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A Framework for Waste Minimization in Laboratory-Scale Additive Manufacturing

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Abstract

Although additive manufacturing (AM) offers a reduction in waste compared to conventional manufacturing processes, AM still generates non-negligible material losses and inefficiencies, from print failures to removable support structures. This research aims to propose a systematic Material Flow Analysis (MFA) framework tailored for AM laboratories. As a comprehensive approach, the framework maps the complete operational process from the filament to the final printed product, rather than focusing on specific printing activities. The case study is the Fused Filament Fabrication division of the Laboratory for Multiscale Mechanics (LM^2) at Polytechnique Montreal. LM^2 is dedicated to 3D printing polymers and composites using commercial printers and filaments. The MFA will be classified into two flow categories: fixed and variable waste. Printed products are highly customizable, which distinguishes their waste management strategies from traditional manufacturing operations. Fixed waste, such as disposable gloves and cleaning wipes, is quantifiable and repeatable in each production cycle. Therefore, the framework proposes direct alternatives (reuse/replace), depending on the waste generation rate. Variable waste, such as support structures, is design-dependent and varies based on the product. In laboratory-scale production, eco-design principles are non-systematic, and different user experience levels complexify their implementation. Therefore, as an alternative systematic approach, the framework proposes mechanical recycling as a key strategy that is assessable based on waste generation and CO_2 eq. emission and adaptable to different design outputs. Overall, the MFA aims to offer a guideline for waste management flow for a customizable manufacturing method at laboratory scale, identifying potential pathways towards a sustainable AM industry.

Keywords
Additive Manufacturing, Recycling, Waste Management, Sustainability, and Advanced Manufacturing.

1. Introduction

Additive manufacturing (AM), also known as 3D printing, is a process that produces complex geometrical structures layer by layer on a platform based on computer-aided design. In contrast to subtractive manufacturing, building a structure layer by layer reduces waste generation during the manufacturing process. Fused Filament Fabrication (FFF) is a category of AM that extrudes thermoplastic polymer-based filaments by passing them through a heated nozzle (ASTM, 2022). FFF is one of the most common 3D printing processes with wide applications in recent years (Pahlevanzadeh et al. 2021). It is particularly cost-effective on material, machine, and maintenance aspects. However, parts produced by the FFF method often require support material for complex geometries, as the part should stably adhere to the printing platform during the process (Au et al. 2016).

Resource consumption and waste management are key factors in the sustainability of FFF (Mastura, Alkahari, & Ikhwan, 2021). Material flow analysis (MFA) has become an essential decision-support tool for evaluating and improving waste management systems. MFA applies the mass-balance principle to quantify material inputs, outputs, and stocks across a defined system, ensuring data transparency and system integrity (Allesch & Brunner, 2015). Recent reviews highlight its increasing use in assessing circular economy strategies, linking waste management practices to material recovery potential and policy design (Widiyanti et al. 2025; Labelle et al. 2024).

While MFA is a powerful tool for waste management, its application in AM is complicated by factors unique to the technology, such as the high degree of user influence on material consumption. Since AM produces anisotropic mechanical properties, users may deliberately orient parts to maximize structural strength, even if it increases waste generation and printing time. In contrast, others may maximize eco-design principles and move towards supportless prints to reduce waste. As a result, the same part printed with identical slicing parameters can yield significantly different patterns, weights, and scrap volumes depending solely on how the user chooses to orient it. This variability complexifies waste management strategies as the quantity of generated waste remains unknown.

The 3D printing market has grown significantly due to the widespread commercialization of FFF technology. Nevertheless, the industrialization of such technologies is hindered in competition with conventional manufacturing methods. Recent advancements in FFF are largely the result of academic research (Singh, Singh, Prakash, & Ramakrishna, 2020). As an example, the FFF division of the Laboratory for Multiscale Mechanics (LM^2) at Polytechnique Montreal is dedicated to improving and optimizing advanced AM of polymer-based composite materials (Therriault & Farahani, 2021). The laboratory uses commercial FFF 3D printers (Bambu Lab X1E, Canada) for teaching and research purposes. Moreover, it is equipped with mechanical recycling equipment for plastics, including a shredder (GP20, 3devo B.V., Netherlands) and a filament-making single screw extruder (Filament Maker One, 3devo B.V., Netherlands). Alongside developments of innovative materials and AM methods, the LM^2 is also focused on advancing sustainable FFF via process modifications and waste management strategies.

1.1 Objectives

The goal of this study is to apply a systematic MFA to evaluate material flows in a 3D printing process at a laboratory scale, with the LM^2 as a case study. The analysis aims to compare current baseline practices with alternative scenarios, identifying sources of waste generation and potential opportunities for waste reduction improvement.

