Design of Plastic bottles to Fuel Conversion Reverse Vending Pyrolysis system using AI

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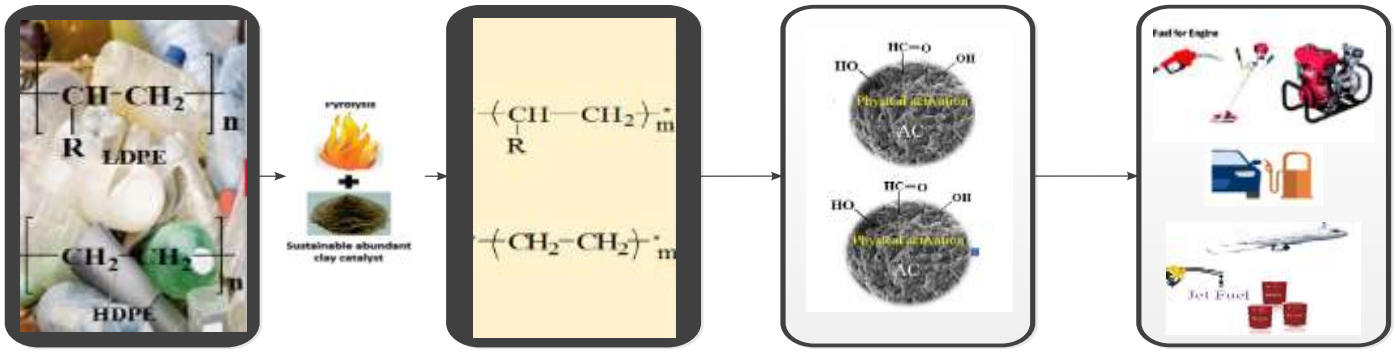
Graphical Abstract:



Abstract- The use of plastics, domestically and industrially, has substantially increased over the past two decades, subsequently increasing the risks of environmental pollution. The contributing factors to this increased use of plastics are its light weight, cost effectiveness, versatility and durability. Different polymers with additives are used in making high strength plastics which also makes it difficult to recycle these plastics. Non-recycled plastics creates a severe threat to the environment and the marine life. Pyrolysis method for converting plastic to fuel has emerged as a popular and efficient method of recycling plastics. This paper presents a system, the pyrolysis plant that is designed to convert plastic to fuel. The main objective is to design a system that will process pet bottles to form fuel. This system is also less harmful to the environment as the pyrolytic chamber is sealed so the residue carbon black settles down at the bottom of the chamber.

Index Terms- *Plastic, environmental pollution, Non-recycled plastic, Pyrolysis, Plastic to fuel, Pet bottles, Pyrolytic chamber.*

I. Introduction

Plastic waste is a rising concern being the major cause of environmental pollution. Major concern with the extensive use of plastic is the disposal of plastic waste effectively, considering the fact that a single plastic bottle can take up to 450 years to decompose. In recent years, recycling has been adopted to cope with plastic pollution. Since plastics are the chain of the petroleum, part of non-renewable energy source, it is only imperative to devise a way of halting the depletion of petroleum by recycling plastics.

Plastic shoppers and handbags, on average, take 20 years to decompose while plastic bottles take 500 years to decay. Global plastic production is approximately 381 million tons while global plastic waste is almost 280 million tons. Plastic waste is contributing to global warming. Burning plastic may results in emission of toxic gasses like furans, mercury, dioxins and polychlorinated biphenyls that may hazardous to human health, animal health and vegetation. Therefore, the best way is to recycle the plastic waste and produce the effective by product like fuel.

The unique composition in plastic provides valuable chemical compounds and fuel constituents. Pyrolysis method is an efficient and flexible method for recovering energy by obtaining fuel from plastic materials. The thermal decomposition of plastic waste is used to obtain excessive strength products like paraffin, olefins, and aromatic hydrocarbons [1]. Moreover, with an excessive H/C ratio, plastic waste becomes extensively utilized as a hydrogen donor in co-pyrolysis with renewable biomass that improves the quality of bio-oils. However, it is a challenge to extract quality fuel, as the broad spectrum of plastic pyrolysis outcome makes it very difficult to use it as conventional fuel on industrial scale. Therefore the need of catalytic pyrolysis process as the use of a catalyst narrows down the spectrum to get the desired products when obtaining fuel from plastic waste[2]. Following figure 1 shows the chemical nomenclature chain of plastic.

