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Introduction to Fused Filament Fabrication (FFF) 3D printing technology

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Introduction to FFF: Fused Filament Fabrication

3D Printing Technology, technically acknowledged as Additive Manufacturing (AM) or Rapid Prototyping, is a manufacturing process where layers of material are built up to create a solid object. There are countless 3D printing technologies, each with its own benefits depending on the application, but this report will focus on Fused Filament Fabrication (FFF) for plastics.

Additive manufacturing technologies

Material Extrusion	Vat Polymerization	Power Bed Fusion (Polymers)	Material Jetting	Blinder Jetting	Powder Bed Fusion (Metals)
FFF	SLA DLP	SLS	Material Jetting DOD	Blinder Jetting	DMLS SLM EBM
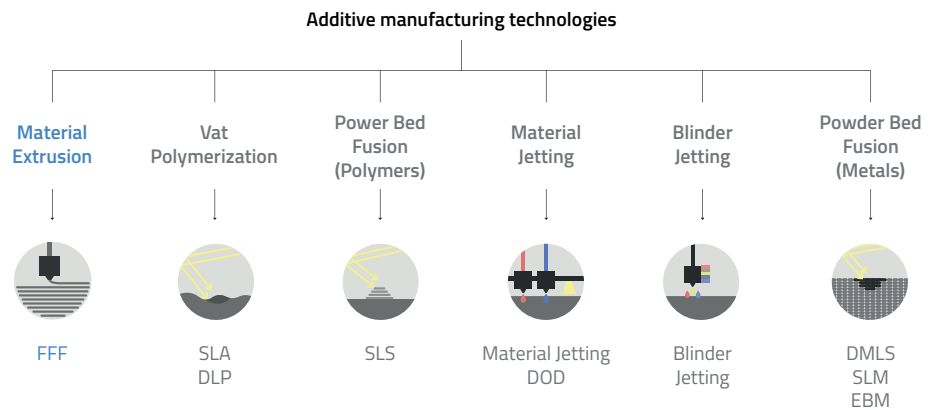
FFF is an extrusion process where the object is built by depositing melted material layer-by-layer. The plastics used, corresponds to the same thermoplastics that can be found in conventional manufacturing processes, such as ABS or Nylon.
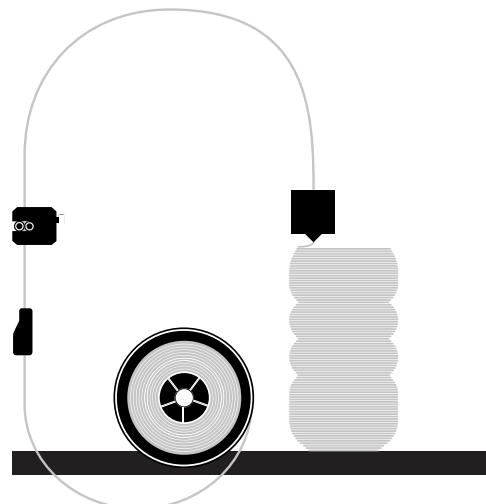

Figure 1. Fused Filament Fabrication basic illustration

Fused Filament Fabrication

Lately, the introduction of in-house 3D printers has widened access to this technology. FFF led this expansion of desktop 3D printers and nowadays it is the most widespread 3D Printing Technology in the market. This was essentially due to the low initial investment needed, the immense variety of applications offered and the little specific knowledge required to access and use this technology.

Figure 2. Main advantages FFF Additive Manufacturing technology

Variety Of Applications

Low Initial Investment

No Specific Knowledge

This introduction has widespread in a large diversity of industries, where 3D printing technologies are revolutionising the way things are manufactured. The versatility and ease of in-house printers, has allowed companies to speed up their product development processes and production.

Since FFF technology has been present for almost three decades and the progress experienced has been significant, both businesses and customers demand high-quality end-use outcomes and printer reliability. That is why FFF 3D Printers manufacturers have worked in improving the quality of their final prints and the trend is to produce professional or industrial-grade machines.

If your business is planning to introduce FFF Printers into its workflow, it is crucial to understand how they operate and which printer will better fit your needs. In this article, some fundamental features of FFF are going to be introduced, as well as the several alternatives users have when they need to print their models.

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How does FFF work?

