Gentian blossom

Cap 209

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Chapter 1

I. Present and Justify a Problem and Solution Requirements

Introduction

Egypt has the goal of achieving sustainable development, where it has all the required natural and artificial resources; however, it faces some major problems that are called “Grand Challenges”. There are about eleven Grand Challenges, where five relevant grand challenges will be discussed only. Those challenges hinder the development of Egypt. They are arid areas, overpopulation, pollution, lack of water resources, and urban congestion. Also, they affect Egypt in many aspects such as the economy, environment, and social aspects. That’s why this project was developed to help Egypt achieve sustainable development, overcoming those challenges.

1.1: Egypt's grand challenge

1.1.1: Increase industrial base in Egypt

The industry is the base of the development of any country: The industry contributes to the production of food, clothes, and many other contributions. The industrial base in many countries, especially Egypt, suffers from significant problems; for example, the process of industrialization in Egypt depends on utilizing technology, natural resources, and labor, but Egypt is a country with very limited natural resources. Most manufacturing technologies are imported and expensive as well.

The industry is not fully utilized in Egypt; in **2001**, manufacturing output represented nearly 20% of the Gross Domestic Product (GDP) employing about only 20% of the active labor power, resulting in many social and economic issues

From 2010 to 2020, the distribution of the Gross domestic product (GDP) across economic sectors has increased, where the industry sector, in **2020**, represents **32.01%** of the share of the GDP **as shown in figure (1)**. This is not the best percentage for the industry, and it has to be developed to increase the effectiveness of the industry in Egypt. Moreover, agriculture and different services represent respectively **11.57%** and **51.76%** of the share of 2020's GDP.

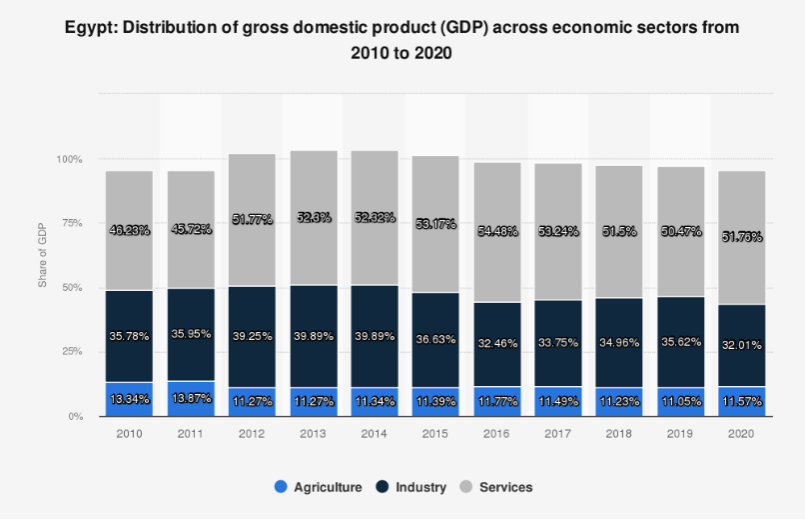

Figure 1 Distribution of GDP of different sectors 2010-2020

The geographical distribution of industrial enterprises varies from one region to another. While **41%** of the industrial production is concentrated in Greater Cairo, Delta has **17%**, Alexandria has **16.8%**, and Canal Zone has **14.2%** of the industrial production. This means that **89%** of the industrial production is located in Cairo and

the Northern regions, while the other **11%** is in Upper Egypt. **Figure 2** shows the Geographic Distribution of the Registered industrial enterprises. It is well noticed that the highest percentage of labor in the industry lies in Greater Cairo, which makes it reasonable why Egypt's industry is concentrated in Cairo.

Region	Governorate	No. of enterprises	Production Value	Investments	Labor	Wages
Greater Cairo	Cairo	8514	34802	29013	359907	1664
	Giza	2383	22776	18553	153055	787
	Kalubeya	1895	9764	9573	121623	698
Delta	Menoufeya	491	6819	5410	32088	177
	Gharbeya	1487	4792	3451	92202	470
	Kafr El Sheikh	310	2216	490	5917	91
	Damietta	902	9052	2280	13840	49
	Dekahleya	1305	4978	4276	42260	209
Northern Upper Egypt	Minya	263	502	368	8193	27
	Beni Souef	109	1247	1114	5003	27
	Fayoum	128	532	379	6192	23
Central Upper Egypt	Assiut	526	1464	934	13531	65
	New Valley	6	13	7	704	2
Southern Upper Egypt	Red Sea	51	86	330	5026	50
	Sohag	268	937	972	10543	71
	Quena	151	2192	4357	21147	290
	Aswan	151	1214	3310	15357	125
Canal Zone	Port Said	287	5128	1966	18455	80
	Suez	89	3591	6634	21503	225
	Esmaeleya	131	1473	1607	13065	90
	Northern Sinai	46	339	1603	1469	15
	Southern Sinai	6	144	1178	2682	31
	Sharkeya	3075	22667	19633	153600	1225
Alexandria Zone	Alexandria	2207	23048	22379	209164	2190
	Matrouh	10	64	32	502	4
	Beheira	471	4531	4161	56518	182

Figure 2 The geographic distribution of industrial enterprises

Another problem of industry in Egypt is the waste produced by factories. It is estimated that **60 million tons** of solid waste are generated every year in Egypt, and about **6.2 million tons** of these solid wastes result from the Hazardous and the Non-Hazardous industrial wastes **as shown in figure (3)**.

Types of Waste	Generation (Million ton /year)
Municipal Waste from Major Cities	9.3
Municipal Waste from Rural areas	5.6
Agricultural Wastes	3.5
Hospital Wastes (Hazardous and Non-hazardous)	0.13
Construction Wastes	4.0
Non-Hazardous Industrial Wastes	5.9
Hazardous Industrial Wastes	0.3
Dredged sludges from canals	29.4
Sludges from Municipal Wastewater treatment	2.0

Figure 3 Generated wastes per year in Egypt.

The industry is one of the main factors that make any country thrive. The industry in Egypt can be thrived by finding sustainable and renewable sources of energy to increase its effectiveness and develop it. Moreover, developing recycling in Egypt will effectively develop the industry in Egypt and enhance it. Furthermore, getting rid of industrial wastes will decrease pollution in Egypt, and this will leave a very positive effect on public health in Egypt. Solving the industrial base problems in Egypt will solve the other challenges that face the Egyptian community.

Causes

Depletion of energy resources.

Egypt's industrial field depends on **32.70%** of the total energy of Egypt which represents about a third of the total energy **as shown in figure (4)**. Egypt depends mainly on Non-renewable resources of energy, and as time passes, it decreases; therefore, the efficiency of industrial fields decreases with it.

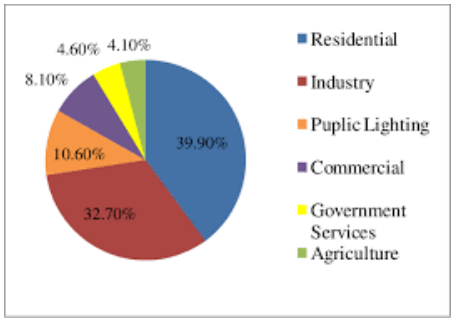

Figure 4 Energy Distribution in Egypt

The lack of modern technology used in factories.

The main industries in Egypt are food processing, tourism, chemicals, pharmaceuticals, construction, cement, metals, light manufacturing, and textiles. All of these Industries need modern technology and expert engineers. The problem is that Egypt sakes expensive Foreign technology, and it costs a lot to import.

Deficiencieses in the number of experienced labor

Egypt has a High population. Nevertheless, the number of factories is limited, and most of them have low-quality salaries, bad management, and No technological experience. Consequently, the government looks for Foreign Experts in the industry field who need a high salary, affecting the economic income.

Impacts

Low economic income.

The efficiency of the industrial sector has a large impact on the economy of the country, and the efficiency is low because of the lack of modern technologies used in factories. when the efficiency of the industrial field is low, the country’s economic income subsequently becomes low.

Emigration of the labors

Because of the economic problems in Egypt, laborers have a low-income salary and lack social insurance. Thus, most of the skilled laborers emigrate to other countries where abundant welfare salaries exist in most factories and industries.

1.1.2: Recycle and Retain Garbage for Recycling

The solid waste problem continues to be a major problem for Egypt. Solid wastes are defined as materials of no value or use in their present state and are disposed of the at source although they may be reused or recycled under other conditions. It is estimated that **60 million tons** of solid waste are generated every year in Egypt from the breakdown of solid waste. Only a small fraction of this waste is recycled or properly processed. The waste collecting method in Egypt remains to be inefficient with continuous conflicts between the local waste collectors and the government. There are no plans whatsoever for upgrading the waste collecting and recycling system and only **30-60%** of the wastes are collected with **2,2236,500 cubic meters** of scattered wastes in Cairo only, **as shown in figure (5),** with the rest being scattered throughout towns. Also, with the rising population, the stress on the recycling problem continues to rise indefinitely with no plans in sight.

Governorates	Scatted Solid Wastes Amount (m^3)
Cairo	2,2236,500
Giza	447,050
Qualubyia	504,395
Gharbyia	1,235,000
Aswan	386,350
Red Sea	107,022
Kafr El Sheik	225,500
Qena	251,700

Figure 5 The volume of scattered solid wastes.

The waste collecting method in Egypt consists mainly of door-to-door collection. About **9,000 to 10,000 tons** of garbage are managed by local waste collectors. Problems became to arise when the Egyptian government signed a contract with two Spanish companies to collect **8,000 tons** per day for **115 L.E. million per year**. Many of the waste collectors' licenses were provoked and many conflicts arose between the waste collectors and the government. The companies were obliged to recycle only **20 percent** of the waste which is much less than the waste collectors.

The factories generally dump their wastes in canals or dump sites. There are no waste treatment and disposal facilities for industrial waste. So, it is treated with municipal waste. This leads to the mixing of industrial waste with municipal waste,

leading to a decrease in the selling value and an increase in the difficulty to recycle the selling value would be **50 to 80 EGP** after a production value of **200EGP**. Also, only a minor fraction of factories use recycled materials.

The waste collectors collect the solid waste, and the solid waste is then managed in different ways. Waste collectors separate the waste and sell the recyclables to middlemen. The organic waste which is **56%** of the total waste **as shown in figure (6)** is eaten by the pigs and the rest is burned in local dumpsites. The poor neighborhoods dump their waste on streets and canals. This poor waste management system results in air and water pollution leading to a decline in public health and all types of diseases. The infant mortality among waste collector families rose to **40 percent**. Surprisingly enough this system also had many hygienic problems. it was very effective in the recycling sector. About **80 percent** of the collected garbage was recycled by selling to middlemen or recycled in local workshops like aluminum and plastic which were changed to silverware and dishes. But, most of the recycling was done by the informal sector of waste collectors with no concrete plans from the government.

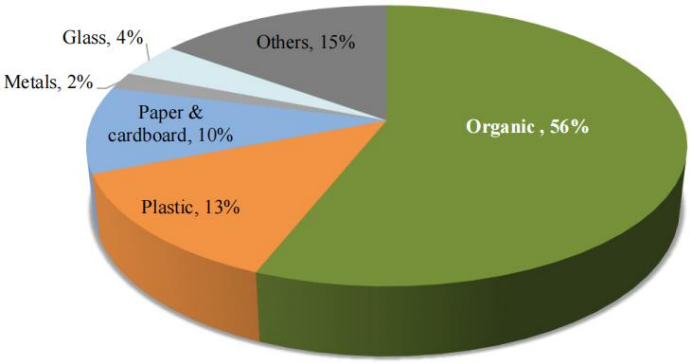

Figure 6 The distribution of total waste by type.

