# Green-Hesive

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Portfolio

## Group 222


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## Pollution

Pollution has been a fundamental problem that faces Egypt for decades, and it has been increasing continuously over the years. As Egypt's population rises every year, these problems become more serious. In 2020, 100 million people will be recorded as the Egyptian population.

Egypt receives about 55 billion cubic meters of water every year; this water is reused because it isn't enough for the people and agricultural fields. Many Egyptians die every year because of poor water quality. The annual cost of health effects resulting from drinking polluted water, sanitation, and hygiene is about 26 billion LE to 56 billion LE in the year 2016/2017. This costs Egypt about 0.75% to 1.61% of Egypt's GDP that year.

The other big problem is poor quality of air, especially in Alexandria, Cairo, and other urban areas. The annual cost of health effect caused by air pollution in greater Cairo is about 45 billion to 48 billion LE in 2016. This equals about 1.4% GDP of Egypt.

In 2017, the United Nations said "40,000 people in different parts of Egypt die every year because of pollution.". Every day Cairo receives big amounts of pollutants composed of 52 percent carbon oxide (CO), 14 percent Sulphur dioxide (SO2), 21 percent hydrocarbons, 10 percent dust, solid materials, and 2 percent (NO) nitrogen oxides.

# Causes

## ❖ The factories emissions and wastes

Cement factories are from the main sources of air pollution in any country. Some factories do not increase the height of their chimneys and do not put fume filters on their chimney because these things cost a lot of money. One of these examples in Egypt is Wadi Al Qamar factory as shown in figure (1.1). These gases harm the populations as they contain poisonous chemical compounds. The harmful gases are arising from burning of fossil fuel inside these factories like methane gas (CH4), carbon monoxide (CO) and carbon dioxide gas (CO2). Also, these Factories get rid of their wastes in rivers, seas or even lacks because the safe way to get rid of these wastes costs a lot of money. This defects the aquatic life and pollutes the water which causes a lot of diseases. The other thing is the soil as it also, being polluted when irrigated from this polluted water.

**FIGURE 1.1 THE SMOKE OF WADI AL QAMAR FACTORY**

## ❖ The cars harmful emissions

Cars emits a lot of smoke from their engines after being burned. 40% of greenhouse gas (GHG) caused in Cairo by the old cars. From the examples of these gases are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). These gases cause an increase in the temperature of the earth, and this is known as greenhouse phenomenon. These gases are harmful for human because it causes diseases like respiratory system infections, heart diseases and cancer.

### ❖ The natural electric generator

The natural electric generators are divided into two types, the nonrenewable resources, and renewable resources. The first type is the renewable resources these sources are the clean sources for generating electricity as they are not generated from chemical reactions. For example, wind, solar and hydro. The second type is nonrenewable sources. These sources pollute the environment as they are generated from burning or reactions like in nuclear, coal, oil, and gas fuels. In figure (1.2) the percentage of electric from renewable and non-renewable source.

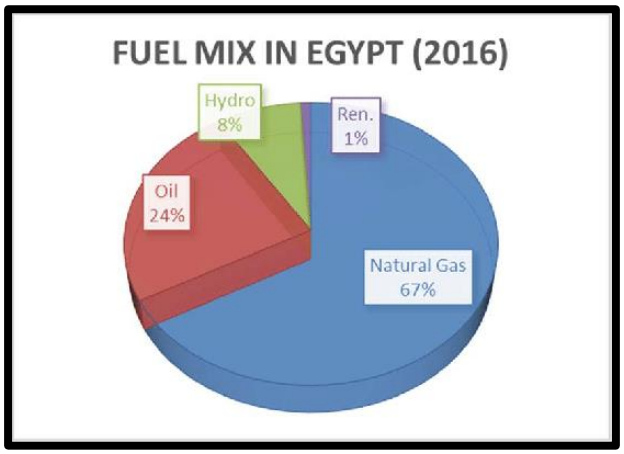



**FIGURE 1.2 THE PERCENT OF EACH POWER SOURCE IN EGYPT**

## Impacts

### ❖ The effect of pollution on public health

The short-term effect revolves around discomfort like causing irritation to the nose, headaches, throat, or effects on vision. On the other hand, the long-term effect air pollution which can last for years; they can lead to bad health problems like heart diseases, lung cancer and respiratory diseases, also pollution can cause damage to people's nerves, brain, kidney, liver, and other organs which sometimes ends up by death. Nearly 42000 deaths in Egypt caused by air pollution. The young children and older adults will be more sensitive to air pollution as their immune system is weak.

## ❖ Effect on environment

FIGURE 1.3 FOREST HAS BEEN AFFECTED BECAUSE OF ACIDIC RAINS

Like animals, plants and people, the ecosystem can be harmed from the bad air quality. Air pollution particles eventually will fall to the earth surface. So, it will directly pollute the water and the soil. All of these will end up by killing crops or reduce yield. Sulfur dioxide (SO2) and nitrogen oxide (NO) can in the air can combine with water and oxygen in the atmosphere forming acidic rain. When acid rain reaches the soil, it changes its composition and when it falls on water surface; it decreases the water quality and causes decay to buildings and monuments. The figure (1.3) shows impacts of acidic rain on the environment.

## ❖ Global warming

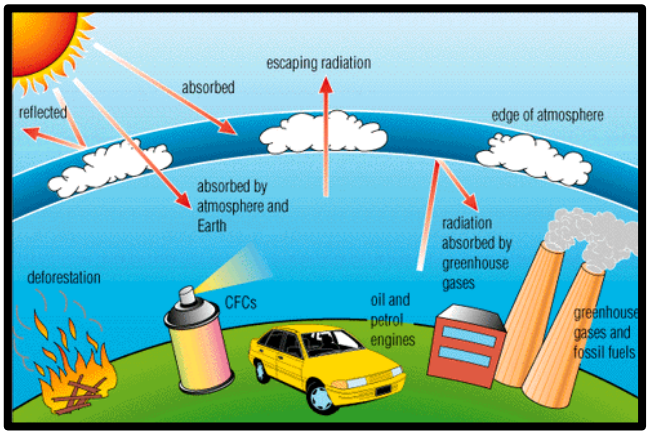



FIGURE 1.4 ILLUSTRATION FOR THE MECHANISM OF THE GLOBAL WARMING PHENOMENON

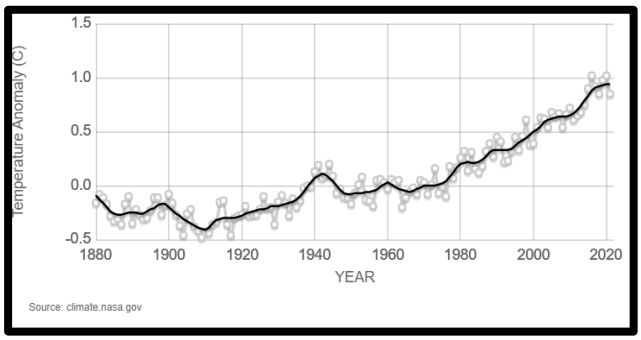
It is an environmental phenomenon refers to rising temperature of the earth and oceans around the world. This happened because of the intensive increase in the greenhouse gases (GHG) in the atmosphere. From the examples of the greenhouse gases (GHG), Carbon dioxide gas (CO2) as it has negative effects on the earth's temperature. Other examples for these gases are methane gas (CH4), nitrous oxide (N2O) and fluorinated gases. Fluorinated gases are like chlorofluorocarbon (CFCs) compound. Figure. (1.4) shows how global warming phenomenon happens.

## ❖ Effect on the aquatic life

Most fish are being died by the mercury which exists from the industrial wastes. All of this affects the aquatic creature and affect our health when drinking this water, and when eating the fish that is supposed to all these pollutions.

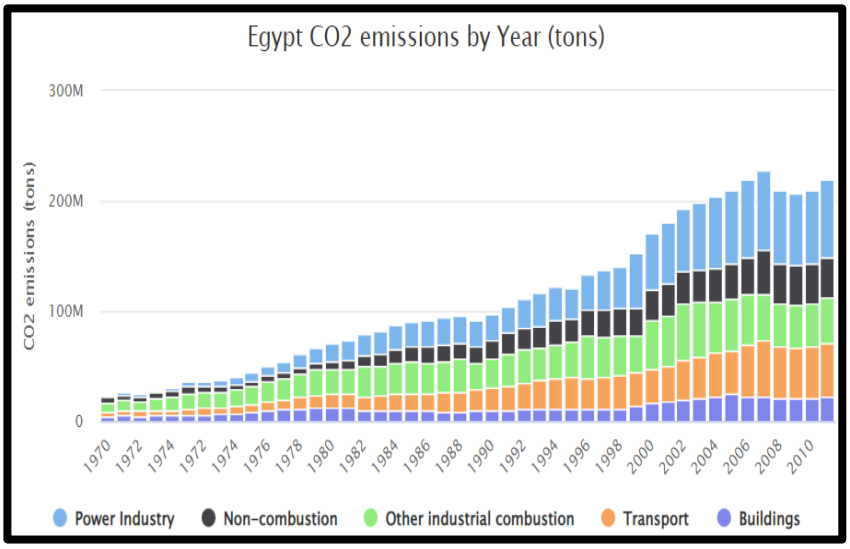
# Reduce and adapt to the climate change effect

Climate change is a general change in the earth's temperature caused by the accumulation of greenhouse gases in the atmosphere. Since the Industrial Revolution started, the CO2 levels have increased in the atmosphere by 48%, which causes the raising in the earth's temperature. As the graph (1.1) shows, the earth's temperature raised from -0.16° Celsius to 0.85° Celsius in the past 140 years.

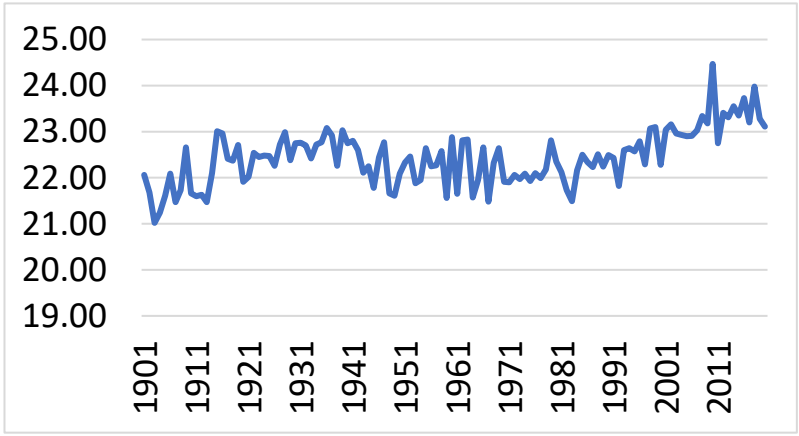



**GRAPH 1.1 THE AVERAGE EARTH'S TEMPERATURE**

In Egypt specifically, the carbon dioxide emissions have risen from 24,266,706 tons in 1970 to 219,377,350 tons in 2016(as graph (1.2) shows), which led to a general increase in Egypt's temperature. As shown in graph (1.3), Between 1901 and 2013, Egypt's average increase in temperature was 0.1°C per decade. Over the last 30 years, the annual temperatures have risen by 0.53°C per decade, indicating a significantly stronger warming trend. Summer warming has been more pronounced than winter warming, with average temperatures increasing by 0.31°C and 0.07°C per decade since 1960, respectively. Furthermore, since 1960, daily minimum temperatures have risen across Egypt, with a decrease in cool nights and an increase in warm nights. Also, Over the last 30 years,




**GRAPH 1.2 SHOWS EGYPT CO2 EMISSIONS BY YEAR (TONS)**




**GRAPH 1.3 AVERAGE ANNUAL MEAN-TEMPERATURE OF EGYPT FOR 1901-2020**

Egypt has seen a statistically significant reduction in annual total precipitation amounts, approximately 22%. Precipitation decreased during the winter and early spring months. Climate change is a serious problem that made all Egypt's government's efforts concentrate on solving the problem. Consequently, it would help if the causes were addressed first to solve this problem.

