# Design and Fabrication of 3D Printing Filament by Using Recycled Plastic

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***Abstract—*** Plastic waste is a big problem for our environment because it can pollute both land and water. When we burn plastic to create energy, it causes air pollution that can be even worse than throwing it in landfills. However, there's a way to help: we can make 3D printing materials from recycled plastics, like those from plastic bottles. This process helps reduce the harm that waste plastics do to our planet. To create 3D printing filament from recycled plastic, we go through several steps. First, the plastic is sorted to remove any unwanted items. Then, it is shredded into smaller pieces, ground down even further, and blended. After that, it is melted and shaped into long strands, which are then wound into spools for use in 3D printers. The goal of studying this recycling process is to find the best methods for turning waste plastics into useful materials for 3D printing. Recent research shows that this recycled filament can be used in many areas, such as medicine, cars, buildings, airplanes, food packaging, and engineering. By using this approach, we can help lessen the negative effects of plastic waste on the environment.

*Keywords—3D Printer, Filament Recycling, Waste Plastic Management, Mechanical Properties, Industrial Application*

## I. INTRODUCTION

Because we produce so many plastic containers, wrappers, and other items, we also create a lot of plastic waste worldwide. This waste contributes to serious problems like land and sea pollution, poor soil quality, and threats to marine life. Plastic can take hundreds of years to break down fully, and burning it releases harmful gases, making it very challenging to get rid of. Therefore, it’s important to find effective ways to recycle or reuse plastic. This project aims to tackle the global issue of plastic waste by turning it into something useful for 3D printing. Instead of letting used plastics accumulate in landfills or harm the environment, we're transforming them into a special material called filament, which 3D printers use to create objects.

Our focus is on recycling PET (RPET), which is the type of plastic commonly used for soda and water bottles. Since RPET is widely available, it's a great option for making sustainable filament. The goal is not only to create this filament but to ensure it is of high quality, performing as well as or better than filaments made from new plastic. This helps reduce the need for new materials, which is beneficial for the environment. The project will unfold over a year. It starts in the lab, where we will select the best types of recycled plastic and see if we need any extra ingredients to make it stronger or more flexible. Once we have the ideal mix, we’ll move to the manufacturing stage, where machines will melt the plastic and shape it into long strands of filament. This step is crucial because the filament needs to have a consistent thickness; if it varies even slightly, it can cause printing problems. Once we create the filament, we will test it thoroughly to ensure it meets important standards like how much it can stretch without breaking and how well it holds up after being dropped.

After these tests, we’ll create real 3D-printed objects to check how the filament performs with different designs and printing conditions. This helps us verify that it can be used for various purposes, from small gadgets to car parts or construction items. Finally, the project will look at the bigger benefits. We will measure how much less carbon is released by using this recycled material compared to traditional plastics. We’ll also explore potential markets, such as schools and companies focused on sustainability, to encourage wider use of this recycled filament. Overall, this project is a way to effectively manage plastic waste by promoting more responsible manufacturing practices for a sustainable future.

## II. PROBLEM IDENTIFICATION

The sheer amount of plastic being created globally is overwhelming our planet. We are constantly seeing an explosion of new plastic products, especially the ones we use just once, like packaging and disposable containers. This ever-growing mountain of material presents a huge problem because plastic doesn't just disappear; it is built to last. Instead of breaking down harmlessly, it simply fragments into tiny pieces called microplastics, ensuring that every bit of plastic ever made is still contaminating the world in some form

Fig:- 1. Land Pollution

This continuous influx of durable waste makes the environment an increasingly dangerous place. The trouble starts long before the plastic is even discarded, as its creation relies on fossil fuels, which adds significantly to the climate change crisis. Once in the environment, the plastic and its chemical additives can contaminate vital resources like our soil and groundwater. Much of this waste ends up littering landscapes and accumulating in massive. The main reason for this environmental leakage is that the world simply doesn't have good enough systems for dealing with all the trash. Most places operate with a waste handling system that is not sufficient to process the enormous quantity of plastic waste we produce. As a result, only a tiny fraction of plastic is actually recycled. The rest is either buried in huge landfills or, worse, dumped directly into rivers and fields. This mismanagement of waste also causes problems in our cities, as plastic bags and bottles frequently clog drainage systems, leading to serious flooding when it rains.

