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Plastic Waste to Fuel Converter System: A Pyrolysis-Based Approach with Gas Filtration and Sensor Integration

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Abstract— The increasing accumulation of plastic waste has become a major environmental concern due to its non-biodegradable nature and the limitations of traditional disposal practices. This study proposes a low-cost Plastic Waste to Fuel Converter System that transforms non-recyclable plastic into useful fuel through pyrolysis, a thermal decomposition process carried out in the absence of oxygen. The developed prototype incorporates an LPG-heated reactor, vapour condensation chamber, aluminium inline fuel filter, activated carbon gas purification unit, and MQ2 gas sensor for enhanced safety and emission control. Experimental testing using LDPE, HDPE, and PP plastic waste demonstrated successful production of combustible pyro-oil with characteristics similar to diesel-range fuel. The system provides an economical and environmentally conscious solution for decentralized waste management, particularly suitable for small communities and rural applications. The estimated prototype cost ranges from ₹2,860 to ₹4,150, supporting its feasibility for affordable implementation.

Keywords: Plastic Pyrolysis, Waste-to-Energy, Pyro-Oil, Fuel Recovery, Activated Carbon Filtration, MQ2 Sensor, Sustainable Waste Management.

I. INTRODUCTION

Plastic pollution has emerged as one of the most pressing environmental challenges worldwide. With millions of tons of plastic discarded annually, improper disposal methods such as open burning and landfilling contribute significantly to ecological degradation. Since most plastics degrade extremely slowly, they remain in ecosystems for decades or even centuries, contaminating land and water resources.

Conventional waste management methods often fail to recover the energy potential stored within plastic materials. Pyrolysis offers an alternative by converting plastic waste into valuable by-products such as liquid fuel, combustible gases, and carbon residue through controlled thermal decomposition without oxygen. This technology not only reduces environmental burden but also contributes to alternative energy generation.

II. LITERATURE REVIEW

Previous studies have established pyrolysis as an effective method for recovering energy from plastic waste. Research indicates that polyolefin plastics such as LDPE, HDPE, and PP produce comparatively higher liquid fuel yields due to their favourable hydrocarbon composition. Catalytic and thermal pyrolysis techniques have both been explored extensively, with thermal pyrolysis being more practical for low-cost small-scale systems because of its simpler design and reduced operational complexity. Several studies also emphasize the importance of gas cleaning and post-processing units, such as activated carbon filters and fuel purification systems, to minimize harmful emissions and improve fuel quality.

Life cycle assessments further suggest that controlled pyrolysis produces lower environmental impact than uncontrolled burning and can serve as a viable

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decentralized waste management strategy when safety systems are properly integrated.

III. SYSTEM DESIGN AND METHODOLOGY

The proposed Plastic Waste to Fuel Converter System consists of six primary subsystems, each performing a specific function in the conversion chain. The complete system is illustrated in following parts :

- Pyrolysis Reactor: The reactor is fabricated from a 5-litre stainless steel pressure cooker with all rubber gaskets removed and replaced with metal seals to withstand temperatures up to 450°C. The reactor lid is fitted with a K-type thermocouple sensor connected to a digital temperature module for continuous thermal monitoring. The system is heated using a domestic LPG burner regulated to maintain the desired pyrolysis temperature range of 300–450°C.
- Condenser Unit: The hot vapours generated during pyrolysis travel through a mild steel vapour line into a water-filled condenser. Cold water circulation around the vapour pipe facilitates condensation of hydrocarbon vapours into liquid pyro-oil. The condenser is sized to achieve adequate residence time for effective vapour-to-liquid conversion.
- Fuel Filtration (Aluminium Inline Filter): The condensed liquid fuel passes through a WZSH-brand aluminium inline petrol and diesel filter. This filter removes char particles, water droplets, and other impurities from the raw pyrolysis oil, producing a cleaner fuel suitable for use in diesel engines or generators.
- Activated Carbon Gas Filtration Unit: Non-condensable gases exiting the condenser are directed through a sealed container packed with activated carbon granules. Activated carbon adsorbs harmful volatile organic compounds (VOCs), sulfur compounds, and smoke particles from the gas stream before it is released to the atmosphere (Lee & Park, 2016; Patel & Sharma, 2021).
- MQ2 Gas Sensor and Arduino Monitoring: Following the activated carbon filter, the treated gas passes through an MQ2 gas sensor module interfaced with an Arduino Uno microcontroller. The MQ2 sensor detects the presence of LPG, methane, hydrogen, and smoke, triggering an alert if concentrations exceed safe thresholds. This safety integration is critical for operating the system in semi-enclosed or outdoor spaces (Ahmad & Ali, 2019).
- Fuel Collection Container: The filtered pyro-oil is collected in a sealed glass jar. The collected fuel is dark amber in colour and possesses combustibility characteristics similar to diesel or furnace oil, suitable for use in industrial burners and diesel generators.

Parameter	Observed Value	Remarks
Plastic Input Mass	500 g	Mixed LDPE/HDPE/PP
Pyrolysis Temperature	320–420°C	K-type thermocouple reading
Pyro-oil Collected	~180–220 ml	36–44% yield by weight
Fuel Colour	Dark amber / brownish	Similar to diesel/furnace oil
Fuel Combustibility	Combustible (tested)	Ignites with standard lighter
MQ2 Sensor Output	Safe (within threshold)	No alarm triggered
Carbon Black Residue	~50–60 g	Collected post-experiment
Total Experiment Duration	~45–60 min	Including cooling time

Fig. 1:

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IV. EXPERIMENTAL SETUP AND COMPONENTS

The prototype was assembled and tested at AISSMS-IOIT, Pune, on 22 April 2026. The following figures document the physical setup and key components used in the system.