## Causes

### ❖ High evaporation rate

The high evaporation rates of the Nile river cause high humidity and the water vapour percentage in the atmosphere. Water vapor is the most plentiful greenhouse gas that traps heat because of its high heat capacity, thus increasing Egypt's temperature.

### ❖ The industrial revolution

Since the industrial revolution in Egypt, carbon dioxide emissions have started growing exponentially in the atmosphere, contributing to the temperature increase.

### ❖ wastes in agriculture, landfills, and rice cultivation

When these wastes are left and decompose, it produces methane gas. It is a hydrocarbon gas produced from natural sources and human activities, and it is one of the most effective greenhouse gases.

### ❖ Lack of green lands

92.3% of Egypt's area is arid, so when the carbon is released from burning fossil fuels, there isn't enough land to absorb this carbon dioxide to maintain its levels in the atmosphere.

## Impacts

### ❖ Increasing the severity of drought

86 % of Egypt's land is from the world's driest areas, increasing the risks of desertification, drought, and a lack of water resources to water poverty. This water poverty will affect agricultural land productivity as global temperatures rise by more than 1.5 degrees, preventing the germination of primary crops, mainly wheat.

### ❖ The rise of the Mediterranean Sea level

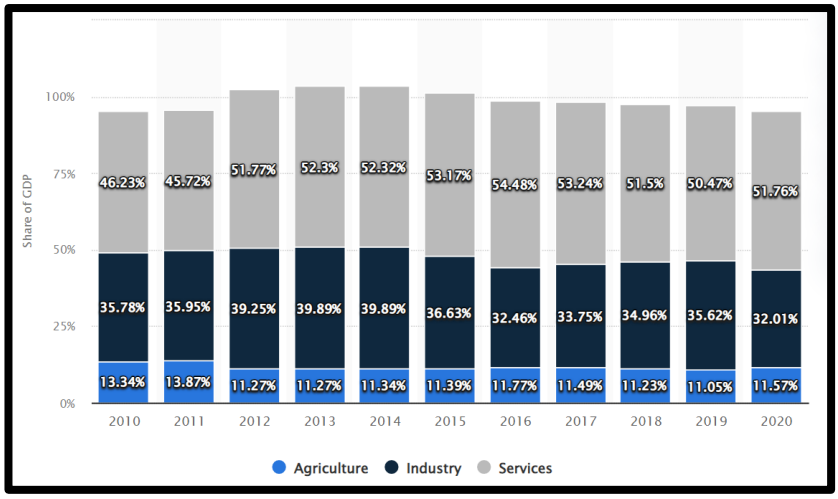
The melting of the two poles' ice is causing the Mediterranean Sea to rise, threatening to drown vast inhabited areas along the northern coast, including five governorates: Port Said, Kafr El-Sheikh, Damietta, Beheira, and Dakahlia, particularly if the water level rose to more than 100cm.

### ❖ Increase the salinity of soil along the northern coast

As the sea level rises, saltwater will encroach on vast swaths of the north delta lands, causing salinity in the soil, deterioration in the quality of crops, loss of productivity, and a scarcity of food.

# Increase Agricultural and Industrial Bases of Egypt

Industry and agriculture are two main parts of the economy of Egypt which contributed by almost 43.5% of the GDP (Gross Domestic Product) of Egypt in 2020. Increasing Egypt's industrial and agricultural bases can contribute to a massive improvement in the Egyptian economy.




**GRAPH.1.4 DISTRIBUTION OF (GDP) ACROSS ECONOMIC SECTORS IN EGYPT**

Agriculture is considered the primary sector of the economy in Egypt. This sector is sometimes known as the "extraction sector" because it involves taking raw materials. Being the primary sector in a country's economy means that agriculture plays a vital role in economic development. In 2020, agriculture alone shared a percentage of about 11.5% of the GDP of Egypt, as shown in Graph 1.4.

Increasing the agricultural base in Egypt aims to increase the production of agricultural materials, which can be achieved by different methods such as increasing the amount of green agricultural areas in the country and involving new technologies in the agricultural processes. For instance, the total size of the agricultural land in Egypt was about 38,500 $km^2$ by 2018, which is about only 3.8% of Egypt's land. Increasing the agriculture base is necessary because agriculture provides food and raw materials to the non-agricultural sectors of the economy, industry, and services sectors.

Industrialization is the process of developing a country's capacity to process raw materials and manufacture goods for consumption or further production. The industry is a crucial factor that affects the economy in Egypt as it contributes by a percentage of about 32% of the GDP of Egypt's economy. Increasing the industrial base of Egypt is not an easy challenge because it should be preceded by increasing the agricultural base as the industrial process is partially dependent on the raw materials produced from agriculture.

## Causes

### ❖ The annual decline in the amount of freshwater from the river Nile

Water provision plays an essential role in affecting the agricultural base in the country, especially when it is threatened by many factors that may lead to water scarcity. One of these threats is the GERD (Grand Ethiopian Renaissance Dam) that Ethiopia has been building since March 2011. GERD will prevent Egypt from getting its complete share of the River Nile. Consequently, this will affect the economy in Egypt because Egypt depends on River Nile to secure about 95% of the water used for different purposes, including agriculture, which will, in turn, affect the industry. Besides, the huge increase in Egypt's population and the population of the countries that share Egypt in River Nile's water also resemble a big problem that affects the amount of Egypt's share of water. This means that whether the GERD works or not, there will be a big water provision challenge related to overpopulation.

### ❖ The need of the government to investors

Since the government does not have enough money to take care of the basic needs as well as the infrastructure of the country, it depends on the investors and private companies to help it pass these challenging days. In 2017, about 68% of the industry sector of the GDP was the share of the private sector. This dependence should not continue for too long so that the government can take a significant part of the income from these agricultural and industrial projects. This can make the government independent of any investors and build what it sees is better for the country in the long term.

### ❖ Using old technologies

The outside world is taking the race of technology in all fields. For instance, in a comparison between the past and the present jobs, many jobs had disappeared, while other new jobs have come out to the market, and almost all of them are because of new technologies, as Graph.x illustrates. Involving new technologies in agriculture and industry is good, but it is not enough to say that the country now uses new technologies because there are new things every day, which makes the current technologies old. So, there should always be a far vision for developing technologies in the agricultural and industrial bases.

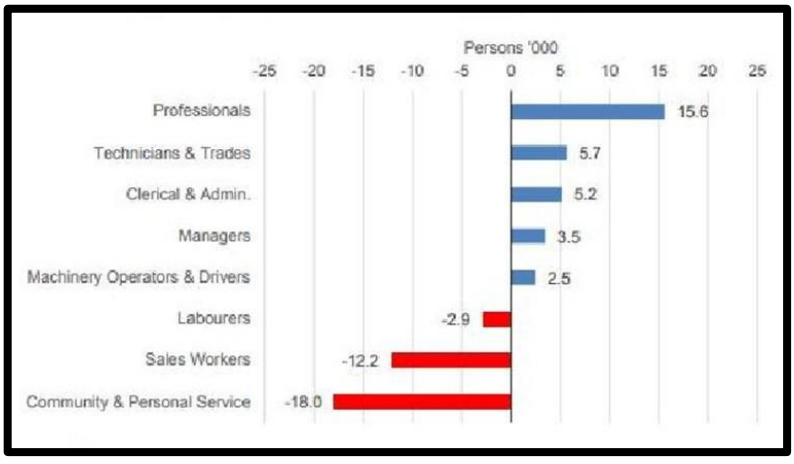
### ❖ Bad mentalities

One of the drawbacks of increasing Egypt's agricultural and industrial bases is that people in Egypt do not appreciate technical schools that provide the country with the workforce needed for agriculture and industry. All people make their children go to universities to get high degrees even if they have no desire to enter fields like those of the universities. This problem had made the unemployment rate among educated persons much higher than that of the not educated. This made the number of educated workmen available to work in agriculture or industry smaller and smaller.

## Impacts

### ❖ Economy deterioration and dependence on imports

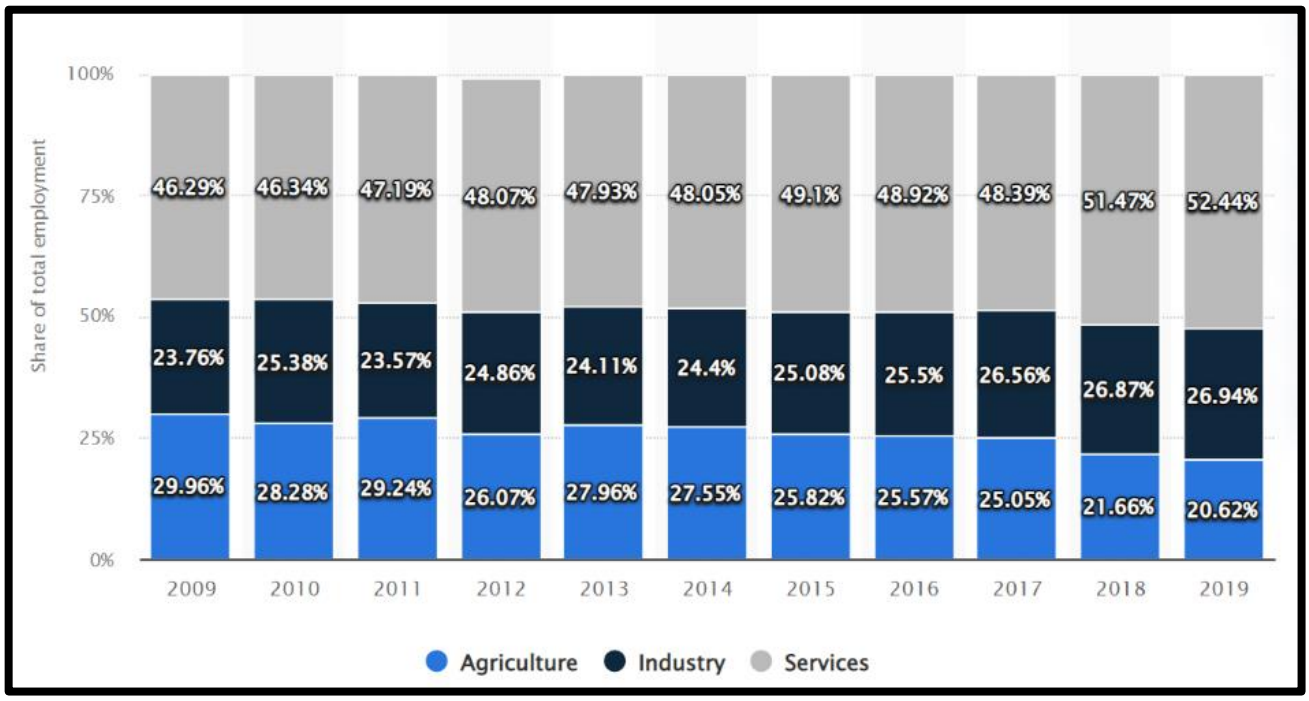
As said, the agricultural and industrial sectors contribute about 43.5% of the GDP in Egypt, which means that a slight decline in any of these two sectors may have a direct effect on the economy of the country, whereas the services sector, the third sector, depends mainly on them. With that being said, the deterioration in agriculture and industry will also lead to a massive increase in the prices of almost all products since the country will depend mainly on imports from the outside world, which cost a lot more than the actual prices of the products.




**GRAPH 1.5 JOBS WITH INCREASING AND DECREASING EMPLOYERS (IN 1000)**

## ❖ Increased rate of unemployment

In Egypt, as shown in Graph 1.6, about 20.6% of the total employment is in the agricultural sector, and almost 27% works in the industrial sector. This means not increasing Egypt's agricultural and industrial bases will significantly affect the unemployment rate because of the absence of newly available jobs in these two sectors.




