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List of abbreviations

Abbreviation	Definition
ABS	acrylonitrile butadiene styrene
CAD	computer-aided design
CNTs	carbon nanotubes
DSC	differential scanning calorimetry
FDM	fused deposition modelling
HDPE	high density polyethylene
LDPE	low density polyethylene
MFI	melt flow index
PA	polyamide
PC	Polycarbonate
PC-BPA	polycarbonate bisphenol A
PE	Polyethylene
PET	polyethylene terephthalate
PETG	polyethylene glycol
PLA	Polylactide
PLA	polylactic acid
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinylchloride
SLA	Stereolithography
SLS	selective laser sintering
STL	Stereolithography
TGA	thermogravimetric analysis
TPU	thermoplastic polyurethane

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Introduction

The present report constitutes deliverable 6.2 “Repair and play – SOCIAL” within the framework of the FRONTSHIP project. The following activities refer to WP6 Circular Systemic Solutions – Plastics and to Task 6.2 Repairing activities for social inclusion. The report provides a comprehensive plan for supporting socially depressed areas by harnessing 3D printing technology and recycling plastic waste. It focuses on the development of local social enterprises, technical skill enhancement, and community empowerment. The initiative involves the provision of 3D printers, training programs, and the creation of a sustainable model for local businesses. The report also explores the use of recycled plastic scrap to produce 3D printing filaments, with the aim of addressing both economic and environmental challenges.

3D printing with recycled filament (plastic scraps) technical expertise

Manufacture of filament from waste materials - state of the art

3D printing filaments are materials used to supply 3D printers and create objects using additive printing. There are many different types of filaments, each with its own properties, applications and characteristics, commonly used materials include PLA (Polylactide), ABS (Acrylonitrile Butadiene Styrene), PETG (Polyethylene Glycol), TPU (Thermoplastic Polyurethane), nylon. Polyolefin PP and PE filaments as well as recycled filaments, are also increasingly used. The manufacturing of filament from waste materials represents a significant advancement in sustainable manufacturing and additive manufacturing technologies. This emerging field focuses on repurposing various types of waste, such as plastic, agricultural by-products, and industrial waste, into high-quality filaments suitable for 3D printing. It is worth remembering that although recycled filaments offer environmental benefits, their quality can be variable depending on the recycling process and the raw materials used in production. Below is a brief overview of types of waste materials.

- post-consumer plastic waste

Polyethylene Terephthalate (PET). Commonly sourced from used water bottles and packaging materials, PET waste is one of the most popular types of recycled plastic for filament production. PET can be processed into PETG (glycol-modified PET), which is widely used in 3D printing.

Polylactic Acid (PLA). PLA, often derived from agricultural waste like corn starch or sugarcane, is biodegradable and one of the most commonly used materials in eco-friendly 3D printing.

Acrylonitrile Butadiene Styrene (ABS). Recycled ABS from electronic housings and automotive parts is also used to produce filaments. However, its production requires careful control to ensure quality and consistency.
- industrial plastic waste

Nylon. Recycled nylon from textiles and industrial fibres can be transformed into strong, flexible 3D printing filaments. This material is suitable for functional prototypes and mechanical parts.

Polypropylene (PP). Waste PP from packaging, automotive parts, and consumer goods can be recycled into filaments, although its lower density and flexibility pose challenges that are being addressed through advanced processing techniques.

- biodegradable and bio-based waste

Agricultural Residues. Materials like wheat straw, rice husks, and wood pulp are being explored as fillers in PLA and other biodegradable polymers, creating composite filaments with unique properties.

Seaweed and Algae. Research is ongoing into converting seaweed and algae into biopolymers that can be extruded into filaments. These materials offer a sustainable alternative to fossil-based plastics.

waste selection, type of polymers (selection of appropriate fractions based on markings and type of waste).

Waste collection for recycling and waste selection are key steps in the waste treatment and reuse process. Labelling of the type of polymer used to produce the material can be the basis for proper waste selection. Pictograms allow consumers and workers to easily identify the type of plastic and sort it correctly, which in turn facilitates the recycling process and increases the efficiency of waste management. Under this system, each plastic type is identified by a symbol with a number, which is placed on packaging or items made from the material.

Here are some of the most common plastic type and their codes following European Directive 2018/851, 2018/852 numbers and their uses:

- PET (Polyethylene terephthalate) - number 1: PET is commonly used for beverage bottles, food packaging, textile fibres, etc. It is a transparent, strong, lightweight and well recyclable material.
- HDPE (High Density Polyethylene) - number 2: HDPE is used to manufacture milk bottles, cooking liquids, bins, etc. It is a high-impact material, resistant to chemicals and relatively easy to recycle.
- PVC (Polyvinylchloride) - number 3: PVC is used to make pipes, windows, doors, drug packaging, etc. It is a flexible material with a long life, but can contain harmful substances, which can make it difficult to recycle.
- LDPE (Low Density Polyethylene) - number 4: LDPE is used to make plastic bags, food packaging, rubbish bags, etc. It is a flexible material, resistant to mechanical damage and relatively easy to recycle.
- PP (Polypropylene) - number 5: PP is used for ketchup bottles, yoghurt bottles, food packaging, garden furniture, etc. It is durable, thermoplastic and relatively easy to recycle.
- PS (Polystyrene) - number 6: PS is used to make beverage cups, food trays, egg packs, etc. It is lightweight, rigid and relatively difficult to recycle.
- Other - number 7: includes all other types of plastics that do not fit into the other categories. This can include materials such as polycarbonate (PC), polyamide (PA), polycarbonate bisphenol A (PC-BPA), etc.

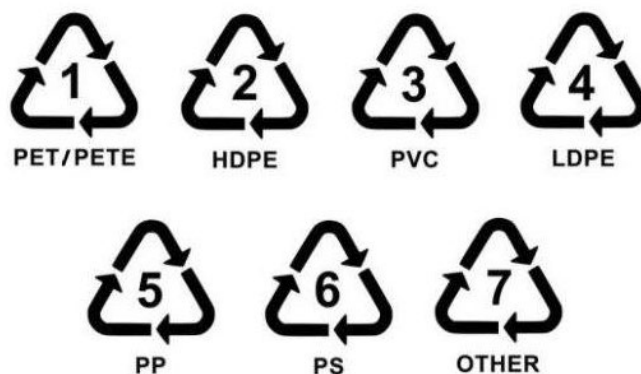


Figure 1 - Recycle symbols for each polymer

The preparation of plastics for shredding is a key step in the recycling process that influences the efficiency and quality of the entire process. Once the appropriate type of material has been collected, selected and segregated by type, it is necessary to subject the waste to the process of removing contaminants such as labels, stickers or product residues. This can be done manually or with the help of machines, such as cleaning machines that remove contaminants mechanically or with water and detergents.

The resulting material must be shredded into smaller pieces using grinding machines. There are different types of machines, such as knife shredders, drum shredders or screw shredders, which differ in their mode of operation and the size of the pieces produced. Water can be used for shredding and cleaning, so it is necessary to dry the product before the next step. After shredding, the plastic pieces may be subjected to quality control to ensure that they do not contain any impurities or undesirable materials.

Filament extrusion is carried out by heating the raw material to a melt state and then pushing it through the capillary die. The most commonly used extrusion machines are screw extruders, in which the plastic is subjected to high pressure and temperature to obtain the desired shape. The plastic extrusion process has many applications in a variety of industries and is one of the most widely used methods for moulding plastics due to its flexibility and efficiency.

A key aspect in the extrusion process is the right choice of raw material. In addition, the right operating conditions such as temperature, pressure and processing speed are important. The control of these parameters is crucial in order to obtain the optimal properties of the final product. Changes in these aspects can affect the quality, strength and appearance of the final product.

Depolymerization. Some plastics, particularly PET, are chemically broken down into their monomers and then repolymerized to create virgin-like materials suitable for filament production. Depolymerization can be divided into thermal, chemical, and catalytic. The easiest is thermal decomposition of polymers under the influence of high temperature. Using depolymerization in the production process of 3D printing filament supports sustainable development by reducing the amount of plastic waste and limiting the use of primary raw materials. Filaments produced in this way can have similar mechanical properties to those of new materials, making them an attractive option for both hobbyists and industry.

Composite Formulation. In cases where pure recycled polymers lack certain properties, they are often blended with virgin materials or additives to enhance characteristics such as strength, flexibility, or printability. This process, often called compounding or blending, aims to combine the advantages of

both types of materials and balance their properties. The recycled material may have slightly lower mechanical properties, such as tensile strength or elasticity, compared to the virgin material. By mixing it with new material, these properties can be improved, making the final product more durable. Adding recycled material reduces the need for virgin raw materials, which is good for the environment. This approach helps reduce the carbon footprint and promotes more sustainable production. Recycled material is usually cheaper than new material, so adding it can reduce production costs. Companies often use blends to achieve a compromise between cost and quality. In some cases, the recycled material may have different thermal properties, which can affect production processes such as injection or extrusion. Adjustments to the production parameters are necessary to ensure proper mixing and processing. In 3D printing filament production, mixing recycled PLA with new PLA is a popular approach that allows maintaining printing properties while reducing costs and increasing production sustainability. However, the mix of recycled and new material must be carefully balanced to avoid printing problems such as nozzle clogging or inaccurate layer formation.

Advanced Additives and Blends

Nano-fillers: Incorporating nano-fillers like carbon nanotubes or graphene into recycled filaments can enhance mechanical properties and electrical conductivity, expanding the range of applications. The production process must be adjusted to prevent their agglomeration and ensure their proper compatibilization, which is even more important for systems with recyclable polymers, the properties of which must be precisely defined. It should also be remembered that nanoparticles are usually more expensive than traditional additives, which can increase the production costs of filaments. Nanoparticles used in commercial products include filaments with carbon nanotubes (CNTs) used in the automotive and aerospace industries and in the production of advanced prototypes; PLA with silver nanoparticles are antibacterial filaments used in printing medical and hygienic elements; filaments with graphene used to create lightweight, strong and conductive elements, especially in electronics and energy; PLA with titanium oxide (TiO₂) nanoparticles resistant to UV, used in outdoor applications and in products requiring durability to sunlight. The addition of nanoparticles can affect the flow of material through the 3D printer nozzle, which can lead to clogging or inaccurate layer formation. It is necessary to adjust printing parameters such as temperature, speed, or nozzle diameter.

Colorants and Stabilizers: Recycled filaments are often enhanced with colorants and UV stabilizers to improve aesthetics and longevity. Stabilizers are chemical compounds added to polymers that help prevent material degradation during processing, storage, and use. In the case of 3D printing filaments, stabilizers have several important functions: protection polymers from decomposition at high temperatures during processing (e.g., filament extrusion) and 3D printing. They help maintain the thermal stability of the material, preventing its degradation. Protect filaments and printed objects from degradation caused by ultraviolet (UV) radiation. Prolonged exposure to sunlight can cause polymers to yellow, crumble, and weaken. They protect polymers from oxidation, which can occur during processing at high temperatures or during long-term storage. They maintain the stability of polymers in the presence of moisture, which is especially important for filaments that are hygroscopic (e.g., PLA). Moisture can cause polymer degradation, which affects print quality and the mechanical properties of prints. Dyes, on the other hand, allow filaments to be obtained in a wide range of colours, which is important for printing objects with specific aesthetic requirements, such as architectural models, figurines or utility items. Dyes and pigments must be compatible with the polymer used to avoid processing problems, such as uneven colour distribution or changes in mechanical properties. Prints

made from coloured filaments must be resistant to fading under the influence of light, heat and chemicals. The addition of dyes can slightly change the mechanical properties of the filaments, especially if they are added in large quantities. In some cases, this can lead to a decrease in the strength or elasticity of the material. Recycled material may contain various additives, which should be taken into account when creating new filaments.

Granulation and extrusion are key processes in plastics processing that play an important role in the production of 3D printing materials, including filaments. Granulation is a process in which polymer raw material (e.g. recycled or virgin) is transformed into small pellets, which can then be processed into filaments in an extrusion process. Granulation steps:

- Raw material preparation: The raw material (e.g. plastic waste, damaged filaments) is first pre-processed. This includes cleaning, sorting and, if necessary, shredding into smaller fragments.
- Shredding: The material is shredded using mills or shredders that transform it into small pieces of the right size.
- Melting and homogenization: The shredded material is melted in special equipment. In this phase, stabilizers, colorants, and other additives can be added to improve the material's properties.
- Pellet Forming: The melt is extruded through a die, then cooled and cut into uniformly sized pellets.

Extrusion is a process that processes polymer pellets into a uniform material, such as 3D printing filament. The extrusion process involves melting the pellets and pushing them through a die to give them the desired shape. Extrusion steps:

- Feeding the pellets.
- Melting and Homogenization: In the extruder, the pellets are heated to their melting point, which transforms them into a homogeneous mass. Additives such as dyes, stabilizers, or nanoparticles can be added at this stage.
- Forcing through the head: giving them the desired shape, such as a filament with a specific diameter.
- Cooling and calibration: The extruded material is immediately cooled to stabilize its shape. The filament is then calibrated to ensure uniform diameter and quality.
- Winding: The finished filament is wound onto spools, allowing for easy storage and use in 3D printers.

For recycled material, it is important to properly analyse them before the extrusion process, including thermogravimetry - determination of the polymer composition of the material, melt flow index - amount of material flowing out in a given time at a specific temperature; these properties determine extrusion parameters: temperature, speed.

Recycled filament on the market

Filaments labelled as recycled products are appearing on the market. The recycled filaments offered on the market, however, come from material returned during the filament creation process, e.g. from the start/stabilisation of the process or spools that do not pass quality control. Available manufacturers include: Prusa (<https://www.prusa3d.com/pl/produkt/prusament-pla-recycled-2kg/>) and Spectrum (<https://sklep.spectrumfilaments.com/ser-pol-62-recycled-PLA.html>). In contrast, the waste used in

the project to produce the filament comes from secondary raw materials, i.e. recycled materials such as plastic bottles or industrial waste.

Research and work carried out

This activity involves the production of filaments for 3D printing using recycled plastic. First step was carried out by project partner Proplast (Consorzio Per La Promozione Della Cultura Plastica Proplast) who conducted some preliminary tests with commercial recycled plastic from a different recyclers and post-industrial waste from K-FLEX (K-FLEX Polska) production. The spools obtained were then sent to Leda Polymer, where 3D printing tests were carried out.

- Equipment and methods used
- Mill – Piovan RSP 15/15

The Piovan mill, model RSP 15/15, is a granulator designed for processing small quantities. It's used for grinding the flakes from a bigger to a smaller size, when needed.

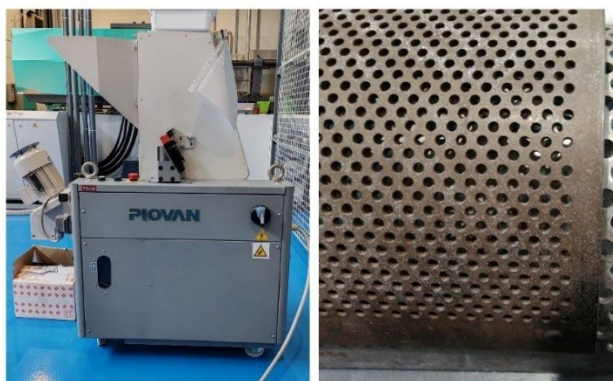


Figure 2 - Piovan mill

- Leistritz ZSE 27 MAXX extruder

The compounds, when needed, are carried out on a corotating twin screw extruder, Leistritz ZSE 27 MAXX, with screw diameter of 27 mm and L/D ratio of 40. The extruding line include also a water-cooling tank, an air dryer and air cut pelletizer Primo 60E. The extruding line is shown in figure 3.



Figure 3 - Extrusion line

- Filament Maker ONE - 3Devo

3Devo extruder is a bench extruder specifically made to obtain filament for the 3D printing. It can reach up to 450° C, with 4 heating zone in the cylinder, each zone can have a different

temperature. The diameter of the filament can be adjusted from 0,5 mm to 3 mm. The diameter of the filament for the 3D printing is 0,75 mm.



Figure 4 - 3Devo filament maker

- 3D printer

Creality Ender 3 The effective working area is 220 x 220 x 250 mm with the option of heating the table (up to 110°C), printing speeds reach up to 180 mm/s, the printing layer thickness is from 0.1 mm to 0.4 mm. It is intended for use with standard, most popular filaments with a diameter of 1.75 mm.



Figure 5 - 3D printer Creality Ender 3

Methods

Differential scanning calorimetry (DSC)

Differential scanning calorimetry (DSC) is a technique used to study the thermal transitions of a polymer. The difference in heat flow between a sample and a reference is monitored as a function of temperature and time, while the sample is subjected to a series of programmed thermal cycles. With this test methodology, information can be obtained relating to:

- Melting temperature, T_m (°C)
- Crystallization temperature, T_c (°C)

The instrument used was the TA Instruments DSC Q2000. The sample weight was approximately 6-8 mg and the nitrogen flow rate was 50 ml/min.



Figure 6 - DSC Q2000

Thermogravimetric analysis (TGA)

The instrument used for sample characterization is the TA Instruments TGA, model Q550. The gas flow rate used is 60 ml/min. This technique studies the weight change of the sample caused by the degradation of the material while it's heated, up to 800/900 °C. The test records the typical temperatures and characteristic degradation steps of each material studied. In addition, it is possible to identify, if present, a percentage of residue, remaining in the sample at the end of the test itself.



Figure 7 - TGA Q550 (TA Instruments)

Thermal analyses, Thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC), are carried out to evaluate the purity of the recycled material.

The TGA was performed in air, from 0° C to 800 °C and the DSC was carried out from 0° C to 300° C with two heating cycle and one cooling cycle.

Melt flow index (MFI)

The melt flow index (MFI), also known as the melt index or melt flow rate (MFR), is a measure of the fluidity of a molten polymer. It is widely used in quality control and to compare different grades of the

same polymer. The MFI is measured by loading the polymer into a heated cylinder at a specific temperature. A weight is applied to the molten polymer using a piston, which exerts a constant force and causes the polymer to flow through a capillary. The weight of polymer extruded in 10 minutes is the melt flow index value.

The polymers were tested at 190°C with a constant load of 2.16 kg for polyethylene or 230°C and 2.16 kg for Polypropylene.



Figure 8 - XNR-400C series from AMSE

- Types and requirements of tested filaments

Table 1 - Materials used for filament production

Material name	Polymer type	Material origin
SERTENE HDPRO 010	mixed polyolefin mostly PE with some PP	Post consume
SERTENE PP X200RC	mixed polyolefin mostly PP with some PE	Post consume
GS FILM Ambra	LDPE	Post consume
BRETENE TSCORE white F003GR186	HDPE from milk bottle	Post consume
Grey pellet (K-FLEX)	LDPE	Post industrial
Light blue flakes (K-FLEX)	LDPE	Post industrial
Light blue pellets (K-FLEX)	LDPE	Post industrial

- SERTENE HDPRO 010 – mixed polyolefin mostly PE with some PP

It is a commercial post consume material.

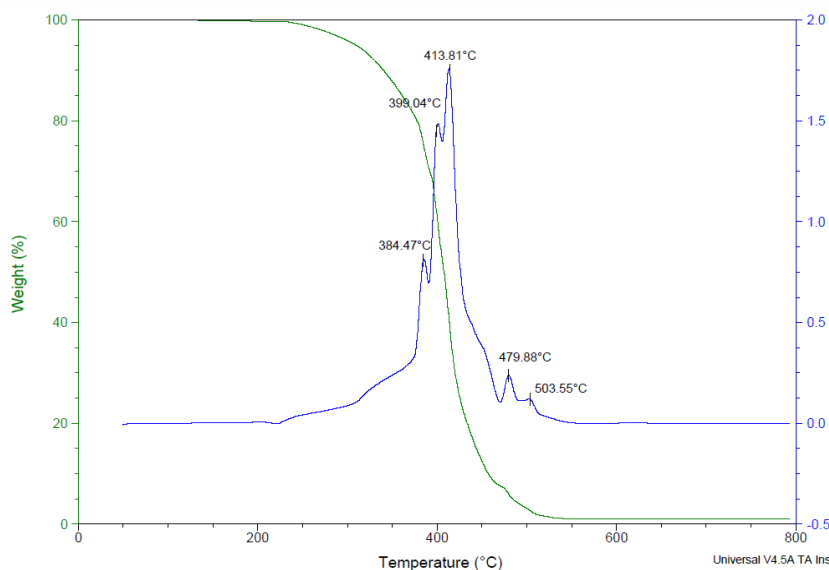


Figure 9 - TGA (AIR) of SERTENE HDPRO 010

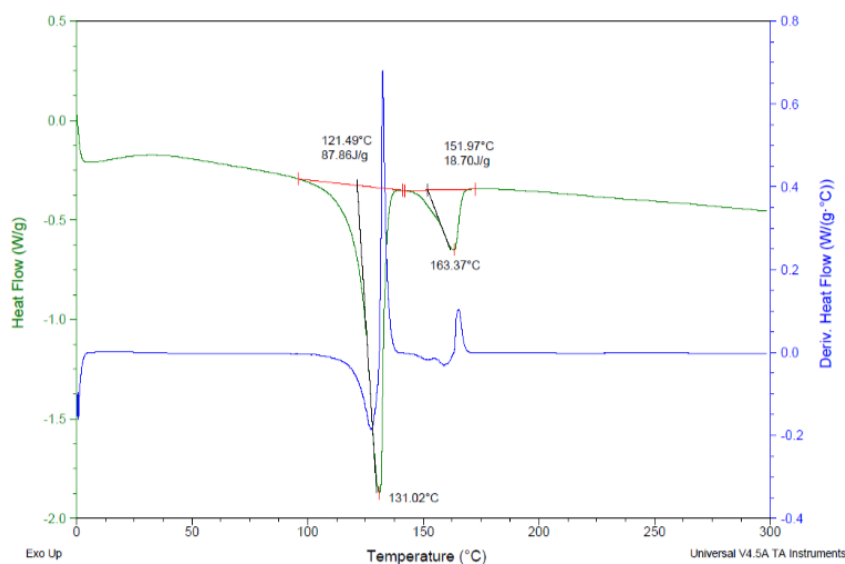


Figure 10 - DSC of SERTENE HDPRO 010

In the DSC analysis there are two peaks: one larger peak at 131 °C corresponding to the phase transitions of PE polymer and one smaller peak at 163° C corresponding to the phase transitions of PP polymer. So, this material is a mostly PE with a little part of PP. This happens because during the recycling process it's very difficult to separate the two polymers.

From the manufacturer's technical data sheet is reported the MFR values at both 190°C, the analysis temperature used for PE, and at 230°C, the analysis temperature used for PP. The values are reported in the figure 11 below.

Properties	Method	Unit	Value
Physical			
Melt Flow Rate (190°C- 2,16 kg)	ISO 1133	g/10'	1,20
Melt Flow Rate (230°C- 2,16 kg)	ISO 1133	g/10'	2,80

Figure 11 - Melt Flow Rate for SERTENE HDPRO10

- SERTENE PP X200RC - mixed polyolefin mostly PP with some PE

This is a commercial post consume material and it's in granules.

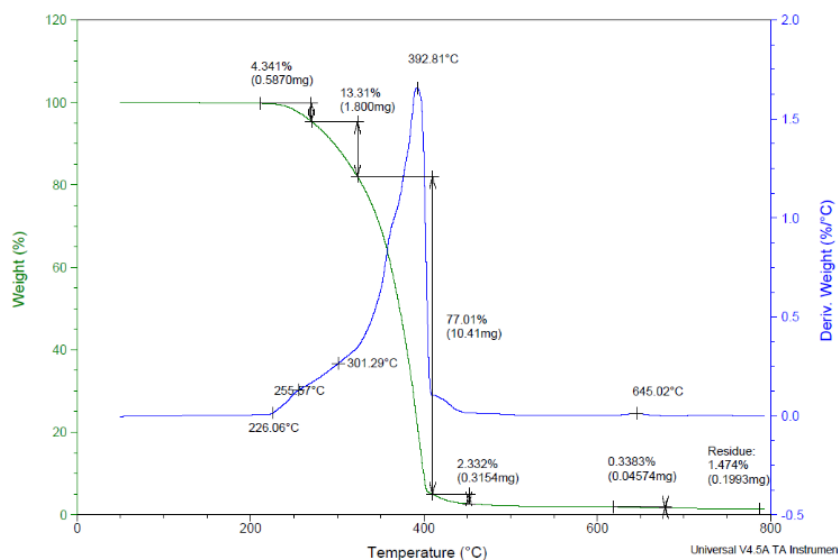


Figure 12 - TGA (air) of SERTENE PP X200RC

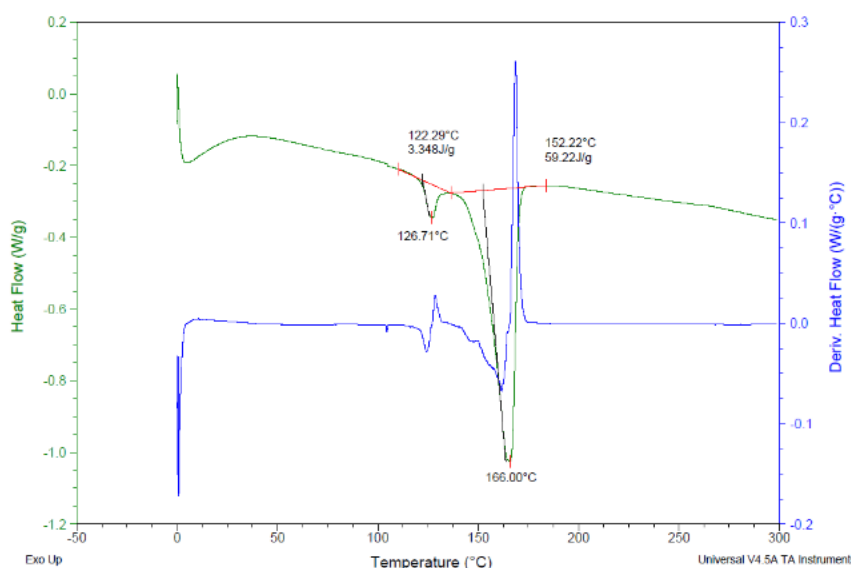


Figure 13 - DSC of SERTENE PP X200RC

In the DSC analysis there are two peaks: one smaller peak at 126 °C corresponding to the phase transitions of PE polymer and a larger peak at 166° C corresponding to the phase transitions of PP polymer. So, this material is a mostly PP with a little part of PE. This happens because during the recycling process it's very difficult to separate the two polymers.

