RECREATEIT: TRANSFORMING PLASTIC WASTE THROUGH COMMUNITY-LED MANUFACTURING

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Abstract

ReCreateIt, led by re:3D, Inc. and partnering with Austin Habitat for Humanity (AHFH) ReStore, Georgia Tech, University of Texas at Austin, Western Sydney University (Australia) and the University of Wollongong (Australia), is developing a local circular economy by deploying a Gigalab, a sustainable manufacturing lab capable of repurposing plastic waste through fused granular fabrication 3D printing.

ReCreateIt has set a goal to divert at least 10,000 lbs of plastic waste from entering landfills, train at least 20 workers in advanced manufacturing and engage and educate more than 500 community members. To create high value items from recycled plastic, re:3D built a Gigalab from a modified shipping container, which houses a GigabotX 3D printer, a granulator, and a material dryer. Georgia Tech is leading the implementation of an interactive design tool customers can use to select and customize home goods. UT Austin and the University of Wollongong are developing a sustainability dashboard which collects and communicates the environmental impacts of the project. Western Sydney University and the previously mentioned collaborators are conducting polymer research to characterize bulk recycled materials, enhance the printability of recycled materials, and ensure the structural integrity of printed parts. All research, metrics and data will be made accessible via a project-built public-facing website.

The ReCreateIt Gigalab installed at a ReStore site in Austin, TX enables customers to design sustainable home goods 3D printed directly from recycled plastic waste collected on-site during normal ReStore operations. The project is increasing access to plastic recycling solutions while stimulating new job creation and education for historically underserved communities. The team is also researching solutions for 3D printing with hard-to-reuse commodity plastics. To date, over 4000 lbs of plastics has been collected, and over 650 lbs has been processed and granulated for 3D printing. Ten employees have been trained or are being trained on the collection, processing and manufacturing processes, and the resulting products created in the Gigalab are creating revenue that supports the AHFH mission.

A part of the National Science Foundation's Convergence Accelerator in Track I: Sustainable Materials for Global Challenges, this project is also funded by CSIRO, Australia's national science agency. The international collaboration is providing the research and development foundations for community-led sustainable manufacturing and a template for transferring the approach to broader community stakeholders.

Introduction and Motivation

Imagine a world in which Habitat for Humanity could support sustainable manufacturing of furnished homes using local waste, while not only diverting garbage from landfills, but also creating jobs and training underrepresented talent. What if this opportunity could be scaled globally in both rural and urban areas in a modular package?

This ongoing project is pioneering such a solution by convening academics and educators, nonprofits and industry experts to provide a deployable, net-zero-footprint manufacturing system that enables lay users to design and manufacture goods from waste onsite, resulting in sustainable infrastructure with significant socio-economic impact.

This solution was designed based upon a need to address the thousands of dollars a year that a single Habitat for Humanity ReStore, a 2nd hand construction supply and furnishing reseller, spends to landfill unused, unwanted, or broken plastic and/or waste generated during construction operations. There are nearly 900 ReStores in the United States. By redirecting that waste from landfills directly into 3D printing feedstock, we are turning an item with a negative value into a product that is useful and valuable. An added bonus of spreading this idea nationwide, is the sharing a library of designs and digital files that can be easily adjusted to meet local waste availability and end user requirements, so that other ReStores and other communities can have access to this asset. AHFH ReStore was specifically approached as a partner because of a measured success in sustainable operations over its long history. It was the first and is the largest ReStore in the U.S. It has diverted over 40 million pounds of usable materials from landfills and powers operations with solar energy, meeting 100% of annual electricity needs. As our end user, ReStores are a stand-in for communities across the world who wish to manage their plastic waste in a way that benefits their neighbors and environment. ReCreateIt envisions a future where communities lead the charge as self-sustaining builders of a circular economy.

The active pilot program with the ReCreateIt Gigalab installed at AHFH ReStore(Fig. 1) is providing key data points to validate this solution including: material viability, economic data, environmental impact and more. The ReCreateIt Gigalab launched in April 2025, and the pilot program is planned to continue through 2027. This paper summarizes ReCreateIt's research through the first six months of the pilot.

Figure 1. ReCreateIt Gigalab at AHFH ReStore exterior and interior views showing the modified shipping containers equipped with GigabotX 2 3D printer.