**GRAPH 1.6 DISTRIBUTION OF EMPLOYMENT BY ECONOMIC SECTOR**

# Recycle and retain garbage for recycling


FIGURE 1.5 CATEGORIES OF SORTING GARBAGE

Reusing items that would otherwise be discarded as waste is referred to as recycling. Upcycling, which involves adding value to an object for reuse, and downcycling, which consists in breaking down an item or substance into its component elements and reusing anything that can be saved, are two types of recycling. Many countries have a standard recycling practice where households sort their garbage into different categories (as shown in fig 1.5).

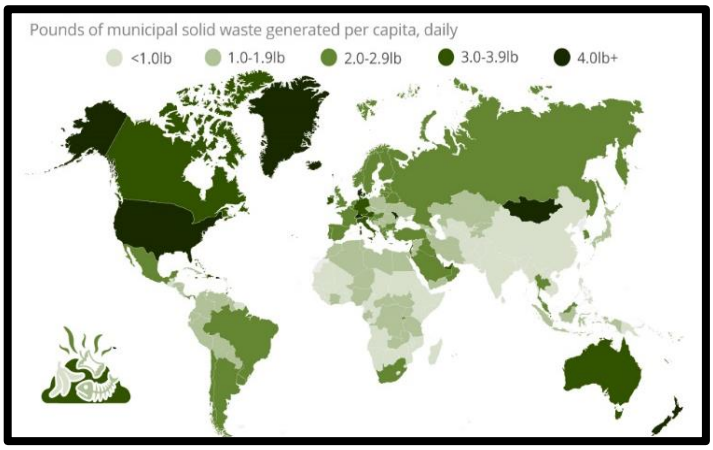
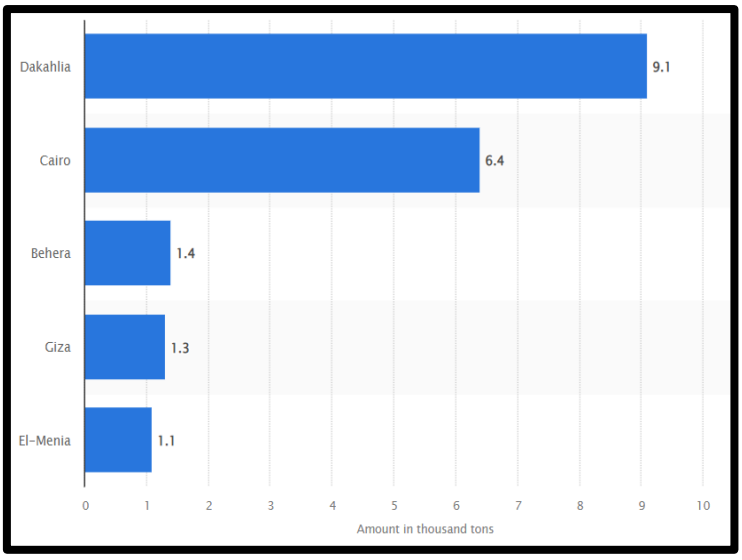



FIGURE 1.6 SOLID WASTES GENERATED AROUND THE WORLD

Every year, the world generates about 2.01 billion tons of municipal solid waste divided by the countries (as shown in graph 1.6). Waste generated per person per day averages 0.74 kilograms but varies greatly, ranging from 0.11 to 4.54 kilograms. Despite having only 16% of the world's population, high-income countries generate approximately 34%, or 683 million tons, of the world's waste.




GRAPH 1.7 DISTRIBUTION OF GARBAGE IN EGYPT

In 2019, the amount of garbage in Cairo was 6.4 thousand metric tons (as shown in graph 1.7). Nonetheless, Cairo's garbage collectors objected to the city's governor's recent decision to set up a system encouraging citizens to sort and sell their garbage. The installation of kiosks is a novel approach tested in a few Cairo neighborhoods in 2018. The idea is to encourage people to sort their trash, sell salvaged solid materials

through these kiosks, and donate the proceeds to their chosen charities. Most of Cairo's garbage collectors live in the Ezbet El-Zabbaleen quarter, also known as Garbage Collectors Village. It is situated along a road leading to the Mokattam neighborhood, where vehicles unload tons of garbage collected by the quarter residents before sorting, processing, and recycling.

## Causes

### ❖ Accumulation of waste

The accumulation of waste is a global problem, not just a national one. If debris accumulates unabatedly, humans may run out of places to bury synthetic waste, or the trash may have disastrous effects on the environment, as is happening unknowingly due to global warming.

### ❖ Threat to the Public Health

Human health is put at risk as a result of our neglect. We continue to generate large amounts of trash and fail to dispose of it properly, which will ultimately be our undoing and that of the environment and wildlife in the ecosystems we all share. If we don't take care of our planet, we won't be able to prevent or enhance lifespan. The longer we live, the more emissions we make due to how much rubbish we generate. Asthma, congenital impairments, cancer, cardiovascular disease, childhood cancer, COPD, infectious diseases, low birth weight, and preterm delivery are only a few conditions that can affect children. Bacteria, rats, and insects are all capable of contributing to the garbage problem.

### ❖ Air pollution

Garbage in landfills decomposes over time and emits a foul odour. Recycling contributes to the reduction of air pollution. Toxins produced by factories to make new products are reduced when we recycle. Using fewer landfills and incinerators reduces pollution and improves health. Furthermore, recycling paper helps to reduce the number of trees that are cut down. As a result of the trees absorbing carbon dioxide in the air, the greenhouse effect is reduced.

### ❖ Depletion of natural sources

Plants are regarded as scarce resources. If these natural resources are subjected to a great deal of stress, they may become depleted quickly. Recycling is the only way to reduce the strain on these resources significantly. According to the United States Environmental Protection Agency, recycling one ton of paper saves approximately 17 trees and 17,000 gallons of water.

## Impacts

### ❖ Saving Energy

Recycling has been shown to save a significant amount of energy. Producing goods from raw materials necessitates using a considerable amount of nonrenewable energy. Compared to companies that source raw materials, companies that use recycled aluminum save up to 95 per cent of energy during the production of aluminum products. Producing goods from recycled fabrics consumes less water and energy and emits less pollution.

### ❖ Providing job opportunities

Recycling occurs in industries. Many recycling plants will be built if recycling becomes more popular. More recycling plants imply more job opportunities. Recycling, on average, generates ten times the number of job opportunities as landfill waste management. Recycling 14,000 tons of waste generates nine jobs, composting generates seven, and landfilling generates only one.

### ❖ Ensuring a sustainable future

The earth has a limited supply of natural resources and a limited capacity to recycle waste. We are doing two great things for our future by recycling: reducing our immediate impact on the planet and developing a sustainable environment for future generations.

## ❖ Maintaining groundwater quality

Allowing landfills to accumulate can have an impact on the quality of groundwater. The majority of landfill management companies make no effort to treat their dumps. They only bury the waste after it has been dug up. A large portion of trash disposed of in landfills is neither eco-friendly nor biodegradable, and contaminants found in these wastes may find their way into groundwater supplies, rendering them unsafe for consumption. Waste recycling will prevent the continuation of this dangerous cycle and reduce groundwater contamination. Recycling products such as batteries and other e-waste materials also aids in preventing contaminants from entering water supplies.

# Problem To Be Solved

## Improving the industry of adhesives using waste materials, green energy, and feedback mechanisms:

An adhesive is a substance that can adhere (stick) to other materials, allowing them to be attached together. Adhesion is the state of attachment based on the attraction between the molecules of the items in contact. Adhesives are tremendously important because they are necessary for many industries of different kinds, small or heavy. For example, adhesives play an essential role in processing and packaging in small industries like food, toys, and stationery items. Also, adhesives are used in machines, furniture, and construction industries.

Adhesives are classified according to their properties into five types: drying adhesives, contact adhesives, thermoplastic adhesives, reactive adhesives, and pressure-sensitive adhesives. First, drying adhesives are a mixture of ingredients dissolved in a solvent. When the solvent evaporates, the adhesive hardens. Second, contact adhesives are those that must be applied to both surfaces and let it to dry before the two surfaces are pushed together. Third, thermoplastic adhesives, also known as hot melt adhesives, are applied hot and simply allowed to harden as they cool. Forth, reactive adhesives work by chemical bonding between two materials, producing a rigid material. The last type is pressure-sensitive adhesives, which form a bond by applying light pressure to bind the adhesive to the adherend. After bonding together, they become hard enough to resist flow, and then stress is applied to the bond.

## If solved (Positive Consequences)

## Environmentally:

Annually, the world generates about 2.01 billion tons of solid waste. Many of these materials are not biodegradable, such as plastic, which makes about 44% of the whole amount of waste. This leads many people to get rid of them only by combustion. This, in turn, harms the whole environment, especially the Earth's atmosphere, where the combustion process produces a great amount of CO2 gas, which is a main cause of the greenhouse effect. With, these harmful effects on the environment can be decreased if that waste materials were recycled to be used in other industries such as the adhesives industry.

## Socially

Since many of the most widespread diseases are due to the contaminated atmosphere that the patients are living in, recycling waste materials instead of burning them or getting rid of them in a harmful way can result in better public health in the world as a whole. In addition, improving the industry of adhesives should apparently involve building new factories, which means providing jobs for many people and decreasing the unemployment rate in the country.

## Economically

There are several positive consequences for improving the industry of adhesives since it involves building new factories, using green energy, and helping the government get rid of the waste materials in a way that can regain the money involved in their recycling. Building new factories means that there can be investments from the government or the private sector, which helps grow the country's economy. Also, using green energy means there will be less money needed to purchase the old energy productive materials like coal and petrol. In addition, recycling the waste materials to produce usable products can improve the economy a lot since the products can gain the money paid for them when paid in the inside or outside markets.

## If not solved (Negative Consequences)

## Environmentally

Leaving the environment without getting rid of the waste materials in an environmentally safe way will lead to massive disasters in the long term. As said before, burning waste materials will increase the greenhouse effect, which has very bad impacts on the planet, such as the melting of the two poles, which raises water levels on the whole planet. In addition, the dependence on traditional energy sources will also harm the environment since nearly all of them depend on combustion as well.

## Socially

The most apparent impact of not solving such a problem is the spread of diseases since the waste materials are usually neglected or gotten rid of in ways that are very harmful to the environment and the people. Besides, the jobs that the new factories could have provided will be eliminated, which means that the unemployment rate will still be as it is, which is not good since it is already high.

## Economically

The continuous dependence on traditional energy sources may lead to a remarkable increase in prices of almost all products since they are non-renewable resources, which means a slower economic development due to the slower selling and buying rate in the markets. In addition, the government would have to spend massive efforts to provide safe ways to get rid of the waste materials generated by its people.

# Research

## Topics related to the solution

### ❖ Feedback control system

A feedback control system is a complex in which the output is controlled by a feedback signal generated by the system's measurement. This feedback signal is compared to a reference signal to produce an error signal, which a controller then sorts to create the control input for the system. Diagram (1.7) shows a better illustration of the system.

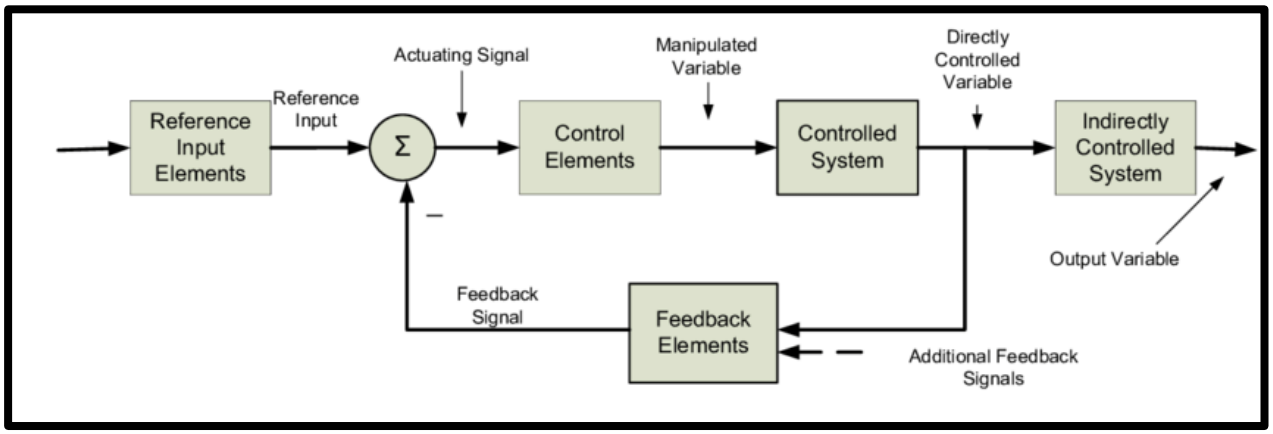



**FIGURE 1.7 THE FEEDBACK SYSTEM DIAGRAM**

Moreover, the feedback system improves control in closed-loop systems by automatically regulating the controller output to eliminate errors. It also provides stability to an unsteady process, resulting in a reliable and repeatable control loop. Furthermore, process variations are significantly reduced by reducing human involvement in the feedback loop. Such a system will substantially improve Egypt's industrial base as it operates industries through technological and automated systems.