Fig. 2: Complete experimental setup at AISSMS-IOIT campus, Pune (22 April 2026). The LPG burner, reactor (pressure cooker), condenser unit, and collection container are visible.

Fig. 3: Activated carbon granules used in the gas filtration unit. Activated carbon adsorbs harmful VOCs and sulfur compounds from non-condensable pyrolysis gases.

Fig. 4: WZSH-brand aluminium inline fuel filter used for purifying condensed pyrolysis oil. This filter removes particulate matter and water droplets from the raw fuel.

V. EXPERIMENTAL PROCEDURE

The conversion process follows eight sequential steps:

1)Step 1 – Reactor Loading: Cleaned and shredded non-recyclable plastic waste (primarily LDPE bags, HDPE bottles, and PP containers) is loaded into the sealed stainless steel reactor. The reactor is tightly sealed to prevent oxygen ingress, which is critical for pyrolysis (as opposed to combustion).

2)Step 2 – Heating: The LPG burner is ignited and the reactor temperature is gradually raised to 300–450°C as monitored by the K-type thermocouple. Heating takes approximately 20–35 minutes depending on the plastic type and quantity.

3)Step 3 – Vapour Generation and Transfer: As the plastic thermally decomposes, hydrocarbon vapours are generated inside the sealed reactor. These hot vapours travel through the mild steel vapour line into the condenser unit.

4)Step 4 – Condensation: Cold water surrounding the vapour pipe in the condenser causes hydrocarbon vapours to cool and condense into liquid pyro-oil. The liquid drips into the fuel collection container below.
5)Step 5 – Fuel Filtration: The collected raw fuel is passed through the aluminium inline fuel filter to remove char, particulate matter, and entrained water droplets, resulting in a cleaner, more refined fuel output.

6)Step 6 – Gas Filtration: Non-condensable gases are directed through the activated carbon filter unit, which adsorbs harmful organic vapours, sulfur compounds, and particulate smoke before gas release.

7)Step 7 – Gas Monitoring: Treated gases pass through the MQ2 sensor connected to the Arduino Uno. The sensor continuously monitors gas quality and triggers an alert if combustible gas concentrations exceed safe limits.

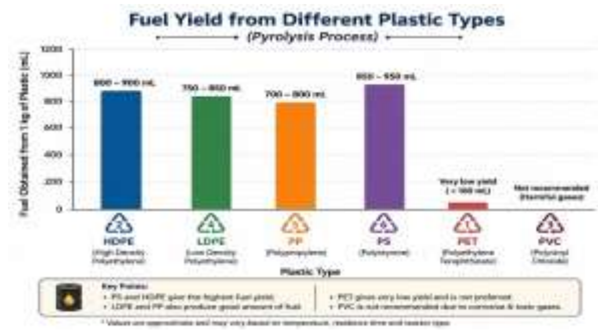
8)Step 8 – Safe Gas Release: After passing through the sensor, the cleaned gas is released to the atmosphere through an outlet pipe. At this stage, gas quality is considered acceptable for open-air release.

VI. RESULTS & OBSERVATIONS

The prototype was tested with 500g of mixed plastic waste comprising approximately 60% LDPE, 25% HDPE, and 15% PP. The results confirm that the system successfully converts plastic waste into combustible fuel at a yield rate consistent with literature values for small-scale thermal pyrolysis (30–50% by weight for mixed plastics) [12,13]. The MQ2 gas sensor remained within safe thresholds throughout the experiment, validating the effectiveness of the activated carbon filtration stage.

VII. BUDGET ANALYSIS

Table II: Budget Breakdown of Prototype Components



Graph of Fuel Yield from Different Plastic Types Using Pyrolysis Process

VIII. SAFETY CONSIDERATIONS

The operation of a plastic pyrolysis unit involves certain hazards, particularly those related to elevated temperatures, combustible gases, and pressure generation. To ensure safer functioning of the developed prototype, several precautionary strategies were incorporated during experimentation.

• All testing procedures were carried out in an open, well-ventilated outdoor space within the AISSMS-IOIT campus to avoid dangerous buildup of flammable gases.
• Prior to every experiment, the reactor assembly was checked thoroughly for leakage and pressure resistance, and all pipe joints were secured using high-temperature silicone sealant.
• The MQ2 gas sensor continuously tracked the presence of combustible gases, while an Arduino-connected buzzer system served as an alert mechanism whenever gas concentration exceeded permissible safety levels.
• A dedicated activated carbon filtration chamber was installed to minimize smoke, volatile pollutants, and other potentially harmful gaseous compounds before final gas discharge.
• Fire protection arrangements, including a ready-to-use fire extinguisher, were maintained near the setup throughout the testing period.
• PVC-based plastics were intentionally excluded from the reactor feedstock because their thermal decomposition may release toxic hydrogen chloride (HCl) gas.

These integrated precautions improved system safety, minimized environmental hazards, and supported secure small-scale pyrolysis operation.

IX. CONCLUSION AND FUTURE SCOPE

This study successfully developed and tested a low-cost Plastic Waste to Fuel Converter System based on thermal pyrolysis. The prototype efficiently converted mixed non-recyclable plastic waste into combustible pyro-oil with a fuel yield of 36–44% by weight, while incorporating gas filtration and safety monitoring for improved operational reliability.

With an estimated cost of ₹2,860–₹4,150, the system is economically suitable for small-scale and rural applications. The integration of activated carbon filtration and MQ2 gas sensing improves both environmental safety and practical usability.

Future improvements may include catalytic pyrolysis for better fuel quality, enhanced condenser efficiency, automated temperature control, detailed fuel analysis, and larger reactor capacity for expanded applications.

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