In the industrial context, factories play a major part in the problem of recycling. Factories generally use single-use materials and not waste material. Of the total amount of solid waste, only **12%** is recycled. This only increases the amount of garbage in contrast to using waste materials which reduces it. Also, without recycling pollution becomes uncontrollable. Without regulations on separating wastes recycling projects will be out of reach. With factories using fossil fuels and burning single-use materials.

Causes:

Conflicts between the government and the private sector:

The regulations posed by the government and inviting foreign companies to manage and recycle the wastes lead to conflicts arising in the waste collectors community leading to a decrease in the total recycled quota.

- **Lack of garbage separating regulations:**

Industrial waste is processed as municipal waste. This mixing leads to an increase in heavy metals. It also leads to inconveniences in recycling and a decrease in the economic value of waste.

- **Inadequate infrastructure:**

There are no factories to separate and use industrial wastes. There are also not enough funds to start recycling projects.

Impacts:

Increasing air pollution:

The unrecycled materials are burned in landfills near neighborhoods. This leads to an increase in air pollution and decreases in public health, especially in poor communities.

Decreasing value of waste material:

Without recycling and proper separation, the value of the waste material in the market decreases.

Decreasing public health:

Without recycling the waste materials become scattered in the streets. This leads to an increase in the number of diseases and a decrease in public health.

Climate change:

The pollution resulting from the burning of waste leads to the emission of greenhouse gases. These gases result in an increase in the ozone hole and an increase in climate change.

1.1.3: Improve the use of Alternative Energies

Manufacturing the various products used in our daily life, operating machines, and transportation are among the most prominent daily activities that require energy. Energy has two types. The first one is non-renewable sources, which are energy resources that decrease in quantity due to daily life usage, including petroleum, natural gas, and oil. Those types primarily pollute the environment. On the other hand, the other type of energy is renewable energy. This type of energy is an alternative type of energy that does not end or vanish, providing an extreme advantage over non-renewable energy in sustainability and being eco-friendly.

Despite their extreme superiority over non-renewable sources of energy, renewable sources of energy are less used in everyday life as they provide 15-20% of the total energy in the world, and Egypt would not be an exception. Egypt represents the most significant non-OPEC (the organization of petroleum exporting country) oil producer African country and occupies second place among the gas-producing countries in Africa. Due to that outstanding place, 95% of Egypt's population has access to electricity. The large percentage of the population, along with the increase in the per-capita electricity production from 1128.721 kWh in 2003 to 1657.769 kWh in 2014 as shown in **figure number 7**, led to the huge electricity demand in Egypt. That demand could not be satisfied by the non-renewable sources of energy alone, encouraging alternative energy use.

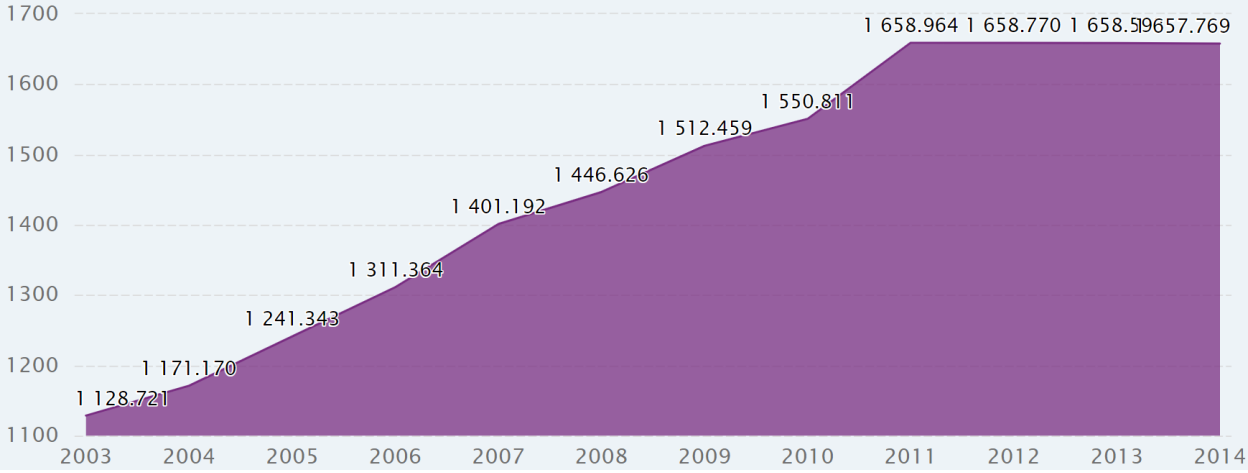

Figure 7 Increase in the per capita energy consumption from 2003 - 2014

In addition to being insufficient, non-renewable sources of energy cause pollution, which, in turn, leads to various health problems. To illustrate better, air pollution, due to the combustion of biomass and fossil fuels, releases a lot of

pollutants into the environment such as CO_2, SO_2, NO_2, and NO_3. Those pollutants cause diseases like cardiovascular and respiratory diseases, chronic bronchitis, and increased morbidity. Notably, the effect of air pollution doesn't affect humans only. That was shown by a study done in the **Shoubra Elkheima** area in Egypt, where some plants in an industrial area expressed a decrease in chlorophyll by **60%.** The effect of non-renewable sources of energy isn't limited to the air but also extends, affecting water. Water is used in many processes that are associated with fosfueluels extraction. For example, water is involved in drilling and fracturing while exploring oil and gas, where water gets polluted during those processes. That implies the necessity of using more eco-friendly energy sources.

There are many sources of renewable energy, and the most important ones are waves, geothermal sources, solar energy, and wind energy. Due to its vast variety of resources, Egypt has a high potential for those types of energy. To better illustrate, the area at the west of the Gulf of Suez (from the south of Sokhna to Hurghada) has promising wind energy resources as the speed of wind there, exceeds 10m/s which directly translates to **20,000 MW/year** of energy. Regarding solar energy, Egypt is blessed with having high-intensity direct solar radiation of **2000–3200 kWh/m^2/year** for about 9-11 hours through most of the year. That is equal to generating **74,000 TWh/year**. Those statistics show that Egypt has great potential for generating renewable sources of energy with promising results. It is noteworthy that a research project in the East Owinat area showed that a PV battery system for water pumping is both efficient and cheaper than using a normal diesel system. That's mainly because systems that depend on solar energy have extremely low lifetime costs due to their durability, so a PV system depends on the cost of buying a PV cell only. Despite being sustainable, renewable sources of energy are still widely used in Egypt as they, including hydroelectric energy, supply 8.6% of Egypt's energy sources during the year 2019.

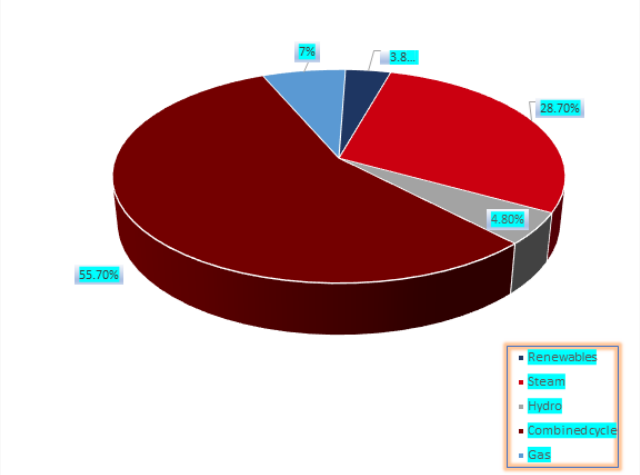

Figure 8 The distribution of Energy sources by percentage in 2019

Causes:

Cost and need to improve infrastructure.

Although renewable sources of energy do not require as much maintenance as non-renewable sources of energy, the cost of first-time installation makes it hard for a customer to buy equipment such as solar panels. Moreover, when investigating the existing power generators, it becomes more convenient to develop an existing power plant instead of building a new wind power or solar power plant from scratch. According to the International Renewable Energy Agency, the prices of various renewable energy sources decreased during the previous ten years. Taking the period between **2018** and **2019** as an example, the price of concentrating solar power, offshore wind, onshore wind, and solar photovoltaic declined **by 1.2%, 8.8%, 9.2%,** and **13.1%** respectively. That decline encourages depending more on alternative energy sources.

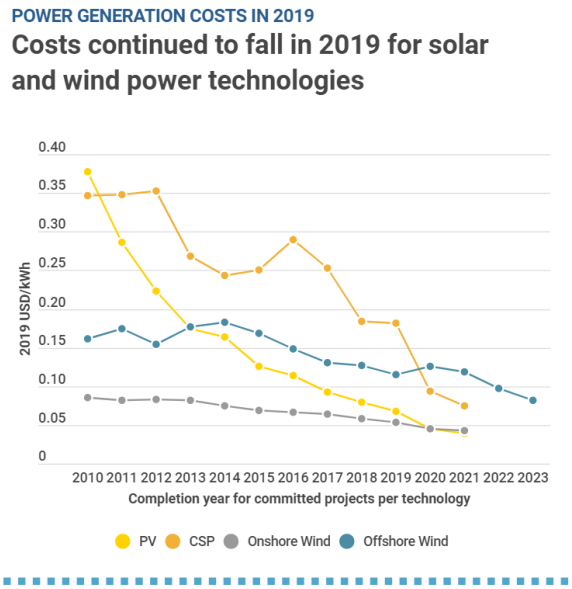

Figure 9 shows the declination of costs of PV cells.

Geographical and environmental limitations

Some geographic limitations hinder the extreme use of renewable sources of energy. To give a better illustration, solar energy is limited due to the variable number of hours of sunrise across the world and the existence of days without sunlight (during the rain periods). Furthermore, wind energy requires large areas of land, and sufficient amounts of wind do not exist all over the world. Hydroelectric dams could be used only at specific locations on the river's shore. Those limitations in producing energy imply the necessity of storing energy during periods of high energy production to be used during its declination; however, storing energy is not as easy as it appears. High-capacity batteries, which are necessary for storing enough energy, are expensive. Recent projects deliver hope for better energy production.

Impacts:

Increasing pollution.

As previously mentioned, the emissions from non-renewable sources of energy cause air pollution along with water pollution which, in turn, cause many diseases for the various systems and organs in the human body. On the other hand, renewable sources of energy do not have those health consequences. That's why the decrease in the use of renewable energy sources deteriorates the health status of the residents of Egypt.

Limited job opportunities.

Since renewable energy sources compose a completely new field, a lot of jobs appear. These jobs include field operations manager, geospatial analyst, and surveying assistant superintendent. The unemployment rate decreases due to the availability of jobs. That's why when talking about non-renewable sources, it becomes evident that those resources limit the number of available jobs.

1.1.4: Reduce Pollution

Expanded communities are encountering a fatal threat that imposes their continuous development; depletes the fundamental economic resources; and affects health and social conditions badly. This arduous threat which is being referred to as *pollution* is a seemingly endless problem that promotes further serious issues.

Pollution is a widespread phenomenon that is generated through most urban, industrial, and even natural activities, such as volcanic and nuclear emissions. Having numerous sources and causes, pollution has a variety of forms that could exist in the surrounding environment. Air and water pollution are the predominant forms of pollution as, besides their unlimited causes, both can lead to many challenges.

