Livrable WP6

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1 Introduction

2 Plastic Issues for the European Union

Since 1950’, our society have gained enormous advantages in terms of quality of life thanks to the technical development of the development of plastic and polymer materials. Plastic is a material that is widely used in our daily lives and plays a fundamental role in industry and economic development. The plastic material are found in almost all our products: food packaging, cars, technological tools, clothing, among others. The main reason is that plastic materials offer a variety of chemical and mechanical properties to be useful for a wide array of applications. Plastics are extremely useful, but their mismanagement has affected the environment and our health. The over-consumption and especially bad practices (single use, difficulty of reuse, etc.), make plastics one of the major societal challenges of an ecological transition that has become imperative. The main problem is the end-of-life treatment which traditionally uses a centralized system where plastic waste often has to travel thousands of kilometers… to be incinerated or landfilled. In addition to the energy and environmental impact of their production, there is also the impact of the end of life.

Unfortunately, the plastic waste pollution poses a major threat because of the issue of non-degradability affecting the ecological environments (Hopewell et al., 2009; Ryberg et al., 2019; Thompson et al., 2009). Indeed, recycling rates remain small (approx. 14%) in the plastic packaging field on a global scale (Hahladakis and Iacovidou, 2018). Even in Europe, which tends to lead on environmental stewardship, the recycling rate is about 32.5 wt% (Plastics, 2019). However, these values consider the amount of plastic waste collected, rather than the total amount in circulation (Kranzinger et al., 2018). Rethinking the development and use of plastics is central to the circular economy paradigm, to provide less harmful options for the environment. Thus, more types of plastic packaging are available, but each reflects diverse circular economy strategies

To tackle this accumulation waste problem, the European strategy for plastics in the circular economy (CE) is gaining attention in the policy and business debate surrounding sustainable development of industrial production (European Commission, 2018; Geissdoerfer et al., 2017). CE tackles a central societal issue concerning the current principle "take, make, dispose" (linear economy) and its negative effects caused by the depletion of natural resources, waste generation, biodiversity loss, pollution (water, air, soil) and non-sustainable economics (van Buren et al., 2016). The validation (technical, economic, legislative) of waste plastic as a secondary raw material in industrial processes is considered now a core target to integrate CE into the plastic value chain (Simon, 2019). Strategies of open and closed-loop recycling as well as upcycling and downcycling functionality approaches can offer paths to validate the secondary raw materials (Zhuo and Levendis, 2014). The promotion of cross-sectorial valorization of plastic wastes through Industrial symbiosis approaches seems to be a relevant strategy for the circular economy strategies of the EU (Karayılan et al., 2021)

3 Context of the 3D Printing of Recycled Plastic Demostrator

3.1 Presentation of the scale of the demostrator: Rives de Meurthe district (Nancy, France)

3.2 Third place Octroi Nancy

3.3 Lorraine Fab Living Lab

4 3D Printing of recycled plastic demonstrator: the "Green FabLab"

4.1 Rationale for the technological system of the 3D printing recycling demonstrator

Based on the context characteristics of the Lorraine Fab Living Lab® and the Octroi local ecosystems, the 3D printed demonstrator also called locally as the "Green Fablab", it is an initial demonstrator of the distributed recycling approach that combines a living lab approach inside a citizen third

place ecosystem.
The logistical validation of a closed-loop supply chain for plastic in DIT approach needs to relied to a certain technology.

The Green FabLab demonstrator aims to experiment the technical feasibility evaluation of a distributed and local plastic recycling for 3D printing technology in the context of these open innovation spaces such as fab labs, Hackerspaces or even industrial prototyping zones. In these geographically distributed spaces, the polymer recycling process of the surrounding areas (streets, neighbourhood, industrial zones) will be carried out at small lot sizes minimizing, energy consumptions, and carbon emissions compared to the tradition centralized systems, as some researches have already explored this path.

The main purpose of this demonstrator in the INEDIT project is to understand the conditions under which to deploy a notion of circular economy with the feedstock of the OS 3D printers. The outputs are, not only by minimizing use of the environment as a sink for residuals but – perhaps more importantly – by minimizing the use of virgin materials. Hence, the environmental impact of this technology is significantly reduced. Moreover, taking into account the exponential growth of these spaces (Fablab, Hakerspace, Makespace), they could help to increase the efficiency to the problem of polymer recycling through the development of a distributed recycling approach.