Fig:-2. Sea Pollution

Ultimately, this plastic onslaught has devastating effects on the ecosystem—the complex web of life on Earth. Marine animals often mistake plastic bags for food, leading to internal injuries and eventual starvation. Larger animals can become hopelessly entangled in discarded nets or lines. Even the smallest creatures at the base of the food chain consume microplastics, which then travel up to contaminate the fish, birds, and animals we rely on. The plastic not only injures and starves wildlife but also introduces harmful toxins, fundamentally disrupting the natural balance of life in our oceans and on land.

## III. Literature Reviews

### A) *Literature Survey:*

Professor Veena Sahajwalla, who has been working in Australia since the 2010s, is known for turning complex waste into useful products. Her main invention, the **Microfactory**, is a small system that can recycle waste on-site and turn it into new materials. It focuses on hard-torecycle plastics from old electronics, which usually contain harmful chemicals and mixtures that large recycling plants can't easily process. The Microfactory uses small machines to sort, clean, and refine these plastics, restoring their quality. The clean plastic is then melted and made into continuous strands for 3D printing. This system makes recycling more efficient and local, reducing transportation needs and turning harmful ewaste into valuable raw materials for new products.

In the UK, **Ian Falconer** started a company in Cornwall around 2016 called **Fishy Filaments**, now known as **OrCA**. His goal was to recycle abandoned nylon fishing nets, which pollute the ocean and are difficult to recycle. He worked with fishing communities to collect these nets, which were then cleaned, shredded, melted, and turned into strong, highquality 3D printing filament. Falconer showed that ocean waste could become a premium product instead of cheap recycled material. This created a system where cleaning up pollution could also make money, encouraging people to protect the environment while supplying manufacturers with sustainable materials.

**Casper van der Meer** co-founded the Dutch company **Refil** in 2016 to make ecofriendly 3D printing filament from common waste materials. Refil used plastics like ABS from old car parts and PET from drink bottles. Since these materials often contain dirt, paint, or glue, Refil developed special cleaning and refining methods to make them suitable for precise 3D printing. Their success showed that reliable, high-quality filament could be made from everyday waste, helping the 3D printing industry move toward sustainability and waste reduction.

**Swaleh Owais and Yang Cheng** created the **Polyformer**, an invention that won the James Dyson Award in 2022. It's a small, easy-to-build machine that turns used plastic bottles into 3D printing filament. The machine cuts bottles into ribbons, heats them, and reshapes them into thin, even strands of filament. The design is open-source, meaning anyone can make their own version using simple parts. This idea helps people, especially in developing regions like Rwanda, create their own affordable filament instead of buying expensive imported ones. The Polyformer not only reduces plastic waste but also supports education, innovation,
and local businesses by turning trash into useful material

### B) *Literature Summary*

The history of creating 3D printing filament from recycled plastic began with the commercial rise of Fused Deposition Modeling (FDM) in the late 1980s, which initially relied only on new, virgin plastics. The need for a sustainable alternative, driven by both the environmental impact of new plastics and the waste from failed prints, grew significantly with the spread of affordable desktop 3D printers in the 2000s and early 2010s.

This shift was initially fueled by the opensource movement and community-led initiatives, which popularized small, rudimentary machines for shredding and re-extruding old plastic waste. Projects like Precious Plastic further democratized this idea, enabling local, small-scale recycling. By the mid-2010s, this innovation became commercial, with specialized companies focusing on using preconsumer and post-consumer waste (such as PET bottles, electronic waste, and fishing nets) to meet the quality demands of the industry. The primary difficulty was maintaining the quality and uniform diameter of the filament due to material degradation from heating. However, advancements in industrial systems including meticulous cleaning, drying, and precise diameter calibration have largely overcome these technical hurdles.