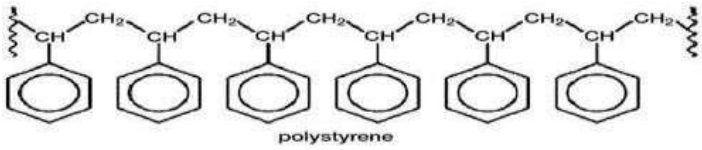


Figure 1: Chain of Plastic

Approximately one metric ton of plastic is thrown every year into oceans in Pakistan, as shown in figure 2.

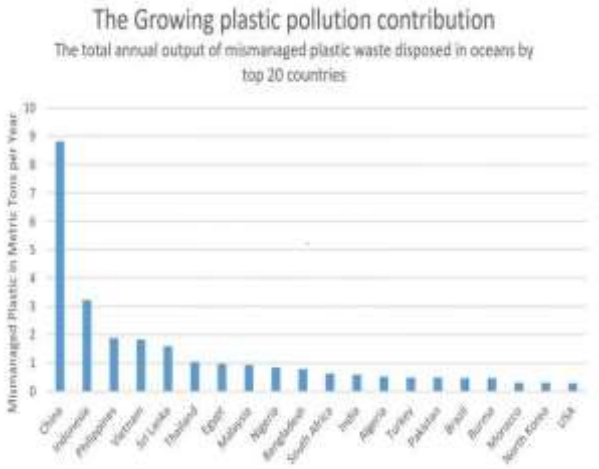


Figure 2: Showing plastic pollution producing countries[1]

Plastic waste has specific elements that inspire many people to pursue alternative methods that can produce the high value chemicals from plastic waste instead of incinerating it which will contribute in emission of greenhouse gases. The alarming increase in plastic waste necessitates the need for working in utilizing this waste and eradicating environmental pollution caused by it. Pyrolysis is a promising alternative that will recycle the waste by extracting valuable products and converting them into hydrocarbon fuel. Since economic growth will inevitably be unstable with depletion of fossil energy, pyrolysis method of fuel conversion benefit the economy by implementing in industries for recovery of fuel and efficient waste management. Converting plastic to fuel is an example of green energy. The world is working on green energy and utilizing materials like piezo plates to produce energy. Plastic to fuel cycle will be helpful in those countries where oil prices are high, and they have to import oil. Pakistan is also one of the countries that import oil, and by using this technology, our import of fuel will reduce and fuel will be locally produced. Following Table 1 shows the compound for pyrolysis.

Compound for Pyrolysis	Plastic
Melting Temperature	70°C - 350°C
Catalyst	Zeolite (NKC-5)
Condensing Temperature	±05°C
Product	Mixed Volatile Fuel
Bi-Products	1. Wax 2. Non-Condensable Partially Flammable Gases
Non-Condensable Gases (C1 – C4)	1. Propene (C3H8) 2. Butane (C4H10) 3. Ethane (C2H6) 4. Methane (CH4) 5. Oxygen (O2)
Residue	Carbon Black

Table 1: Conditions of yield

There are four essential strategies for the conversion of organic wastes to synthetic fuels: (1) hydrogenation, (2) pyrolysis, (3) thermal and catalytic cracking, (4) gasification, and bioconversion. In our scenario, we have used the pyrolysis process. The process can be carried in the presence or absence of a catalyst. We have used Zeolite catalyst in our method [3].

Pyrolysis is a sort of tertiary recycling technique, as shown in figure 3. The polymer pattern is heated in an inert environment, inflicting the carbon-carbon bonds to interrupt the polymer backbone.

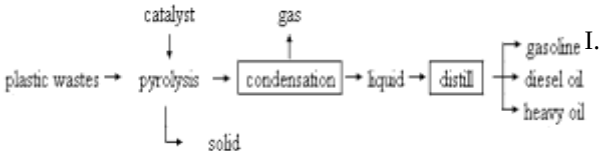


Figure 3: Showing simplified pyrolysis process

This de-polymerization produces the short-chained compounds. Generally, three types of product are formed from a pyrolysis reaction: oil, gas and char. All these products have potential to be used as a chemical feedstock or as a fuel thus bring an intrinsic value to the entire technique. Japan has introduced the technique for polyolefins decomposition. The Fuji technique uses catalysts to produce a gasoline-rich oil from polypropylene, polystyrene and polyethylene [4].