Air pollution is the existence of pollutants within the atmosphere. Those pollutants can be toxic gases (Sulfur dioxide (SO_2) for example), pesticides, or debris and fractional solids. Similarly, Water pollution has very close pollutants to that of air pollution, except that they all exist in a liquid form.

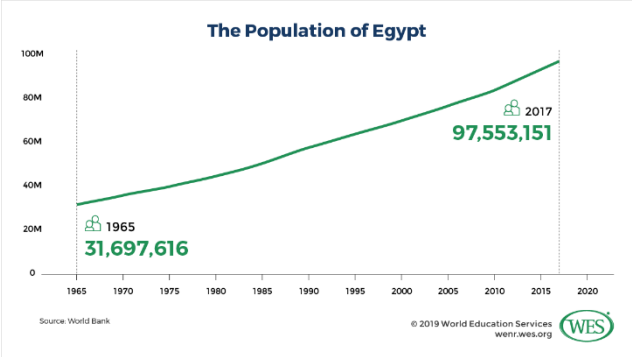

Figure 10 The increase in Egypt's population from 1965 to 2017.

Developing countries, including Egypt, usually suffer from high levels of contamination. But, unlike other developing countries, Egypt faces many hurdles that make overcoming pollution a daunting task. The population growth, for example, has increased substantially from 1965 to 2017, as **illustrated in figure 10**. This jump was engaged with increasing rates of air pollution in Egypt where the concentrations of different greenhouse gases were increased **as shown in figure 11**.

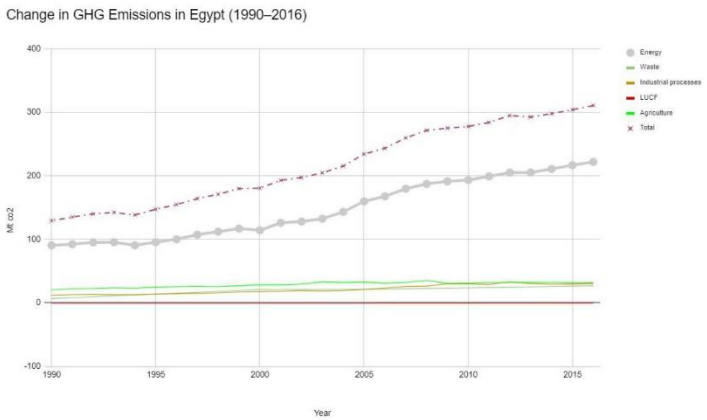

Figure 11 The increase in concentrations of different greenhouse gases by time.

Causes:

Burning of fossil fuels

Fossil Fuels burning inside manufactories and vehicles contribute excessively to air pollution. Coal and other petroleum derivatives emit greenhouse gases during combustion which cause an immense amount of contamination. Sulfur dioxide, Carbon monoxide, and Nitrogen oxide of which are present during the combustion process; all of these gases have bad health effects on living organisms.

Agricultural activities and intensive use of pesticides

Pesticides sometimes lake into groundwater. Thus, it would rise polluted water into the plants' roots. Additionally, Ammonia and other chemical fertilizers whenever they are mixed with groundwater, they contaminate it. Egypt's villages and rural areas in which residents depend on groundwater for daily activities suffer significantly.

Modest technologies:

Although Egypt is continually adopting new technologies and techniques, many places use subtle techniques of medicine thatoften lead to emerging more health issues.

Impacts:

Declination of average public health:

Pollution possesses many significant impacts on the environment, but the most striking, also the most obvious, the impact is the deterioration of public health. In Egypt, most of the prevailed diseases (mainly respiratory diseases) are emerging from polluted environments. **In the opposite figure 12**, the prevalence of Schistosomiasis (commonly known as Bilharzia) is increasing as the level of pollution increases.

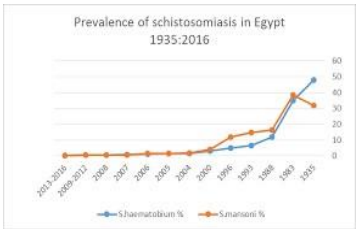

Figure 12 The increase in prevalence of schistosomiasis in

Environmental issues: Disrupting the Environmental balance, Pollution is the main threat to the surrounding environment. Pollution can be presented in an environment in several ways: polluted rivers can lead to some Aquamarines extinction; land pollution can upset the suitable habitats of animals, and air pollution would result in many atmospheric problems.

Climate Change: GHG (greenhouse gases) are the main outcomes of air pollution. After some intensive chemical reactions between the GHG, they release Ozone gas where a high concentration of it causes a depletion in the stratosphere, making a phenomenon which is known as an Ozone hole. Ozone holes can lead to other harmful issues such as long-term climatic change: the variations in the temperature within a particular time interval.

Economic growth limitation: Pollution put a huge burden on the economic growth of developing countries like Egypt. Crop yield loss, deficiencies in the productivity of industrialized activities, and the accumulation of Labor related problems, high health expenditure, for instance, all are direct consequences of air pollution, as **illustrated in figure (13)**. Economic restrictions could result in a big decline in the market value of the currency and other serious issues associated with trading and development.

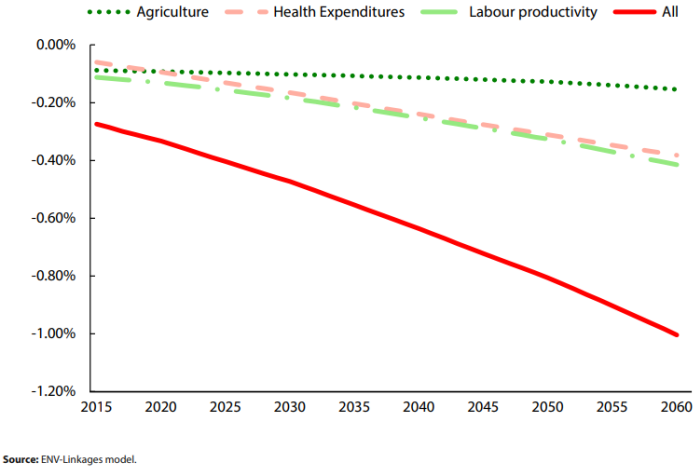

Figure 13 Effect of Pollution on Agriculture, Health, and Labor.

1.2: Problem to be solved

"Improving traditional industries by using green energy/waste material coupled with a feedback mechanism"

The industry is the backbone of civilized life in any nation. Egypt is thriving for progress and renovation. So, the industry must be at the heart of any plans in Egypt. In the year **2019**, industry represented **27%** of the total employment in Egypt**.** Industrial development in Egypt has two main streams. The first is establishing new technological competitive industries. The second one is the expansion and renovation of existing industries to increase their productivity which is an example of coupling feedback mechanisms with existing traditional industries to improve them.

The manufacturing sector is one of the most important sectors of the economy of Egypt. Manufacturing products represented around **20%** of the GDP (Gross Domestic Product). Only **seven** industries represent more than **80%** of the manufacturing sector in Egypt. The three largest industries are textiles, food, and beverages. Most industrial establishments are naturally related to them. The industrial establishments in Egypt are distributed into **21541** micro units, **1264** small-size units, **774** medium-size units, and **1290** large-size industries totaling **24869** establishments **as shown in figure (14)**.

Registered Establishments at GOFI	Volume of Investments LE				Total
	Less 2 mil.	2-5 mil.	5-10 mil.	More 10 mil.	
1- Spinning, Weaving and Garments	3752	230	148	215	4345
2- Leather	1192	28	16	13	1249
3- Food Industries	3983	310	197	346	4836
4- Basic Chemicals and their products	1800	228	119	189	2336
5- Engineering Industries	4644	217	133	272	5266
6- Basic Metal Industries	381	28	23	47	479
7- Wood and its products	2411	28	17	21	2477
8- Paper and its products & printing and publishing	1318	70	34	65	1487
9- Building materials and Ceramics	1619	70	40	85	1814
10- Other Process Industries	399	52	41	26	518
11- Poultry and Fishery	12	-	-	-	12
12- Extraction of Iron materials	-	-	-	1	1
13- Mines and Quarries	30	3	6	10	49
Total	**21541**	**1264**	**774**	**1290**	**24869**

Figure 14 shows the investments in different types of industries

The main obstacles to further improvements in Egypt are the fluctuations in the raw materials and the non-utilization of cleaner production methods. There are also other factors such as the lack of professional labor, the high price of importing pollution regulation devices, and the lack of limited technical knowledge. Most of the factories in Egypt use fossil fuels which cause unimaginable damage to the environment. The CO_2 emissions from Egypt were around **169** million tons in **2007** making it the **10th** largest greenhouse gas emitter in the world. The industrial sector consumes around 32% of the total energy. The total renewable energy in Egypt

amounts only to around 5%. Nearly after the obvious impact of climate change and the unpredicted environmental issues, It became necessary to make a balance between the environment and the development of the industry. The new industrial strategy has many regulations. The most prominent of them is that new technologies must use cleaner energy sources and that production processes must use technology to reduce the use of raw materials. which are aspects that can be met by using green energy as energy resources instead of fossil fuels.

In addition to green energy implementation in the industry, a perfect systematic mechanism has been developed to enhance industrialization's efficacy by minimizing the amount of raw material used, this mechanism is known as the feedback control system. The feedback control system also decreases the time consumed to operate the whole process of the manufactory. Finally, the feedback control system contributes to both the industrial base and the environment in a very positive way.

Positive consequences (if solved):

Creating jobs for people:

Unemployment in Egypt in the year **2020** was around **10.45%.** Improving traditional industries by using feedback mechanisms can create more job opportunities. These jobs can help solve the problem of unemployment in Egypt.

Achieving economic prosperity:

By improving traditional industries in Egypt and using waste material or green energy, economic prosperity can be achieved. This can reduce the number of wasted materials and provide more energy resources that can improve the economy.

Decreasing pollution:

By Improving traditional manufacturing methods and using green energy, pollution can be talked. The amount of renewable energy used will increase, so the different pollution levels will decrease substantially.

Solving the problem of raw materials:

The decrease in available raw materials stands in the way of future industrial development plans. By using waste materials in industry instead of raw materials the industrialization of Egypt will become much easier.

Negative consequences (if not solved):

Reduction in the export rate:

Without improving traditional industries, the problems will stay as they were. This will decrease the export rate of Egypt which is around **36.7** billion dollars.

Food insecurity:

As mentioned earlier food related productions are among the top productions with beverages. Without the improvement of traditional food industries, food insecurity may arise shortly because of limited resources.

Increasing the problem of waste management in Egypt:

There are already many wastes scattered in the Egyptian streets. All these wastes lead to a decrease in public health. By using waste materials instead of raw materials, the waste problem can be reduced.

Energy problems:

The continuous demand for power supply in Egypt is far more than the supply. Continuing to depend on fossil fuels will lead to energy problems a couple of decades from now. This will lead to depletion of nonrenewable energy resource which will result in huge energy crisis.

1.3: Research

1.3.1: Topics Related to the Problem

Burning fossil fuels:

Burning fossil fuels is one of the most dangerous and rigorous problems that are related to the problems of the industry in Egypt. Moreover, this problem is one of the causes of the weak industrial base in Egypt and consequently the low-quality products from the industry. The reason for this is that fossil fuels are non-renewable energy and leave lots of waste after the manufacturing of any products in the factories; therefore, fossil fuels are one of the reasons for the pollution in Egypt. Unfortunately, Egypt depends mainly on fossil fuels as the main source of energy. **As shown in figure (15)**, it is clear that crude oil is the most important source of energy, representing **53.11%** of the total resources. Electricity from the High Dam in Aswan accounts for a share of about **5%** and natural gas accounts for **41.89%** of the total resources. Notably, renewable sources of energy represent small percentages of the total production of energy, which emphasizes that new energy must be used instead of fossil fuels.

