

So that when the interest rate of the is 8%, and the initial investment is 2000$/Kw, the project will be economically feasible as the net present value is positive, the B/C ratio 2.69 >1 and the rate of return is higher than the interest rate, means the project with these assumption can be adopted.

In the second case of this scenario the assumption can be seen table (31) below, where the project life is the same, initial investment is also the same, and the changes will happen in the interest rate.

Table (31): sensitivity parameters in the second case

Project life	30 years
interest rate (i)	10%
Initial investment	2000$/kw
Inflation rate	4%

Therefore the cash flow diagram in figure (43) below shows the year of payback period which is the same of the first case in this scenario, due to the stability of the initial investment and the project life

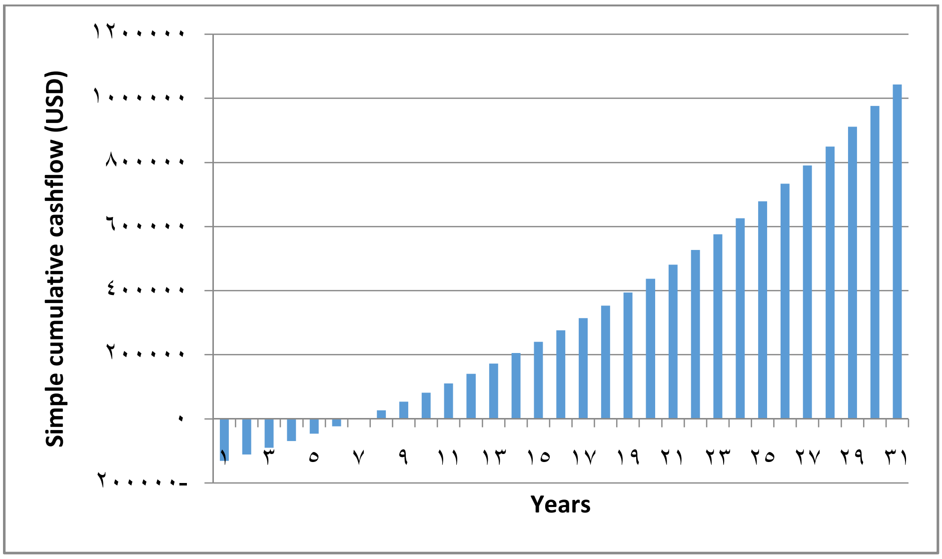


Figure (44) :cash flow diagram for the second case of the second scenario.

When it comes to evaluating the project under these conditions, table (32) is showing the value of each of the net present value, rate of return, B/C ratio, and the simple payback period.

Table (32): economic indicator results for the second case of the second scenario

SPP	7 years
NPV	$ 276,654.67
ROR	19%
B/C	2.11

Depending on the net present value the project is classified as a feasible project, where the net present value is > 0 , and the internal rate of return is higher than the interest rate.

At the third case the change will be in the interest rate as can show in table (33) below, where this change decrease the saving in LPG cost.

Table (33): sensitivity parameters in the third case

Project life	30 years
interest rate (i)	12%
Initial investment	2000$/kw
Inflation rate	4%

Then the cash flow diagram if this case can be seen in figure below (44) which shows that the investment will be also recovered at year 7.

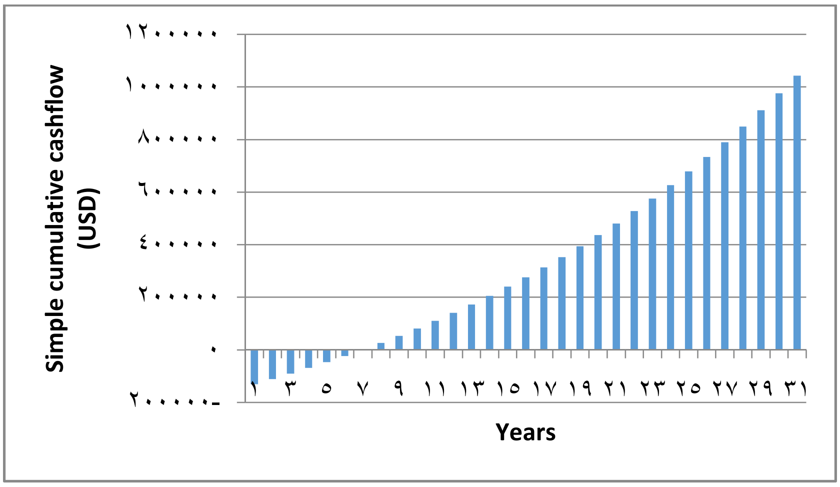


Figure (45) : cash flow diagram for the third case of the second scenario.

The evaluation results in this case of the project are shown table (34) below, it was found that the project in this case is also economically feasible based on the values of the net present value, rate of return and the B/C ratio.

Table (34): economic indicator results for the third case of the second scenario

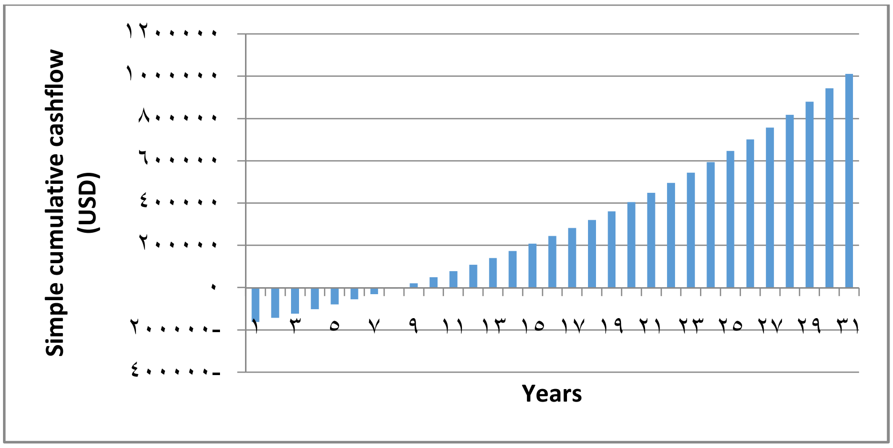
SPP	7 years
NPV	$ 223,214
ROR	19%
B/C	1.7