## ❖ Green energy

FIGURE 1.8 DIFFERENT FORMS OF GREEN ENERGY

Any renewable energy derived from natural resources such as sunlight, wind, or water is green energy, as shown in figure 1.8. Wind power, solar energy, geothermal energy, and hydroelectric power are all examples of green energy. These technologies generate energy differently, whether by harnessing the sun's energy with solar panels, via wind turbines or through water flow. Such resources cannot produce pollution, as fossil fuels do, to be classified as green energy, which means that not all renewable energy sources are environmentally friendly(green).

Green energy sources also avoid mining and drilling, which can harm ecosystems. As a result, it is significant in the solution because it replaces the harmful effects of fossil fuels, such as the production of greenhouse gases, with more environmentally friendly alternatives. Many of Egypt's problems, such as pollution and climate change, could be solved if the reliance on this type of energy increased.

## ❖ Recycling


FIGURE 1.9 EXAMPLES OF RECYCLABLE MATERIALS

Recycling is the process of gathering and processing materials which would otherwise be discarded as waste and then transforming them into new products. This concept also includes the recovery of energy from waste materials. Glass, plastic, paper, textiles, cardboard, metal, tires, batteries, and electronics are all recyclable materials. Also, Composting and other biodegradable

waste reuse, such as food and garden waste, are examples of recycling. Other examples are mentioned in fgure 1.9.

The ability of a material to reclaim the properties it had in its original state determines its recyclability. It's a greener alternative to traditional waste disposal, saving resources and reducing greenhouse gas releases. It can also lessen the waste of potentially useful materials and the consumption of fresh raw materials, lowering energy consumption, air pollution (due to incineration), and water pollution (from landfilling). Consequently, recycling is an essential part of modern waste reduction. Removing raw material input and redirecting waste output in the economic system promotes environmental sustainability.

### ❖ Technology

Manufacturing and engineering technology can make production more efficient, faster, and straightforward. New tools and techniques for performing specific tasks in production, distribution, and data processing can be introduced using technology. It can also be used to improve the mechanization of the manufacturing process or to achieve a higher level of technical production system autonomy from human control, responsibility, or intervention. Subsequently, it alters technical production systems' nature and degree of integration, resulting in increased interdependence and an improved industrial base. Finally, it improves technical performance capabilities by increasing the efficiency of tools, equipment, and techniques in performing specific tasks, resulting in higher-quality products.

# Topics related to the problem

### ❖ Fossil fuels and CO2 emissions

Fossil fuels are formed from the decay of buried carbon-based organisms that died millions of years ago. They produce deposits rich in carbon, which are mined and burned for energy. They are non-renewable and currently provide about 80% of global energy. In addition, they are used to produce plastic, steel, and a variety of other things. The three types of fossil fuels are coal, oil, and gas.

Unfortunately, the Intergovernmental Panel on Climate Change (IPCC) has determined that fossil fuel emissions are the primary cause of global warming. Fossil fuels and industry accounted for 89% of worldwide $CO_2$ emissions in 2018. In the same year, the fossil $CO_2$ emissions in Egypt almost raised to 250 million tons. According to Graph.1.10, the total emissions from the industrial sector only was 15% of the total emissions of $CO_2$ this year. These emissions contribute to increasing global warming, which harms all living organisms on Earth in the long term.

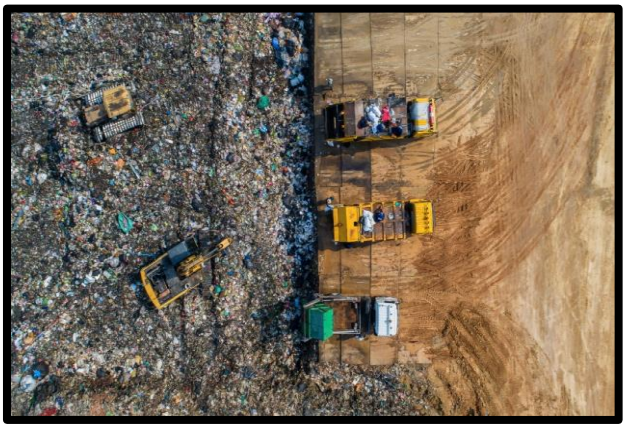
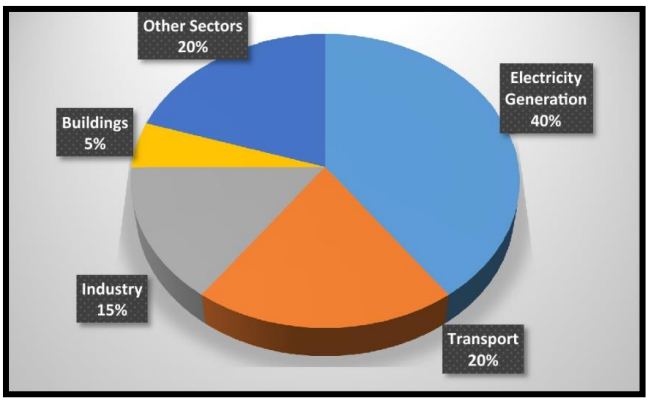


**FIG.1.10 GETTING RID OF INDUSTRIAL WASTE INTO UNSANITARY LANDFILLS**

## ❖ Safety challenges facing the recycling industry

The recycling industry has considerable safety challenges. For instance, chemical exposure, flammable dust explosions, machine guarding risks, and exposure to heavy machinery with moving parts are among them. Industry leaders should always take a proactive approach to safety, beginning with a thorough safety compliance audit at each plant and comprehensive safety training for all personnel to raise safety standards to the required level. This process may be a drawback for investors as they will spend more money training their workers. Also, because the recycling industry mainly uses waste materials that are not human-usable, any error in the process of recycling will lead to a big problem considering quality and safety measures.




**GRAPH 1.8 SOURCES OF CO2 EMISSIONS IN EGYPT IN 2018**

### ❖ Lack of proper waste management

Waste management is not an easy task to convince people to do. In Egypt, the factories, especially the private sector, get rid of their wastes in old traditional ways. They usually get rid of them by open-air incineration or dumping them in unsanitary landfills, as shown in *Fig.x*. These old ways are very harmful to the environment mainly because of the produced emissions from the combustion of these wastes. They may also result in significant environmental risks such as water, soil, and air pollution. With that being said, this lack of proper waste management will lead to a serious risk to human and animal health, and it will also impact the economy, especially the tourism industry.

# Prior solutions

## Environmentally friendly plywood made from recycled plastic

Wood is the only sustainable material among four critical types of raw materials (steel, cement, and plastics). It is also an ecological substance in the growth of many economies and cultures. So, in roughly 2010, a new study was conducted in China to replace traditional adhesives with compounds manufactured from recycled plastic shopping bags to produce hot-melt plywood (as shown in fig 1.11) utilizing varying amounts of plastic film variable hot-pressing temperatures and hot-pressing periods. The intensity and water resistance of plywood are affected by all three elements. The findings reveal that the bonding strength of plywood does not increase as the amount of plastic film is increased.

FIGURE 1.11 PLYWOOD AFTER THE PROCESS

Plywood is an engineered wood product that can be used for various purposes, including outdoor building, furniture, and décor. Plywood is manufactured by gluing thin strips of wood together. Exterior plywood sheets for usage outside are produced with a waterproof adhesive to withstand the elements. This project proposes a new method of reusing plastic trash that, in the end, may solve the problem of formaldehyde emissions without harming the environment and hence has enormous market potential.

## Mechanism

The project consisted of three steps to replace traditional adhesives with compounds made from recycled plastic shopping bags to generate hot-melt plywood:

### ❖ Preparation of plywood

This is the first step where the plastic bags that had been recycled were washed, treated with a chemical reagent, dried, and shredded. The plywood was then hot-pressed according to the conditions listed in Table 1.1 after a quantity of recycled plastic bags were weighed and placed between aspen veneers.

| Treatment | Amount of plastics ($g \cdot m^{-2}$) | Hot-pressing Temperature (°C) | Hot-pressing time (min) |
|---|---|---|---|
| 1 | 60 | 130 | 3 |
| 2 | 60 | 140 | 4 |
| 3 | 60 | 150 | 5 |
| 4 | 60 | 160 | 6 |
| 5 | 80 | 130 | 4 |
| 6 | 80 | 140 | 3 |
| 7 | 80 | 150 | 6 |
| 8 | 80 | 160 | 5 |
| 9 | 100 | 130 | 5 |
| 10 | 100 | 140 | 6 |
| 11 | 100 | 150 | 3 |
| 12 | 100 | 160 | 4 |
| 13 | 120 | 130 | 6 |
| 14 | 120 | 140 | 5 |
| 15 | 120 | 150 | 4 |
| 16 | 120 | 160 | 3 |

TABLE 1.1 CONDITIONS TO PRESS PLYWOOD

### ❖ Measurement of bonding strength

The plywood's bonding strength was tested in the second step by GB/T 9846.7-2004 (Plywood of Standard of the People's Republic of China, Part VII). The samples were placed on the testing machine straight, both ends fastened in a movable holding fixture, and the sample center at the testing machine fixture's center axis.

### ❖ Measurement of formaldehyde emission

Finally, the samples utilized for formaldehyde emission measurements were produced by GB/T 9846.7-2004, too. The specimens were stored for 24 hours in wide-mouth bottles (500 mL) at a temperature of 20°C. A formaldehyde determination was used to measure the amount of formaldehyde released.

## Conclusion

The products were mainly three-layer or five-layer urea-formaldehyde-resin bonded or phenolic-resin bonded plywood following all of these treatments. Currently, urea-formaldehyde and phenolic resins are the most commonly used adhesives in plywood manufacturing, accounting for 87.1 per cent and 9.6 per cent of all adhesives used. Urea-formaldehyde resin is non-flammable, has good adhesive strength, is resistant to changes in high temperature, light, and corrosion, has a quick curing time, and has low production costs.

## Advantages

### ❖ Cost-effective

This technique has a minimal cost because it requires a few technologies and procedures. Plastic shopping bags can also help businesses save money by lowering the cost of the entire manufacturing process.

### ❖ Energy consumption is reduced

Raw materials are processed with a lot of energy in the typical adhesive manufacturing process. However, in this study, adhesives were built with compounds generated from recycled plastic shopping bags to produce hot-melt plywood, which helps to reduce energy consumption, which is vital in large-scale operations such as mining and refining.

## Disadvantages

### ❖ Difficulty in operation

To ensure that the task is done correctly, the project's operations require highly competent observers. The project's steps are tough to manage since they need highly skilled individuals who have received substantial training.

### ❖ Environmental impact

Each item of recycled plastic poses a hazard to the environment. VOC emissions are produced during the melting and recycling of plastic, and they can harm plant and animal life near the industrial site. The heat required to melt plastic emits carbon dioxide, contributing to global warming.