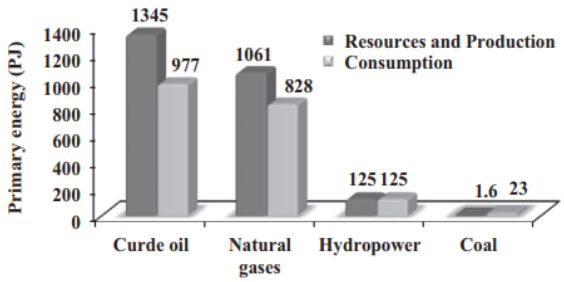

Figure 15 shows the resources and consumption of different energy resources.

Low-quality products

The weak industrial base in Egypt results in low-quality products. The low-quality products impact negatively on the trading between the countries and hence affect the economy of Egypt. Trading and commerce are the main factors that can make Egypt thrive between the other countries. Therefore, Egypt must increase its trading among the other countries in the world, and consequently, it will enhance the economical status of Egypt.

Solid wastes

the problem of the solid wastes resulting from the factories is one of the main factors that affect the industrial base in Egypt, and as a result, this problem causes pollution in water, as the factories get rid of the solid wastes by throwing them in the freshwater, and hence affecting the public health among the population as the water, after throwing the wastes, contains microbes and bacteria that lead to many diseases, such as bilharzia, and can result in the death of some people who have weak immune systems. Nonetheless, the amount of scatted solid waste in Egypt is significantly high, especially in Cairo, where the scatted solid wastes amount in Cairo is **2,2236,500 cubic meter**s as **shown in figure 16**. This is a very high number of solid wastes, and the government has to eradicate this problem by making recycling systems that benefit from these solid wastes.

Governorates	Scatted Solid Wastes Amount (m^3)
Cairo	2,2236,500
Giza	447,050
Qualubyia	504,395
Gharbyia	1,235,000
Aswan	386,350
Red Sea	107,022
Kafr El Sheik	225,500
Qena	251,700

Figure 16 Solid wastes in cubic meter by governorate.

Underutilizing usage of green energy

Despite all the efforts that the Egyptian government made in the promotion of the usage of renewable energy, green energy specifically, the green energy in Egypt is still not fully utilized. **As shown in figure 17**, only **1%** of solar and wind energy available in Egypt is used properly, and only **2%** of the hydropower is available in Egypt. Therefore, there must be a solution to this problem, since it will be beneficial in the field of industry. Utilizing green energy resources of energy will decrease the consumption of fossil fuels. Furthermore, this will reduce the solid waste arising from the factories' disposal.

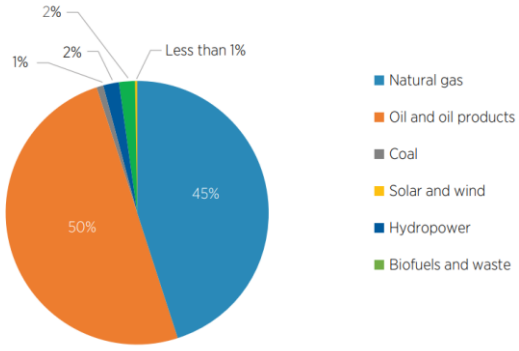

Figure 17 Usage of different energy sources in Egypt.

1.3.2: Topics Related to the Solution

Feedback Control System:

The solution involves using a feedback control system, so it is mandatory to investigate the meaning of a control system. A system is a collection of physical components, forming a complete unit. Calling a system “a control system” requires making the system’s purpose to give orders for organizing itself or another system. Each control system is characterized by receiving input and sending a certain response or output. An input is a motive or a signal from a certain energy source to obtain a certain desired response or output. The output is a certain response obtained from the system, where it may be an exact copy of the desired output.

Control systems consist of two types according to their dependence on the obtained output, where those types are open-loop control systems and closed-loop (feedback) control systems. Open-loop control systems continue producing the same output regardless of their output. A Potential example is a sprinkler that keeps watering plants even if they got watered completely. On the other hand, a feedback control mechanism produces an output that varies according to the errors which occur in the preceding output. An illustrative example is an oven with sensors. The sensors allow the oven to increase the temperature as long as a certain temperature, defined previously by the user, needs to be reached. Once the temperature is reached, the oven stops working till the temperature of the oven goes below the required temperature, and the cycle goes on.

The feedback control mechanism consists of eight main parts **as shown in figure 18**. The system is the process that is controlled by the feedback control system, where it receives input to produce the desired output. A sensor is required to measure the difference between the actual output and the desired output (usually called a reference input). A controller changes the input of the system or the process according to the error in the output which was measured by the sensor. The science which is responsible for designing and implementing a control system is a branch of engineering called control engineering.

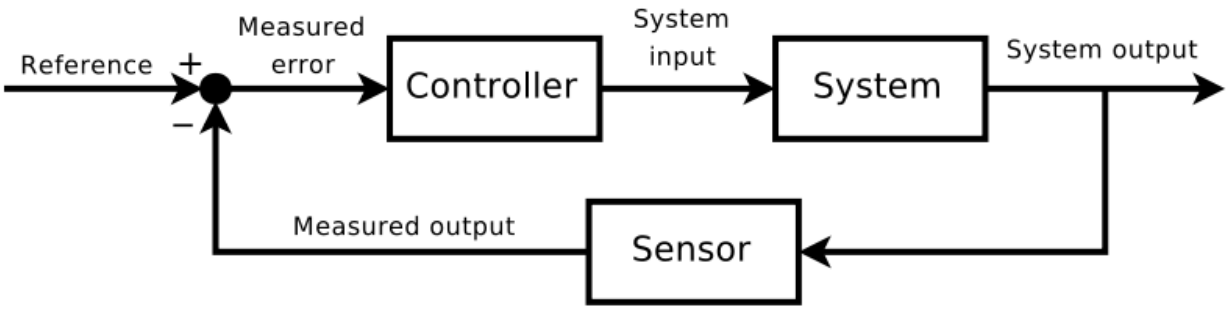

Figure 18 Block Diagram of a feedback control system

Arduino & Sensors:

During the discussion of a feedback control mechanism, it was declared that the controller ought to do some changes to the input of the system according to the measured output. To make the system automated, it is mandatory to use a sort of computer as a controller. That computer must be able to read the input, analyze it, and produce the required output. Arduino is the needed computer, where Arduino boards can read inputs and produce outputs. Arduino boards have the positive advantage of being inexpensive as it does not cost as much as other boards such as raspberry pi. Moreover, Arduino boards are available through most operating systems and their use is flexible with C++ programming language libraries and pieces of code. Those two factors make Arduino boards easy to learn and used, encouraging their use.

To make the Arduino able to read the input, sensors are required. Those sensors measure the physical quantities such as pressure, temperature, sound, humidity, and light which then are transmitted to the output pins of the Arduino board. Output pins connect the Arduino board to the other sensors to receive or send signals and provide them with the current. Those sensors have different functions and mechanisms according to their type. As an example, an ultrasonic sensor, which is **shown in figure 19**, is used to measure the distance between two objects. It depends on sending ultrasonic waves, waiting for them to reflect and return, and then recording the time that the waves took to move that distance. The taken time is helpful as it is known that the speed of light is **299 792 458** meters per second, and hence, it is easy to collect the distance by knowing the time taken by light only. Other types of sensors include light sensors (controls light), temperature sensors (records temperature around it), water level sensor (detects the depth of

water level), and others. Those sensors will help complete the controller stage in a feedback control system.

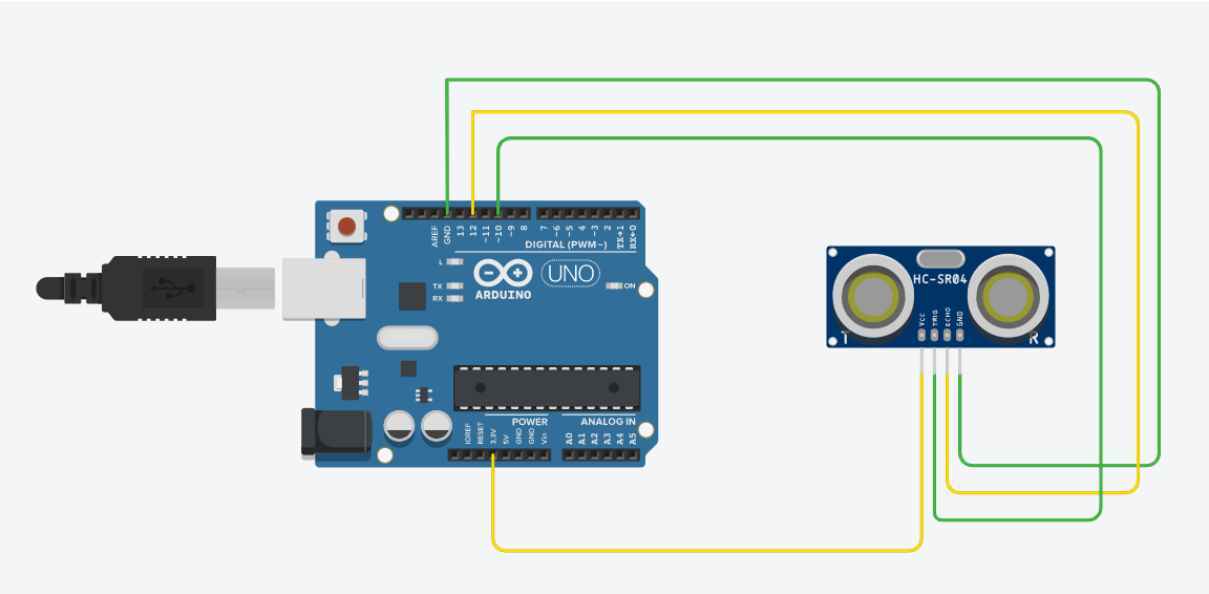

Figure 19 A diagram for arduino and ultrasonic sensor on TinkerCad platform.

Photovoltaic Effect:

To supply a home with solar energy, several solar panels are needed. Each panel consists of several cells, and each cell supplies an average of 0.5V to the battery. Each cell consists of at least three layers. The most important of them is a layer consisting of a semiconductor material, primarily silicon. The upper part is thin and called the n-layer, and it contains negative charges (electrons). The lower part is called the p-layer, and it contains holes, resembling positive charges. Holes at the p-layer try to reach the n-layer, forming a layer of positive charges; on the other hand, electrons at the n-layer try to reach the p-layer, forming a layer of negative charges. The layer of neutral atoms between the p-layer and n-layer is called the depletion layer, and after the photons – from the sun – hit the neutral atoms in the depletion layer, the neutral atoms split into positive charges, which join the p-junction atoms, and negative charges that reach the n-junction atoms. Notably, the motion of electrons causes the generation of current in the cell. The other two layers of the photovoltaic cell are conductors and connect the formed electricity with a circuit.

Actuators:

During the comprehensive discussion of the feedback control system, it was observed that a controller receives the amount of error between the given output and the desired output. After the controller does the required computations, it starts to change the input of the process with the purpose of reaching the desired output. To implement the required changes, the controller wants a thing that can affect the input of the process, and that thing is an actuator. **As shown in figure (20)**, actuators require a signal from the controller (Arduino boards) and input energy (primarily electric energy) to operate and affect the process' input both carefully and correctly.