On the other hand, From the beginning of the fourth case until the sixth case, the investment value will be fixed at 2,500 $/kW and the change will be in the interest rate value. Therefore table (35) shows the assumption of the fourth case

Table (35):sensitivity parameters in the third case

Project life	30 years
interest rate (i)	8%
Initial investment	2500$/kw
Inflation rate	4%

Figure (45) below shows the cash flow of the fourth case, where the simple payback period can be easily seen through it at the year 8. As the increase in the initial investment led to increase the in simple payback period



Figure(46) : cash flow diagram for the fourth case of the second scenario.

Table (36) summarize the result of this case including the net present value, rate of return and the B/C ratio.

Table (36): economic indicator results for the fourth case of the second scenario

SPP	8years
NPV	$ 351,828
ROR	16%
B/C	2.15

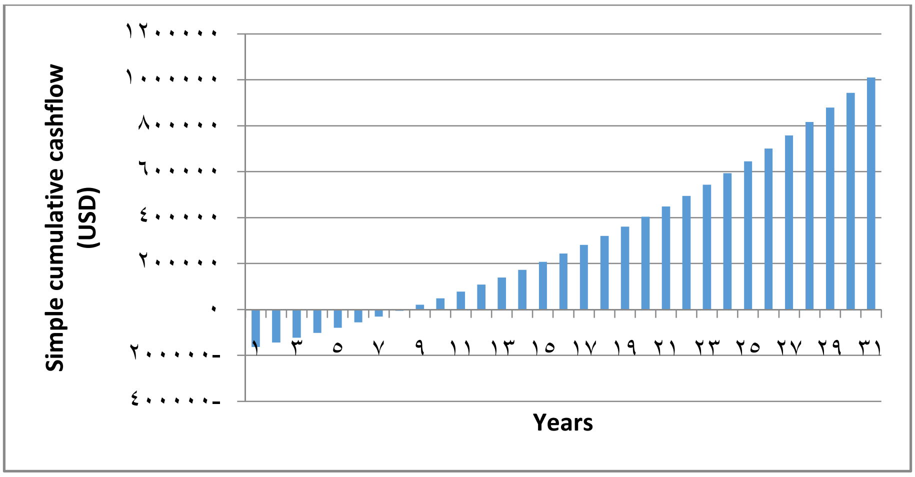
According to these results and depending on the net present value, the project with these assumptions is considered as a feasible project.

Fifth case will take the same conditions of the fourth one, but with a different interest rate, table (37) below shows the values takes for the sensitive parameters.

Table(37): sensitivity parameters in the fifth case

Project life	30 years
interest rate (i)	10%
Initial investment	2500$/kw

Accordingly, the cash flow diagram of this case can be show in figure (46) below, where the investment will be recovered also at year 8



Figure(47) : cash flow diagram for the fifth case of the second scenario.

The economic indicators of this case can be seen in table (38) below, As its results show that the project is still economically feasible where the net present value is positive, B/C ratio is higher than one, and the rate of return is higher than the interest rate, more over the simple payback period at year 8.

Table (38): economic indicator results for the fifth case of the second scenario

SPP	8years
NPV	$ 276,654
ROR	16%
B/C	1.69

In the six case where the interest rate is 12% and other parameters are the same as can shows in table (39) below

Table (39): sensitivity parameters in the sixth case

Project life	30 years
interest rate (i)	12%
Initial investment	2500$/kw
Inflation rate	4%

Cash flow diagram appear in figure (47) below,

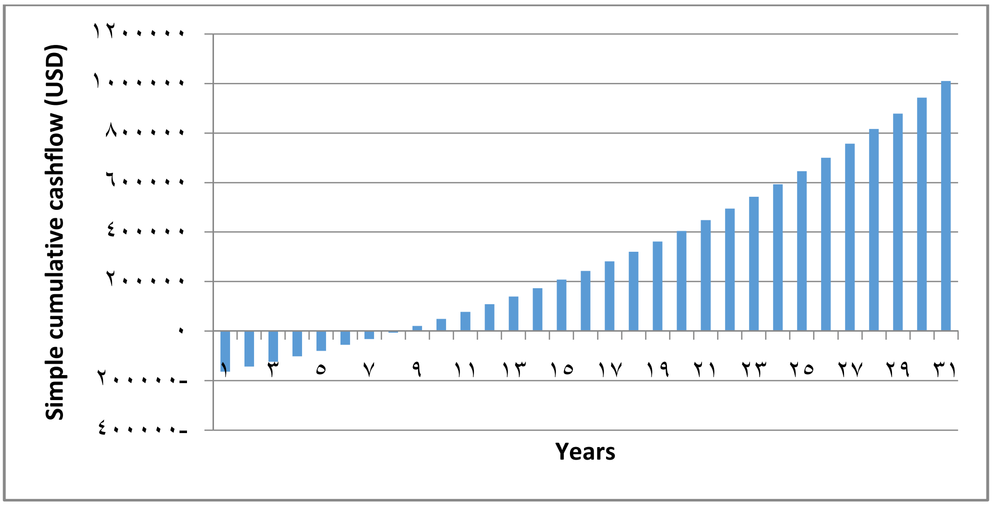


Figure (48) : cash flow diagram for the sixth case of the second scenario.

The economic indicators of this case can be seen in table (40) below, As its results show that the project is economically feasible where the net present value is higher than 0 , B/C ratio is higher than one, and the rate of return is higher than the interest rate, moreover the simple payback period at year 8.