# C2CA Concrete Recycling


**FIGURE 1.12 CONSTRUCTION AND DEMOLITION WASTES**

Construction and Demolition Waste (CDW) (as shown in fig 1.12) is currently generated across the EU 28 countries at a pace of 461 million tons per year, with an average recycling rate of roughly 46%. The updated Waste Framework Directive (WFD) states that by 2020, the minimum recycling proportion of non-hazardous CDW shall be at least 70% by weight. The CDW's heaviest component is known to be end-of-life concrete. It is conceivable to move closer to the 2020 World Food Day target objective by recycling a portion of the CDW concrete component into high-quality construction materials such as gravel, sand, and hardened cement. High-quality recycled aggregate production and reuse in countries like the Netherlands, Belgium, and Denmark are already well-studied and implemented. In Delft, Netherlands, the project of recycling concrete fines into hardened cement and clean sand was first carried out. Although most standards still ban the use of substantial crushed fines in fresh concrete production, concrete built from recycled aggregates is becoming a practical reality in the building construction sector. In a C2CA project industrial trial, 600 tons of AF were successfully used to create Portland cement in a Heidelberg cement industrial cement kiln in the Netherlands. The average percentage of CaO and SiO2 in the used AF was reported to be 11.7 per cent and 75.5 per cent, respectively, even though the cement produced in this trial was of good quality.

# Mechanism

Recycling concrete into Hardened Cement and Clean Sand is a lengthy process (as shown in fig 1.13). The project's processes begin with crushing EOL concrete, followed by autogenous milling to remove loose mortar from the aggregates' surface. The loose mortar must be removed to improve the recycled aggregate's mechanical strength.

After autogenous milling, a new low-cost classification method called Advanced Dry Recovery (ADR) removes fines and light impurities, with a cut-point for mineral particles adjusted between 1- and 4-mm. ADR employs kinetic energy to dissolve the bindings produced by moisture and tiny particles, allowing it to classify practically moisture-independent materials. When the material is split up into a jet, the fine particles are separated from the coarse particles.

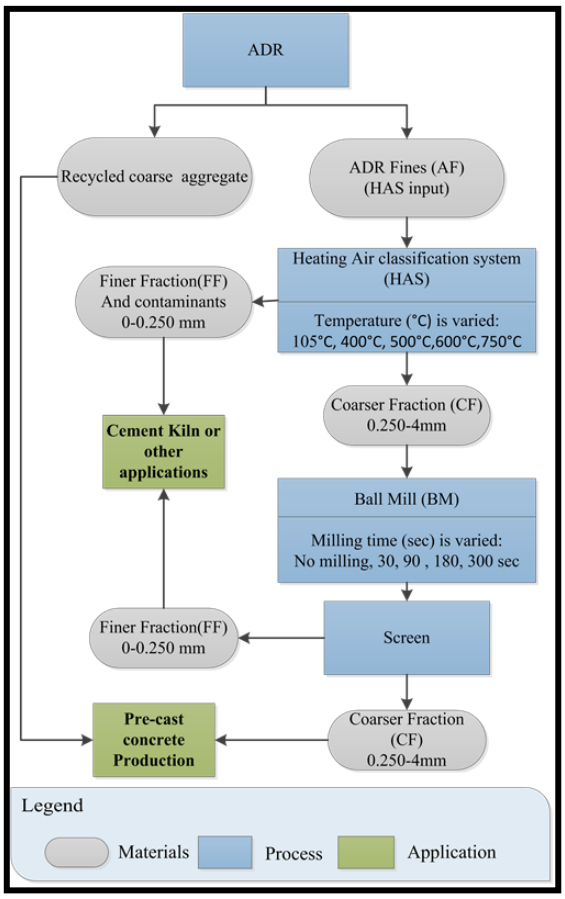



**FIGURE 1.13 STEPS OF THE RECYCLING PROCESS**

The Heating-Air classification System (HAS) is then utilized, followed by material grinding in a Ball Mill (BM). HAS is constructed from a 600 mm long inclined pipe. To prevent heat dissipation, the pipe is capped with a steel lid. The chamber is heated by three burners with a flame temperature of 1410 C. Three thermocouples connected to a computer are used to measure the temperature within the pipe. Air classification is used from the pipe's downer opening to separate the Finer Fraction (FF) from the Coarser Fraction (CF). As a result, FF and light pollutants can be collected in a container attached to HAS's upper section. Following the heating of the materials, the CF is pulverized in a ball mill. Steel balls are inserted into the mill chamber to aid sand liberation from cement powder.

For automated online quality control and assurance, the C2CA technology develops two types of sensors: hyperspectral imaging and laser-induced breakdown spectroscopy. Aside from in situ processing and local aggregate reuse, another key target of C2CA is to reduce CO2 emissions in cement manufacturing by concentrating part of the cement paste from EOL concrete into a distinct fraction that may be reused as a low-CO2 feedstock to replace primary limestone. In this regard, various attempts have lately been made to utilize crushed concrete fines or ADR Fines (AF) as low-CO2 input materials for clinker production.

## Advantages

### ❖ Minimal residues

The project's operation makes use of the highest quality processed recycled materials. The materials are treated at various stages throughout the production.

### ❖ Saving Energy

The C2CA's operations did not require a significant amount of energy. It only needed a small amount to operate the heater burners and process the materials through the various stages of the project.

## Disadvantages

### ❖ Expensive Construction

The project's construction is costly. The facility's construction and personnel training and other expenses will cost a lot of money. Furthermore, the project will require maintenance to replace the defective item and resolve technical concerns.

### ❖ Difficult to operate

The project's operations necessitate highly skilled observers to ensure that the work is followed. The project's steps are challenging to maintain since they require highly experienced people with extensive training to operate.

# Recycling of Fiberglass Polyester Waste Composite for Glass-Ceramic Material Manufacturing.

FIGURE 1.14 GLASS FIBER

The long-term removal of composites is still a challenge currently. On the one hand, worldwide composites material output grows every year and is predicted to reach 10.3 Mt in 2015. Approximately 90% of these composites are thermostable composites with glass fibers (as shown in fig 1.14) (fiberglass reinforced polymers) (FGRP). Furthermore, the United Kingdom and Germany have made it illegal to discard this garbage. So, around 2012, a project was carried out in Madrid, Spain, to recycle Glass Fibers from Fiberglass Polyester Waste Composite to manufacture Glass-Ceramic Materials. The viability of reusing a glass fiber obtained from the thermolysis and gasification of waste composites to produce glass-ceramic tiles is presented in this project. Composites are challenging to recycle since they often comprise two or more components (filler, fiber, resin, etc.). Thermoset composites are particularly difficult to recycle. The resulting material cannot be remolded once the thermoset matrix molecules are crosslinked. Furthermore, most thermosetting resins, such as polyester and epoxy resin, cannot be depolymerized to their constituents. This project demonstrates how waste composites can be valorized through a thermolysis and gasification process and the appropriateness of glass fiber as an alternative raw material in producing plagioclase glass-ceramic material for architectural purposes.

## Mechanism

The polyester fiberglass (PFG) waste used in this project is made up of E-glass fiber ($SiO_2$, $Al_2O_3$, CaO, MgO, $B_2O_3$) and unsaturated polyester resin manufactured from orthophtalic acid and styrene (as shown in Table 1.2).

| Component | Proportion (wt%) |
|---|---|
| Ortho-phthalic polymer resin | 32.8 |
| Organic catalyst | 0.3 |
| Styrene monomer | 1.2 |
| Zn stearate lubricant | 1.2 |
| Fiberglass | 64.5 |

TABLE 1.2 THE COMPOSITION OF PFG WASTE

PFG was treated in a 9.6 dm3 thermolytic reactor, including a heating system and a gas condensation apparatus, at 550°C for 3 hours. Based on preliminary research, a temperature of 550°C was chosen as the operating temperature. The thermolysis process resulted in a solid residue, oil, and non-condensed gas. The difference between the starting weight of PFG and the number of liquids and solids collected was used to estimate the amount of gas created. In an air atmosphere, the solid residue generated after thermolysis was oxidized. Following thermolysis, compressed air (20 l/h) was introduced into the reactor to keep the temperature at 550°C. The end product is glass fiber that is free of organic materials. The recovery of weight in glass fiber during the gasification stage was calculated using Equation (1.1). where "Yt" is the yielding mass of the solid residue obtained during thermolysis, "Yg" is the mass loss during gasification and WGF is the glass fiber of the initial PGF waste.

$$R_{GF}(\%) = \frac{(Y_t) - (Y_g)}{(W_{GF})} \times 100$$

**EQUATION 1.1 MEASURES THE RECOVERY OF WEIGHT**

The morphology of the post-thermolysis solid residue (char-covered glass fibers) was studied using a scanning electron microscope (SEM). For observation, the samples were coated in graphite. After gasification, the clean glass fibers were gold plated and inspected with a field emission microscope (FEM). Individual fiberglass filaments were subjected to tensile tests. The fibers were painstakingly retrieved using ordinary tweezers and then put onto a cardboard frame using epoxy adhesive (Araldite). A small thin rectangle, about 1 mm by 8 mm, with a small rectangle cut from the middle, about 0.5 mm by 4 mm, makes up the frame. For the tensile tests, the cardboard frame was attached to the grips of a microelectromechanical testing machine. The load was applied to the fiber immediately after cutting the cardboard sides, and the tensile test was performed under stroke control at a crosshead speed of 2 m per minute. The fiberglass filament's young modulus was also calculated.

## Advantages

### ❖ Low energy demand

It takes less energy to make items from recycled materials than it does from new raw materials. There can be a significant disparity in energy levels at times. Recycling glass fibers into ceramic glass, for example, consumes 20% less energy than producing it from its raw material.

### ❖ Reducing demand for raw materials

More of the world's poorest and most vulnerable people (for example, those living near forests) are uprooted from their homes or exploited in many ways as the world's desire for new products develops. As a result of the desire for inexpensive wood, forest communities may be displaced, and rivers may be ruined or poisoned by industrial waste. Fiberglass recycling for glass-ceramic material manufacturing will help to lessen the demand for new glass-ceramic materials.

## Disadvantages

### ❖ High cost

The cost of this process is very high as it needs many technologies and also because the thermoset composites therefore commonly end up in landfills. Since the components are nonbiodegradable, the economic costs of such disposal can be very high.

### ❖ Contamination during sorting

Different components in the glass might impair the quality of recycling collections while separating the materials, increasing treatment costs; removing contamination requires time and effort.

## Recycling of paper pulps

Many papers are utilized daily, yet most are discarded as useless and thrown away. The ecology is impacted by industrialized paper production upstream and downstream, where raw materials are purchased and processed. Nowadays, about 90% of paper pulp is made from wood. Paper manufacture is responsible for roughly 35% of all tree destruction and 1.2 per cent of global economic activity. A tone of newsprint saves around one tone of the wood, whereas a tone of printing or copier paper saves more than two tons of wood.

As a result, the design and implementation of a waste paper recycling plant is a positive move because it will ensure that the source of raw material for paper manufacturing is multiplied, as well as that waste paper that would otherwise end up in the waste stream is recycled for various productive purposes. Recycling has become a multibillion-dollar industry that saves energy, reduces landfill demand, and conserves natural resources. Because different types of paper are processed differently during the paper recycling process to produce various recycled paper goods, this assignment will require sorting newsprint, computer paper, and magazine paper.

## Mechanism

This process has multiple parts, with the first being converting waste paper to pulp. The sorted paper is typically immersed in a pulper containing both water and chemicals. Discarded paper is shredded into small particles. When the combination is heated, the paper breaks down more quickly into small strands of cellulose (organic plant material) called fibers. The old paper gradually degrades into pulp, which is a mushy substance.

The pulp is driven through screens with holes and slots of various shapes and sizes. The screen removes small contaminants such as plastic shards and glue globs. Screening is the term for this process. Centripetal pressures also eject heavy impurities from the cone, whereas lighter contaminants gather in the cone's center and are removed. This practice is referred to as cleaning. The pulp has been purified and is now ready to be recycled into paper. The recovered fiber can be utilized alone or in combination with new wood fibers to increase strength and smoothness. Chemicals and water are added to the pulp until 99.5 per cent water.