2. Literature Review

2.1. Waste Management in Polymer Processing

In polymer processing, effective waste management follows the hierarchy of prevention, reduce, reuse, recycle, and recovery, with landfilling as the least desirable option. Despite increasing policy efforts and technological advances, polymer processing industries continue to face challenges in balancing material efficiency with environmental performance. In Europe, only about 30% of the 25.8 million tons of plastic waste generated each year is recycled. In comparison, 39% is incinerated, and 31% still end up in landfills, revealing a persistent gap between policy targets and industrial implementation. This large-scale challenge in polymer recycling highlights the critical need to establish sustainable, circular practices at every level of the value chain, starting with the research and development stage in academic laboratories. (Drzyzga & Prieto, 2018; University of Oxford, s.d.)

Studies have demonstrated that polymer waste minimization relies heavily on improved design for recycling, enhanced collection systems, and development of infrastructure for sorting and reprocessing. In particular, polymers and polymer-based composites pose recycling difficulties due to multi-layer structures and additives that hinder separation. Therefore, systematic approaches integrating process optimization, waste categorization, and performance-based recycling indicators are needed to close the loop in polymer processing. (Lase et al. 2022)

2.2. Mechanical recycling

Mechanical recycling remains the dominant strategy for valorizing polymer waste, primarily through physical reprocessing steps such as sorting, washing, drying, and extrusion (Okan et al. 2019). However, the method faces quality degradation over multiple cycles due to polymer chain scission, contamination, and additive loss. Research shows that for post-consumer flexible plastics, improved mechanical recycling processes, such as the quality recycling process, can significantly enhance granulate quality while maintaining comparable yields (64 - 66%) to conventional recycling systems. Performance evaluation of such systems combines quantitative indicators (process yield, net recovery) with qualitative indicators (polymer purity, transparency). While conventional recycling often results in low-grade outputs suitable only for downcycled applications such as park furniture or garbage bags, enhanced processes incorporating advanced washing and extrusion technologies can generate higher-quality materials fit for semi-closed-loop applications. (Lase et al. 2022; Mastellone et al. 2017)

Similarly, in the context of AM, mechanical recycling of thermoplastic, such as polylactic acid (PLA) has shown to maintain acceptable mechanical and environmental performance over multiple cycles when reprocesses via FFF (Sibille, et al., 2025). This highlights the potential of modular, MFA-based recycling models to guide future developments in mechanical recycling, including applications for AM waste streams.

2.3. MFA in waste management

At the macro level, dynamic MFA models have been developed to account for temporal changes in product lifetimes, consumption patterns, and recycling quality. Eriksen et al. (2020) demonstrated that combining collection improvement, design-for-recycling, and better recovery technologies could elevate European recycling rates for polyethylene terephthalate, polyethylene, and polypropylene above 55%, covering up to 65% of annual demand with recycled material. Similarly, recent bibliometric analyses reveal a growing trend in MFA applications that integrate life cycle assessment (LCA) and circular economy (CE) frameworks, supporting multi-criteria decision-making and sustainability policy development (Widiyanti et al. 2025).

MFA thus provides both quantitative and qualitative insight: it helps identify inefficiencies in material use, supports evaluation of recycling technologies, and measures the environmental performance of circular strategies. The integration of MFA with LCA enables more holistic decision-making, particularly in complex systems such as polymer waste management and additive manufacturing.

2.4. Waste management in AM

Although AM reduces waste compared to conventional subtractive methods (Sunil Chandrakant & Abdullah Azhar, 2015), laboratory-scale AM still generates substantial amounts of fixed and variable waste. Fixed waste includes consumables such as wipes and gloves, while variable waste stems from failed prints, support structures, and design iterations. Unlike industrial production, AM laboratories operate with diverse materials, limited batch sizes, and varying user experience levels, leading to inconsistent waste generation patterns.

Several studies have sought to quantify AM-related waste or valorize discarded materials, even without formal MFA frameworks. For instance, Despeisse et al. (2017) analyzed how 3D printing contributes to circular design and resource efficiency, while Ferreira et al. (2021) highlighted the potential of industrial symbiosis in AM by repurposing polymer and metal waste streams into new printing feedstocks within circular economy settings. Such research underscores that while waste quantification and valorization have been explored conceptually, few approaches provide a systematic, process-level mapping of material flows within AM laboratories.

Applying MFA in AM environments allows researchers to systematically map all material flows from feedstock (filament or pellets) to printed products and discarded residues, quantifying losses and identifying hotspots of inefficiency. In addition, integrating eco-design principles can reduce support material use, while internal mechanical recycling (e.g., re-extrusion of failed prints) can enhance circularity. The approach aligns with the findings of Lase et al. (2022), who demonstrated that modular MFA frameworks could improve decision-making by linking process-level data to recycling performance metrics.