## IV. Research Methodology

- *SMPS (Power Supply)*
  Controller is a device which works as a power supply. It converts A.C. to D.C. which helps to decrease the temp of the chamber by controlling the palter device and cooling fans.


Fig :- 3. SMPS Power Supply

• *Thermocouple (temperature sensor)*

The most commonly measured physical parameter is temperature whether in process industry applications or in laboratory settings. Exact measurements are critical part of success.

A temperature sensor is a device, usually an RTD (resistance temperature detector) or a thermocouple, that collects the data about temperature from a particular source and converts the data into understandable form for a device or an observer. Temperature sensors are used in many applications like HVand AC system environmental controls, food processing units, medical devices, chemical handling and automotive under the hood monitoring and controlling systems, etc.

The most common type of temperature sensor is a thermometer, which is used to measure temperature of solids, liquids and gases. It is also a common type of temperature sensor mostly used for non-scientific purposes because it is not so accurate. It is used to measure the temperature from the heat release.

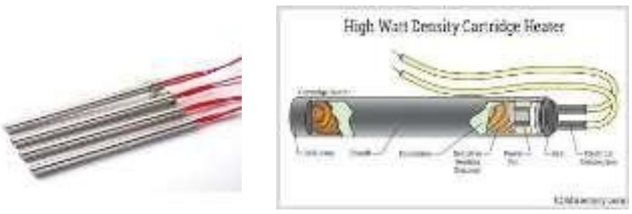
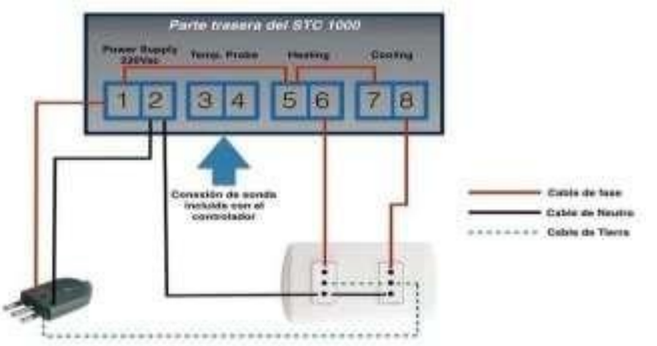



Fig:- 4.Thermocouple

• *STC1000 (Temperature controller)*

The STC-1000 temperature controller is a small, digital thermostat widely used for various temperature-controlled systems like domestic freezers, water tanks, refrigerators, industrial chillers, and homebrewing setups. It operates by utilizing an NTC sensor to measure the temperature and features a clear LED display for readability. It is designed for dual heating and cooling control, meaning it has two independent relay outputs—one for connecting heating equipment and one for cooling equipment. This allows it to automatically switch between modes to maintain a user-defined target temperature range

Various models are available, often operating on different supply voltages such as AC 220V, DC 12V, or DC 24V.




Fig_– 5.Connections of STC 1000 Temperature

It supports a programmable difference value (hysteresis) to prevent rapid cycling of the connected devices and a compressor delay time to protect refrigeration equipment. It also includes functions for temperature calibration and an automatic over-temperature alarm.

• *Regulator*

A regulator is a device or circuit designed to automatically maintain a designated characteristic, such as voltage, pressure, or speed, at a desired constant value or within a specified range, regardless of fluctuations in the input or changes in the load conditions.

In the context of electronics, a voltage regulator is a common type. Its function is to produce and maintain a fixed output voltage, protecting sensitive electronic components from damage due to voltage spikes or drops in the power source. Voltage regulators are essential in power supplies for virtually all electrical and electronic devices, from computers to medical equipment. They can be classified into different types, such as:

* Linear Regulators: These maintain the output voltage by dissipating excess input power as heat. They are generally simpler and produce less electrical noise, but are less efficient, especially when the input voltage is much higher than the output. A subset is the Low Dropout (LDO) regulator, which can maintain regulation even when the input and output voltages are very close.