From the manufacturer's technical data sheet is reported the MFR values at 230°C, the analysis temperature used for PP. The values are reported in the figure 16 below.

Properties	Method	Unit	Value
Physical			
Melt Flow Rate (230°C- 2.16 kg)	ISO 1133	g/10'	10

Figure 14 - MFR value for SERTENE PP X200RC

- GS FILM Ambra – LDPE from post consumed film

This is a material derived from post consumed film and it's mostly based on LDPE.



Figure 15 - Granules of GS FILM Ambra

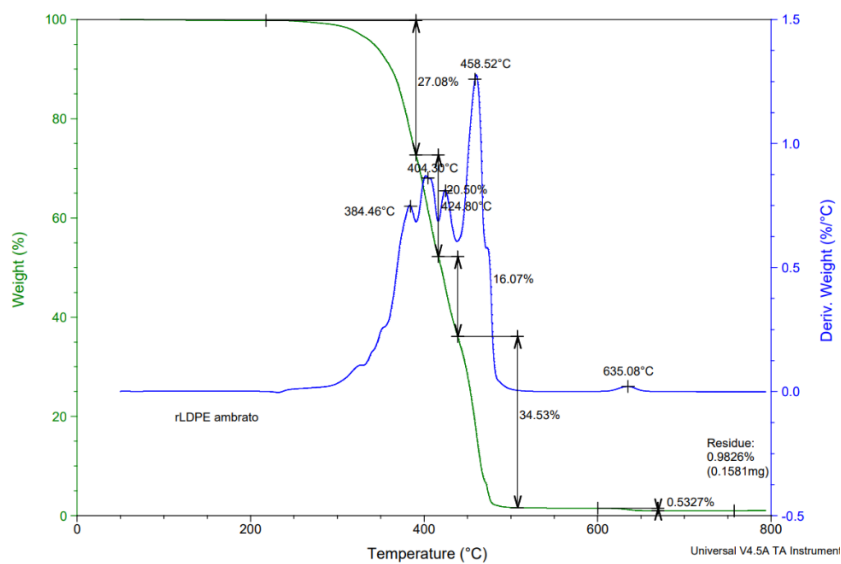


Figure 16 - TGA in air of the GS film Ambra

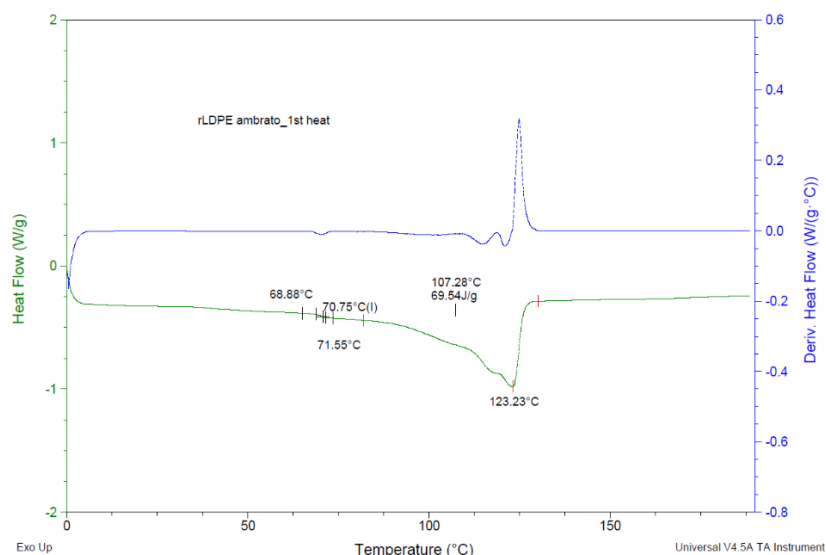


Figure 17 - DSC of the GS film ambra

The main peak at 123° C, correspond to the phase transitions of LDPE polymer. The shape of the peak is wide, due to the presence of other minor polymers that are used in multilayer film structure (EVA or others). The TGA, confirm the presence of other polymers or different grades of PE included in the composition. The main peak at 458 °C is the one of PE, the other polymers show an anticipated degradation. This material has also a lot of impurities because it's a post consume material. Currently, the separation process of film plastic doesn't allow an output material with high purity, so the material is a blend of several polymer. The Melt Flow Rate value is 0,84 g/10 min, the other values obtained from the analysis are reported in the table below.

Table 2 - Melt flow rate of GS film ambra

GS FILM AMBRA - 190°C 2,16Kg			
	MVR (cm ³ /10min)	MFR (g/10min)	melt density (g/cm ³)
Media	1,09	0,84	0,771

- HDPE BREtene TSCORE white F 003GR186 – HDPE from milk bottle

This is a material derived from post consumed milk bottle. It's HDPE in granules form. The recycling process is made from the producer of this polymer.



Figure 18 - Granules of HDPE BREtene

The TGA was performed in N2 from 0° C to 600 °C and in air from 600 °C to 800 °C.

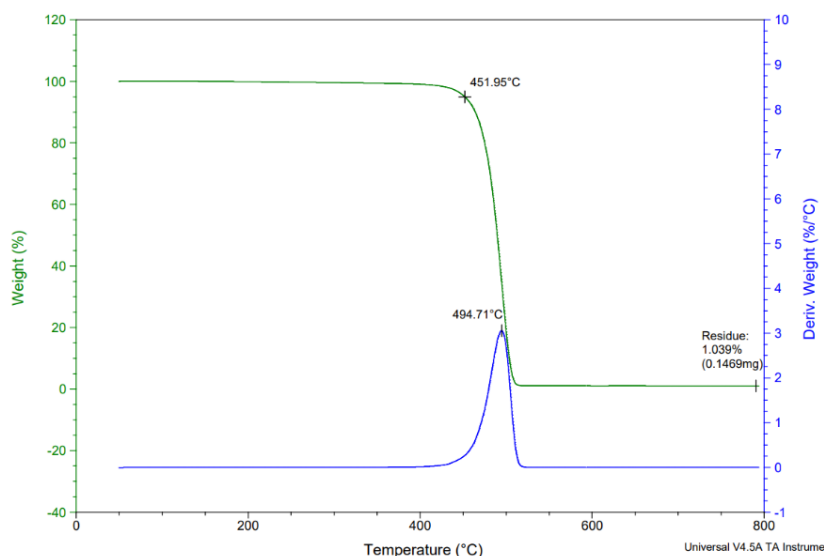


Figure 19 - TGA in N2/air of the HDPE Bretene

From the TGA analysis it's possible to see that there is just one peak of degradation, at 494 °C, this means that the material has high purity and it doesn't contain additives or impurities even if it's a post consume material. The reason is that this material is derived from a single source of waste, the milk bottle. The Melt Flow Rate value is 0,27 g/10 min, the other values obtained from the analysis are reported in the table below:

Table 3 - Melt flow rate for HDPE Bretene

HDPE BREtene - 230°C 2,16Kg			
	MVR (cm ³ /10min)	MFR (g/10min)	melt density (g/cm ³)
Media	0,37	0,27	0,74

- K-FLEX – grey pellet LDPE

This is a post industrial material provided from K-FLEX and it's in little pellets. It's possible to extrude the material like that.



Figure 20 - Grey pellets of K-FLEX LDPE

The TGA was performed in N2 from 0° C to 600 °C and in air from 600 °C to 800 °C.

From the TGA analysis it's possible to see that there is just one peak of degradation, at 486 °C, this means that the material has high purity. The Melt Flow Rate value is 2,52 g/10 min, the other values obtained from the analysis are reported in the table below.

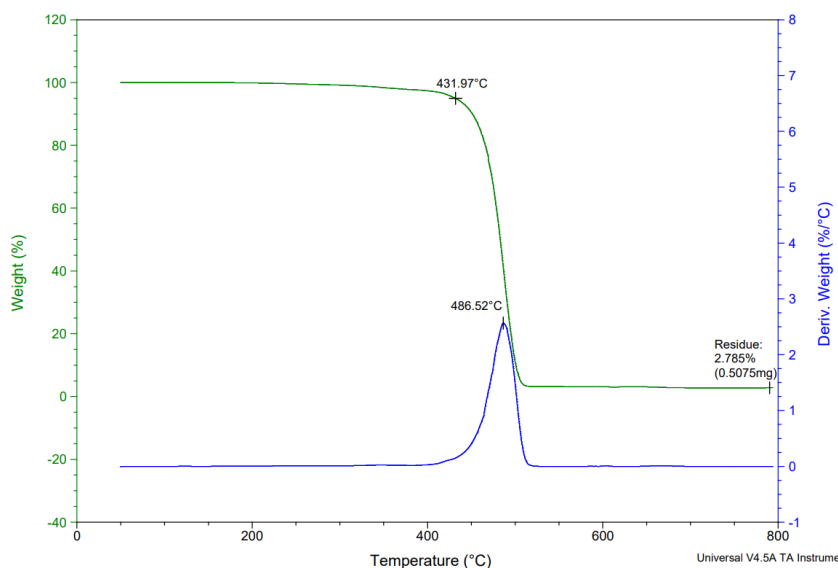


Figure 21 - .TGA in N2/air of grey pellet - LDPE

Table 4 - Melt flow rate of grey pellet - LDPE.

grey pellet LDPE - 190°C 2,16Kg			
	MVR (cm ³ /10min)	MFR (g/10min)	melt density (g/cm ³)
Media	3,25	2,52	0,78

- K-FLEX – light blue flakes LDPE

This is a post industrial scrap provided by K-FLEX. The original flakes needed to undergo to a further grinding step to permit a better feeding. This step is described in the next paragraph. The grid mounted on the mill has holes of 6 mm. In the picture the sample before and after grinding.



Figure 22 - Blue flakes of K-FLEX LDPE

The analysis of this material was not possible because it was all used to produce filament. The following material was analysed and it's reported to be the same material as this one from its manufacturer.

- K-FLEX – blue pellets – LDPE

This is a post industrial material provided from K-FLEX, already provided in pellets form. Being the same material as the blue flakes just described the analysis were done only on the present granules. This material was mixed with other virgin polymer to increase the adhesion properties. This process, and the compounds made are described in the next paragraph.



Figure 23 - Blue pellets from K-FLEX

The TGA was performed in N₂ from 0° C to 600 °C and in air from 600 °C to 800 °C

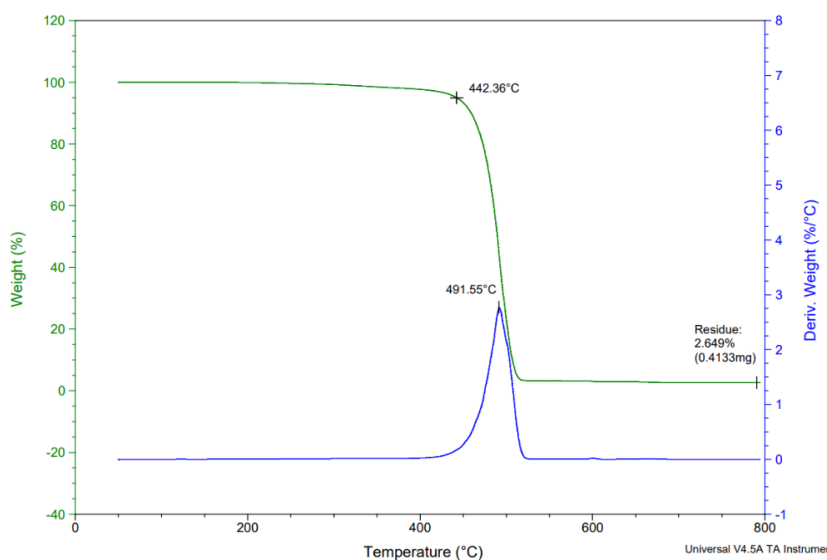


Figure 24 - TGA in N₂/air of blue pellet - LDPE

From the TGA analysis it's possible to see that there is just one peak of degradation, at 491 °C, this means that the material has high purity. The Melt Flow Rate value is 2,49 g/10 min. The other values

obtained from the analysis are reported in the table below. This value is similar to the grey pellets value.

Table 5 - Melt flow rate of blue pellet - LDPE

blue pellet LDPE - 190°C 2,16Kg			
	MVR (cm ³ /10min)	MFR (g/10min)	melt density (g/cm ³)
Media	3,19	2,49	0,78

Processing description

Compounds were prepared to improve the adhesion properties of the LDPE from K-FLEX (blue pellets material) on the 3D printer plate. The polymers considered are a virgin LDPE, Eraclene MS80, with low viscosity, and a virgin EVA, Elvax 260, a polymer having good adhesion properties. The formulations are reported in the table below.

Table 6 - Formulations with rLDPE from KFLEX and LDPE and EVA.

Compound name	PE0156	PE0157	PE0158
Ingredients	% weight	% weight	% weight
LDPE blue pellets - KFLEX	90	85	80
LDPE ERACLENE MS80			20
EVA ELVAX 260	10	15	

The components of each formulation were weighted and dry mixed together.

The compounds were made on the Leistritz extruder. The extruding parameters for each formulation are reported in the below table.

Table 7 - Extruding parameters

Batch	Screw speed	Torque	Melt pressure	Melt temperature	Heating zone temperatures in °C										
						HZ 1	HZ 2	HZ 3	HZ 4	HZ 5	HZ 6	HZ 7	HZ 8	HZ 9	DIE
PE158	150	42	15	184	SET	160	170	170	170	175	175	175	180	180	180
					ACTUAL	160	170	170	170	175	175	175	180	180	180
PE156	150	44	21	198	SET	160	170	170	170	175	175	175	180	180	180
					ACTUAL	160	170	170	170	175	175	175	180	180	180
PE157	150	46	23	181	SET	160	170	170	170	175	175	175	180	180	180

					ACTUAL	160	170	170	170	175	175	175	180	180	180
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There was no issue during the extrusion process. 3 kg of material were made for each formulation.



Figure 25 - Extrusion process

The melt flow index of the compounds was measured to verify if the viscosity has decreased. The results of the analysis of the compounds compared to the MFI of the virgin material are reported in the table below.

Table 8 - Comparison of MFI

blue pellet LDPE - 190°C 2,16Kg			
	MVR (cm ³ /10min)	MFR (g/10min)	melt density (g/cm ³)
blue pellet LDPE	3,19	2,49	0,78
PE0156	3,54	2,77	0,78
PE0157	3,78	2,96	0,78
PE0158	5,85	4,53	0,77
EVA elvax 260	-	6*	-
LDPE Eraclene MS80	-	27*	-

*MFR value taken from the TDS of the polymer.

The addition of the EVA polymer in the compounds PE0156-157, increase a little the MFI of the polymer because the MFI of the virgin EVA is higher than the MFI of the K-FLEX LDPE. The addition of virgin LDPE increase even more the MFI of the compound PE0158.

Filaments extrusion

It has been possible to extrude all the materials. The process parameters from the extruder are reported in the table below:

Table 9 - Extruding parameters

	Mostly PE SERTENE HDPRO	Mostly PP SERTENE X200RC	LDPE Ambra	HDPE Bretene	LDPE light blue flakes	LDPE grey pellets
Extruding temperature (°C)	180	190	180	190	180	180
Speed (rpm)	3	3	3	3	3	3
Filament diameter (mm)	1,75	1,75	1,75	1,75	1,75	1,75

LDPE – GS film Ambra

This material is produced from post consumed film and it still contains some impurities that caused some problem to maintain constant the filament diameter during the filament extrusion. This material was the most difficult between all, but it was still possible to obtain one spool with diameter 1,75 mm.

HDPE – Bretene from milk bottle

This material has been extruded at a higher temperature than the LDPE. The filament was constant at 1,75 mm during the extrusion.

LDPE – Grey pellets

During the extrusion the diameter of the filament was constant at 1,75 mm.

LDPE – light blue flakes

During the extrusion of the filament the feeding was inconsistent for the shape of the flakes. It was possible to obtain two half full spool.

Next time we will make pellets from the flakes before the filament extrusion.

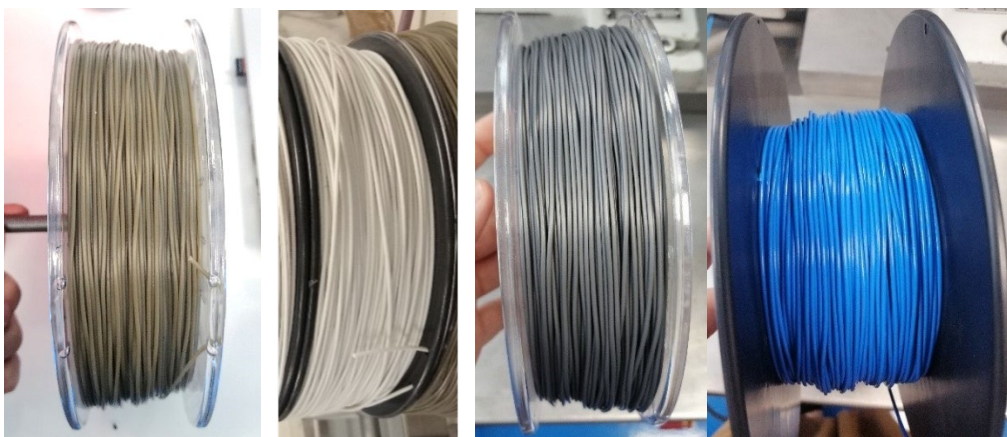


Figure 26 - Some of spools obtained

In the table below are reported the extrusion parameters for the PE0156-158 formulations. The filament was constant at 1,75 mm during the extrusion of all the formulations.

Table 10 - Filament extrusion parameters for the PE0156-158 parameters

Hygttf5	PE0156	PE0157	PE0158
Extruding temperature (°C)	190	190	190
Speed (rpm)	3	3	3
Filament diameter (mm)	1,75	1,75	1,75

There was no issue during the extrusion process for all the materials.



Figure 27 - PE0156-158 spools

- 3D printing results - summary and comparison (determining printing parameters - for each filament: printing and table temperature, adhesive agents used; determining the possibility of printing elements: adhesion between layers and shrinkage during printing)

SERTENE PPx200C RC – for every samples were use glass bed and adhesive "Devil design".

Table 11 - Printing parameters of the filament prepared from SERTENE PPx200C RC

Nozzle temperature [°C]	Bed temperature [°C]	Effect
200	60	50% of printing
200	80	Worst adhesion than first trial
200	50	
220	70	
150	50	
170	50	
190	50	Good adhesion, only problems are corners because after some time there are starting going up. Sample made of it has low connection between layers, probably due to thinner layer,

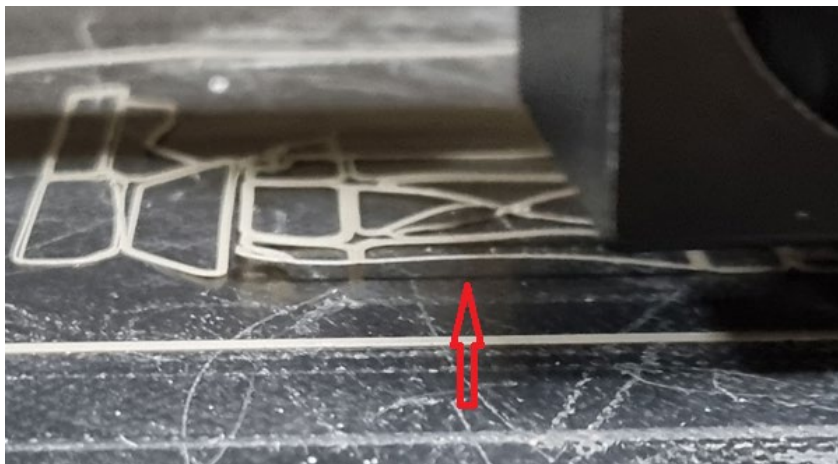


Figure 28 - Peeling off the object during the printing using SERTENE PPx200C RC.



Figure 29 - Printing using SERTENE PPx200C RC

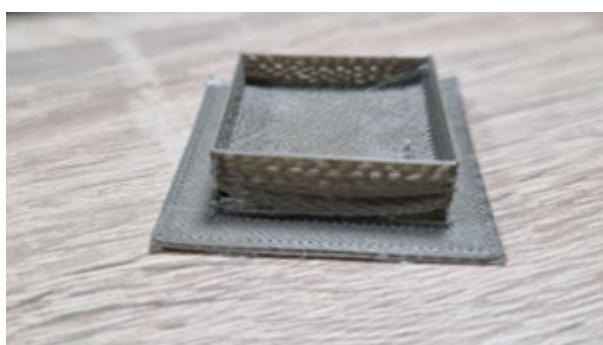


Figure 30 - Element made with SERTENE PPx200C RC

SERTENE HDRPO 0100 - for every samples were use glass bed and adhesive "Devil design".

Table 12 - Printing parameters of the filament prepared from SERTENE HDRPO 0100

Nozzle temperature [°C]	Bed temperature [°C]	Effect
200	60	

220	80	Impossible to make even small element because of no adhesion to table
160	80	
200	50	
220	70	
170	70	
190	70	For that parameters filament has a suitable adhesion, probably has a similar thickness to PP, but there is no possibility to print a high element with it. After leaving the nozzle, the material shrinks and already in the first layer there are quite high stresses that cause it to peel off from the table. The finished fragment is not flat, but has bulges.



Figure 31 - Peeling off the object during the printing using SERTENE HDRPO 0100

HDPE – milk bottle, BRETENE TSCORE white F 003GR186

Table 13 - Printing parameters of the filament prepared from Bretene

Nozzle temperature [°C]	Bed temperature [°C]	Effect
200	80	Too high temperature
200	70	
180	60	Too low temperature
190	70	Good option but problems with adhesion

LDPE (K-FLEX) – made from blue flakes

Table 14 - Printing parameters of the filament prepared from light blue flakes

Nozzle temperature [°C]	Bed temperature [°C]	Effect
-------------------------	----------------------	--------

160	60	Too low temperature of nozzle and bed
170	70	
180	80	Good parameters
190	80	The best parameters, but problems with adhesion (it is possible to get small piece but only one layer)
200	80	Too high nozzle temperature

LDPE (K-FLEX) – from grey pellets

Table 15 - Printing parameters of the filament prepared from grey pellets

Nozzle temperature [°C]	Bed temperature [°C]	Effect
200	70	Adhesion problems
190	65	Too low nozzle temperature
200	60	Good parameters but it gets hooked
200	50	Too low bed temperature
200	60	Second trial do not give the same effect than previous one with the same parameters

LDPE - GS FILM Ambra

Table 16 - Printing parameters of the filament prepared from GS film Ambra

Nozzle temperature [°C]	Bed temperature [°C]	Effect
200	70	None of the parameters cause adhesion to the stage and immediately curls up despite extrusion
200	80	
220	80	
190	80	

All materials were tested at 3 different speeds: standard (100%), 80% and 110%. however, changing the speed did not increase adhesion or made it worse. In addition, the created layer was much thinner than the standard filament.

It is necessary to use PP adhesive tape for the samples to ensure proper adhesion to the substrate. It is necessary to reduce the heating temperature of the table. However, it allows printing from both waste from K-FLEX. Optimal parameters are nozzle 190°C and bed 50°C.



