22-311

Ministry of education
STEM Egypt
Sharkia STEM

Automonitor Trough System

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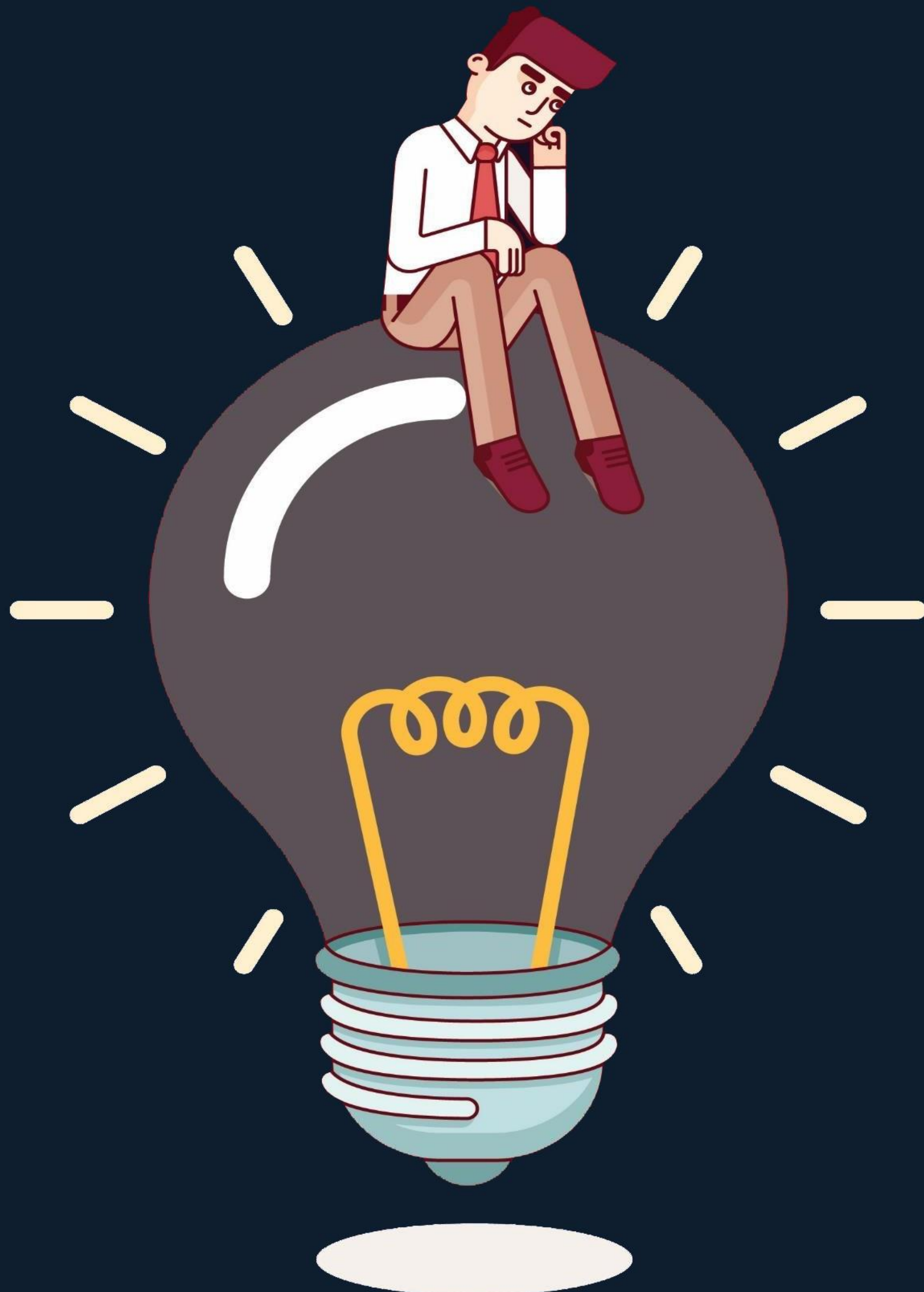
Introduction

Through our faith in the soul of our Teamwork and working together as one hand.

We are happy to introduce our portfolio to you. This portfolio represents our work, achievements, and the result of the integration between learning outcomes in our study throughout our second year in STEM schools. It is a pleasure to present our ideas in our portfolio, hoping that it will assist the nation to solve its problems and issues. As known, the Egyptian nation faces challenges, and through our work, we will try to solve some of these challenges like Improve the use of alternative energies in addition to, Improve the scientific and technological environment for all. The previous challenges are barriers for our country; to reach the desired target, which is sustainable development goals (SDG) and the perfect for the nation so that our project is trying to assist our country in beating these problems.

So, we will do our best to overcome the problem and we will make a new and creative design, that satisfies our needs; using the engineering design process, scientific research, and innovation; achieving a helpful assist for the Egyptian nation. We hope that our work admires your pleasure.



Present and Justify a Problem and Solution Requirements

<u>Egypt's Grand Challenges</u>

- **Improve the use of alternative energies.**
- **Recycle garbage and waste for economic and environmental purposes.**
- **Deal with urban congestion and its consequences.**
- **Work to eradicate public health issues/disease.**
- **Increase the industrial and agricultural bases of Egypt.**
- **Address and reduce pollution fouling our air, water and soil.**
- **Improve uses of arid areas.**
- **Manage and increase the sources of clean water.**
- **Deal with population growth and its consequences.**
- **Improve the scientific and technological environment for all.**
- **Reduce and adapt to the effect of climatic change.**

Improve the use of Alternative Energies

Energy resources exist in different forms. Some are exhaustible and the others are inexhaustible and unlimited. Renewable energies (Alternative energies), often referred to as: clean or green energies are energies generated from natural unlimited energy sources like solar rays, wind, hydro and water cycle. Although they are called "clean and green energies" this still doesn't mean that these energies aren't harmful to the nature or doesn't have zero impact. Instead, they have a low effect on the environment compared to fossil fuels and greenhouse gases.

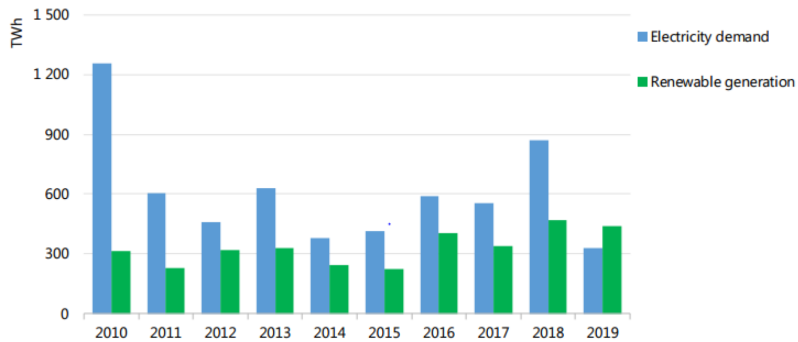


Fig. (1): show the electricity demand and renewables generation growth, 2010-19

Non-renewable energies are the energies that came from limited sources. Compared to renewable energy which referred to as "clean energy", non-renewable energy referred to as "unclean energy sources" because our usage and exploration for this type of energy emit a lot of harmful gases called greenhouse gases. These gases considered to be heat-trapping gases which affect the nature through climate change, global warming and some other terrible environmental effects. Non-renewable energy sources exist in the form of fossil fuels which are 3 major types: coal, oil, natural gas.

According to IEA (International Energy Agency) in 2019, the renewable energy use increased by 3.7% globally from the previous year. Also, in the same year, the global electricity generation from renewables increased 440 TWh (6.5% year-on-year), the second-highest rise after 2018. Combined with weak electricity demand growth, The year-on-year growth of renewables generation was 6.5%, faster than any other fuel including coal and natural gas.

The share of renewables in global electricity supply reached 27% in 2019, the highest level ever recorded. Wind power, solar PV and hydropower together made up over 85% of renewables growth. Fig. (1) illustrates the electricity demand and renewable generation growth over the past decade.

Types of alternative energies:

1- Solar energy:

This type of energy comes directly from solar radiation (sunlight). The solar radiation absorbed by certain sensors in 2 different ways:

- Absorbing sun rays and converting them directly into another energy such as electricity by photovoltaic panels (PV panels). This way has to deal with light beam photons by photoelectric effect.
- Absorbing sun rays and converting them into heat that warms water or air and use the generators by water vapor. This way has to deal with UV from the light beam.

The amount of sunlight that received by earth per year makes the sun the most important and promising unlimited and alternative energy source. According to the **National Renewable Energy Laboratory** "more energy from the sun falls on the Earth in one hour than is used by everyone in the world in one year".

2- Wind power:

The wind's kinetic energy makes the wind turbines spin creating a mechanical movement for the generators that transform this mechanical energy into electricity. There are many types of wind turbines such as: onshore (on the land), offshore (in the water) and floating wind turbines. And each of them has its advantages and disadvantages but operating with the same principle.

3- Hydroelectric power (Hydro power):

The turbines transform the kinetic energy of water (rivers, waves and tides) into mechanical energy for the generators to convert the mechanical movement into electricity.

4- Biomass:

Biomass is energy derived from organic materials such as plant and animals' materials. When the organic materials are burned, it releases energy in a picture of heat. The general resources for producing biomass energy are wood and coal. Although biomass is derived from renewable sources and we can consider it as a renewable energy, the process of burning organic materials releases carbon dioxide emissions in the atmosphere so, the resulting emissions must be compared with another source of biomass that is looking to replace.

5- Geothermal energy:

The word Geothermal comes from the Greek words geo (Earth) and therme (heat). The Earth stores and generates geothermal energy. In other meaning radioactive materials decayed inside the Earth are emitting energy (A process that happens in all rocks). Geothermal energy is renewable because heat is produced within the Earth continuously. Depending on the used technology for using thermal energy, there are the ways to use geothermal energy:

- Generating electricity directly from Earth's heat.
- Producing heat from hot water boiling on the Earth's surface.

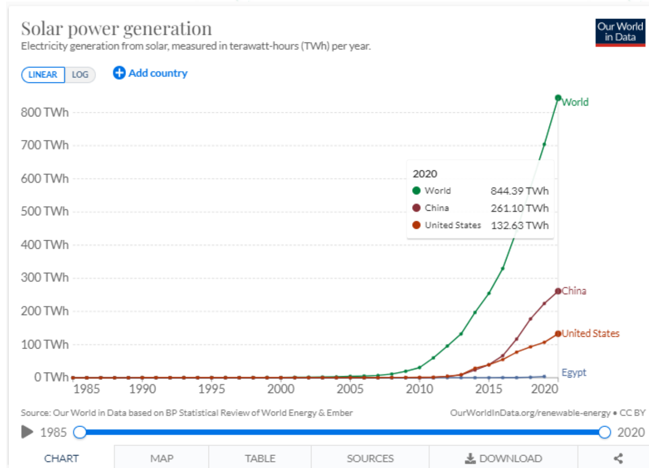


Fig. (2): show the amount of generated energy by solar power each year over the past years

<u>Renewable Energy situation around the world:</u>

1- Solar energy:

Solar energy can be harvested in 2 ways: by PV panels and thermal energy technologies (like CSP Concentrated Solar Power).

For an overall outlook in solar power, fig. (2): shows the amount of generated energy by solar power each year over the past years. According to “OUR WORLD IN DATA” and the statistics, solar energy is a growing renewable energy source that a huge amount of energy can be harvested from it.

- **For solar photovoltaic (PV):**

Electricity generated from solar PV increased from 88.7 GWh in 1990 to 354.6 TWh in 2019, achieving a 34.5% annual growth rate, as being considered the fastest of all renewable electricity technologies.

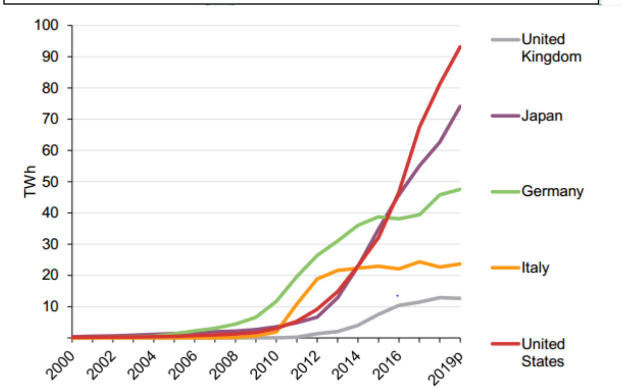


Fig. (3): IEA and OECD data on growth rate for 5 biggest countries using solar PV.

According to IEA (International Energy Agency) and OECD (Organization for Economic Co-operation and Development), the growth rate for the 5 biggest producing countries for electricity by solar PV is illustrated in fig. (3).

- **For solar thermal:**

According to Statista "The global cumulative capacity of solar thermal energy has increased dramatically since 2006 until 2018, from around 127 gigawatts thermal to approximately 480 gigawatts thermal. Capacity additions for solar thermal energy reached their peak between 2012 and 2013, and since then, new installations have decreased. China and Europe have played a major role in the installation of solar thermal energy globally."

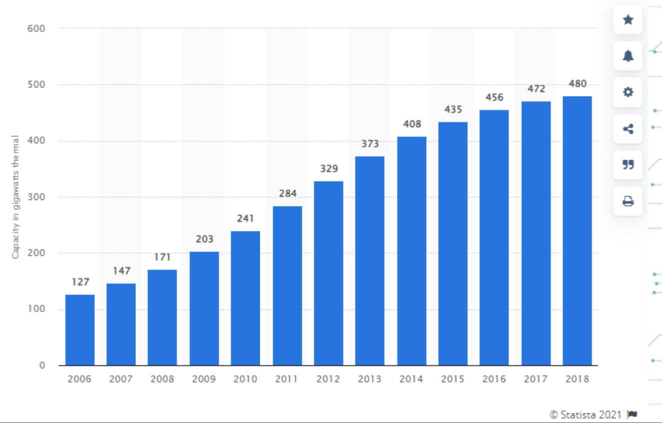


Fig. (4): shows Cumulative capacity of solar thermal energy

worldwide from 2006 to 2018(in gigawatts thermal).

Fig. (4): shows Cumulative capacity of solar thermal energy worldwide from 2006 to 2018(in gigawatts thermal)

2- wind power:

Electricity generated from wind power increased from 269.8 TWh to 838.5 TWh between 2010 and 2019 leading to a growth rate of 13.4%. Wind had the third fastest growth rate in this period, behind solar PV (31.2%) and solar thermal (22.6%).

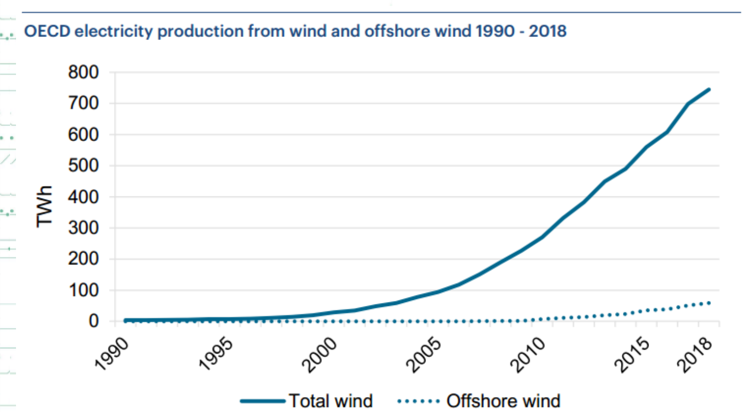


Fig. (5): shows the OECD countries' electricity production by total

wind power and offshore wind turbines.

Wind turbines can exist in onshore (on the land) and offshore (on the water surface). Fig. (5) shows the OECD countries' electricity production by total wind power and offshore wind turbines.

3- Hydroelectric power (Hydro power):

The output from hydro is dependent on rainfall, and fluctuations in weather patterns. Which effect on a country's hydroelectric production.

Fig. (6): shows the hydroelectricity output percentage in total electricity production for some countries.

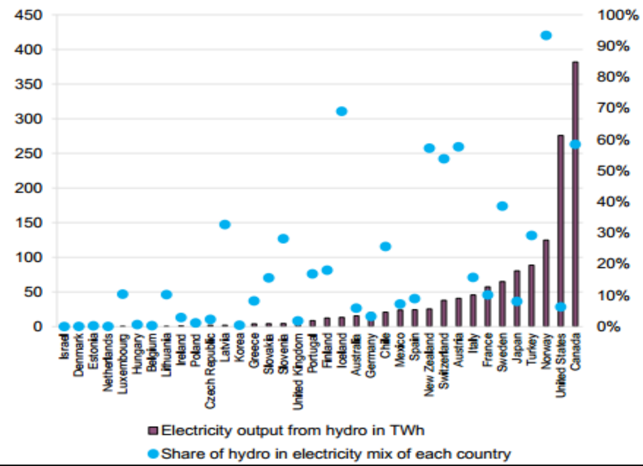


Fig. (6): Hydroelectricity output in the OECD in 2019.