* Switching Regulators: These maintain the output voltage by rapidly switching the input voltage on and off. They are much more efficient than linear regulators as they minimize power loss, but they are generally more complex and can introduce more electrical noise. Common types include Buck (step-down), Boost (step-up), and Buck-Boost (can step-up or step-down).

Beyond electrical applications, regulators are widely used to manage other physical quantities: * Pressure Regulators: These devices are used in fluid systems (gases or liquids) to reduce a high, fluctuating input pressure to a constant, lower, and more stable output pressure. Examples include diving regulators and those used in industrial fluid lines.

* Speed Regulators (Governors): These mechanical or electronic devices maintain the speed of an engine or machine, such as the classic Watt centrifugal governor on steam engines or modern cruise control systems in cars.


Fig 6. Construction of Regulator

• *DC Motor*

DC motors are used in many devices, from small toys and household gadgets to electric cars and robots. They're useful because they can easily adjust how fast or strong they move. They work by turning electricity into motion. When electric current passes through the motor's coils, it creates a magnetic field that pushes against magnets inside, making the motor spin.

In everyday life, DC motors power things like fans, electric toothbrushes, and automatic window blinds, helping them run smoothly and change speeds as needed.There are two main types: brushed and brushless. Brushed motors are cheaper and simpler but wear out over time and need maintenance. Brushless motors last longer and work more efficiently but are more expensive.

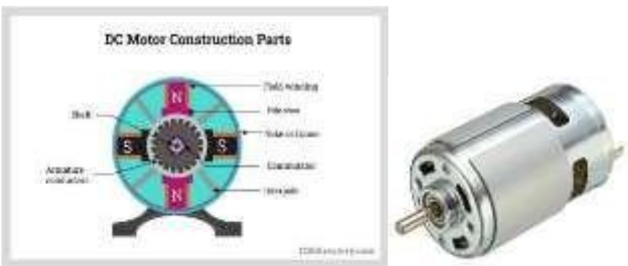


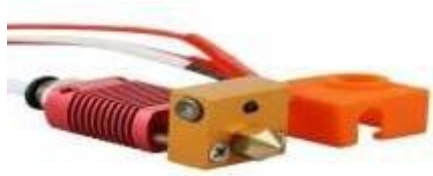

Fig:- 7 Construction of DC Motor

• *MK8 Extruder*

An extruder is a machine used to shape materials by pushing them through a heated tube and a specially designed opening called a die.

In simple terms, here's how it works: a raw material—like plastic pellets, dough, or a pharmaceutical mixture—is placed into the machine. Inside, the material is heated until it becomes soft or melts. Then, a rotating screw inside the extruder pushes this melted or softened material forward. When it comes out through the die at the end, it takes the shape of that opening—for example, a tube, sheet, or strand.

Extruders are used in many industries. In plastic manufacturing, they make things like pipes, films, and bottles. In food processing, they produce items such as pasta, snacks, and breakfast cereals. In pharmaceuticals, they can be used to form tablets or other dosage forms. Even 3D printers work in a similar way—they melt plastic filament and push it through a small nozzle to build objects layer by layer. This process is popular because it can make large amounts of products quickly and consistently. By simply changing the die, manufacturers can produce many different shapes and designs without needing



- Fig 8.. MK8 Extruder :

• *Spool*

A spool is an object used to wind and store long, flexible materials like wire, thread, or plastic filament. You can think of it as a reel that keeps these materials neat and easy to use. A spool has a round, tube-like center (called the core) with flat circular sides on each end. The material—such as thread or wire—is wrapped evenly around this core. This design makes it simple to unwind the material smoothly when needed, without it getting tangled or damaged. Spools are used in many industries. In textiles, they hold thread or yarn for weaving and sewing. In electronics, they store cables or wires neatly for manufacturing and assembly. In 3D printing, spools hold the plastic filament that feeds into the printer.In everyday life, you'll see spools in sewing machines, where they store thread, or in 3D printers, where they supply filament for printing objects.Spools come in different sizes and materials—for example, plastic, wood, or metal—depending on what they're used for. They are important because they keep materials organized, easy to handle, and safe from tangling or breaking.