Figure 32 - Element made with light blue flakes from K-FLEX

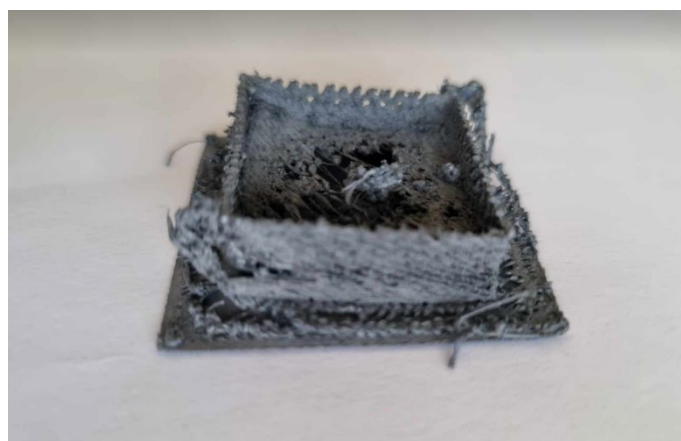


Figure 33 - Element made with grey pellets from K-FLEX

PE0156, PE0157, PE0158 - All filaments were printed in the following parameters: nozzle temperature: 190-200°C, fan speed 100%, table temperature 30°C with a layer of tape and Devil Design adhesive. These are the appropriate parameters for printing.

The addition of LDPE (PE0158) causes further separation from the table and the element cannot be printed till the last layer.

EVA allows for better adhesion, but its additive is limited, better prints are created with 10% of the additive.



Figure 34 - Elements made with blue granulate from K-FLEX with pure polymers

Filaments made from recycling can be used for 3D printing. Their properties and printing capabilities depend on the specific material. However, it should be remembered that in the case of using waste itself, adhesion to the table and between layers may be a problem. To ensure better properties, it seems appropriate to use pure polymer additives to LDPE waste, such as EVA, in a 10% content and use some adhesives on the plate, the use of which gives the best results. Additionally, it should also be remembered that it is possible to carry out further tests of filaments created using other proposed waste, which could give better results when using the addition of pure polymer. It would be necessary to select the appropriate additive and optimize the composition and printing parameters, but tests performed on blue flakes allow us to expect good results.

Socially oriented implementation concept

New occupational concepts and training program

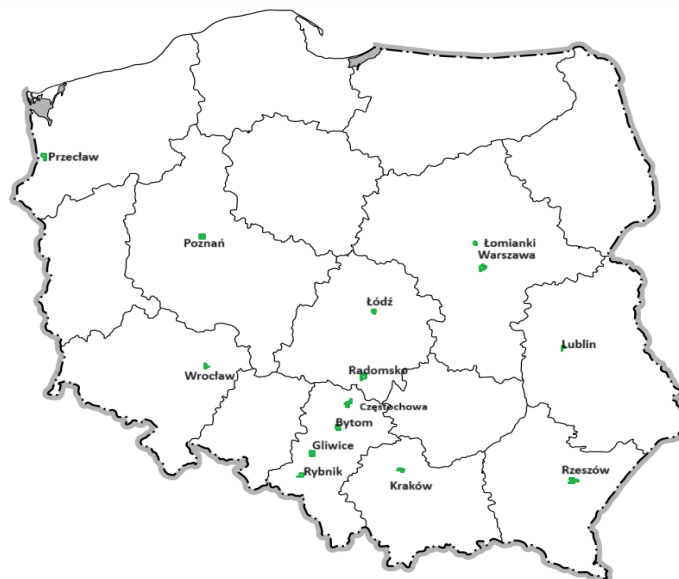
According to projected trends [Budzik, Wozniak, Przeszlowski 2022], the 3D printing industry is in a growth phase, which signals, among other things, that there will be a need for workers for the aforementioned area in the near future as well. Analysed reports on incremental technologies show that sales of 3D printers worldwide have been growing over the past years (the cited Wohlers Report showed increasing sales of 3D printers worldwide - the years analysed were 2009 (1,816 units) - 2017 (528,952 units)). The Polish market is also on the rise - domestic 3D printer startups like Zortrax, ZMorph, Omni3D, HBot 3D, Ubot 3D, 3 Novatica - are brands that are gaining popularity both in Poland and internationally. An analogous situation is observed among filament manufacturers (Fiberlogy, PRI-MAT3D, AEMCA) [Budzik, Wozniak, Przeszlowski, p. 32]. An increase in awareness and interest in the use of incremental technologies, as measured by the number of implementations, is observed in the SME sector (increasing the number of implementations from 14.5% in 2018 to 18.3% in 2020). Industries where 3D printing plays an important role are: electromechanical, aerospace, automotive, military, foundry, industrial design, construction, medical. Other areas where 3D printing is also being used on an increasing scale include didactics (integration into educational processes), marine, food, fashion, among others. In the UK, there is a separate profession, which is 3D printing technician - in order to educate oneself in it, one must take university courses or internships, certification is also provided. The skills that a person in such a position should have are specified - these include knowledge of production and manufacturing processes, engineering and technology, operation and control of equipment, knowledge of mathematics, computer literacy and major software packages, the necessary competencies are accuracy, attention to detail and analytical skills.

During the review of (mainly) online sources, including available reports and analysis, the information mainly mentioned above was sought. The main issue with which the search began was an analysis of the types of training that are offered in the topic of 3D printing. The training courses offered can be described as basic - which applies to both the subject matter covered, the audience, and the timing. The available training on the market is commercial, and a significant part is dedicated to the educational sector (including teachers).

A desk research analysis was conducted, mainly of the online research type in search of professional training related to 3D printing topics. The search phrases were "3D printing training", "3D printing vocational training"; "3D printing training WUP/ PUP". A total of 23 websites (various sites) that offer 3D printing training in February-March 2024 were analysed. The following is a brief description of the offerings. In the Polish context, no separate profession with specific qualifications and skills for its practice was found, which may indicate the (so far) relatively low popularity of this profession.

Companies offering training

The map below shows the distribution of places where companies offering training are located. Companies, organizations providing the above mentioned training are located (starting from the voivodeship with the largest number of bidders) in: mazowieckie (6), śląskie (5) wielkopolskie (2), łódzkie (2), podkarpackie (2), małopolskie (2), dolnośląskie (2), lubelskie (1), zachodniopomorskie (1).



Characteristics of training providers

There is great diversity among entities offering 3D printing training. After analysis, they were divided into companies specializing in incremental printing (8); training companies (8); and research institutes and centres for specialized (technical) training (3); the other category included a scientific foundation, an educational publishing house, a non-public teacher training institution and an online technical magazine. In 3D printing companies, training is an additional branch next to the core business. They are offered to a variety of audiences - often tailored individually to the needs of the subjects - the range of topics offered suggests that these are often “introductory” training courses - dedicated to subjects who just want to introduce such technology into the field of activity or are beginners in it; another type are courses offered for hobbyists. Similarly, diversity is characterized by training companies that undertake the above-mentioned courses subject matter - among those offering 3D printing training, we will find training companies that offer courses diversified in subject matter, and 3D printing training seems to be an additional attractive topic to present. Among those analysed, we also found professional training centres (e.g., technical) offering multi-day series, divided by levels of knowledge and subject area (e.g. separately for those wishing to specialize in plastic, metal, resin additive printing) aimed at professionals. Among those analysed, for example, there were no training courses dedicated to specialized industries as previously described as those in which 3D printing is often used - only one specialized course dedicated to the dental and orthodontic industry was found. A significant portion of those analysed fall into the area of didactics.

Training courses are mainly prepared for an audience in the education industry - the picture that emerges from the analysis is that 3D printing is currently popular with two groups of customers:

1. A great popularity in schools (as an element of enriching children's education). These are the groups for which special offers are prepared - from the technical basics of operating printers and the preparation of classes for children where the theme of the lesson is to be 3D printing - perhaps this is an element of preparing future potential employees and familiarizing the youngest with new technologies.

2. Among start-ups / companies and hobbyists. One of the more comprehensive training courses, covering 21h of training, is offered by the engineering training centre - their cycles (divided into different levels and thematic modules).

An example of the scope of the training: principles of health and safety, operation of the equipment and principles of operation; preparation of the model; at subsequent levels, ensuring printing efficiency and quality, diagnosis and troubleshooting of incremental printing; maintenance of equipment; application of advanced control techniques; principles of multi-material and multi-colour printing; learning the principles of automation; digitizing. An in-depth course on SLA printing issues is also offered, e.g. <https://3lian.pl/szkolenia-druk-3D/>

The great variety (and probably quality) of training courses is also evidenced by the formula and price. Prices of online training oscillate between PLN 148 and PLN 2500, while stationary training courses range from PLN 750 to PLN 2500. There are "courses", "trainings" on "3D printing" in the form of a webinar (the shortest lasting 1.5 h for 150 PLN) or a series of webinars (from 350-1400 PLN), to which you can buy access, and for an additional fee you can get training materials and a certificate of completed training. There were even materials in the form of an online video costing PLN 2,000 for a three-hour video. On the other hand, the cost of stationary training courses, depending on the scope of the topic and the target group, ranges between PLN 750-2,500. It is difficult to observe the regularity of the price to content - as sometimes training for hobbyists cost more than the more specialized training offered (dedicated to companies, for example). Also, not all entities specify the price of the offered course, as this is adjusted individually to the needs of the potential customer. For comparison, one foreign site found a course on 3D printing in the form of several months of weekend conventions with min. 80 h course, the organizer of which was a technical university.

Scope of topics

Not all the offered training courses present the detailed scope that will be covered in the course - sometimes this is due, among other reasons, to individualize the offer to specific customers and their needs. On the other hand, the scopes are varied - from the history of printing, to topics related to design, modelling, pricing of services; types of 3D technology; basics of operation and use of equipment, to more extensive including in the scope of the course: principles of health and safety, operation of the device and principles of operation, proper operation; preparation of the model; ensuring the efficiency and quality of printing, diagnosis and troubleshooting of incremental printing; maintenance of equipment; use of advanced control techniques; proper selection of materials for different types of printing; principles of multi-material and multi-colour printing; learning the principles of automation; digitizing the construction and principle of operation of printers in selected technologies; ways to obtain models for printing; choosing the optimal printing method; preparing the 3D model for printing; selecting print parameters; preparing the printer for work; monitoring the printing process; finalizing the 3D printing process; reverse engineering based on 3D scanning technology. Slightly different courses are offered for teachers, because they are related to a specific brand of device - containing, in addition to the basics of operating the device, training in lesson scenarios for students (an example module for teachers: building a 3D printer; operating the 3D printer menu; connecting to the network and updating the 3D printer; levelling the 3D printer platform; installing and operating the Z-SUITE software; loading and unloading material into the 3D printer; working with models step by step).

Labor market

In addition to the training itself, job listings for the topic of 3D printing were reviewed - "3D printing specialist" and "3D printing job" were entered into the search phrases. Searches were made on olx.pl and pracuj.pl. There are few job offers in this area - a total of 9 were found - 3 of which were related to education (employers were looking for people without much experience, with student status, to teach 3D printing to children in schools), and they were also looking for an assistant/teacher for an orthodontic lab that prints parts on 3D printers. Three of the offers were dedicated to engineering specialists, whose duties will include preparing models, selecting materials. This seems to show the low popularity of the profession that a 3D printing technician could be/is. This rather slim analysis shows how diverse the 3D printing market is and with what 3D printing activities employees are/will be needed. There is a shortage of job advertisements for mid-range professionals with basic 3D printing skills 3.

In summary, it is also possible to notice advertisements for high-end specialists, but they are also singular). In the context of 3D printing, it is therefore difficult to define what specific competencies an employee wishing to become professionally involved in this field should have. There are several reasons for that - including the very wide expansion of the 3D printing market and the need for employees at different levels to perform different activities (from programming, modelling, machine maintenance; through printer operation to sales or training) or the stage of development of the 3D market in Poland (referred to as the growth phase).

Training market

Similarly, the analysis of training offerings for 3D printing specialists has also provided an opportunity to observe the 3D printing market in this area. Most announcements, training offers are for hobbyists AND fans of 3D printing. The training offered can be described as basic - which applies both to the subject matter covered, the audience and the time. On the market, the available training courses are commercial, and a significant part of them is dedicated to the education industry (among others, teachers). These trainings offer a very basic scope based on available modelling programs and the basics of 3D printing. The industry that seems to be the most promising in this regard is the education industry. From the analysis, the picture that emerges is that 3D printing is currently very popular in schools (as an element that adds variety to children's education) and an element that implements modern technologies at various levels of education. This aspect was taken into account when planning the services of the social enterprise.

Example of the Training Program

A Comprehensive Introduction to 3D Printing

Target group: beginners, interested in 3D printing technology, aged 16+.

General Purpose: To familiarize participants with the basics of 3D printing, 3D model design and practical 3D printing.

Specific Objectives:

- To introduce the stages of 3D printing design.
- To familiarise participants with the 3D modelling program.
- Explaining the program's tools that will be used during the next workshop activities.

- Discussing the designs that participants will be modelling.
- Discussing the necessary functions.
- Modelling and saving the design in appropriate formats.
- Independent design.
- Discussing the functions of cutting programs.
- Demonstration of how these functions work.
- Independent preparation of designs for printing.

Duration: 7 classes of 1.5 hours each (10.5 hours total)

Useful materials: Computers with internet access and 3D design software (e.g. Tinkercad) and cutting software (e.g. Cura) installed, 3D printers (FDM type models preferred), PLA Filaments, SD cards for, saving G-code files, Flipchart/Tablet for note taking.

Circular economy practices addressed in this workshop: Reuse, Recycling, Sharing, Leasing.

Class 1: Introduction to 3D Printing (1.5 hours)

1. **Welcome and introduction (10 minutes).**
 - ☐ Welcome to the participants.
 - ☐ Brief introduction of the presenter and introduction of the workshop series plan.
2. **Discuss basic concepts and technologies of 3D printing (40 minutes).**
 - ☐ What is 3D printing (additive technology)?
 - ☐ History of 3D printing (resin vs. filament printers).
 - ☐ Overview of various 3D printing technologies (FDM, SLA, SLS).
 - ☐ Applications of 3D printing in various fields (medicine, industry, art, education).
 - ☐ Presentation of different types of 3D printing filaments and materials.
3. **Discussion and questions (20 minutes).**
 - ☐ Open questions from participants.
 - ☐ Discussion of participants' expectations and experiences.
4. **Summary of the class and introduction to the next class (20 minutes).**
 - ☐ Summary of topics discussed.
 - ☐ Brief introduction to the next class, which will focus on 3D design.

Class 2: Introduction to 3D Design (1.5 hours)

1. **Introduction to 3D design programs (20 minutes).**
 - ☐ Discussion of popular 3D design programs.
 - ☐ Examples of simple 3D models.
2. **Design basics in a 3D modelling program of your choice (30 minutes).**
 - ☐ Creating simple solids (cube, sphere, cylinder).
 - ☐ Combining solids into more complex shapes.
 - ☐ Adding holes, cutting out shapes.
3. **Practical exercises (30 minutes)**
 - ☐ Independent design of simple models by participants.
 - ☐ Saving and exporting files in STL format.
4. **Summary and questions (10 minutes).**
 - ☐ Discussion of the design experience.

- ☐ Answers to questions from participants.

Class 3: Advanced 3D Design (1.5 hours)

1. **Recap of design basics (10 minutes).**
 - ☐ Brief reminder of the most important topics from previous classes.
2. **Advanced design techniques(40 minutes).**
 - ☐ Creating more complex shapes.
 - ☐ Working with grouping and combining solids.
 - ☐ Creating objects with moving parts.
3. **Practical exercises (30 minutes).**
 - ☐ Designing more advanced models by participants.
 - ☐ Exporting STL files.
4. **Summary and questions (10 minutes)**
 - ☐ Discussion of advanced design techniques.
 - ☐ Answers to participants' questions.

Class 4: Model Settings in Cutting Programs (1.5 hours)

1. **Introduction to cutting programs (20 minutes).**
 - ☐ Discussion of the basic functions of cutting programs.
 - ☐ Examples of settings for different types of filaments and models.
2. **Model preparation for printing (30 minutes).**
 - ☐ Importing STL files into cutting programs.
 - ☐ Setting printing parameters:
 - ☐ Layer height.
 - ☐ Nozzle and table temperature.
 - ☐ Printing speed.
 - ☐ Filling (infill).
 - ☐ Use of supports and raft.
3. **Practical exercises (30 minutes)**
 - ☐ Preparing models for printing by participants.
 - ☐ Generating G-code and saving files to SD card.
4. **Summary and questions (10 minutes).**
 - ☐ Discussion of printing settings and parameters.
 - ☐ Answering questions from participants.

Class 5: Preparing the 3D Printer (1.5 hours)

1. **Introduction to 3D printer operation (20 minutes).**
 - ☐ Discuss basic operation of 3D printer.
 - ☐ Calibrating the printer (levelling the table, checking the nozzle).
 - ☐ Loading the filament.
2. **Practical printer preparation (30 minutes).**
 - ☐ Preparing the printer for printing by the participants.
 - ☐ Calibrating and loading the filament.

3. **Start printing (30 minutes).**
 - ☐ Transfer of generated G-code files to SD card.
 - ☐ Starting the printer and starting printing.
4. **Summary and questions (10 minutes)**
 - ☐ Discussion of first experience with the printer.
 - ☐ Answering questions from participants.

Class 6: Monitoring the Printing Process (1.5 hours)

1. **Observation of the first layers of printing (30 minutes)**
 - ☐ Monitoring of the first layers of printing.
 - ☐ Correcting errors.
2. **Problem solving (40 minutes).**
 - ☐ Discussion of typical problems and how to solve them.
 - ☐ Practical problem solving on the spot.
3. **Practical exercises (10 minutes)**
 - ☐ Participants independently monitor the printing process and solve problems.
4. **Summary and questions (10 minutes)**
 - ☐ Discussion of problems encountered and ways to solve them.
 - ☐ Answer questions from participants.

Class 7: Summary and Presentation of Results (1.5 hours)

1. **Presentation of printed models (30 minutes).**
 - ☐ Presentation and discussion of printed models by participants.
 - ☐ Discussion of experiences and possible problems encountered during printing.
2. **Q&A (30 minutes).**
 - ☐ Open questions from participants.
 - ☐ Tips on next steps and developing 3D printing skills.
3. **Presentation of certificates of participation (20 minutes).**
 - ☐ Presentation of certificates of participation in the workshop to participants.
 - ☐ Acknowledgement for participation and encouragement to further develop skills.
4. **Summary and conclusion of the workshop (10 minutes).**
 - ☐ Brief summary of the entire workshop series.
 - ☐ Farewell to the participants.

Market analysis summary

The concept of implementation of the initially assumed project, i.e. Implementation of a social enterprise based on printing spare parts for household appliances and electronic equipment, turned out not to be fully feasible in Polish conditions and market conditions. Taking into account the legal conditions for the operation of social enterprises employing people at risk of social exclusion (minimum employment in such an enterprise should be at least 3 people, working time min. 1/2 full-time, i.e. 80 hours per month), the profitability of such an enterprise would have to be high and the current 3D printing market does not provide such guarantees.

The definition and conditions for operation are defined in Polish law by the *Act on Social Economy of August 5, 2022, CHAPTER II Social Enterprise Chapter I.*

Of course, a newly established enterprise would not have to meet the conditions set forth in the Act, but the status of Social Enterprise gives such an entity many advantages. The operating costs of a social enterprise, for which the 3D printing service is the leading one, are quite high (costs of labour, energy, materials for the implementation of services, operation of equipment).

Another barrier we have identified is the market for 3D printing services described in the market segment analysis. According to the analysis above, the market for mass-consumer 3D services in Poland is in its initial stage of development. The overall market segment according to the analysis looks promising.

"Incremental printing is one of the elements categorised as Industry 4.0, however it has been under development for many years. It is now entering a more advanced phase, and the technology is finding more and more applications. "3D printing has the potential to expand industrial processing. First of all, it can improve short-run or 'on-demand' production, but that's not all. It will also help reduce storage and transportation costs." - states Julio Vial of IDC. The medical, aerospace or fast-moving, personalised products industries have found their space for growth. The author of "BUSINESS PLAN FOR USING 3D PRINTING TO BUILD A CLOSED CYCLE OF WASTE MANAGEMENT IN PARZĘCZEW MUNICIPALITY" has identified market segments based on the analysis:

- Highly specialised segment, printing based on modern materials and raw materials, implementing unique design solutions, prototyping. Used in companies with specialised high technology, especially medical, biotechnology.
- The segment of hobby printing- performed by hobbyists, self-taught, on the simplest, inexpensive equipment.

3D printing also offers many advantages when it comes to waste generation (additive technology), far less waste is created compared to traditional product manufacturing methods, and as such, it may be within the scope of the circular economy. It is also ideal in cases of creating prototype solutions.

As the study's author concludes, 3D devices can quickly and cheaply produce replacement parts for unique or discontinued equipment, keeping old machinery and vehicles out of the scrapyard and eliminating the need for more raw materials and energy to produce new machinery and industrial components. They make it possible to print a part that hasn't been produced for decades, such as life extensions for older machinery vehicles that are no longer available from the original supplier and would be too costly for the manufacturer using traditional means. We took such an aspect into account when planning the project.

Thermoplastics used in packaging, can be an inexpensive and sustainable raw material for 3D printing, providing high-quality production from plastic waste, according to a closed loop. Using local plastic waste as a raw material is one of the potential major advantages of incremental manufacturing.

The purpose of our activity was to see to what extent 3D printing could use a raw material that would be produced from plastic waste and as such be feasible for use in offering 3D printing services by a social enterprise. Research and analysis showed (described above) that at the current stage of the quality of plastic packaging (composition, labelling) and the accuracy of plastic waste segregation, it is not possible to produce a good quality filament based on plastic waste. In order to implement the idea, it would be necessary to set up (at the company) a line for processing plastic waste into pellets and

producing filament from the appropriate waste fractions. Under current conditions, this does not seem to be possible due to technical conditions and high capital expenditure.

As part of building a circular economy system, recycled filaments will be promoted. The idea of making your own 3D printer consumable would solve a lot of waste problems that arise in every municipality. Theoretically, both leftovers from failed 3D prints or plastic waste - bottles, packaging, toys, etc. - could be used to produce it. This would be an ideal way to implement a circular economy at the local level. In practice, the process of making filament is so complicated that what would theoretically be self-produced would be of abysmal quality - and that's provided that the raw material used would be homogeneous in quality (i.e., our filament would be created from PLA scraps). This would generate another challenge - creating local waste segregation points for use in particular types of filaments. Hand-held filament extruders are a technology that requires precision and special conditions-complex technology, unfriendly working conditions (noise and fumes coming out of the machine while melting the material) and the need for a very meticulous selection of raw material. All of this makes it possible to think about independent filament production at most research and development centres, where the need is to produce and test small quantities of material, or research departments in companies involved in the production or processing of plastics.

This makes building a circular economy a possibility, but definitely on a larger scale, it's more of a regional level, where you can logistically design a path from waste collection at the municipal level, to waste segregation at the county level, to transfer selected waste to filament manufacturers who will take the risk of producing filament from recycled materials. The recycled waste goes back to local 3D printers. They become part of the offerings of various brands of plastics for printing spatial objects using the FFF/FDM technique. Examples include: Spectrum Filaments and Fiberlogy, among others.

Summary

Both analyses show that in the medium 3D printing segment in Poland, the market is not developing or is at a very early stage for the time being. Printed products are relatively expensive and less accessible to the average customer.

Taking into account the project's assumptions to offer small spare parts for consumer electronics and household appliances through the 3D printing service, we conclude that the idea is not very feasible, due to regulations related to the availability of spare parts and the requirement to service and repair equipment. They are forcing the market to create companies that offer affordable spare parts for appliances, such as north.co.uk, and we can see that it will grow.

In addition, if it was to be a social enterprise that employs and reintegrates socially vulnerable people through its services, it seems to be a very risky idea, due to the factors mentioned earlier.

Another major limitation is the use of plastic waste for the production of filament (as a raw material for printing). In the course of developing the concept of 3D printing, the idea arose to show, using the example of the Parzęczew municipality, the possibility of involving residents in a closed-loop economy in the collection of plastic waste suitable for processing into pellets that can be used for the production of filament. Leda Polymer's research has shown that the filament made from waste is a low-quality product and is hardly suitable for 3D printing, especially for example, household appliance spare parts, which need to be resistant to factors such as water, temperature, light. (Results and conclusions of the study in the appendix/at LEDA POLYMER..). Leaving aside the technical aspect, the economic effect

would not be satisfactory either, to serve the purpose of maintaining jobs for those at risk of social exclusion.

In summary, the constraints associated with the 3D printing market in Poland are as follows:

1. Weak development of the 3D printing service market, especially in the medium, consumer segment.
2. High cost of offering the service (energy, labour) of 3D printing.
3. low demand on the labour market for specialists in the area of 3D printing, and therefore also low interest in investing in professional development in this area.
5. Low offer of professional training in the area of “3D printing techniques” (rather not a niche, but shows the lack of demand for such qualifications).
6. Low quality of plastic waste filament.
7. Legal conditions for social enterprises (min. 3 jobs).

Local social enterprises

Taking into account the above-mentioned limitations and the information contained in the study by Katarzyna Książczak entitled “BUSINESSPLAN OF USING 3D PRINTING TO BUILD A CLOSED CYCLE OF WASTE ECONOMY IN PARZĘCZEW MUNICIPALITY”, we decided to develop a concept and business model that would meet the project's assumptions, take into account 3D printing and printing of small spare parts. The described business model also takes into account the above-mentioned limitations and the principles of circular economy.