The following processes were primarily used in the recycling of wastepaper.

Pulping Waste was mixed with water paper to make pulp. After experimentation with various wastepaper and water ratios, the best pulp was determined using a ratio of 100 grams of wastepaper to 4 litres of water. To make pulp, a hand-operated pulp machine was employed.

### ❖ Screening

When the pulp was obtained, it was placed on the screener. As a result, the pulp slurry settled down on the screener.

### ❖ Rolling

The pulp was rolled using a hand roller to remove any leftover water following the screening.

### ❖ Drying and Paper Making

After rolling, it was dried in the sun for about 2 hours. After drying, it was carefully pulled over the screening.

## Advantages

### ❖ Reducing Global warming

As previously said, recycling paper can aid in the reduction of global warming. Paper production is responsible for the destruction of numerous trees in various circumstances. However, because trees absorb CO2 from the air, which releases enormous amounts of CO2 into the atmosphere, it contributes significantly to the problem of global warming if done on a wide scale.

### ❖ Protecting the environment and animal habitats

The removal of trees to create paper may cause severe damage to animal habitats. This is especially concerning when rare or endangered species' habitats are threatened. We can reduce the need for these trees to be damaged by recycling. We can safeguard the environment and help sustain natural habitats rather than destroy them by attempting to repurpose items rather than simply discard them.

## Disadvantages

### ❖ Polluting water

The wastewater produced by the paper industry is diverse, contains considerable amounts of organic contaminants, and is highly polluted. The pulping and paper-making wastewater has complicated physical features and various organic contaminants. It's one of the most problematic industrial wastewaters to deal with. Solid pollutants, soluble pollutants, colloidal pollutants, and other contaminants are common in wastewater from the paper industry.

### ❖ Deinking and bleaching

The waste paper must be deinked and bleached before being used to make recycled paper. Chemical pollutants will be produced by the paper industry's drinking portion. Chlorine bleaching is commonly used in the bleaching sector. As a result, bleaching wastewater has a high concentration of chlorinated organic compounds. It is extremely difficult to deal with chlorine phenol, fatty acid chloride, chloride resin acid hazardous, and other chlorinated organic compounds. They're also a potent toxin that can result in many cranial nerve lesions.

# Chapter two

# Solution Requirements

## ❖ Sustainability and durability

Sustainability and durability are necessary characteristics that must be available in any factory because they are often built inside industrial areas where the atmospheric conditions are not always perfect. Sometimes, it may be very hot with incredible wind speed that needs a solid building to tolerate it. Besides, factories and industrial projects are often built to be in continuous production of their specific product. So, they should be constructed from materials that can last for too long without being eroded or need maintenance frequently.

## ❖ Eco-friendliness

Eco-friendliness is a vital property of the solution where almost any industry produces waste materials that may harm the environment. So, the solution should consider using materials that are not harmful to the environment, and their wastes can be recycled easily. Also, the solution must contain a systematic way to collect and recycle the wastes produced from the primary production process.

Besides, the solution must consider using green sources of energy instead of the usual non-renewable energy sources that harm the environment. Non-renewable sources like coal are very harmful as their combustion contributes to increasing the greenhouse effect. On the other hand, green energy sources like solar and wind energy are not harmful to the environment. They can also work without the burdens of extraction and transportation of non-renewable sources.

## ❖ Using modern technologies

Technology is now considered the base factor that can ultimately change any process into a more efficient form. Using modern technology can provide the industry with the needed system to control the industrial processes. That level of control can go from basic operations to feedback mechanisms and even automation. So, the solution must include available technology systems like the various types of sensors and motors. Besides the mentioned advantages of modern technologies, technology can also improve the production rates of almost any industry by accelerating the speed of the subprocesses in the industrial process.

### ❖ Location

Many industries emit things that are tremendously harmful to living organisms, such as smoke or dangerous waves. So, building factories away from residential areas must be considered to reduce the harm as much as possible. However, it should also be considered to build them not too far from the raw materials or the waste materials that will be recycled to reduce transportation burdens.

### ❖ Protection and considering safety precautions

Most factories are home to a lot of chemical processes that are usually dangerous. So, they must be constructed of materials that suppress and tolerate any sudden hazardous accidents that may happen in the future. Also, the security systems of the factories must include anti-disaster tools. For instance, if the industrial process comprises flammable materials, the security system must be prepared with fire extinguishers to counter any unexpected accidents.

# Design requirements

For any prototype, it is a must to have parameters to measure the degree of its success. These parameters are the design requirements. The design requirements are simply the goals of the prototype, and the design requirements for this project are the following:

### ❖ Adhesion

The adhesion is how the attachment between the adhesive and the substance needs to be glued. This attachment may be mechanical, chemical, or through Var der Waals forces. Adhesion can be measured from different aspects, such as shearing, bend adhesion test, and other test types. Particularly, the design requirement is making the beechwood stuck with the EPS adhesive endure 47.6 newtons / $centimetre^2$ through bend adhesion test.

### ❖ Energy consumption rate (power)

Energy consumption rate (power) is one of the most important aspects of any project's success criteria as the energy consumption rate detects the cost of the production. Our design requirement is to consume no more than 10 watts from green energy resources.

# Selection of solution

## ❖ Solar energy

The Sun is a tremendously powerful source of energy, and the sunlight is, by far, the most abundant source of energy that Earth receives. The total amount of solar radiation incidents on Earth far outnumbers the world's current and projected energy needs. This highly diffused source has the power to fulfil all future energy needs if adequately harnessed. In contrast to the finite fossil fuels coal, oil, and natural gas, it is an appealing green renewable energy source because of its infinite supply and nonpolluting nature. Using such an energy resource in the project to power the manufacturing process will be valuable, as it is sustainable and doesn't pollute the environment. Also, it is considered the best fit for the project because the adhesive production process itself doesn't require that much energy.

## ❖ Technology

Technology is one of the most effective things humans have invented, and as time passes, technology becomes more and more engaged in different aspects of life. One of these aspects is industry. Technology is used to do complex or even impossible tasks for them. Using the technology, many industries can be completely automated, efficiently producing products, saving time and effort, and reducing errors. The technology will be used in the project to make the solar panels automatically adjust their position by rotating vertically to make the panel perpendicular to the sunlight rays. This mechanism will provide maximum efficiency in energy harnessing.

## ❖ Recycling expandable polystyrene wastes

The expanded polystyrene granule (EPS) is around forty times the volume of the initial polystyrene granule, with more than 95 % air and only about 5 % plastic EPS. It is one of the most widely used commodity polymers in the world. EPS is a solid foam with unique properties, including lightness, insulation, and durability, making it broadly used in everyday life as packaging, construction, and household appliances, among other things. On the other hand, Waste EPS has caused significant environmental pollution due to its inability to decompose naturally. These environmental problems lead to using it as an input in the manufacturing process of adhesives.

## ❖ Feedback control systems

1. Refilling feedback mechanism

   In the recycling process of expandable polystyrene wastes, ultra-low-sulfur diesel (ULSD) must be used to make the process work. However, ULSD evaporates in the air rapidly, making it needs a continuous refill. Consequently, a feedback control system can be used to automatically make this refill through the negative feedback given by a sensor that measures the level of ULSD. When the ULSD level decrease, the sensor sends negative feedback to the system to refill it. Such a control system provides a continuous process without human interference.

2. Energy-saving feedback mechanism

   The production of the adhesive process must contain a stirring stage to mix the expandable polystyrene foam with ULSD. Another feedback system can be used to stop stirring when the adhesive is ready to manipulate this process. As the adhesive is formed, the resistance to the stirrer increase, so the sensor sends negative feedback to stop stirring. This system also helps to know the process's state and preserve energy consumption.

# Selection of Prototype

The selected prototype consists of two main parts: an energy-generating part and a recycling part. The two parts integrate to complete the process of recycling foam into an adhesive material and generate the energy needed to complete the whole process.

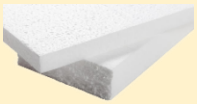
The first part consists of two solar panels. These two solar panels are fixed on a structure of wood. A motor and a specific sensor will track the light with the highest intensity available and rotate the solar panels towards them to produce as much energy as possible. This energy will charge a battery that is going to be used to power the other part of the prototype.

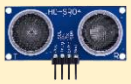
The second part of the prototype comprises a glass container with two metal jars fixed inside it. The dimensions are 0.3m in length, 0.3m in width, and 0.25m in height. One of them stores the organic solvent used to dissolve the waste polystyrene foam to make adhesive. The other jar will contain the chemical process between the foam and the solvent. There will be a motor to stir the product in the second jar, and it will be connected to a sensor to make a feedback mechanism that controls and accelerates the adhesive production. Also, there will be a pump that brings the stored organic solvent to the second jar when needed. This pump is based on a feedback mechanism that utilizes the pump and a sensor that gives the ability to measure the volume of the solvent in the second jar.

The formed adhesive can then be used to stick two pieces of wood, as an example, in order to measure the first design requirement, which is the strength of the adhesive. Also, the energy consumed during the process of adhesive production will be measured to evaluate the second design requirement. In addition, the prototype as a whole can be tested by putting the prototype in the sun to charge the battery from the solar panels and then start the process of adhesive production.

# Chapter three

## Materials

| Item | Quantity | Cost | Source of purchase | Picture | Description / Usage |
|---|---|---|---|---|---|
| Ultra-low-sulfur diesel | 1 bottle (1 liter) | 60 L. E | chemicals store |  | It is used in dissolving the EPS. |
| Expanded Polystyrene (EPS) foam | 0.1 kg | 20 L. E | home appliances store |  | It is dissolved by ULSD to make the adhesive. |
| Arduino UNO | 1 Arduino UNO board | 200 L. E | Future electronics shop |  | It is used to Control how electricity is distributed throughout the prototype. |
| Lithium-ion polymer (Li-Po) Battery (3.7V 2200mAh) | 1 battery | 80 L. E | Future electronics shop |  | It is used to store the solar energy and then provide the prototype with it in need. |
| Lithium Battery Charger Module | 1 chip | 30 L. E | Future electronics shop |  | It is used to charge the lithium batteries from the solar panels. |
| Step-up transformer | 1 transformer | 25 L. E | Future electronics shop |  | It is used to increase the voltage from the battery's 3.7 V to 5 V. |

| | | | | | |
|---|---|---|---|---|---|
| Current sensor | 1 current sensor | 40 L. E | Future electronics shop |  | It is used to detect the electric current in the motor. |
| Micro Metal Gear DC Motor (30 RPM) 6V | 1 motor | 40 L. E | Future electronics shop |  | It is used to stir the ULSD with the EPS. |
| 5V Water Pump | 1 water pump | 30 L. E | Future electronics shop |  | It is used to pump the ULSD into a container to dissolve the EPS. |
| Ultrasonic Distance Sensor Module HC – SR04 | 1 chip | 30 L. E | Future electronics shop |  | It is used to measure the distance to the adhesive. |
| Solar Panels | 2 rectangle-shaped panels (0.15m×0 .13m) | 2×110 L. E | Future electronics shop |  | It is used to generate solar energy to charge the battery. |
| Light Dependent Resistor (LDR) | 2 LDRs | 2×7 L. E | Future electronics shop |  | It is used to adjust the solar panels' direction according to the light rays. |
| Micro Servo Motor | 1 motor | 35 L. E | Future electronics shop |  | It is used to rotate the solar panels. |
| Bluetooth HC 05 Module | 1 chip | 35 L. E | Future electronics shop |  | It is used to send and receive data from Arduino to the android app. |

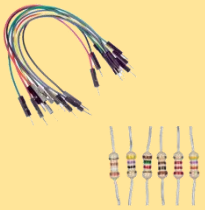
| | | | | | |
|---|---|---|---|---|---|
| Electric wires and resistors | As much as needed | 20 L. E | Future electronics shop |  | They are used to make the electric circuit. |
| Glass container | 1 container (0.3m×0.3m×0.25 m) | 115 L. E | Glass shop |  | It is used to keep all the prototype's components into it. |

**TABLE 2.3 – THE MATERIALS OF THE PROTOTYPE**

## The total budget is 994 L.E

# Methods

The most important materials used in constructing and building the prototype, their illustrations, and the quantities used are all shown in table (1). These materials were used to build the prototype as follows:

1) The two solar panels were fixed together on a wood frame and connected to the 2 LDRs and the micro servo motor to rotate the solar panels towards the light with the highest intensity available, as shown in Fig (1.15).
2) The Li-Po battery was connected to the solar panels through the lithium battery charger module for the first time to be charged. On discharge, it is connected to the Arduino to power the system. A step-up transformer is used between them to increase the voltage to suffice the need of the Arduino.
3) A glass container was made with dimensions 0.3×0.3×0.25m to contain the recycling part of the system. Also, a metal jar was fixed inside the glass container to hold the chemical process, as illustrated in Fig (1.16).
4) The current sensor and the micro metal DC motor joined with a wood hand are fixed at the top of the glass container. A feedback mechanism is made using these two components to control the adhesive production.
5) The ultrasonic distance sensor was fixed at the top of the metal jar inside the glass container. Also, the water pump was set on another metal jar that stores the whole amount of diesel, as shown in Fig (1.17). The ultrasonic sensor and the water pump form a feedback mechanism to control the amount of diesel in the primary chemical process.