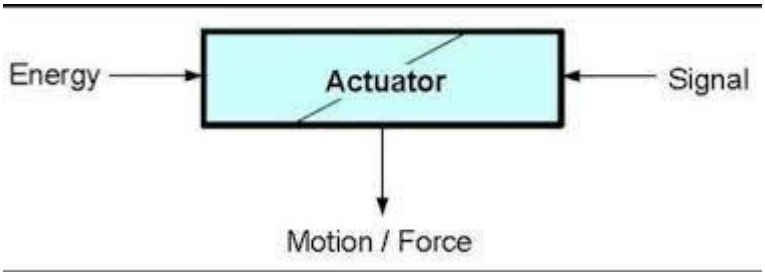

Figure 20 Schematic Diagram showing an actuator in action

There are many types of actuators, where the most famous types of them are electric actuators, pneumonic actuators, and hydraulic actuators. Hydraulic actuators depend on using a non-compressible liquid such as water and oil to control the state of the actuator. When water is supplied, the valve of the actuator opens, and the actuator begins to work. Pneumonic actuators are similar; however, hydraulic actuators are commonly used with the largest weights (above 10kN). Pneumatic actuators are characterized by having larger speeds. Both hydraulic and pneumonic actuators require valves and chambers to set them up; however, electric actuators require less configuration as they are directly connected to an electric source. Although their setup is easy, electric actuators have lower speeds and cannot handle heavy weights the same way.

1.4: Other Solutions Already Tried

1.4.1: Smart grids in solar energy production in the USA.

Demands on harvesting renewable energy sources were not significant as multiple challenges limited the production of such energy: The high economic interests required to operate the machinery and the inefficient production rate. But now because of the need to reduce the impact of non-renewable resources, harvesting renewable energy has become a substantial challenge. To overcome the inefficiency of renewable energy, a deliberate control system has been established. Smart grids are the main control processing system that aims to enhance the efficiency and capabilities of solar panels (also applied in wind turbines) in delivering reliable electricity in significant quantities. Smart grids are the digitalized system that is responsible for adjusting, monitoring, and analyzing the bidirectional flow of solar energy, from the panels to the consumer

Mechanism of working:

Smart grids are the electrical infrastructure that spread all over the USA to provide widespread energy transportation for homes **as shown in figure (21)**. To accomplish this, Smart grids constitute multiple sensors that work together to obtain feedback and control behavior through.

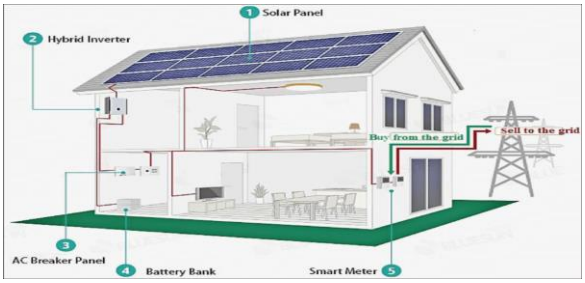

Figure 21 Diagram of the system from the power tower to the home.

Two-way dialogue communication between the consumer and the generator. Using smart meter thermostats, Smart grids calculate the total consumption of the establishment and send the estimated information to the source of energy. The main function of those grids is to measure, control, and compute the thermal variables by using different devices and sensors to ensure a reliable, stable feedback system. AC Transmission devices, automatic voltage regulators (AVRs), and an intelligent hybrid inverter, a device that helps in storing the excess solar energy in a battery bank. A hybrid inverter is **illustrated in figure (22)**. Finally, the feedback control system in Smart grids involves a multi-step process to ensure stability in the production and consumption

Figure 22 Illustration of the input & output currents to the Hybrid Inverter.

of energy. The whole feedback control system is demonstrated in the **opposite schematic diagram number (23)**.

Points of Strength:

- **Ease of use**:

Even though smart grid software is, by far, the most advanced energy control system, it is still very simple to use. All screens and features are intended to improve operator efficiency and usability. To reduce overall equipment cycle-time, smart grids take great care to keep software operations as fast as possible.

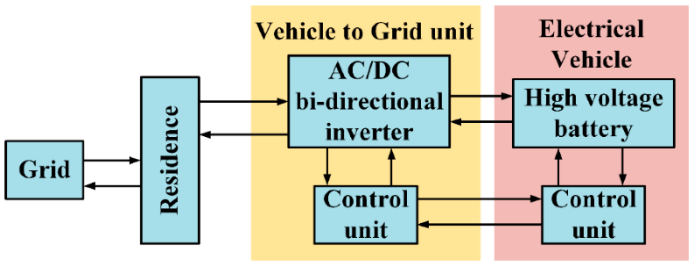

Figure 23 Block Diagram of the unit's feedback control system.

The Environmental impact:

The process of obtaining clean electricity from the solar panel's system was associated with some bad environmental issues like disrupting the land for the sake of establishing the solar panels or wind turbines, or polluting the water as it is used to cool down the energy towers and factories. Smart grids have demolished all of these environmental problems.

Improving system efficacy:

With the direct implementation of the feedback control system, the efficiency of the whole energy pathway has been improved substantially. The smart grids have provided the system with more secured pathways; minimized energy loss during transmission and consumption, and enhanced the quality of the electrical output supply.

Increasing the reliability:

Easing the monitoring and analysis of the energy system, Smart grids have allowed consumers to optimize their wanted performance and maintain a suitable production rate.

Points of weakness:

The intermittency and uncertainty of the energy supply:

In any renewable energy production, there is an inevitable challenge which is the intermittency of the sources: Even though sun and wind are the most efficient energy sources, their efficiency is not continuous, and it is affected by different circumstances like weather conditions; The same turns out to be true for Smart grids system.

Expensive:

Not all countries can afford such a complex technology. Furthermore, the cost of Smart grids is higher than that of other alternative renewable energy sources.

1.4.2: Smart Sulfur Recovery Unit (Claus's unit), China.

The sulfur recovery unit is the main desulfurizing process by which it recovers the fundamental Sulphur from the hydrocarbons, sour water, and hydrogen sulfide. Also, the Sulfur recovery unit participates in removing the environmental contamination from the streams of acid gases before being released back into the surrounding atmosphere. The Sulphur recovery unit, which is also known as the Claus reaction, is a multistep process that depends mainly on the feedback control system within its procedures. The importance of a control system is significant in the sulfur recovery unit as it is a very sensitive process that involves many thermal and chemical variables, and any sensitive error in these variables can promote further serious issues. One of Claus's units in china is presented in the **corresponding image (24)**.

Figure 24 A Sulphur recovery unit in China.

Mechanism of working

The Hydrogen sulfide **(H_2S)** and other acid gases are pumped into a furnace with a temperature estimated to be above **850°C**; this is where the Combustion reaction takes place. Inside the furnace, elemental sulfur precipitates. The whole stochiometric reaction that happens inside the furnace is demonstrated in **figure (25)**.

$$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O \quad \Delta H = -518\,\mathrm{kJ/mol}.$$

Figure 25 Equation Hydrogen sulfide and oxygen.

Afterward, the uncooled Sulphur and some of the acid gas go to the catalytic phase. There, they are combined with some chemical catalysts, such as activated alumni or titanium oxide. This reaction produces uncondensed **elemental Sulphur** (the required output of this process); This reaction is known as **the Claus reaction**, and

$$2H_2S + SO_2 \rightarrow 3S + 2H_2O \quad \Delta H = -41.8\,\mathrm{kJ/mol}$$

Figure 26 Equation of reaction of Hydrogen Sulfide and Sulfur Dioxide.

it is **shown in figure (26)**.

Sensors and software analyzers are implemented in the Sulfur recovery unit's refinery to guarantee a constant work loop with a faults detection mechanism. The

feedback control system in SRU has 3 major functions: measuring the entire unit's temperature regularly to prevent any burning accident; preventing the accumulation of condensed sulfur on a hot surface as it would enter an infinite aimless loop, and

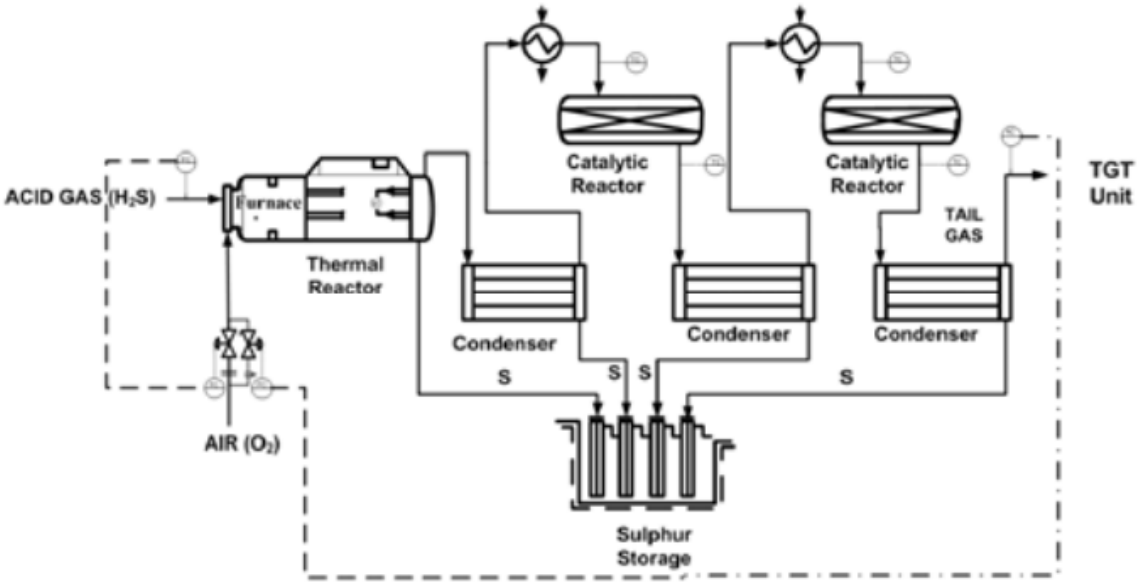

Figure 27 Block Diagram of feedback control system of sulfur recovery unit.

preventing sensors from overheating. The block diagram of the feedback control system of the Sulfur recovery unit is given **in figure (27).**

Points of strengths:

Eco-friendly:

The Sulphur recovery solution is eco-friendly, an eco-friendly solution is a solution made of non-polluting materials. In other words, materials that do not harm human health and the surrounding environment's organisms. Additionally, SRU could be environmentally friendly by using non-polluting materials and using waste materials or by-products to eradicate their existence from the environment by implementing them in the production of sulfur.

High capacity of production:

The capacity of the Sulphur recovery unit is significantly large, and, for instance, it can hold many tons of condensed sulfur.

Evidently automated process:

Due to the existence of several sensors and a fine-tuned feedback control system, a Sulfur recovery unit is an entirely automated process that does not expose a human's life to danger.

Points of weakness:

Difficulty to install and operate:

Like the big industrial projects, Sulfur recovery units are not easily installed and need an intensive amount of energy to work out.

Expensive industry:

Not all countries can support such kind of industry as it need a well-suited infrastructure, and an untold amount of money to obtain those units.

1.4.3: Batik industry development in Yogyakarta, Indonesia

Batik is a type of cloth that has beautiful drawings on it, and those drawings emerge from Indonesian culture. Batik was recognized by UNESCO as a masterpiece of the heritage of humans. Those drawings are implemented by drawing them using a dye-resist wax along with dying the cloth. That's why the piece of cloth becomes colorful, and the drawings remain with the bright color of the wax. The problem with the industrial process is that the wax must be used in a molten state, and the batik wax is molten through a kerosene stove. That stove uses fossil fuels, polluting the environment. Moreover, there are many kerosene outages in Indonesia. In addition to those outages, kerosene prices are increasing rapidly. Although the factories have electric stoves, those stoves are not enough sophisticated to contain a battery. That's why they depend on commercial power (power delivered by power factories and companies), and that power is not reliable in Yogyakarta due to rain conditions.