Description of the business model

Location: a large city, such as Lodz. Parzęczew is a small rural municipality with a small population, and locating such a business in the municipality would make it difficult to reach potential customers and deliver value to the customer. It would generate a higher cost of delivering value and generate a carbon footprint inadequate for the social and economic value proposition. We estimate that the location of the enterprise should be in a city with a minimal population of about 100 000. In Poland, these are the cities like Gdynia, Częstochowa, Rzeszów, Radom, Toruń, Kielce, Sosnowiec, Gliwice, Olsztyn, Zabrze, Bielsko-Biała, Bytom, Zielona Góra, Rybnik, Ruda Śląska, Opole, Tychy, Gorzów Wielkopolski, Elbląg, Płock, Dąbrowa Górnicza, Wałbrzych, Włocławek, Tarnów, Chorzów, Koszalin and larger provincial cities.

The customer of such a company is a higher-earning person, aware of the need to save raw materials and ready to make the extra effort and expense to repair damaged equipment.

The main idea of the business model is that the 3D printing service should not be the printing of more items (gadgets, jewellery, or others) to make a profit, but that it should be the printing of components/items to replace missing or damaged components, without which the device, item cannot function. You can call this service “niche” and this value is unique. Hence, in order to achieve the profitability of the model, it is necessary to supplement the company's offer with other services related to the 3D printing market. The business model described below does not directly apply to plastic waste, due to the limitations mentioned earlier. Printing from plastic waste would be difficult to implement both economically and practically.

Business Model Canvas				
Project's name: 3d-printing and design- small add parts, gaming gadgets, repair and maintenance services, filament sales, residual waste collection				
Legal conditions: Act on the obligations of entrepreneurs in the field of management of certain wastes and on the product fee of 11 May 2001; U S T A W A of December 14, 2012 on waste			Trends: European Green Deal 2019, Industrial Strategy 2020, change in the system of raw materials and waste management, increase in the price of raw materials, search for new solutions in the circular economy, development of research	
8. Key Partners - repair cafes, - organizations with an educational and environmental character, - environmental activist communities, - schools, - eco-filament manufacturers (cooperation)	7. Key Actions - preparation of premises facilities, - purchase of 3d printer - offering 3d printing - diversifying with other services - training and workshops - building a logistic chain - waste - collection - producer of eco-filament - printing based on eco-filament - creation of 3 jobs	2. Unique Value Proposition Using equipment, not spending money on new equipment-allocating it to other needs; Environmental protection; Service: design and 3D printing of replacement parts for household appliances, other parts, such as game figures Service: 3D printing training (live and online) Service: minor repair; service of 3D printers sale of eco-filament collection of residual waste Values: design, accessibility, low price, low cost, efficiency, availability	4. Customers service The way of customer service in both cases is individual, personalized - due to the specific part- scan, matching equipment- (locally) - customers from all over Poland- hobbyists, who want to improve their skills- customized training - B2C due to the specifics of prints- individualized	1. Key customers groups Individual (B2C) residents, (B2C) Individual: role players, hobbyists, modelers, "handymen"; (B2C) Individual: 3d printing hobbyists (training: printer operation, printing, modeling, equipment maintenance) (B2B) Institutional: repair shops, services (mechanics, servicemen add. ity), repair cafes; (B2B) Institutional: organizations, educational institutions; (B2B) Institutional: schools
	6. Key sources 3 job positions - Managing person - Printing and office room - Equipment of printing places - Car 4 laptops - Software + licenses 2 printers - Raw material for printing and sales		3. Key channels... Individual clients: social media-groups, repair cafes, educational-environmental organizations, schools, Institutional clients: direct contact, website, social media, flyers	
9. Key costs/ structure of costs Fixed costs: salaries of 3 people + 1 manager, rental of premises utility costs, printer lease, software license, accounting, office and printing room rental The most expensive among fixed costs is the cost of salaries and rent (depending on location and space) Variable costs: energy, fuel, eco-filament, spare parts The most costly activity is 3D printing (time-consuming and energy-intensive)			5. Key revenues Printing: total small revenue up to 20% of total revenue eco-filament sales- 20% training: 3D printing, (permanent and on line)- 30% repair service, maintenance, waste collection, workshops, sold in packages- 30%	
10. Positive impact: - repairing - replenishing individual components-not acquiring whole, new equipment - reprocessing- recycling - raising customer awareness - development of 3D printing industry as more efficient and rapid prototyping services - increasing the scale of collection and recycling services			11.Negative impact: - relatively high energy consumption (use of renewable sources) - high cost of processing plastic waste (high oil price will force activity in this area, - carbon footprint associated with movement (collection and delivery to recycler) - carbon footprint associated with reaching customers (some services e.g. on line training)	

Legal conditions: The Act on the Obligations of Entrepreneurs with respect to the Management of Certain Waste and on the Product Fee of 11 May 2001. U S T A W A of 14 December 2012 on waste;

Trends: European Green Deal 2019, Industrial Strategy 2020, change in the raw material and waste management system, increase in raw material prices, search for new solutions in the circular economy, development of research in the area of circular economy.

Key customers:

Individuals (B2C)

- Individual: residents, aware of the need to repair damaged equipment, from larger cities, higher earners, willing to make the effort to repair equipment,
- role-players, hobbyists, modellers, 'self-repairers': printing small parts, damaged parts, figures, etc,
- 3D printing hobbyists (training: printer operation, printing, modelling, equipment maintenance).

Institutional (B2B)

- repair shops, service centres (mechanics, home appliances, consumer electronics repairmen), repair cafes: printing of small parts needed to run the repaired appliance,
- organisations, educational institutions: filling in missing parts of models, appliances, games,
- schools: training (operation and maintenance of printers, modelling, 3D design, GOZ), sale of eco-filament, repair and maintenance of 3D printers.

Key services and values:

- 3D printing (printing finished parts from a model, printing with 3D design and modelling, scanning and printing),

- ☐ servicing and repair of 3D printers (service offered mainly for hobbyists and in training packages for schools),
- ☐ 3D design and modelling (separate service, or combined in a package with printing),
- ☐ training and workshops about 3D printing,
- ☐ sale of eco-filament on a reselling basis (for schools in a package with training and maintenance and repair, and optional residual waste collection),
- ☐ collection of residual waste from customers,
- ☐ ecology, circular economy, recovery of equipment and objects, equipment repair, education, knowledge,
- ☐ a platform for exchanging items and advice.

*The value for institutional customers will be offered in packages, and will be a comprehensive service (from the provision of raw material - for schools, printing service including modelling, to training in the use and service and repair of printers).

Key investments

- ☐ printer unit 1: min. requirements: e.g. 3D printer BCN3D Epsilon W27 (approx. PLN 32,000),
- ☐ electric car - leasing: requirements - transport of equipment and accessories,
- ☐ 3D scanner - e.g. 3D scanner Shining3D EinScan-SP V2 (approx. PLN 13,000),
- ☐ 4 laptops min. (including one office laptop) with a good graphic card and processor,
- ☐ software licence: you will need slightly more advanced software for more complex geometries like solid Edge, Inventor professional, Fusion etc,
- ☐ eco-filament for printing,
- ☐ eco-filament for sale.

Total investment: 80-100 000 PLN

Key costs

- ☐ salaries: 3 full-time employees,
- ☐ rent of premises: office and technical premises for printing, raw material stock and repair,
- ☐ fuel: mainly for travelling to the site of the training, repair and/or maintenance service. In the city it is possible to travel by public transport and/or cargo bicycle, but transporting items requires a car.
- ☐ energy: operation of equipment - printers, tools and office equipment,
- ☐ eco-filament: thanks to cooperation with a filament manufacturer, a reselling service, the purchase of this raw material can be at a more attractive price than the general market rates,
- ☐ operation and maintenance of printers and car,
- ☐ administrative costs (management and accounting, office costs),
- ☐ training costs (cost of materials, travel, working time),
- ☐ other.

Fixed costs: salaries of 3 people + 1 manager, rent of premises + utility costs, lease of printer, software licence, accounting, office and printing room rental. The most expensive among the fixed costs is the cost of salaries and rent (depending on location and space). We estimate the monthly fixed cost to be approximately 30,000 PLN.

Variable costs: energy, fuel, eco-filament, spare parts. The most costly activity is 3D printing (time- and energy-consuming).

Example of the cost of printing small part:

Cost analysis of printing a screw nut measuring 8.4x7.3x3.9 cm made from an optimised 3D model in prusa slicer software from R-PLA material (https://sklep.rosa3D.pl/product/r-pla-black-175mm-1kg/?gad_source=1) :

Printing time: 4h 12min

Amount of material used: 70,29g

Cost of material: PLN 4.56

Current consumption: P (power) t (operating time) E=336 Wh

Analysis of the cost of printing a screw measuring 4.6x4.0x6.9 cm based on an optimised 3D model in prusa slicer with R-PLA material.

(https://sklep.rosa3D.pl/product/r-pla-black-175mm-1kg/?gad_source=1) :

Printing time: 1h 54min

Amount of material used: 32.10g 1kg 65 PLN

Cost of material: 2,08zł

Power consumption: P (power) t (operating time) E=152Wh

Analysis of the cost of printing a chess pawn with dimensions 4.8x4.7x4.6 cm made on the basis of an optimised 3D model in the prusa slicer programme from the R-PLA material (https://sklep.rosa3D.pl/product/r-pla-black-175mm-1kg/?gad_source=1) :

Printing time: 1h 43min

Amount of material used: 15.56g 1kg for 65 PLN

Cost of material: PLN 1.00

Power consumption: P (power) t (operating time) E=137Wh

In addition, the unit cost of printing would have to be increased by min. 50% of the variable and fixed costs associated with running the business.

Key revenues

- ☐ printing of items: service,
- ☐ training and workshops: service,
- ☐ training (for schools), sale of eco-felt, maintenance and repair of printers,
- ☐ repair and maintenance of printers: service,
- ☐ sale of eco-filament + maintenance and repair of equipment,
- ☐ printing and design service,
- ☐ design service.

Printing of individual items; small total revenue up to 20% of total revenue.

Sale of eco-filament - 20%.

Training: 3D printing, (permanent and on line)- 30%.

Repair, maintenance, waste collection, workshops, sold as packages- 30%.

All services can be sold in packages, especially for institutional clients such as schools. An example of a comprehensive service package for an institutional customer includes:

- ☐ advice and training on how to use the 3D printer,
- ☐ design and modelling of objects to be printed based on computer programmes,
- ☐ sale of eco-filament,
- ☐ repair and maintenance of the printer,
- ☐ residual waste collection.

It is possible to estimate the cost of a fixed subscription of the described service for an institutional client, which would guarantee a constant, predictable income for the company.

Targeting channels

The channels for reaching customers depend on the characteristics of the customers. Due to the rather extensive and diverse customer portfolio, one of the people employed should have sales and marketing competence.

Individual customers: outreach through hobby groups in the area of 3D printing, modelling, gaming groups - social media, advertisements in repair cafes, in educational and environmental organisations, in schools.

Institutional customers (mechanics, service technicians of various household appliances, electrical appliances, schools - a slightly differently structured service): require individual outreach, showing the benefits of printing a single part and convincing them to purchase the service.

Key partners

Partners in a business model can create additional business value. In the business model described, they can contribute to better sales results and to the recycling of raw material (residual waste, which can be collected from customers and delivered to the eco-filament manufacturer as part of the service). Key partners include: repair cafes, educational and environmental organisations, environmental activist communities, schools, eco-filament producers, e.g. <https://fiberlogy.com/pl/zostan-resellerem-fiberlogy/> (co-op) and recyclers.

Key resources

To launch the activity and sustain the social enterprise the following resources are needed:

- ☐ 3 job placements (persons from the area at risk of exclusion). The competence of these persons should be at a high enough level in terms of technical competence (2 persons). An additional value could be a previous hobby in 3D printing.

Positions:

1. **Sales and marketing specialist** and customer service (tasks: organising and conducting sales of services and products, creating a customer base, establishing and maintaining business contacts, developing promotion and sales plans, managing social media and website)
2. **3D printing technician + service implementation + repair** and maintenance (implementation of the printing and pre-press service, repair and maintenance of printers at the customer's site). Competencies: technical, ability to design, model designs for printing, ability to operate 3D printer, repair and maintenance of equipment.

3. **Print technician/educator-** implementation of service + educational activities (implementation of training services and educational activities for designated client groups). Technical competence, 3D printer skills, communication and teaching competences.

Necessary competences and skills are: knowledge of production and production processes, engineering and technology, operation and control of equipment, knowledge of mathematics, ability to use a computer and major software packages, necessary skills are accuracy, attention to detail and analytical skills. The above-mentioned competences and skills should be possessed by these individuals at least at an intermediate level in order to effectively and efficiently deliver the specified services. At least one of these persons should also have soft competences, such as the ability to transfer knowledge, social competences at a high level.

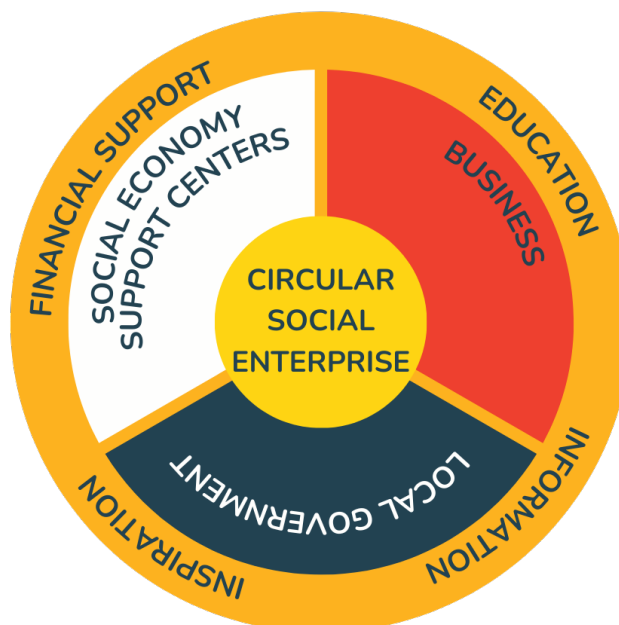
It seems that the group of people to be employed in the company could be young people, at least with a technical education, with difficulties to enter the labour market, e.g. with disabilities.

- ☐ Manager: deals with liaising with clients, organising work, securing deliveries and a smooth service delivery schedule.
- ☐ Room for making and preparing prints and office space.
- ☐ Necessary equipment for printing workplaces, e.g. tables, table overlays, work chairs, containers for printing waste, others.
- ☐ Electrically powered car, or in a larger city - other means of transport that facilitates movement around the city, e.g. cargo bike (delivering shipments of filament to customers, getting to training and workshops, or on-site printer repair and maintenance).
- ☐ 4 laptops with the necessary software and programme licences, e.g. solid Edge, inventor professional, Fusion.
- ☐ Raw material for printing - eco filament.
- ☐ Eco filament for sale.

Variants

1. A stand with a 3D printer in a repair cafe, operated by 1 person, an instructor (can implement the submission of a business model, i.e. printing missing spare parts, missing parts of sets, kits). An additional aspect in this case is the possibility to obtain local grants for the operation of this type of 'cafe' and to develop services, e.g. with a platform for the exchange of services and things.
2. Trained instructors in schools where 3D printers are in operation and not being fully utilised.
3. Establish, in a social enterprise format, an additional value chain in cooperation with an industrial company producing products that result in a large amount of plastic waste meeting the criteria and setting up a raw material recovery and filament production line. The proposed option would use the ideal model of a social enterprise in a circular economy proposed in Report 7.1. This model involves combining business potential with social potential and value. It would be worthwhile in this option to ensure collaboration with a laboratory or scientific research unit that will develop and provide analyses of the extracted waste and assess the feasibility of reuse.

SOCIAL ENTERPRISE IN CIRCULAR ECONOMY



This model was developed for Report 7.1 on the basis of the collected examples and opportunities for cross-sectoral cooperation. In the case of the social enterprise model described in the present document, it would be worth adding scientific and research units, which could play an important role in this case.

Summary of the described social enterprise model based on 3D printing

Positive impact:

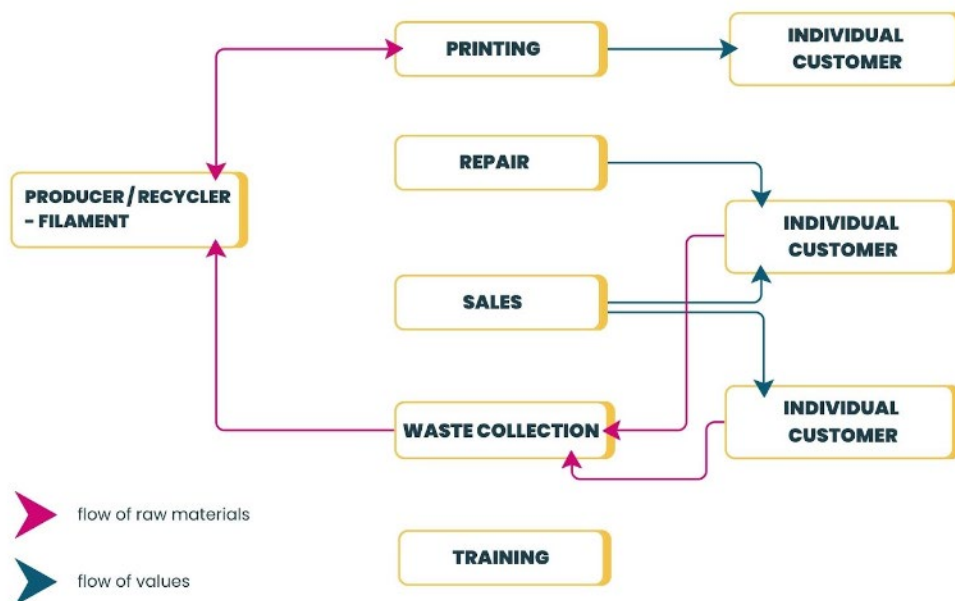
- ☐ repairing- printing of spare parts, facilitation of repairing 3D printers,
- ☐ supplementing of individual components - not purchasing whole, new devices,
- ☐ reprocessing- recycling of residual waste from test prints or pre-print residues,
- ☐ raising customer awareness of the need to repair and use less raw materials,
- ☐ developing the 3D printing industry as a more efficient and rapid prototyping service,
- ☐ social impact (inclusion of highly competent people with poorer labour market opportunities),
- ☐ increasing the scale of collection and recycling services.

Negative impact

- ☐ relatively high energy consumption (use of renewable sources),
- ☐ high costs of plastic waste processing (high oil price will force activity and search for alternative raw materials in this area),
- ☐ carbon footprint of transport (collection and delivery to the recycler - possibility to replace the car with a cargo bike),
- ☐ carbon footprint of reaching customers (possibility to provide some services online, e.g. training).

Diagram shows the flow of value and materials

Values and materials flow map



Conclusions

Recycling filament production from post-production waste offers significant potential for sustainability but faces several technical hurdles. Recycling waste materials into filaments for 3D printing presented a viable option, although the performance and properties of these filaments depended on the specific type of recycled material used. Filaments made from recycled waste exhibited varying properties based on the type of waste material. Common issues included adhesion problems with the print bed and between layers during printing. To improve filament quality, incorporating pure polymer additives such as EVA into LDPE waste enhanced performance. A suggested concentration was 10% EVA, which helped improve adhesion and overall printing results. Additional research was needed to evaluate filaments made from other types of waste materials. Optimizing the composition by experimenting with different pure polymers and additives could yield better results. Preliminary tests on blue flakes showed promising potential, indicating that careful selection of additives and adjustments to printing parameters could enhance filament performance.

Recycling post-production waste into 3D printing filament supports circular economy principles by reducing plastic waste and minimizing the need for virgin raw materials. This approach can significantly decrease environmental impact, aligning with global sustainability goals and enhancing the environmental credentials of businesses involved. Current technology for recycling plastic waste into filament is sophisticated and often requires specialized equipment, which can be costly and challenging for small-scale operations. Establishing a closed-loop system for filament production involves significant investment in equipment and infrastructure. This includes machinery for waste processing and filament extrusion, which must be operated under controlled conditions to ensure high-quality output. Maintenance and operational costs add to the complexity and feasibility concerns for smaller enterprises. Yet integrating recycled filament production can foster job creation and skill development in the recycling and 3D printing sectors. It offers opportunities for local enterprises to engage in sustainable practices, potentially creating new market niches and contributing to local economic growth.

Analysis of the 3D printing training market in Poland in terms of the possibility of creating a training program for people at risk of social exclusion

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Substantive cooperation:
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Łukasz Waszak

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Introduction

According to the diagnoses contained in the analysed reports [including: Głab 2020; Jabłonko, Zug 2023; Budzik, Woźniak, Przeszłowski 2022], Poland is on the threshold of the 4.0 revolution, which means that many areas of the economy are transforming towards digitalization, automation and robotization. These changes bring many opportunities, and challenges, including how to prepare society, particularly people, for the changes that will take place in the labour market. According to labour market analysts, there are currently no industries operating outside the digital world - according to them, new jobs will be related to new technologies, artificial intelligence and robot operation. Employment is expected to increase in industries related to information, knowledge and data processing as well as new technologies, in the financial sector, medicine and natural sciences, biotechnology and environmental protection. However, what is disturbing, in the next decade, the percentage of positions at risk of job loss among people with the lowest education will be approximately 30-44% [Jabłonko, Zug 2023, p. 102].

In this context, the modern labour market will require employees to acquire additional competencies, including digital ones as well as systematically improving their qualifications and developing skills: cognitive, social, adaptive, communication, stress resistance, rational decision-making skills, as well as having digital skills [Jabłonko, Zug, p. 103]. The latter includes competencies: **IT** (the ability to use a computer and electronic devices; use the Internet, software, applications; operate devices), **information** (defined as the ability to search for, verify, understand and interpret information) i **functional** (related to: work and professional development, pursuing interests; health, finances, everyday matters, relationships with loved ones and civic involvement) [Ibidem]. Due to changes in the labour market and an attempt to specify new areas of skills that an employee will need, competences are mentioned. **“transversal”**, referred to as the so-called “soft” - in the new technological environment, it is expected that employees will need to develop interaction competences interpersonal skills, non-routine social and emotional skills, creativity and abilities that are difficult to automate [Głomb, p. 22].

In the context of 3D printing, it is difficult to determine what specific competences an employee who wants to become professionally involved in this area should have. The problem in specification has several causes - including: very wide expansion of the 3D printing market and the need for employees at various levels of advancement and to perform various activities (from programming, modelling, machine maintenance; through printer operation to sales or training) or the stage of development of the 3D market in Poland (referred to as the growth phase) .

According to the forecast trends [Budzik, Woźniak, Przesztowski 2022], the 3D printing industry is in the growth phase, which is signalled, among others, by: that in the near future there will be a need for employees for the above-mentioned area. The analysed reports on additive technologies show that the sales of 3D printers in the world have been increasing in recent years (the cited Wohlers Report showed the increasing sales of 3D printers in the world - the years 2009 (1,816 pcs.) - 2017 (528,952 pcs.) were analysed). The Polish market is also experiencing growth - domestic startups producing 3D printers such as Zortrax, ZMorph, Omni3D, HBot 3D, Ubot 3D, 3 Novatica - these are brands that are becoming more and more popular both in Poland and internationally. A similar situation is observed among filament producers (Fiberlogy, PRI-MAT3D, AEMCA) [Budzik, Woźniak, Przesztowski, p. 32]. An increase in awareness and interest in the use of additive technologies measured by the number of implementations is observed in the SME sector (an increase in the number of implementations from 14.5% in 2018 to 18.3% in 2020). Industries where 3D printing plays an important role are: electrical machinery, aviation, space, automotive, military, foundry, industrial design, construction, and medical. Other areas where 3D printing is also used on an increasing scale include: teaching (inclusion in educational processes), maritime, food and fashion industries [Ibid., pp. 35-45]. Therefore, in the context of analysing the 3D printing training market, reference was also made to the above-mentioned areas.

In Great Britain, there is a separate profession, which is a 3D printing technician - to train in it, you need to take university courses or internships, and certifications are also provided. The skills that a person in such a position should have include knowledge of production and production processes, engineering and technology, operation and control of devices, knowledge of mathematics, ability to use a computer and major software packages, and also be accurate and pay attention to details, have analytical skills¹. In the Polish context, no separate profession with specific qualifications and skills for its performance has been found, which may indicate (for now) the relatively low popularity of this profession.

¹ <https://nationalcareers.service.gov.uk/job-profiles/3d-printing-technician> [accessed March 2024].

Print training market analysis

This report presents the findings from desk research analysis on 3D printing training.

The main research questions that were asked are:

- To what extent can 3D printing be an opportunity for people at risk of social exclusion?

To answer this question, specific questions were asked:

- what does the 3D printing training market look like / who is on the 3D printing training market?
- Is 3D printing a chance on the labour market?
 - In this light, what educational barriers and opportunities can be identified (who may find it easy/difficult) as a potential employee in this sector?
 - What competencies are key to performing this type of profession?

