HSSMI

SUCCESS STORY:

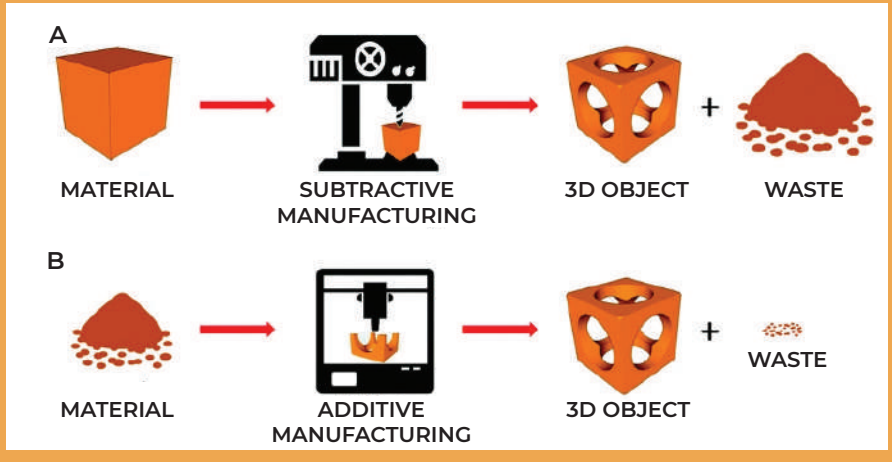
CREATING A CLOSED LOOP SUPPLY CHAIN FOR 3D PRINTING FILAMENTS

INTRODUCTION

Additive manufacturing is a rapidly growing sector. According to a 2017 Wohlers Associates report, the industry market will grow 4.3 times to about 26.2 billion by 2022.[1]

Additive manufacturing is generally regarded as more sustainable than traditional manufacturing methods because it is based on material-efficient design. In additive manufacturing, an item is 3D printed by adding material layer by layer. In contrast, subtractive manufacturing, which is what most manufacturing is based on, takes material from a stock and then removes excess, which is disposed of. Ultimately, the subtractive manufacturing process creates more waste than additive manufacturing.

However, the lack of an established end of life (EoL) processing system in additive manufacturing for 3D printed polymer parts has led to increased environmental concerns around this rapidly growing sector. Although 3D printed parts are made with less material, they ultimately end up being disposed of as low value general waste rather than recycled.



SUBTRACTIVE VS ADDITIVE MANUFACTURING IMAGE FROM 3D NATIVES

[1] *Ian Campbell (UK), Olaf Diegel (Sweden), Joseph Kowen (Israel), Terry Wohlers (U.S.), Ismail Fidan (U.S.) and David Bourell (U.S.), "Wohlers Report 2017," Wohlers, Fort Collins, Colorado, 2017.*

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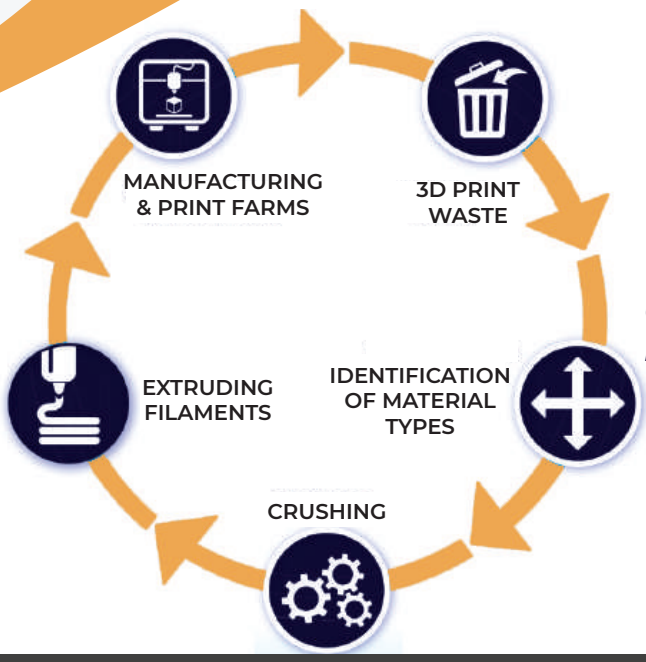


CLIFFF'S CLOSED LOOP SUPPLY CHAIN

THE CHALLENGE

HSSMI worked in a collaborative research project called Closed Loop Innovation in Fused Filament Fabrication (CLIFFF) with In-Cycle and GoPrint3D. The project aimed to take 3D printed waste, such as failed or discarded prints, and convert it into high value recycled filaments.

HSSMI led the work on 3 main aspects of the project:

1 - Research the 3D printing industry to identify the main materials and technologies used in 3D printing, as well as the main companies and industries active in 3D printing.

2 - Find the necessary volumes of waste to create a reverse logistics system for collecting and producing recycled filament.

3 - Compare the environmental impact between virgin filament and CLIFFF's recycled filament.

THE APPROACH

3D PRINTING MARKET REPORT

Throughout this report, HSSMI identified sectors that generate plastic waste and their interactions with 3D and additive manufacturing technologies. The report compares different 3D printing technologies and materials, and benchmarks companies that produce recycled filaments.

The report was based on desk research of existing literature, HSSMI's 3D printing expertise and insights from manufacturers, 3D printing studios, universities, and 3D printing resellers.