The Green FabLab project aims to demonstrate that plastic waste material can have several uses, and therefore several values, during its life cycle. The same material could be recycled and transformed into new raw material for different products. It is in this spirit that many associations, SMEs, local authorities and individuals are developing new local recycling practices that could allow us to aim for an economy that is more respectful of the environment, fairer for society and more engaging for local politicians

The Additive manufacturing (AM) -also known as 3D printing- is an important industrial vector in the and its direct (and distributed) manufacturing capabilities is becoming a key industrial process that could play a relevant role in the transition from a linear to circular economy (Despeisse et al., 2017). AM technologies is expected to transform the production process (Chen et al., 2017; Jiang et al., 2017; Rahman et al., 2018) thanks to its ability to transform a numerical model into a deposition of material (points, lines or areas) to create a 3D part (Bourell et al., 2017). The expiration of the first patents has contributed to an increased interest, creating consumer value and potential for disruption (Beltagui et al., 2021; West and Kuk, 2016). In economic terms, the global additive manufacturing market is expected to reach USD 23.33 billion by 2026 (Data, 2019). However, determining when and how to take advantage of the benefits is a challenge for traditional means of production. From a societal viewpoint, Jiang et al. (2017) reported that the product development could change from traditional stage-gate models to iterative, agile processes changing the scenario by 2030.

The technical development of INEDIT's demonstrator is based on the distributed recycling via additive manufacturing (DRAM) approach (Cruz Sanchez et al., 2020). This approach is a major scientific output from the INEDIT project as a proposition of the future industrial landscape.

DRAM is defined as the use of recycled materials by means of mechanical recycling process in the 3D printing process chain. In the literature, DRAM approach emphasizes the technical steps required to reuse plastic waste through the recycling chains for material-extrusion-based 3D printing

(Cruz Sanchez et al., 2020; Little et al., 2020). The use of recycled material, either in the form of raw material or blended with virgin material, is a method of special interest to contribute to sustainable manufacturing (Zhao et al., 2018).

Figure 1 illustrates the conceptual model of DRAM.

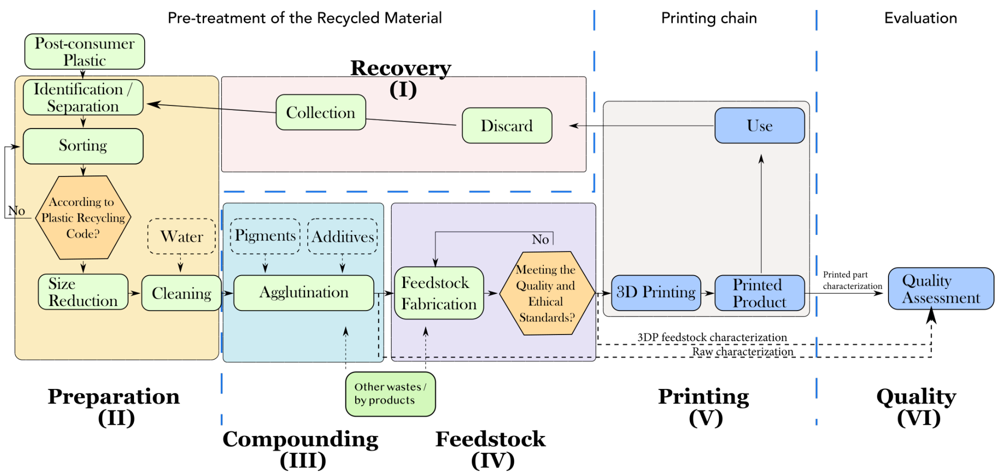


Figure 1: DRAM

In a general overview, the **Recovery (I)** phase concerns the logistic operations to consider to collect the plastic wastes to be reused in DRAM. The **Preparation (II)** phase corresponds to the actions and strategies to identify, separate, sort, size reduce and clean waste plastic to guarantee adequate quality for DRAM. The **Compounding (III)** phase refers to the development of mono- and composite-materials. The **Feedstock (IV)** phase identifies the actions to fabricate the material usable for the printing process, either filament for Fused Filament Fabrication (FFF) or the particle size for Fused Granular Fabrication (FGF). The **Printing (V)** stage identifies applications and process improvements for the recycled printed part. The **Quality (VI)** phase identifies the multi-level technical characterization performed to the recycled material.