During the review of (mainly) online sources, including available reports and analyses, the information mainly mentioned above was sought. The initial focus of the search was on analysing the types of 3D printing training available. The training offered can be described as basic - which applies both to the topics covered, the target group and the time. The training available on the market is commercial, and a significant part is dedicated to the educational industry (including teachers).

Analysis has been done *desk research*, mostly in type *net research* in search of professional training related to 3D printing. The searched phrases were "3D printing training", "3D printing professional training"; "WUP/PUP 3D printing training". A total of 23 websites (various places) that offer 3D printing training in February-March 2024 were analysed. A brief description of the offer is presented below.

Companies offering training

The map below shows the distribution of places where companies offering training are located. Companies and organizations offering the above-mentioned training courses are located (starting from the voivodeship with the largest number of bidders) in: Masovian Voivodeship (6), Silesian Voivodeship (5), Greater Poland Voivodeship (2), Łódź Voivodeship (2), Podkarpackie Voivodeship (2), Lesser Poland Voivodeship (2), Lower Silesian Voivodeship (2), Lublin Voivodeship (1), West Pomeranian Voivodeship (1).



Characteristics of entities offering training

There is significant diversity among entities offering 3D printing training. After analysis, they were divided into companies specializing in additive printing (8), training companies (8) and research institutes and centres providing specialized (technical) training (3); the other category included: a scientific foundation, an educational publishing house, a private teacher training institution and an online technical magazine. In companies dealing with 3D printing, training is an additional branch of the basic activity. They are offered to various recipients - often individually tailored to the needs of entities - the range of proposed topics suggests that these are often "introductory" training - dedicated to entities that just want to introduce such technology into their area of activity, or are beginners in it; another type are courses offered for hobbyists. Similarly, training companies that undertake the above-

mentioned activities are characterized by diversity. topics - among those offering 3D printing training, we can find training companies that offer courses on various topics, and 3D printing training seems to be an additional attractive topic to present. Those analysed also included professional training centres (e.g. technical) offering several-day cycles, divided into knowledge levels and thematic scope (e.g. separately for those who want to specialize in additive printing from plastic, metal, resin) addressed to specialists. The analysed entities did not include, for example, training dedicated to specialized industries as previously described as those in which 3D printing is often used² - only one specialized course dedicated to the dental and orthodontic industry was found. A significant portion of the analysed training courses cater to the education sector.

The training is mainly prepared for recipients from the education industry; the analysis shows that 3D printing is currently very popular in schools (as an element diversifying children's education). These are groups for which special offers are prepared - technical basics of using printers and preparing classes for children where the topic of the lesson is 3D printing - perhaps this is an element of preparing future, potential employees and familiarizing the youngest with new technologies. The next groups are entities and companies (starting/at the beginning) of development and hobbyists. One of the more comprehensive training courses, covering 21 hours of training, is offered by an engineering training centre - their cycles (divided into various levels of advancement and thematic modules) cover issues such as: occupational health and safety rules, device operation and operating principles; model preparation; at subsequent levels, ensuring printing efficiency and quality, diagnosing and solving problems related to additive printing; equipment maintenance; use of advanced control techniques; principles of multi-material and multi-colour printing; learning the principles of automation; digitization. An in-depth course on issues related to SLA printing is also offered.

The format and price also prove the great diversity (and probably the quality) of the training. Online training prices range from PLN 148 to PLN 2,500, while stationary training prices range from PLN 750 to PLN 2,500. "Courses" and "training" in "3D printing" are offered in the form of a webinar (the shortest lasting 1.5 hours for PLN 150) or a series of webinars (from PLN 350-1,400), to which you can purchase access and, for an additional fee, obtain training materials and certificate of completed training. There were even materials in the form of an online film costing PLN 2,000 for a three-hour film. However, the cost of stationary training, depending on the thematic scope and target group, ranges from PLN 750 to PLN 2,500. It is difficult to observe any regularity in determining the price and content - because sometimes training for hobbyists costs more than the more specialized training

² Electrical machinery, aviation, space, automotive, military, foundry, industrial design, construction, medical, maritime, food and fashion industries.

offered (e.g. dedicated to companies). Also, not all entities determine the price of the course offered, because it is individually adjusted to the needs of the potential client. For comparison, on one of the foreign websites there was a 3D printing course in the form of several-month weekend meetings with, among others, 80 hours of courses, organized by a technical university.

Thematic scope of training

Not all training providers include detailed issues that will be the subject of the course - this may be due to, among others, individualizing the offer to a specific client and his needs. However, the scopes are diverse - from the history of printing, to topics related to design, modelling, and valuation of services; types of 3D technology; basics of operation and maintenance of devices, to more extensive ones including: occupational health and safety rules, device operation and principles of operation, proper operation; model preparation; ensuring printing efficiency and quality, diagnosing and solving problems related to additive printing; equipment maintenance; use of advanced control techniques; appropriate selection of materials for various types of printing; principles of multi-material and multi-colour printing; learning the principles of automation; digitization, construction and principle of operation of printers in selected technologies; ways to obtain models for printing; selection of the optimal printing method; preparing a 3D model for printing; selection of print parameters; preparing the printer for work; monitoring the printing process; finalization of the 3D printing process; reverse engineering based on 3D scanning technology. Slightly different courses are offered for teachers, related to a specific brand of device - containing, in addition to the basics of using the device, also training in lesson scenarios for students (example module for teachers: building a 3D printer; operating the 3D printer menu; connecting to the network and updating the 3D printer ; levelling the 3D printer platform; installation and operation of the Z-SUITE software; loading and unloading material to the 3D printer; working with models step by step).

Summary

In addition to the training itself, job offers related to 3D printing were reviewed - the search phrases included "3D printing specialist" and "3D printing job". Searched on olx.pl and Pracuj.pl. There are few job offers in this area - a total of 9 were found - 3 of them were related to education (people were sought without much experience, with student status to conduct 3D printing classes for children in schools), an assistant was also sought for an orthodontic laboratory, which prints elements on 3D printers. Three of the offers were dedicated to specialist engineers whose duties will include, among others: preparing models, selecting materials. This seems to show that the profession of a 3D printing technician is not very popular. This rather limited analysis shows how diversified the 3D printing market is and what activities related to 3D printing require/will require employees - from people with very basic knowledge to specialized engineers for production companies. And each of these areas would require a separate analysis.

The analysed training included only commercial, paid training offered to various groups - entrepreneurs, the educational industry, hobbyists. No training was found or any mention in the reports about the potential that 3D printing may have for people at risk of exclusion (e.g. thanks to the quick possibility of training). As mentioned, the training offered had a rather modest thematic scope and a limited number of hours during which the potential recipient would complete the course. The topics covered the history of printing, technical aspects of printing, or, in the case of teachers, the use of this technology to diversify classes with children or teenagers. For comparison, analogous training courses abroad were also searched for (3d Printing courses were entered in the cursesea.com search engine) - courses offered by universities were found, more extensive in terms of the scope of course hours - e.g. lasting, for example, 80 hours of training (2 months).

The aim of the analysis was to answer the questions:

- To what extent can 3D printing be an opportunity for people at risk of social exclusion?

To answer this question, specific questions were asked:

- what does the 3D printing training market look like / who is on the 3D printing training market?
- Is 3D printing a chance on the labour market?
 - In this light, what educational barriers and opportunities can be identified (who may find it easy/difficult) as a potential employee in this sector?
 - What competencies are key to performing this type of profession?

With various definitions of social exclusion and specific groups of people at risk of social exclusion or socially excluded, the following are distinguished: unemployed people registered at the District Labor Office, people with disabilities, mental disorders, people leaving prisons, becoming independent, leaving foster care or supported by the Social Welfare Centre. However, in addition, these people often have only vocational education, their salary is at the minimum wage level, they may be digitally excluded, they have basic knowledge of reading and writing in their native language and lower language skills, as well as limited family cultural capital.

Each story and each case is different, people have different life histories, different competences and skills, different desires. Ryszard Szarfenberg, analysing the concept of social exclusion, following Hilary Silver, presented a list of groups of people who may be at risk of exclusion: the long-term unemployed and the unemployed with short periods of employment; employed in uncertain conditions and in jobs that do not require qualifications (older workers, not protected by the labour code); low-paid workers and the poor; landless peasants; people without qualifications, illiterates, school dropouts; mentally and physically handicapped and disabled; addicted to psychoactive substances; criminals, prisoners, people with a criminal past; single parents; abused children growing up in problematic families; young people, especially without professional experience or school diplomas; working children; women; foreigners, refugees and immigrants; racial, religious, linguistic and ethnic minorities; deprived of civil rights; social assistance recipients; in need, but not entitled to social assistance [Szarfenberg 2008, p.3].

The question posed to what extent 3D printing is an opportunity for socially excluded people is a difficult question to answer unequivocally. Primarily because, first of all, when we talk about people who are excluded or are at risk of exclusion, we are dealing with an extremely heterogeneous group of people - women, men, of different ages, with different levels of education and willingness/motivation to learn; with various ailments (e.g. disabilities, mental disorders), in various social and cultural situations, in short, with a group of people who find/have the potential to find their way on the labour market in various ways. On the other hand, the 3D printing market is also very broad - from highly specialized technologies (and therefore the needs of highly qualified employees); to the production of more basic items (e.g. gadgets). There is also a need for employees in various positions in companies dealing with 3D technologies - from modelling and design; to the operation of machines (of various levels of advancement) and maintenance; to activities related to marketing, promotion, sales and training.

Taking these ambiguities into account, the first conclusion is that training in acquiring digital skills or new technologies, in the currently changing reality, would undoubtedly be of great value to people

struggling with various problems, including those related to finding their way on the labor market. Especially if the forecasts contained in the report already mentioned are correct, that in the near future people without digital and technological competences and with the lowest education may be potentially at risk of unemployment. [Jabłonko, Zug 2023, p. 102]. Trainings are offered at various price ranges and concern slightly different elements related to 3D printing - therefore, participation in them could enable familiarization and acquisition of various skills that would enable a person to work in this sector. Another issue is that, as the analysis shows, there are relatively few job offers in the area of 3D printing, so from this perspective, training people for a sector that is only developing in Poland may not be adequate to market needs at this point and will not bring immediate results.

In this light the diagnosis of the potential in running a Social Enterprise in the area of 3D printing shows that currently, given the Polish realities (market, price (including filament) and technological advancement), a social enterprise in this sector has no reason to exist.

Lp.	Entity name	Type	Training offered	Link
1	3D3D	An additive printing company	The company offers training in 3D printing from scratch, i.e. how to design; how to price 3D printing services; and training dedicated to printing in various technologies (metal, plastic, resins). The training is mainly dedicated to companies that would like to deal with this technology. Various "levels" are offered for students. They have an online formula and the price of training ranges from PLN 1,550 - PLN 1,700 gross depending on the subject of the course.	https://centrumdruku3d.pl/szkolenia-druku-3d/
2	3D printing training	Training company; no more information about the activity	A training company that offers paid access to videos - courses on 3D printing - 14 hours of webinar. This is an introduction to the topic - the course is dedicated to people interested in the above-mentioned technology. Three payment levels are proposed - when purchasing a larger package, the participant receives additional materials. The price ranges from PLN 399 for the basic course to PLN 1,399 for the so-called expert - the basic service is 14 hours of webinars, while when purchasing subsequent packages, the participant receives, among others: training materials, has the opportunity to take part in a quiz and receive a "suitcase with materials").	https://szkoleniadruk3d.pl/#program
3	3D Printing Laboratory	A company with machinery that deals with 3D printing	The course is aimed at "students, hobbyists" and is intended to prepare you to work independently with a 3D printer. It has a stationary formula and the cost is PLN 1,000.	https://laboratoriumdruku3d.pl/szkolenia/
4	Engineering Training Centre	Technical training centre specializing in the organization of courses and 5 training courses in the field of mechatronics and broadly understood engineering techniques	The company offers stationary 3D printing training at various levels of advancement. The issues covered include occupational health and safety rules, device operation and operating principles; model preparation; at subsequent levels, ensuring printing efficiency and quality and diagnosing and solving problems related to additive printing; equipment maintenance; use of advanced control techniques; principles of multi-material and multi-colour printing; learning the principles of automation; digitization. An in-depth course on issues related to SLA printing is also offered. This is one of the more advanced courses found in market analysis - dedicated to specialists. The course costs are PLN 2,500 gross for 3 days of training (21 hours).	https://emt-systems.pl/druk-3d-kurs.html
5	Certo Technical training	A company specializing in technical training	The course is dedicated to people starting to work with 3D printing and covers the acquisition of knowledge on the proper operation and service of 3D printers, the appropriate selection of materials for various types of printing, learning the basics of 3D modelling. The training includes 3 days of on-site training (24 hours) for the amount of PLN 995.	https://certo.pl/szkolenia/inzynieria-materialowa/druk-3d/kurs-modelowania-i-drukowania-3d/
6	CADXPRT	A company specializing in the dissemination of 3D printing	The company offers training and webinars for those interested in additive technology. They prepare an individual offer depending on the entity's needs.	https://cadxpert.pl/kontakt/
7	Print 3D.edu	A company providing training in 3D printing in education (school)	The company offers webinars (online courses) on various topics related to 3D printing - this offer is addressed mainly to the educational industry (schools, teachers). The price of 1 module is PLN 750. Topics: 3D printing training in education; Flashforge Adventurer 3 Printer Installation; Introduction to 3D printing; Basics of 3D printing; Flashforge Adventurer 3 printer support; FlashPrint software; Troubleshooting 3D printing problems; Basics of 3D	https://druk3d.edu.pl/

			modelling; Lesson plans for creating 3D models; Flashforge Adventurer 4 Printer Installation; FlashCloud 3D Library.	
8	Łukasiewicz Network – Industrial Institute of Automation and Measurements PIAP	Research institute	Personalized training is focused primarily on the effective use of the potential of 3D printing in industrial applications and production. Therefore, the main goal of the training is to focus on the client's real problems or case studies that he would like to use, implement or simply verify. 2 modules - introductory and advanced. The training offered is prepared in accordance with individual needs.	https://piap.lukasiewicz.gov.pl/kontakt/
9	Programming Giants	Educational facility (children/youth), founded by programmers	The company offers stationary training in 3D printing - 7 hours of training for PLN 350. The topic concerns the basics of 3D printing and is mainly dedicated to the area of education (e.g. teachers) or hobbyists.	https://www.giganciprogramowania.edu.pl/kursy/42-warsztaty-z-druku-3d-kurs-podstawowy
10	EduKids	A company dealing with the education of teachers, children and youth (innovative technologies)	The company offers training for teachers who will conduct 3D printing classes. The aim is to acquire skills in installing and operating innovative educational materials, such as 3D printers or VR goggles. The cost of the training is PLN 1,500 gross per course divided into 5 parts.	https://edukids.pl/37-szkolenia
11	Courses zone	A company providing training for hobbyists	Online course for PLN 99 for people who want to buy a 3D printer (probably a form of advertising, because participation in the course entitles you to discounts). The course is an introduction to the principles of operation and servicing of printers; learning about additive technologies; selection of materials.	https://strefakursow.pl/kursy/projektowanie/kurs_modelowania_i_drukowania_3d.html
12	Epax	A company implementing projects in education	Stationary training in the use of 3D printers; PLN 1,890; The 3D printer training is aimed at private individuals and educational institutions interested in starting a business in the field of 3D printing, who do not yet have a 3D printer or have just become one. The training aims to show what a 3D printer can be used for in the field of broadly understood education, as well as to help in the implementation and preparation of teaching staff for the "Laboratories of the Future" program; How to start and configure a 3D printer, How to store, apply and change filaments, ; Where to download free models for 3D printing and how to know if they are suitable for printing at all?; How to effectively search for 3D models that will be used during subject classes; How to adapt models to your 3D printer; Sample lesson plans; How to navigate 3D printing software; Printer calibration, joint printing with teaching staff to consolidate the acquired knowledge.	https://epax.pl/stacjonarne-szkolenie-z-obslugi-drukarki-3d-p-85.html
13	B3D	A company specializing in additive technologies	Courses offered in stationary and online form for entrepreneurs dealing with / wanting to engage in 3D printing. Price and scope of topics adjusted individually with interested parties.	https://b3d.com.pl/szkolenia-i-konsulting-3d/
14	2B3D	The company is an online store specializing in additive technologies	Stationary or online training (to choose from) for teachers on 3D printing (basic operation / preparation of classes for students. The price for the training is PLN 2,000 - 2,500 gross (2 hours) depending on the formula.	https://2b3d.pl/pl/c/Szkolenia-dla-nauczycieli/360
15	Egg system	Educational publishing house supporting students with special needs; also a manufacturer of 3D printers	Training and workshops on 3D printing and 3D pens. The training is aimed at preparing for the use of modern technologies in therapy and in the classroom. The training is available online with provided materials and is divided into levels of advancement. Dedicated to the education industry and teachers.	https://www.eisystem.pl/136-szkolenia-druk-3d
16	Socrates training	Private teacher training facility	Online course (1.5 h) in the amount of PLN 148 intended for all people who want to learn the basics	https://www.szkoleniasokrates.pl/courses/druk-3d/

			of 3D printing and the possibilities of using it in education. The course consists of discussing several topics: construction of a 3D printer; 3D printer menu support; connecting to the network and updating the 3D printer; levelling the 3D printer platform; installation and operation of Z-SUITE software; loading and unloading material to the 3D printer; working with models step by step.	
17	3D Phoenix	A 3D printing company	The company offers training in the basics of 3D printing and the basics of 3D printing and modelling. One training session lasts 6 hours, and the price is determined individually depending on the needs of the institution.	https://3dphoenix.pl/service/szkolenia/
18	3D in practice	A company engaged in education in additive technologies	The company offers training in 3D printing using polymer resin technology - generally open to various industries, including special ones dedicated to dentistry. Depending on the length (3-6 hours), courses cost from PLN 350 to PLN 1,650 (the more expensive ones are targeted at the dental industry).	https://3dwpraktyce.pl/2021/09/szkolenie-druk-3d-z-zywic-fotopolimerowych-w-stomatologii/
19	Mentor Audiovisual Systems	A company specializing in the production of specialized electronic devices and training	The company offers various training courses in 3D printing, mainly for schools and teachers - the training sessions last 3 hours, are online and cost PLN 2,500. Their topics include operating 3D printers, designing models for 3D printing; conducting classes with students. The training is divided into various levels of advancement and adapted to different audiences, from general education students to specialized technical schools.	https://www.sklep.audiowizualne.pl/pl/c/Szkolenia/198
20	3Lian	Shop with products used in additive technologies; also offering training	The training has a stationary format - the duration is 8 hours and the cost is PLN 750. One consists of topics: principles of operation of 3D technology; design; printer support and STEM development.	https://3lian.pl/szkolenia-druk-3d/
21	MTachnik	Magazine and portal for young people, covering broadly understood technology	The courses are intended for schools that want to diversify their classes with 3D printing. The scope of the course includes topics related to preparing classes for students; 3D printers and materials. No information about the course length and price.	https://mlodytechnik.pl/eksperymenty-i-zadania-szkolne/kursy/25877-praktyczny-kurs-druku-3d
22	Synteia	A company specializing in IT training and consulting; training in the field of edutech	The company offers training dedicated to educational institutions; training, labour market; companies dealing with 3D printing - wanting to improve the competences of their employees. The training consists of elements of design for 3D printing and printing itself. The training program includes: types of 3D printing technologies; construction and principle of operation of printers in selected technologies; ways to obtain models for printing; selection of the optimal printing method; preparing a 3D model for printing; selection of print parameters; preparing the printer for work; monitoring the printing process; finalization of the 3D printing process; reverse engineering based on 3D scanning technology.	https://synteia.pl/kwalifikacje/programowanie-i-obslugiwanie-procesu-druku-3d-z-wykorzystaniem-wirtualnej-rzeczywistosci/
23	Tygiel Foundation	Scientific foundation	The training is organized by a scientific foundation: it is dedicated to people interested in the conscious use of additive technologies in a wide range of applications in various fields of scientific research, everyday life and industry. There are 2 days of training (online), the cost of participating in both is PLN 1,100. The training includes information about the history of printing; technical aspects, selection of materials; preparing models for printing.	https://fundacja-tygiel.pl/druk-3d/

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**BUSINESS PLAN FOR THE USE OF 3D
PRINTING TO CREATE A CLOSED-LOOP
WASTE MANAGEMENT SYSTEM IN THE
MUNICIPALITY OF PARZĘCZEW**

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INTRODUCTION

The invention of printing in the 15th century popularized books. Inkjet printers in the 1990s facilitated correspondence and document circulation. Today, 3D printing offers contemporary users virtually unlimited possibilities for creation. Using 3D printing at home is gradually becoming as obvious and accessible as printing documents or photos with traditional inkjet and laser printers. Modern additive manufacturing technologies are increasingly affordable.

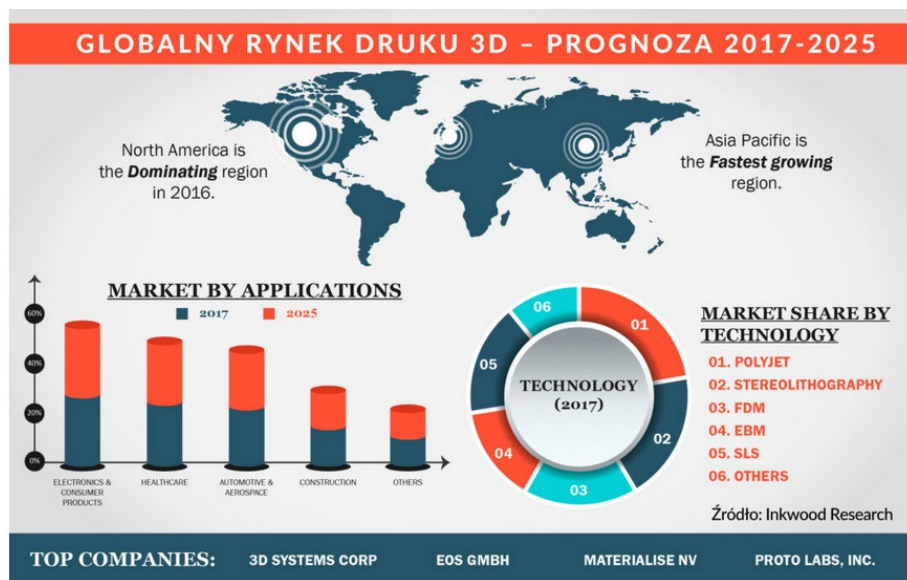
3D printing allows for the creation of three-dimensional, physical objects based on a computer design. "3D prints are described as an additive manufacturing process, which is based on various types of additive technologies. Objects are created layer by layer from powdered or solid materials. The first commercial use of a 3D printer took place in 1987. Each year, new solutions and technologies emerge in the market that improve existing printing methods. Today, 3D printing is faster and cheaper, which creates enormous opportunities for its commercial use. For many people, it has become a way to start a business." (source: <https://b3d.com.pl/drukarnia-3d-biznes-przyszlosci>)

Although it seems that this technology is relatively new, the spatial printing system was patented in 1984 by Charles Hull, who is considered the father of 3D printing. Since then, the industry has evolved significantly, and its applications have expanded across various sectors.

3D printers are no longer a novelty. Today, they print models, prototypes, and finished products for many different industries worldwide. The devices are used for projects on both a micro and macro scale.

The increasingly cheaper low-budget printer models and the growing accessibility to knowledge about additive technologies are causing all limitations to disappear, and the possibilities for application seem limitless. From parts for household appliances, the production of an entire boat, to limb prosthetics. Thanks to 3D printing technology, we will soon be able to **print not only industrial models or toys in a few moments but also houses, bridges, various components for the IT industry, and even food.** One could almost dare to say that the technological possibilities of 3D printing are limitless, and the production of any products will only be limited by the materials used.

The cheapest printers now cost a few hundred złoty, so they are eagerly bought by private individuals fascinated by the work of these devices. A professional 3D printer, on the other hand, costs about a few hundred thousand złoty. The wide range of devices on the market has made 3D printing a fairly popular service, offered in every major city.



(Source: <https://przemysl-40.pl/index.php/2018/09/19/rynek-druku-3d-coraz-bardziej-dojrzaly/>)

"Four billion dollars – this is the current estimated value of the global additive manufacturing market, according to analysts from IDC. Additionally, in the next four years, the value of this sector in Europe could double – mainly due to investments in additive printing technologies by Western European economies. The main recipient will be the industry, while the fastest market growth will concern the countries of the Central and Eastern Europe region." (Source: <https://przemysl-40.pl/index.php/2018/09/19/rynek-druku-3d-coraz-bardziej-dojrzaly/>)

Additive printing is one of the elements included in Industry 4.0, although it has been developed for many years. It is currently entering a more advanced phase, and the technology is finding increasingly broader applications. "3D printing has the potential to advance industrial processing. Primarily, it can streamline short-run production or 'on-demand' production, but that's not all. It will also help reduce storage and transport costs," says Julio Vial from IDC.