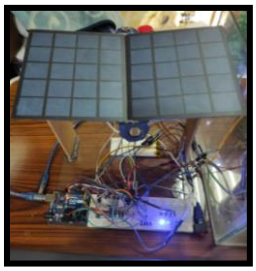


FIGURE 1.15 - FIRST PART OF THE PROTOTYPE

FIGURE 1.16 – SECOND PART OF THE

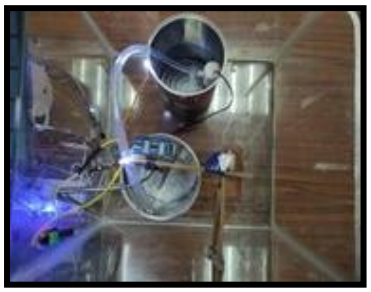


FIGURE 1.17 – INNER PARTS OF THE SECOND PART

After powering the Arduino from the Li-Po battery and building the main parts of the prototype, it was necessary to connect all the components to the Arduino to control the system.

6) The Arduino was connected to the previously mentioned motors and sensors using basic materials needed for electric circuits, such as a breadboard, wires, and resistors.

7) After finishing the essential connections, a Bluetooth module was connected to the Arduino, and a mobile application was developed to manage the system remotely.

## Safety precautions

Wear gloves because ultra-low sulfur diesel (ULSD) can irritate, dry, and break the skin; if the skin is exposed to it for an extended period of time, burns may occur. Wearing a mask while dealing with the ULSD because it can cause respiratory problems. Wearing appropriate eye protection during the process as the ULSD is volatile and can harm your eyes. Avoid touching the adhesive with your naked hand as it may stick to your hand.

# Test Plan

1) Waste EPS was collected and cleaned. Its mass was measured before dissolving in ULSD.
2) The prototype was put in a sunny place of moderate conditions to charge the Li-Po battery. Also, the LDR has been tested to see how the angle of the servo motor changes to track the sun.
3) In the main process, a sample EPS was put in 0.1L of ULSD. The motor started to stir the mixture.
4) The mixture became a little hard, the current sensor detected the increase in current, and the motor stopped. Simultaneously, the ultrasonic sensor was reading the height of the diesel in the container, and when the level of the diesel decreased, the water pump started to work to compensate for this low level.
5) After finishing the process, the resulting adhesive sample was used to glue a piece of beech wood, which was then tested with various masses to test the strength of the adhesive.

# Data Collection

## Negative results

The prototype experienced a problem after testing and acquiring the necessary data, resulting in negative results. The problem was that we used acetone to dissolve the EPS at first, which made it sticky yet didn't dissolve it entirely. As a result, the problem was solved by using ultra-low sulfur diesel (ULSD), making the glue stickier, resulting in higher efficiency.

## Positive results

The prototype has been tested and achieved excellent results. It was created to provide a new way of manufacturing adhesive for wood, plastic, and other similar materials using recycled materials. As a result, it has been tested in terms of adhesion (which is the property of sticking together like glue and wood) and the power used to manufacture the adhesive compared to the traditional method. After dissolving 70 g of EPS in 100 mm of ULSD, the relation produced between the EPS and the ULSD is illustrated in this equation "$y = \frac{7}{10}x$" (where y is the ULSD in milliliters and x is the EPS in grams).

To eliminate errors caused by observational error, poor instrument calibration, or environmental impacts, a test plan was made, and three trials were carried out. After that, the average was calculated as the most accurate representation of the exact result. Our requirement has been met, as evidenced by the adhesion property results (as shown in table 3.1) with an average equal to 47.6 ± 0.6 N/cm$^2$.

The other design requirement, which is lowering energy consumption rate (power), was tested, and great results were achieved (as shown in table 3.1), indicating that the prototype consumes about 4.5 ± 0.2 J/s. These results were calculated using the "Power= potential difference × current intensity" formula.

| Property | 1st trial | 2nd trial | 3rd trial | Average |
|---|---|---|---|---|
| Adhesion strength | 50 ± 0.6 N/cm$^2$ | 45 ± 0.6 N/cm$^2$ | 47.8 ± 0.6 N/cm$^2$ | 47.6 ± 0.6 N/cm$^2$ |
| Energy consumption rate (Power) | 4.8 ± 0.2 J/s | 4.1 ± 0.2 J/s | 4.6 ± 0.2 J/s | 4.5 ± 0.2 J/s |

TABLE (3.1) – POSITIVE TEST RESULTS

# Analysis and Discussion

After the results had showed how the project achieved the design requirements, the following is an attempt to explain how these results were achieved in a scientific-based way.

## The adhesive synthesizing

The adhesive synthesizing process depends mainly on two components: expanded polystyrene (EPS) and ultra-low-sulfur diesel.

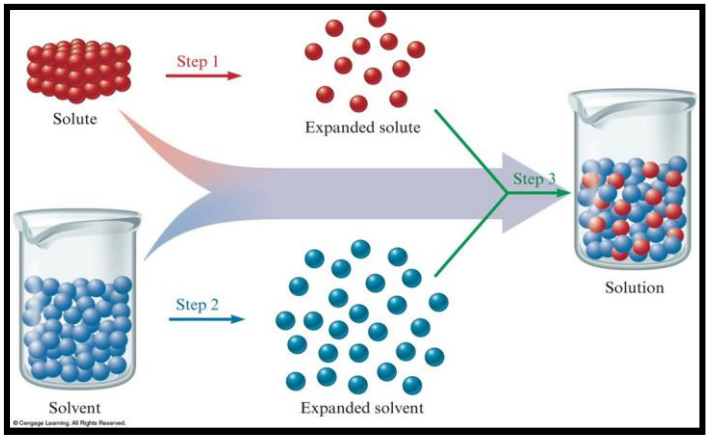



**FIGURE (3.4) – THE MOLECULAR DIAGRAM OF THE DISSOLVING EPS PROCESS**

Starting with EPS, it is a lightweight cellular plastic material consisting of tiny polystyrene beads expanded with an expanding agent, a chemical that produces a gas when heated. This agent could be carbonate or a volatile liquid, a liquid that quickly makes gas (such as pentane). The agent expands the beads and fills them with air. As a result, air makes up most of the gas in the solid foam, and EPS is about 95% air and only 5% plastic.

On the other hand, the Ultra-low-sulfur diesel is a low sulfur content Petro diesel composed of a mixture of hydrocarbons. The EPS may appear to disintegrate in diesel. However, it doesn't; as shown in Fig (3.4), it softens as it absorbs the diesel and enables the air to escape, causing the foam to collapse. The evolved gas is created by a physical mechanism rather than a chemical reaction because the diesel serves as an organic solvent for the EPS, which is organic. Diesel molecules are scattered in a network generated by a tangle of massive polystyrene molecules in the resulting water-proof sticky colloidal gel.

## Lithium Polymer (Li-Po) Battery

Li-Po battery is a secondary 3.7V galvanic cell that can be recharged by reversing its spontaneous redox reaction, as learned in Chemistry LO 2.09. Li-Po battery is considered a lithium-ion battery but with a high conductive polymer electrolyte instead of a liquid electrolyte. The Li-Po battery operates on deintercalation and intercalation of lithium ions from positive electrode (cathode) materials to negative electrode (anode) materials.

The Li-Po cell consists of a negative graphite electrode (anode), a lithium metal oxide positive electrode (cathode), and a separator layer, as shown in Fig 3.5. Manganese, nickel, cobalt oxide compounds, or mixtures make lithium metal oxide. The mixed-metal cathodes have greater charge capacity, power output, and shorter recharge times.

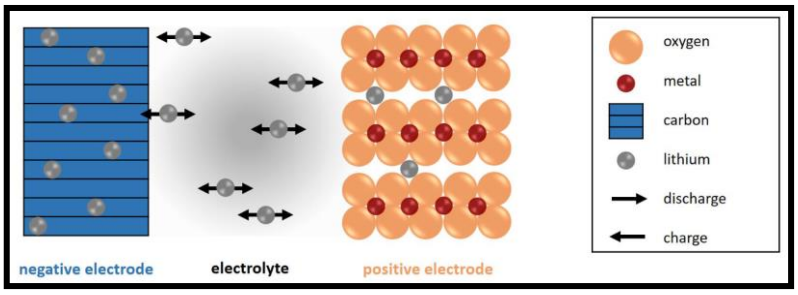



FIGURE (3.5) – COMPONENTS OF THE CELL OF LI-PO BATTERY

## Reactions inside Li-Po cell:

During the discharge of the Li-Po cell, two complementary reactions take place inside the cell, oxidation at the anode and reduction at the cathode. These two half-reactions at each electrode form the whole redox reaction on which the cell depends.

## Oxidation half-reaction:

At the anode, an oxidation reaction occurs, which produces electrons ($e^-$) and positive lithium ions ($Li^+$), as in equation (3.1). This process is also known as the deintercalation of lithium from graphite, where the lithium leaves the graphite as an ion and starts to move towards the cathode.

$$Li_xC_n \underset{L}{\overset{E}{\rightleftharpoons}} C_n + xLi^+ + xe^-$$

EQUATION (3.1) – OXIDATION HALF REACTION

## Reduction half-reaction:

At the cathode, a reduction reaction takes place where the positive lithium ions are being reduced, increasing the mass of the lithium metal oxide cathode, as in equation (3.2).

$$Li_{1-x}MO_2 + xe^- + xLi^+ \underset{L}{\overset{E}{\rightleftharpoons}} LiMO_2$$

EQUATION (3.2) – REDUCTION HALF REACTION

Combining these two half-reactions form the net reaction of the cell illustrated in equation (3.3). This equation is reversed during the charging of the battery, where the direction of movement of electrons and ions is reversed, and a lithium intercalation process occurs at the graphite electrode.

$$Li_{1-x}MO_2 + Li_xC_n \underset{L}{\overset{E}{\rightleftharpoons}} LiMO_2 + C_n$$

EQUATION (3.3) – REDOX REACTION

## Lithium battery charger (TP4056 module)

Charging voltage above the maximum value, discharging voltage below the minimum value, or charging variable current can create unstable conditions inside the battery, increase pressure, and cause thermal runaway. Consequently, specialized electronics must be used: TP4056 module.

The TP4056 is a complete constant-current/constant-voltage linear charger for single-cell LiPo batteries. Thermal feedback controls the charge current to keep the die from overheating during high ambient temperature or high-power operation. The charge voltage is fixed at 5V, and the charge current can be programmed up to 1A. When the charge current lowers to 1/10th of the programmed value after the maximum float voltage is reached, the TP4056 automatically terminates the charge cycle. TP4056 other features include a current monitor, under-voltage lockout, automatic recharge, and two status pins to indicate charge termination and the presence of an input voltage, as shown in Fig (3.6).