2.5. Research Gap and Contribution

Despite the increasing adoption of MFA in polymer waste studies, to the best of our knowledge, no existing framework has been tailored specifically to laboratory-scale AM. Previous research has focused on large-scale systems, emphasizing municipal or industrial plastic flows, whereas small-scale AM environments remain underexplored. To the best of current knowledge, there is no framework that distinguishes fixed and variable waste within AM processes while simultaneously integrating MFA, mechanical recycling, and environmental indicators such as CO_2-equivalent emissions.

Developing such a framework would bridge the methodological gap between polymer recycling studies and the operational realities of AM laboratories, offering a scalable model for waste minimization, circular material use, and sustainability assessment in emerging manufacturing technologies.

3. Methods

3.1 System Definition

The scope of the analysis was defined at the production cycle level, with a single 3D printing cycle serving as the functional unit. Each printing process involves four general steps. First, the printing platform is cleaned using one pair of nitrile gloves (VWR® International), one Kimwipes™ laboratory wipe (Kimtech Science™, United States), and isopropyl alcohol (IPA) (VWR® International), followed by an optional step where printing glue (Bambu Lab, Canada) is added to the platform surface. Then, the geometry is sliced using the Bambu Studio software with user-selected parameters. Subsequently, the generated code is sent to the printers to print the part. Finally, the part is removed from the platform, and post-processing removes scraps such as support structures or calibration flow patterns. Since AM production cycles vary from one product to another, a representative geometry, showcased in Figure 1a and hereafter referred to as the "reference geometry", was designed and used consistently throughout this study. The reference geometry represents a bridge commonly used as a demonstration in 3D printing courses. Details such as a curved overhang (without a supporting base) and narrow handles were included to showcase the complexities in printing and require support generation, as shown in Figure 1b. Figure 1c represents the 3D-printed part, scaled down for demonstration purposes. The reference geometry in its full scale served as the functional unit for all material flow analyses, and all calculations regarding weight and printing time were based on the full-sized geometry and software-driven data.

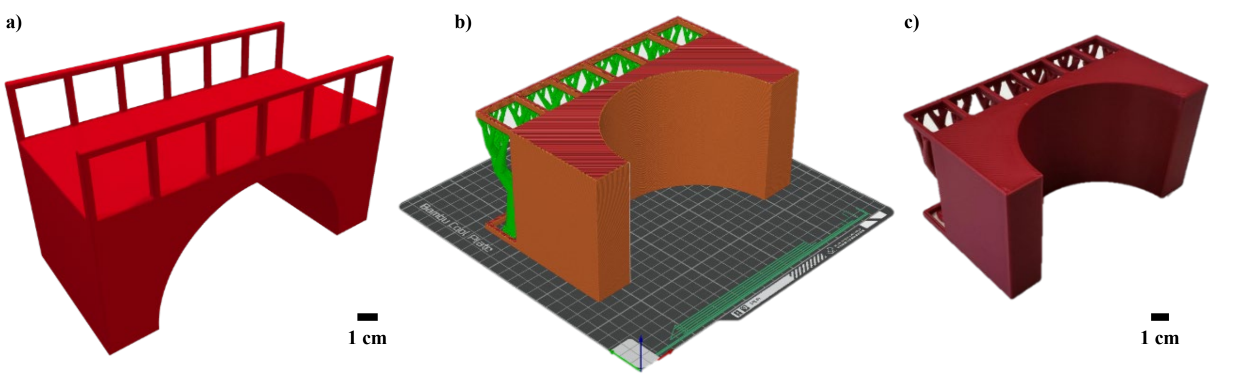


Figure 1. The reference geometry used in this study. a) An arched bridge developed using computer-aided design (CAD), b) Slicing the reference geometry in the 3D printing software, where red areas show the product and green regions show support structures, c) Printed part (scaled down for demonstration to reduce material usage).

The orientation of a part on the build plate has a direct effect on how it is sliced, and, consequently, on the amount of material used. Overhangs created by specific orientations may require additional support structures, resulting in increased scrap material. In this study, the auto-orient setting was used in the software, as shown in Figure 1b, an option that chooses the optimal orientation based on the overhang area, adhesion to the printing platform, and part stability during printing. Other printing parameters were selected using the standard preset provided by the software for a 0.4 mm nozzle. The key parameters involved in waste generation are described in Table 1. The selected material was polylactic acid (PLA) filament (Bambu Lab, Canada), which is the most used 3D printing material in the LM^2 laboratory. The weight of the final product and scraps is estimated in the software based on polymer density. Figure 1c shows a scaled-down sample printed in PLA before post-processing and support removal for demonstration.