To convert plastic into fuel, we have to melt the plastic in an oxygen-free environment. Solid plastic is placed inside the flask, heat is provided to plastic through the burner, and nitrogen is supplied to eliminate oxygen[5]. When plastic is converted to vapour form, it will pass through the condenser, the vapours will convert to liquid form. Recycling rate Depend on the grade of the plastic determine by the SPI codes. There are seven grades for the plastic-type, which determines their quality and recycling rate[6].

During the melting phase Polyethylene terephthalate (PET) bottle is shredded through a crusher. Heat is provided using a burner that is installed beneath the heating chamber RTD temperature probe was placed in the pyrolysis chamber. This is used to monitor and maintain the required temperature. The end product contains: non-condensable gaseous products, condensable liquids, and solid residue, which is carbon black. All the systems from the crusher to the condenser are automated using a PLC[7].

The purpose of using vending machine in our project aims to realize that they can make cash from trash so they will not pollute the environment and give the plastic to industries and earn money according to quality and quantity of plastic. It will motivate people to keep the environment clean, work for the community, and not litter. In this paper, an Autonomous thrash crusher based on object detection was one approach for efficient collection of garbage make the one step ahead toward the neat and clean environment [8]. In this work, object detection is done by using keras using Python and OpenCV. A new model is created, no pre-trained model is used. The developed model is implemented based on CNN Algorithm. The preference is given to CNN compared to RNN because of its efficient performance in real-time simulation. A similar system design for a bottle recycling using a machine learning algorithm was presented by Dhulekar [9]. This approach is also capable of recycling the bottle, so eliminating the bottle waste pollution spreading risk.

II. OBJECTIVE

The objective is to build up a system which will process the plastic to form a fuel that can be used as a fuel source. It is also less harmful for the environment as the pyrolytic chamber is totally sealed so the residue carbon black is settled down at the bottom. This work solely depends upon four steps which is the detection of the given plastic bottle using raspberry Pi and then the detected plastic undergoes the crushing phase where it is crushed in small chunks of plastic for melting in the melting chamber where it is heated to the programmed temperature. It then undergoes condensation phase where hot gas is passed through the compressor at a high-pressure rate towards the condenser as it will help in dropping down the high temperature of gases. After the completion of all mentioned processes raw fuel is obtained. This project will benefit the society in term of money, equipment, materials, Information and technology. This project also assists in solving some of the commonly encountered issues like using problem-solving techniques to minimize Carbon monoxide (CO) production during burning of plastics and waste drainage in to the oceans and Lands which evidently affects marine life and living creatures. In this project we create an innovative system, the vending machine system, through research-based knowledge. that can be use to insert, detect , validate the grade of plastic bottles from where it will go through recycling process. Depending on the grade of the bottle it also credit the amount against each inserted bottle. The project will serve multiple benefits to the environment, seas and ocean, The motive of this project is "Cash from Trash". The project can be further enhanced by applying principle-based approaches and broadening its implementation by utilizing its bi-products to make roads, bricks, t-shirts, inks and much more.

The objective of this experiment is to get the optimized solution for maximizing the fuel oil from plastic using pyrolysis process. The idea is to obtain green energy by turning plastic into fuel using pyrolysis process to counter environmental and climate change because green energy will provide more efficient results without harming nature. The idea promotes the concept of recycling and motivates people to invest in the recycling industry. The recycling procedure is still a complex procedure because of the separation process. Separation requires great accuracy because different plastic grades can have variable compositions. The factor on which pyrolysis process depends upon are feedstock chemical composition, heat rate, cracking temperature, reactor and residence type and catalyst [10]. In this project we used pre-trained model that can separate PET bottles of different grades. Most of the product prices in Pakistan increases due to an increase in the price of oil lubricants. When we start producing the oil from plastic waste, it will benefit our economy and stabilize the market value of products. We also obtained some non-condensable gases that are partially flammable and can be used in burning. From the test experiment we have obtained the non-condensable gases like oxygen (O2), methane (CH4), ethene (C2H4), ethane (C2H6), propane (C3H8), butane (C4H10), and four different unidentified species[11].