Current State of the Technology Industry Uses

Plastic waste pollution is an increasingly prevalent environmental issue, with a recycle rate of only 9% for all of the worldwide plastic ever produced.[1] In 2017 the US alone generated over 35 million tons of post consumer plastic waste, with 77% going to landfills.[2] China historically imported plastic waste for recycling from 43 countries, including America, but starting in 2018, China banned the import of non-industrial plastic waste.[3] Due to the new policy, an estimated 109 million tons of plastic worldwide will be displaced by 2030, driving the need to rapidly develop domestic recycling solutions. One novel solution is to use additive manufacturing (AM) to mechanically upcycle waste plastic.

Additive manufacturing (AM), or 3D printing, has key benefits over traditional manufacturing methods. AM enables on-demand, onsite, customized manufacturing without the extensive equipment and up-front costs required by traditional manufacturing.[4] This makes AM solutions quickly deployable and especially well-suited for lower production runs. Furthermore, the distributed nature of consumer plastic waste creates logistical collection challenges,[5] making 3D printing a promising solution for upcycling plastic waste closer to the location where it is produced, reducing transportation and storage costs.

To adapt additive manufacturing to take recycled plastic feedstock, re:3D developed Gigabot X, a 3D printer that prints directly from recycled polymer pellets, and flakes/regrind, thereby mechanically upcycling plastic waste for a wide variety of applications.[6] Gigabot X was conceived using NSF SBIR Phase 1 and 2 grants, for which the research was awarded a 2020 Tibbetts Award,[7] it is a large-format cartesian printer with a build volume starting at 5.8 cubic feet. The pellet extruder on Gigabot X consists of an extrusion barrel with three heating zones, a compression screw, and interchangeable nozzles to print at different resolutions. With its high heat input and nozzle sizes up to 5mm, Gigabot X can extrude up to 0.8kg/hr of material, or 20 times faster than a traditional filament printer.

Currently the most common AM solution is Fused Filament Fabrication (FFF), which uses thin plastic strands manufactured from virgin plastic and extruded through a heated nozzle. There are a limited number of companies producing 3D printer filament from recycled plastics,[8,9] but filament is on average 10x more expensive than pellets due to the energy and monetary cost incurred by the filament manufacturing process. By switching from filaments to pellets as input, we eliminate the need for the intermediate step of filament fabrication and therefore enhance the capacity of the 3D printing system to recycle at scale. Cost and energy savings multiply with the amount of material printed, making it economically viable to print large, functional objects. For example, due to a large build volume, a single Gigabot X pellet printer has the potential to repurpose 30,000 water bottles per month into functional products as large as a kitchen chair.

Efforts like ReCreateIt's do not exist in isolation. The increasing global acknowledgment of the growing plastics challenge has led to many creative responses to the problem. The Ellen MacArthur Foundation highlights that global efforts to reuse & repurpose plastics have led to avoiding 14 million tonnes of virgin plastic since 2018, the equivalent of 2 trillion plastic bags.[10] In the US, state laws implementing Extended Producer Responsibility, requiring manufacturers to take responsibility for the end life of products, are encouraging more adoption of circular methods. California is increasingly implementing these requirements, and as it is such a large part of the US economy, its standards will have an effect on manufacturers across the country. Recycling plastic via 3D printing can be one of the tools in the toolkit that manufacturers use to meet these standards.

Technology Approach

This project is focused on convergence research that brings together expertise in manufacturing, engineering design, computational engineering, sustainability and life cycle analysis(LCA), materials science, the sustainable built environment, and opportunities for building the human-technology partnership to create new economies and job opportunities around plastic recycling to benefit under-resourced communities.

The interdisciplinary research is focused on four, interconnected pillars:

1. 3D printing from waste and associated material science
2. Design of a minimum footprint, mobile, recycling and 3D printing system - the Gigalab
3. Life cycle analysis and sustainability metrics
4. Design in collaboration with end users: digital design tools with integrated LCA data

Discussion

1. 3D Printing from Waste and Associated Material Science

Throughout 2024 and continuing into 2025, waste plastics at AHFH ReStore were sorted by their recycling codes and colors, resulting in a broad view of the types of plastics typically found in these locations. The vast majority of identifiable materials in the waste stream were polypropylene (PP), followed by high density polyethylene (HDPE) and low-density polyethylene (LDPE) (Fig. 2). Unidentifiable plastics along with those that were too dirty for processing were discarded. In total, there were 241kg of plastics discarded, leaving 86% of the 1738kg plastics collected available for research and processing into products via 3D printing.