As previously introduced, FFF consists of an extrusion process of melted plastic. In order to generate the part, a print head travels around the printing surface depositing the material. Here is the FFF fabrication workflow:
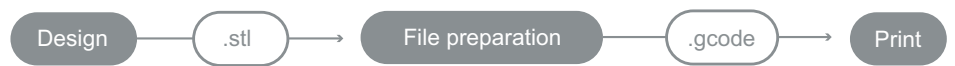
Design → .stl → File preparation → .gcode → Print

Figure 3. Workflow 3D printing

• The first stage consists of generating the 3D model with any design software, such as Solidworks, Catia, Rhino or Inventor. The 3D model needs to be exported in STL format.

• File preparation: To configure the model to be printed, it is necessary to use a slicing software where all the printing requirements will be included. This configuration will contain the material selection and the nozzle size of the printer. The software also separates the model into layers and the printing quality, and movement commands can be configured.

• The printing phase is the deposition of the melted plastic and consists of 3 stages:

  1. A filament spool is loaded into the printer. The nozzle has to reach the melting temperature of the raw material and then the filament is fed into the print head, where it will be melted.

  2. The print head is able to move over the printing surface in the X, Y and Z directions. It deposits the plastic to create a thin layer, cooling down the filament until it finally solidifies.

  3. When the previous layer is finished, the printing surface moves down and the next layer is deposited. This process is repeated until the model is completed.

How does FFF work?

Part
Filament

Extrusion
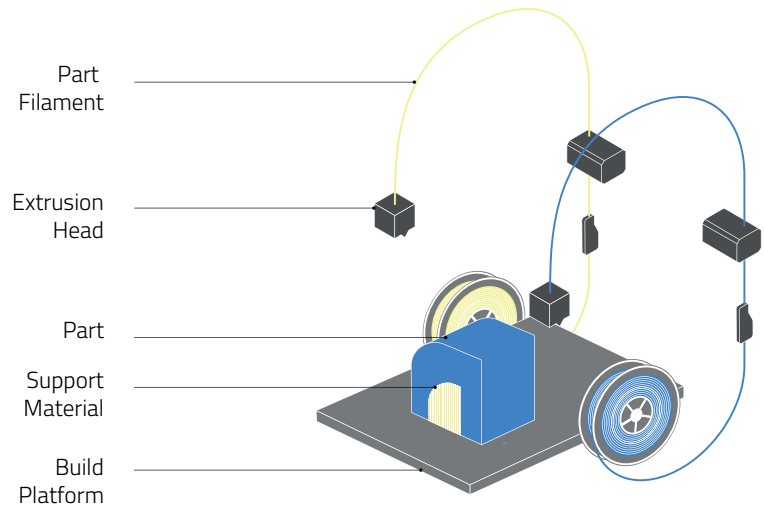Head

Part

Support
Material

Build
Platform

Figure 4. Basic illustration of a desktop 3D printer

Because of the manufacturing strategy, sometimes it is required to build auxiliary support structures for those models with overhangs shallower than 45° from the horizontal plane. A secondary extruder with a different material is dedicated to create these support structures.

03 In-house desktop 3D printers: FFF vs SLA

The most popular 3D printing technologies are FFF and SLA. SLA consists of a liquid photopolymer selectively cured by UV light. Both technologies will be now compared in order to define which are their benefits and disadvantages.

• Materials and Derived Costs
One of the main interests of FFF printers is that they accept a large range of printable materials. Users can find materials to fulfill all part requirements in terms of mechanical resistance, elasticity or stiffness, whereas SLA printers can only use resins, limiting the variety. Resins' mechanical properties are mostly poor, making them useful for visual aids and not for practical use.

The price of materials has also a major influence when choosing the machine, as FFF raw material costs around 25€/kg and SLA resins are up to 100€/kg. When extrapolating to a whole year it accounts for a substantial difference, even more considering SLA implies extra processing and waste costs.

• Equipment
SLA printers normally require a special work area with the following conditions: equipment to post-process all the printed parts, protection from the UV light and safety, storage and disposal equipment.

FFF Desktop printers need equipment to remove water-soluble supports, but there are no complexities in material storage or disposal.

• Level of Detail
SLA creates parts with a smooth surface finish directly off the machine, presenting a high level of detail and accuracy. FFF has also high accuracy and is able to print fine details using small nozzles, but the layer lines will be always visible.