• *Heating Cartridge*

A heating cartridge is a small but powerful device used to generate heat in machines that need controlled and focused heating. You can think of it as a mini electric heater that fits inside equipment parts to warm them up precisely where needed. inside the cartridge, there's a resistive wire (the heating element) wrapped in insulation and enclosed in a metal tube (usually stainless steel). When electricity passes through the wire, it resists the flow of current, and this resistance creates heat. The metal casing then transfers the heat to the surrounding parts or materials.

Heating cartridges are used in many applications. In 3D printers, they heat the printer's nozzle so that the plastic filament melts and can be shaped into objects layer by layer. In heat guns, they provide fast, high-temperature air for tasks like removing paint or softening plastic. They're also found in industrial equipment, packaging machines, and molds where precise, consistent heating is important.

In daily life, you benefit from heating cartridges whenever a device needs reliable and concentrated heat.These cartridges can be made with different temperatures, sizes, and power levels (wattages) depending on the machine they're used in. They're valued for being efficient, durable, and capable of reaching high temperatures quickly while maintaining consistent heat output.

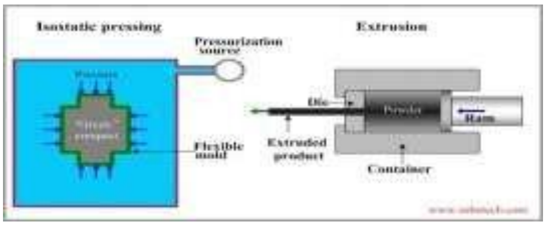



Fig:- 9. Heating Cartridge

• *Relay*

A relay is an electrical device that acts like a switch, allowing a small amount of electrical power to control a much larger amount of power. It's very useful when you need to turn on or off high-power machines or circuits safely using a low-power control signal. a relay has three main parts — an electromagnet, a movable armature, and contacts. When electricity flows through the electromagnet, it creates a magnetic field. This magnetic force pulls the armature, which moves to open or close the contacts (the switch). By doing this, the relay can turn a high-power circuit on or off without the control circuit needing to handle large amounts of current directly.

Relays are used almost everywhere. In cars, they help control things like headlights, fuel pumps, or air conditioners using small switches or electronic signals. In home appliances such as washing machines, they manage parts like water valves or motors. In HVAC systems, relays switch heating or cooling units on and off. In industrial machines and telecommunications, they help manage complex electrical systems safely and efficiently. There are two main types of relays:

- Electromechanical relays, which use moving parts to make or break electrical contact. They are strong and reliable for heavy-duty applications.
- Solid-state relays, which have no moving parts. They use electronic components to perform the switching, making them faster, quieter, and longer-lasting. Overall, relays are essential for safely controlling highpower devices using smaller, low-power signals — much like using a light switch to control bright overhead lights without touching the main electrical wires.