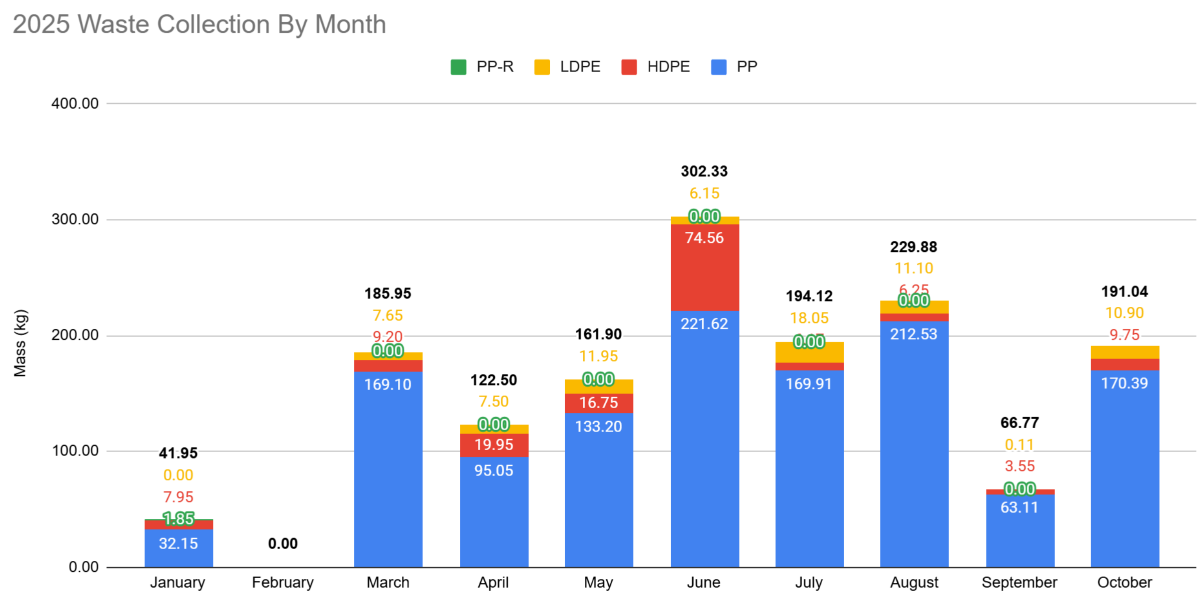

Figure 2. Identifiable waste plastics found at AHFH ReStore in 2025 waste surveys.

ReCreateIt has been using the GigabotX 2 (GBX) 3D printer for use in research labs and the ReCreateIt Gigalab to 3D print with virgin and recycled polycarbonate (rPC), polypropylene (rPP), polyethylene terephthalate glycol (rPETG), high density polyethylene (rHDPE) and low-density polyethylene (rLDPE). These materials are printable in flake, yet some of them require additional intervention, especially rPP and rHDPE, due to warpage and first layer adhesion concerns. These materials are often used in injection molding, but their performance during layer-by-layer fused granular fabrication as performed on GBX was less understood, even more so with recycled polymers. Consequentially, the team is determined to tackle these more difficult materials in order to expand the knowledgebase for AM.

The long term success of this initiative depends upon printing rPP as it is the most commonly found polymer at the AHFH Restore, and ReCreateIt material science teams are focused on identifying the material characteristics and properties that most heavily influence 3D printing success, or printability, an especially complex challenge given that we are working with recycled materials from unknown sources that have unknown usage history, degradation and unknown formulations beyond their base polymers. Thus far, crystallinity and viscosity have been identified as key drivers of printability with further research underway. ReCreateIt's major aim is to create a simple desktop test series that trained operators can employ within the Gigalab to quickly evaluate a material's printability regardless of the material type. Data from the material testing undergone by ReCreateIt polymer testing teams is available at https://recreateit.org/materials/. Testing data of recycled polymers includes mechanical testing, microstructural, spectroscopic and thermal studies, among others.

ReCreateit is conducting long term studies of material durability and degradation on identified polymers. Initial results have shown that printing parameters have a clear impact on long-term strength under creep testing with, for example, rPET specimens with 30% infill showed weak resistance, failing after 6 days (50% load) and 92 days (25% load), whereas specimens with 80% infill demonstrated significantly improved durability with tests still ongoing after over 2 months at both loads. We have also seen strength reductions in rPP that have significant impact on long term durability. ReCreateIt material scientists are investigating naturally and sustainably sourced additives and compatibilizers that can mitigate these issues and allow for large scale 3D printing from 100% recycled materials.