PET (Polyethylene Terephthalate) has been the high-quality preference for plastic packaging for diverse meals products, in particular, liquids like mineral water, soft drink bottles, and fruit juice containers.. PET waste is categorized with their grades, waste having specific grades and colorations make it inefficient restorative and uneconomical for recycling technique. The liquid oil yield in pyrolysis process exists mainly because of ash content and volatile matter. Greater ash contents can cause less production of liquid oil, resulting in increased gaseous yield and char formation. While high volatile matter could result in better liquid oil production. These properties of plastic proves that the pyrolysis method has the potential to produce large quantity of liquid oil [12, 13]. In this experiment we opted the same idea by using large amount of PET bottles inside the pyrolytic chamber, thus getting an increase in the efficiency of the results by obtaining liquid fuel in greater quantity. [14, 15].

III. METHODOLOGY

Training of data set: The system modelling is based on a deep learning approach that uses CNN algorithm classifier to detect the type and separate grade of the bottle. The real-time detection of trash is accomplished by taking pictures with the Raspberry Pi Camera. Then the classifier with pre-trained dataset classify plastic bottle from the thrash as shown in following figure 4.

Figure 4: Showing sample pictures

The created dataset to attain a higher accuracy of our model is done by taking pictures of items with the Raspberry Pi Camera Module. The digital digicam module takes images at a decision of 640x480 pixels. Our dataset has snapshots for two classes: PET bottles and other things. Each class consists of Five Thousand snapshots[16, 17]. In order to avoid overfitting problem the captured snapshots in dataset was selected by a technique called PCA. The tensor flow image classification was used to classify images [18]. Sample snapshots of our dataset are shown in following Figure 5.

Figure 5: Showing sample pictures

The accuracy result curve for train and test is shown in following Figure 6.

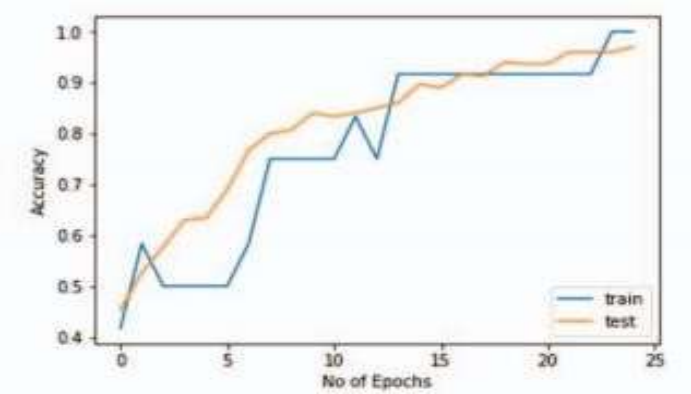


Figure 6: Showing efficiency of trained data

The user starts the Vending Machine system after giving his information for amount collection, either their bank account number or Easy paisa/Jazz Cash. As the user puts the bottle on the weight panel of the vending machine, the sensor senses the weight on it, the Pi-Cam takes the snapshot of the object and ships this photo to the raspberry Pi to check whether it is a PET bottle or not, if the system detects a PET bottle, then the weight is calculated, and the servo arm opens the gate to drop out the bottle from the stand [19]. The setup for amount collection is made easy and hassle-free by doing this part virtually using SQL. The information of the user's bank, initially taken by the interactive screen, is fed in the SQL through which all the information is given to the backend control from where a person is responsible to transfer the amount to the user's bank account accordingly with the weight of the PET bottle. The Vending machine structure is shown in following figure 7.

Figure 7: Reverse Vending Machine

Flow of the Experimental Process: The Reverse Vending Machine is the central part and the starting section of the project. The reverse vending machine idea was encapsulated from a similar approach as proposed by Aditya [20] The Crusher is the second primary part. It is the mechanical part that is operated by using a PLC. The Crusher starts when the proximity sensor detects the bottle. The bottle is then passed to the crusher section with the help of the mechanical arm attached to a servo motor. The crushed plastic will then be sent to the pyrolytic chamber where the burner and plastic will provide heat for melting. When plastic starts melting, the vapors will be passed through the condenser, resulting in the production of fuel and gas.