SUPPLY CHAIN ENGAGEMENT

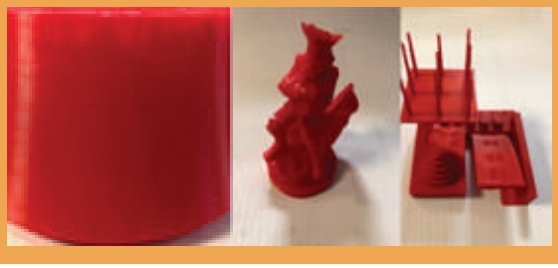
HSSMI and GoPrint3D engaged with companies that used FFF technology and PLA material. The aim of this exercise was to find relevant organisations that generate enough PLA waste to develop a reverse logistics supply chain and test the recycling process line developed by In-Cycle.

LIFE CYCLE ASSESSMENT (LCA)

Two types of recycled filaments were produced on In-Cycle's recycling line: 30% recycled PLA and 50% recycled PLA. Both filaments were tested by GoPrint3D. Test results showed that the recycled filament was as good as (and better than some) leading brands of filament, i.e. overall test results showed that the CLIFFF filament preformed as well as the recycled Filament from Filamentive and virgin filament from Ultimaker and Filkemp.

1. CLIFFF batch CR02 with 30% recycled content.

2. CLIFFF batch CR05 was produced with 3D printing waste exclusively from "Filamentive" filament. This was a test batch CLIFFF created due to the close cooperation with universities that already use Filamentive.



CLIFFF'S FILAMENT TESTING PARTS

HSSMI assessed the carbon emission savings between a virgin PLA filament and the two recycled filaments produced in the CLIFFF project. It is important to highlight that CLIFFF collects binned spools and reuses them, so the production of the spool is not considered in the LCA of CLIFFF's filaments.

THE RESULTS

3D PRINTING MARKET REPORT

The main outcomes of the report developed by HSSMI were:

- Fused Filament Fabrication (FFF) is the leading 3D printing technology, with 66% of printers on the market being FFF printers.
- Among 3D printing technologies, FFF does not rank as the most precise or the fastest, but its relatively low price and ease of use enables companies to develop cost-effective prototype designs.
- FFF is mainly used for education, rapid prototyping and grips, jigs and fixtures.
- Polylactic acid (PLA) or Acrylonitrile butadiene styrene (ABS) are the preferred materials, as they are easy to use and they have proven to be reliable and have a competitive price, as well as good mechanical properties.
- Packaging and spools are one of the waste streams generated by FFF. Usually a kilogram of filament comes wrapped around a plastic spool weighing about 250 grams.
- Failed prints, prototypes that are not used anymore and support material are also a significant

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SUPPLY CHAIN ENGAGEMENT

The data acquired from the main organisations is presented in the table below.

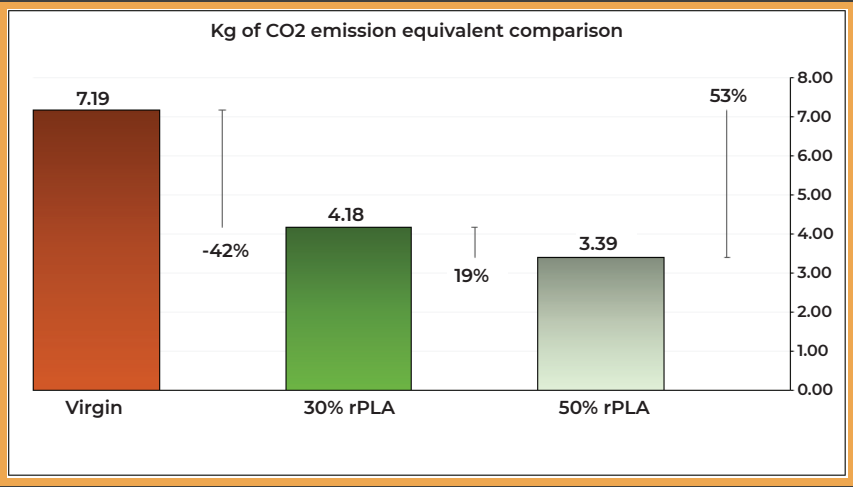
	Number of FFF printers	PLA filament use (kg/month)	Waste (kg/month)	Colour and supplier	Spool waste	Would you use recycled filament?
Organisation 1	30 - 40	30	~10	Mainly black	yes	yes
Organisation 2	50 - 60	70 - 80	~40	80% white, 20% black	yes	yes
Organisation 3	25	30 - 40	~5	White	yes	yes
Organisation 4	30	60	~15	Any colour	yes	yes
Organisation 5	60	70	~30	Black	yes	yes

During the project it was determined that the main organisations that generate the most waste are universities. Many of them have several FFF printers that students use for prototyping.

The project found enough PLA waste volumes and tried to develop a closed loop supply chain. However, the main barrier to developing the closed loop supply chain was the quality of the waste collected. The volume of quality waste was not high enough to efficiently sort it. Most of the waste was small pieces and it could not be guaranteed that they were not contaminated, making it very difficult to recycle.

LIFE CYCLE ASSESSMENT (LCA)

The Life Cycle Assessment was done using SimaPro LCA software and the result can be seen in the chart below.



LIFE CYCLE ASSESSMENT COMPARISON

The results show that the CLIFFF filament is not just competitive in terms of quality and performance but is also more sustainable than any virgin filaments. Many universities and 3D hubs are aware of this and many of them already use recycled filaments. HSSMI expects that the use of recycled filament will become more widespread and generate a commercial opportunity for the filament developed in CLIFFF.

"HSSMI did a great job developing a 3D printing market report and engaging with universities. This helped the project to understand the opportunities and barriers of developing a closed loop supply chain."

Mike Lee, Director of In-Cycle and lead partner of CLIFFF project

"The work of HSSMI was very helpful in terms of engaging with the supply chain and finding potential partners who helped to determine the commercial viability of CLIFFF."

Jo Young, Managing Director of GoPrint3D