Table (40): economic indicator results for the sixth case of the second scenario

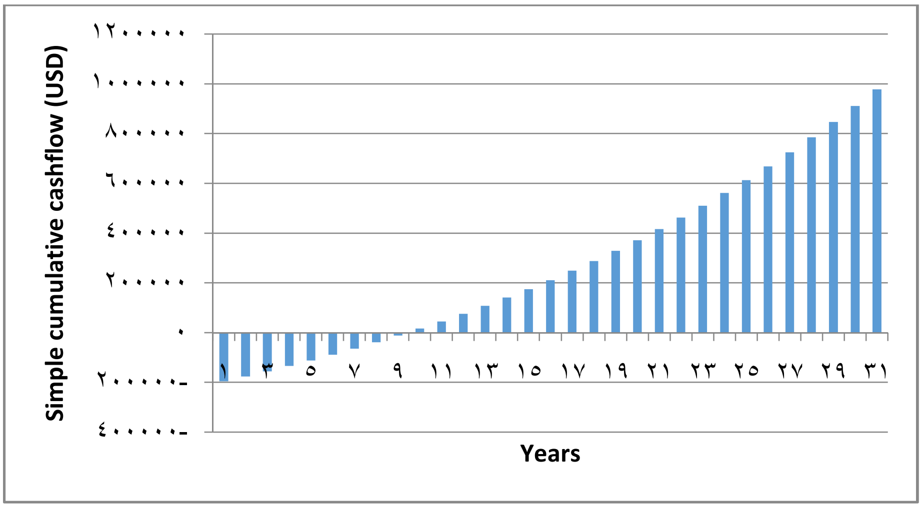
SPP	8years
NPV	$ 223,214
ROR	16%
B/C	1.36

Hence, at the beginning of the seventh case and the end of the ninth case, the life of the project will remain the same as it is 30 years, and the cost of investment will change to 3000$/kW, with the usual change in the interest value of the project. Table (41) below shows the values of the changes in the sensitivity parameters.

Table (41): sensitivity parameters in the seventh case

Project life	30 years
interest rate (i)	8%
Initial investment	3000$/kw

Through figure (50) and table (42) below, it was found that the recovery of the capital investment will take place in the 8th year in this case. As it has been noted, that the payback period depends mainly on the capital invested at the beginning of the project, so the greater the investment, the more years needed to recover the capital. So the figure (48) for the coming stages will not change significantly.



Figure(49) : cash flow diagram for the seventh case of the second scenario.

Table (42): economic indicator results for the seventh case of the second scenario

SPP	9 years
NPV	$ 351,828
ROR	14%
B/C	1.79

These results show that the project is economically viable, based on the net present value, where it is positive and the rate of return is more than the interest rate, and the B/C ratio higher than 1.

In the eighth case, the changes made to the parameters are shown in the table (43).

Table (43): sensitivity parameters in the eighth case

Project life	30 years
interest rate (i)	10%
Initial investment	3000$/kw

And the cash flow diagram is shows in figure (49). With the payback period is appears at the year 9 of the project life.

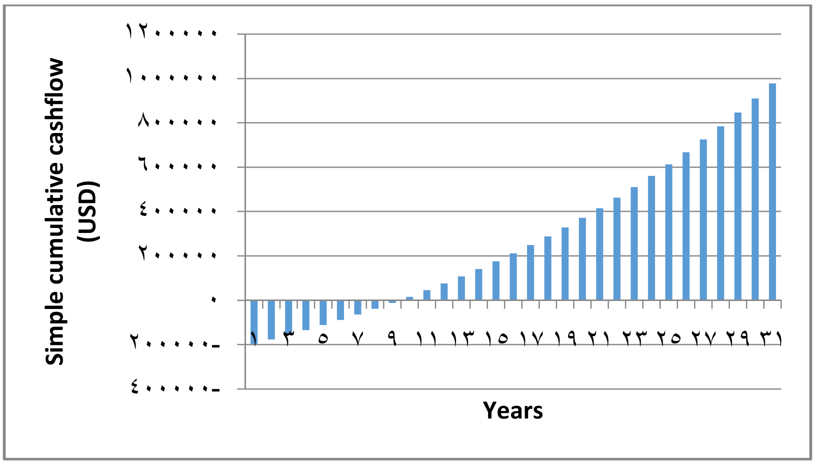


Figure (50) : cash flow diagram for the eighth case of the second scenario.

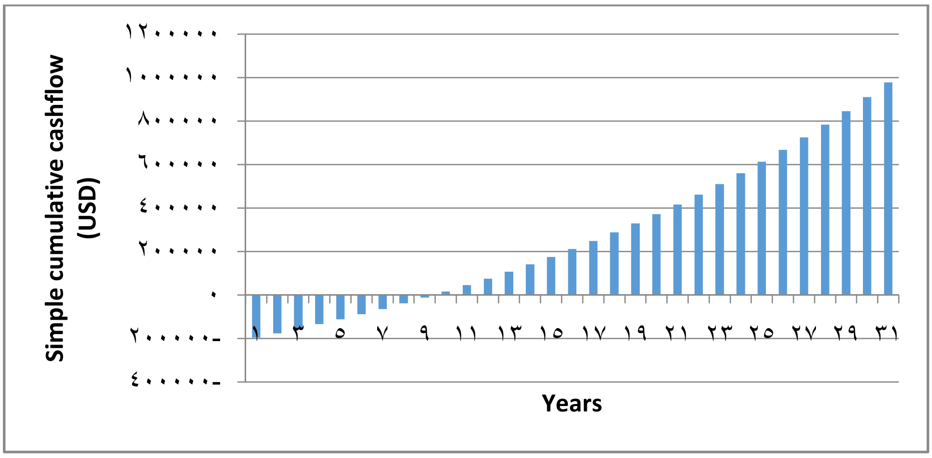
The results in table (44) below show that the project is encouraging, where the value of the returns on it will be more than the costs, as indicated by the positive value of the NPV, in addition to that, the rate of return value is higher than the interest rate. And payback period is 9 years

Table (44): economic indicator results for the eighth case of the second scenario

SPP	9years
NPV	$ 276,654
ROR	14%
B/C	1.14

Finally in the last case, the interest rate will be 12% for the same lifetime of the project and the investment price is 30,000$/kW.