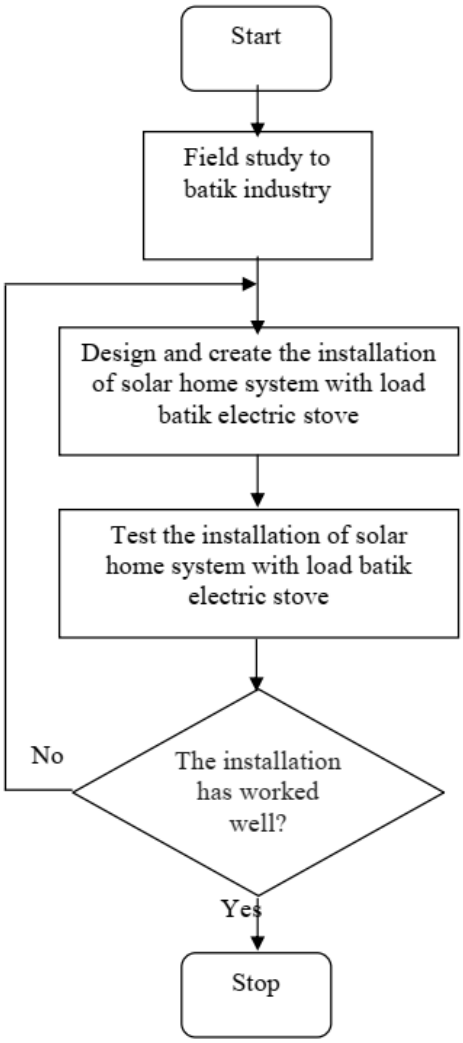

Figure 28 The feedback control system in the design of the solution of the Batik factory in Yogyakarta

The first step in designing the solution to the problems of the batik industry is to use an electric stove that is designed for the batik industry specifically, and that stove should be connected to a solar panel system, where the process of improving the batik industry used a feedback control mechanism from the scratch. During the process of improving, the industry, problem-solving steps were taken, and a feedback control system was designed to help implement the solution. At first, a field study was made to know the process in depth, and the information gained from that field study was an input to the design of the solar system. That design should be tested thoroughly, and after testing the output, decisions will be made regarding the effectiveness of the process. If the process makes difference,

the design would be kept and used. If the process gives an inefficient output, the design should be improved again **as shown in figure (28)**.

The solution consists of **two** steps: the **first one** is designing an electric stove for the batik industry, specifically and the **second one** is designing a solar system that is proficient in providing enough electricity for an average of two stoves per factory as the solution is intended for small-scale factories. The provided electricity should be a continuous power supply of **125 watts** for each of the two stoves. That implementation is currently successful and provides enough electricity for the factory.

Strength Points:

Increasing Production

The average batik production improved from **200 pieces** of cloth per month to **250 pieces** of cloth per month. That meant an increase in the average monthly gross product **from 5 million** Indonesian rupias **to 6 million** Indonesian rupias.

Spreading of the Yogyakarta culture

The produced batik invaded the markets around Indonesia, where factories dared to supply batik shops around both Jakarta and Bandung. Since batik is a unique component of the Yogyakarta culture, the spreading of the batik industry caused the spread of the Yogyakarta culture around Indonesia.

Weakness Points:

The micro size of the solution.

The solution is intended for small and medium-sized batik factories, so the solution may not be reliable in large-sized factories or may need many improvements.

The solution is also limited

Since solar energy is always limited due to the limited hours of efficient solar energy, weather conditions, and the inability of storing excess electricity. Although the solution showed creativity in storing electric energy and bypassing some of the limitations, it is still limited.

Chapter 2

II. Generating and Defending a Solution

2.1: Solution Requirements:

Availability:

The materials of the feedback control system and all the materials included in the process must be available to make the system available in every place in the country. Furthermore, the availability of the materials of the system has a good impact on the cost of it as it reduces the cost of the system, and as a result, the feedback control system-based industry becomes available in every place in Egypt.

Durability:

The materials that the feedback control system-based industry is made of must be durable and strong enough to make it able to bear the environment and sustain itself under the worst conditions. For example, the design of the system must be made of durable materials that could sustain environmental changes and resist any chemicals involved in the process. Another reason is that it must be made of durable components to prevent over-maintenance.

Effectiveness:

The feedback control system-based industry must be effective which means that it must produce products without any faults and errors. Furthermore, the feedback control system should be accurate and efficient in detecting any mistakes before the products are produced. The feedback control system-based industry, to be effective, should consume low power for the sake of effectiveness.

Eco-friendly:

The feedback control system-based industry should be eco-friendly which means that the materials from which the system is made should be non-polluting and do not harm the environment. Moreover, the system must not leave bad pollutants after the process of manufacturing such as the carbon footprints which can affect

the health of the people. Therefore, solar panels can be used in the feedback control system to reduce pollution.

Cost:

Cost is one of the most essential requirements that must be taken into consideration in any project. The cost of a feedback control system-based industry should be moderate or, in other words, economical. This means that the system should be available at any time, and there is no need for big financials to make this project. In other words, the feedback control system-based industry should be affordable.

2.2: Design Requirements:

Since the project should be tested to check its success, it is mandatory to choose two testable design requirements that could denote its success.

pH:

For gentian violet, many physical and chemical properties can be measured. After doing extensive research, the property that was chosen as a design requirement was the pH. That's because of the relation between gentian violet's pH and its chemical & physical properties. Gentian violet's color changes from yellow to violet over a pH range of 0.0 to 1.0. So, the pH was chosen as a design requirement to make sure that the compound is properly prepared. Furthermore, pH is related to the concentration of components of gentian violet, so if the ideal pH is maintained, the gentian violet solution is guaranteed to be optimal.

Efficiency:

The efficiency of the prototype was measured by calculating the saved time by the project, which equals the time used by traditional industry minus the time used in the prototype. The efficiency of the project will be calculated via the ratio between the time taken by the automated process of the prototype and the consumed time of the traditional, manual, process.

2.3: Selection of Solution:

Traditional manufactories represent a notable sector of Egypt's whole industrial base. Gentian violet (crystal violet) could be exploited in several different industries: As a pharmaceutical product, it can be used to treat fungal infections; a dye made of gentian violet is implemented in the textile industry, and Paper dye is made out of gentian violet. These manufactories are examples of the various applications of gentian violet in traditional industries.

The production of gentian violet, like most of the traditional industries, needs to be improved to increase the efficiency of the whole process and overcome the associated issues. Indeed, the whole process is time-consuming and is operated manually. The most important issue of the process is the significant errors in the final output. These errors might come out as a result of the inaccurate concentration of ingredients.

Therefore, an intricate feedback control system will aid in maintaining a consistent process that works on producing infallible output. Additionally, making the whole process automated will boost efficiency and decreases the time required to accomplish the output. The production of gentian violet will be operated by using green energy resources to avoid polluting the environment.

The solution was chosen to diminish any possible fault in the process and minimize the harmful impacts of gentian violet on both humans and the surrounding environment.

2.4: Selection of Prototype:

The prototype shall contain four parts, put on a wooden stand. That stand has multiple levels, and each chamber is put on a level.

Solar panels: The solar panels, which are necessary to add the green energy function to the prototype, should be put on the top level of the stand. Being on the top level of the stand, solar panels will collect the biggest possible amount of solar radiation, generating the biggest possible amount of electricity.

The materials chamber: The materials (mainly gentian violet and ethanol) should be put in a separate container, where each container should be connected to small DC water pumps through water hoses. Pumps work and stop according to the signals of an Arduino.

The stirring container: The steering container that is capable of holding the solution of crystal violet. That container should be put on a 6-V Arduino DC motor that rotates for the sake of stirring the added materials (poured by the materials chamber) together.

The electronics: Since the motors, pumps, and Arduino all require a place to be put in, those electric parts will be connected to the other parts of the project and put on the upper level of the stand. That part should be connected to the green energy source (solar panels).

Chapter 3

III. Constructing and Testing a Prototype

3.1: Materials and methods

Name	Quantity	Description	price	Image
Gentian violet	22 grams	A main chemical compound ($C_{25}N_3H_{30}Cl$)	100 L.E	
pH sensor	1	calculating solutions' pH	400 L.E	
Pump	2 pumps	5-volt pump Transfers water to the cup	40 L.E	
Arduino uno board	1	Micro-controller	350 L.E	
Solar panels	2 solar panels	5 watt, 5.5 volts solar panels	150 L.E	
Lithium-ion battery	1	3.7 volts, 5.5-ampere lithium-ion battery	25 L.E	
Transformer	1	Used to step up the volt up to 5 volts	45 L.E	

Stirring mug	1	Used to stir the solution.	60 L.E	
Jumpers, hose, and charging module	10 jumpers 1 hose 1 charging module	1-meter-hose, male-male, male-female jumpers, charging module for lithium battery	10 L.E 10 L.E 15 L.E	  

Table (1): The materials used in the prototype.

3.1.1: Safety precautions

A lot of safety precautions were taken into consideration while constructing our prototype:

(1) Wearing clothes that provide maximum body coverage (lab coat -gloves – face mask) for protection.

(2) When carrying out experimental work we wore a lab coat to be safe from any accidents.

(3) We wore long trousers or jeans to cover all of our legs.

(4) Make sure we know the location of fire extinguishers, fire blankets, and, most importantly, the fire exits. In case of a fire.

(5) Not eating or drinking while working on the prototype to make sure the prototype will be fine.

(6) Keep the work area tidy and clean up any spills, including water, on the floor.

(7) Be careful while working with chlorine and prevent eye exposure to chlorine

(1) Three samples of gentian violet of concentrations **0.5%**, **0.75%**, and **1.0%** were prepared in beakers in the chemistry laboratory, to test the relation between pH and concentration as shown in figure (29) and a linear relation between the concentration and the pH was deduced.

Figure 29 The samples of the laboratory

(2) The pH sensor was calibrated to measure accurate pH results and connected to the A0 pin. After that, the Arduino UNO board was linked to the laptop as shown in figure (30).

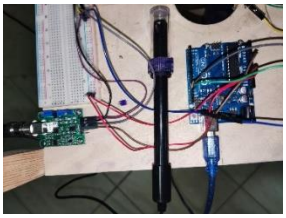

Figure 30 pH sensor connection

(3) The lithium-ion battery of 3.7V was connected to the charger module as shown in figure (31) to charge the battery, and afterwards, they were connected to the solar panels of 5.5V and 5W at an angle 25 degrees.

Figure 31 lithium ion battery and solar panel connection

(4) A step-up transformer was connected to the battery as shown in figure (32) to increase the emf to 5 volts which is suitable for powering each of the two pumps.

Figure 32 connection of the transformer.

(5) The pump was connected to the relay to control the intervals of opening and closing the pump as shown in figure (33), and the relay was connected to the Arduino UNO.

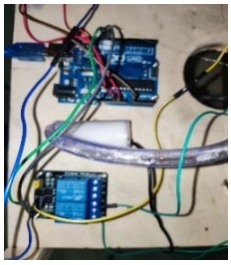

Figure 33 connection of the pumps and the relay.