Table 1. Printing parameters used as a standard preset throughout this study

Parameter	Standard Preset	Description
Layer Height	0.20 mm	Smaller layer height gives finer detail, but increases printing time.
Infill Density	15%	Higher percentages increase weight and printing time.
Number of Walls	2 walls	Increasing the outer shell material increases strength and weight.
Support Settings	Tree (Default automatic)	Supports increase material use and are removed as scraps.
Weight of Product	262 g	Measured in the software using the filament density and volume.
Weight of Scraps	17 g	Includes support structures and calibration flows.
Printing Time	5h19m	Estimated by the software.

The system boundaries for this study included raw material inputs, supporting consumables, the printing process, and the finished product. Material flows upstream of raw material production (e.g., virgin filament synthesis) or downstream of the finished product were excluded. Inputs included virgin filaments, while supporting consumables included nitrile gloves and laboratory wipes. IPA and printing glue were excluded from the scope because they are volatile and cannot be quantitatively assessed. Output included the finished product, scraps, and waste. Failed attempts at printing often contribute significantly to 3D printing waste. However, they are not directly measurable as many reasons may contribute to a failed print, including design faults, unsuitable material choice, and machine errors. Due to their unpredictable nature, they were excluded from the present analysis.

To study the variability of waste generation in each printing cycle, a sample of three undergraduate and three graduate students were selected, all of whom had received similar training on the 3D printer and slicing software at this laboratory. The small sample size (n=6) can demonstrate illustrative results as a proof-of-concept, although a larger sample will be required in future studies to report statistically generalizable results. Each participant was instructed to slice the reference geometry in Bambu Studio according to their own judgment using the same material, and their chosen orientations and parameters were documented. For each case, the predicted final part weight, scrap weight, and printing time were recorded and compared across users. Mechanical properties that may vary with different parameters remained outside the scope of this study.

3.3 Material Flow Analysis Framework

The methodological approach in this study is based on MFA, a systematic framework for quantifying material flows within defined system boundaries according to the principle of mass conservation. MFA was selected as it represents inputs, outputs, stocks, and internal recycling loops, facilitating comparison of waste management scenarios. The baseline scenario was defined as the current 3D printing and waste management practice observed in the laboratory. Waste generation within this baseline was analyzed, providing the reference case for comparison. In addition, an alternative scenario was developed based on these observations, focusing on a modified waste management strategy aimed at reducing material losses. The software STAN 2.7.101 (subSTance flow ANalysis) (Cencic & Rechberger, 2008) was used to visualize flows for both scenarios.

While MFA is often studied over a given period, laboratory-scale production is not consistent. Therefore, a functional unit was used to provide a comparable basis in the laboratory. The MFA boundary considered one representative printing cycle for the reference geometry to ensure that inputs, outputs, and flows are quantifiable and comparable between different scenarios. Such unit-level MFA can then be scaled up using operational data to approximate a time-bound MFA for future studies.

In all scenarios, the flow categories studied were the ones involving polymer materials. Supporting consumables were not directly included in the mass balance, as they do not directly enter the printing cycle and do not circulate in the system. Instead, their use was counted per cycle, assuming each item becomes waste immediately after use. Mass data was sourced from the Bambu Studio printing software and production records at the LM^2. To enable comparison between the baseline and alternative waste management scenarios, the waste generation rate (%) was defined as the mass of material waste relative to the total material input, excluding stock, which serves as a quantitative indicator of system performance. Since every unit of waste has an associated carbon footprint from the material itself and waste treatment, a lower waste generation rate indicates lower CO_2 emissions.

4. Results and Discussion

4.1 Baseline Scenario

The material flows of the baseline scenario for one production cycle of the reference geometry are illustrated in Figure 2, with values expressed in grams. In a 3D printing cycle at this laboratory, the polymer enters the process as a one-thousand-gram spool, shown in the diagram as the raw material input. Printing the reference geometry requires support structures that are printed and subsequently removed during post-processing, after which they are discarded. Furthermore, each printing cycle generates a fixed quantity of waste during filament loading and calibration of the flow. In the diagram, support structures and machine waste are illustrated as output scraps. The primary output of the process is the final product after post-processing. At the same time, the remaining filament is stored in stock for future use, as illustrated in the printing process node of the diagram. According to the approximated mass of the final product and scraps from the printing software, this baseline scenario has a waste generation rate of 6.1%. Lastly, each printing process requires one cleaning wipe and one pair of nitrile gloves as supporting consumables to prepare the platform, which are then disposed of directly.