This make the cash flow diagram be as shows in figure (50) below, so that the 9th year is the year in which the project capital will be restored, and then in the 10th year to start getting the profits from the project.



Figure(51) : cash flow diagram for the ninth case of the second scenario.

Moreover, table (45) shows briefly the results of the economic analysis of the used indicators, such as NPV,ROR, B/C ratio, and the simple payback period. And It turns out that the project in this case is also acceptable.

Table (45): economic indicator results for the ninth case of the second scenario

SPP	9 years
NPV	$ 223,214
ROR	14%
B/C	1.13

At the end, all these analysis can be summarized as in table (46) for the first scenario with the life time project of 25 years, the results indicate that the project is economically acceptable in all cases, but the project is at its best, based on the first scenario at assumptions of (i= 8%, and investment 200$/kW), In addition to that Figure (51) shows the effect of different investment costs on the effectiveness of the project with respect to the NPV

Table (46): cases results summary for the first scenario

n=25	I = 0.08			I = 0.1			I = 0.12		
investment	PW ($)	ROR	B/C	PW	ROR	B/C	PW	ROR	B/C
2000	9,858.61	9%	1.21	-13,794	9%	0.980	-30,740.2	9%	0.80804
2500	-20,372.8	7%	0.971	-43,475.8	7%	0.784	59,892.01	7%	0.646432
3000	-50,604.3	5%	0.809	-73,157.6	5%	0.653	-89,043.8	5%	0.538694

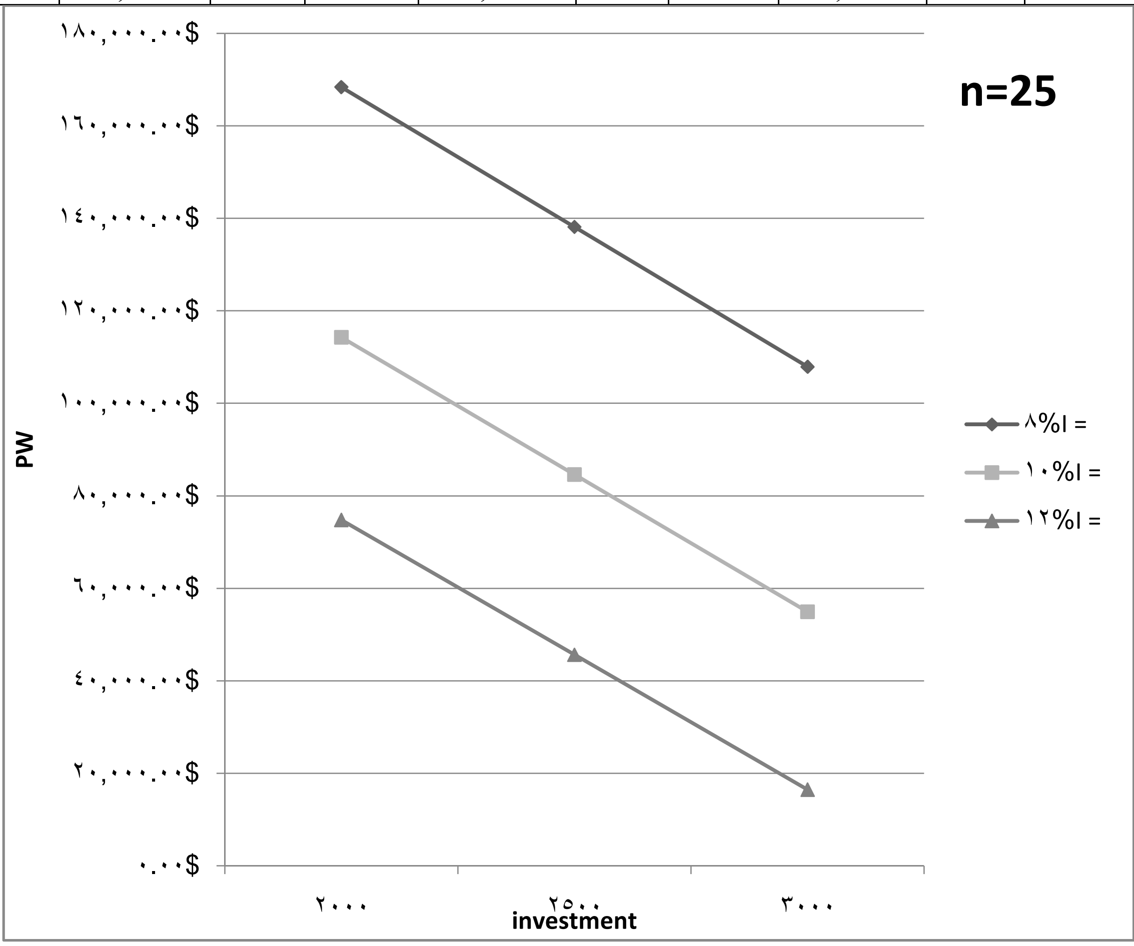


Figure (52) : Relation between investments and PWs for the assumed interests rate.

Moreover, table (47) below summarize the results of the second scenario of a 30 years life time project. Where all cases in this scenario is also feasible cases, and the best choice would be at the first assumptions of (i=8%, and initial investment 2000$/kW).

Table (47):cases results summary for the second scenario

n=30	I = 0.08			I = 0.1			I = 0.12		
investment	PW ($)	ROR	B/C	PW	ROR	B/C	PW	IRR	B/C
2000	25,719.2	10%	1.34	-4,463.4	10%	1.059	-25,194.8	10%	0.854
2500	-4,512.2	8%	1.077	-34,145.2	8%	0.847	-54,346.6	8%	0.683
3000	-34,743.-7	6%	0.897	-63,827.	6%	0.706	-83,498.3	6%	0.569

Therefore figure (52) shows the results of the relationship between investment and present worth values, at the three interests rate that have been worked on.