(6) One pump was connected with distilled water for transferring the suitable amount of water to decrease the concentration of the solution in case of a pH was higher than 3.4. The other pump was connected with gentian to increase the concentration in case of the solution was diluted as shown in figure (34).

Figure 34 The pumps are connected to the solutions.

(8) The pH sensor was put in the stirring mug to measure the pH directly. The Arduino code was operated, and the feedback control system maintained the pH in the ideal range by controlling the concentration of the product as shown in figure (35).

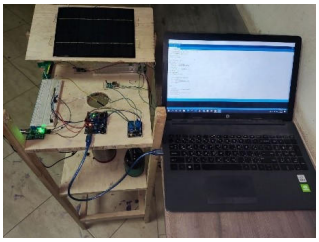

Figure 35 Connection of the Arduino to the laptop.

3.1.2: Design requirements

(1) Efficiency
(2) pH measurement

3. 1.3: Safety Precautions

Lots of safety precautions were taken in consideration: coats were worn to be protected from the chemical solutions. Masks and glasses were also worn.

3.2: Test plan

(1) Three solutions of gentian violet with different concentrations (diluted, ideal, and concentrated) were brought, and they were put in the stirring mug with the pH electrode.

(2) The code was run, and the feedback control system was tested according to these three solutions. The pH of the three products was measured and compared to the ideal pH. The pH values were recorded before and after the feedback. The time taken to make each ample was recorded and the increase in efficiency was calculated by dividing the amount of saved time (the time taken by traditional industries – the amount of time taken by the prototype) by the time taken by traditional industries.

3.3: Data collection

Negative results

While constructing the prototype, there were negative results. The Arduino UNO was burned due to the wrong connections of the wires as the positive and negative poles were reversed. Moreover, the pH sensor was not calibrated correctly which affected the results at the beginning. However, another Arduino UNO was brought, and a buffer solution was used to calibrate the pH sensor correctly, and positive results were obtained.

Positive results

The results of the following table show that the prototype has adjusted the pH of the diluted and the concentrated gentian violet solutions efficiently, without affecting the pH of the ideal solution, and the time is taken (average of 3.50 ± 0.01 (min)) for the process has been reduced, which reveals that the prototype achieved the design requirements successfully.

	Diluted (Trial 1)	Ideal (Trial 2)	Concentrated (Trial 3)
Before trial 1	5 ± 0.01 pH	3.4 ± 0.01 pH	2.5 ± 0.01 pH
After trial 1	3.6 ± 0.01 pH	3.4 ± 0.01 pH	3.3 ± 0.01 pH
Before trial 2	5.5 ± 0.01 pH	3.4 ± 0.01 pH	2.2 ± 0.01 pH
After trial 2	3.62 ± 0.01 pH	3.4 ± 0.01 pH	3.28 ± 0.01 pH
Average for after trials	3.61 ± 0.01 pH	3.4 ± 0.01 pH	3.29 ± 0.01 pH

Table (2): Positive Results Table

The efficiency of the prototype was measured by calculating the saved time by the project, which equals the time used by traditional industry – the time used in the prototype (6 – 3.5 = 2.5 minutes). The increase in efficiency was measured by dividing the saved time by the time taken by traditional industries and was found to be around 40%.

Chapter 4

IV. Evaluation, Reflection, Recommendations

4.1: Analysis

Chemistry of Gentian Violet

Gentian violet is an aniline-derived dye with antifungal and antibacterial properties. It is a triarylmethane dye that is synthesized with organic compounds containing triphenylmethane as a backbone. To synthesize crystal violet, Dimethyl aniline is condensed in the presence of Carbonyl chloride and Phosphoryl chloride, which yields Michler's ketone. The compound is then heated in the presence of the previous compounds, which results in the final product of crystal violet. It has the chemical formula of C25H30N3.Cl as shown in figure (36). It is a monochloride salt of the crystal violet cation. The gentian violet salt is a green powder with blue-violet color in water. Gentian violet is used in many different sectors such as dyes, fungal infection treatment, ballpoint pens ink, and gram staining. Gram staining differentiates between gram-positive and gram-negative bacteria. Gentian Violet (GV) dissociates into positive GV+ ions and negative Cl- ions. The GV+ ions interact with negatively charged components of the bacterial cell wall including peptidoglycan. Gram-positive bacteria are colored in violet and gram-negative are colored in red. This is because the thick layer of peptidoglycan in gram-positive bacteria retains crystal violet. The thin layer in gram-negative bacteria does not retain crystal violet and, hence, is not colored in violet. The solubility of Gentian Violet is 4g/L in water at 25°C. The color of Gentian violet changes according to pH, where it changes from yellow to violet at pH 1. Hence, it is sometimes used as a pH indicator.

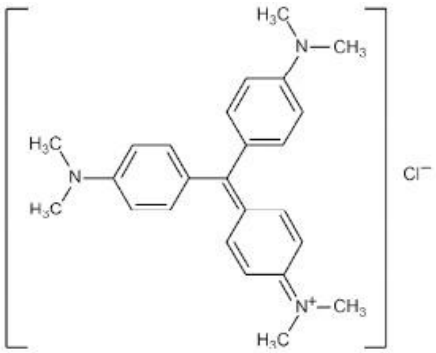

Figure 36 The structure of the GV+ ion

Dependence of pH on gentian concentration:

Four samples of different concentrations were made. The concentrations were 1%, 0.75%, and 0.5%. The pH measured for the three samples was 3.4, 3.6, and 3.8, respectively. After carefully comparing the results and plotting them on a figure (37), a relation between the pH and the concentration of gentian violet was found. It

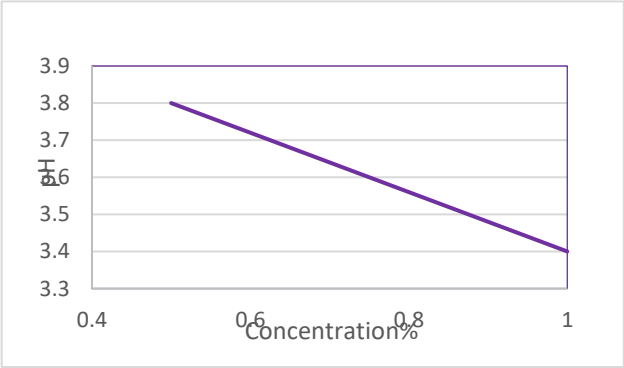

Figure 37 The dependence of pH on conecntration of GV

was found that with increasing the concentration of gentian violet, the pH decreases and vice versa. The relation was defined by the equation y=-0.8x+4.2 as shown in figure (38). This is the main idea behind the feedback mechanism. The ideal gentian violet product is of concentration 1% and pH 3.4. If the output product value is larger, the feedback decreases the pH by adding gentian violet, and if the output value is smaller the feedback increases the pH by adding distilled water to decrease the gentian concentration.

$$y = -0.8x + 4.2$$

Figure 38 The equation of the line, representing the dependance of pH on concentration

pH electrode:

The pH electrode is the main sensor of the feedback mechanism, giving the controller values of the gentian violet product. The electrode is a concentration cell. In the galvanic cell, the potential is dependent on the concentration of the two compartments. The pH electrode as shown in figure (39) has three main components: a standard electrode of known potential, a special glass electrode that changes potential according to concentration, and a potentiometer to measure the potential between the electrodes. There is also a reference solution inside the glass membrane of known pH value, so when the electrode is dipped in a solution, the potential changes according to the difference of [H+] concentration. This cell potential is automatically changed to a pH reading.

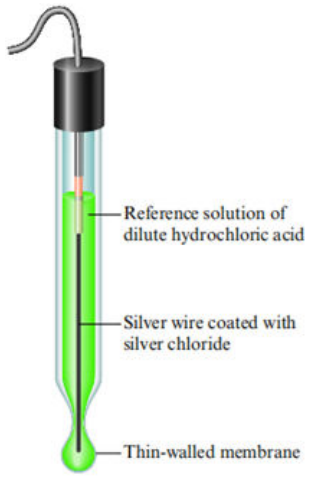

Figure 39 The structure of a pH electrode

pH sensor calibration:

The calibration finds a relation between the measured pH and the voltage. When the sensor is first used, calibration is needed for accurate results. The electrode has a voltage of 0 to 5V. The calibration is done by using two solutions of known concentration. The solutions used were buffer solutions of pH 4 and 10. The pH electrode is dipped in both solutions, and the voltage is obtained. From these results, two points expressing the relation between voltage (read by the sensor) and pH are obtained. Then, by using these two points, a linear equation

between the voltage and the pH is calculated. This equation is used in the code to get future pH results.

Micro Submersible water pump:

The Arduino-operated water pump (presented in figure number (40) transports both distilled water and Gentian Violet and adjusts their flow at a very efficient rate. The internal structure of a mini water pump consists of a Brushed DC-Motor that converts electrical into mechanical energy. A brushed motor's main structure consists of a stator, armature, and brushes. It works on the principle of magnetic torque, one of the electromagnetic laws that state that the wound armature experiences two identical forces acting in opposite directions and have the same line of action, causing the coil to face a magnetic torque. By rotating the commutator, the armature rotates in two half-cycles, each starting from a different position, and interchange their positions. Thus, it continues rotating with constant rotational speed.

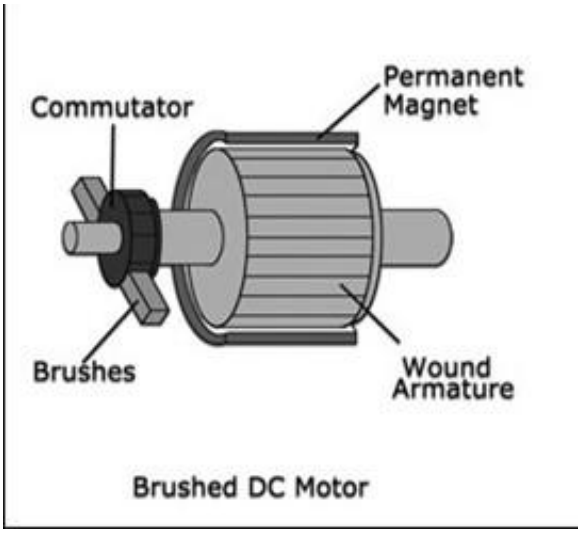

Figure 40 The structure of a DC motor.

Photovoltaic cell

Solar energy was chosen to be the main energy resource for the prototype due to being green and efficient. Solar panels are composed of numerous solar cells connected in series, a schematic diagram shown in figure (41), to increase the output voltage.

Each solar cell produces a small voltage ranging from 0.5 to 0.7 volt, but the series arrangement of those cells adds the voltage generated inside each cell. Solar cells, known as photovoltaic cells, convert solar energy into electrical energy through a stepwise process called “The photovoltaic effect’’. A single photovoltaic cell consists of a P-type and an N-type semiconductor.

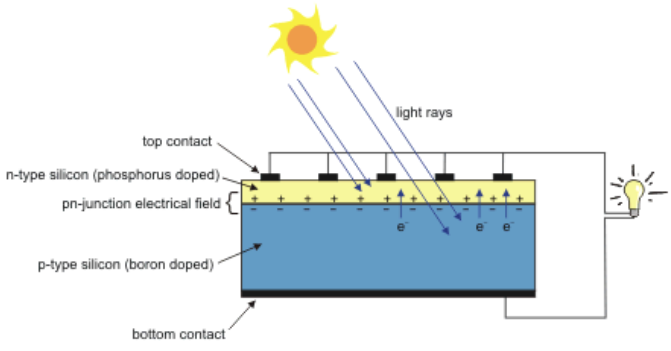

Figure 41 Schematic Diagram of the connection of PV cells.