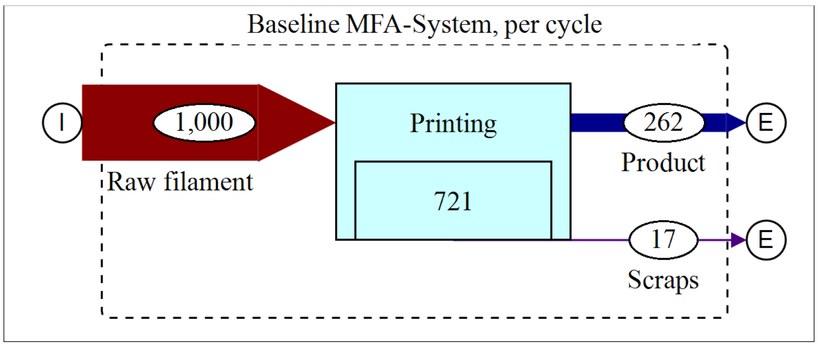
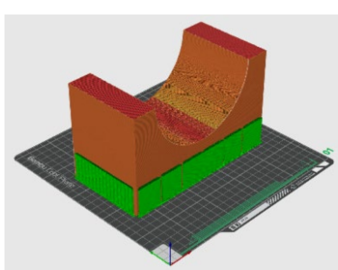
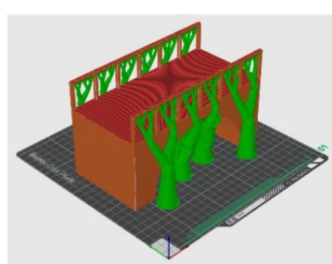
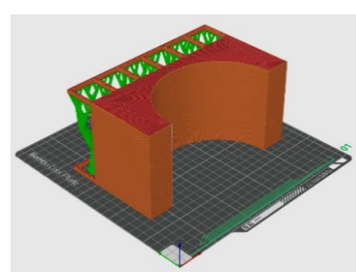


Figure 2. Baseline scenario MFA of the 3D printing process for the reference geometry. Arrows represent material flows, with thickness proportional to flow magnitude. Values are expressed in grams per production cycle. The diagram includes raw material inputs, stock quantities, product outputs, and scrap generation.

4.2 Variable Waste Generation in 3D printing

Analysis of the slicing profiles provided by the six laboratory students revealed notable variation in product mass across users. Table 2 showcases three profiles submitted by the users as examples. Using the same material, 3D printer, and printing speed, differences arise in printing orientation, layer height, infill percentage, number of walls for the hollow structure, and support generation settings. For instance, Student #1 selected a dense support structure to improve the surface quality and stability of the print, acknowledging that this approach consumes more material and generates more waste (127 g of scraps). On the other hand, Student #3 chose to print the bridge on its side, as it improves the quality of the arch and requires less support (17 g of scraps).

Table 2. Samples of different printing orientations by three laboratory users, and their resulting waste generation and printing time

Parameter	Student #1	Student #2	Student #3
Part Orientation			
Layer Height	0.20 mm	0.20 mm	0.24 mm

Infill Percentage	15%	15%	17%
Number of Walls	2 walls	2 walls	3 walls
Support Settings	Grid (Default automatic)	Tree (Default automatic)	Tree (Default automatic)
Weight of Product	269 g	265 g	305 g
Weight of Scraps	127 g	63 g	17 g
Printing Duration	7h 21m	8h 43m	8h 22m

Figure 3 demonstrates the variability of the final product weight, the weight of scraps, and the printing time across the sample users. The data showed a mean weight of 250 g for the final product, with a standard deviation of 42 g, indicating substantial fluctuation across users which stems from their choice of printing parameters. For example, an increase in the number of walls and infill density directly increases the weight of the final product. Similarly, an average printing time of 424 minutes with a standard deviation of 89 minutes reflected the high degree of inter-user variability that was hypothesized.

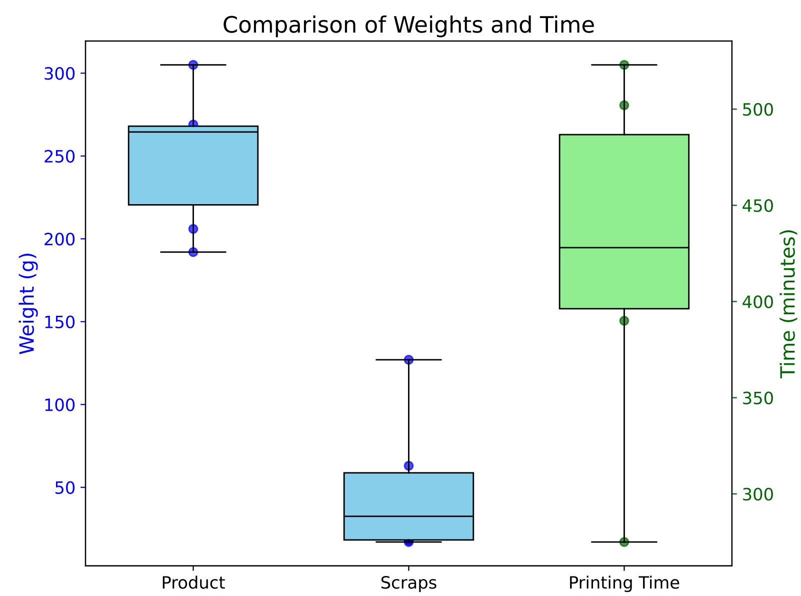


Figure 3. Comparison of the weight of the final product, the weight of scraps, and printing duration measurements across six participants. Blue boxes represent weight data; green boxes represent time data, with individual data points overlaid for clarity.