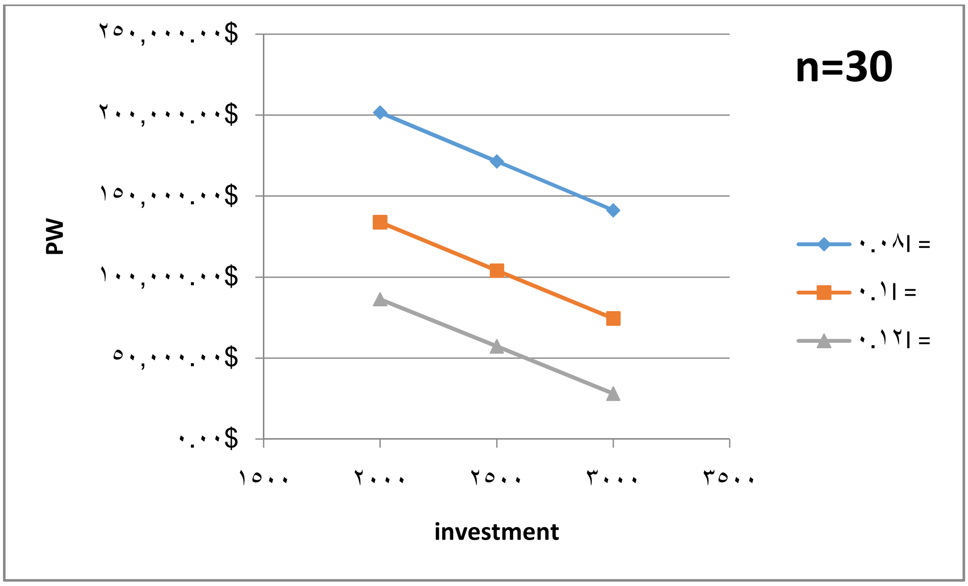


Figure (53) :Relation between investments and PWs for the assumed interests rate.

Finally, if comparison will be done between the first and the second scenarios, then the 30-year-lifetime project is better than the 25-year-lifetime project, as shown in the previous tables (46,47), that the value of PW in the second scenario cases is greater than in the first scenario. this can also be seen through figures (53-54), where the value of the PW in the first case of the 25 years project life is $168,396.58 While the value of it in the first case of the 30 years life project is $201,633.65

LPG Price variation effect

What if the price of natural gas was increased to reach 0.90$/ liter instead of 0.75$/ liter, where the fuel and natural gas prices differ from time to time Will this affect the feasibility of the project in a positive way?. Taking into account all the previous assumptions in table (9), but with the change in the price of LPG natural gas, By following the same previous steps and taking into account the same economic indicators that were adopted in the previous economic analysis that relied on the real price of LPG. As the cash flow diagram can show in figure (53) below, And with working on the economic equations (33-46), where are found in chapter 5, the annual savings in fuel that reach 62.3 Kg and in conjunction with the increase in its price to 0.90$/ liter, brought the savings in the price of fuel up to 26913.6$/year

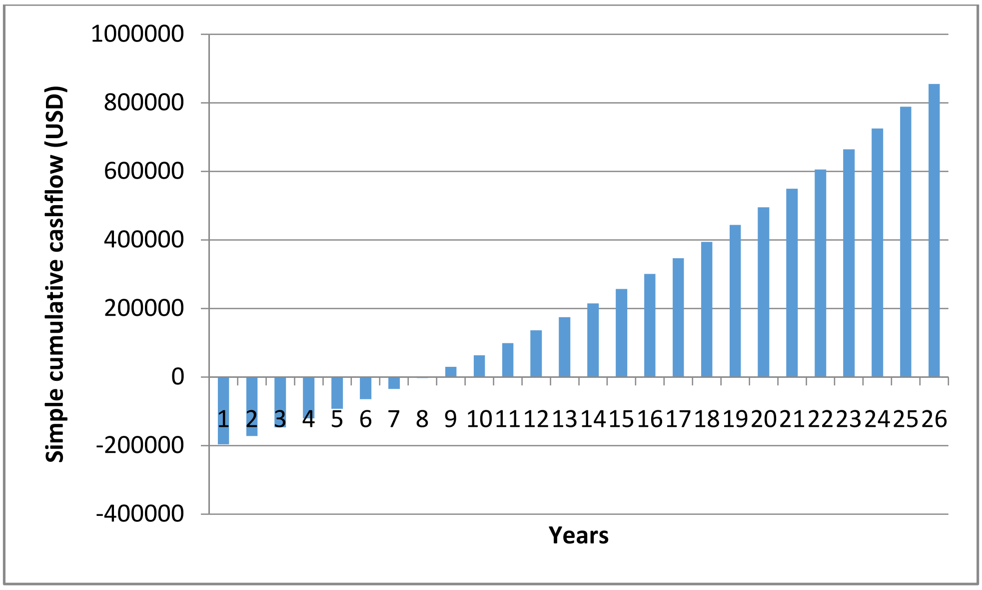


Figure (54) : total cash flow when the price of LPG is 0.90$/kg.

Therefore with the economic assumption in table (48) below, showing the total capital cost and the new LPG cost, the financial analysis of this new situation could be done by using the previous economic equations and indicators such as SPP, NPV,B/C ratio, and ROR.

Table (48): assumption for the new CSP of the proposed system

interest rate	12%
Project life	25 years
Debt ratio	0%
Fuel type	Propane
Fuel cost	0.90$/ liter
Fuel saving	7476.207 kg/year
Total Initial cost of the project	195900$
Operation and maintenance costs	2807.9 $/ year

The change that occurred in the price of fuel led to a noticeable and somewhat positive change in the payback period to recover the initial investment of project, which decreased by one year as can be seen in figure (55), to reach year 8 instead of year 9 This improvement encourages consideration of the other economic indicators.