4- Biomass:

Biomass data includes 3 branches, data for: biogases, liquid biofuels & solid biofuels.

- **For biogases:** it is the 4th largest growing source of renewable energy for electricity. Biogases electricity production by an annual rate of average 11.3% since 1990. But in the period of 2010 to 2019, biogases were the 5th growing renewable source for electricity production. The biggest contributor for this growth was Europe which accounted for 81.5%/annum since 1990.
- **For solid biofuels:** electricity generation from solid biofuels from 1990 to 2019 grow with an average annual rate of 2.4%. The electricity generation from solid biofuels grew from 94.3 TWh to 186.4 TWh. In the period from 2010 to 2019. Solid biofuels accounted for 6.3% of renewable electricity generation in 2019. The top producing countries for electricity by solid fuels are: Unites states, United Kingdom, Japan, Finland and Germany.
- **For liquid biofuels:** generating electricity from liquid biofuels is a new technology. Germany is credited with producing electricity from liquid biofuels in 2001 with only 15 GWh. There was increasing number of countries started to use this technology until 2019, 14 countries reported a total of 7 TWh of electricity generation.

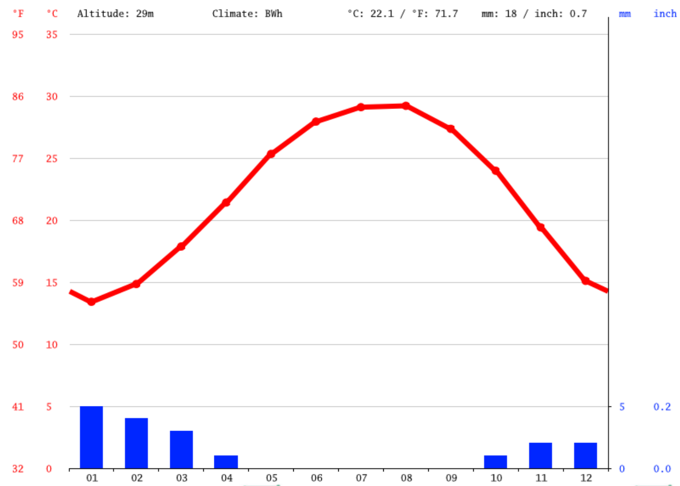
5- Geothermal:

Similar to hydropower, geothermal does not have a significant growth between 1990 to 2019. It has an annual increasing average rate of 2.9% between 2010 to 2019 as the electricity generated from geothermal grew from 43.4 TWh to 56 TWh

Reduce and adapt to the effect of climatic change

Introduction:

Climate change is a natural phenomenon that is constantly happening nonstop because of; human factors, that have had the majority of impacts on climate change for centuries, which are good for some and bad for many. And the climate change is expected to lead to significant changes in fresh water use, including people's lives, livelihoods and biodiversity. Climate change is largely caused by human activities, and it presents a serious threat to nature and people. Without ambitious global warming mitigation efforts, temperature rise this century will exceed 4°C above preindustrial levels, with catastrophic consequences for the whole planet.



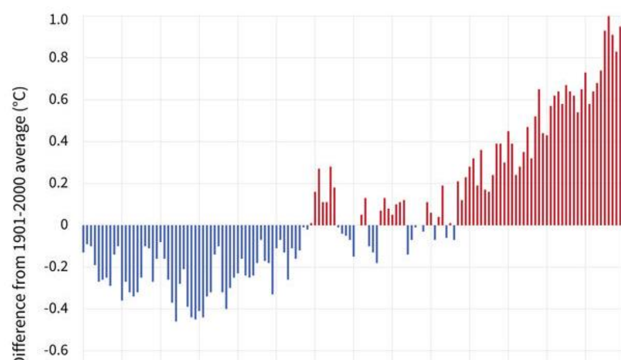
Graph (7): Rate of change in temp. in Cairo.

In the Egyptian mother nation, the annual average temperatures increase by 1.07°C to 1.27°C by 2030, Owing to, alteration the measurements on the Egyptian coast indicate, that sea level is continuously rising at a rate of 1.8 and 4.9 mm/year with an average of 3 mm/year. The relative sea level shows an upward increasing trend.

Causes: -

1- rising average temperatures:

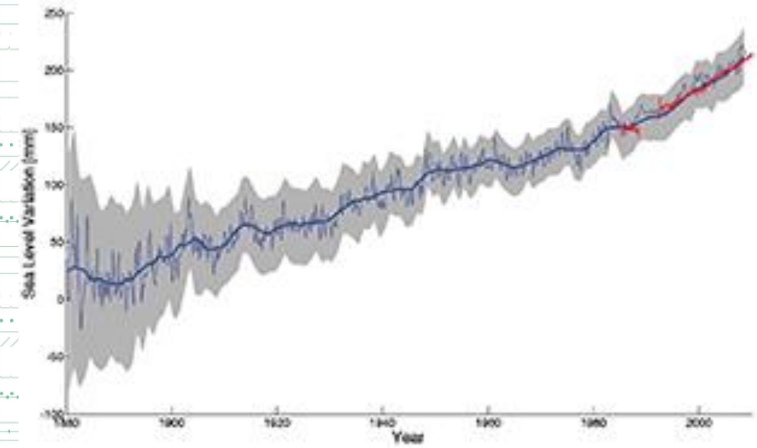
Earth's temperature has risen by 0.08° C per decade since 1880, and the rate of warming over the past 40 years is more than twice that: 0.32° F (0.18° C) per decade since 1981. Therefore; it alters the shape of the continents, so affects the population rates and congestions in the world.



Graph (8):

Difference of average °C from 1901-2000

2- rising sea levels:



Graph (9):

Rate of sea level rising

One of the major physical impacts of a rise in sea level include erosion of beaches, inundation of deltas as well as flooding and loss of many marshes and wetlands. Increased salinity will likely become a problem in coastal aquifers and estuarine systems as a result of saltwater intrusion and increases the risk percentage in confronting tsunamis. As soon as, long-term measurements of tide gauges and recent satellite data show that global sea level is rising, with the best estimate of the rate of global-average rise over the last decade being 3.6 mm per year (0.14 inches per year).

Solutions:

1- natural climate solutions:

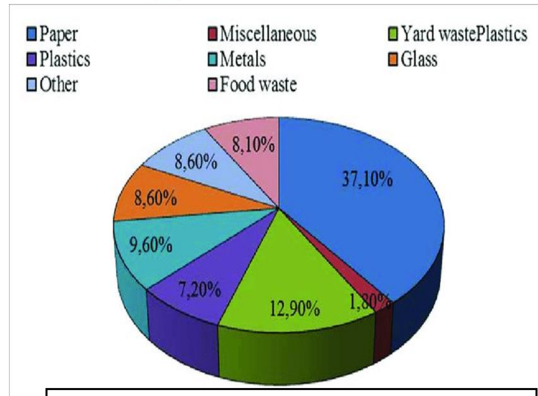
The natural world is very good at cleaning up our emissions, but we need to look after it. Planting trees in the right places or giving land back to nature through 'rewilding' schemes is a good place to start. This is because photosynthesizing plants draw down carbon dioxide as they grow, locking it away in soils.

Graph (10):

Trees eats CO2

2- Reduce plastics:

Plastic is made from oil, and the process of extracting, refining and turning oil into plastic (or even polyester, for clothing) is surprisingly carbon-intense. It doesn't break down quickly in nature so a lot of plastic is burned, which contributes to emissions. Demand for plastic is rising so quickly that creating and disposing of plastics will account for 17% of the global carbon budget by 2050.



Graph (11):

Material consumption in the global

3- Reforestation:

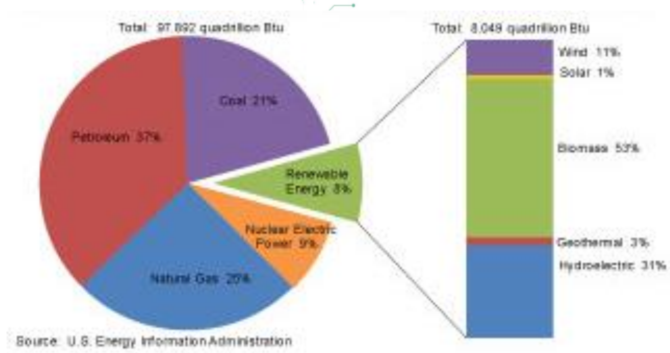
Globally, an estimated two billion hectares (4.9 billion acres) of land has been deforested or degraded. Because trees are the best carbon-capture and storage technology the world has, reversing these numbers would bring a significant reduction in global carbon levels. We estimate that the world could capture three gig tons of CO2 annually equivalent to taking more than 600 million cars off the roads simply by planting more trees.

Graph (12):

Reforestation

4- Invest in renewable energy:

Changing our main energy sources to clean and renewable energy is the best way to stop using fossil fuels. These include technologies like solar, wind, wave, tidal and geothermal power.



Graph (13):

Percentages of renewable energy use

Problem to be solved

Energy and electricity:

People often use the terms ‘electricity’ and ‘energy’ interchangeably.

Energy: describes the total work and heat available from all energy carriers. It is the sum of all energy including electricity, heating and transport. The energy carriers which supply the world today are: fossil fuels, biofuels, nuclear fuels, the wind and solar radiation and etc.

Electricity: it is the most visible form of energy we rely on daily; electricity is one form of energy carriers.

Renewable energy situation in Egypt:

According to IRENA (International Renewable Energy Agency), Egypt is the 5th of highest oil-producing countries in Africa with a daily production of 588,000 barrels and more. And it is the first consumer in Africa for gas and oil.

The energy problem in Egypt lies on the great production of electricity from non-renewable energy sources with a 90% comes only from oil and natural gas. Besides, Egypt is exposing to a high population growth estimating by 1.3% per year. Causing a complicated problem for energy access in the future.

Non-renewable energy sources exist in the form of fossil fuels which are 3 major types: coal, oil, natural gas. According to Energypedia, data on oil and natural gas situation in Egypt is presented in table. (1).

	Oil	Natural Gas
Total Production	680,000 bbl/day	2 trillion cubic feet/day
Global Production-Share	0.72%	1.7%
Proven Reserves	3,900,000,000 bbl	65.3 trillion cubic feet
Global Proven Reserves-Share	0.2%	1%
% Total Domestic Consumption	41%	53%
Imports	80,000 bbl/day	To Be Updated
Exports	189,000 bbl/day	0.1 trillion cubic feet/year
Export Destinations	EU (56%), India (28%), China (13%), Others (3%)	EU (56%), India (28%), China (13%), Others (3%)

Table (1): shows oil and natural gas situation in Egypt

Energy capacity is the maximum output of electricity generated in a country from a source or a generator when working at full potential. According to Statista, renewable energy capacity in 2019 in Egypt was 5,972 megawatts. Resulting in a growth rate of 24.1% from the preceding year 2018. The renewable energy capacity over the last decade in Egypt is illustrated in fig. (14) by Statista.

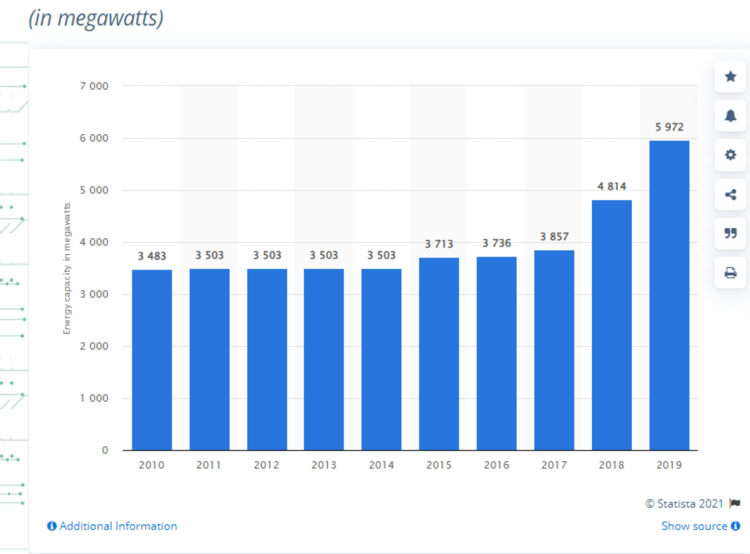


Fig. (14): shows the renewable energy capacity in Egypt over the past decade in megawatts.

A detailed analysis on renewable energy by sector is introduced as follows:

1- Solar energy:

- Egypt is one of most appropriate regions for utilizing solar energy for electricity generation and thermal heating applications. According to IRENA, Egypt is considered a country with high and favorable solar radiation intensity of 2000-3200 KWh/m^2/year from north to south and annual direct normal intensity of 1970-3200 Kwh/m^2. In addition, Egypt has 2900 and 3200 hours of sunshine annually.

- Egypt is a leading country with the share of 23% of solar power generating projects in the Middle East and North Africa (MENA) region. Data is introduced by statista fig. (15) for solar power capacity generation in Egypt for 2019.

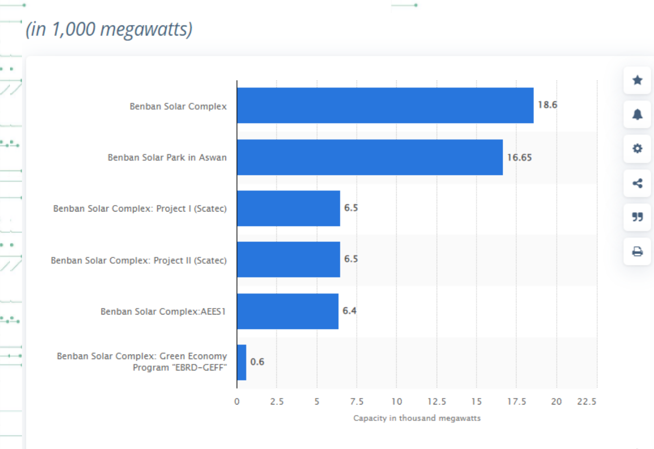


Fig. (15): Operational projects for generating solar power capacity in Egypt in 2019.

2- Wind power:

- Egypt has one of best locations in the world for harnessing wind energy that is because of the wind high speeds (8 – 10 m/s) which are stable even at height of 100 meters. Also, there are more regions discovered east and west the Nile River with good wind speeds like Beni Suef, El Menya and The New Valley governments.
- According to IRENA (International Renewable Energy Agency), The total installed capacity of wind energy to generate electricity was from 260 GWh in 2001/2002 to 2,058 in 2015/2016 avoiding CO2 emissions by the rate of 143,000 tons in 2001/2002 and 1.131 million tons in 2015/2016.
- in 2019, the total global electricity comes from wind was about 5.5%. And about 1.45% of Egypt's electricity comes from wind. Data by "our world in data".

3- Hydroelectric power:

- The main hydro source of hydropower in Egypt is the Nile River with the biggest potential and movement in Aswan (The High Dam) where there are power stations with the total of power which is 2,800 MW to generate electricity by amount of 13,545 GWh annually.
- In 1960s and 1970s, Hydroelectric power represented almost 50% of Egypt's generated electricity.
- According to EEHC (The Egyptian Electricity Holding Company), in 2015/2016, there were increasing in the thermal power stations so, the hydroelectric power represented only 7.2% of Egypt's total generated electricity.
- In 2019, about 6.45% for the world's and 3.07% for Egypt's electricity came from hydropower.

4- Biomass:

- Egypt has large sources of biomass from agriculture waste, animal dung and urban solid waste.
- Agriculture waste totals about 35 million tons annually. Urban waste average 0.5 kg/person/day totaling to almost 10 000 tons per day inn greater Cairo.
- Different technologies for biomass have been demonstrated in Egypt providing jobs in some villages and cities.

5- Geothermal:

- In Egypt, the hydrothermal energy potential estimated to be $\mathbf{158 \times 106}\ \boldsymbol{kWh}$ while EL Faliq high heat-generating granite in Egypt has the potential to generate billion kWh of electricity. By these 2 ways, Egypt has a good opportunity to participate in the efforts to reduce the carbon dioxide amount by 20 million tons and to provide freshwater to agriculture and industrial sectors.
- Geothermal manifestation: geothermal occurs along the eastern and the western margin of the Suez Gulf (at Ayoun Mousa and Ain Sukhna) and at Kharga, Dhakla, Bahariya and Siwa. As shown in Fig (16).