As a result, waste generation in laboratory-scale 3D printing can be categorized into fixed and variable waste. Supporting consumables and machine calibrations are constant in each process and do not rely on printing parameters or the final product. This fixed waste is quantifiable and repeatable. However, part of the printing scraps, such as support structures, vary with each product and each user. Therefore, a systematic waste management approach is required that can handle this variable waste, regardless of the product or user relevance.

4.3 Alternative Waste Management Scenario

In the alternative scenario, fixed and variable waste are treated separately. Fixed waste includes machine calibration, considered unchangeable in this study, and supporting consumables. Both categories of consumables, namely disposable gloves and wipes, can be substituted with reusable alternatives, thereby eliminating them from both input and output streams and reducing the fixed waste generated per production cycle. Since each consumable item has an associated carbon footprint, its elimination directly translates into a reduction in CO_2 emissions linked to the process. To reduce waste and convert scraps into useful material input, mechanical recycling is proposed as a solution. Mechanical recycling is a systematic approach that can circulate scraps, including fixed calibration waste and support structures, back into the system regardless of their quantity. Therefore, it is not user or product-dependent. For the purposes of this mass-based flow analysis, the recycled filament is assumed to be a functionally equivalent substitute for virgin material. The assessment of property degradation is a crucial next step for future work.

Figure 4 shows the MFA diagram of this alternative process, introducing two process nodes for mechanical recycling: shredding and filament making. The printing scraps enter the shredder, which chops them into flat pellets with a diameter of 3-5 mm. Based on production records from previous recycling projects, it is estimated that approximately 1% of the material input into the shredder is lost as waste during routine operation and cleaning procedures. These loss rates are based on two recycling batches of short carbon fiber-reinforced PLA conducted at the LM^2 laboratory in previous projects, providing a locally relevant estimate for the model. Uncertainties in this estimated loss may arise from potential contamination from previous materials and inconsistent pellet size.

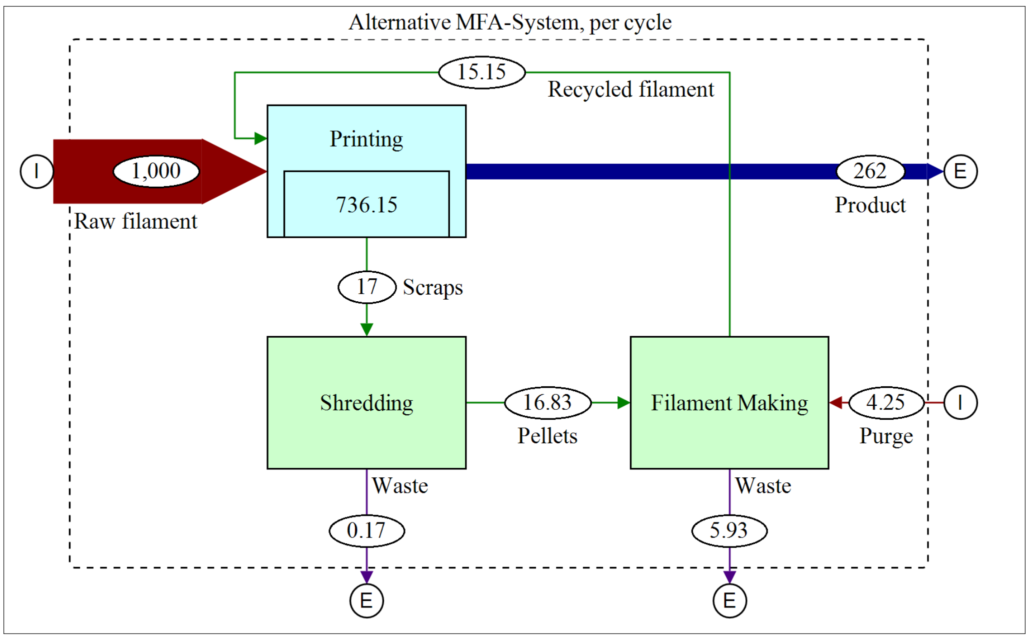


Figure 4. Alternative scenario MFA for the Reference Geometry, with internal recycling represented as a closed loop within the system boundary. Arrows represent material flows in grams per production cycle, with thickness proportional to flow magnitude.