Fig :- 10. Construction of Relay

### *Detail Working & Construction*

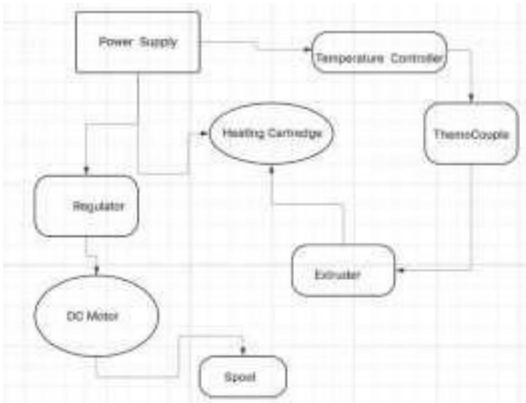



Fig:- 11. Block diagram of Experiment

### *Circuit Diagram:*

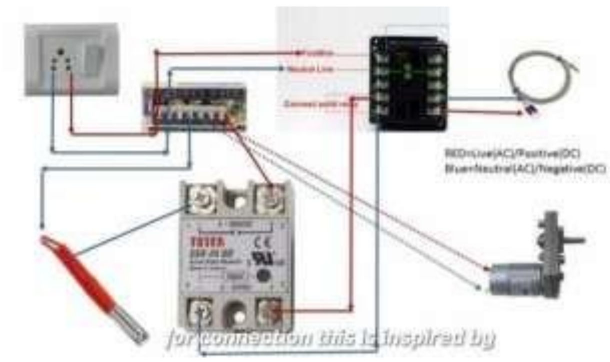


Fig 12. Circuit diagram

### *Working*

- The collected plastic bottles get's clean in hot water to remover impurities like dust, sand, stickers, etc. • The heater or hair dryer is used to heat the bottle to remove the patterns on it so the strips of the plastic bottles will be same in size and shape. To make the filament with same dimeter
- The customized cutter is used to cut the strips of plastic bottles in same thickness. This strips letter used to feed to the MK8 extruder to make the filament out of it.

- The SMPS takes the AC input and convert the 220v AC current into the 12v DC current as output. This 12v DC supply is used the run the other components such as regulator, heating cartridge which are directly connected to the SMPS. The SMPS work as the power house of the circuit
- The STC1000 is directly connected to the AC supple. The STC1000 is set on the required temperature to control the temperature of heating cartridge
- The heating cartridge is connected to the heating block where the mk8 extruder is mounted. The SSR relay and STC1000 temperature controllers controls the temperature regarding to the material to make the filament of plastic bottles
- When extruder gets heated on the required temperature the plastic strips of the bottles is passes through the extruder because of the heat the plastic strips get's melted and exits from the nozzle of the extruder in a semi-solid form.
- The semi-solid filament gets solidified as soon it comes inContact of the air, by using the plier the hot filament is wind to the spool
- As soon the filament is winded on the spool the DC motor is started and rotates the spool to wind the filament around the spool.
- The regulator is connected to the DC motor to control the speed of the motor

## V. Results And Discussions

3D printing filament is the main material used in 3D printers to create plastic objects. It's usually made of plastic because plastics have many useful properties—they're lightweight, easy to shape, resistant to rust and corrosion, flexible (ductile), able to absorb shocks, and resistant to electricity, heat, and chemicals. In recent years, people have started using waste plastic to make recycled 3D printing filaments. This is a good idea because it not only lowers the cost of producing 3D-printed parts but also helps the environment by reducing plastic waste. Instead of throwing used plastics away, they can be melted down, processed, and reused for 3D printing.

However, recycling plastics for 3D printing isn't always simple. Recycled plastics can lose some of their strength, flexibility, or print quality after being reused. To fix this, scientists and manufacturers add special chemicals or materials known as additives or fillers.

These include:

- **Nucleation agents** – help control how the plastic hardens and improves its strength.
- **Dopamine and oxidizing stabilizers** (like hydroquinone and tropolone) – protect the plastic from degrading when exposed to heat or air.
- **Cellulose and biocarbon** – natural fillers that make the plastic stronger and more eco-friendly.
- **Chain extenders** – repair broken plastic molecules during recycling, helping the material regain its toughness.

By adding these substances, recycled filaments can perform almost as well as new ones, making 3D printing more sustainable**,** affordable**,** and environmentally friendly.

## VI. Advantages

We believe that plastic filament maker offers a number of advantages

- Reduce Plastic Waste
- Conserves Natural Resources
- Reduce Pollution
- Cost Effective
- Reduce Production Costs
- Comparable Performance
- Improve Public Images

## VII. APPLICATIONS OF SYSTEMS

1. *General and Functional Applications*

- Prototyping and Tooling: Creating quick, cost-effective prototypes, jigs, fixtures, and custom tools for manufacturing lines.
- Functional Parts: Producing durable, tough, and wearresistant final parts for various uses, such as gears, casings, brackets, and mechanical components.
- Household Items and Decor: Manufacturing custom home decor, kitchen gadgets, planters, storage containers, and artistic models.
- Educational and Research Models: Printing models for schools, universities, and research labs, often at a lower cost than new materials.
- Custom Electronics Enclosures: Creating protective covers and light casings that require specific dimensions.