For further reading, ReCreateIt polymer research has resulted in multiple published articles so far, including one on the influence of printing parameters on mechanical properties of rPET and rPETG,[11] and another on the influence of colorants and morphology on the material properties of rPP.[12]

2. Design of a Minimum Footprint, Mobile, Recycling and 3D Printing System - the Gigalab

Preparing the AHFH Restore for the addition of a ReCreateIt manufacturing lab produced from a modified shipping container required coordinating design requirements and design constraints from the solar powered electrical system at AHFH ReStore, the industrial granulator, material dryer and GBX needed to operate in the Gigalab as well as site specific location, networking connection and incorporating monitoring equipment. ReCreateIt, assisted by container fabricator EMS, designed the structural, electrical and equipment layouts for the ReCreateIt Gigalab. The system was then installed and began operating at AHFH ReStore in the spring of 2025.

A detailed CAD model of the Gigalab was developed prior to the installation(Fig. 3) and following the installation, a Matterport 3D scan was conducted to enable virtual access to the Gigalab. The team also conducted an extensive study of commercially available sensors to monitor CO2, humidity, temperature, particulate matter, volatile organic compounds (VOCs) and energy consumption. ReCreateIt identified the optimal sensors by comparing factors such as sensor capability, cost, installation complexity, communication protocols, internet connectivity, and the availability of support materials. The equipment was then installed at both the ReCreateIt Gigalab as well as the University of Wollongong Australia (UOW) to pair the real world Gigalab with a virtual version to help track sustainability data and our progress towards net-zero.

Figure 3. CAD model of the ReCreateIt Gigalab and equipment installed in the Gigalab following installation.

3. Life Cycle Analysis and Sustainability Metrics

For the purposes of life cycle assessment(LCA), ReCreateIt studies both the Gigalab itself and the products manufactured within it. A pre-pilot program LCA of our manufacturing method resulted in a conclusion that manufacturing with GBX can significantly reduce climate impact by 82.1% relative to filament based 3D printing and 70.6% relative to injection molding for a specified unit product.[13] As the pilot program progresses, ReCreateIt is continually assessing these metrics. The quantities listed in Table 1 represent the emissions reduction of printing 38.02 kg of products with recycled plastic waste over printing with virgin plastic and over traditional plastic manufacturing (i.e. injection molding, which would represent buying a new product from the store). The LCA incorporates emissions from electricity using assumptions about the local grid mix, equipment power draws and efficiencies, and a specific print form factor of a stool. It is important to note that the AHFH Restore is almost exclusively powered by solar PV, rather than from the grid. As the project progresses, the sensors installed in the Gigalab will provide daily outputs on energy consumption, allowing the LCA to become more and more accurate over a much larger production volume.

Table 1. Climate Impacts (as of Sept 2025)

	Numerical Reduction [kg CO_2-equivalent]	Percentage Reduction
Emissions Avoided Compared to Virgin Plastic Printing	778.03	86.4%
Emissions Avoided Compared to Traditional Plastic Manufacturing	50.42	29.2%

Further LCA work is underway on the GBX printer and the as-built Gigalab using OpenLCA 2.0 and the Ecoinvent 3.9.1 database. The next step is to integrate the structured equipment datasets into OpenLCA to create a robust "cradle-to-gate" model. To advance this goal, we have developed a formal plan for a full Dynamic LCA (dLCA) model, moving beyond a static "snapshot" to create a "cinematic narrative" of the GigaLab's environmental performance over its entire predicted 25-year lifespan. Based on a methodological framework analysis, we will implement a hybrid approach that integrates System Dynamics (SD) with Dynamic Material Flow Analysis (dMFA). The SD sub-model will simulate the "why" of the system, modeling plausible future scenarios for key drivers such as annual production volume, the evolving energy mix powering the GigaLab, and technological learning efficiencies. The dMFA sub-model will provide the rigorous "what" and "where," tracking the physical stocks and flows over time, including the annual consumption of materials and the generation of potential waste streams. By linking these time-dependent foreground flows to our existing static background LCI data from OpenLCA, this integrated model will allow us to plot environmental impacts over time, identify temporal hotspots, and precisely quantify the "impact crossover" point where the system's benefits outweigh its initial environmental debt.
Taken together, the LCA data is then integrated into the interactive design tool discussed below, providing users real time plain language feedback on the equivalent amount of plastic waste the manufacturing with the ReCreateIt Gigalab saves.