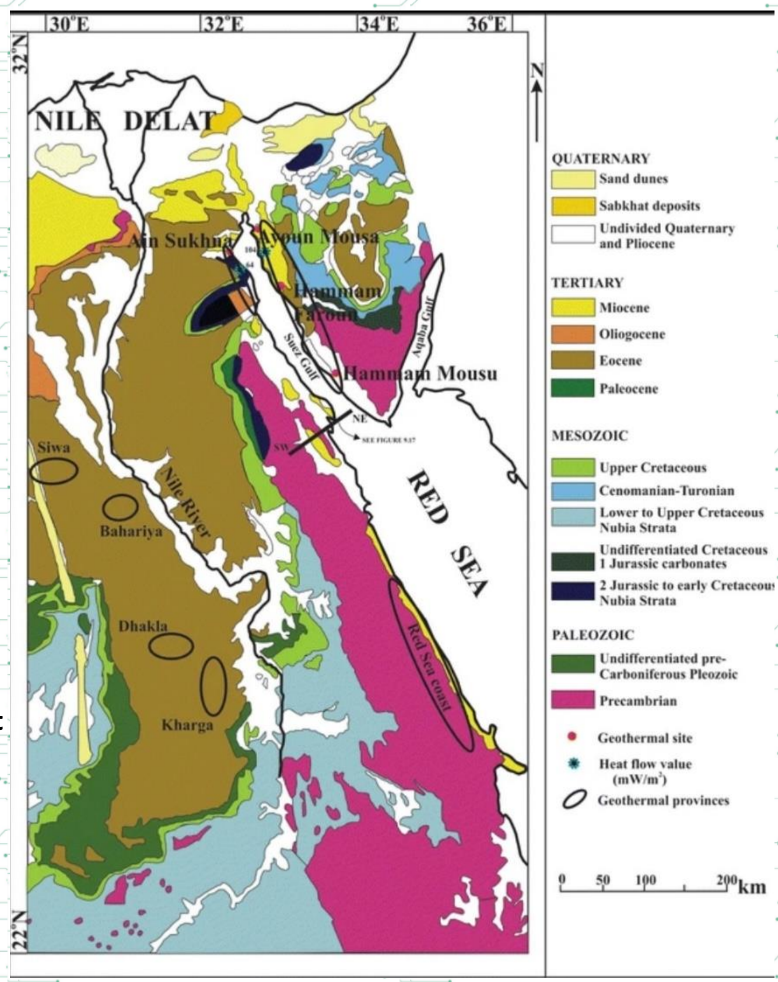


Fig (16): shows the geological map of Egypt with geothermal provinces.

Electricity demand and production:

Electricity demand:

According to "Our World in Data" and "BP Statistical Review of World Energy & Ember 2021", the electricity consumption by an average person in 2019 in Egypt is about 1,928 kWh. Fig. (16) shows the average Egyptian person consumption for electricity.

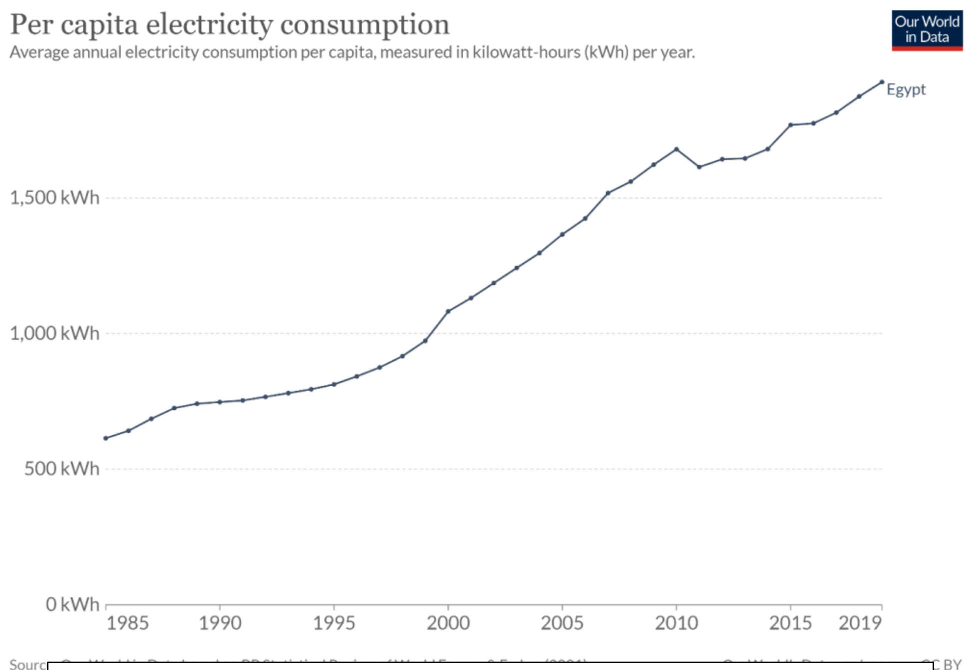


Fig. (16): illustrates the annual average person consumption for electricity in Egypt.

According to IRENA, the electricity consumption by sector is shown in Fig. (17) in 2015/2016.

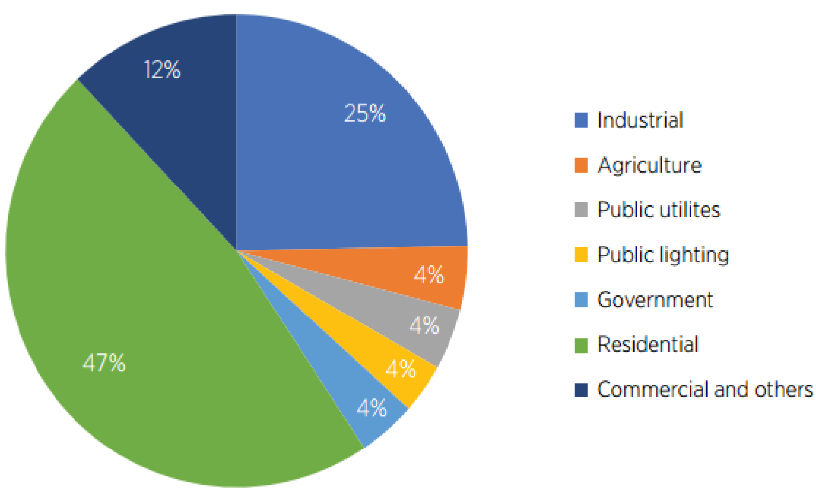


Fig. (17): clarifies the electricity consumption by sector in Egypt in 2015/2016. Data made by IRENA.

Electricity production by renewable energy:

In the period from 2017 to 2019, the share of renewable energy in the electricity generation has been increasing after demanding on the fossil fuels for long time. Fig. (18) shows the share of renewable energy in electricity generation in Egypt.

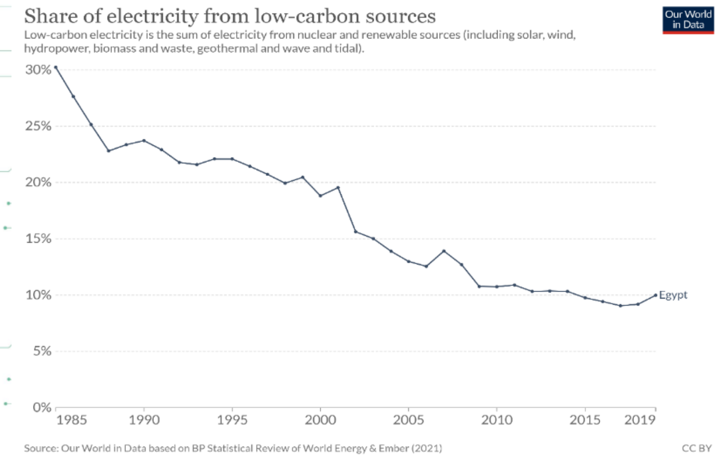


Fig. (18) shows the share of renewable energy in electricity generation in

Energy crisis and challenges in Egypt:

- Current Egypt's energy mixture is not diversified as being Egypt mainly depends on oil, natural gas and hydroelectric power from the Nile which is nothing compared to Egypt's demand on oil and natural gas, leading the last 2 aforementioned sources to represent approximately 94.4% of the total primary energy consumption till 2014.
- According to "Solar Atlas in Egypt", Egypt has proven oil reserves of 4.4 billion barrels and natural gas reserves of 78 trillion cubic feet. Even though, there is an increasing rate of the daily production that is being used to meet the country's growing energy demand.
- Egypt's electricity demand is growing rapidly due to the rapid population growth hence, developing alternative power resources is urgent. Data given by "Solar Atlas in Egypt" shows that the demand is in an annual increasing rate of 1500 to 2000 MW.

- Although the electricity access in Egypt is 100% of population fig. (19) by latest Tracking SDG7 Report. There is an energy gap between energy needs and energy being introduced to people. Fig. (20) shows the energy gap until 2022.

- Supporting data from "worldometers.info", in 2017, Egypt consumed **4,012,356,526,000 BTU (British Thermal Unit) which is equivalent to 1.1759 TWh of energy. And producing** 3,445,085,097,000 BTU which is equivalent to 1.0096 TWh. meaning that Egypt covers 86% of its energy consumption need. So, there is a gap between the energy produced and needed.

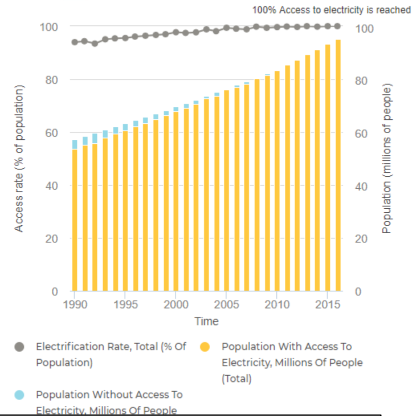


Fig. (19): shows the population electricity access in Egypt. Data represented by latest Tracking SDG7 Report.

Fig (20). shows the energy gap in Egypt till 2022. Data is represented by "Solar Atlas in Egypt"

Specific problem.

Concentrated solar power (CSP) in Egypt:

1. **Working and under construction plants in Egypt:**

CSP is a growing industry all over the world because of its potentials to produce power and heat for thermal applications. There are 2 working plants in Egypt. ISCC Al Kuraymat fig. (21) with 140 MW capacity and MATS concentrated solar power plant in Borg El Arab near Alexandria fig. (22).

Fig. (21): the ISCC power plant in Egypt.

Fig. (22): the concentrated solar

According to latest news, Egypt aims to build extra five Concentrated Solar Power plants with $1.2bn investment.

2. CSP plants for cogeneration of power and freshwater:

CSP can produce both power and distilled water for domestic use. There are lots of processes to desalinate water are classified is fig. (23):

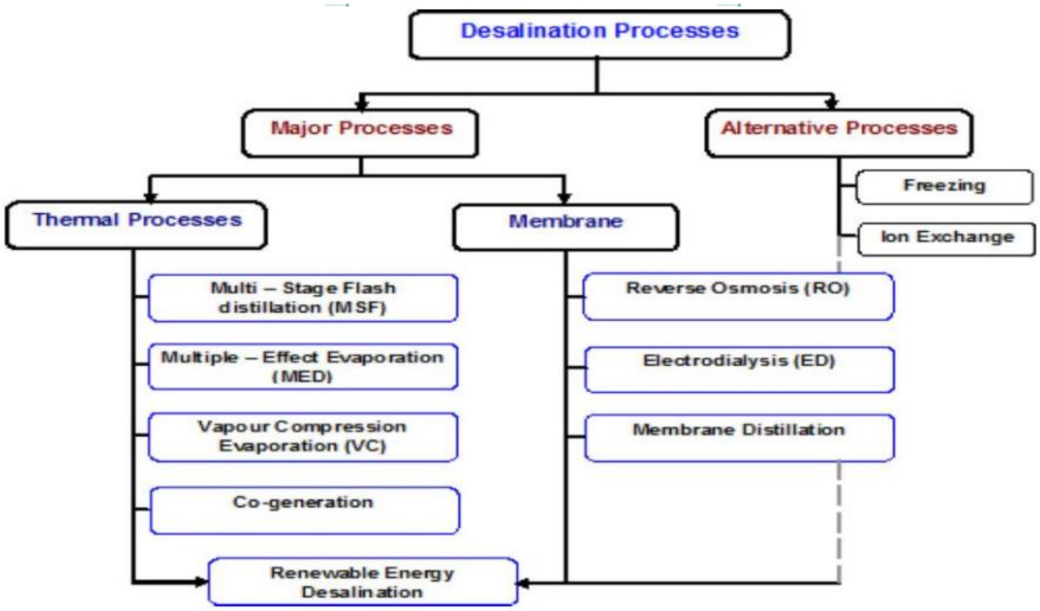


Fig. (23): classification of water desalination options with concentrated solar power.

3. A deficiency in the hybrid CSP plant:

Although the hybrid system's great potentials in terms of power and freshwater production, it still has some defectives affect the overall system effectiveness. After studying the system, we found that the feedwater pump has high electrical energy consumption in the system due to less monitoring for its operation. Data on the load and energy consumption of Andasol 3 power plant is Spain which is a 50 MW parabolic trough plant is illustrated in table. (2).

DESCRIPTION			PEAK POWER CONSUMPTION (kW)
SYSTEM	EQUIPMENT	DUTY CYCLE	
HEAT TRANSFER FLUID SYSTEM	HTF MAIN PUMPS	4 X 33% duty	3398
	FREEZE PROTECTION PUMPS	2 X 100% duty	239
	OVERFLOW RETURN PUMPS	2 X 100% duty	127
FEED WATER SYSTEM	FEED WATER PUMPS	2 X 100% duty	957
THERMAL ENERGY STORAGE SYSTEM	TES PUMPS	2 X 100% duty per tank (hot and cold tank)	903
COOLING WATER SYSTEM	CIRCULATING WATER PUMPS	3 X 50% duty	322
	COOLING TOWER CELLS FANS	4 X 25% duty	592

Table. (2): shows the main load consumers of power in of Andasol 3 50 MW power plant and their duty cycle.

the feedwater pump has high consumption of 957 kW relative for other system components. That is applied in all parabolic trough system for cogeneration of power and freshwater or for the power production only. In both cases, water besides heat transfer fluid (HTF) are needed in the cycle.

4. A solution on the observed problem:

One way has the potential for less consumption by the feedwater pump through the system cycle. The feedwater pump can operate in a regulated way to feed water in the boiler heat exchanger (BHX) where water and heat transfer fluid (HTF) exchange heat between each other and water evaporated for steam turbine and then the condensation for freshwater production.

Overlook on the system, feedwater pump and the boiler heat exchanger is illustrated in fig. (24).

A suggested solution to minimize the feedwater pump consumption is by regulating its operation to feed water in the boiler heat exchanger when the HTF temperature decreases. HTF temperature will be monitored by temperature sensor and the feedwater pump will operate according to HTF temperature.

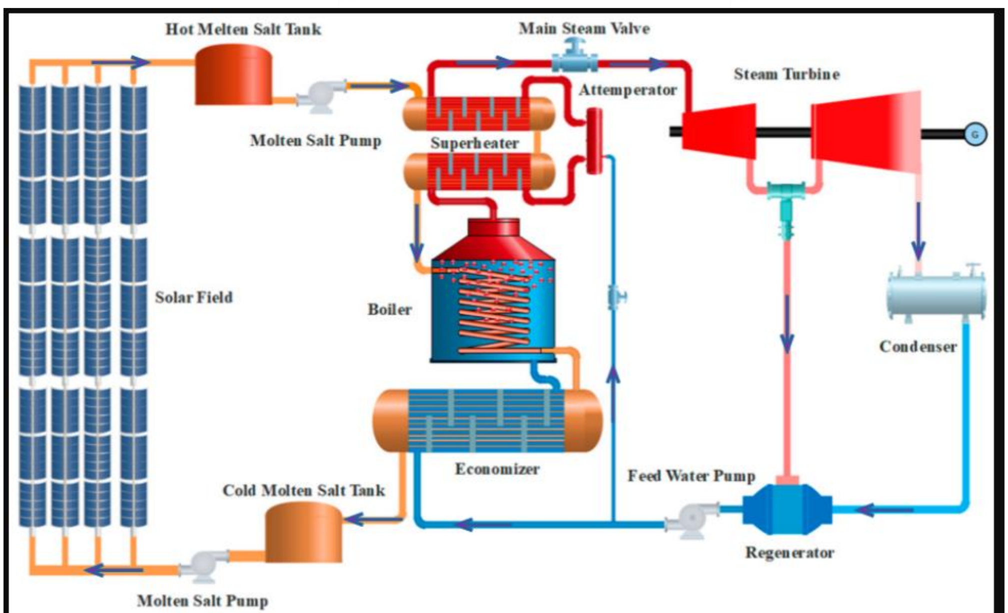


Fig. (24): schematic diagram for parabolic trough

Overview on the addressed specific problem and dealing with it:

According to aforementioned data:

- Egypt is considered a country with high and favorable solar radiation intensity of 2000-3200 KWh/m^2/year from north to south and annual direct normal intensity of 1970-3200 Kwh/m^2. In addition, Egypt has 2900 and 3200 hours of sunshine annually.