In the DRAM methodology, consumers have an economic incentive to recycle. This is because they can use their waste as feedstock for a wide range of consumer products that can be produced for a fraction of the conventional cost of the equivalent products. Moreover, 3D printing is especially well suited because it enables the production of parts with (almost) no waste, and could reduce the waste related to the material by more than 40 %, reusing 95% of the unused material (Petrovic et al., 2011). Currently, most of the cost of 3D printing is associated with filament (Wittbrodt et al., 2013). By recycling raw materials such as Polylactic acid (PLA), one of the most frequently used materials in 3D printing, it is possible to reduce the carbon dioxide emissions that are incurred by transport to landfills or shipping to customers, offering environmental benefits (Santander et al., 2020).

A large number of products can already be manufactured with AM, which affects the geographical spread and density of global value chains (Laplume et al., 2016). It is expected that the reach of AM printable products will be much greater in the future, as the production of multi-material and built-in functionalities (e.g. electronics) will be possible to a large extent. In addition, the production of spare parts can be carried out on-site, modifying the role of suppliers in the production lines (Zanoni et al., 2019). Matt et al. (2015) explored the stages of distributed model factories and decentralized production types ranging from distributed capabilities to cloud production. Thus, the need of transport will be much more carefully because the fact that AM will enable decentralization of production to localities near customers or in the most extreme distributed scenario at the customer's premises (Bonnín Roca et al., 2019; Petersen and Pearce, 2017; Wittbrodt et al., 2013). Moreover, AM technology makes it possible to reduce market entry barriers, reduce capital requirements and achieve an efficient minimum scale of production to promote distributed, flexible forms of production (Despeisse et al., 2017).

This enables an alternative option from an economy-of-scale to an economy-of-scope, where the products are highly personalized satisfying niche communities or even individuals (Hienerth et al., 2014; **Petrick2014?**). For these reasons, the AM technology could be a driver for a shift in manufacturing from globally distributed production to local facilities. Significant efforts are being made by industry and the scientific community to move AM techniques from rapid prototyping and tooling stages towards direct digital manufacturing (DDM) (Gibson et al., 2010; Holmström et al., 2016), with the concomitant environmental and social benefits. Nevertheless, Niaki et al. (2019) demonstrated that environmental and social benefits are not the key preferential factors in the adoption of AM technologies in different industrial sectors. Only the economic factor remains relevant in the AM implementation, considering time- and cost-saving as the most important reasons.

4.2 Positionnement of Use case for OMDF Functions

4.3 Hypothesis of UL case for deployment in reality

4.4 Technical characterization of the 3D printing of recycled demonstrator

4.4.1 Recovery I

The first step in the implementation of the OMDF of the Green Fablab is the activity of *Recovery I*. This phase aims to establish a minimal baseline logistic operations to consider to collect the plastic wastes to be recycled in the process. In the scientific literature, the recovery is one of the main activities to considered in the recycling process given that this structures a supply chain that certainly is variable (i.e. in fuction of the public supoprt to sort the material in the specific points of collection). This process is the first step to create a closed-loop supply network approach for the distributed manufacturing (Santander et al., 2020).

The collection tasks consists of collecting plastic waste at different established points, which are then transported to a treatment center where it is recycled. The collection and recycling process aims to generate a recycling micro-network at the local level (neighborhood scale), which allows the recovery and revaluation of plastic waste through 3D printing. This allows to save impacts related to the traditional treatment of plastic waste, as well as to increase the recycling capacity in the city, giving more independence over the recycling process. Figure 2 illustrates the process model considered.

The main difficult relies in the pertinent identification and the quality state of the plastic waste. Therefore, in the framework of the INEDIT project, the UL case demonstrator developed a "smart

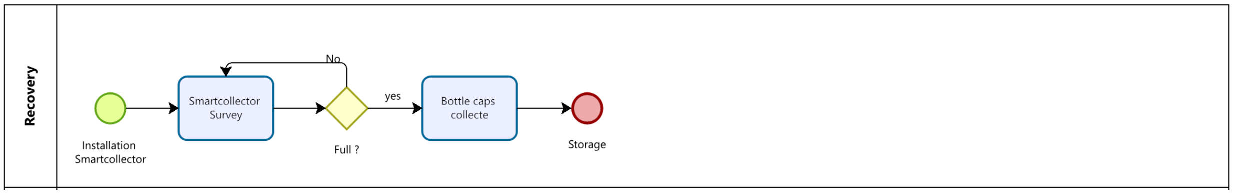


Figure 2: Recovery processus of the Green Fablab

collector prototype". The complete documentation of the technical device can be found in the following open access reference (Gabriel and Cruz, 2023). Given the possible implementation in other contexts, the source files are shared in open-source repository with the purpose that open communities to take advantage the experiences developed at the Université de Lorraine. Eventually, the open communities can propose improvements and better versions.