2. *Automotive and Engineering*

- Low-Volume Vehicle Parts: A notable case study involves using recycled dental aligner molds to create fuel-line clips for cars, demonstrating highperformance, cost-effective industrial applications.
- Durable Functional Parts: Printing components that require high impact resistance and stability under temperature fluctuations.
- Jigs and Fixtures: Manufacturing custom workshop tools and manufacturing aids.

*3. Consumer Goods and Furniture*

- Furniture and Home Goods: Creating durable, weatherresistant outdoor and indoor furniture, often from recycled PET bottles.
- Fashion and Aesthetics: Printing components for accessories or decorative pieces, sometimes using recycled fishing nets (rNylon) for strong, resilient, and eco-friendly items.

4. *Medical and Health (Non-Invasive*)

- Orthotics and Prosthetics: Creating custom insoles, scoliosis braces, and other non-invasive orthotic solutions.
- Medical Device Components: Manufacturing non-critical parts, housings, and protective gear.
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*5. Marine and Environmental*

- Products from Ocean Waste: Filaments made from recycled ocean plastics, like fishing nets (rNylon), are used to print durable marine or outdoor parts, contributing directly to ocean cleanup efforts.
- Water-Resistant Objects: Recycled PET's low moisture absorption makes it ideal for outdoor items and utility clips

## VIII CONCLUSION

This review discusses how using recycled plastics (polymers) in additive manufacturing (AM)**—**also known as 3D printing—can help make manufacturing more environmentally friendly and **s**ustainable.

By reusing plastic waste in 3D printing, industries can move closer to net-zero carbon emissions**,** which means balancing the amount of carbon released into the atmosphere with the amount removed. This approach also supports the idea of a circular economy, where materials are reused and recycled instead of being thrown away, reducing waste and conserving resources. .Although using recycled plastics in 3D printing offers great environmental benefits, there are still some challenges. One major issue is materia**l** variability, meaning that recycled plastics don't always have the same quality or properties as new materials. There are also regulatory limitations, such as safety and quality standards, that can make it harder to use recycled materials in certain products.

To overcome these issues, researchers and industries are working together to improve how recycled materials are collected, processed, and tracked. Efforts are being made to ensure material traceability (knowing exactly where materials come from), set ethical and environmental standards**,** and optimize recycling methods so the final materials are strong, reliable, and safe to use. Looking ahead, achieving widespread use of recycled polymers in 3D printing will depend on continued research, supportive government policies, and collaboration between industries. With these combined efforts, recycled materials could play a major role in building a greener, more efficient, and more sustainable manufacturing **s**ystem for the future.

## IX Recommendation

. More research is still needed to make recycled 3D printing filaments perform as well as those made from new (virgin) plastic. When waste plastic is recycled, its strength and flexibility can decrease, so scientists are studying how to improve its mechanical **properties** using the right **a**dditive**s—**special substances that can make the material stronger, smoother, and more durable.

One of the main problems when using recycled filament in 3D printers is nozzle clogging. Impurities or uneven melting can block the printer's nozzle, stopping the printing process. This issue needs to be carefully studied and solved to make recycled filament more reliable for everyday use. Researchers also need to better understand how different types of recycled plastics can be processed or combined, and which of them require specific additives or processing aids to perform well in 3D printing. Not all plastics behave the same way when heated or melted, so finding the right blend and treatment method is essential.

Another important challenge is moisture control. Recycled plastics often absorb water from the air. If the filament isn't dried properly before printing, the trapped moisture can turn into steam when heated. This causes small bubbles or voids inside the printed layers, which weakens the final part and reduces its quality. Therefore, it's crucial to find effective ways to remove and prevent moisture in recycled filaments. Solving these issues— improving strength, preventing clogs, optimizing mixing, and controlling moisture—will help make recycled plastics a dependable, high-quality material for sustainable 3D printing.

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