- Although the electricity access in Egypt is 100% of population fig. () by latest Tracking SDG7 Report. There is an energy gap between energy needs and energy being introduced to people. Fig. () shows the energy gap until 2022. Egypt can cover 86% of its energy consumption.

- The concentrated solar power (CSP) is a growing industry for its high potentials in power production and thermal applications. Egypt has 2 working parabolic trough plants: ISCC Al Kuraymat with 140 MW power capacity production and MATS concentrated solar power plant in Borg El Arab near Alexandria. In addition, Egypt aims to build 5 extra plants according to latest news.

Also, after studying the parabolic trough system:

- Some defectives affect the overall system effectiveness. that the feedwater pump has high electrical energy consumption in the system due to less monitoring for its operation.

- The high consumption was observed on a 50 MW-Andasol 3 power plant in Spain. The feedwater pump has high consumption of 957 kW relative for other system components. That is applied in all parabolic trough system for cogeneration of power and freshwater or for the power production only

- A suggested solution was made to minimize the feedwater pump consumption through regulating its pumping for water into the boiler according to HTF temperature which will be monitored by temperature sensor.

Research

Grand Challenges:

Improve the use of Alternative Energies.

- Introduction

- Renewable energies
  1- Solar power
  2- Wind power
  3- Hydroelectric power (hydro power)
  4- Biomass
  5- Geothermal energy

- Non-renewable energies:
  - What are fossil fuels:
  - Types and formation:

- Benefits of using renewable energies:

Reduce and adapt to the effect of climatic change

- Introduction
- Causes
- Solutions

Problem to be solved & specific problem.

- Renewable energy situation in Egypt:

Introduction:

1- Solar Energy
2- Wind power
3- Hydroelectric power
4- Biomass
5- Geothermal

- Electricity demand and production**:**

1- Electricity demand
2- Electricity production by renewable energy

- Energy crisis and challenges in Egypt:

Specific problem:

- Concentrated solar power (CSP) in Egypt**:**

1. Working and under construction plants in Egypt:
2. CSP plants for cogeneration of power and freshwater:
3. A deficiency in the hybrid CSP plant:
4. A solution on the observed problem**:**

Overview on the addressed specific problem and dealing with it:

Other solution already tried:

- IoT-based Pico-Hydro Power Generation System using Pelton Turbine.
- Development of Smart System for Renewable Energy Hybrid Power System Base on SCADA
- IoT (Internet of Things) Based Efficiency Monitoring System for Bio-Gas Plants

Other Solutions Already Tried

IoT-based Pico-Hydro Power Generation System using Pelton Turbine:

Hydro power systems are most reliable one among potential renewable energy resources. The dynamic force of natural water can be found available in springs, streams, creeks, water-falls, tributaries and rivers especially the pico-hydro system. The Internet of Things (IoT) integrated in connectivity offers a host of development opportunities in control, monitoring, and maintaining remote systems in the pico-hydro system.

Generation systems:

1. Hydro Power Generation:

Hydro Power is extracted from the energy in the free-flowing water resources and transformed to mechanical energy, moreover, this energy can be used directly or can be converted to electrical using a generator. Also, the differential velocity of falling water or its pressure or both on the turbine blade surfaces produces a force causing rotation motion generating electricity. In order to generate electricity, the turbine output shaft is connected to the generator. The generator produces electricity using electromagnetic induction. The generated electricity is transmitted to application loads.

2. Pico-Hydro Power Generation System:

Hydro power plants can be classified according to its capacity, head, purpose, facility types, hydrological radiation, and transmission system. Under the classification on capacity, the pico-hydro power generation system is appropriate and useful in local rural areas that needs only a little amount of electricity. Normally, pico-hydro power generation system can generate of under 5 kW. This system set-up is typically run-of-the-river, which uses pipes to divert the flow of water and can be found in rural areas.

The head and the flow are two important components needed in this particular system. The head component refers to the water pressure that determines the vertical fall of water. Also, this component develops an altitude for the water opening and turbine. The flow plays a vital part in harnessing the water power. It specifies the water quantity or the water flow rate. In a normal case, the maximum flow is calculated to be less than maximum stream flow. This proposed project will be implemented in the provinces of Ifugao and Aurora in the Philippines because a continuous flow of water as a source is determined to power-up the Pelton turbine.

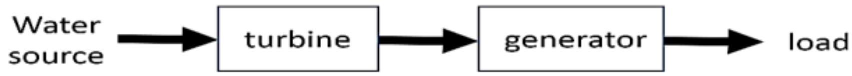


Fig. (25): shows the water flow in the system.

3. Turbine:

The task of a turbine converts water power into rotational force to drive the generator. Choosing a right turbine is very important because the over-all efficient of the system depends on this part. The required relation of the generator speed to turbine should not be above 3:1. The main components of a hydro-electric system are classified into two groups: the hydraulic system parts that consist of a turbine, the associated conduits like penstocks, tunnel and surge tank including its control system. On the other hand, the electric system components made by the synchronous system generator and its control system. The Hydraulic turbines are generally classified as impulse and reaction turbine.

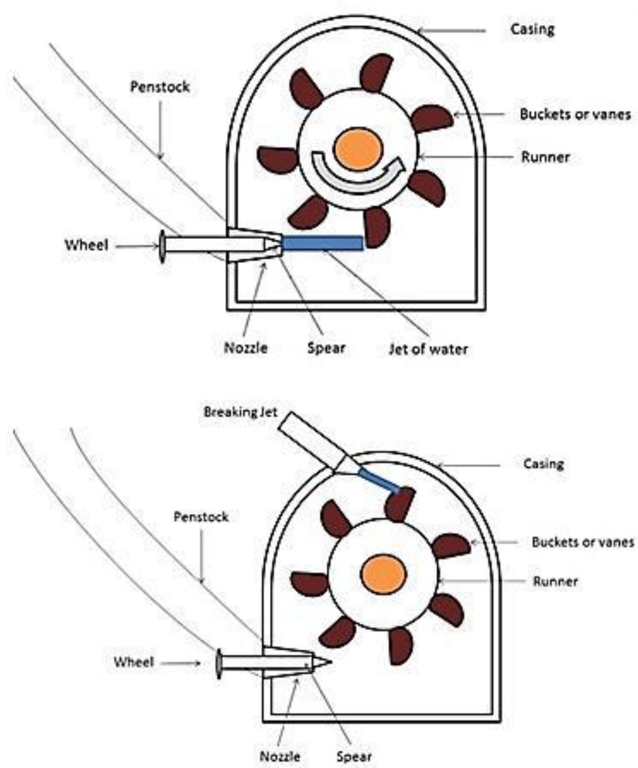


Fig. (26): shows the turbine

4. IoT System:

The proposed system design has an attached low-cost embedded system device for real time monitoring of water level, flow rate, and even pH sensor in Internet of things (IOT) platform. IOT is a new technology paradigm to link a real time communication in able to monitor, control or analyze the shared information from certain applications over a public or private internet protocol (IP) network.

Proposed systems:

1. Pelton Turbine:

In this project, the Pelton turbine was utilized due to its appropriateness especially for high head and low flow rate of water. the Pelton turbine that used during the experimental testing and has a diameter of 0.16 m with 20 buckets of 18 degrees for each blade mounted and a shaft to give a smooth rotation.

Fig. (27): shows the Pelton turbine

2. Generator:

The generator converts the rotational energy from water energy converted into mechanical to electrical energy, the AC induction generator was used. developed induction generator having 1,400 turns using the SWG26 magnetic coil. It generates an AC output and to be feed in a boost converter to achieve an appropriate needed power for transmission to remote communities.

3. IoT System:

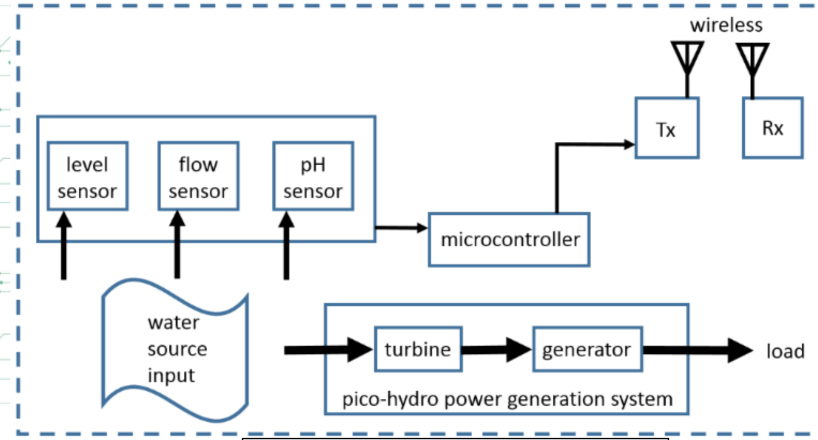


Fig. (28): shows the IOT system.

This system consists of sensors, an ASIC-microcontroller, and a GSM module. The three sensors: the level sensor detects the appropriate water level due to seasonal fluctuating water levels because the unit will not generate power when there is too little water and cannot power-up the Pelton turbine; the water flow sensor measures how much water has moved through; the pH sensor measures the hydrogen-ion activity in water to maintain the durability of the system over-time. The ASIC microcontroller is a Raspberry Pi microcontroller that reads the inputs from the three sensors and send the information via IoT for monitoring purposes. The GSM module or any telemetry system to feedback the community for monitoring**.**

Development of Smart System for Renewable Energy Hybrid Power System Base on SCADA:

Location: Kuala University, Indonesia.

Process: smart energy monitoring and control system
for Renewable Energy Hybrid Power Generation System (REHPGS) using SCADA.

Brief:

The Renewable Energy Hybrid Power Generation System (REHPGS) consists of:

- photovoltaic system
- wind system
- gen-set system

The technology and telecommunications system consists of:

- Supervisory Control and Data Acquisition (SCADA) is integrated with microcontroller-remote terminal unit, variety of transducers and control devices

SCADA is used to monitor and control the operation of Hybrid Power System (HPS) in real time. Hybrid system composed of PV-Wind-diesel generator hybrid system. Which is most preferable in remote areas for economic performance and pollution and for reliable and cost-effective power supply.

Materials & Methods:

A) SCADA hardware: remote terminal unit

- Remote Terminal Unit (RTU) is set up to perform data acquisition and control each substation for certain data logging and measurements to be monitored.

- RTU is tasked to find out any conditions of high voltage equipment through the collection of electricity quantities, equipment status and alarm signals

- RTU transmits them to the control center via the telecommunications network data.
- RTU can also receive and execute commands to change the status of high voltage equipment via the command signals sent from control center.
- Equipment in substations in introduces as I/O module (input/output) and consists of:
  - Telemetering devices (TM) come from transductors to the Input module and they are:

1. Voltage measurement (Volt)
2. Power Active measurement (kW)
3. Power Reactive measurement (kVar)
4. Current measurement (A)
5. Frequency measurement (Hz)

  - Tele signaling (TS) which sends signals for changes in the substation.
  - Telecontrol (TC) coming from the output module and connected to substation equipment for loading and production regulation.

B) <u>ViscontDua remote terminal unit:</u> Viscon dual Remote Terminal Unit (RTU) fig. (29) is a hardware device that can control the activities of electric power system intelligently.

Fig. (29): Viscon Dual Remote Terminal

C) <u>SCADA software: SMART controller</u>

- The Controller is developed using modular concept and written using Microsoft Visual Basic 6 programming language.

- The high-level SCADA system contain information about system and equipment behavior and interaction that is essential to the controller functions such as scheduling of generators, switch in to utility grid- connected power supply, ensuring power balance, grid stability, etc.

- The controller senses the load if solar power (PV) power is available (i.e. between 8AM to 6PM), the PV will supply power to the load. If solar power (PV) is less than the load, then Wind Power and generator set will run depending on the range setting. When solar power (PV) is unavailable (6PM to 8AM), this is the time where power from Wind and Generator set used to supply the load. Figure. (30) shows the flow diagram of the integrated power. The controller inputs are solar power (PV), Wind power and generator set power and average hourly load demand.

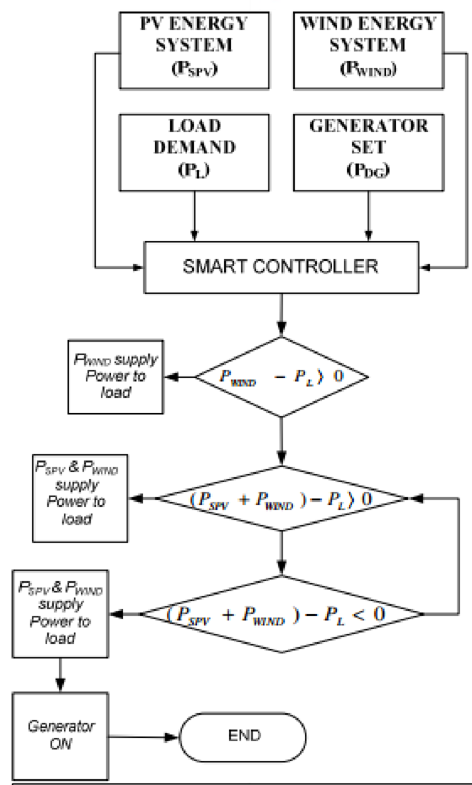


Fig. (30): Smart controller flow

Configuration and overview of the system:

Fig. (31) shows the multifunctional digital power meters and the relation between control center and RTU.

The control center's main function is to set up between itself and RTU. The control center is used to send and receive data from the RTU and then translate that information into understandable language, distributing the information to the Man Machine Interface (MMI).

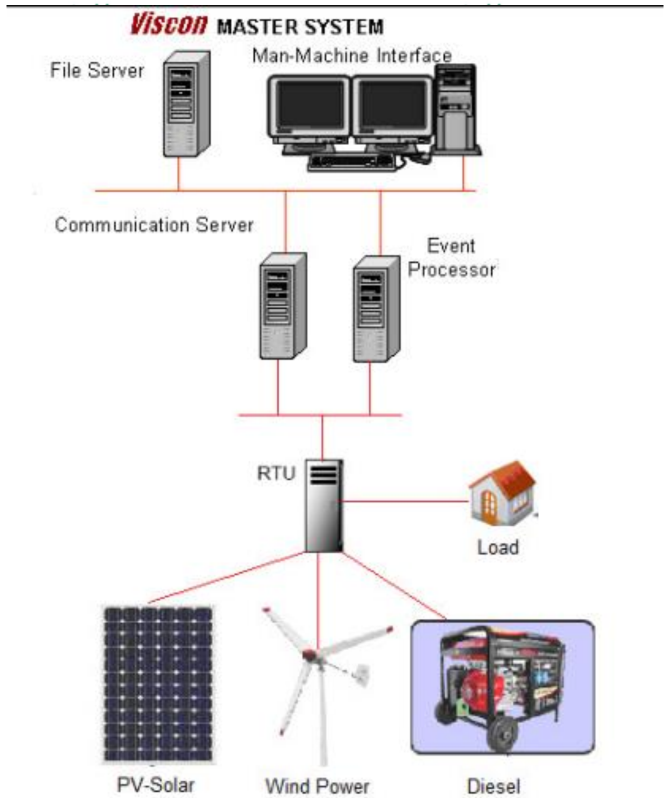


Fig. (31): Configuration of development smart system for wind-PV-diesel hybrid power system.

Results & discussions:

The electricity consumption data used is measured and recorded for a typical off-grid remote house for a 24 hours period. The data is recorded every 2 hours.

Table. (32) shows the daily load for the remote off-grid house for 24 hours.

Time (h)	PV Power (W)	Wind Power (W)	Gen Power (W)	Total Power (W)	Load (W)
24.00	0	625	0	625	150
02. 00	0	500	0	500	120
04. 00	0	375	0	375	120
06. 00	0	0	1000	1000	900
08. 00	232	500	1000	1732	1550
10.00	1230	375	1000	2605	2100
12.00	1330	375	0	1705	1400
14.00	710	250	0	960	780
16.00	270	750	0	1020	680
18.00	90	1000	0	1090	920
20.00	0	750	1000	1750	1700
22.00	0	500	1000	1500	1500
23.00	0	625	0	625	300

Table. (32): The daily load for the remote off-grid house for 24 hours.

To determine the power of load, sensors detect fluctuations in the load. So, in this case the sensor will read the load conditions to provide information to the RTU, which is (the mode I) of needs 500W, (mode II) load power is between 500W and 1500W and (mode III) is above 1500W.