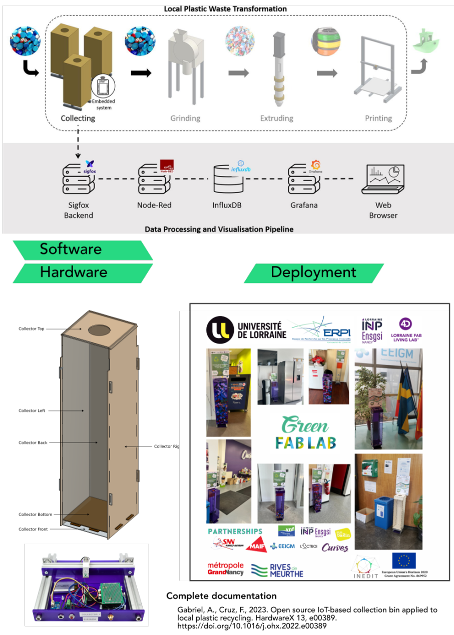
This is a relevant strategy given the cross-line of Industry 4.0 and circular economy, which is opening up fields such as smart waste management systems options to improve the effectiveness of different materials, including plastic waste (Ranjbari et al., 2021) using information technology tools with the advent of the Internet of Things (IoT) Rejeb et al. (2022). Smart waste management system (SWMS) consists of public garbage collectors with embedded technology that is used to monitor real-time level of garbage bins in public places (Bano et al., 2020). The interest of this system is to optimize the path for the garbage collecting van that eventually reduces fuel cost. However, this work is mainly based on simulation. Therefore, there is an avenue to simplify experimentation in this domain using common open-source technology (hardware and software) (Pearce and Mushtaq, 2009) to implement projects that require heavy infrastructure such as routers and a gateway to deploy in the territory.

The main functional requirement of the smart collector is to collect and provide data about plastic waste production in order to design a local and distributed recycling chain of value. However, the smart collector may be used in various use cases such as:

- Monitoring the quantity of any other product that is collected over a large area.
- Generating data about behavior to more precisely dimensions public infrastructure.
- Monitoring the transformation and recycling process inside the transformation unit to follow the state and quantity of raw material and final product.
- Initiating a digitization process in the waste management process as the information system element present here is flexible and commonly used in various types of projects.

The device uses a controller compatible with batteries and use WAN technology to avoid the deployment of routers for data acquisition. Although using various types of sensors allows us to achieve better results (Catania and Ventura, 2014) by crossing data, the main indicator remains the weight.

The process illustrated by the Figure 3a can be described in the as follows:



(a) Description of the developed Smart collector

(b) Prototypes deployed at the local territory

Figure 3: Famous Elephants

1. **Smart Collector installation**: The first step is to identify the main actors in the neighborhood through meetings, visits and interviews in order to propose integration into the recycling network by installing a smart collector on their premises.
2. **Supervision**: The monitoring is done through a dashboard that provides direct information sent by the smart collector. This allows to know the weight of each installed smart collector, allowing to have an approximation of its degree of occupancy.
3. **Receiving and storing plastic waste**: The storage area must be organized and functional with respect to the needs of the demonstrator.
4. **Plan and execute the collection**:

In the scientific literature, the reverse logistic and closed loop supply chains have been extensively studied in the scientific literature. For instance, (**Santander2021?**) evaluated the benefits of a near loop and closed loop recycling network focused on additive manufacturing, mainly producing recycled filament. The main results show an economic and environmental benefit of sourcing filament from recycled plastic rather than purchasing exported virgin filament.

4.4.2 Preparation II

The second phase of the corresponds to the actions and processes to identify, separate, sort, size reduce and clean waste plastic to guarantee with the purpose to obtain feedstock material that is adequate for the distributed recycling process.