4. Design in Collaboration with End Users: Digital Design Tools with Integrated LCA Data

ReCreateIt and the AHFH ReStore end users are partnering to sustainably produce unique household goods that can be sold in ReStores to support revenue generation for the nonprofit. To ensure that the 3D printed goods meet the preferences of the end users, their feedback has been incorporated into the design process. Such interaction is especially important because GBX prints directly from recycled thermoplastics, producing mono-material products, which may lack the functionality (e.g. comfort) and aesthetics of the multi-material version.

a. Interactive Design Tool

This research focuses on the development of a machine learning (ML)-enabled interactive framework for the co-design of home goods that are not only sustainable and structurally sound but also aesthetically and functionally pleasing to the user. Both the framework and database will be accessible to AHFH customers via an easy to use, interactive digital tool located at AHFH ReStore and in the future at recreateit.org.

This tool builds upon an interactive structural design framework developed at UT Austin.[14] The ML-enabled framework allows human designers to use their expertise and intuition to guide computational algorithms quickly towards promising structural solutions. Users can select from a range of objects to customize, including vases, tables, and stools (Fig. 4). The backend of the framework is designed with scalability in mind, allowing new home goods to be added seamlessly in future updates. All objects share a common set of real-time slider-based parameters for shape modification, ensuring a consistent and intuitive user experience. However, each object type varies in overall size and includes unique functional features. Users can save models to their “Favorites” tab or explore new designs generated by an algorithm that learns from a user’s previously liked designs, continuously refining its recommendations to deliver designs optimized for that individual’s unique preferences.

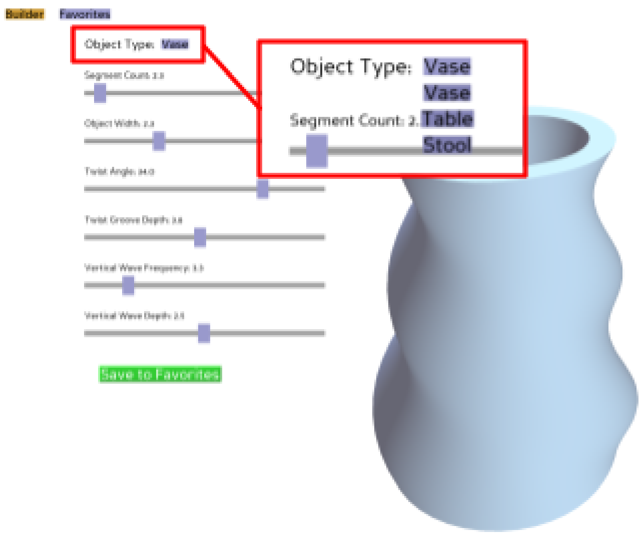

Figure 4. Design tool with sliders for dynamic model adjustment and dropdown menu for object type.

One important consideration when using the design tool is the printability of each customized object. While users are given a wide range of parameters to modify through the sliders, this flexibility introduces the possibility of creating designs that cannot be feasibly 3D printed. The primary limitation arises from excessive overhangs in certain features. Because this tool operates in conjunction with the GBX printer, it is crucial that object geometries do not exceed a 50-degree overhang to ensure successful printing and structural stability. To provide users with maximum design flexibility while maintaining printability, an overhang check has been integrated into the tool. This feature continuously monitors the geometry of the model to ensure that it remains within feasible printing limits. If an object exceeds the maximum allowable overhang, the user is immediately notified (Fig. 5), helping prevent unprintable designs and ensuring a smoother fabrication process.