In order to evaluate the NPV equation (41) has been used

As for looking at the third indicator that was taken into consideration, it became clear once again that the project is stimulated to be established in the factory as the result of dividing the discounted cost on the discounted benefit of the project was more than one, which confirms that the project is feasible, since the more higher the value of B/C ratio, The higher the benefit derived from the project. Note that the simple interest-to-cost ratio is insensitive to the size of the net benefit, and therefore projects with small costs and benefits may be preferred over those with higher net benefits. Therefore equation (44) form chapter 5 had been used to find the B/C ratio.

Consequently, the other calculations for the economic indicators will follow the same curve and keep the project reviews not positive. Although, the calculation or the internal rate of return had also been done, with helping of the economical equations in chapter 4 epically equation (46).

Where the interest rate of return was unknown and needed to be fined, to compare the old interest rate that had been taken before for the project with the new one that will be founded in this section, where these numbers have been calculated using excel.

Table (49): the economic indicators results for the LPG price variation

SPP	8 years
(NPV)	$ 253,272.20
Benefit-Cost (B-C) ratio	1.29
ROR	16%

Chapter Eight

Conclusion and Recommendations

Chapter Eight

Conclusion and Recommendations

8.1 Conclusion

In conclusion, the CSP system is consider as an important plant to produce electrical and thermal energy for buildings, factories and even cities. it gives the world a good step for a clean environment from harmful emissions Resulting from the use of traditional methods of producing energy, whereas the CSP parabolic trough power plant reduced the Gross annual GHG emission by (93%). as well An increase in the plant capacity also help in reducing the annual GHG emission as At a 100MW CSP plant reduction is equivalent to (26809- 58281) cars and light trucks that are not used.(Davidson and Mbaimbai, 2015)

The question here is how to apply this type of alternative energy, especially in Palestine? Will it be expensive?, In fact, applying this type of facility requires large capital costs, including land and water, knowing that the increasing in capacity of the plant needed increase in the necessary area.

This research has presented a new case study, aiming to combine a conventional existing system with a solar energy-based one for an actual ice-cream factory located in Nablus, Palestine, and analyzing and assessing it thermodynamically through energy analyzes and performance evaluations, based on actual data. Some concluding remarks of this study have to be mentioned, that the energy consumption of the actual system is calculated to be 1440491.4 kWh/year, while the energy that could be saved from the proposed system is calculated to be 192960 kWh per year. According to $250m^2$ on the roof of the factory. Moreover, the payback period of the proposed integrated system is found to be 8 years.

though, considerable energy savings can be achieved by the development of solar assisted promising system. It is expected in the future that these processes can redeem itself in a short period of time related to the technological improvements in PTSC systems.

It is worth to mention that starting works on building CSP plants and other sustainable projects will help provide job opportunities for the emerging generation and give them great experiences. We desperately need to develop our society and work seriously on providing energy, especially as we, a Palestinian people, need to work on self-sufficiency to prevent Concern about the violations and outages that may pass us by the occupation.

8.2 Recommendations

Through investigations and analysis of available data, it is never possible to install a parabolic trough CSP system based on the current conditions of Al-Arz factory in producing a thermal energy to carry out production work. Therefore, there are some recommendations that can be relied upon if a similar project is worked on in this case:

1. It is possible to work on using the CSP system to produce electrical energy as well, not only thermal energy in, as the project may become actually more feasible, if the CSP plant is a combined heat and power plant

2. Further, It is also possible to work on building a solar energy project on the basis of producing a specific heat capacity, and not being restricted to the available space, where the project can be built, therefore the thermal energy required for Al-Arz factory will fully produce by the concentrated solar power plant.

3. Also The project may be feasible and effective if the parabolic trough CSP system is worked on; As an alternative to diesel boiler, not an LPG boiler.

References

[1] Abd-Ennour, A., Bouhelal, G., Chakib, S., & Saïd, A. (2015). Mathematical Modelling of a Solar Parabolic Trough Collector Coupling with an absorption machine. *International Journal Of Engineering Research & Technology (IJERT)*, *4*(2), 1-8.

[2] Acciona. 2021. What is climate change? | ACCIONA | Business as unusual. Retrieved 23 January 2020. Available at: https://www.acciona.com/climate-change

[3] Ajlouni, E., & Alsamamra, H. (2019). A Review of Solar Energy Prospects in Palestine. *American Journal Of Modern Energy*, *5*(3), 1-14.

[4] Alarz .2015. Al Arz| News. (Al Arz| News, 2015). Retrieved 5 April 2019 Available at: https://www.alarz.ps/news2.php .

[5] Anabtawi, R., 2016, Amayreh, H., . News program [Economic Magazine], The success story of Al-Arz Factory, Palestine TV, Palestine,Ramallah.

[6] Bata, H., 2014. Dooz- Al-Arz ice cream : A local factory with regional ambition. Dooz.ps. Retrieved 7 April 2020. Available at: https://www.dooz.ps/p/15570

[7] Blanco, M. J., & Miller, S. (2017). *Introduction to concentrating solar thermal (CST) technologies. Advances in Concentrating Solar Thermal Research and Technology, 3–25.* doi:10.1016/b978-0-08-100516-3.00001-0

[8] BP global. 2020. Energy Outlook | Energy economics | Home. Retrieved 27 March 2021 Available at: https://www.bp.com/en/global/corporate/energy-economics/energy-outlook.html

[9] Clean leap. 2019. How Power Tower Works | Cleanleap. Retrieved 6 February 2020 Available at: https://cleanleap.com/2-power-tower/how-power-tower-works .