The plastic waste preparation process aims to conditioned the collected plastic to the requirements of 3D printing. For this process 3 main sub-processes are considered:

- **Identification and Sorting**: These two processes aim to identify the type of plastic given the regular standard for the polymer industry. The process of identification and separation of plastics is done manually and allows to separate the plastics that can be used as raw material for further production processes.
- **Cleaning**: This process is aims to remove the traces of any other substance that may be present in the plastic waste. In this way the processing machines will not be exposed to possible anomalies linked to material impurities.
- **Size reduction**: The size reduction process is carried out to possible obtain an adequate granulometry. This process allows to adapt the plastic waste for the direct injection process and/or the extrusion process.
- **Drying phase**: This step prevents the formation of bubbles in the recycled material when it is melted during the following extrusion or densification step (**Niaounakis2013?**). Moreover, complete elimination of water prevent hydrolytic decomposition of the molecular chains during the melting or plasticization, so that the treated material has to be as dry as possible.

4.4.3 Compounding III

The *Compounding* phase is related to the operation, strategies in the development of composite materials using recycled feedstock intended to be use in a printing process. There have been several literature reviews about the technical aspect of composite materials in the additive manufacturing context Mohan et al. (2017).

Special attention has been paid on material extrusion technologies in the production of polymer/composite feedstocks as it is economical, environmentally advantageous and adaptable to flexible filament material (Singh et al., 2017). For example, Mohan et al. (2017) presented a review on composite materials and process parameters optimisation for the fused deposition modelling (FDM) process for improving the mechanical properties (i.e. tensile strength, fatigue). Brenken et al. (2018) reported a detailed summary of mechanical properties of printed parts for different composite material for fused filament fabrication. Five majors strategies are elucidated from the literature review such as:

In the context of the Green Fablab demonstrator of INEDIT project, the focus is to study the 1) mono-recycled material and 2) the virgin-recycled blend material. The development of recycling niches of mono-material where the additive manufacturing can be implemented is key to study. Different studies in laboratory conditions have been made to show the technical feasibility of recycling. They include HDPE Kreiger and Pearce (2013), Biomass-derived poly(ethylene-2,5-furandicarboxylate) (PEF) (Kucherov et al., 2017), PLA (Cruz Sanchez et al., 2017), Linear Low Density Polyethylene (LLDPE)/ low density polyethylene (LDPE), (Hart et al., 2018), thermoplastic elastomer (TPE) (Woern and Pearce, 2017). In fact, Hart et al. (2018) demonstrated the reconstitution of residual polymeric packaging waste from Meals-Ready-to-Eat (MREs) generated by soldiers around the world into additively manufactured appliances. One conclusion of these studies is the positive technical use of recycled mono-material for additive manufacturing purposes.

However, it has to be highlighted that one major assumption of these studies relies in that the material used is already sorted, cleaned and using a same type of discarded product. For INEDIT project, the interest is to take into account the inner variability that could be in the recovery process, concerning the type of material given the fact, while there are seven types of recycling symbols for each type of polymer, one major constraint in the current systems is that each manufacturing company have a patented use of the additive in the polymer matrix, in order to fulfil its initial function of the product.

4.5 Feedstock IV

The Feedstock III phase refers to the processes in order to transform the plastic waste into usable material material for the fabrication stage. Two outputs are seen in this etape: 1) the filament feedstock and 2) the pellet feedstock. The use of filament or pellet material are in coherence with the machine process used in the fabrication (cf section 4.4.5). The figure XX present the modeling of the process:

The filament and pellet production process makes it possible to produce the necessary raw material from plastic waste. The production of these intermediate products allows the use of different technologies related. Before using these products (filaments and pellets) it is necessary to carry out evaluation tests to assess the geometrical characteristics that are necessary in the printing process.

Figure XX and table present the technical characteristics of the material equipement

Bibliography

Anderson, I., 2017. Mechanical Properties of Specimens 3D Printed with Virgin and Recycled Polylactic Acid. 3D Printing and Additive Manufacturing 4, 110–115. https://doi.org/10.1089/3dp.2016.0054

Bano, A., Ud Din, I., Al-Huqail, A.A., 2020. AIoT-Based Smart Bin for Real-Time Monitoring and Management of Solid Waste. Scientific Programming 2020. https://doi.org/10.1155/2020/6613263

Beltagui, A., Sesis, A., Stylos, N., 2021. A bricolage perspective on democratising innovation: The case of 3D printing in makerspaces. Technological Forecasting and Social Change 163, 120453. https://doi.org/10.1016/j.techfore.2020.120453