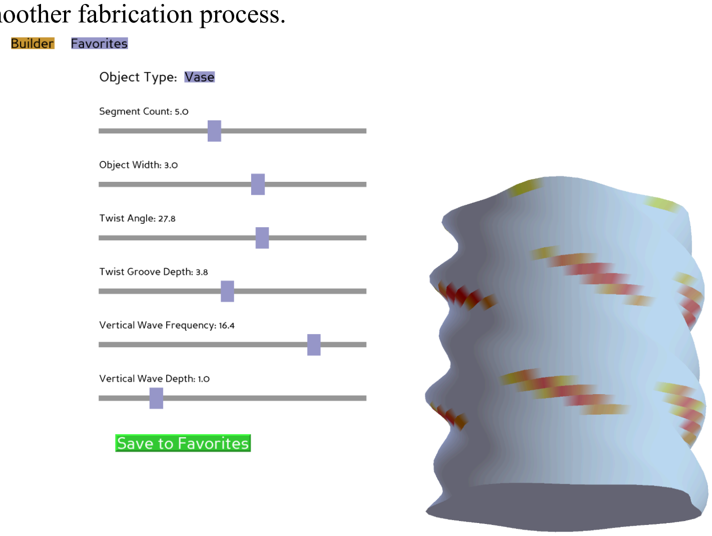

Figure 5. Design tool interface with visual printability warnings marked in orange and red.

b. Community-Led Design

This research project creates jobs for AHFH ReStore employees to expand beyond retail skills into manufacturing and digital design. The Gigalab Associates undergo thorough training in safety, equipment operation, material processing, and 3D design. In addition to in-person instruction, a robust training guide developed jointly by ReCreateIt experts and AHFH integrates standard operating procedures (SOPs) and safety protocols into a sequential, modular format. This structure enables the identification of competency milestones for ReStore staff training. The framework employs topic-specific modules that address essential knowledge and skills for each system function. Ten ReStore employees have been trained on at least four competencies in the ReCreateIt process, well on the way to a goal to have at least 20 trained by the end of the pilot program.

Gigalab Associates master and then pass on their new skillsets to ReStore team members, integrating their deep understanding of the ReStore customer base with CAD skills to create products (Fig. 6) such as seasonal decor and light fixtures that integrate 3D printed lamp shades with available lamp bases in the store. The lamps create an enticing draw to the ReCreateIt merchandising shelf and catch the attention of customers browsing the nearby lighting department. This circular use of the sustainable technology, the added skills, and the Gigalab Associates' unique knowledge of their community and customer base creates cascading innovations for the project that would not have been possible in a pure research environment.

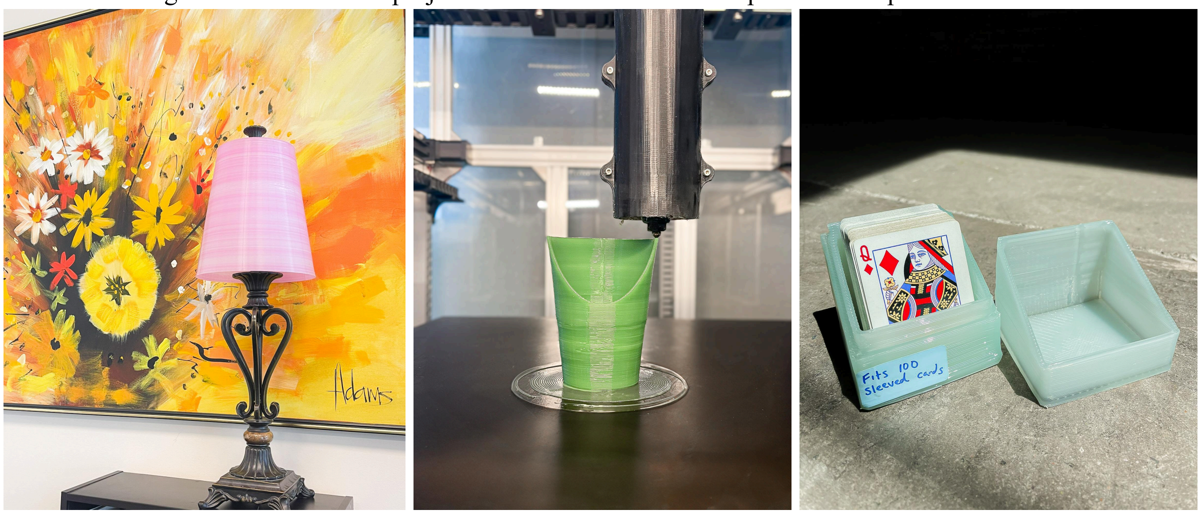

Figure 6. Products designed by Gigalab Associates and printed from 100% rPP during the first 6 months of the pilot program.