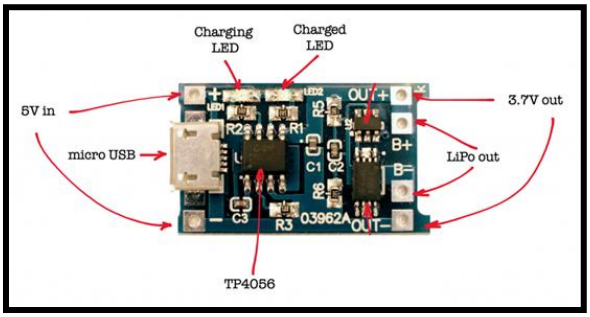



**FIGURE (3.6) – LITHIUM BATTERY CHARGER TP4056 MODULE COMPONENTS**

## Solar Panels

In solar panels, photovoltaic cells are placed between semiconducting materials like silicon layers. Each layer is energized when photons from the sun impact it, creating an electric field that generates electricity in the form of direct currents. Throughout our prototype, the solar panel plays the role of a green energy generator, supplying enough electricity to charge the Li-Po battery that will power the Arduino and keep the process operating.

## Step-up transformer

A step-up transformer converts low voltage (LV) and high current from the primary side to high voltage (HV) and low current on the secondary side by applying the principles of magnetic induction. As we have studied in L.O 11 in Physics, the transformer is a piece of static electrical equipment that converts electrical energy (from the primary transformer side) to magnetic energy (in the magnetic core of the transformer) and back to electrical energy (on the secondary transformer side) using mutual induction. In our prototype, the step-up transformer is utilized to increase the

voltage from the battery's 3.7 V to 5 V, which is the minimum voltage required to run the Arduino and automate the process.

## Mobile Application and Bluetooth HC 05 Module

Bluetooth is a technology used to exchange data between two devices wirelessly. It allows data exchange in radio waves between two paired devices. When two devices are paired, they are set to the same frequency in the range of 2.45 GHz. Then, they can exchange data by varying the wave's amplitude, where the transmitter at one end encodes the data, and the receiver at the other end decodes it.

The Bluetooth HC 05 Module has four necessary pins that must be connected to the Arduino to power the chip and start to exchange data. The chip's VCC and GND pins are connected to the 5V and the GND pins of the Arduino, respectively. Also, the chip's TX (Transmitting pin) is connected to the RX (Receiving pin) of the Arduino and vice versa.

## Working with the Mobile App

A mobile application was developed using the Flutter framework to monitor the system's status and control the process inside it over the air using Bluetooth. As the HC 05 Module works on serial communication, it receives the data and orders from the app and sends it through the TX pin of the module to the RX pin of the Arduino. Also, Arduino sends live status to the application using the same way.

## Feedback control mechanisms

## Solar tracker

The light-dependent resistor is a light-sensitive sensor. It's built out of a piece of exposed semiconductor material like cadmium sulfide, which alters its electrical resistance from thousands of Ohms in the dark to a few hundred Ohms when exposed to light. It can therefore be employed in light-sensing circuits. Therefore, two LDR sensors are put next to the solar panels in our prototype. The feedback process uses these sensors to adjust the solar panels' direction according to the light rays and generate the most energy achievable.

## Controlling the adhesive production

To speed up the adhesive production process, a stirrer is used to mix the EPS with the diesel. This process is done automatically through the feedback system

installed in the stirrer. As the system turned on after adding the EPS and the diesel, it will keep working even after the adhesive get ready, which will cost more electricity and subsequently higher cost. A feedback system is designed to terminate the process after the adhesive is prepared to avoid this problem.

As the adhesive forms ultimately, the load increases on the motor, making the coil in the motor slow down. Thus, the back-induced voltage decreases, leading to an increase in the current in the external circuit. Such an increase is detected by Current Sensor ACS712. Then, it sends signals to the Arduino to stop the current flowing in the motor. Studying electromagnetic induction in learning outcome eight helped us to understand more the working mechanism of the ACS712 current sensor.

## Automatic refilling system

The ultrasonic sensor is an electronic device used to measure the distance between the sensor and an object by using ultrasonic waves. It consists of two primary components: the transmitter and the receiver. The transmitter emits sound waves, and the receiver receives the waves reflected from the object, as illustrated in Fig (3.7). After the receiver receives the waves, the module measures the distance to the object using equation (3.4), where $D$ is the distance, $T$ is the time, and $C$ is the speed of sound.

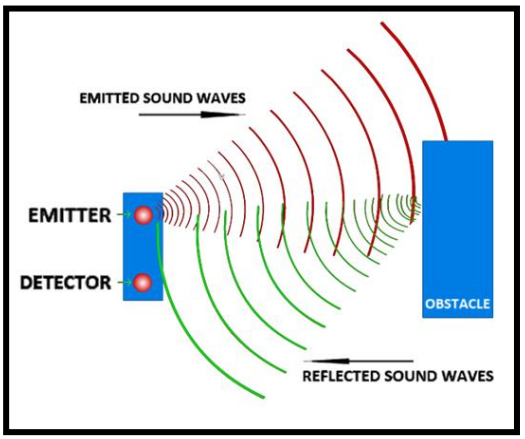



**FIGURE (3.7) – ULTRASONIC SENSOR WORKING PRINCIPLE**

The ultrasonic sensor is utilized here to measure the height of the diesel in a container of known dimensions, which gives the ability to measure the diesel volume in the container. This working principle resembles a negative feedback mechanism in which decreasing the amount of diesel in the container increases the distance between the ultrasonic sensor and the diesel. So, when the distance from the ultrasonic sensor decreases to a specific point, the Arduino triggers the pump fixed above the container to pump in more diesel.

$$D = \tfrac{1}{2} T \times C$$

**EQUATION (3.4) – DISTANCE FORMULA FOR THE ULTRASONIC SENSOR**

# Conclusions

All circumstances considered, it was concluded that the project's main challenge is to improve Egypt's industrial base. The specific problem is that the adhesives industry uses traditional techniques that consume high energy and pollute the environment. To solve this problem, any product's typical manufacturing method needs to be altered to reduce energy use. Solar panels, recycled materials, and feedback systems are employed to create the most efficient solution. The project's main idea is to use the recycled EPS by using ultra-low sulfur diesel, which converts it into adhesive through a series of procedures detailed in the methods. Multiple rounds of testing ensured that the project successfully achieved the design requirements. These results demonstrate that the project was successful and can be applied in the real world.

# Recommendations

## Prototype recommendations

### ❖ Remote control

The prototype is controlled by a mobile application that transfers data through Bluetooth. However, Bluetooth can’t transfer data farther than 10 meters, so it is recommended to connect the prototype to a server. This server will be connected to the internet, and our mobile application should be developed to access this server through the internet, so the project can be controlled from any place in the world.

### ❖ Auto cleaner (dust sensor)

When the solar panel get dirty or covered by contaminants, its efficiency decrease as the light rays are interrupted from reaching the solar panel surface. A feedback system can be installed, comprising a dust sensor (shown in Fig 3.8), a water pump, and an automated cleaning machine. When the panel surface gets dirty, the cleaning machine and the water pump are triggered to work.

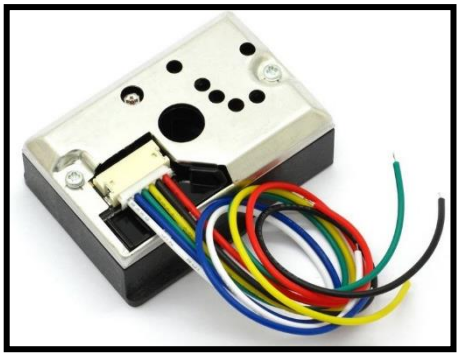


FIGURE (3.8) – DUST SENSOR

# Real-life project recommendations

## ❖ Location

The real-life project will be located at Aswan because it has the highest average direct normal irradiance (the net solar power reaches a specific area) in Egypt, which results in the highest from the solar panel. Further, the prototype will be scaled up by 100 to construct the real-life project.

## ❖ Complete automation

An additional system will be installed to extract the adhesive when ready. The first part is rotating the adhesive container by 45° and making a door opening in the side of the container from the bottom. Then, this door will be controlled by a motor that will receive the feedback from the current sensor when the adhesive is ready to pass the glue through a production line and then get packed, as shown in Fig (3.9).

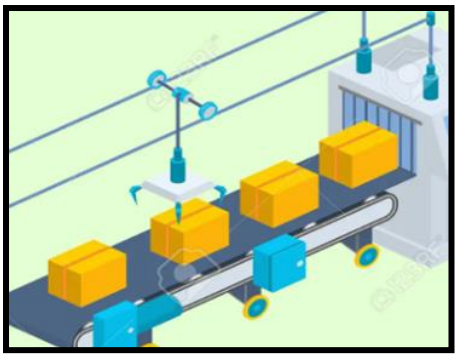


FIGURE (3.9) – THE PRODUCTION LINE AND PACKAGING

# Learning Outcomes

| subject | Learning outcome | usage |
|---|---|---|
| Math | MA.2.07 | Studying derivatives was essential for calculating the instantaneous rate of change in the project's many variables, such as the solar panel. Using derivatives helped to get more accurate results in testing as the environmental conditions vary continuously. |
| Math | MA.2.09 | Studying integration helped us calculate the total power generated from the solar panel as the current produced isn't constant. Hence, it was essential to calculate the area under the curve to get the full current generated to get the total energy generated. |
| Mechanics | ME.2.05 | Studying the laws of power helped us calculate the energy consumption by multiplying the power by time to get the total energy consumed. We used to calculate the cost for the production of 1 kilogram of EPS adhesive. |
| Physics | PH.2.09 | Learning faraday's law of induction helped us understand the working principle of the current sensor ACS712 that depends on indirect sensing. Indirect sensing works by measuring the voltage induced and then calculating the current intensity. |
| physics | PH.2.11 | We learned about electric motors in this learning outcome, which convert electric energy to kinetic energy depending on torque. These motors' speed is regulated by back emf. We used this idea to construct the feedback system because when the back emf decreases, the current intensity increase, which is detected by the current sensor. |
| Physics | PH.2.12 | Learning about mutual induction and transformers helped us in our prototype as we used a step-up transformer in the circuit to increase the voltage powering the Arduino. |
| Chemistry | CH.2.09 | In the second chemistry learning outcome this semester, we studied the galvanic cell, which is the base idea of every battery. Also, we have learned the difference between primary and secondary batteries. We used the Lithium-ion polymer(LiPo) battery as a primary battery to be charged with the solar panel. |

| | | |
|---|---|---|
| chemistry | CH.2.10 | We started learning organic chemistry in this learning outcome: hydrocarbons and fuels. We also studied their behavior with each other. For example, we know from it that the organic compounds (EPS) dissolve in organic solvents like ultra-low-sulfur Diesel. |
| Biology | BI.2.09 | Learning about the feedback systems that control the gametogenesis and pregnancy in a human was a perfect inspiration for the three different feedback systems we performed in our project: solar tracking, auto-filling, and energy-saving systems |
| Geology | ES.2.09 | In this learning outcome, we have studied the evolution of the geosphere, and the specific materials located in specific locations such as the greenstone belts at the subduction zone. These studies helped us to identify the available materials to use (because of their cheapness) for preserving the EPS glue |
| Geology | ES.2.10 | In this learning outcome, we have learned about the evolution of the hydrosphere and atmosphere. Also, we have studied the mechanism of cooling the earth's temperature through successive evaporation and condensation. We were inspired by this idea and applied it to our project through an an automatic refill feedback system. |
| chemistry | CH.2.08 | Learning the basics of the electric cells and redox reactions helped us understand the working principle of the LiPo battery. We also studied the electrolytic cell, which is the mechanism of charging the batteries. |

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