Bonnín Roca, J., Vaishnav, P., Laureijs, R.E., Mendonça, J., Fuchs, E.R.H., 2019. Technology cost drivers for a potential transition to decentralized manufacturing. Additive Manufacturing 28, 136–151. https://doi.org/10.1016/j.addma.2019.04.010

Bourell, D., Kruth, J.P., Leu, M., Levy, G., Rosen, D., Beese, A.M., Clare, A., 2017. Materials for additive manufacturing. CIRP Annals 66, 659–681. https://doi.org/10.1016/j.cirp.2017.05.009

Brenken, B., Barocio, E., Favaloro, A., Kunc, V., Pipes, R.B., 2018. Fused filament fabrication of fiber-reinforced polymers: A review. Additive Manufacturing 21, 1–16. https://doi.org/10.1016/j.addma.2018.01.002

Catania, V., Ventura, D., 2014. An approch for monitoring and smart planning of urban solid waste management using smart-M3 platform, in: Conference of Open Innovation Association, FRUCT. IEEE Computer Society, pp. 24–31. https://doi.org/10.1109/FRUCT.2014.6872422

Chen, L., He, Y., Yang, Y., Niu, S., Ren, H., 2017. The research status and development trend of additive manufacturing technology. The International Journal of Advanced Manufacturing Technology 89, 3651–3660. https://doi.org/10.1007/s00170-016-9335-4

Cruz Sanchez, F.A., Boudaoud, H., Camargo, M., Pearce, J.M., 2020. Plastic recycling in additive manufacturing: A systematic literature review and opportunities for the circular economy. Journal of Cleaner Production 264, 121602. https://doi.org/10.1016/j.jclepro.2020.121602

Cruz Sanchez, F.A., Boudaoud, H., Hoppe, S., Camargo, M., 2017. Polymer recycling in an open-source additive manufacturing context: Mechanical issues. Additive Manufacturing 17, 87–105. https://doi.org/10.1016/j.addma.2017.05.013

Data, R.A., 2019. ReportsAndData2019. Additive Manufacturing Market To Reach USD 23.33 Billion By 2026.

Despeisse, M., Baumers, M., Brown, P., Charnley, F., Ford, S.J., Garmulewicz, A., Knowles, S., Minshall, T.H.W., Mortara, L., Reed-Tsochas, F.P., Rowley, J., 2017. Unlocking value for a circular economy through 3D printing: A research agenda. Technological Forecasting and Social Change 115, 75–84. https://doi.org/10.1016/j.techfore.2016.09.021

European Commission, 2018. A european strategy for plastics in a circular economy, COM (2018). European Commission, Brussels. https://doi.org/10.1021/acs.est.7b02368

Fatimah, Y.A., Govindan, K., Murniningsih, R., Setiawan, A., 2020. Industry 4.0 based sustainable circular economy approach for smart waste management system to achieve sustainable development goals: A case study of Indonesia. Journal of Cleaner Production 269, 122263. https://doi.org/10.1016/j.jclepro.2020.122263

Gabriel, A., Cruz, F., 2023. Open source IoT-based collection bin applied to local plastic recycling. HardwareX 13, e00389. https://doi.org/10.1016/j.ohx.2022.e00389

Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J., 2017. The Circular Economy – A new sustainability paradigm? Journal of Cleaner Production 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Gibson, I., Rosen, D.W., Stucker, B., 2010. Additive Manufacturing Technologies, Assembly Automation. Springer US, Boston, MA. https://doi.org/10.1007/978-1-4419-1120-9

Hahladakis, J.N., Iacovidou, E., 2018. Closing the loop on plastic packaging materials: What is quality and how does it affect their circularity? Science of The Total Environment 630, 1394–1400. https://doi.org/10.1016/j.scitotenv.2018.02.330

Hart, K.R., Frketic, J.B., Brown, J.R., 2018. Recycling meal-ready-to-eat (MRE) pouches into polymer filament for material extrusion additive manufacturing. Additive Manufacturing 21, 536–543. https://doi.org/10.1016/j.addma.2018.04.011

Hienerth, C., von Hippel, E., Berg Jensen, M., 2014. User community vs. Producer innovation development efficiency: A first empirical study. Research Policy 43, 190–201. https://doi.org/10.1016/j.respol.2013.07.010