Hospitals and laboratories have invested in 3D printing equipment, software, and services. Models of hearts are printed there, which cardiothoracic surgeons use to prepare for operations, as well as joint elements that are modelled based on natural originals. *"Medicine has found applications in 3D printing, but it is the aerospace industry that benefits the most from spatial printing technology. One successful example of the application of spatial printing is the new GE ATP Engine turboprop engine, which is made of 35% 3D-printed components. The new 'printed' engine provides 10% more power with 20% less fuel consumption. The time and costs associated with GE Aviation's preparation and implementation of the engine were also lower compared to conventional solutions. The development of spatial printing will also affect fast-moving consumer goods. Twenty percent of companies from the Gartner Global Top 100 list will use 3D printing to create customized products from 2018 to 2021. Soon, shoes will not only be sewn but also custom-printed. Examples include Adidas and Nike's virtual stores, where customers can personalize purchased products. Another footwear manufacturer, Brooks, has gone a step further, allowing not only the design of the look of one's model but also fitting it to the buyer's foot anatomy."* (Source: <https://przemysl-40.pl/index.php/2018/09/19/rynek-druku-3d-coraz-bardziej-dojrzaly/>)

There are many ways to make money with spatial printing. It can be a good business idea in both small and large cities, as well as a home business idea. Each 3D printing service can be different – its character is determined by the companies for which it provides services. **The main difference for an entrepreneur who wants to take their first steps in this industry may primarily involve the technology used, meaning the printers and filaments.** Of course, this entails appropriate space requirements – industrial 3D printing may require dozens of square meters of space, while in the case of 3D printing toys or decorative items, a space of several square meters may suffice.

A key aspect of successfully implementing 3D printing services will be having knowledge in 3D project creation. Each print requires a project to be prepared by computer graphics specialists. The project is complex due to its spatial nature.

Depending on the project's complexity, the cost of such a project depends on many factors. It is worth emphasizing that 3D printing is a business that rewards creativity – the possibilities for using a 3D printer are almost limitless, just like the variety of materials that can be used to create prints. Owning a 3D printer allows one to:

- Create personalized gadgets, such as original, self-designed phone cases, designer jewelry, keychains, everyday items, and even miniature figurines of customers.
- Print and sell accessories and spare parts for household and electronic devices.
- Sell tutorials and ready-made item designs prepared for novice 3D printing enthusiasts who cannot design them themselves.
- Plan and implement activities focusing on using 3D printing to create sustainable development systems.

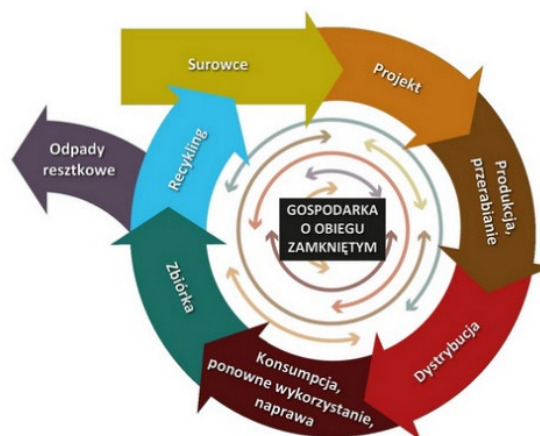
This last area is an idea that will be verified in this business plan. Implementing [3D printing](#) can be an important step in terms of a positive impact on the environment and sustainable development on various levels. This can be reflected in reducing the carbon footprint, producing less waste, and reducing energy and raw material consumption.

The essence of the 3D printing method, or additive manufacturing, is the creation of various products by adding material instead of subtracting it and generating waste. This offers a very good perspective for creating various products and prototypes, allowing for waste reduction, in contrast to traditional production methods. Take the simple example of furniture production – printing them on a 3D printer [uses significantly less material](#) than processing them from traditional materials. Similar savings can be seen in the creation of functional prototypes of furniture elements, which can be printed on a [3D printer](#) as a single part instead of being injection-molded from, for example, three separate molds that require assembly.

According to a [European Commission study](#), by 2050, additive manufacturing (AM) can save up to 90% of the raw material needed for production. [The U.S. Department of Energy](#) estimates that AM can reduce waste production and costs by nearly 90% and energy consumption by half compared to traditional production.

This is encouraging news for any company considering the economic and environmental advantages of 3D printing (source: "E-mobility: visions and development scenarios" edited by Jerzy Gajewski, Wojciech Paprocki, and Jana Pieriegud). Analyzing various sources indicates a trend that confirms that companies have saved time, money, and materials by using 3D printing instead of sculpting in foam, metalworking, or plastic or clay molding.

This has led the newly established trade organization focused on sustainable development in additive manufacturing, the Additive Manufacturing Green Trade Association (AMGTA), to commission two studies to shed light on this issue. The first, published in November 2020, [reviews existing research](#) on sustainable development and metal additive manufacturing to draw new conclusions and identify areas for further research (<https://amgta.org/>). The second will compare the environmental impact of the production and life cycle of two identical large metal parts for the aerospace industry, one using conventional forging or casting and the other using additive manufacturing. The latest AMGTA research indicates that "AM generally has a significantly higher carbon footprint per kilogram of processed material than CM (conventional manufacturing), considering only the direct production process." However, the sustainability of additive manufacturing does not begin and end at the production stage. [3D printing](#) as a sustainable practice encompasses the entire life cycle of a part – from initial design to recycling, illustrating the concept of a circular economy.



(Source: <http://technika.gliwice.pl/nowe-mozliwosci/>).

A key issue in sustainable development is finding solutions to problems related to waste, pollution, and excessive energy and raw material consumption.

This process is equally important at both the local (e.g., municipal) and global levels. It begins with simple actions such as shortening supply chains and transitioning to more environmentally friendly practices, like using energy-efficient products, placing recycling bins, using energy-efficient bulbs, and placing plants in company premises or offices. The next step is applying practices focused on reuse, repair, refurbishment, regeneration, and recycling. This minimizes the use of raw materials and reduces waste, pollution, and carbon emissions.

One example is the European Union's goal to make all plastic packaging in Europe recyclable by 2030 (source: <https://portalkomunalny.pl/ke-w-2030-roku-wszystkie-opakowania-musza-nadawac-sie-do-recyklingu-531202/>). The 3D printing method fits perfectly into this goal, using filament, a *thermoplastic material designed for use in FDM (fused deposition modeling) 3D printers – manufacturing by depositing hot thermoplastic material layer by layer. In this method, the material is extruded through a nozzle heated to its melting temperature. It functions like ink in a traditional 2D printer. Thermoplastics are plastics that behave like a viscous, dense liquid at a specific temperature and pressure. This property allows them to be shaped into various intricate patterns. Heated thermoplastics are layered through a nozzle, and upon cooling, they solidify into a solid mass – a finished 3D print. Filaments are made from various thermoplastic materials that differ in their physical and chemical properties, including melting temperature. They appear as thin threads, so filaments typically have one of the two most common diameters, 1.75 mm or 2.85 mm* (source: <http://businesspl.com/index.php/informacje-prasowe/19663-filament-do-drukarki-3d>). Thermoplastic materials used in packaging can be an inexpensive and sustainable raw material for 3D printing, providing high-quality production from plastic waste, in line with a [circular economy](#). Utilizing local plastic waste as raw material is one of the potential main advantages of additive manufacturing. The 3D printing method enables material reduction, reuse, repurposing, and recycling.

[3D printers](#) can produce parts with shapes and features unattainable by other production methods. Designing with an emphasis on sustainability will create more efficient products that use less material. For example, products that once consisted of many parts can now be printed as a single unit, saving material, time, and labor thanks to Industry 4.0.

This solution also generates an additional benefit of additive manufacturing in transportation. The use of single-piece, better-fitting, and lighter parts for transportation means less fuel consumption by cars, airplanes, or other means of transport, leading to lower greenhouse gas emissions.

[3D devices](#) can quickly and inexpensively produce spare parts for unique or discontinued devices, keeping old machines and vehicles out of scrap heaps and eliminating the need for more raw materials and energy to produce new machines and industrial components. They allow for printing parts that have not been manufactured for decades, extending the lifespan of older machines that are no longer available from the original supplier and would be too costly for the manufacturer to produce using traditional methods. [The availability and relatively small size of 3D printers](#) enable local production of

parts, prototypes, and products instead of ordering them from the other side of the world, resulting in a smaller environmental impact from transportation.

For example, during the pandemic, when global supply chains in factories were disrupted, local companies with [3D printers](#) began producing face shields, ventilator parts, and other personal protective equipment for responders in their communities. Many hospitals were able to print their own equipment or sign contracts with local companies for relatively small 3D prints. Another advantage is printing on demand or in small batches instead of maintaining a stock of spare parts and inventories, many of which may never be needed. An example is the dozens of eyewear brands that have partnered with Materialize, a 3D printing service provider, to bring 3D-printed eyewear collections to market. Each eyeglass frame can be customized for the user and produced on demand.

Additive manufacturing requires fewer tools, parts, and processes than traditional manufacturing, eliminating a significant portion of labour, equipment, and energy, and is often faster. The same models made through plastic molding methods first require separate molds for each item, and then a machine melts one plastic and pours it into the mold – a process that must be done in a factory. With 3D printing, a university can create any medical model, even patient-specific ones, using just one machine that fits in an office. One device can replace several components of traditional production equipment because it can print a variety of parts from various materials. Less equipment means smaller factories and fewer emissions.

A 3D printing company can be located in city centres or closer to where printed elements are needed. Additionally, from a noise pollution perspective, they are significantly quieter than traditional production devices.

All these aspects have led to the challenge of implementing a local closed-loop model based on the above assumptions in the municipality of Parzęczew. The idea also stems from market trends:

According to a report prepared by the Digital Poland Association titled "Printing in Poland," *"in the coming years, spending on spatial printing in Europe is expected to grow annually by 15%. Although Western Europe invests the most in this solution, Central and Eastern Europe is expected to see a greater increase as local companies become its largest consumers. By 2024, the global 3D printing market is expected to reach \$35 billion, with the value of printing materials estimated at about \$1.5 billion"* (source: <https://centrumdruku3d.pl/artykul-partnera-portalu-kim-sa-drukarze-xxi-wieku/>).

As part of building a closed-loop economy system, filaments produced from recovered raw materials will be promoted. The idea of creating your own consumable material for a 3D printer would solve many problems related to waste generated in every municipality. In theory, both failed 3D prints and plastic waste—bottles, packaging, toys, etc.—could be used for its production. This would be an ideal way to implement a closed-loop economy at the local level. In practice, however, the filament production process is complex enough that what would theoretically be self-produced might have poor quality—assuming the raw material was homogeneous (i.e., the filament would be made from PLA waste). This would create another challenge—establishing local waste sorting points for specific types of filaments. Small-scale filament extruders require precision and special conditions—complex technology, unfavourable working conditions (noise and fumes from the machine during material melting), and the need for very detailed raw material selection. This means that only research centres, which need to produce and test small quantities of material, or R&D departments in companies involved in the production or processing of plastics might consider self-producing filament.

This leads to the conclusion that building a closed-loop economy system is feasible but on a much larger scale, likely at the regional level, where logistical planning can start from waste collection at the municipal level, through sorting at the county level, to passing selected waste to filament producers who will take the risk of producing filament from secondary raw materials. Processed waste returns to local 3D printing.

It becomes part of various brands' offerings for 3D object printing using FFF/FDM techniques. Examples include Spectrum Filaments and Fiberlogy.

S.A. Brzezie 387; 32-014 Brzezie is the owner of the Fiberlogy brand, which has created **Fiberlogy R**. These are **recycled filaments**. The components of these 3D printer materials come from recovery. Plastic waste has thus gained a second life, becoming filaments for 3D spatial printing using FFF/FDM technology. Fiberlogy materials are produced using only recycled raw materials, making them 100% recycled filaments. This process reduces the negative environmental impact, which is continually polluted by plastics. The manufacturer ensured that the raw materials used to create the filaments were of high quality. Plastic waste underwent strict selection before being used as a raw material for the final product intended for 3D printers. Fiberlogy recycled filaments offer a broad range of materials for FDM/FFF 3D printing. The Fiberlogy R line includes:

1. R PLA is a recycled filament and one of the representatives of the Fiberlogy R line. Its base component is polylactic acid. This biodegradable polymer is the foundation of PLA filaments. Printing 3D objects with Fiberlogy material is very simple. Users of 3D printers who are new to 3D printing structures using FDM/FFF will also find it easy to handle R PLA filament. The individual layers of Fiberlogy material adhere well to each other, making prints not only aesthetically pleasing but also fairly durable. The discussed recycled filament also features a decent level of rigidity.



A figurine printed from recycled polylactic acid filament, or R PLA, by Fiberlogy (©Fiberlogy)

Fiberlogy R PLA Filament - Basic Information

Material Type: Recycled filament

Base Component: PLA

Fiber Diameter: 1.75mm

Printing Parameters:

Printing Temperature: 210°C to 230°C

Bed Temperature: 50°C to 70°C

Enclosed Chamber: Not required

Fan: 75% to 100%

Flowrate: 95% to 105%

Print Speed: Less than 100mm/s

Bed Surface: Glass or masking tape

Direct Retraction: Yes, 2mm to 3mm

Bowden Retraction: Yes, 4mm to 6mm

Retraction Speed: 20mm/s to 45mm/s

Drying Conditions: 50°C/4h

Suggested Minimum Nozzle Diameter: 0.5mm

2. R ABS is another representative of the Fiberlogy R line. Its base component is recycled acrylonitrile butadiene styrene (ABS). This material is known for its high mechanical strength and impact resistance. ABS filament from recycling is also highly impact-resistant, meaning it withstands dynamic loads (including impacts) well. 3D prints made from R ABS have surfaces that are difficult to scratch. The recycled filament also features high thermal resistance and can be further processed, either mechanically or with appropriate chemicals, for smoothing the printed 3D object.



A figurine printed from recycled ABS filament, or R ABS, by Fiberlogy (©Fiberlogy)

Fiberlogy R ABS Filament - Basic Information

Material Type: Recycled filament

Base Component: ABS

Fiber Diameter: 1.75mm

Printing Parameters:

Printing Temperature: 250°C to 265°C

Bed Temperature: 90°C to 110°C

An Enclosed working chamber is recommended

Fan: 0% to 10%

Flowrate: 95% to 105%

Print Speed: Less than 100mm/s

Bed Surface: Glass, masking tape or ABS juice

Direct Retraction: Yes, 2mm to 3mm

Bowden Retraction: Yes, 4mm to 6mm

Retraction Speed: 20mm/s to 45mm/s

Drying Conditions: 60°C/4h

3. R NYLON is made from polyamide sourced from recycling. It is characterized by very high mechanical strength. The recycled polyamide filament also boasts excellent resistance to various chemical substances. 3D prints created from R NYLON are furthermore highly resistant to potentially negative effects of relatively high temperatures. Fiberlogy's material is relatively flexible and is also resistant to destructive frictional forces. Thus, the recycled polyamide filament does not fall short of traditional nylon materials for 3D printing.

R NYLON Fiberlogy - Basic Information

Type of Material: Recycled filament

Base Component: PA (polyamide, nylon)

Filament Diameter: 1.75mm

Printing Parameters:

Printing Temperature: 255°C to 270°C

Bed Temperature: 100°C

Closed Chamber Required

Airflow: 0% to 10%

Flowrate: 95% to 105%

Print Speed: 35mm/s to 60mm/s

Build Surface: Glass or PVA Glue

Direct Retraction: Yes, 2mm to 3mm

Bowden Retraction: Yes, 4mm to 6mm

Retraction Speed: 20mm/s to 45mm/s

Drying Conditions: 70°C for 4 hours

4. **R PP** is a filament for 3D printing using the FFF/FDM technique, based on **polypropylene** sourced solely from recycling. This filament has all the characteristics typical of classic PP materials. Fiberlogy's product is therefore **lightweight** and **odorless**. The recycled polypropylene filament also has **excellent chemical resistance**. R PP is also **non-toxic** and **durable**. Its durability results not only from the high level of chemical resistance but also from its **excellent mechanical strength**. The recycled polypropylene filament is a great alternative to traditional PP materials and is produced in line with zero-waste principles.



*A figurine printed with recycled polypropylene filament, R PP by Fiberlogy
(©Fiberlogy)*

R PP Spectrum - Basic Information

Type of Material: Recycled filament

Base Component: PP (polypropylene)

Filament Diameter: 1.75mm

Printing Parameters:

Printing Temperature: 220°C to 250°C

Closed Chamber: Not Required

Airflow: 0% to 50%

Flowrate: 100% to 105%

Print Speed: Less than 45mm/s

Build Surface: Packing Tape

Direct Retraction: Yes, 2mm to 3mm

Bowden Retraction: Yes, 4mm to 6mm

Retraction Speed: 20mm/s to 45mm/s

SPECTRUM GROUP SP. Z O.O.; PARKOWA 85; 05-806 PĘCICE is a Polish brand offering a wide range of 3D printing materials for FDM/FFF technology. Their rich inventory of 3D printer materials includes recycled filaments. These materials are made from production waste that has been processed to produce high-quality products. Spectrum Filaments' recycled filaments are available in a wide range of colours, which is undoubtedly a significant advantage. The offered materials are based either on polylactic acid (PLA) or PET-G (polyethylene terephthalate glycol). The filament is produced from recycled extrusion waste streams. The material is collected, shredded, re-mixed, and homogenized into high-quality and easy-to-print PLA filament. Spectrum rPLA retains the characteristics of classic PLA, such as ease of printing and effectiveness, with very low shrinkage and relatively high tensile strength. To make 3D printing more sustainable, Spectrum rPLA is wound on a cardboard, eco-friendly spool. The rPLA filament is very easy to handle and has low shrinkage during processing. Prints made from it exhibit good dimensional stability. The recycled polylactic acid filament from Spectrum Filaments is excellent for creating decorative objects.

rPLA Spectrum - Basic Information

Type of Material: Recycled filament

Base Component: PLA

Filament Diameter: 1.75mm

Printing Parameters:

Printing Temperature: 195°C to 215°C

Bed Temperature: 40°C to 50°C

Closed Chamber: Not Required

Airflow: Up to 100%

Print Speed: 40mm/s to 150mm/s

Flowrate: 100% to 105%

Direct Retraction: 1mm to 3mm

Bowden Retraction: 4mm to 6mm

Retraction Speed: 25mm/s to 45mm/s

1. rPETG is a recycled filament based on polyethylene terephthalate (PET) enriched with glycol, i.e., PET-G. Spectrum rPETG is an eco-friendly 3D printing material aligned with sustainability initiatives. The filament is produced by reusing waste streams from extrusion that have been recycled. The raw material is collected, shredded, re-mixed, and homogenized into a high-quality, easy-to-print recycled PETG filament with significantly reduced environmental impact. Spectrum rPETG retains the properties of classic PETG, such as ease of printing and effectiveness, with very low shrinkage and relatively high tensile strength. It features high mechanical strength and relatively high levels of thermal and chemical resistance. The recycled copolyester filament is an excellent material for printing functional 3D objects—not just decorative ones.



Recycled filament spool - rPETG - from Spectrum Filaments (©Spectrum Filaments)

Spectrum rPETG - Basic Information

Type of Material: Recycled filament

Base Component: PET-G

Filament Diameter: 1.75mm

Printing Parameters:

Printing Temperature: 230°C to 255°C

Bed Temperature: 60°C to 80°C

Closed Chamber: Not Required

Airflow: Up to 100%

Print Speed: 30mm/s to 70mm/s

Flowrate: 100% to 105%

Direct Retraction: 1mm to 3mm

Bowden Retraction: 4mm to 6mm

Retraction Speed: 25mm/s to 45mm/s

(Source: <https://zadar.pl/filament-z-recyklingu-czyli-zero-waste-w-swiecie-druku-3d>)

KEY PARTNERS

3D printer manufacturers in Poland come from cities such as Wrocław, Poznań, Częstochowa, Biłgoraj, and Darłowo. Łódź is also increasingly making its mark on the map. Although no significant, original designs have emerged from here yet, Łódź is home to Printila, the official distributor of Leapfrog (based in nearby Zgierz), IPrint3DStore.com, the first Polish online service with 3D printing designs (based in nearby Pabianice), and the 3D Printing Center. Since August, Get3D.pl, an online store for filament, has joined this group and recently also became the official distributor of RepRapPro, a 3D printer branded with the name of the RepRap system creator, Adrian Bowyer.

The majority of 3D printers find their buyers through traditional online stores and auction sites.

Thanks to modern internet marketing techniques, sellers can easily reach the potential target audience for these devices. These sellers often encounter companies that can most benefit from the advantages of 3D printing, such as architectural studios.

The growing popularity of 3D printing has also been noticed by nationwide electronics retailers. 3D printers are now easily available in stores like Komputronik, Euro RTV AGD, and Morele.net, confirming the high interest in this equipment among Polish consumers.

Another group consists of material suppliers—filament manufacturers. The filament production industry is developing at a rapid pace, with suppliers competing to offer users increasingly new options.

Popular materials such as PLA, and similarly priced ABS and PETG are available for several dozen PLN per kilogram spool. One spool lasts a long time, considering that a 1-kilogram spool of filament can be over 300 meters long.

Manufacturers also offer filaments with lower weights—this is a cost-effective solution, especially when a given material is used less frequently. The full range of consumable materials is much broader and includes materials with special properties or striking appearances, such as metallic filaments. The second most popular material—this time for SLA devices—is light-cured resin. Available in liquid form, typically in 0.5 kg containers, it is very convenient to use.

The first factor is choosing the printing technology. The second is the type of filament used. The third is the amount of material consumed, the number of layers, and the total printing time. When calculating

the cost of printing, one should also consider the consumed electricity, equipment depreciation, and the post-printing processing tasks.

UNIQUE VALUE PROPOSITION (BENEFITS DIFFERENT FROM COMPETITORS)

Commercial 3D printing is increasingly popular in Poland, where, according to "Market Research on 3D Printing in Poland" by Printelize, the majority of the market consists of microenterprises (85.6%) and sole proprietorships (27.8%). Most of these businesses focus on B2B sales, catering primarily to architects, engineering firms, and design companies. **This market is challenging and demands broad knowledge across various fields, including marketing and spatial design, alongside valuable experience in other sectors.**

However, a sufficiently creative business idea, combined with high-quality services and products, **can attract strong investor support and foster robust growth** in this cutting-edge sector. It is a fact that today's 3D printing can be very eco-friendly and may become even more so with advancements in recycling technology and the development of materials. *"There are technologies that can radically reduce the impact of 3D printing—by about 70% less... compared to injection molding—due to low energy consumption during printing with non-toxic, renewable, compostable ingredients with regulated physical properties"*, notes Faludi in his [2017 research](#).

However, companies that use toxic, non-renewable materials; print without considering material protection or employee safety, and dispose of unused prints instead of recycling them, are not practicing additive manufacturing to harness its sustainable potential.

Ultimately, it is not the production method but the choices of end-user companies—or even additive manufacturing as an industry—that may determine the sustainability of 3D printing. *"Sustainability can be—and should be—one of the selling points for adopting AM"*, says Sherry Handel, Executive Director of AMGTA.

Current and potential government regulations in the EU and the US, which penalize companies for their carbon footprint and reward—through grants and tax incentives—efforts to adopt sustainable practices, provide another incentive for embracing additive manufacturing.

Moreover, the attractiveness of sustainability for consumers should not be underestimated. Environmental sensitivity is becoming increasingly important in consumer decision-making, especially as younger consumers choose "more eco-friendly" companies over their competitors.

Companies opting for additive manufacturing can boast materials that save resources. In return, consumers may feel good about purchasing products that promote sustainability, such as Adidas [sports shoes](#) made from plastic collected from ocean trash or products from the Canadian store [The Rogerie](#), which are 3D-printed from local plastic waste.

3D printing will become even more eco-friendly over time.

Additive manufacturing is still a young industry, full of innovative startups seeking ways to differentiate this market from traditional manufacturing. Startups involved in additive manufacturing are well aware of their potential to offer sustainable production alternatives to companies that wish to be environmentally friendly. Since AM is heavily reliant on technology, it can be more adaptable and have a greater chance of adopting even more eco-friendly approaches in the coming years.

As the popularity of additive technologies grows, so does the number of individuals looking to try their hand in this field and find ways to start a business in the 3D printing industry. The 3D printing industry is quite demanding, many potential areas are already occupied, and projects with the greatest chance of success require their creators to leverage innovation.

This does not mean that there is no room for new companies or that it is not worth starting a business in this area. Two key factors are crucial here—financial resources and the aforementioned innovation. If one is lacking, we must be very strong in the other. The best companies in the market are leaders in both areas—innovative companies with substantial financial resources.

Depending on the type of product/service offered, customer needs may include:

- Determining the necessary parameters to achieve the desired effect, such as the scope of the service, the final product, etc.
- Preparing the material for printing in the chosen technique.
- Preparing and executing the project on behalf of the client.

Customer expectations in different segments will vary in scale and scope. Small and micro-enterprises are looking for more affordable offers.