FFF vs SLA

· **Intricate Parts**

FFF printers that use Dual Extrusion Technology are able to generate water-soluble supports to produce complex geometries with smooth surface finish. SLA is only able to use one material at a time, so the part and the supports must be the same and the removal of supports is exclusively mechanical. That may damage the surface and causes a loss of surface quality.

Both FFF and SLA printers are both excellent options. The main fact is not which technology is better, but what your business needs to accomplish with the printer.

		FFF Desktop	SLA Desktop
MATERIALS	Technology	Fused Filament Fabrication	Stereolithography
	Material recommendations	· Material is inert and harmless before and after printing. · Store in a cool, dry place.	· Requires special handling equipment (chemical-resistant gloves), resins are skin-irritant and may cause eye irritation when uncured. · Material needs to be shaken regularly to avoid pigment settling. · Store in a cool, dry place.
	Accepted Materials	· Wide range of thermoplastic materials. · Material cost is low. · Medium flexural strength. · Work for functional applications. Properties depend on layer adhesion and orientation.	· Resins, limited range of materials. · Material cost is medium-high and there are derived processing and waste costs. · Low flexural strength. · Not possible to produce functional parts. Not suitable for outdoor use.
	Materials - Global score	● ● ● ● ○	● ● ● ○ ○
WORK AREA	Working area	· Can be used in any work area (office environment or industrial plant).	· Work area protected from natural light, not suitable for all environments. Not usable near ignition sources.
	Equipment required	· Water-soluble support removal system.	· Post-processing equipment. · Rinse tanks with IPA. · UV Light booth. · Storage and disposal equipment.
	Waste	· Parts and excess material can be disposed of in regular waste.	· Liquid resin waste requires special disposal, as it is classified as hazardous waste.
	Work Area - Global score	● ● ● ● ○	● ● ● ○ ○
DETAIL	Complex Designs	· Potential for dual material with dissolvable support.	· Single material with mechanical removal of support.
	Detail	· Limited detail, high accuracy, layer lines visible.	· High detail and accuracy, layer lines hard to see in some cases.
	Detail - Global score	● ● ● ○ ○	● ● ● ● ○

Figure 5. Comparison table - FFF vs SLA desktop 3D printers

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Professional desktop vs industrial 3D printers

The FFF technology market, has different printer categories in relation to price and printing quality. In this section, the focus will be to compare Professional Desktop Printers and Industrial FFF Printers.

	Professional Desktop Printers	**Industrial FFF Printers**
Project Lead Time	<24 hours	<24 hours
Initial Cost	2.500€ - 7.500€	40k€ - 250k€
Material Cost	~25€/kg	~125€/kg
Print Cost vs Professional Desktop Printers	1x	5x
Costs: Long Term	Basic machine maintenance	Mandatory service contract (~10k€)

Figure 6. Comparison table - Professional desktop vs industrial 3D printers

· Costs

The initial investment makes the first significant difference between both types of printers, as the price of an Industrial FFF Printer is at least 20 times the price of a Professional Desktop Printer. Material costs are lower in the latter case and maintenance costs evidently lower as the purchase of an industrial FFF printer includes mandatory service contract.

· Lead Times

The leading times are approximately the same. Both machines are limited by the FFF technology. An Industrial FFF Printer can handle high number of models in a single print job due to its massive printing volume. Some Professional Desktop Printers can reduce lead times using high-productive printing modes. These modes can print two identical parts or one part and its symmetrical simultaneously, doubling the productivity.

· Accessibility

Professional desktop printers can be used by anyone, as their setup and use are intuitive. The interaction with the machine is simple and prepared for non-expert users, including guided and detailed assistants. Since the use of an industrial printer is normally more complex, it requires specialized technicians and dedicated workspaces.

Professional desktop vs industrial 3D printers

• **Quality**

Thanks to their controlled environment throughout the machine, Industrial FFF Printers offer a higher degree of accuracy than professional desktop printers. However, the level of detail that can be achieved is similar. Using different nozzles sizes, professional desktop printers can adapt to any part or geometry, ranging from complex details to rough, big prints.

Finally, the available range of loadable materials for Professional Desktop Printers is wide, as they often accept filaments from other manufacturers. Industrial Printers do not offer a broad range of filaments, as they only accept certain materials to minimize interference and ensure the quality standard of the end result.