Hofstätter, T., Pedersen, D.B., Tosello, G., Hansen, H.N., 2017. State-of-the-art of fiber-reinforced polymers in additive manufacturing technologies. Journal of Reinforced Plastics and Composites 36, 1061–1073. https://doi.org/10.1177/0731684417695648

Holmström, J., Holweg, M., Khajavi, S.H., Partanen, J., 2016. The direct digital manufacturing (r)evolution: Definition of a research agenda. Operations Management Research 9, 1–10. https://doi.org/10.1007/s12063-016-0106-z

Hopewell, J., Dvorak, R., Kosior, E., 2009. Plastics recycling: Challenges and opportunities. Philosophical Transactions of the Royal Society B: Biological Sciences 364, 2115–2126. https://doi.org/10.1098/rstb.2008.0311

Jiang, R., Kleer, R., Piller, F.T., 2017. Predicting the future of additive manufacturing: A Delphi study on economic and societal implications of 3D printing for 2030. Technological Forecasting and Social Change 117, 84–97. https://doi.org/10.1016/j.techfore.2017.01.006

Karayılan, S., Yılmaz, Ö., Uysal, Ç., Naneci, S., 2021. Prospective evaluation of circular economy practices within plastic packaging value chain through optimization of life cycle impacts and circularity. Resources, Conservation and Recycling 173, 105691. https://doi.org/10.1016/j.resconrec.2021.105691

Kranzinger, L., Pomberger, R., Schwabl, D., Flachberger, H., Bauer, M., Lehner, M., Hofer, W., 2018. Output-oriented analysis of the wet mechanical processing of polyolefin-rich waste for feedstock recycling. Waste Management & Research 36, 445–453. https://doi.org/10.1177/0734242X18764294

Kreiger, M., Pearce, J.M., 2013. Environmental Impacts of Distributed Manufacturing from 3-D Printing of Polymer Components and Products. MRS Proceedings 1492, 85–90. https://doi.org/10.1557/opl.2013.319

Kucherov, F.A., Gordeev, E.G., Kashin, A.S., Ananikov, V.P., 2017. Three-Dimensional Printing with Biomass-Derived PEF for Carbon-Neutral Manufacturing. Angewandte Chemie International Edition 56, 15931–15935. https://doi.org/10.1002/anie.201708528

Laplume, A.O., Petersen, B., Pearce, J.M., 2016. Global value chains from a 3D printing perspective. Journal of International Business Studies 47, 595–609. https://doi.org/10.1057/jibs.2015.47

Little, H.A., Tanikella, N.G., J. Reich, M., Fiedler, M.J., Snabes, S.L., Pearce, J.M., 2020. Towards Distributed Recycling with Additive Manufacturing of PET Flake Feedstocks. Materials 13, 4273. https://doi.org/10.3390/ma13194273

Matt, D.T., Rauch, E., Dallasega, P., 2015. Trends towards Distributed Manufacturing Systems and Modern Forms for their Design. Procedia CIRP 33, 185–190. https://doi.org/10.1016/j.procir.2015.06.034

Mohan, N., Senthil, P., Vinodh, S., Jayanth, N., 2017. A review on composite materials and process parameters optimisation for the fused deposition modelling process. Virtual and Physical Prototyping 12, 47–59. https://doi.org/10.1080/17452759.2016.1274490

Niaki, M.K., Torabi, S.A., Nonino, F., 2019. Why manufacturers adopt additive manufacturing technologies: The role of sustainability. Journal of Cleaner Production 222, 381–392. https://doi.org/10.1016/j.jclepro.2019.03.019

Pearce, J.M., Mushtaq, U., 2009. Overcoming technical constraints for obtaining sustainable development with open source appropriate technology. TIC-STH'09: 2009 IEEE Toronto International Conference - Science and Technology for Humanity 814–820. https://doi.org/10.1109/TIC-STH.2009.5444388

Petersen, E., Pearce, J., 2017. Emergence of Home Manufacturing in the Developed World: Return on Investment for Open-Source 3-D Printers. Technologies 5, 7. https://doi.org/10.3390/technologies5010007

Petrovic, V., Vicente Haro Gonzalez, J., Jordá Ferrando, O., Delgado Gordillo, J., Ramón Blasco Puchades, J., Portolés Griñan, L., 2011. Additive layered manufacturing: Sectors of industrial application shown through case studies. International Journal of Production Research 49, 1061–1079. https://doi.org/10.1080/00207540903479786

Plastics, E., 2019. Plastics - the Facts 2019.