Since a large portion of small and micro businesses and organizations still do not utilize the opportunities provided by 3D printing, the offer in this area will be directed at this segment, preceded by an informational campaign. Initially, the campaign will be local—targeting Parzęczew and neighbouring municipalities.

I anticipate that the expectations of each company will differ, so services will be flexible and tailored to customer needs. **The competitive advantage of the offered services will be their comprehensiveness, favourable quality-to-price ratio, and the highest quality of after-sales service.** In the area of 3D printing services, prices will be competitive for different market segments. Additionally, there will be a systematic effort to educate about the benefits of additive manufacturing. By building relationships and dedicating significant time to understanding the client, it will be possible to capture industry nuances and enable the creation of innovative products that the client would not obtain through other techniques. An interesting idea for additional revenue could also be offering consulting and training services. The industry needs professionals with expert knowledge and essential competencies. The proximity of an academic centre like Łódź offers the opportunity to access the best experts. This solution can be considered a good idea for expanding the business.

BUILDING RELATIONSHIPS WITH EXISTING CLIENTS

3D printing remains a relatively risky investment, and the 3D printing industry is quite insular. **Although additive technologies are becoming more prevalent in the market, they still do not have full understanding and trust across many industries and companies.** Direct contact with clients, building relationships, and providing personalized approaches are crucial elements in the client acquisition strategy. Building a portfolio of services to highlight individual and unconventional approaches will be important. Pricing will be individually negotiated to ensure competitiveness. A creative approach to the scope of services will ensure maximum flexibility for clients.

Particularly important in the market entry strategy will be the educational element for clients. Emphasis will be placed on building awareness among clients about the benefits of the services offered.

This will be a multidimensional message covering direct benefits (high quality, fast turnaround, good price) as well as indirect benefits related to the ecological nature of the service. Often, it will be necessary to spend additional time educating clients about the possibilities and benefits, particularly in the context of sustainability, which is increasingly important for consumers.

My target audience includes individual clients, small businesses, and social economy entities, who will need an individualized approach to each order from various perspectives. They often lack knowledge about what and how they can utilize, hence the idea of educating clients through webinars, videos published on social media, or presentations at industry fairs and social economy events for non-governmental organizations.

TARGET GROUPS

When analysing target groups, it's important to ask: What can be produced with a 3D printer? The answer will simultaneously define who our potential customers might be. 3D printing has proven indispensable in so many industries that it's difficult to list all the users of this technology. Certainly, architects and designers, model makers, and artists use it to print various props, figurines, and functional forms. 3D printing is also widely used in industry, resulting in the creation of molds, production elements, and parts, and sometimes even finished products. Jewellers use 3D printers to create resin molds for casting. 3D printers are becoming increasingly important in modern medicine, producing perfectly fitted prosthetics and medical accessories. 3D prints are also created by teachers and lecturers as teaching aids. Private individuals who are passionate about this technology or developing their businesses also frequently use 3D printers. In modern schools, students have access to them, allowing them to work on projects they have conceived themselves or those assigned by teachers.

Depending on the type of printer, we can produce: decorations, everyday items, spare parts for devices, product prototypes, architectural models, figurines, and even firearms. It is possible to print with plastic, metal, and even glass. The potential is vast, and the scale of 3D printing usage is continually growing.

A 3D printing service can cater to industries such as machinery, automotive, medical, electronics, jewellery, advertising and education. 3D printing is utilized in jewellery workshops, the cosmetics industry, toy manufacturing, medical fields, electronics, automotive, furniture production, and even in the military and aerospace sectors.

It is especially valuable where complex models and spatial elements of any shape are needed, which cannot be produced using standard serial production methods.

Key industries that will likely be our customers to varying degrees include:

1. **Medicine – Various prosthetics made from metals such as titanium and surgical steel are being created, and advancements in technology may even lead to the development of artificial organs.** Research is ongoing into bioprinting, which involves using materials containing live cells. In the future, bioprinting could facilitate the repair of burn injuries to skin tissues and potentially replace animals in

clinical trials. Currently, 3D printers are utilized in the medical field for producing advanced prosthetics, printing tablets, and, in extreme cases, even skull implants. Recently, a miniature, anatomically accurate heart was printed. Although it is the size of a walnut, the rapid and significant advancements suggest that it will not be long before we hear about the first implanted heart created using bioprinting. (Source: <https://blog.doktortusz.pl/drukowanie-3d/>)

This requires that as a business owner, you secure funds to either hire a specialist in medical printing with at least basic knowledge or employ experts in this field.

2. **Industry – Spare parts for various devices, models, and prototypes.** Ordering specific parts or prototypes from a 3D printing service is much cheaper and faster compared to manufacturing them through traditional industrial methods. Small and medium production runs, large single components, or small, complex parts can be produced. Additive manufacturing technologies allow for the creation of a wide range of items without needing to be an expert in industrial machinery. A good example of this technology's flexibility is the production of face shield frames for medical staff during the pandemic. There was a need, and a solution was found.
3. **Construction – The use of appropriate materials and 3D printing devices allows for the creation not only of basic structural elements for buildings, roads, or bridges but even the production of entire structures.** In recent years, a 3D-printed steel bridge has been created, which will be used in Amsterdam.
4. The most significant theoretical breakthrough in the 3D printing industry is the construction of the first houses using this technology. Although marketed as a super cheap and fast option for building homes, it is still not widely popular. Entrepreneurs must still adhere to construction regulations stipulated by law, and although the resulting structures are not defective, the regulations are not adapted to these new methods.
5. **Toys and Decorations – These are definitely the easiest products to produce with 3D printing.** Initially, the planned business will focus on these items.
6. **Gastronomy – Printing chocolates or other types of sweets.** The first attempts at printing food occurred in China. Since then, 3D devices have been increasingly used in the food industry, particularly in confectionery. Items produced include chocolate decorations or sculptures, delicious candies, sugar glass elements, and even entire cakes. This is simply an enhancement of existing production lines.

7. **Automotive Industry** – The automotive sector requires testing the fit of designed parts for various models. 3D printing allows for rapid prototyping and testing of components before mass production, which can significantly reduce costs and time in the development process.
8. **Education – 3D printing can be used to create props that enhance lessons in almost any subject.** These can serve as exhibits for close examination, be passed around in class, or used as elements in student tasks. This interactive approach can deepen students' understanding and engagement with the material.
9. **Fashion Industry** – 3D-printed shoes, dresses, and jewellery have already made appearances on Fashion Week runways. Although 3D-printed textiles are not yet seen as everyday clothing, footwear and accessories are gaining popularity.

This trend showcases the potential for innovative designs and custom fashion items in the industry.

10. **Custom Design Services** – Meeting the diverse needs of clients who request specific 3D-printed items is a significant part of the business. Both hobbyists and large-scale 3D printing departments benefit from this technology. **Custom design services will be a core aspect**, offering valuable industry experience and building the brand.

Depending on the needs, 3D printers can serve constructors, prosthetists, artists, jewellers, model makers, architectural and design firms, educational institutions, and even households needing hard-to-find parts. For example, a customer might want to replace a broken knob on an amplifier that has not been manufactured for 30 years.

RECOURCES NEEDED TO LAUNCH THE OFFER

The technology of 3D printing offers numerous ways to start a business in the industry. In practice, it will depend on project assumptions and creativity. Regardless, it is essential to design what will be needed for the startup.

Key investments necessary to start a business in this segment include:

1. **Purchase of a Suitable 3D Printer.** Simple models for self-assembly are available on the market, costing up to 2,000 PLN (models from brands such as Anet, Creality, Anycubic, Biqu, Artillery, Velleman, Prusa). However, they do not guarantee the precision required for many projects. The cost of professional devices ranges from several to tens of thousands of PLN (higher-end models include Snapmaker, a multi-functional workstation for printing, engraving, and milling, or the renowned Polish brand Zortrax devices). For example, one of the most popular printers on the Polish market, the Zortrax M300, costs around 18,000 PLN. This equipment is recommended for commercial use—its working area is 30 cm³, and the minimum wall thickness is 400 microns.
2. **Space Requirements.** This also depends on various factors. For small-scale production of toys or decorative elements, any space allowing for free movement and basic sanitary facilities will suffice.
For industrial printing, renting (or buying) a production hall will be necessary.
3. **Parts, Tools, and Accessories** significantly facilitate [3D printing](#). The cost of producing details practically does not change since most accessories are purchased once and used for a long period. However, these accessories can indirectly increase printing efficiency by better protecting 3D printer components from damage/wear and improving printing conditions. Essential equipment includes a flexible build plate cover that protects the platform surface and improves model adhesion, Kapton tapes that enhance the first layer's adhesion to the bed, and special needles and cleaning filaments for nozzle cleaning. Many printer manufacturers offer complete accessory and spare part kits, including interchangeable nozzles—when printing with materials containing additional particles, nozzles may wear out significantly. Having such basic accessories ensures uninterrupted operation and extends the equipment's lifespan.

Investment Funds - securing capital through **various support programs offered by both the national government and the European Union, including repayable instruments. An alternative could be increasingly popular crowdfunding platforms** in the technology sector, **where private investors**

support all kinds of startups or creative ideas. In this case, to encourage investors to contribute, it will be necessary to offer something in return—often, the final product at a significantly reduced price is sufficient. **It is also important to take care of the marketing aspect of the crowdfunding campaign.**

Example 3D Printer

The **Creality Ender-3 3D printer** is an affordable device that allows for three-dimensional prints using the **FDM/FFF** method. Its immense popularity among 3D printing enthusiasts is not only due to its **reasonable price** but also its **excellent technical specifications**. The Ender-3 model features a **large build area of 220x220x250 mm**, enabling the creation of prints with a significant range of sizes.

The machine is equipped with a heated build platform, with a maximum temperature of **110°C**. The highest achievable printing temperature is **255°C**.

The Ender-3 supports printing with various types of filaments, including not only **PLA** but also **TPU** and materials enhanced with **carbon fibre** or **wood particles**. The Ender-3 is an excellent machine for technology enthusiasts, offering good technical specifications at a relatively low cost. Additionally, the Ender-3 can be easily modified. Proper modifications can lead to a significant increase in the machine's performance. One such possible modification is adding an enclosure, which allows for 3D prints using ABS filaments.



Creality Ender-3 3D Printer - Product Information

Basic Data:

Dimensions of the Printer (without spool): 440×410×465 mm

Dimensions: 600×350×160 mm

Weight: 8.6 kg

Weight (with packaging): 10 kg

Printing Features

Printing Technology: FDM

Number of Print Heads: 1

Filament Diameter: 1.75 mm

Build Volume: 220×220×250 mm

Build Surface: Heated with BuildTak pad

Maximum Platform Temperature: 110°C

Build Platform Calibration: Manual

Standard Nozzle Diameter: 0.4 mm

Layer Thickness: From 0.1 mm to 0.4 mm

Supported Filaments: PLA, TPU, Wood, Carbon, Others

Maximum Nozzle Temperature: 255°C

Maximum Printing Speed: 180 mm/s

Electrical Data

Power Supply: AC 100-265V 50-60Hz / DC 24V 15A

Power Consumption: 360W

Additional Information

Connectivity: SD Card

Hardware Requirements: Windows, Mac OS, Linux

Software: Cura, Simplify

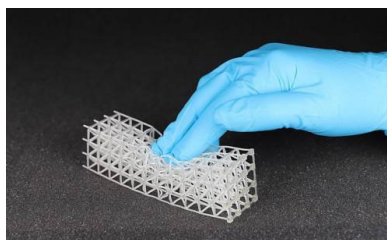
Supported File Formats: .stl, .obj, .gcode

The Zortrax Inkspire 2 (20787 PLN, (source: <https://global3d.pl/pl/drukarki-3d/zortrax/609-drukarka-3d-zortrax-inkspire-2-5902280827559.html>) is a resin 3D printer operating with UV LCD technology, featuring a build volume of 192 x 120 x 280 mm. Inkspire 2 is compatible with resins from leading global manufacturers such as BASF Forward AM and Henkel/Loctite. There are also post-processing devices available, such as the Zortrax Cleaning Station and Zortrax Curing Station.

These devices, together with the printer, create a professional, cohesive ecosystem. The printer is equipped with a proprietary LED panel designed entirely by Zortrax engineers. It features a UV diode array that illuminates a monochromatic screen to achieve uniform UV exposure for each pixel on the large build platform, maintaining the highest precision.

This results in 3D printed models with excellent quality, whether they are positioned in the centre or along the edges of the platform. Additionally, the new light matrix is seven times more powerful than a standard UV LCD screen. The Zortrax Inkspire 2 features full automation in key elements of the 3D printing process, making resin printing simpler and cleaner. The printer is suitable for both beginners and advanced users.

The broad range of resins - Inkspire 2 includes engineering resins provided by the most trusted global manufacturers. Available materials include standard, flexible, rigid, durable, high-temperature, and casting resins.



Elastomeric Resins

Elastomeric resins are high-quality materials resembling various types of rubber. These materials are used to produce seals, gaskets, or hinges, and are characterized by different levels of flexibility, mechanical strength, and thermal properties. This makes them adaptable to a wide range of engineering needs.



High-Stiffness Resin

These resins are primarily characterized by high stiffness. Finished prints made from these resins do not deform under stress, maintaining their shape until they break. They are ideal for structural frameworks, positioning devices, and handles.



Tough Resins

Tough resins have increased resistance to very high loads. They deform more quickly under stress but require more force to reach the breaking point compared to other rigid materials. They are used in the production of mechanical parts that work under significant loads.



High-Temperature Resins

High-temperature resins can withstand exposure to high temperatures without losing their mechanical properties. They are used for printing parts with properties comparable to injection molding or for manufacturing components working in high-temperature environments.



Casting Resins BlueCast

BlueCast casting resins are designed for use in the production of metal parts. The material allows for printing precise casting patterns that leave minimal or no ash during burnout.



Zortrax Basic Resins

Zortrax Basic resins offer an excellent price-to-quality ratio. Basic resins come with pre-configured print profiles that ensure the best possible thermal and mechanical properties.

The Inkspire 2 features a special build platform that facilitates the removal of resin prints and the disposal of resin residues. The platform is easy to assemble and factory-calibrated, making the printer ready for use right out of the box. The printer includes a system that monitors the amount of resin in the tank and determines how much material is needed to complete the print. This system consists of three separate components that work together. To achieve all the properties declared by the manufacturer, the finished print requires post-processing. To facilitate this process, Zortrax offers post-processing devices such as the Zortrax Cleaning Station and Zortrax Curing Station, which complement the Inkspire 2 printer in an advanced ecosystem. The Zortrax Cleaning Station is used for removing uncured resin from the model's surface, while the Zortrax Curing Station provides additional curing for finished models.



Specifications

Printing Technology: UV LCD

Build Volume: 192 x 120 x 280 mm

Printing Platform: Factory-calibrated; ready for 3D printing right out of the box

Layer Thickness: 25, 50, 100 μm

Supported Print Formats: .zcodex2

Display Type: 8.9" monochrome

Connectivity: WiFi, LAN, USB Port

Software: Z-SUITE

Supported File Types: .stl, .obj, .3mf, .dxf (2D models only), .ply

Operating Systems: Mac OS Mojave and newer / Windows 7 and newer

Light Source: Integrated LED panel (wavelength 405 nm), ensuring even light distribution across the entire platform

Storage Temperature: 0°-35° C

Touch Screen: 4"

Support Structures: Removable mechanically - printed with model material

Room Temperature: 20-40 °C

Power Consumption: 340 W

Warranty: 12 months

External Materials Supported: Yes

Pixel Size: 50 μm

Input Current: 100-240 V AC 6.2 A 50/60 Hz

Package Contents: Zortrax Inkspire 2, UV resin, resin bottle holder, FEP Film (set), scraper, float, Starter Kit

CHANNELS FOR REACHING POTENTIAL CUSTOMERS

It is crucial to build a strong image from the first day of operation. This will require a comprehensive promotional and advertising strategy using various tools and methods. All materials will feature the logo and appropriate colour schemes that will reinforce the message directed at the customer.

A key element of the marketing strategy will be demonstrating the benefits of sustainability, which will be part of the planned company's focus. Emphasizing the ecological solutions offered to customers will be an integral part of the messaging.

Various promotional tools will be utilized, as described below. A competitive advantage will be built systematically, primarily based on the aforementioned benefits of sustainability and fast service delivery times, due to a shorter management path compared to large 3D printing companies.

Service sales will occur through several channels:

- Direct Sales - meetings with clients will be organized at the business location, at the client's premises, or directly at the site where the service will be provided.
- Online Sales through the Company Website - through the website, clients will be able to review the offer and contact directly via a provided contact form or by phone.
- Social media - promotional campaigns (LinkedIn, Facebook)
- Presence in Industry Media
- Extensive public relations activities and networking

COST STRUCTURE

Although forecasts are optimistic and more and more industries are interested in using 3D printing, it is still important to carefully calculate how much money will be needed to start a business and whether there will be enough customers before making the decision to start a company. In theory, the competencies of an entrepreneur wishing to open a 3D printing business can vary depending on the size of the investment and the costs involved.

Key Cost Categories:

1. 3D Printer Filaments: Filaments are the primary material for future prints, analogous to ink in inkjet printers. There are various types of filaments intended for different types of printers and prints—polymeric and rubber filaments are the most popular, although industrial printing can also use wood or metal filaments. Costs can vary—basic starter filaments cost a few hundred PLN.
2. Maintenance Costs: It is obvious that any machine may eventually experience a malfunction requiring intervention from a trained technician. If the machine park includes several printers, a specialist will be needed at a later stage to handle maintenance, technical audits, and necessary repairs. The cost of hiring such a worker can be several thousand PLN per month.
3. Operational Costs: While a 3D printer wears out almost imperceptibly during operation, the fastest-depleting workshop supplies are consumables.

Filament is what we print with—analogous to paper in a regular printer. In the case of FFF/FDM technology, this refers to filament, a thermoplastic material wound on a spool.



(Source: <https://botland.com.pl/zestawy-filamentow/20816-zestaw-filamentow-print-me-swift-petg-175mm-12kg-12-kolorow->

[5906190619501.html?cd=20301957095&ad=&kd=&gclid=Cj0KCQjwldKmBhCCARIsAP0rfxdh1sBPSjD7fislibaZ2rzMig3UDEQI1TMEeR697oFSYADR_kb2gsaAmuBEALw_wcB](https://www.frontship.eu/5906190619501.html?cd=20301957095&ad=&kd=&gclid=Cj0KCQjwldKmBhCCARIsAP0rfxdh1sBPSjD7fislibaZ2rzMig3UDEQI1TMEeR697oFSYADR_kb2gsaAmuBEALw_wcB)

Can printed parts replace metal parts? Yes, if we use high-strength, structural materials for printing. What are the strongest materials in FDM technology? What do we need to use them?

3D printing is often associated with plastic models of low strength and limited functionality. However, additive manufacturing offers much more than just printing vases and selfie holders. Here is our ranking of the most durable thermoplastic materials for 3D printing in FDM technology.

Basic Prototyping Materials:

The most commonly used materials for 3D printing in FDM technology are PLA, ABS, and PETG. These are the most accessible, economical, and versatile materials, suitable for simple models or prototype versions. Such filaments generally do not require specialized manufacturing conditions, are easy to print, and do not present many problems, even in home settings. They are also compatible with most 3D printers available on the market.

However, if you need to create more functional models, production tools, or replacement parts, it is better to use engineering-grade, durable materials. These materials can be as strong as metal parts but at a lower weight.

To achieve high strength, metal with high density is required, resulting in high mass. Specialized filaments can offer comparable strength, toughness, and stiffness at significantly lower material densities. Consequently, you can print a strong part that is much lighter. Additionally, you can design an internal structure, such as a honeycomb, that reinforces the part while reducing its weight. This is particularly important for production or assembly tools used by humans.

Some 3D printing materials have properties (in addition to high strength) that allow them to replace metal parts. These materials can be resistant to strong chemicals and lubricants or can be certified for flame retardancy.

Ranking of Strongest 3D Printing FDM Materials

Carbon Fiber Nylon

Carbon fibers are used to reinforce plastics. Composite materials mixed with carbon fibers have excellent mechanical properties, are stiffer and more impact-resistant, and have higher fatigue strength. Due to the low density of carbon fibers, these properties can be achieved at a low product weight.

For 3D printing, carbon fiber-reinforced nylon is most commonly used, although other materials like ABS or PETG can also be mixed. The strength of prints made from this material depends on the percentage of carbon fiber in the filament.

MakerBot Nylon Carbon Fiber

Carbon Fiber Content = 10%

Fiberlogy NYLON PA12+CF15

Carbon Fiber Content = 15%

Stratasys Nylon Carbon Fiber

Carbon Fiber Content = 35%

It is worth noting that carbon fiber-reinforced materials are difficult to print and require special conditions. Printing temperature should be around 255-270°C, a closed, heated build chamber is recommended, and a reinforced extruder is necessary.

Applications:

- Production tools and instruments (handles, clips, mounting sockets)
- Quality control instruments (gauges, templates)
- Bicycle frame components
- Replacement parts for machines

PEI Material, i.e., Stratasys Ultem 9085

Polyetherimides are thermoplastics with high rigidity and mechanical strength. The material is also resistant to chemicals and stable under high temperatures. PEI parts show excellent tensile strength with low detail weight. In 3D printing technology, this type of material is available as Stratasys Ultem 9085, supported by industrial Fortus 450mc and F900 systems (formerly Fortus 900mc). Stratasys Ultem 9085 has been tested and certified for flame retardancy. The 3D printing material meets the EN-45545-2 standard and can be used in the railway industry for components installed in wagons and locomotives. Ultem 9085 prints have been tested for Flame, Smoke, and Toxicity (FST).

Stratasys Ultem 9085 has a flammability rating according to UL 94 V-0. This is the most demanding test for a vertically suspended sample, which means:

- 1) None of the five tested samples formed a flame for more than 10 seconds after the burner was removed.
- 2) The total burning time in 10 ignition tests did not exceed 50 seconds.
- 3) None of the tested samples burned or glowed at the mounting point.
- 4) None of the tested samples had burning pieces detach and fall, igniting the cotton placed under the sample.
- 5) For each sample, the glow time did not exceed 30 seconds.

Ultem 9085 is used in the rail vehicle industry, aerospace, automotive, for manufacturing bus and public transport vehicle components, and even in space technology.

According to the Printelize report, more than half of the 3D printing companies in Poland provide no more than 10 services per month, with the average order value estimated at around 1500 PLN. However, it should be noted that the price range in this industry is very broad—everything depends on the type and size of the order. Printing a small item (gadget) costs around 30 PLN, and one must also consider the service completion time, especially if serial production is planned. Depending on the printer and project, printing one small item can take from a few to even several hours. (Source: <https://www.ifirma.pl/blog/pomysl-na-biznes-z-drukarka-3d.html>)

SOURCES OF REVENUE

In the initial phase of development, the method used **will involve setting the sales price by adding a margin to the cost of production or acquisition of the product**. The advantage of this method is its relative simplicity in determining prices. It involves adding a standard margin (markup on costs) to the base costs. This operation is used to determine the final product price so that, in addition to covering the cost of the product, the company also achieves a profit. Pricing is influenced by many factors, particularly production and sales costs, the type of market (especially considered in so-called market formulas, which take this factor as the primary consideration when setting the final product price), production scale, and the financial situation of the company. After final calculations, it is also advisable to compare the price of the product with prices at competing companies to ensure it is acceptable to potential customers and profitable for the company.

The cost of printing depends on several factors, which can be adjusted to achieve the desired result at the lowest possible cost. The price consists of two components: the time spent printing the element and the cost of the material used. The cost for an hour of 3D printer operation, with models provided by the client in formats like ".stp," ".stl," or ".step," is 11.50 PLN/hour net.

If the detail is ordered along with design services (based on technical documentation or a detailed part that can be measured), the price is 18 PLN/hour net. For larger orders or ongoing cooperation, the price is determined individually.

To accurately price the hour of 3D printer operation, one must consider not only the amount of material used (e.g., [filament](#) or [resin](#)), electricity, equipment depreciation costs, and the complexity of prints, but also their quantity and the need for project execution. Thus, the cost of an hour of 3D printing can range from a few dozen to several hundred PLN.

The cost of a 3D project depends on several factors. The first is the complexity, the second is the level of detail, and the third is the size. Additionally, the cost of a 3D project can vary between large agencies and beginner freelancers, with initial rates starting around 100 PLN.

Parameters Affecting Print Time:

1. Size of the Detail:

A 3D printer can create details with maximum dimensions of 20x20x18 cm.

2. Material (Filament):

The materials used differ in various physical (hardness, impact resistance) and visual (available layer thicknesses, transparency, surface finish, colour) parameters. When selecting the material for our needs, it is also necessary to estimate its cost.

3. Surface Finish Quality:

The main parameter affecting the final appearance of the detail is the appropriately selected layer thickness of the printed element. Increasing thickness reduces printing time but also worsens quality.