[10] D. Al Assi & R. Tayeh, 2016. Palestine. "Energy Efficiency Improvement for Al-Arz Factory.", An-najah National University, ,

[11] E. Davidson, I., & K. Mbaimbai, N. (2014). Modelling and Analysis of a CSP Plant Technology for Small Power Networks -Technical and Financial Evaluation. Academia. In *4th Solar Integration Workshop, International Workshop on Integration of Solar Power into Power Systems* (pp. 1-7). Berlin, Germany.

[12] Barlev, D., Vidu, R., & Stroeve, P. (2011). Innovation in concentrated solar power. *Solar Energy Materials And Solar Cells*, *95*(10), 2703-2725. doi: 10.1016/j.solmat.2011.05.020

[13] Draidi, O., 2016. feasibility study of implementing CSP technology in Palestine. Palestine: AL-Najah national university.

[14] E&C. 2019. Causes, Effects and Solutions for Resource Depletion - E&C. Retrieved 5 April 2019 Available at: https://environmental-conscience.com/resource-depletion-causes-effects-solutions/

[15] Energy. 2019. Solar Water Heaters. Retrieved 8 May 2020 Available at: https://www.energy.gov/energysaver/water-heating/solar-water-heaters

[16] Encyclopedia Britannica. 2015. pasteurization | Definition, Process, Inventor, & Facts. Retrieved 20 October 2019 Available at: https://www.britannica.com/technology/pasteurization

[17] Environment. 2021. Acid Rain. 20 October 2019 Available at: https://www.nationalgeographic.com/environment/article/acid-rain

[18] Global sola atlas. 2019. Global Solar Atlas. 20 March 2019 Available at: https://globalsolaratlas.info/map?c=32.462847,35.283279,10&s=32.270878,35.25238&m=sitehttps:%2F%2Fglobalsolaratlas.info%2Fmap

[19] G.N and A. [Tiwari] , 2016. Handbook of Solar Energy Theory, Analysis and Applications. Springer.

[20] Hafez, A., Soliman, A., El-Metwally, K., & Ismail, I. (2016). Solar parabolic dish Stirling engine system design, simulation, and thermal analysis. *Energy Conversion And Management*, *126*, 60-75. doi: 10.1016/j.enconman.2016.07.067

[21] Hierarchy Structure. 2019. Energy Management Hierarchy | Hierarchical energy management system. 20 March 2019 Available at: https://www.hierarchystructure.com/energy-management-hierarchy/

[22] IEA. 2021. World Energy Outlook 2019 – Analysis - IEA. 20 March 2019 Available at: https://www.iea.org/reports/world-energy-outlook-2019

[23] Inc. C., 2021. Energy3D (free) download Windows version. Free Download Manager. 21 February 2021 Available at: https://en.freedownloadmanager.org/Windows-PC/Energy3D-FREE.html

[24] International Renewable Energy Agency, 2012. Renewable energy technologies : Concentrating Solar Power. cost analysis series. United Arab Emirates: IREA

[25] IRENA, 2019. Renawable power generation costs in 2018. Abu Dahbi: International Renewable Energy Agency.

[26] Jin, Z., 2013. Concentrated Solar Power Generation. Thesis. ARIZONA STATE UNIVERSITY.

[27] Juaidi, A., Montoya, F., Ibrik, I., & Manzano-Agugliaro, F. (2016). An overview of renewable energy potential in Palestine. *Renewable And Sustainable Energy Reviews*, *65*, 943-960. doi: 10.1016/j.rser.2016.07.052

[28] Kizilkan, O., Kabul, A., & Dincer, I. (2016). Development and performance assessment of a parabolic trough solar collector-based integrated system for an ice-cream factory. *Energy*, *100*, 167-176. doi: 10.1016/j.energy.2016.01.098

[29] L. Chandra & A. Dixit. 2018. Concentrated Solar Thermal Energy Technologies. U.S Energy Efficiency and Renewable Energy . NREL.

[30] Li, Q., Zheng, C., Shirazi, A., Bany Mousa, O., Moscia, F., Scott, J., & Taylor, R. (2017). Design and analysis of a medium-temperature, concentrated solar thermal collector for air-conditioning applications. *Applied Energy*, *190*, 1159-1173. doi: 10.1016/j.apenergy.2017.01.040

[31] Live science. 2021. Acid Rain: Causes, Effects and Solutions. 20 March 2019 Available at: https://www.livescience.com/63065-acid-rain.html

[32] Macmillan, A., 2019. Global Warming 101. NRDC. 20 March 2019 Available at: https://www.nrdc.org/stories/global-warming-101

[33] Naik, H., Baredar, P., & Kumar, A. (2017). Medium temperature application of concentrated solar thermal technology: Indian perspective. *Renewable And Sustainable Energy Reviews*, *76*, 369-378. doi: 10.1016/j.rser.2017.03.014

[34] NREL, 2001. Renewable Energy: An Overview. U.S: National Renewable Energy Laboratory.

[35] National renewable energy agency , 2012, System Advisor Model (SAM):Case Study: Andasol-1.

[36] Palestinian Central Bureau of Statistics. 2008. Palestine. Energy Consumption in the Palestinian Territory Annual Report 2006.

[37] Palestinian Energy Authority, 2010. National plan for energy efficiency and rationalization of consumption. Palestine: Palestinian Energy Authority.