The shredded output then enters the filament-making process. To clean the single screw extruder after each cycle, purge material is required to enter the system. At this laboratory, HDPE Flush (3devo B.V., Netherlands) is used, and previous filament-making records show that the quantity of purge material required per cycle is approximately 25% of the material input into the extruder. Furthermore, 10% of the input material and all of the purge go to waste during each process. The quantity of purge material required can be reduced if the filament is produced in larger batches. Finally, approximately 89% of the scraps are recovered and enter the printing process as recycled filament.

It should be noted that shredding and filament-making processes are represented in scale per cycle. The LM^2 laboratory equipment requires a minimum of 200 g of input for these two processes. Therefore, the input and output values can be adjusted according to scale in future work. Nevertheless, the alternative scenario has a waste generation rate of 2.3%, representing a 62% reduction. While lower landfill waste and a reduction in virgin material reduce CO_2 emissions, two process nodes are added to the cycle. Internal mechanical recycling increases electricity demand. Therefore, as future work, an environmental impact assessment is required that considers the CO_2 emission factor per unit waste as well as emissions from each process node. For instance, a comparative life cycle assessment (LCA) can be conducted to determine if the CO_2 emissions from increased electricity consumption of mechanical recycling are offset by the emissions saved from producing 15.15 g of virgin filament. The presented mass flow illustrates the systematic application of the MFA framework. It can later be refined based on empirical data for a comprehensive analysis.

5. Conclusion

Waste management strategies in AM differ from conventional manufacturing methods, as waste generation is highly variable. The manufacturing process of each product is highly dependent on the user and the application for which it is intended. This study proposes a systematic solution to waste management in laboratory-scale AM that involves mechanical recycling as a reliable solution for variable waste generation. The MFA framework shows a meaningful reduction in landfill waste and material input requirements. This framework is applied at the production cycle scale to consider the variability in 3D printing and differs from traditional MFA in scope. Such an approach ensures repeatability, allowing for the comparison of alternative waste management strategies applicable to various materials and geometries.

While the study provides insights into material flows and waste management in laboratory-scale AM, certain limitations must be acknowledged and addressed in future work. The exclusion of failed prints from this analysis understates the quantity of waste generated by AM and can be addressed in subsequent studies. Moreover, recycling requires scraps to be correctly sorted, cleaned, and processed. Any contamination during filament fabrication may lead to the disposal of entire batches of material. Furthermore, mechanical recycling is known to degrade thermoplastic polymers. The resulting filament will not possess the same properties as the virgin material, which can impact the product's performance.

Such limitations require further research into each process node, focusing on three key areas: 1) Conducting a comprehensive LCA comparing the baseline and alternative scenarios, incorporating measured electricity consumption data and regional emission factors, 2) Expanding the framework to include other common polymers used in AM which present different recycling challenges, 3) Investigating the mechanical properties of parts printed with the recycled filament to quantify the effects of material degradation on product performance. Overall, the MFA framework can be further refined with experimental data and used as an effective decision-making tool, providing a pathway for future research on sustainable AM.

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Biographies

Ghita El Anbri is a doctoral candidate in Industrial Engineering at École Polytechnique de Montréal, specializing in additive manufacturing, logistics, and circularity in the aerospace industry. She was fast-tracked into the PhD program in recognition of her academic performance, having previously completed a Bachelor of Business Administration with Honors in Operations Management and Logistics at HEC Montreal. Her research spans product life cycle management, circular economy, and multi-criteria decision-making, with applications in aerospace and sustainable manufacturing. She has lectured at Polytechnique and HEC Montréal, earning the award for Best Laboratory Lecturer from the Industrial Engineering Department (AÉCSP) in 2024, and is a member of the graduate study council of Polytechnique. Ghita has been widely recognized for her academic and research contributions. In 2025, she was part of the winning team in the international Young Engineers Challenge, organized by SAMPE Europe and presented at JEC World 25 in Paris. She won the Woman Leadership Scholarship by Axium Infrastructure in 2024 and was named one of the 100 student leaders from 50 countries by AUF in 2023, won 2nd place in the EV Competition at the IEOM 2023 Conference, and received the Emerging Women in Aerospace Scholarship from CRIAQ and the Howmet Aerospace Foundation Women's Excellence Scholarship. In 2022, she led a Polytechnique–HEC team to win 1st prize for poster presentation at the Space Resources Week in Luxembourg and was awarded the HEC Montréal Sustainable Development Research Fund. Her expertise bridges industrial engineering, sustainability, and the integration of advanced manufacturing.