4. Fill Density:

Increasing fill density enhances the product's durability but prolongs printing time and increases filament consumption. There are five types of fillings:

- Maximum
- Large
- Medium
- Minimum
- Mesh

5. Model Segmentation:

There is also the option to split the print into several parts along planes parallel to the base directly on the printer. This allows for changing the filament colour without needing to glue parts together afterward. For such an order, each colour change incurs an additional 0.5 hours of printing time, i.e., 6 PLN gross (time required to change the material). There is also the option to commission additional sanding and painting of the detail to achieve a high degree of surface smoothness, but achieving very high surface quality after painting is possible only for models with smooth surface transitions. The cost of this procedure is also individually assessed and primarily depends on the variety of colours, ranging from 30 to 100 PLN per piece.

After determining the variable costs related primarily to material and energy consumption described above, it is necessary to establish the second significant fixed cost item—mainly salaries. Considering only the gross minimum wage (projected to be 4242 PLN for 2024) plus additional charges (about 20% of the gross amount), the salary cost for three planned employees will be a minimum of 15,200 PLN per month. Fixed costs will be increased by expenses for administrative, accounting, promotional, media services, and other external services. Only after estimating all these items can the price of the offered products and services be determined.

It is, however, crucial to verify this price against competitor prices to ensure it is acceptable to the customer. Pricing based solely on costs does not contribute to building a competitive advantage. This method is necessary during the startup phase of the venture.

However, its significant drawback is ignoring customer needs—this strategy is entirely focused on the company rather than the consumer. Every business should monitor costs but neglecting the customer can result in them seeking another company that does not forget about their needs.

In the next phase of the company's operation, after gaining control over the startup processes, it will be necessary to start collecting market information to transition to the next pricing method setting prices based on customer-provided data. This is the most effective way to determine product prices, as obtaining feedback from consumers has never been easier. The internet has brought great opportunities for contacting customers (email, surveys, social media, etc.). This method also offers an additional benefit not provided by other methods—engaging the customer in the company's processes.

A relationship with the customer based on two-way communication will help build a competitive advantage through eco-friendly solutions that are the basis of the company's operations in the Parzęczew municipality. A major advantage of this method is prioritizing the customer, which allows for increased profits and customer acquisition.

Alternative Development Directions Related to 3D Printing

1. 3D Printer Sales

Instead of focusing on production, it might be better to concentrate on sales. The number of companies implementing 3D printing solutions in the industrial sector is steadily increasing. There are even more people interested in purchasing a device but still searching for the right one for

their company. Therefore, being a successful salesperson in the 3D printing industry requires more than just technical knowledge. One must possess a range of traits and skills that define salespeople in any other industry. Being a good listener and advisor, as well as knowing the market, is essential. Due to the logistical constraints of the Parzęczew municipality, this idea is more likely to be feasible in the long term. Online sales would be a suitable approach in this case.

2. Sales of 3D Printer Consumables

To effectively generate leads that lead to the sale of such products, one must not only have extensive knowledge of materials but also sales skills, similar to those required for 3D printers. Therefore, individuals with experience in sales, which is significantly more demanding than knowledge of additive technologies, will excel in this area. A large number of commercial contacts with potential clients and the ability to negotiate collaboration terms are crucial. An alternative to selling filaments for budget 3D printers includes resins and powdered plastics. Interest in SLA and SLS technology has significantly increased in recent years, along with the applications of additive technologies in industry. Many industrial companies now use resin and powder 3D printers, creating a need for material replenishment. There are relatively few local distributors of specialized materials, which extends the delivery time from manufacturers in other regions.

3. 3D Printer Maintenance

The number of 3D printer owners continues to grow, leading to increased demand for maintenance services, especially when the manufacturer has exited the market. Some entrepreneurs offering budget solutions do not even provide such services as part of the device's sale. Additionally, devices produced in China often require modification and servicing before their first use. A person with knowledge of basic electronics and mechanics would excel in the role of a 3D printer technician.

4. 3D Design

The 3D printing industry is still dominated by professionals. Its biggest problem is the constant influx of new individuals lacking the necessary competencies, which negatively impacts service quality. 3D design is currently the most sought-after skill in the service market. This is not just about simple detail modelling but involves creating spatial models, incorporating engineering knowledge in plastic processing. Specialists are needed who can, for example, design a detail considering material

shrinkage during the 3D printing process, optimize geometry for 3D printing, or prepare it in a way that eliminates a range of issues related to subsequent processing.

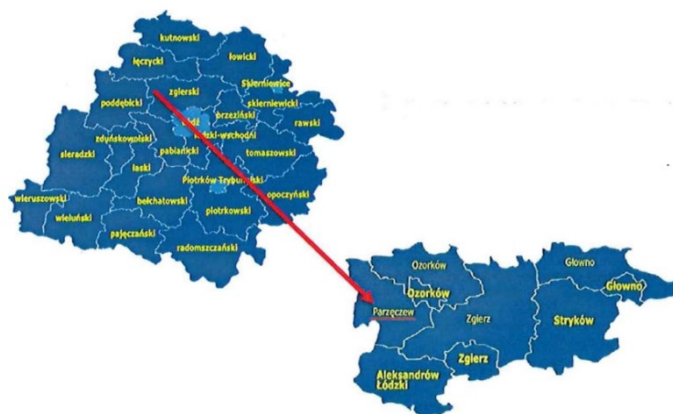
Proper project optimization for 3D printing helps save time and money without compromising mechanical properties.

Parametric design optimized for additive technologies requires a combination of 3D design knowledge and additive manufacturing expertise. The 3D printing industry needs specialists in this field, and a significant advantage of this career path is the initial investment. The largest expense is the software. However, there are free programs available that can eliminate this initial cost factor.

ENVIRONMENTAL ANALYSIS – SELECTED ELEMENTS OF THE DEVELOPMENT STRATEGY FOR THE PARZĘCZEW MUNICIPALITY FOR 2021-2023 AND RELATED BUSINESS PLAN CONCLUSIONS

1. Demographic Data

The Parzęczew Municipality covers an area of 103.9 km², placing it fifth in Zgierz County. The municipality comprises 44 villages, organized into 23 administrative districts and one housing estate.



The location of the Parzęczew municipality in the Łódź Voivodeship and the Zgierz County. (Source: gminy.pl)

By the end of 2020, the population of the Parzęczew Municipality was 5,125 (according to population records), representing 3% of the total population of Zgierz County. The area has a higher number of men than women. Over recent years, the population has slightly increased. The municipality predominantly consists of people in the working age, accounting for 61.51% of the total population.

In the town of Parzęczew, there are: a branch of the Cooperative Bank of Ozorków, a branch of the Ozorków Post Office, the Municipal Utility Company, the Municipal Health Centre, the Social Welfare Center, an elementary school, a preschool, the Municipal Public Library, the Forum of Creative Initiatives, the Development Foundation for Municipalities "PRYM," the Local Action Group Association "PRYM," the Fishing Local Action Group Association "With Roe," the "Creative Parzęczew" Association,

the Cycling and Tourism Association "PELETON," the "Friends of Plastuś" Association, the Volunteer Fire Department, the "Orzeł" Parzęczew Sports Club, the Parzęczew Football Academy Association, and the "Dolina Skrzatów-PS."

2. Location and Development

According to the Municipality's Strategy for 2021-2030, a characteristic feature of the Parzęczew Municipality is the coexistence of agricultural functions, primarily in its northern part, and recreational-residential functions in the southern part, which is noted for its significant forest coverage. Furthermore, the Parzęczew Municipality has a low percentage of industrial, warehousing, and service activities. Detailed analysis of investment status and areas designated for investment indicates that currently, about 20% of the municipality's area is developed.

3. Waste Management

The municipal waste management system covers 4,972 people. Municipal waste from the municipality is collected in mixed and selective forms. Selective waste (paper, plastics, metal, multi-material packaging, glass, and bio-waste) is collected in appropriate bags. Selective collection is also carried out at the Municipal Selective Waste Collection Point (PSZOK) for the following fractions: expired medicines and chemicals, used batteries and accumulators, electrical and electronic equipment, furniture and other bulky waste, construction and demolition waste, used tires, multi-material packaging, biodegradable waste, paper, metal, plastics, and glass. Additionally, selective collection of furniture and other bulky waste, used electrical and electronic equipment, and used tires is carried out during periodic collections twice a year at the point of origin. Some bio-waste is composted by residents.

In 2020, 1,694.95 Mg of waste was collected from property owners in the Parzęczew Municipality, while 103.9 Mg of waste was collected at PSZOK. In 2020, the Parzęczew Municipality achieved recycling levels required by the Minister of Environment's regulation of December 14, 2016, on the levels of recycling, preparation for reuse, and recovery by other methods of certain fractions of municipal waste (Journal of Laws of 2016, item 2167). The recycling level for the fractions of municipal waste: paper, metals, plastics, and glass (in 2020) was 51.56%. The recycling level, preparation for reuse, and recovery by other methods for non-hazardous construction and demolition waste (in 2020)

was 100%. The level of reduction of biodegradable municipal waste sent to landfills (in 2020) was 20.52%.

4. Economy

The economic zone of the Parzęczew Municipality is characterized by average growth in economic potential. The key economic indicators achieved by the municipality are higher than those of Zgierz County. In terms of the dynamics of economic potential development, a municipality like Parzęczew, being distant from a large city, needs to seek development factors based on its own potential, particularly the entrepreneurship of its residents and natural assets, as well as creating competitive conditions for large investors. It should be noted that the municipality has many micro and small enterprises, so it is important to create increasingly better conditions for their growth. Support in the form of consulting services on obtaining grants for business development or preferential loans, as well as organizing training, is necessary. Such activities could be managed by the upcoming Regional Development Centre in Parzęczew, which will provide conditions for organizing workshops and training for potential future entrepreneurs and community activation.

Moreover, there is an opportunity to activate the economic potential of rural areas towards economic and ecological agricultural activities and activities related to or beyond agriculture.

However, advice is also important in this direction, especially for young farmers who are shaping their business profile. Additionally, the municipality should utilize its investment areas in Parzęczew and Bibianów to attract a major strategic investor, which would impact the labour market.

5. Tourism and Culture

Entities by ownership sectors	2013	2014	2015	2016	2017	2018	2019	2020
Total national economy entities	361	373	394	402	412	408	431	455
Public sector - total	28	28	28	25	27	27	27	27
State and local government budgetary units	7	7	7	8	6	6	6	4
Private sector - total	333	345	366	373	385	380	403	427
Individuals conducting business activities	255	264	276	280	289	288	309	344

Commercial companies	26	26	29	29	32	26	26	25
Cooperatives	3	3	3	3	3	1	1	1
Associations and social organizations	14	14	20	23	23	24	25	26

The development of tourism in the Parzęczew Municipality is supported by natural conditions, including extensive forest complexes and water bodies. Historical monuments and places of historical memory, as well as the continuously developing recreational infrastructure, can also attract tourists.

Historic sites in the Parzęczew Municipality include:

- The brick parish church of Our Lady of the Assumption in Parzęczew, built in 1802 at the initiative of the Stokowski brothers from the nearby Piaskowice.
- The wooden church of St. Roch in Parzęczew, built in the 16th or early 17th century. Legend has it that this church was gifted by King Sigismund Augustus to Wojciech Piaskowski, the owner of the village of Piaskowice.
- The wooden church of St. James the Apostle in Leźnica Wielka from the early 18th century, maintained in Baroque style.
- The wooden water mill in Chociszew from 1918, built on the site of an older mill from the 17th century, which used the waters of the Bzura River (mill stream, water drive, mill wheel). Currently, it is moved about 25 meters from the river and has an electric drive.
- The brick two-story pavilion built around 1920 in Parzęczew (now a training and conference centre).

On the edge of the former town, in the manor park area, there is a mound, a relic of a historic settlement dated to the 14th-15th centuries, surrounded by a cluster of trees and shrubs, among which several old beech and oak trees are recognized as natural monuments.

The southeastern part of the Parzęczew Municipality is particularly attractive for tourism, with high natural values, including rivers such as the Bzura and Linda. This area is becoming an important centre for recreation and relaxation, as evidenced by the expanding network of holiday cottages and so-called second homes, mostly belonging to residents of the Łódź agglomeration.

In these areas, there is the only agritourism farm in the Parzęczew Municipality, "Synowcówka." Located in Tkaczewska Góra, this farm has recreated the atmosphere of an old village through appropriately designed buildings and their furnishings. The owners of "Synowcówka" maintain traditional practices related to food processing and bread baking. "Synowcówka" is a winner and laureate of the "Golden Pear" competition for the best agritourism farm in the Łódź Voivodeship.

Another attraction in these areas is the Chociszew Valley of Gnomes – the Park of Gnome Stories, Fun, and Exhibitions. This picturesque place, surrounded by forests, features dozens of figures, houses, intricately arranged streets, bridges, and ladders, where meetings with a Gnomologist take place. In the Valley of Gnomes, dynamic storytelling activities are organized based on Gnome life scenarios, interspersed with puzzles. The story is enhanced by workshops for making old Slavic toys, learning through play, viewing models, and live exhibits.

The entire experience promotes permaculture – an ecological branch consisting of three principles: caring for the Earth, caring for people, and sharing the surplus of essential resources. The "Gnomes" show visitors how to incorporate permaculture principles into daily life.

Among the municipality's tourist attractions are two water bodies: the reservoir in Parzęczew with an area of 1.58 ha and the artificial reservoir in Leźnica Wielka with an area of 14.5 ha. The area around the Parzęczew reservoir has previously served as a venue for municipal cultural and entertainment events. A comprehensive redevelopment of this area, including the construction of a bike path, is planned for 2022-2023.

The second reservoir, located in Leźnica Wielka, is an artificial body of water that previously served as a supervised bathing area. The beach, campsite, and sports fields for beach volleyball, volleyball, and soccer require renovation and better development to restore its former recreational functions.

Near the reservoir is the largest accommodation facility in the Parzęczew Municipality - the Korona Palace Hotel in Leźnica Wielka. This modern banquet and conference center has guest rooms and offers three ballrooms – one large and two smaller, one large conference room, and nearly forty guest rooms. Korona Palace also features a SPA & Fitness area and an English-style garden. The hotel offers training, conference, business meeting, and event organization services.

The Parzęczew Municipality encourages hiking and cycling tourism. Its area is traversed by the "Battle of the Bzura" hiking trail and four cycling trails:

- "Po Ziemi Parzęczewskiej" – a local trail,
- "W centrum Polski" – a regional trail,
- "Szlak Okolic Poddębic" – a regional trail,
- "Łódzka Magistrała Rowerowa" – a national trail.

Additionally, the Parzęczew Municipality hosts the National Masters Cycling Races for the Polish Cup at various frequencies.

These races are organized by the Parzęczew Municipality and the Cycling and Tourism Association PELETON. Participants include cycling enthusiasts ranging from preschoolers to competitors over eighty years old, both amateurs and professionals from across the country. Cyclists race over distances up to 90 km on routes through the Parzęczew Municipality and neighboring municipalities in Poddębice County.

Summary

In summary, the Parzęczew Municipality is one of the smaller rural municipalities in the Łódź Voivodeship, covering an area of nearly 104 km². The municipality features various forms of nature protection, numerous historical monuments, and tourist trails. It has a well-developed recreational infrastructure, including playgrounds, outdoor gyms, and sports fields, which is continually expanding, such as the new pumptrack opened in 2023. Areas with exceptional natural and scenic values within the municipality are popular destinations for day trips, particularly cycling and hiking tours. To attract more tourists, further investment in recreational infrastructure is crucial.

The Parzęczew Municipality does not have its own public transportation system. Only two public transport routes operated by PKS Łęczyca Sp. z o.o. pass through the municipality, running along the main county roads. The limited transport capacity and lack of internal communication could pose greater challenges in the future, especially as the aging population will need improved access to healthcare and social services. To better connect Parzęczew with larger cities, the potential of the existing PKP Chociszew and PKP Ozorków/Nowe Miasto stations, serviced by Łódź Agglomeration Railway, should be utilized. Improved internal transportation would enhance residents' access to larger

cities where they study and work. The lack of communication leads to social exclusion in job searching, which in turn affects social status.

The technical infrastructure of roads is at a poor level. Over half of the roads are unpaved or gravel, which causes travel difficulties and negatively impacts environmental quality. The Parzęczew Municipality is progressively working on constructing new roads with asphalt surfaces. There are no large industrial plants within the municipality that pose significant environmental burdens.

The biggest environmental threat is air pollution, mainly caused by low emissions from household heating systems. Efforts should focus on social campaigns promoting eco-friendly heating methods and renewable energy sources. Another important issue is municipal waste management. The low competitiveness of companies providing these services results in high costs for residents, and solving this problem is not easy and does not stem from the poor intentions of the municipality's management.

The desired state, both for the environment and the municipal budget, is to slow down the increase in waste production while maximizing the percentage of waste segregation. The first step towards this goal could be the construction of a modern Municipal Waste Selective Collection Point (PSZOK) within the municipality. An important action is to conduct social campaigns among residents and install proper eco-friendly attitudes from an early age for the benefit of the environment.

CONCLUSIONS FOR THE 3D PRINTER BUSINESS PLAN

The Parzęczew Municipality is a small agricultural municipality with poor road infrastructure and limited economic base. Its geographical location does not facilitate attracting investors. In terms of waste management, it only meets the minimal required levels. On the other hand, an important asset of the municipality is tourism, which, based on various local entrepreneurs' and non-governmental organizations' initiatives, helps build potential. Considering these factors, implementing a closed-loop economy model involving 3D technology seems unrealistic.

Based on the above analyses, a less ambitious plan for applying 3D technology in waste management could include:



1. Preparing the premises

This could involve a small commercial space or, if unavailable, a container. The premises should include a "production" area, a small filament storage area, and office and sanitary facilities.

2. Purchasing a basic 3D printer

An example of a basic 3D printer suitable for starting a machine park with minimal investment risk is the Creality Ender-3. This model is excellent for fast and affordable 3D printing of detailed objects. It is equipped with features like a heated bed up to 110°C, an active cooling nozzle, and an automatic print resume function after power outages. It has a built-in 24V power supply, so it only requires connection to a power source with a voltage of 110 to 240V (50 or 60 Hz).

Project data can be delivered to the device online or via an SD card, with supported file formats including STL, OBJ, and G-Code (using software like Cura, Repetier-Host, or Simplify3D). As the business grows, the technology park can be expanded with more advanced 3D printers.

3. Offering less advanced 3D printing services

- Given the municipality's specifics and the need to minimize investment risk by purchasing a cheaper printer, the initial offering will focus on:
- Individual customers: printing figurines for game enthusiasts, model making, simple jewellery, custom gadgets, parts for household equipment, toys, decorations, and items like custom-designed phone cases, designer jewellery, keychains, and everyday items.
- Clients needing interior accessories: e.g., headphone holders, accessories, and spare parts for household and electronic devices.
- Schools: production of educational aids and custom gadgets.
- Entrepreneurs: simple components for machines and devices.
- The tourism sector: especially in the Gnome Valley, such as creating souvenir figurines for visitors.

Most of these products can be created from free designs that can be customized for the client.

4. Diversifying the offer with additional services

- Due to the limited range of 3D printing services, additional services will be needed to diversify revenue sources and utilize available resources. Initial phase offerings could include:

- Workshops for schools on 3D printing – a valuable audience that will return if attractive activities are offered.
- Educational shows for tourists as an addition to the Gnome Valley offer.
- Ecology training and workshops with a focus on the closed-loop economy model – both on-site (as part of the tourism offer) and online, covering topics like creating products from recycled materials, composting workshops, and repair cafes.
- Education and implementation of the closed-loop economy model for other municipalities.
- Selling tutorials and ready-made designs for beginners who cannot design them independently.

As the business develops, additional offerings could include:

- The sale of 3D printers, due to the logistical conditions of the Parzęczew Municipality, is more likely to be implemented in the form of primarily online sales based on dropshipping. The cornerstone of this logistical model is cooperation with a dropshipping warehouse, which delivers products directly to the end customer, i.e., the person ordering them from the store. Dropshipping is widely used by new and developing online stores because it allows ordering products only after they have been sold. Selling without maintaining inventory offers real benefits, including: Ordering from the warehouse without a minimum logistical order, Minimizing the costs of operating an online store, Access to a very wide range of products
- Order Fulfillment Process in Inventory-Free Sales



(Source: <https://dofirmy.pl/pl/i/Dropshipping/18.>)

- Selling consumables for 3D printers – as a distinguishing feature that generates leads leading to product sales, besides standard sales tricks, you can focus on building a brand in relation to the idea of sustainable development.
- 3D Design – The 3D printing industry currently has the most in-demand skills in the service market. Competitive advantage can be built based on Łódź's resources as an academic city.
- 3D printing of complex products – as the venture develops and the market is better understood, it will be possible to invest in more advanced 3D printing technologies using various raw materials.

5. Educating society on waste segregation

Conducted primarily as educational services offered by the company, supplemented by projects in collaboration with local NGOs and schools.

6. Introducing a waste management motivation system

Develop a motivation system for waste segregation based on public consultations, such as local tax discounts, 3D printing discount cards, competition awards, or village rivalry.

7. Building a logistics chain: waste-sorting-filament production

Utilize the planned waste sorting infrastructure within the municipality's Development Strategy and optimize the logistics path between the sorting facility and eco-filament manufacturers. Consider whether this second stage should involve cooperation with neighbouring municipalities to achieve economies of scale.

8. 3D printing with eco-filament

Design and print using materials derived from recycling as primary materials, and educate clients about this approach.

9. Creating 3 jobs

Based on the above assumptions, create three positions:

- 3D printing and design specialist

- Education and sales specialist
- Driver and logistics coordinator

10. Educating and implementing the model for other municipalities

After implementation and verification of the model, share best practices, exchange experiences, and build an educational platform.

SUMMARY

3D printing is undoubtedly an interesting and growing industry where both experienced professionals and newcomers can operate. The entry threshold is lower than it was a few years ago—3D printers have become cheaper, easier to purchase, and there are more courses and specialized guides available about printing itself. Therefore, if you have an idea, knowledge, and initial capital, it's definitely worth a try.

This technology is evolving and offers new possibilities, especially in the area of sustainable development. Everyday objects made from recycled materials are no longer surprising. The circular economy continues, and we can expect more products made from so-called secondary raw materials. One example is the new product line Tarfuse rPLA, which consists of 3D printing filaments made from granules that are 100 percent industrially recycled. This material is produced from the reuse of residual waste.

Grupa Azoty began the commercial sale of products for FDM technology under the Tarfuse brand in March 2020. The basic raw material for the filament line (materials used by 3D printers in the process of spatial printing) is polyamide 6 produced by Azoty and its modified varieties. Importantly, the new recycling filament line has mechanical and utility properties comparable to the basic Tarfuse line. "3D printing products are produced in Tarnów. We are consistently modifying our product portfolio in line with the idea of sustainable development. We continuously seek solutions that allow us to introduce products that address, among other things, the challenges posed by the circular economy. The new line of filaments made from granules that are 100 percent industrially recycled is an excellent example of how we are implementing the circular economy in our technologies," says Tomasz Hinc, President of the Management Board of Grupa Azoty.

Polylactic acid (PLA) is a fully biodegradable polymer belonging to the group of aliphatic polyesters. It is derived from renewable resources, such as corn flour. It decomposes in the natural environment in the presence of microorganisms. At the end of the biodegradation process, only natural and harmless substances remain, such as water, CO₂, and organic matter. "The new line from recycled material is yet another modification of the original Tarfuse line. We see that an increasing number of our customers are not only focusing on product quality but also on how they are produced and their

environmental impact. We have the technology and experience to meet all these requirements," says Grzegorz Kądziałowski, Vice President of the Management Board of Grupa [Azoty](#).

Last year, Azoty introduced the Tarfuse envi line for 3D printing—biodegradable and eco-friendly filaments made from thermoplastic starch. Due to their structure, they undergo rapid biodegradation. The Tarfuse envi recipe was developed with environmental protection in mind—during degradation, it releases less CO2 into the atmosphere.

The direction indicated by Grupa Azoty is not a venture for Gmina Parzęczew, but it can serve as inspiration for creating larger, more resource-rich systems that realize the principles of sustainable development based on 3D printing with recycled materials. This is an excellent starting point for forming regional or sector-specific clusters where circular business models can be developed. *The book "Waste to Wealth" presents the concept of dividing circular business models into five groups:*

- 1. Closed Supply Chain - Providing renewable energy and/or bio-based materials that can be fully recycled. This allows for repeated use of the same resources.*
- 2. Recovery and Recycling - Recovering useful resources or energy from disposed products, turning waste management costs into revenue from responsible resource management.*
- 3. Extending Product and Component Life - This includes repairing, updating, and reselling to generate revenue from the product's lifecycle, rather than from the sale of the products themselves.*
- 4. Sharing Platform - Enhancing product utilization efficiency by enabling consumers and/or businesses to share and exchange goods through a centrally provided service.*
- 5. Product as a Service - Offering access to a product rather than ownership, allowing customers to pay only for its effective use while ensuring maximum durability, updates, and servicing of the products.*

(Source: <http://circularhotspot.pl/pl/zrownowazona-produkcja-modele-biznesowe>)

Gmina Parzęczew could be an inspiration for finding local solutions that create one of the above models.