Figure 7. Quality comparison table - Professional desktop vs industrial 3D printers

	Professional Desktop Printers	Industrial FFF Printers
Standard Accuracy	± 0.20 mm	± 0.15 mm
Layer Thickness Range	0.05-0.5 mm (depending on the nozzle diameter)	0.15-0.5 mm (depending on the printer)
Printing Surface	Medium	Large
Common Materials	PLA, ABS, PETG, TPU, PA. Accepts filaments from other manufacturers	ABS, PC, ULTEM. Only filaments accepted by the manufacturer

05 Outsourcing 3D printing production

In those cases when the number of parts to produce is low and the usage is planned to have low frequency businesses may consider to outsource the 3D printing service. If the plan is to work in a medium-long term project, the acquisition of 3D printers can considerably reduce costs. This acquisition implies an initial investment, but then the price per part is approximately 20 times cheaper.

*Figure 8. Comparison table - Professional desktop 3D printers vs Outsourcing*

	Service Bureau	Professional Desktop Printers
Project Lead Time	1-2 weeks	<24 hours
Initial Cost	0€	2.500€ - 7.500€
Print Cost vs Professional Desktop Printers	20x	1x
Costs: Long Term	N/A	Free two-years warranty
Accessibility	· External. · Internal designs are sent to strangers. · Limited number of design iterations.	· Internal. · Designs are not shared. · Unlimited number of design iterations.

Outsourcing 3D printing production

• Example: uHandle

In order to analyze when it is necessary to outsource production, we are going to look into the uhandle user case. uHandle is a company that tries to help leprosy patients on its daily life avoiding stigmatization, developing tools and other devices that will assist them in their daily needs. Although leprosy can be cured, this illness affects poor countries with no resources to treat the patients in a proper way. This disease affects the skin and the external nervous system, causing deformation in hands and feet. It is very important to facilitate the production of customized devices and tools to help these patients.
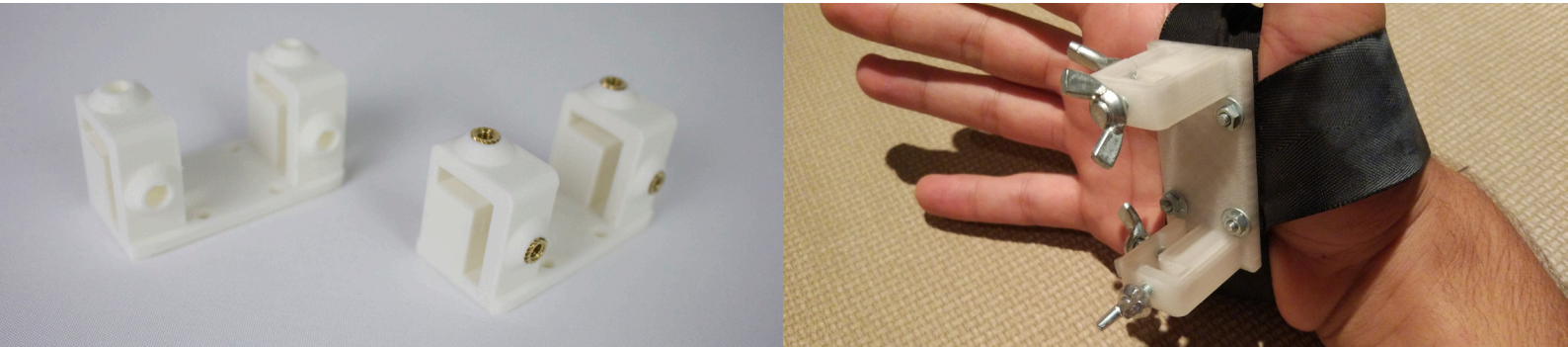
In this case, the studied tool aims to help the patient to hold cutlery, making them more autonomous to eat improving feeding and patients' selfesteem. The price of producing this part with a Professional Desktop Printer is 0,50€ while outsourcing it would cost approximately 15€. The following figure compares both options.
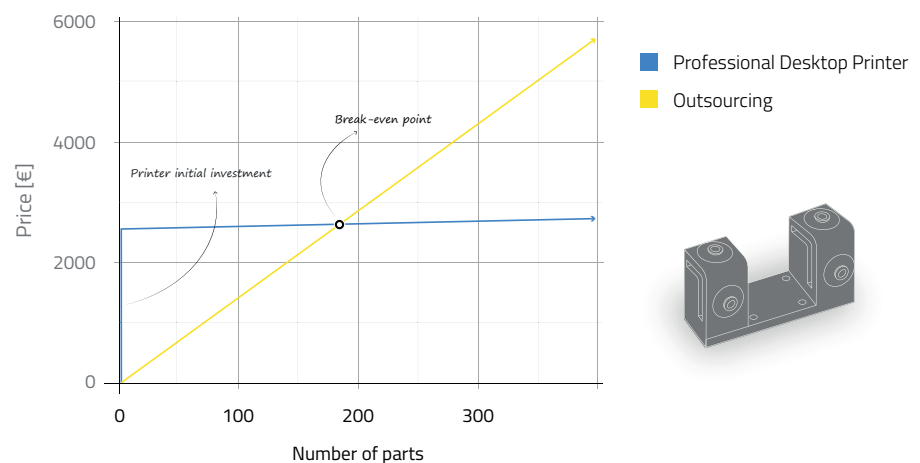