Then the characteristic of Renewable Energy (RE) power also used for power distribution control, such as PV and wind power is equal to zero so that the power supply is taken over by generator set. If one of RE generation is zero, so that the RE is supplying to the load up to the maximum, but when exceeding, the generator set will be turned on. RTU work based on this logic and it can be ordered MMI to running the generator is required.

In Table 1, where the load will be read by a sensor at 24.00am-4.00am when the power average required is 130 W giving a signal to RTU as the logic is mode I. So, the RTU will instruct MMI to run the sources generating sufficient capacity. In this condition, the smart system will only turn ON the wind energy generation as shown in Figure (33).

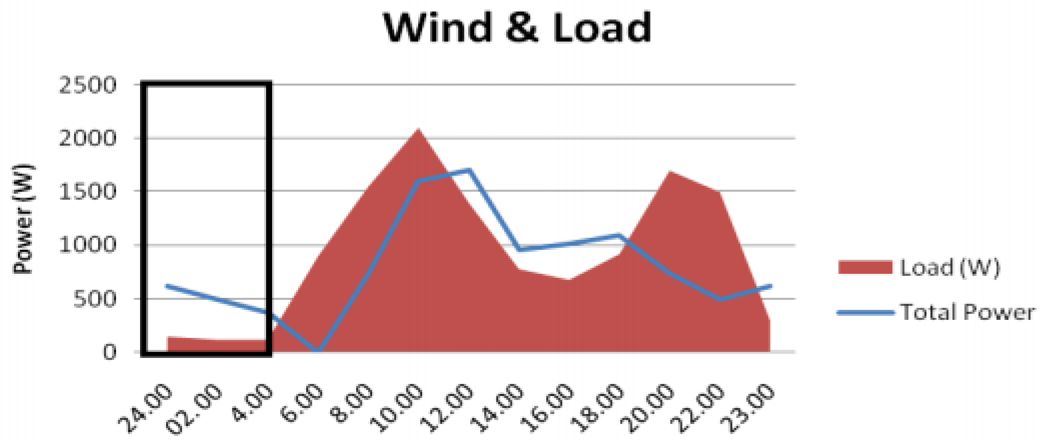


Fig. (33): The wind power to supply load

<u>Efficiencies:</u>

- Smart energy systems used based on SCADA can optimize the power distribution of hybrid power system for renewable energy generation.

- For remote areas, the setting hybrid wind power, solar and diesel has more economical beneficial impacts and can meet the electrical energy needs for 24 hours as some renewable energy sources does not last all the day.

- The control of SCADA-based energy systems can be performed by computing at remote monitoring center.

- SCADA-based intelligent system can maintain the power generation equipment from premature wear due to the using of it is not continuous for all day.

<u>Deficiencies:</u>

- The data obtained by the system from households in remote areas expenses power averaged only 2200-volt ampere and peak loads occurs only after 2 hours, so the use of diesel should not be too long, just 2 hours.

IoT (Internet of Things) Based Efficiency Monitoring System for Bio-Gas Plants

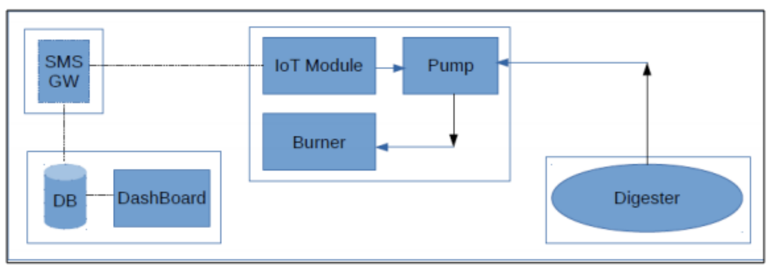
Location: India

Main theme: Monitoring and facilitating the use of Biogas.

Brief idea:

This previous solution was applied in India in order to manage and facilitate the access to Biogas sources in a way that can be monitored and calculated using Arduino modules and sensors.

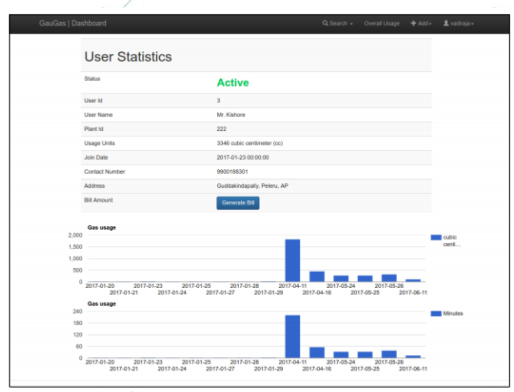
Mainly the usage of IOT was to connect between many different things together firstly is monitoring the main production of the system and giving instant feedback about the individual's consumption and connecting it through a webpage showing statistics of all biogas consumption with a login profile and special ID. Arduino Uno board is used to measure Temperature, pH and pressure by sensors. Secondly, they used an electronic module which pushed the consumption data to a mobile phone as an SMS enabling the user to take direct actions. Remote communication was also used in order to be able to shut down or turn on the system remotely if the user didn't pay the bill.



Fig(34): show an overview of the steps of the

Methods and Material:

First, An Arduino microcontroller integrated the measurements of pH, temperature and pressure using sensors. Then the biogas digester was fed by cow dung and the flow of gas was monitored and calibrated using a flow sensor. Secondly, by using an IOT module the biogas consumption of each individual was recorded and the data is sent through an SMS to the user's mobile. The Data is then pushed to a designed web dashboard to record the statistics of the biogas consumption of individual user in a data base (DB) as shown in figure (34) and figure (35). Finally, same IOT module was also used to remotely shut down the system or turn it on. This feature was tested and was proved that if you send a message to the IOT



Fig(35): shows the web dashboard displaying individual's consumption of module “LOCK” the plant with automatically shut down and will not pump gas and if a message was sent “UNLOCK” the system will turn on again this feature is really useful especially in cases when members didn’t pay the bills.

<u>Advantages:</u>

this solution really showed advantageous results and fitted the population consumption. By applying this solution, it caused the increase of usage of renewable biogas gas as it facilitated accessing to it and also put restricted rules and managed the consumption by each individual and also giving detailed monitoring through a web platform.

<u>Disadvantages:</u>

The main disadvantage with this solution is that it doesn’t supply long term monitoring and it is recommended to add as SD module to the system in order to store more data and give more space to monitoring larger data for longer times.

Generating and Defending a Solution

Solution and Design requirements

Solution requirement: (factors that make the solution successful)

Since every solution has some requirements and characterizes to be successful, we are going to discuss this requirement:

1) **Effectiveness:**

For a successful solution, positive effectiveness must be applied and in solar thermal systems and concentrated solar power in specific (CSP) effectiveness can be observed in different specialties and different phases:

1.1 Optical geometry:

The geometry of the mirror is based on the calculations of concentration ratio for getting the maximum possible efficiency by the mirror considering its dimensions for its weight for best optimization of the mirror assembly with the stepper motor.

The concentration ratio is the ratio of reflected solar flux quantity from the aperture area (area of mirror) on the area of the pipe receiver allocated in the focal line.

The maximum possible concentration ratio for any parabolic trough is 68.3. the biggest the ratio, the lowest the thermal loss, the more useful Q (energy) is obtained.

1.2 System energy consumption:

To run a system, you have to consume electricity and since you want to run an energy producing system then the energy consumption of the system must be considered. In a CSP system there are many gadgets that require electricity for example fluid pumps as water pump and Heat transfer fluid (HTF) pump and motors like that are used in sun tracking technologies all these examples use electricity to function properly and this is all called the energy consumption of the system itself. In order to observe effectiveness in this area you have to work on decreasing the consumption of the system itself in order to increase the ratio between the system's production and the system's consumption of energy so you are able to increase the effectiveness of the system.

1.3 Minimizing Heat loss:

For a CSP system that mainly collects solar heat, the Heat loss by the system must be calculated and maintained. One of the main attempts to prevent heat loss and must be presented in a successful plant is the vacuum tube. The vacuum tube surrounds the tube that carries the HTF fluid at the focal point of the trough. It is basically a glass tube that is vacuumed from air and surround the main tube to prevent heat loss. (Thermal insulation boiler)

1.4 Sun tracking technologies:

Sun tracking is the ability of the mirrors of the system to track the sun and modify their position according to the sun's position. This technique enables the system to follow the sun the whole day in order to advantage from the sun as much as possible.

2) Optimum use of material:

3.1 Mirror reflecting material:

The only thing that outstands a CSP system from one another is the reflecting material used for concentrating sun rays it must have the perfect reflectivity percentage which is the percentage of reflected light rays from the fallen light rays on the mirror (a normal mirror has about 95% reflectivity) so as in order to achieve the highest thermal production we must reflect the most of light rays.

3.2 Receiver material:

The receiver is the tube that carries the HTF at the focal point of the mirror and it must be made from a specific material with good heat diffusivity to spread heat through the HTF fluid and make it heated for example metals and alloys.

3) **Thermal storage:**

A flexible CSP plant is the plant that has Thermal storage added to it. Thermal storage is storing of hot molten salts in special tanks in order to be able to access thermal energy through night or even times when the sun is not available. This characteristic enables the plant to produce energy at any time wanted rather being thermal of electrical energy**.**

4) **Cost effective:**

Being a cost-effective plant can be very advantageous especially in a developing country as it will be easy and not harmful to the economic to build solar thermal plants.

5) **Location:**

A successfully build CSP plant must have a location that had been chosen wisely and according to specific criteria like sun's intensity and solar energy falling on this area and also the land space availability.

Design requirements:

we are going to discuss design requirement that we intend to apply in our solution:

1) **Effectiveness:**

1.1 Optical geometry:

The geometry of our parabolic trough mirror will be conducted based on concentration ratio analysis. We are aiming to make a parabolic trough with concentration ratio of 32.57 which means 47.68% of the maximum possible concentration ratio 68.3. concertation ratio has great potentials in terms of reducing thermal losses from the receiving pipe and increasing the rate of heating the pipe and HTF within it.

1.2 System energy consumption:

We will focus on regulating the energy consumption of the water pump in the Parabolic trough CSP system as we will make it work periodically according to the temperature of the HTF with the aid of Arduino and IOT technologies which will cause a decrease in the system's electricity consumption causing the overall effectiveness to increase.

1.3 Minimizing Heat loss:

In our project we are aiming to obtain maximize thermal efficiency. We will apply this requirement by covering the fluid tubes that circulate the system and the boiler heat exchanger with isolating material to prevent heat lose through HTF movement in tubes.

1.4 Sun tracking technologies:

We will apply this requirement using Arduino, Light sensor and a stepper motor. The light sensor will track the sun light and move the stepper motor accordingly with the control of the Arduino. We chose this requirement because it is mostly related to our challenge which is implementing communication technologies to a power generating system.

2) Optimum use of material:

3.1 Mirror reflecting material:

We chose to apply this design requirement because it is mostly important to our system. We will apply it by using Acrylic flexible mirror which has about 85% reflectivity which is different from a plane mirror which has reflectivity of about 95% but the acrylic mirror is less weight, less expensive and can be bended to take different shapes and curves with losing the ability to reflect light.

3.2 Receiver material:

Since we aim to achieve thermal efficiency, choosing the material of the tube that carries the HTF is important. It must have High heat diffusivity in order to transfer the heat from Sun rays to the HTF. We intent to use copper as the material that carries the HTF and circulates the system since it has High Heat diffusivity (about 107–112 $\boldsymbol{m^2/s}$) when it is compared to other metals like steal and aluminum.

Selection of solution

A) Description of solution that we decided to pursue:

A parabolic solar trough system for cogeneration of power and freshwater was chosen to work on and being integrated with an IOT and communication system.

The process of water circulation with the heat transfer fluid (HTF) was studied. The saline water and the HTF exchange heat in the boiler heat exchanger hence the water heated up and evaporated to generate electricity by steam turbine and then condensed. The circulation of water is operated by feedwater pumps without a regulation as a consequence, the system consumption of electricity is relatively high.

A water proof temperature sensor is optimized to measure the HTF temperature and according to that temperature, the feedwater pump is operated to when to feed water into the boiler heat exchanger or not.

The purpose is to generate the same amount of energy by consuming less electrical energy by the feedwater pumps.

The hardware components are Arduino, Wi-Fi module, temperature sensor and pumps.

The IOT system is conducted by integrated all hardware components with the RemoteXY app for monitoring or manual controlling.

B) <u>Reasons and steps to choose our solution:</u>

1- Solar Energy and Egypt:

Egypt is considered a country with high and favorable solar radiation intensity of 2000-3200 KWh/m^2/year from north to south and annual direct normal intensity of 1970-3200 Kwh/m^2. In addition, Egypt has 2900 and 3200 hours of sunshine annually.

2- Solving the problem of covering the Egypt's need of energy:

Although the electricity access in Egypt is 100% of population by latest Tracking SDG7 Report. There is an energy gap between energy needs and energy being introduced to people. Fig. (36) shows the energy gap until 2022.

Fig. (36): the energy gap in Egypt till 2022. Data is represented by "Solar Atlas in

Supporting data from “worldometers.info”, in 2017, Egypt consumed 4,012,356,526,000 BTU (British Thermal Unit) which is equivalent to 1.1759 TWh of energy. And producing 3,445,085,097,000 BTU which is equivalent to 1.0096 TWh. meaning that Egypt covers 86% of its energy consumption need. So, there is a gap between the energy produced and needed.

3- CSP is a growing energy industry in Egypt:

CSP technologies has great potentials in terms of power production and thermal energy applications. MENA countries (Middle East and North Africa) have to deal with the hybrid concentrated solar power plant for power and freshwater production due to their high dessert regions**.**

There are 2 working plants in Egypt:

- ISCC Al Kuraymat: A 140 MW CSP project in Kuraymat.
- MATS concentrated solar power plant: in Borg El Arab near Alexandria.

The projects under preparation are:

➢ 100 MW CSP Kom Ombo Project.

Also, according to latest news, Egypt aims to build 5 concentrated solar power plants.

4- The process of water circulation with heat transfer fluid (HTF) was studied:

The water is in a closed cycle with the HTF to gain the heat from the HTF in the heat exchanger. This circulation is continuous by water pump until the HTF required temperature is obtained. Hence, there is a great electricity consumption by the system.

The high electricity consumption observed when studying the 50 MW Andasol 3 parabolic trough power plant in Spain. The feedwater pump has high consumption of 957 kW relative for other system components table. (3).

DESCRIPTION		PEAK POWER CONSUMPTION (kW)
SYSTEM	EQUIPMENT	
HEAT TRANSFER FLUID SYSTEM	HTF MAIN PUMPS	3398
	FREEZE PROTECTION PUMPS	239
	OVERFLOW RETURN PUMPS	127
FEED WATER SYSTEM	FEED WATER PUMPS	957
THERMAL ENERGY STORAGE SYSTEM	TES PUMPS	903
COOLING WATER SYSTEM	CIRCULATING WATER PUMPS	322
	COOLING TOWER CELLS FANS	592

Table. (3): shows the main load consumers of power in of Andasol 3 A 50 MW parabolic trough power plant.

6- IOT system with sensors based on study:

A regulation of the water feed pump is put into assumptions. The regulation is conducted by putting a temperature sensor for the HTF for measuring the required temperature needed to evaporate the water and feed it into the boiler heat exchanger Fig. (37) illustrates the system. Once, the sensor got the required reading it orders the pump to operate. Thus, there is a reduction in the system electricity consumption by the pumps.