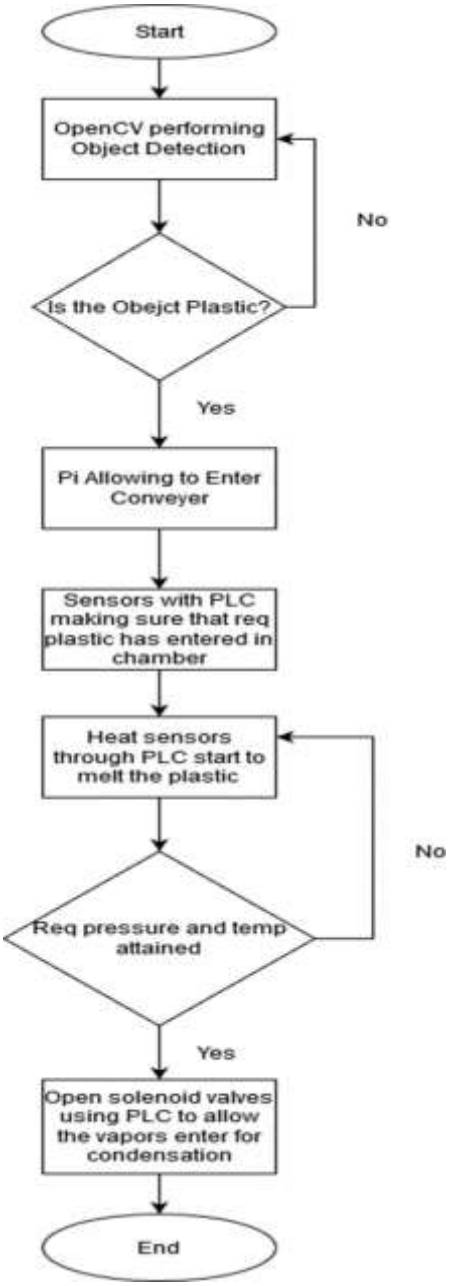


Figure 8: Flow Chart of the Experiment

Design Components:

Vending Machine: A camera is placed inside the vending machine operated by raspberry-Pi to detect the plastic using convolutional neural network technology. After detecting the plastic, it will generate the specific amount according to the mass of plastic that a weight sensor will measure.

Crusher: Crusher is made using two DC motors; one motor will rotate clockwise while the other will turn in the anti-clockwise. order. Motor propellers consist of tile cutting blades welded on two steel bars simultaneously

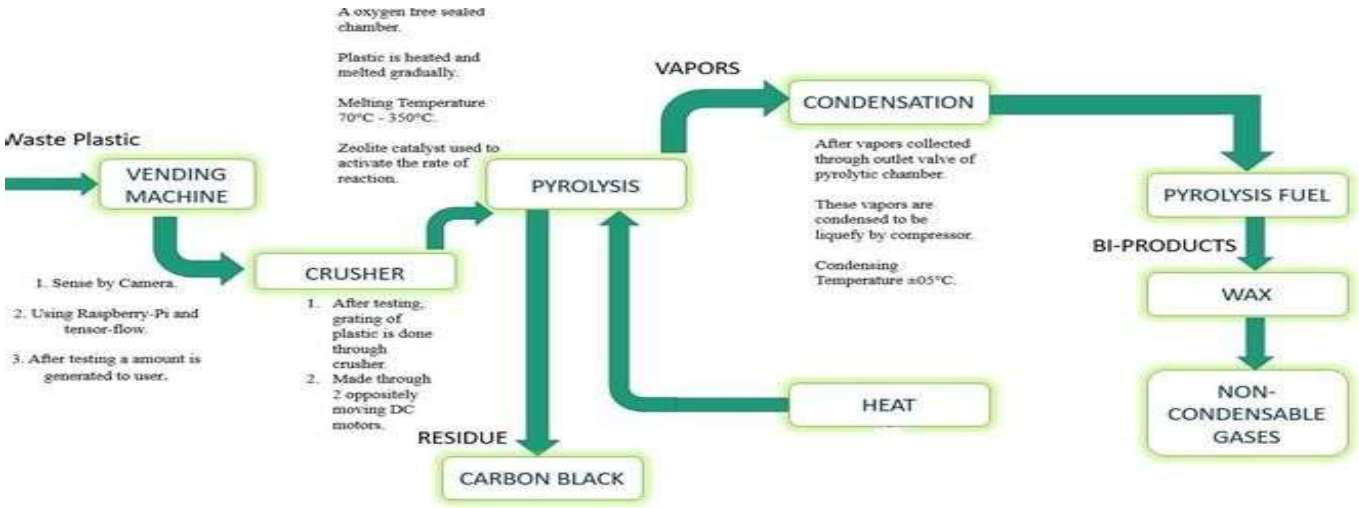


Figure 9: System Block Diagram

Pyrolytic Chamber: The pyrolytic chamber will contain crushed plastic. It will be oxygen-free and will be sealed. A burner will heat it to melt the crushed plastic present in it. When plastic starts to melt, vapors are formed which are then collected at the condenser.