Figure 9. Production parts comparison graph - Professional desktop 3D printer vs Outsourcing

Should the number of parts to be produced had been under 180, outsourcing the production would have been the best solution in terms of costs. However, the goal was to produce at least 300 units of the device. Based on this, uHandle decided to invest in a Professional Desktop Printer to obtain a long term benefit.

Additionally, using its own printer, uHandle could also develop the product with several iterations in order to fully optimize the design. By purchasing its own in-house Professional Desktop Printer uHandle gained flexibility. The company was able to develop the product observing several iterations and was able to fully optimize and tailor the end design.

06

Which solution better fits your needs?

As explained before, there are many options when choosing how to print the 3D models. It is important to define all the requirements and select which might be the best option. In the following graphs, the cost per part and the project lead time of a generic part of 50cm3 has been calculated in different manufacturing processes.
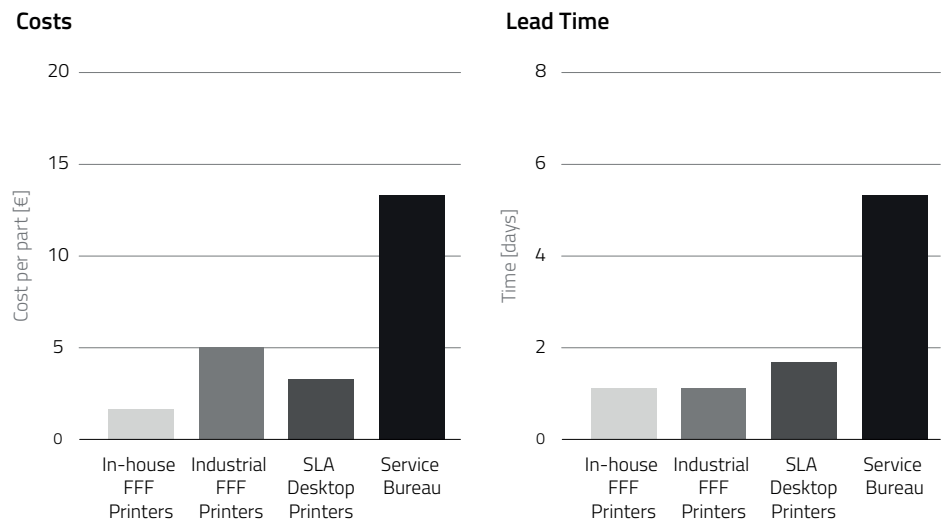
Costs

Lead Time

In-house FFF printers offer the best combination of costs and lead times. However, investing in both FFF and SLA printing technologies will give your company full versatility when producing parts. Each technology has its own benefits and applications, so the answer to the following questions about your 3D printing needs will be crucial when choosing the best solution for your company.

- What is my budget?
- Does my company have specialized equipment to support the 3D Printer?
- Do I have a need to print out mechanically demanding parts?
- Will there be designing and application versatility?
- How many printed parts does my company required?
- What is the lead time my company requires?

Maximizing productivity
with the most versatile 3D printers

If you are considering implementing 3D printing technologies into your workflow, ask for a BCN3D Sample Part in the following link in order to see the results of a professional FFF 3D Printer **Request a Free sample >**

Explore more about 3D printing. **Learn more >**

Wondering what's new in the 3D printing world? **Use Cases >**

Request a quote for a professional desktop 3D printer. **Request a quote >**

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