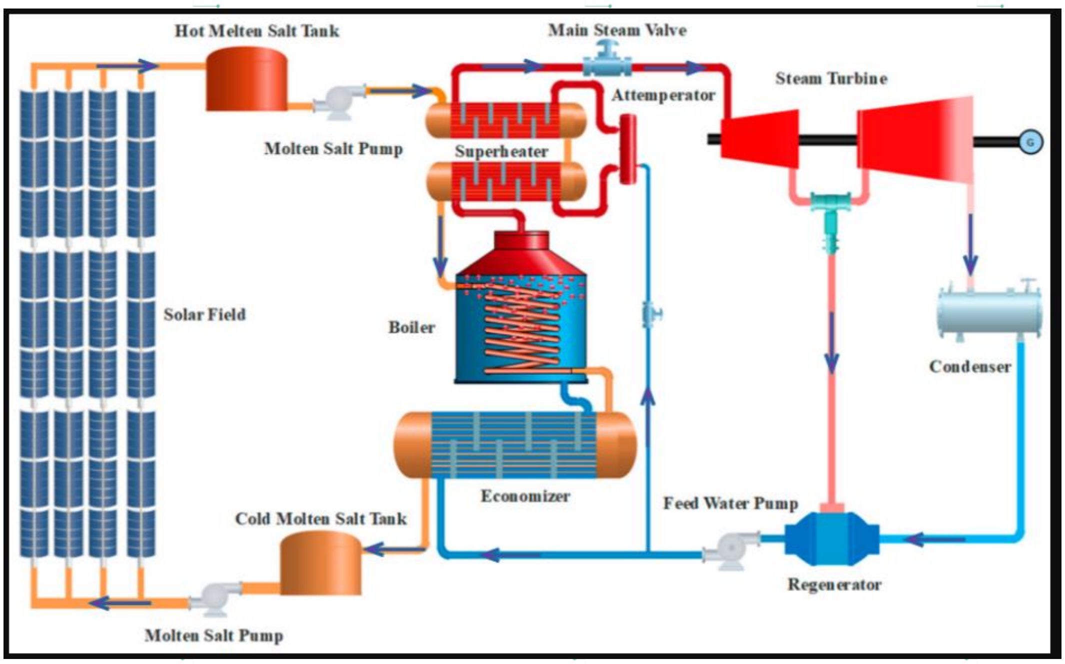


Fig. (37): A schematic diagram for the parabolic trough

The sensor and the pump will be integrated with the RemoteXY app for monitoring or direct manual controlling.

Selection of prototype

We are going to construct our prototype in manners of our chosen design requirements, and this would be demonstrated beneath:

A) the Parabolic mirror Dimensions and construction:

The mirror dimension will be 80 cm length and 65 cm width according to concentration ratio equations which is also proportional to the weight of the mirror. This will help us apply the design requirement of optical geometry.

The reflective material will be an acrylic mirror with reflectivity of about 93% and the mirror itself will be made from wood.

B) General overview of the prototype:

The porotype will have a base made of a thick wooden board of about (80 cm x 65 cm) and a thickness of (3.5cm). the mirror will be hanged at a distance 15 cm from the base and there will be two columns to carry the mirror about 60 cm height.

Beneath the mirror there will be all the other tanks and different stages that are in the process all standing of the wooden base of the porotype.

C) The Heat Exchanger:

The heat exchanger is the considered the most important stage in our project since it is the place where the oil (HTF) will exchange heat with water to evaporate it. It will be made from a customed metallic cylindrical tube with a diameter of 12 cm and a height of 25 cm (can carry about 2826ml of water). The oil tube will be coiled inside the cylinder in order to increase the surface area of the hot tubes exchanging heat with water.

The cylinder will have four holes; one for the oil inlet and the other for the oil outlet, the third opening is for the steam outlet and the last one is for water inlet.

D) The Next Stages of the process:

Next to the Heat exchanger there will be the Steam Generator box where Steam will move a fan to generate electricity and get condensed and this will help us apply the water quality design requirement.

on the other side of the heat exchanger from the side where the oil tube outlets there will be the oil tank which is resistant to hot fluids. There will be also the water tank near the heat exchanger which will have a water pump in it.

E) Tubes and Circulations:

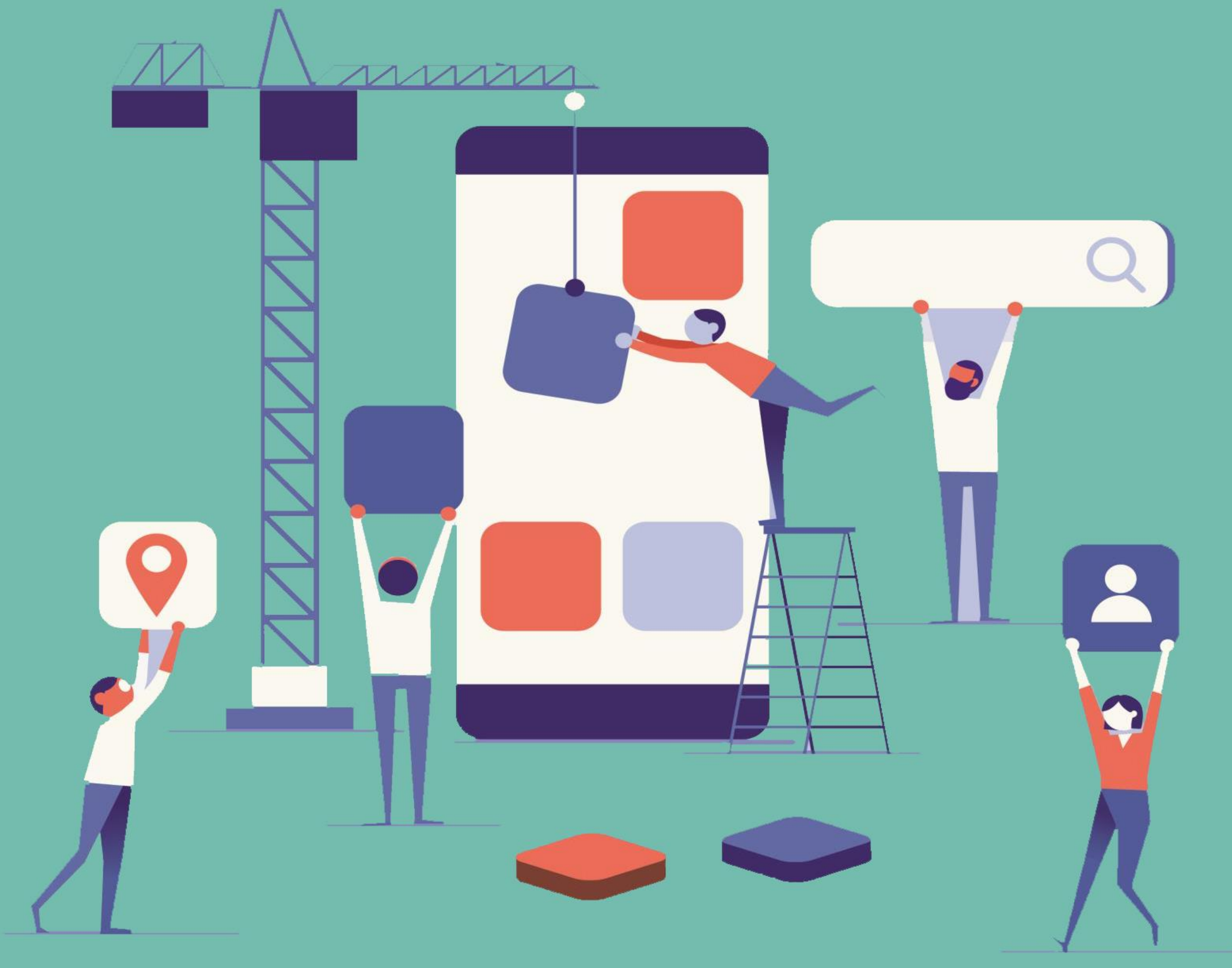
For tubes that transfer fluids through the system we will use copper tubes since they are available and transfer heat perfectly and has high heat diffusivity (to apply the design requirement of optimum use of material). We will also use flexible rubber tubes that are resistant to heat in order to help in shaping and movement of tubes. Tubes will be covered by an isolating material to prevent heat loss and apply the design requirement of preventing heat loss**.** Oil will circulate through the system using a gear pump.

F) is the electronic interaction and function:

First, we will put a temperature sensor on the oil tube that leaves the heat exchanger to indicate when will the oil be cold and when will it be hot in order to control the water pump and regulate the energy consumption of the water pump in order to apply the design requirement of effectiveness increase of the system. **Second,** we will put a WIFI module that will send the temperature value regularly to a mobile app and help the user to monitor the temperature. This will help as approach the condition of using communication in our solution.

Third is the sun tracker, the sun tracker will be an independent system that uses light Arduino sensors and a servo motor to track the sun accordingly (apply sun tracking design requirement).

Constructing and Testing a Prototype

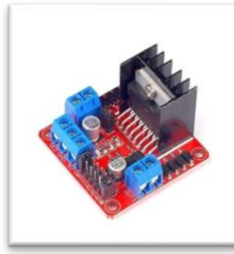


Material and methods

Material:

Item	Usage	Cost	Picture	Quantity	Place of purchase
Recycled wood	Used is to build the mirror body and the prototype base	Recycled from a carpenter		2 m^2	Carpenter
Copper and Rubber Tubes	Used it to carry Oil (HTF) and to Gain thermal energy from the mirror	150 LE		5 meters X 30 LE	blacksmith shop
Recycled plastic containers	We used it to represent the stages of the process (hot oil container, water container, Steam generator room)	Recycled from home		3 small platic containers	From Home
Recycled metal	We used it to build the heat exchanger	Recycled from a smith		40 cm x25 cm plate	blacksmith shop

Epoxy glue	Used to stick wood and plastics	12 LE		1 tube	Tool market
Acrylic Mirror	Used as the reflective material that concentrated light	170 LE		70 x80 cm	Building tool shop
Gear Pump	Used to cycle the Oil in the system	130 LE		1 pump	Filter's store
Water Pump	Used to Pump water in the system's heat exchanger when needed (consumes 0.084 watt)	50 LE		1 pump	Maker electronics
Arduino IDE	A software used to program the Arduino	Free Software		N/A	Online
Arduino board	Used for the independent system of the sun tracking	130 LE		1 board	Maker electronics

Arduino Mega board	The main board (the brain of the project) used to build the communication system	Free From the fab lab		1 board	School's Fab lab
Motor Driver	An electronic piece used to run the stepper motor	55 LE		1 driver	Maker electronics
Nema 17 stepper motor (Used)	Used in sun tracking to move the mirror with an angel	95 LE		1 motor	Maker electronics
LDR (Light sensor)	Used to track sun light	2 x (6 LE) = 12 LE		2 LDRs	Maker electronics
WIFI Module	Used to send Data of Temperature recorded to a mobile phone application	50 LE		1 Module	Maker electronics

NTC Temperature sensor	Used to read the temperature of the Oil in the system	20 LE		1 sensor	Maker electronics
Bread Board	Used to connect wires	30 LE		2 boards	Maker electronics
Jumper Wires	Connecting wires for electronics	40 LE		A punch of wires	Maker electronics
Isolating material	Used to prevent heat loss	5 LE		2 x 30 cm	Tool's store
DC Motor (generator)	Used to generate electricity	10 LE		1 motor	Maker electronics
Thermal oil	Used to transfer heat	30 LE		1 bottle	Oils shop

TOTAL Cost: 989 LE

Safety precautions:

1. We wore lab coats while working on the prototype and while doing the test plan
2. We were carful while using any gules or burning materials
3. We were careful while dealing with Wood

Constructing prototype methods:

Firstly, the Parabolic mirror Dimensions and construction:

Figure (38): Overview of prototype and mirror

The mirror dimension are 80 cm length and 65 cm width according to concentration ratio equations which is also proportional to the weight of the mirror. The reflective material will be an acrylic mirror with reflectivity of about 93% and the mirror body will be from wood.

Secondly, General overview of the prototype:

The porotype will have a base made of a thick wooden board of about (80 cm x 65 cm) and a thickness of (3.5cm). the mirror stands at a distance 15 cm from the base by two wooden columns that carry the mirror at 60 cm height. Beneath the mirror there will be all the other tanks and different stages that are in the process all standing of the wooden base of the porotype as shown in figure (38).

Thirdly, The Heat Exchanger:

Figure (39): Heat exchanger

It is made from recycled metal at a cylindrical shape with a diameter of 12 cm and a height of 25 cm (can carry about 2826ml of water) as shown in figure (39). The oil tube was coiled as shown in figure (40) and put inside the cylinder in order to increase the surface area of the hot tubes exchanging heat with water. The cylinder will have four holes; one for the oil inlet and the other for the oil outlet, the third opening is for the steam outlet and the last one is for water inlet.

Fourthly, The Next Stages of the process:

Figure (40): Coiled tube of oil

Next to the Heat exchanger there will be the Steam Generator box where Steam will move a fan to generate electricity and get condensed. on the other side of the heat exchanger from the side where the oil tube outlets there will be the oil tank which is resistant to hot fluids (shown in figure (40)). There will be also the water tank near the heat exchanger which will have a water pump in it.

Fifth, Tubes and Circulations:

We used copper tubes because they are flexible and can transfer heat perfectly this can help us in coiling the tube as shown in figure (40). Tubes will be covered by an isolating material to prevent heat loss. Oil will circulate through the system using a gear pump.

Figure (41): Stages of prototype

Finally, is the electronic interaction and function:

First, we will put a temperature sensor on the oil tube that leaves the heat exchanger to indicate when will the oil be cold and when will it be hot in order to control the water pump and regulate the energy consumption of the water pump. Second, we will put a WIFI module that will send the temperature value regularly to a mobile app (RemoteXY) (shown in figure (42)) and help the user monitor the temperature. This will help us approach the condition of using communication in our solution. Third is the sun tracker, the sun tracker will be an independent system that uses light Arduino sensors and a servo motor to track the sun accordingly.

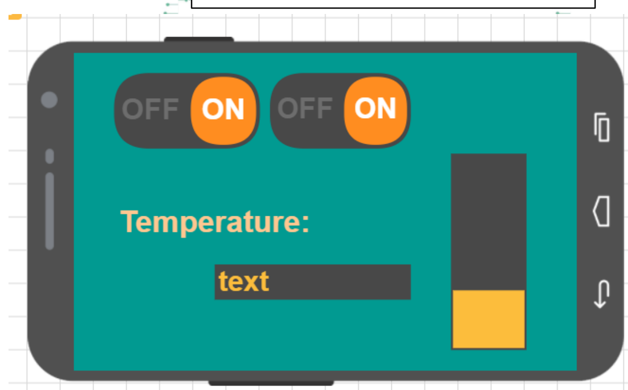


Figure (42): Show RemoteXY application

Test plan

Design requirements that would be applied in the prototype:

1- Effectiveness:

- **System energy consumption:**

For our prototype, we will regulate the feedwater pump for its pumping into the boiler heat exchanger. The regulation will be optimized with the Arduino integrated with the temperature sensor readings for the oil and pipe temperature. It is predicted that the energy consumption will decrease by a rate about less than 20% due to the reasonable working temperatures in the system.

- **Optical geometry:**

Optical geometry is the ratio between the reflected solar flux from the mirror aperture area on the receiver pipe. Concentration ration has a rule to play in terms of minimizing heat loss and increase the parabolic trough efficiency. We are aiming to conduct a concentration ratio of 32.57 which is a 47.68% of the maximum concentration ratio of 68.3. The equation of the mirror will be $\boldsymbol{y = \frac{1}{4f}x^2}$. The focal length of the mirror will be at 16.25 cm and the width will be 65 cm.

- **Minimizing Heat loss:**

We are aiming to minimize heat loss by covering the boiler heat exchanger by insulation material to maintain heat inside it as much as possible. Also, the concertation ratio will have great contributions in terms of minimizing heat loss hence increasing the overall parabolic effectiveness.

- **Sun tracking technologies:**

We used a Stepper Motor and light sensors to build a sun tracker. The Light sensor is put to detect in deflection in the sun's angel which will in turn signal the motor to position itself accordingly.

2- Optimum utilized materials:

- **Mirror reflecting material:**

The reflectivity of reflective material is very important because it is considered to be the input energy that comes and reflected from the sun beam. We will apply it by utilizing acrylic mirror with a reflectivity of 85%.

- **Receiver material:**

Choosing the receiver pipe material is a key-playing factor in the parabolic trough collector because it determines how fast the reflected sun energy is absorbed and distributed along the pipe. The copper receiver pipe will be utilized in the system because it has a diffusivity rate of (about 107–112 $\boldsymbol{m^2/s}$) meaning that it transfers heat quickly to the heat transfer fluid (HTF).

Steps of test plan:

The Design requirements we decided to conduct in the test plan are effectiveness including optical analysis, system's energy consumption and sun tracking techniques:

Optical analysis: we tested this requirement as the receiver tube at the mirror reached to 50 °C in 8 minutes

System's energy consumption: We tested this requirement by time calculations as we Conducted two configurations for the system first before adding our solution and second after adding it and we calculated the time difference which in turn affected the energy consumption.

In the 1st configuration (without our solution):

- Firstly, the working time of feedwater pump was 92 seconds (until the boiler was filled with water).
- Secondly, the condensed water was 15 ml.
- Thirdly, the working time for the generator was 10 seconds.

In the 2nd configuration (with our solution):

- Firstly, the working time of feedwater pump was 78 seconds (until the boiler release less vapor at 90°C).
- secondly, the condensed water volume was 10 ml.
- thirdly, the working time for the generator was 10 seconds.

Data Collection

After testing the prototype, we got the results and after that got the collected data.

Data collection in the test plan:

To verify the solution the test plan must be done in 2 different system configurations. The 1st one is to show the defective in the parabolic trough system without using our modification. The 2nd one is to show how this defective is adjusted by the modification.