Most energy transfers in the boundary between the two semiconductors are called a P-N junction. The light photons strike the depletion region of the P-N junction, carrying free charge carriers (holes and electrons). Those new excess charges create an internal electric field inside the depletion region. Electrons start moving toward the N-semiconductor layer, and holes move toward the P-layer, destabilizing the thermal equilibrium of the whole P-N junction and promoting the diode to act as a small battery that produces an external current that can be implemented in operating the two pumps.

Arduino Analysis:

Arduino boards, as shown in figure (42), consist of a microcontroller, analog (input) pins, digital pins, and a 5V pin. A microcontroller consists of memory and a CPU. There are 6 input pins, named A0 to A5, responsible for receiving data from sensors. There are 14 digital pins used for output and input, with an output current of 40 mA. A 5V pin is necessary for outputting the current with 5V for the pH sensor.

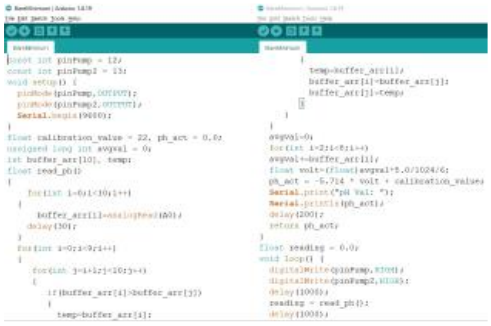

Figure 42 The used code in the project.

The code starts with making the two pumps release the amount of solution necessary for making a 1% gentian violet solution, where the Arduino gives an order for the self-steering mug to steer the solution for 3.5 minutes and gives orders the sensor to measure the pH of the solution after steering. If the pH was less than the ideal range, the solution is concentrated and should be diluted by operating the water pump. If the pH was more than the ideal, the solution is diluted and should be concentrated by using the gentian violet pump, so the result is a product of a gentian violet solution with ideal pH of 3.4.

Feedback Control Mechanism:

A Control system is a collection of units, forming whole parts, that give orders to control itself or another system. A feedback control mechanism is a control system that gives orders after investigating its output. It consists of input, controller, process, output, and feedback. On operating the system, the controller takes input from the surrounding environment, processes them, and makes decisions. After the process produces output according to the orders of the controller, the feedback

processes that output again, giving more orders. For example, if the output is fine (checking the output is done by comparing it to the ideal product), the controller won't give more orders. Otherwise, the controller will give orders. Actuators are the things that do an action according to the orders.

In our project's control system design, as shown in figure (43), the Arduino is the controller and takes input via the pH sensor, and the pumps are the actuators. On operating the prototype, the Arduino orders the pump to transfer gentian violet and water and orders the steering cup to mix them. After mixing, the Arduino makes the pH sensor process the output solution and makes decisions according to the sensor's processing. If the pH is high, the solution should be concentrated, and if it is low, the solution is diluted. No action is made if the solution is in an ideal pH range.

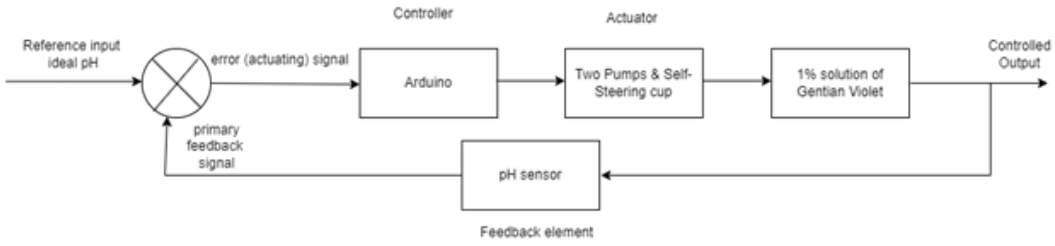

Figure 43 Block Diagram of the project's feedback control mechanism.

Lithium-ion battery:

Galvanic cells are electrochemical cells that convert chemical energy into electric energy by harnessing electrons from the basic oxidation-reduction chemical reactions, happening in two separate compartments. Each of the compartments has an electrode, called anode and cathode respectively. Oxidation is the process of losing electrons of an atom, changing into a positive ion at the anode. Reduction is the process of gaining electrons of an atom, changing into a negative ion at the cathode, so electrons transfer from anode to cathode through the wire connecting the compartments. There is a salt bridge between the anode and the cathode to maintain the spontaneity of the reaction by neutralizing the charge of the two compartments and maintaining the potential difference between the compartments.

Lithium-ion batteries, as shown in figure (44), are galvanic cells that consist of a metallic over, encapsulating three sheets (anode-cathode-isolator), where they are dipped in the electrolyte. The electrolyte solution is lithium hexafluorophosphate. The anode is lithium graphite, and the cathode is lithium cobalt oxide. Overall Reaction: $LiC_6(s) + CoO_2(s) <-> C_6(s) + LiCoO_2\ (s)\ E^0 = 3V$. The battery can be recharged because the reaction is reversible. The lithium-ion battery is used in our project to collect the power, generated by the solar panels, to be stored.

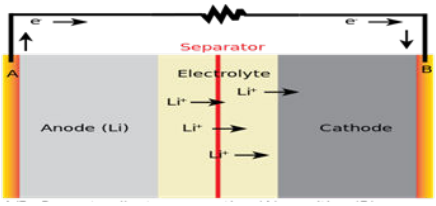

Figure 44 Schematic Diagram of the lithium ion battery Chemistry.

4.2: Recommendation

Electronic pipette: It is highly recommended to use the electronic pipette shown in figure (45) instead of the pumps as they are very accurate and precise because they work by dripping very small amounts and uses a motor to maintain the movement of the piston in the electric pipette. Therefore, they will dispense the volume programmed exactly which means that the error in the concentration of gentian will be near zero. However, it has a disadvantage which is the cost: the cost of the electronic pipette is high which resulted in the limitation of its usage.

Figure 45 Illustration of an electronic pipette.

Magnetic stirrer: it is highly recommended to use the magnetic stirrer **shown in figure (46)** instead of the stirring mug as it is much faster than the stirring mug where its speed can reach 1500 rpm (rounds per minute) which means that the efficiency of the process of making gentian violet will increase, and hence the time, taken for the process of the feedback control system, will decrease. However, it has a disadvantage which is its cost. Also, it has a high capacity, which is not suitable for our project. However, it will be convenient for real-life applications.

Figure 46 illustration of the magnetic stirrer

Real life application: The most important point when applying the prototype in real life is considering the source of energy and the use of the product. The prototype uses solar panels as an energy source, and on applying the prototype in real life, it is necessary to put it near Benban Solar Park shown in figure (46) in Aswan Governorate. Benban Solar Park is the world's 4th largest photovoltaic power station, which is characterized by an annual production of 3,800 GWh. That amount of energy would be enough to produce massive amounts of Gentian Violet solution if the real-life application was done there. Gentian violet will be used as a dye, and it would be beneficial to use the produced solution in the textile factories in upper Egypt (the area where the Benban Solar Park is located). Taking Qena's textile factory as an illustrative example, it is important to know that the factory has a daily production of 2 textile tons. That production needs a minimum of 60,000 liters of Gentian Violet each day. If the prototype is enlarged at a scale of 30, it will give 1234 liters per day. To generate 60,000 liters per day a system of 49 units should be used. a single unit consisting of one prototype uses 5.4 KWh. Each year this will lead to power consumption of 2.9 GWh. The enlargement of the prototype can be done by using a magnetic steerer.

Figure 47 The location of the Banban Solar Park.

4.2.1: Recommendation to other teams

The scientific process is a continuous process. Each one is built upon the knowledge of their predecessor. The same goes for this project. If a team was to build this project, they should start from the point where this project stopped. The team should learn from the previous mistakes and avoid repeating them. This is the same for any other project. This allows the project to get developed and sustained as possible. Furthermore, it prevents time loss and unnecessary mistakes. If a team were to start to build this project, there should be some points to consider before building it. The first thing, they should avoid past mistakes and search for the connections of the wires in the Arduino UNO to avoid it from burning. Moreover, the team should work with the recommended material. They should use the magnetic stirrer as it can make the gentian violet solution stirred faster. The team should also take into consideration using electronic pipette as it is more precise and accurate in dispensing the alcohol and water. It would also be recommended to use a stronger pump to increase efficiency and decrease the time taken for the alcohol and water to flow to the gentian violet.

4.2.2: Project's benefits

The project had a great influence on the team from the scientific, engineering, and social aspects. First is the scientific aspect. the team learned many new scientific concepts that are proven to be useful. Some of these scientific concepts include feedback control system, the Arduino UNO construction, and the chemistry of the gentian violet. The team learned about the problems of the industry in Egypt and the challenges facing it. We learned about the significance of finding new ways for developing the industrial base in Egypt and their effect on socio-economic life. The second is the engineering aspect. to build the prototype the team learned to find engineering solutions to make the prototype as effective as possible. The team also learned the EDP process and how to build a project in a correct scientific sequence. Critical thinking was one of the most important things that we learned. The third is the social concept. The team learned how to communicate efficiently. We also learned how to tolerate each other's mistakes and accept opposing opinions.

4.3: Learning outcomes

4.3.1: Table of Learning Outcomes

Learning outcome	Concept	Content	Relation
Physics (PH.2.10)	DC Motor	This LO explained how a DC motor works.	The two pumps, which transport the water and the alcohol, is based on the DC motor. So, this LO was needed for the calculations related to the DC motor
Physics (PH.2.11)	. Step up and step-down transformers	This LO explained the idea of the operation of the transformer and how to increase the voltage	A step-up transformer was used to increase the voltage of the circuit to 5 volts which is suitable for operating the two pumps.
Physics (PH.2.15)	. The P-N junction . Diodes	This LO explained the concepts of the P-N junction and Diodes and how they work in an electric circuit	The solar panels are composed of the P-N junction and diodes. Therefore, this LO was used to study the solar panels thoroughly
Physics (PH.2.03)	. Dynamic electricity . Electric current . Potential difference and voltage.	This LO illustrated the Dynamic electricity, and how to calculate the voltage and the current.	This LO was used to calculate the voltage and the current intensity passing through the electric circuit.
Chemistry (CH.2.09)	The path of electricity in a battery	This LO illustrated the battery components, and how the electricity passes through it	This LO was used to study the behavior of the battery in the electric circuit and gave an illustration of the methods of connection with the other components of the circuit.
Chemistry (CH.2.10)	Aromaticity	This LO illustrated the aromatic organic compounds and their structure and function.	The gentian violet is composed of aromatic organic substance. This LO illustrated the structure and the uses of the gentian violet.
Chemistry (CH.2.03)	. pH scale . Acids . Bases . Acid–Base Properties	This LO explained the idea of measuring the acidity and basicity by the pH scale.	It was used to calculate the pH of gentian violet solution.

Chemistry (CH.1.11)	. Stoichiometry . Mole . molar mass	This LO illustrated the stoichiometry and how to calculate the moles of a substance	This LO was used to calculate the moles of the gentian violet solution.
Math LO 2.01	Polynomial functions and relations between variables	It illustrates the different functions, and how to express relations between variables	It was used to know the relations between different variables, and a linear relation was deduced between the concentration and the pH.
Mechanics (ME.2.05)	Power	This LO illustrated the concept of power and how to calculate the power consumption`	This concept was to calculate the power consumption of the battery used in the prototype.

Table (3): The table of the used learning outcomes.

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