[38] Palestinian Meteorology, 2019. Climate of Palestine. 20 March 2019 Available at: http://www.pmd.ps/viewPalClimate.do

[39] Palestinian Statistics Center. 2021. PCBS | Energy Balance of Palestine in Physical Units, 2019. 20 March 2019 . Availableat: http://www.pcbs.gov.ps/statisticsIndicatorsTables.aspx?lang=en&table_id=526

[40] Palestinian Statistics Center. 2021. PCBS | Imported Energy in Palestine by Type of Energy and Month, 2019. 20 March 2019 . Availableat: http://www.pcbs.gov.ps/statisticsIndicatorsTables.aspx?lang=en&table_id=525

[41] Sebastián González, R., & Flamant, G. (2014). Technical and Economic Feasibility Analysis of Using Concentrated Solar Thermal Technology in the Cement Production Process: Hybrid Approach—A Case Study. *Journal Of Solar Energy Engineering*, *136*(2). doi: 10.1115/1.4026573

[42] Society, N., 2021. Climate Change. National Geographic Society. 20 March 2019 . Available at: https://www.nationalgeographic.org/encyclopedia/climate-change/

[43] Solar paces. 2019. Ashalim (Negev) | Concentrating Solar Power Projects. Available at: https://solarpaces.nrel.gov/ashalim .

[44] Soria, R., Portugal-Pereira, J., Szklo, A., Milani, R., & Schaeffer, R. (2015). Hybrid concentrated solar power (CSP)–biomass plants in a semiarid region: A strategy for CSP deployment in Brazil. *Energy Policy*, *86*, 57-72. doi: 10.1016/j.enpol.2015.06.028

[45] The World from PRX. 2021. Biodiversity loss has an enormous impact on humans, according to a UN report. 20 March 2019 Available at: https://www.pri.org/stories/2018-04-21/biodiversity-loss-has-enormous-impact-humans-according-un-report

[46] Trieb, F., 2002. In: Concentrating Solar Power Now. German Space Center (DLR), .

[47] Turner, W. and Doty, S., 2006(Turner and Doty, 2021). Energy management handbook. 6th ed. The Fairmont Press.

[48] US EPA. 2021. What is Acid Rain? | US EPA. 7 March 2019 . Available at: https://www.epa.gov/acidrain/what-acid-rain .

[49] Union of Concerned Scientists. 2017. Benefits of Renewable Energy Use. Available at: https://www.ucsusa.org/resources/benefits-renewable-energy use?gclid=Cj0KCQiAkePyBRCEARIsAMy5Scvx-vAXfo3PWUPz_GV0-t5iM_kgB3x8_ljt8f_mWNjqWpLmJh25sYIaAkXoEALw_wcB&utm_campaign=CE&utm_medium=search&utm_source=googlegrants

[50] Wafa- Palestinian News and Information Agency. 2019. Renewable alternative energy in Palestine. 15 Jun 2019 Available at: https://info.wafa.ps/ar_page.aspx?id=9073

[51] Worldometers. 2019. World Population Clock: 7.9 Billion People (2019) - Worldometer. 3 January 2019. Available at: https://www.worldometers.info/world-population/

[52] Yasen, A. and Dradi, O., 2016. Design and Sizing Characteristics of a Solar Thermal Power Plant with Parabolic Trough Collectors for a Typical Site in Palestine. Palestine. Energy and Environmental Protection in Sustainable Development 1, 1-8.

[53] Yılmaz, İ., & Söylemez, M. (2014). Thermo-mathematical modeling of parabolic trough collector. *Energy Conversion And Management*, *88*, 768-784. doi: 10.1016/j.enconman.2014.09.031

[54] Yiting Wang, 2008.Concentrating Solar Power - Parabolic Reflector Technologies, NREL.

جامعة النجاح الوطنية
كلية الدراسات العليا

تصميم وتقييم لنظام حوض القطع المكافئ الشمسي المركز لفلسطين: دراسة حالة مصنع الأرز للبوظة

اعداد
رند حسن عبد الفتاح خريشي

اشراف
د. محمد السيد

قدمت هذه الأطروحة استكمالاً للمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الاستهلاك بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.

2021م

تصميم وتقييم لنظام حوض القطع المكافئ الشمسي المركز لفلسطين: دراسة حالة مصنع الأرز للبوظة

اعداد

رند حسن عبد الفتاح خريشي

اشراف

د. محمد السيد

الملخص

في هذه الأطروحة ، تم اقتراح نظام جديد للطاقة المتجددة قائم على الطاقة الشمسية ومتكامل مع PTSCs (مجمعات الطاقة الشمسية ذات الأحواض المكافئة) ، وتحليله لمصنع البوظة الواقع في نابلس ، فلسطين. يشتمل النظام الحالي على نظام PTSC للتعاون مع غلاية التسخين في المصنع لتلبية الطلب على الطاقة الحرارية لتسخين خليط البوظة . تم إجراء تحليلات شاملة للطاقة في النظام لتحديد خصائص أداء العمليات الفعلية والمقترحة. بدلاً من موارد الطاقة التقليدية ، يفترض أن إنشاء هذا النوع من أنظمة الطاقة يوفر ظروف تشغيل أفضل من حيث الطاقة والاقتصاد والبيئة بشكل مستدام. أظهرت النتائج أن كمية الطاقة المنتجة من النظام الفعلي هي (487.66 kW) عند استهلاك (750.25 kW) ، بينما الطاقة التي يمكن ان يوفرها النظام المقترح 804 كيلوواط ساعة في اليوم ، مع تقيده بمساحة معينة و هي 250 متر مربع ، و من ناحية أخرى يعمل النظام على توفير ما يقرب من 407.9 كجم من ثاني أكسيد الكربون يوميًا.

الجدير بالذكر أنه تم إجراء تغييرات على بعض عوامل الحساسية مثل سعر الفائدة ، عمر المشروع ، الاستثمار الأولي للمشروع. حيث أن هذه التغييرات أثرت على نتائج المشروع بشكل عام ، بحيث أدت إلى جعل المشروع مجديًا اقتصاديًا في ظروف معينة ، بما في ذلك الوقت الذي يكون فيه عمر المشروع 30 عامًا ، قيمة الفائدة 8٪ ، وقيمة الاستثمار 2000 دولار لكل كيلو واط وفي سيناريو اخر عندما يكون عمر المشروع 25 سنه، قيمة الفائدة 8٪ والاستثمار الاولي لمشروع 2000 دولار لكل كيلو واط.