1st configuration data (without regulating the water pump):

- The pipes:

  Got to a temperature of 110°C in 20 minutes.

- The feedwater pump:

  Starts operating at 110°C and never stops until the water fills the heat exchanger.

  Electrical energy consumed by feed water pump is given by:

  $E1= IVt1$, $E1= 0.03\times2.8\times92 = 7.728$ joules of electrical energy.

  The time of feedwater pump operation is 92 seconds. This time indicates the begging of working at 110°C until the water fills the boiler heat exchanger (working without stopping).

- Initial water temperature:

  It was about 25°C.

- The water condensed volume:

  15 ml

2nd configuration data (with regulating the water pump):

- The pipes:

  Got to a temperature of 110°C in 20 minutes.

- The feedwater pump:

  Starts operating at 110°C and stops at 90°C.

  Electrical energy consumed by feed water pump is given by:

  E2= IVt2, E2= 0.03×2.8×78 = 6.552 joules of electrical energy.

  The time of feedwater pump operation is 78 seconds. This time indicates the begging of working at 110°C until the temperature sensor read 90°C of pipe's temperature. At that specific temperature the water vapor is very little so we consider that the pumping water at that time has no meaning and the pump must be stopped to wait the oil and pump reheat again.

- Initial water temperature:

  It was about 25°C.

- The water condensed volume:

  10 ml

The reduction effectiveness of feedwater pump is given by:

$$\frac{\boldsymbol{E1-E2}}{\boldsymbol{E1}} \times \mathbf{100} = \frac{\mathbf{7.728-6.552}}{\mathbf{7.728}} = \mathbf{15.21\%}$$

Visual representation: of all conducted test plan results:

Parameter	1st configuration (before solution)	2nd configuration (after solution)
Pipes	To 110°C in 20 min.	To 110°C in 20 min. From 110 to 90 in the boiler in 76 seconds
Feedwater pump	Operates at 110°C Never stops until the heat exchanger is full with water.	Operates at 110°C Stops at 90°C
Electrical Energy consumed by feedwater pump	E_1=0.084 watt × 92 sec. = 7.728 J of electrical energy (time indicates from the begging until the water fills the heat exchanger)	E_2= 0.084 watt × 78 sec. = 6.552 J of electrical energy.
Initial Water Temp.	25°C	25°C
Generator (E) generation.	$E = IVt_1$ E = 0.03 A×0.68 V×10 sec. = 0.204 J of electrical energy.	$E = IVt_2$ E = 0.03 A×0.68 V×10 sec = 0.204 J of electrical energy.
Water condensed volume	15 ml	10 ml

Table. (4): visual representation of all conducted test plan

Conclusion about the collected data:

1- There is an electrical energy decrease in usage by feedwater pump between the 2 system configurations. A decrease of 15.21% fig. (43) from the non-adjusted system configuration was observed in the system where the feedwater pump is regulated.

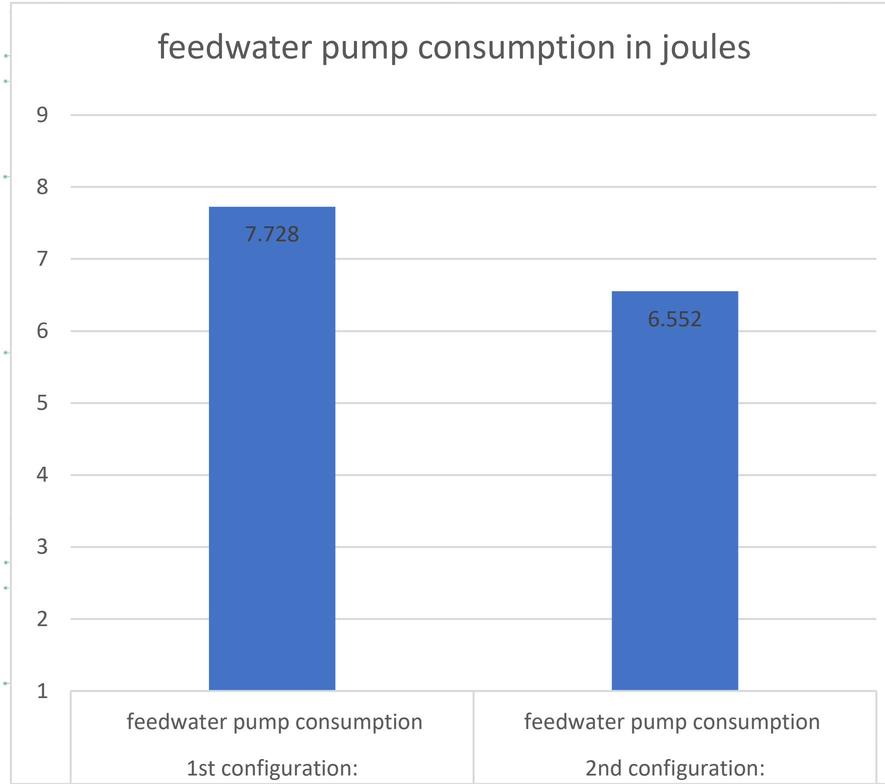


Fig. (43): a comparison between the 1st (non-adjusted) and the 2nd (adjusted) systems in feedwater pump consumption.

2- There is a negative result of condensing less condensed water in the 2nd system (regulating feedwater pump) comparing it to the 1st system (with feedwater pump). Resulting in a 10 ml of condensed water produced in the modified system and a 15 ml of condensed water in the unmodified system.

Tools of measurements that we used:

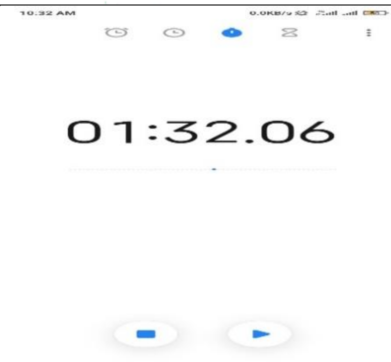
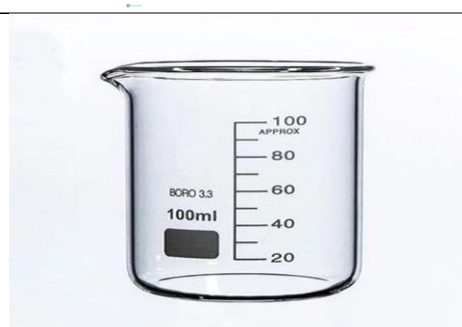
Tool	Picture
Avometer	
Mobile timer	
Temperature sensor	
Small graduated beaker	

Table. (5): show the instruments

Our level of precision of measurement determined by:

- Using Avometer to measure the voltage and ampere of any system component that consumes or produces electrical energy.
- Measure the initial water temperature in the both system configuration to compare them in the same conditions by temperature sensor.
- Measure the time of working of feedwater pump by the mobile timer.
- Using small graduated beaker to measure the volume of condensed water.

Constructing and Testing a Prototype

Analysis and discussion

In order to build a successful simulated prototype and make a successful test plan to solve a main grand challenge in Egypt: increase the use of alternative energies. We certainly followed some scientific methods knows as EDP (Engineering design process) to find out a way to conclude our main problem, solution, and test behavior. And the scientific methods are:

1- Define the problem:

We observed from our research how Egypt is depending heavily on non-renewable energy sources to generate electricity and power with a 90% comes from oil and natural gas.

We determined our problem as increasing the use of alternative energies due to a lot of factors such as**:**

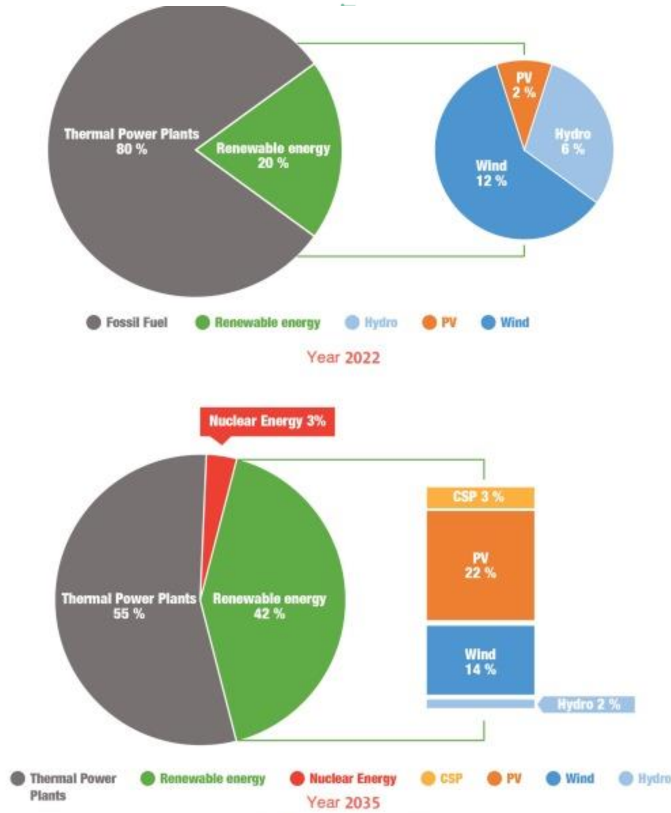


Fig. (44): shows the predictable increase of CSP share of Egypt energy

- Non-renewables: Egypt is depending heavily on oil and natural gas with a 90% share of them in electricity generation.
- Population growth and energy gap: Egypt is exposing to a high population growth estimated by 1.3% per year. And although the electricity access is 100% of population, there is an energy gap in Egypt causing a complicated problem for energy access in the future.
- Energy coverage in Egypt: Data from "worldometers.info", in 2017, Egypt consumed **4,012,356,526,000 BTU (British Thermal Unit) which is equivalent to 1.1759 TWh of energy. And producing** 3,445,085,097,000 BTU which is equivalent to 1.0096

TWh. meaning that Egypt covers 86% of its energy consumption need. So, there is a gap between the energy produced and needed.

- Promising renewables share: Energy capacity is the maximum output of electricity generated in a country from a source or a generator when working at full potential. According to Statista, renewable energy capacity in 2019 in Egypt was 5,972 megawatts. Resulting in a growth rate of 24.1% from the preceding year 2018. The renewable energy capacity over the last decade in Egypt is illustrated in fig. (44) by Statista. The data provides the motive to work in renewables sector as alternative energy.

2- Identify and Brainstorm the solutions:

- We studied the parabolic trough system as the system is widely used around the world and in Egypt. Egypt has 2 working plants:

- ISSC Al Kuraymat with 140 MW capacity.
- MATS concentrated solar power plant in Borg El Arab near Alexandria.

Also, Egypt aims to build 5 concentrated solar power plants meaning that the CSP is a growing industry in Egypt according to data from "New & Renewable Energy Authority" annual report 2020 fig. (44).

- We found out a defective in the system causing a high consumption of electricity by the parabolic trough system. That was for the single system for power generation only or freshwater water production only and for the hybrid system for cogeneration of power and freshwater production.

An observation occurs from data on the load and energy consumption of Andasol 3 power plant in Spain which is a 50 MW parabolic trough plant. Data is illustrated in table. (6).

DESCRIPTION		PEAK POWER CONSUMPTION (kW)
SYSTEM	EQUIPMENT	
HEAT TRANSFER FLUID SYSTEM	HTF MAIN PUMPS	3398
	FREEZE PROTECTION PUMPS	239
	OVERFLOW RETURN PUMPS	127
FEED WATER SYSTEM	FEED WATER PUMPS	957
THERMAL ENERGY STORAGE SYSTEM	TES PUMPS	903
COOLING WATER SYSTEM	CIRCULATING WATER PUMPS	322
	COOLING TOWER CELLS FANS	592

Table. (6): shows the main load consumers of power in of Andasol 3 50 MW power

The data work relatively for the single and hybrid parabolic trough system for cogeneration of power and freshwater.

The solution was chosen based on the previous data. A way to make the feedwater pump less consumable as it is the most power consumer in the system.

3- Select the solution, put the hypothesis, and applying the hypothesis:

Select the solution:

In the system configuration Fig. (45), the feedwater pump pumps water into the boiler heat exchanger to exchange and gain heat from the heat transfer fluid (HTF) coming from the parabolic trough mirror. The water boils and evaporates and then steam is deriving a steam turbine to generate electricity and then the steam condenses.

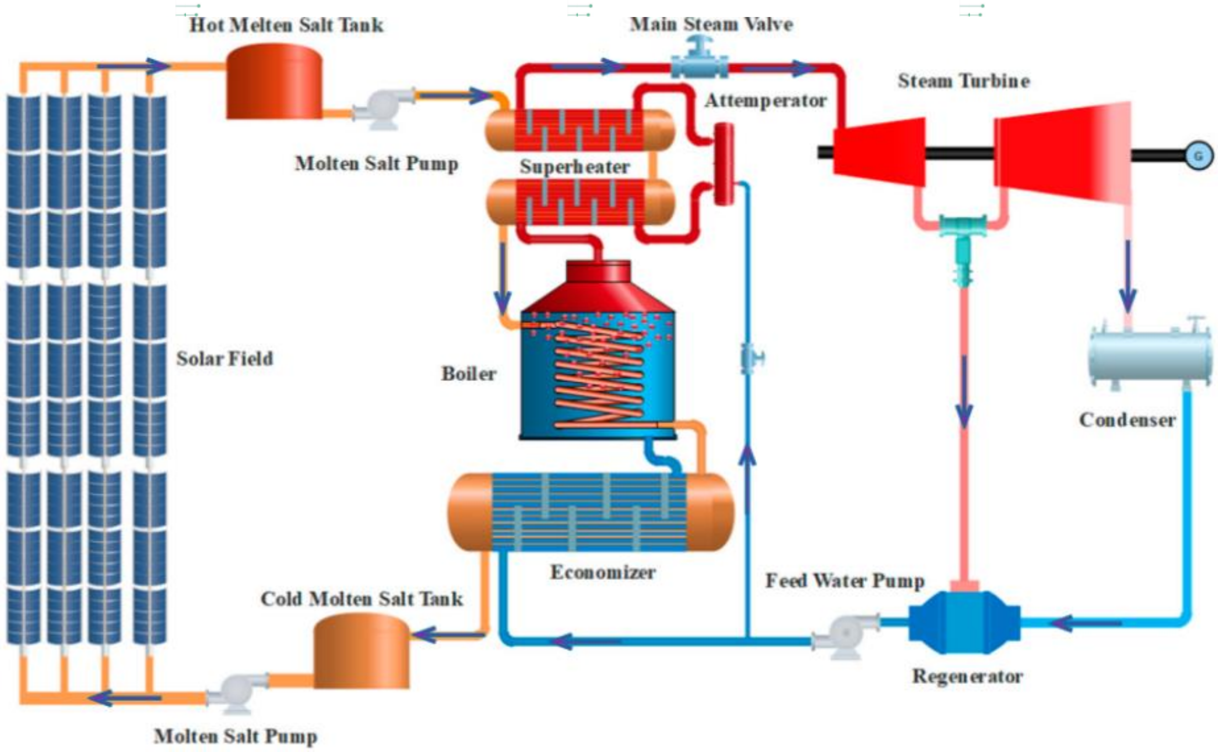


Fig. (45): schematic diagram for parabolic trough

A suggested solution to minimize the feedwater pump consumption is by regulating its operation to feed water in the boiler heat exchanger when the HTF temperature decreases. HTF temperature will be monitored by temperature sensor and the feedwater pump will operate according to HTF temperature.

Put some hypothesis:

The hypothesis was put for 2 main calculations: the effectiveness of the modified system and the geometry of the parabolic trough mirror.

- For the modified system effectiveness:

Since we are regulating the feedwater pump pumping into the boiler a decrease in the pump electrical energy consumption must be observed.

The power consumed by the pump is given by:

- P = IV (P is the power in watt, I is the current in ampere and V is the voltage in volts).

Since the volt and ampere of the feedwater pump are constant and since we are regulating the pump for specific time, the time of operating has a rule to play in the calculations.

- E = Pt (where E is electrical energy in joules (J), P is power in watt (J/S) and t is time of operation in seconds (s)).

1st system configuration (without regulating the water pump) (E1):

The electrical energy consumed is given by:

- E1 = Pt1

2nd system configuration (with regulating the water pump) (E2):

- E2 = Pt2

For calculating the effectiveness of reduction of the electrical energy consumption:

- Reduction effectiveness = $\frac{|E2 - E1|}{|E1|} \times \mathbf{100}$

- For the optical geometry: assumptions

The dimensions of the mirror were conducted based on concentration ratio calculations considering its weight for the stepper motor to hold it.