Negar Aghigh is a PhD candidate in the Department of Mechanical Engineering at Polytechnique Montréal, under the supervision of Prof. Daniel Therriault. With a BSc in Mechanical Engineering from the University of Tehran, her direct doctoral studies specialize in multimaterial additive manufacturing of self-healing thermoplastic composites. Her project is in collaboration with the Multifunctional Composites Group of North Carolina State University, USA, led by Prof. Jason F. Patrick. With a background in manufacturing and automation, her research focuses on fused filament fabrication of smart materials, particularly sensors and heaters, with the goal of developing sustainable materials that offer improved durability and multifunctional performance. She serves as a teaching and laboratory assistant at Polytechnique Montreal and facilitates 3D printing workshops in schools and libraries across Quebec for the Centre de Recherche sur les Systèmes Polymères et Composites à Haute Performance (CREPEC). Negar has received multiple academic and professional recognitions. In 2025, her team from Canada won the SAMPE Europe Young Engineers Challenge, presenting at JEC World 25 in Paris for innovation in sustainable composite engineering. She was awarded the PBEEE Scholarship (2024–2025) by the Fonds de recherche du Québec for her doctoral research. At the University of Tehran, she ranked fourth among 125 students in the Mechanical Engineering program in 2023.

In 2022, she earned fourth rank in the 27th National Student Scientific Olympiad in Mechanical Engineering. Earlier, she ranked in the top 0.2% nationwide in Iran's 2019 nationwide entrance exam for undergraduate studies.

Daniel Therriault is a full professor in the Department of Mechanical Engineering at Polytechnique Montréal. He has obtained his Bachelor's and Master's degrees from École Polytechnique de Montréal and pursued his doctoral studies in aerospace engineering at the University of Illinois at Urbana-Champaign, USA. He previously held the Industrial Chair in Additive Manufacturing (AM) of Polymer Composites (FACMO Chair, 2018-2023) and a Canada Research Chair in the Fabrication of Advanced Microsystems and Materials (2009-2019). He serves as co-director of the Laboratory for Multiscale Mechanics (LM2). His research focuses primarily on AM of advanced materials and multifunctional composites, with recent projects emphasizing sustainable practices in thermoplastic composites, including self-healing, recycling, and sustainable manufacturing. His contributions include pioneering innovative AM processes (such as 6-axis non-planar printing and multi-material, multi-process approaches) and advancing the design and fabrication of multifunctional materials (including carbon fiber-reinforced thermoplastics, abradable thermosets, and piezoelectric materials). These developments target advanced aerospace applications, with strong potential impact across transportation, energy, and biomedical sectors. His work has been recognized with several prestigious awards, including the 2020 Prix d'excellence en recherche et innovation from Polytechnique Montréal, and being twice named among top ten innovations of the year (Les 10 découvertes de l'année) by Québec Science magazine in 2010 and 2018.

Sampada Bodkhe is an associate professor in the Department of Mechanical Engineering at Polytechnique Montréal, supported by a B.E. in Mechanical Engineering from Visvesvaraya Technological University (Bangalore, India), an M.Tech in Aerospace Engineering from IIT Kanpur (India), and a Ph.D. in Mechanical Engineering from Polytechnique Montréal (2017). Before starting her PhD, she worked as an Edison Engineer at GE Aviation in India, where she focused on structural and thermal assessments of components for LEAP 1B engines. Her doctoral research focused on piezoelectric inks and co-extrusion-based direct-write 3D printing of piezoelectric sensors. These self-power sensors were recognized among the top ten innovations of the year (Les 10 découvertes de l'année) by Québec Science magazine in 2018. Following her doctoral studies, she conducted postdoctoral research at ETH Zurich, where she expanded her expertise in adaptive systems and multifunctional additive manufacturing. She holds the title of Canada Research Chair Tier 2 in Advanced Manufacturing of Multifunctional Adaptive Structures. Currently, she works on the development of smart morphing composite structures with adaptive sensing and actuating abilities. Her research interests include additive manufacturing, smart materials, flexible actuators, multifunctional materials, automated fiber placement (AFP), 4D printing, and sustainable manufacturing.

Samira Keivanpour is an associate professor in the Department of Mathematical and Industrial Engineering at Polytechnique Montréal, holding a B.Sc. in Electrical Engineering and an MBA in Operations Management from the University of Tehran, as well as a Ph.D. in Industrial Engineering from Université Laval, Canada. She also worked as a postdoctoral researcher and professional researcher in the Department of Mechanical Engineering at Université Laval. She has previously been a sessional faculty member at Thompson Rivers University. As a member of CIRODD and CIRRELT, she actively contributes to several research projects. Her expertise includes operations management, logistics, Industry 4.0, expert systems, and artificial intelligence, with a primary focus on the "Industry of the Future and Digital Society," and complementary interests in "Environment, Economy, and Society," as well as "Modeling and Artificial Intelligence." In this sense, she created and leads the Poly Circle X.0 Laboratory at Polytechnique Montreal. Her research focuses on digital innovation and sustainable operations, with key interests in circular economy and end-of-life product management, sustainable and circular supply chains, human-robot collaboration and smart automation in logistics, and the use of AI to drive sustainability in operations.