Condenser: Condenser will condense the vapors to liquefy them and obtain fuel and gas.

Figure 10: Mechanical Setup of Project

IV. Results And Discussion

The results were satisfactory. We used a large amount of plastic which resulted in just a small amount of fuel. The gas could not be collected. The biggest hurdle in the project was to level the different hardware components because each part of hardware was linked with another, and one error or non-seriousness could result in a negative result. Three products were obtained from pyrolysis and that are oil, gas, and wax. Initially, at this stage, we don't know which compounds are obtained. We only know we obtained liquid oil, flammable, non-condensable gases, a heavy amount of wax, and solid residue in the pyrolytic chamber. Following shows the calculation of percentages of different parameters

$$\text{Conv}(\%) = \frac{Mass\ of\ Plastic(90\ grms) - Mass\ of\ Residue(8grms)}{Mass\ of\ Plastic(90\ grms)} \times 100$$

$$\text{Conv}(\%) = 91.11\%$$

$$\text{Fuel}\ (\%) = \frac{\text{Mass of Fuel (0.07 grms)}}{\text{Mass of Plastic (90 grms)}} \times 100 = 0.077\%$$

$$\text{Wax}(\%) = \frac{\text{Mass of Wax (0.1 grms)}}{\text{Mass of Plastic (90 grms)}} \times 100 = 0.077\%$$

$$\text{Residue}(\%) = \frac{\text{Mass of Rssidue(8 grms)}}{\text{Mass of Plastic (90 grms)}} \times 100 = 8.89\%$$

We received an impure mixture consisting of 55% of wax, 15% of Non-condensable gases & 30% of fuel [21].

Figure 11: Experimental results showing formation of fuel

After performing the preliminary test and succeeding in our initial results, we re-performed our experiment in the presence and absence of the catalyst and stored all of the specimens, received after successful completion of the investigation, for a laboratory test. This was done to assure which gases are being held during the process and how much fuel and bi-products are obtained from it. The results from the laboratory test are presented in a bar graph, as shown in figure 12, while figure 13 shows the sample of the final product.

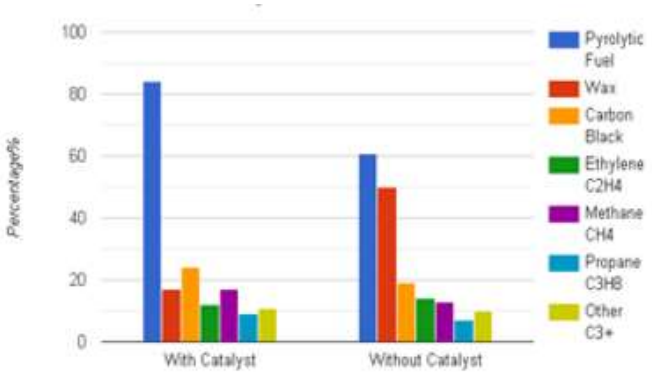


Figure 12: Experimental results of pyrolysis process with and without Catalyst fuel at 500°C.

Figure 13: Left side sample is obtained in the absence & Right-side sample is obtained in the presence of catalyst

V. Conclusion

The experiment was successfully performed and tested, thus providing four main constituents which included oil, non-condensable gas, wax, and tiny amount of char. In addition to this, the gaseous fraction contains hydrocarbons which have the potential to be utilize as a fuel. Through this experiment, we concluded that 30ml – 45ml of fuel is obtained by thermal cracking of 100grams of plastic. This project is designed to provide not only efficient pyrolysis process but also innovating some new features like reverse vending machine, thus motivating people to earn cash by recycling plastic which will inevitably reduce plastic waste to a large extent. The project will benefit the economy and maintaining clean environment, thus promote recycling thrash rather than burning it, which is the main motive of this project.

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