Assumptions for the focal distance were made to get a reasonable width of the mirror for the best optimization of concentration ratio and the mirror weight for the stepper motor for sun tracking. The last focal distance we reached is at 16.25 cm.

For the visual representation of the parabolic trough collector (PTC), a cross-section of the PTC is illustrated in Fig. (46).

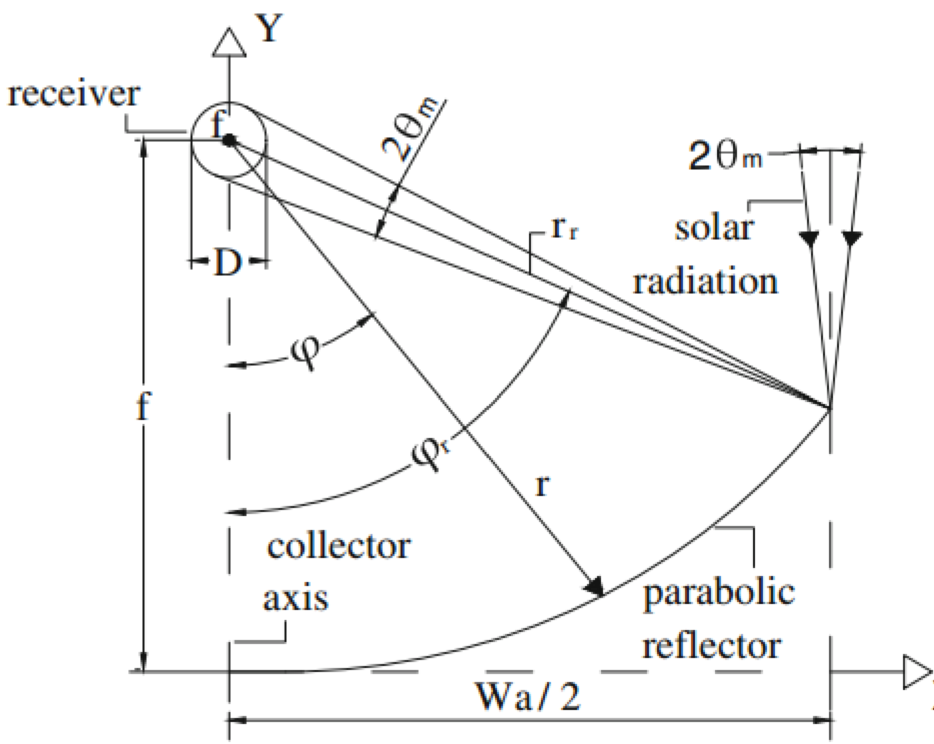


Fig. (46): illustration of a PTC (parabolic trough collector) cross-section.

Some definitions:

- F: is the focal distance of the mirror where the sun beam is concentrated.
- rr: rim radius is the maximum mirror radius since the radius of the mirror increases as the angle between rr and F increases.
- Φr: rim angle is the maximum angle between the rr and F.
- Θm: is the half-acceptance angle for the perfect tracking mechanism for the sun beam. Its value is 0°16`.
- C: is the concentration ratio.
- Aa: aperture area of the mirror.
- Ar: area of the receiver.

The rim radius rr is obtained from the rim angle Φr:

- rr = $\frac{2f}{1 + cos(\Phi r)}$ Eq 1. The maximum concentration ratio will be at Φr = 90°.

The aperture width of the parabola W is given by:

- W = 2rrsin(Φr) Eq 2.

substitute Eq 1 in eq 2 to get:

- W = $\mathbf{2} \times \frac{2f}{1+cos(\Phi r)} \times sin(\Phi r)$

  W = $4ftan(\frac{\Phi r}{2})$ Eq 3.

For the perfect alignment and diameter D for the receiver pipe:

- D = 2rrsin(Θm) Eq 4.

The concentration ratio is obtained from:

- C = Aa/Ar (aperture area over the receiver area).

  C = $\frac{W \times L}{\pi DL}$ so, C = $\frac{W}{\pi D}$ eq 5.

Substitute with W Eq 3 and D Eq 4 in eq 5.

- C = $\frac{4ftan(\frac{\Phi r}{2})}{\pi(2rrsin(\Theta m))}$ so, after simplifying C = $\frac{sin\ (\Phi r)}{\pi sin(\Theta m)}$ Eq 6

Solve for Eq 6 for maximum concentration ratio at Φr = 90°:

- Cmax = $\frac{sin(90)}{\frac{22}{7}\times sin\ (0°16`)} = \mathbf{68.3}$

At assumption of 16.25 for the focal length:

- rr = $\frac{2\times 16{,}25}{1+cos(90)} = \mathbf{32.5\ cm}$.

  So, W = $\mathbf{2\times 32.5\times \mathit{sin}(90)}$ = 65 cm.

The equation that satisfies the mirror dimensions is:

$$y = \frac{1}{4f}x^2$$

Taking the pipe of 0.25 inch.

- C = $\frac{65}{\frac{22}{7}\times(0.25\times 2.54)} = \mathbf{32.57}$ which is 47.68% of the maximum concertation ratio 68.3.

The benefit of concentration ratio:

The useful energy is given by the absorbed energy – the loss energy:

- $Qu = Qs - QL$
- $Qu = FR[(Gbn)(Aa)\tau\alpha\rho - ULAr(Tfi - Tair)]$

Where FR is a term calculated for the PTC due to its geometry and the heat loss.

Gbn is Beam radiation on a normal surface (W/m^2)

Aa is the aperture area of the mirror,

τ is the transmittance of the glass cover.

α is the absorptance of the absorber,

ρ is the reflectively of reflective material,

UL is an overall loss coefficient calculated for each mirror.

Ar is the receiver area,

To calculate the efficiency of parabolic trough collector:

It is given by the useful energy divided by solar energy intercepted by the collector aperture area, Sa (input energy)

$\boldsymbol{Sa = Gbn \times Aa}$

$$\eta = \frac{Qu}{Sa} = FR\left[\boldsymbol{\tau\alpha\rho} - Ul \times \frac{Ar}{Aa}\frac{Tfi - Tair}{Gbt}\right]$$

Ar/Aa is 1/C so the efficiency equation will be:

$$\eta = \frac{Qu}{Sa} = FR\left[\boldsymbol{\tau\alpha\rho} - \frac{Ul}{C}\frac{Tfi - Tair}{Gbt}\right]$$

We can use this data to conduct that:

PTC efficiency can be increased by:

1- Using selective coating (increase $\boldsymbol{\alpha}$)
2- Evacuation for tubes (decrease UL)
3- Increase the concentration ratio (C) to minimize the energy loss (QL) term.

Applied design requirements in the prototype:

6) Effectiveness:

1.1 Optical geometry:

The geometry of our parabolic trough mirror will be conducted based on concentration ratio analysis. We are aiming to make a parabolic trough with concentration ratio of 32.57 which means 47.68% of the maximum possible concentration ratio 68.3. concertation ratio has great potentials in terms of reducing thermal losses from the receiving pipe and increasing the rate of heating the pipe and HTF within it. The equation of the mirror will be $\boldsymbol{y = \frac{1}{4f} x^2}$. The focal length of the mirror will be at 16.25 cm and the width will be 65 cm.

1.2 System energy consumption:

We will focus on regulating the energy consumption of the water pump in the Parabolic trough CSP system as we will make it work periodically according to the temperature of the HTF with the aid of Arduino and IOT technologies which will cause a decrease in the system's electricity consumption causing the overall effectiveness to increase. An effectiveness of 15.21% of energy consumption reduction was reached.

1.3 Minimizing heat loss:

In our project we are aiming to obtain maximize thermal efficiency. We will apply this requirement by covering the fluid tubes that circulate the system and the boiler heat exchanger with isolating material to prevent heat lose through HTF movement in tubes.

1.4 Sun tracking technologies:

We will apply this requirement using Arduino, Light sensor and a stepper motor. The light sensor will track the sun light and move the stepper motor accordingly with the control of the Arduino. We chose this requirement because it is mostly related to our challenge which is implementing communication technologies to a power generating system.

7) Optimum use of material:

3.1 Mirror reflecting material:

The reflectivity of reflective material is very important because it is considered to be the input energy that comes and reflected from the sun beam. We applied it by utilizing acrylic mirror with a reflectivity of 85%.

8) Receiver material:

Choosing the receiver pipe material is a key-playing factor in the parabolic trough collector because it determines how fast the reflected sun energy is absorbed and distributed along the pipe. The copper receiver pipe will be utilized in the system because it has a diffusivity rate of (about 107–112 $\boldsymbol{m^2/s}$) meaning that it transfers heat quickly to the heat transfer fluid (HTF).

4- Test the prototype and improve it:

While testing the prototype, a deflection was observed. The focal line was deflected some millimeters due to some optical errors. We modified the prototype by adding moving supporters fig. (47).

Fig. (47): shows the focal line

The test plan was done in 2 different system configurations. The 1st one is to show the defective in the parabolic trough system without using our modification. The 2nd one is to show how this defective is adjusted by the modification.

1st configuration data (without regulating the water pump):

- The pipes:

Got to a temperature of 110°C in 20 minutes.

- The feedwater pump:

Starts operating at 110°C and never stops until the water fills the heat exchanger.

Electrical energy consumed by feed water pump is given by:

$E1 = IVt1$, $E1 = 0.03 \times 2.8 \times 92 = 7.728$ joules of electrical energy.

The time of feedwater pump operation is 92 seconds. This time indicates the begging of working at 110°C until the water fills the boiler heat exchanger (working without stopping).

Initial water temperature:

It was about 25°C.

The water condensed volume:

15 ml

2nd configuration data (with regulating the water pump):

The pipes:

Got to a temperature of 110°C in 20 minutes.

The feedwater pump:

Starts operating at 110°C and stops at 90°C.

Electrical energy consumed by feed water pump is given by:

E2= IVt2, E2= 0.03×2.8×78 = 6.552 joules of electrical energy.

The time of feedwater pump operation is 78 seconds. This time indicates the begging of working at 110°C until the temperature sensor read 90°C of pipe's temperature. At that specific temperature the water vapor is very little so we consider that the pumping water at that time has no meaning and the pump must be stopped to wait the oil and pump reheat again.

Initial water temperature:

It was about 25°C.

The water condensed volume:

10 ml

The reduction effectiveness of feedwater pump is given by:

$$\frac{\boldsymbol{E1-E2}}{\boldsymbol{E1}} \times \mathbf{100} = \frac{\mathbf{7.728 - 6.552}}{\mathbf{7.728}} \times \mathbf{100} = \mathbf{15.21}\%$$

Conclusions about the analysis (positive **and negative results):**

3- There is an electrical energy decrease in usage by feedwater pump between the 2 system configurations. A decrease of 15.21% fig. (48) from the non-adjusted system configuration was observed in the system where the feedwater pump is regulated.

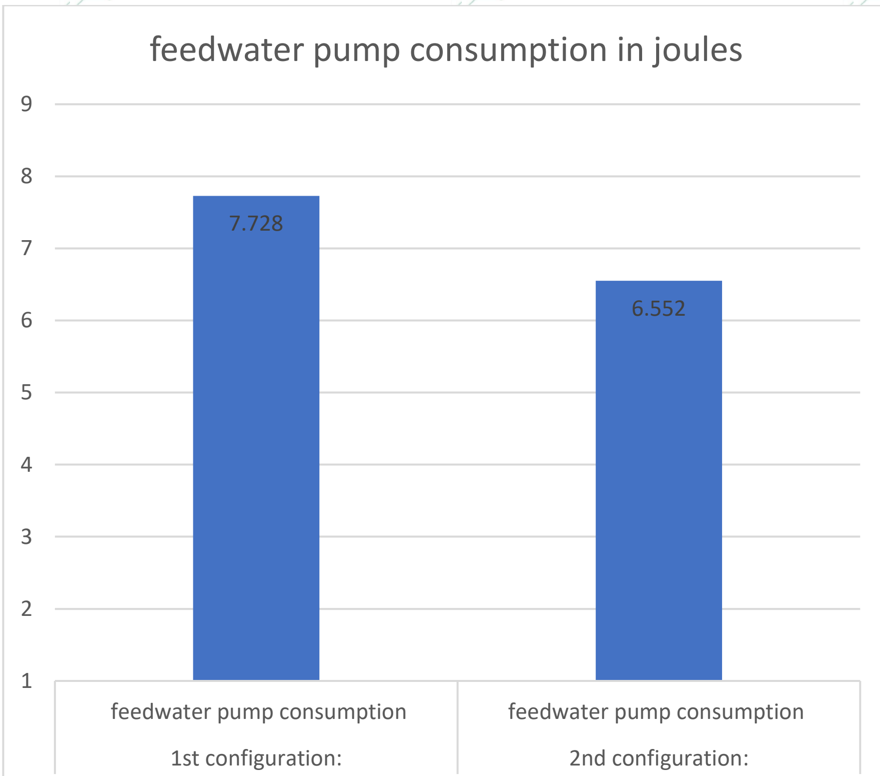


Fig. (48): a comparison between the 1st (non-adjusted) and the 2nd (adjusted) systems in feedwater pump consumption.

4- There is a negative result of condensing less condensed water in the 2nd system (regulating feedwater pump) comparing it to the 1st system (with feedwater pump). Resulting in a 10 ml of condensed water produced in the modified system and a 15 ml of condensed water in the unmodified system.

Recommendation

Since Every project has its limitations so some recommendations are needed for developments in future for both prototype and real project:

1) Firstly, to cover the copper tube by transparent vacuumed tube to prevent any heat loss by convection.
2) Secondly, utilizing a high reflecting material to collect the thermal energy from sun light without any absorption for the energy.
3) Thirdly, harness a high heat capacity transfer fluid as molten salt to maintain evaporating more amount of water in less time.
4) Fourthly, applying an Alternated current (AC) motor to increase the transmission power without wastages.
5) Fifthly, development of sensors is fundamental for instance applying high range temperature sensor and wide range Wi-Fi module.
6) Sixthly, Dryers are recommended to be presence in the boiler to filter steam from water droplets.
7) Finally, thermal storage system can be added to work the project day and night. location is important for building a real project so the consideration should be in normal beam radiation and plant location respect to the water source.
8) All the ideas above are recommended to be applied in Kuraymat Concentrated Solar Cell in Egypt same as our solution that will show perfect effectiveness of 15.21% same as what we found on Andasol 3 in Spain.

Learning outcomes

Subject:	Description:	Advantage:
Mathematics (MA.3.01)	Differentiation	We studied the implicit differentiation, parametric differentiation, related time rates (for the theoretical concepts of the project), and higher derivative for understanding the heat energy laws.
Mathematics (MA.1.07)	Quadratic Functions	Concepts of parabolic functions helped us to understand and confirm the equation of the parabolic mirror in the prototype.
Mechanics (ME.3.02)	Analyzation for systems in General Equilibrium	We studied the general equilibrium and torque, that aided us in putting the stepper motor to detect the sunlight and find the equilibrium position for the parabola.
Mechanics (ME.2.05)	Power	Concepts and laws of power helped us to conduct an equation to calculate the energy.
Physics (PH.1.10)	Thermodynamics	We studied the main concepts of the thermal energy transfer for the theoretical concepts of our project. To understand how heat loss happens by convection and conduction.
Physics (PH.2.04)	Analyzing DC circuits	Concepts of this outcome helps us to calculate the power in wattage from the system.
Physics (PH.3.03)	Reflection of light	We understood the laws of reflection in various mirrors types and determining the focal point with its laws. Also, assisted in understanding the concentration ratio laws.
Physics (PH.3.04)	Communication	Determination of sensors and understanding their mechanisms were based on this learning outcome.
Physics (PH.3.05)	Communication	We understood the choosing of the transmission of data for the RemoteXY application from the Wi-Fi module by Arduino.

Chemistry (CH.3.01)	Scientific reports and analyze for methodology	We studied scientific methodology, precision, accuracy, uncertainty, qualitative and quantitative analysis in chemistry, as we used them in our project. We used accuracy and precision in our calculation on electric consumption, optical geometry, and TDS ratio. Quantitative analysis as it is one of our project characteristics.
Chemistry (CH.3.03)	Connection of microscopic level with the macroscopic level	We learnt how the steam can rotate the DC generator from Kinetic Molecular Theory and Particle collisions of gases.
English	Academic writing	We studied different types of essays like comparative essay and cause and effect essay, as well as, descriptive essay, which we got benefit from them in out writing in the portfolio and the poster. Also, the academic writing lessons as it we used it, the academic writing, in our writings

APA citation

Grand challenges:

Increase the use of alternative energies:

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For the RemoteXY application & temperature sensor:

https://github.com/RemoteXY/RemoteXY-Arduino-library

https://github.com/YuriiSalimov/NTC_Thermistor

For reflective material information:

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