Rahman, Z., Barakh Ali, S.F., Ozkan, T., Charoo, N.A., Reddy, I.K., Khan, M.A., 2018. Additive Manufacturing with 3D Printing: Progress from Bench to Bedside. The AAPS Journal 20, 101. https://doi.org/10.1208/s12248-018-0225-6

Ranjbari, M., Saidani, M., Esfandabadi, Z.S., Peng, W., Lam, S.S., Aghbashlo, M., Quatraro, F., Tabatabaei, M., Shams Esfandabadi, Z., Peng, W., Lam, S.S., Aghbashlo, M., Quatraro, F., Tabatabaei, M., 2021. Two decades of research on waste management in the circular economy: Insights from bibliometric, text mining, and content analyses. Journal of Cleaner Production 314, 128009. https://doi.org/10.1016/j.jclepro.2021.128009

Rejeb, A., Suhaiza, Z., Rejeb, K., Seuring, S., Treiblmaier, H., 2022. The Internet of Things and the circular economy: A systematic literature review and research agenda. Journal of Cleaner Production 350, 131439. https://doi.org/10.1016/J.JCLEPRO.2022.131439

Ryberg, M.W., Hauschild, M.Z., Wang, F., Averous-Monnery, S., Laurent, A., 2019. Global environmental losses of plastics across their value chains. Resources, Conservation and Recycling 151, 104459. https://doi.org/10.1016/j.resconrec.2019.104459

Santander, P., Cruz Sanchez, F.A., Boudaoud, H., Camargo, M., 2020. Closed loop supply chain network for local and distributed plastic recycling for 3D printing: A MILP-based optimization approach. Resources, Conservation and Recycling 154, 104531. https://doi.org/10.1016/j.resconrec.2019.104531

Simon, B., 2019. What are the most significant aspects of supporting the circular economy in the plastic industry? Resources, Conservation and Recycling 141, 299–300. https://doi.org/10.1016/j.resconrec.2018.10.044

Singh, S., Ramakrishna, S., Singh, R., 2017. Material issues in additive manufacturing: A review. Journal of Manufacturing Processes 25, 185–200. https://doi.org/10.1016/j.jmapro.2016.11.006

Thompson, R.C., Moore, C.J., vom Saal, F.S., Swan, S.H., 2009. Plastics, the environment and human health: Current consensus and future trends. Philosophical Transactions of the Royal

Society B: Biological Sciences 364, 2153–2166. https://doi.org/10.1098/rstb.2009.0053
van Buren, N., Demmers, M., van der Heijden, R., Witlox, F., 2016. Towards a Circular Economy: The Role of Dutch Logistics Industries and Governments. Sustainability 8, 647. https://doi.org/10.3390/su8070647
West, J., Kuk, G., 2016. The complementarity of openness: How MakerBot leveraged Thingiverse in 3D printing 102, 169–181. https://doi.org/10.1016/j.techfore.2015.07.025
Wittbrodt, B.T., Glover, A.G., Laureto, J., Anzalone, G.C., Oppliger, D., Irwin, J.L., Pearce, J.M., 2013. Life-cycle economic analysis of distributed manufacturing with open-source 3-D printers. Mechatronics 23, 713–726. https://doi.org/10.1016/j.mechatronics.2013.06.002
Woern, A., Pearce, J., 2017. Distributed Manufacturing of Flexible Products: Technical Feasibility and Economic Viability. Technologies 5, 71. https://doi.org/10.3390/technologies5040071
Zanoni, S., Ashourpour, M., Bacchetti, A., Zanardini, M., Perona, M., 2019. Supply chain implications of additive manufacturing: A holistic synopsis through a collection of case studies. The International Journal of Advanced Manufacturing Technology 102, 3325–3340. https://doi.org/10.1007/s00170-019-03430-w
Zhao, P., Rao, C., Gu, F., Sharmin, N., Fu, J., 2018. Close-looped recycling of polylactic acid used in 3D printing: An experimental investigation and life cycle assessment. Journal of Cleaner Production 197, 1046–1055. https://doi.org/10.1016/j.jclepro.2018.06.275
Zhuo, C., Levendis, Y.A., 2014. Upcycling waste plastics into carbon nanomaterials: A review. Journal of Applied Polymer Science 131, n/a–n/a. https://doi.org/10.1002/app.39931