Conclusions & Recommendations

Challenges

The NSF Convergence Accelerator model has enabled the collaborative cross-disciplinary framework for this project, and the flexibility of the program has provided ReCreateIt opportunities to learn from and then refine project goals as research continues. For example, when the team initially tested designs on GBX at the outset of the project, we tested the designs using rPETG, a material typically used in 3D printing and known to scale in large-format applications. Once long term waste surveys were underway at AHFH ReStore, the abundance of rPP in the waste stream necessitated a shift towards research with that material and further understanding its limits and opportunities. rPP Is prone to severe warping and struggles with good bed adhesion, a necessity for successful 3D printing. This has limited the scale of goods we can manufacture for the first 6 months of the pilot while the materials scientists conduct research on formulations that can counteract these challenges.

We've also encountered an impressive number of operational challenges that have provided learning opportunities. The ReCreateIt Gigalab has been broken in to, had sensors damaged by lightning strikes, offgassed odors beyond typical timelines and had some impressive 3D print failures. All of these created opportunities to engage with a broad range of experts, such as the labs that provided air quality testing reports to help us understand the odors were not harmful to workers and how to mitigate them. These challenges have helped us build stronger instruction guides, make our equipment more robust and understand how to support future Gigalabs wherever they are deployed.

More broadly, Closed-loop recycling methods such as ours add to a globally growing effort to creatively reclaim materials. Efforts include Plastic Whale, based in the Netherlands, who collect waste bottles and recycle them into boats and office furniture.[15] Nairobi, Kenya based Gjenge Makers collect plastic garbage and form it into bricks and building materials.[16] These projects coexist beside policy efforts to combat plastic waste, such as negotiations for a Global Plastics Treaty, an effort to develop an international legally binding instrument on plastic pollution, including in the marine environment. The Treaty has not yet reached agreed terms, however, despite a recognition that plastics pollution will cause an estimated $281 trillion in damages between 2016 and 2040.[17] Without a global agreement, the creative approaches we and others have undertaken in our communities remain vitally important, and information sharing is paramount in order to help others not have to re-learn solutions in isolation.

Future work

As the pilot program continues, ReCreateIt is examining the economic viability of on-site manufacturing with recycled plastics. We are tracking home good sales, which have exceeded $1000.00 thus far and growing, and plan to weigh that against cost of operation and cost reductions for our processes. We are interested in understanding the effect of the project on not just the AHFH ReStore, but the greater community, and that is why community education is a large part of our project. We share our work on social media and at local and regional events, the largest of which has been the Habitat for Humanity International Carter Work Project 2025, where 2000 volunteers built 25 homes in a week in an Austin, TX neighborhood. ReCreateIt is 3D printing new goods out of leftover HDPE water bottles made available to volunteers at the event.

The Design tool is going to go through additional iteration and rounds of user testing, both in the AHFH ReStore and in Atlanta where the developers are based. The goal will be to have a publicly available version of the tool available on the ReCreateIt website by the end of the project, so more people will have access to machine learning enabled design.

A sustainability dashboard with life cycle analysis will be added to the ReCreateIt website, evaluating the Gigalab manufacturing method against traditional manufacturing with actively updated data from the sensors in the lab.

Investigating HDPE and additional materials is in the research plan for our material scientists along with understanding how to mitigate warping for large-scale 3D printing so that we can expand into a broader variety of available goods. As mentioned above, we aim to create a printability test that can quickly evaluate waste polymers for 3D printing regardless of material type.

ReCreateIt envisions a future where communities thrive as self-sustaining builders of a circular economy. Through our work, we can greatly expand the accessibility of community based recycling and maximize socioeconomic impact, enabling ReCreateIt Gigalab methods to be used in remote or isolated communities, such as island nations, who often struggle with managing their own plastic waste due limited landfill space and the expense of shipping waste off- island. The goal is to make these methods accessible to a broader range of people than previously possible and support expanding skillsets that transform waste from a burden into a multifaceted, net-positive output.

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About the Author(s)

ReCreateIt is a pioneering initiative dedicated to transforming plastic waste through community-led manufacturing. Led by re:3D while partnering with Austin Habitat for Humanity ReStore, University of Texas at Austin, University of Wollongong, Western Sydney University, Georgia Tech and supported by the National Science Foundation's Convergence Accelerator, ReCreateIt aims to revolutionize waste management practices, empower underserved communities, and advance sustainable manufacturing solutions. For more information, visit https://recreateit.org/.

Co-PI and Project Manager Charlotte Craff will present the project at the conference.