FEASIBILITY STUDY: PRODUCTION OF RECYCLED 3D PRINT FILAMENT

MARCH, 2016

Content

1. Summary

3D filament is the basic consumable resource that most types of 3D printers use for printing. As a traditional printer needs ink cartridges in order to print, 3D printers need plastic filament. Most of the filament produced today is from virgin, unused petroleum based plastic which generates not only increasing amounts of global waste but contributes to carbon emissions, resulting in significant environmental damage. This provides a unique recycling opportunity to make filament out of used, plastic waste, specifically from PET plastic, which is the basis of soda bottles, consumed by many people around the world.

This section summarizes the main findings of the feasibility assessment of filament production from recycled PET plastic waste and aims to identify market potential, challenges and opportunities, and the range of costs and benefits associated with several alternatives. The main findings are summarized below.

The 3D printing market is booming: it was globally valued at US$2.5 billion in 2013, and is estimated to grow to a staggering $16.2 billion market by 2018. Similarly, the market for polymers used in 3D printing for the production of filament reached $310 million in 2014 and is estimated to grow to $1.4 billion by 2019.[1]

Overall, additive manufacturing has become one of the most widely accepted emerging technologies and its services are being used by various industries like medical, automotive, consumer products, military, academics and others. However this new technology is not restricted to large industries and instead has also reached individual consumers. According to a recent Forbes article, a survey of 1,000 U.S. consumers found that one in three Americans would consider buying a 3D printer for their home in 2014.

Filament is produced through a simple six-step process: collect, clean and shred, extrude and spool, test package, and ship. The two main things needed are a supply of good quality, clean plastic and an extruder machine. Based on some basic assumptions, the cost of producing a spool of filament amounts to approximately $2.84 p/kg.

Currently the largest 3D printer markets are the USA, Germany, Netherlands and China. The Middle East and African markets are also expanding rapidly. The domestic East African market is currently very limited due to lack of knowledge, infrastructure and clear use cases, but has a high potential for growth. The target market for recycled PET filament can be either businesses (companies, universities, FabLabs) and/or individual consumers (3D print enthusiasts or home owners), both local and international.

Globally, a spool of filament is priced between $19-$175p/kg depending on material, diameter (mm), colour or other specific characteristics. In Tanzania, a spool of filament can cost up to $60-$80 including shipping costs from China.

Among the main challenges of the production of recycled PET filament is complexity of the distribution. This is particularly true if shipping to many locations as the shipping costs risk being very high. In fact, average shipping costs from Tanzania to different locations in

1 http://www.3dprinterworld.com/article/14-billion-plastics-sales-from-3d-printing-2019, accessed March 2016

Europe, the US, India or China range between $4,757 and $7,110 or $0.93 and $0.67 per spool, for a 20ft and 40ft container respectively. If the containers are not filled, the price per spool will be much higher. In addition to the shipping costs, import/export duties and tariffs need to be kept in mind. Each country has different regulations, requirements and fees. Last mile delivery can be as low as $8 (~€7) within a country such as the Netherlands (up to 10kg) but significantly more if the product has to be shipped overseas (e.g. up to $35 between the UK and the US).

Ensuring an ongoing, clean and high quality supply of plastic is also a significant challenge to producing recycled PET filament. This can be done either by working directly with waste pickers or through a third party (i.e. a local recycler who in turn works with waste pickers).

Additional challenges identified are creating a social brand in a market which is currently unbranded and increasing the popularity of PET filament as opposed to more widely used plastics such as ABS and PLA. On the other hand, there are significant opportunities in producing recycled PET filament. As mentioned above, the 3D printing market in booming in the US and Europe and growing rapidly in many other areas. In addition, the market for recycled filament is still relatively small and currently unbranded. There is a unique opportunity to create a strong social brand and to stay ahead of the technological revolution.

2. Introduction

3D filament is the basic consumable resource that most types of 3D printers use. As a traditional printer needs ink cartridges in order to print, 3D printers need plastic filament. Plastic filament is available in a variety of types of material, colours, diameters and lengths. An easy and nice material to print with is PET (PolyEthylene Terephthalate) and has become well known from plastic beverage bottles.

On the other hand, for more than 50 years global production of plastic has been on the rise. Some 299 million tons of plastics were produced in 2013, compared to 5.5 million tons in the 1950s.[2] Recycling remain insufficient and millions of tons of plastics end up in landfills and oceans each year.

So why produce 3D filament from virgin petroleum based plastic, increasing the amount of global waste, carbon emissions and environmental damage, when it can be done using recycled bottles? This report studies the feasibility of filament production from recycled PET plastic waste and aims to identify market potential, challenges and opportunities and the range of costs and benefits associated with several alternatives.

2 http://www.worldwatch.org/global-plastic-production-rises-recycling-lags-0 ;
, accessed March 2016

3. Background

3.1 3D Printing Market

In 2013 the 3D printing market, including 3D printer sales, materials and associated services was valued at US$2.5 billion globally, and estimated to grow to a staggering $16.2 billion market by 2018.[3] Some experts even predict the market to exceed $21 billion in worldwide revenue by 2020.[4]

Additive manufacturing is one of the most widely accepted emerging technology and its services are being used by various industries like medical, automotive, consumer products, military, academics and others. Alongside the usage of 3D printers in various industries, entry level printers which produce products of relatively smaller volumes are also currently available and mainly purchased by hobbyists educational institutes and design firms.

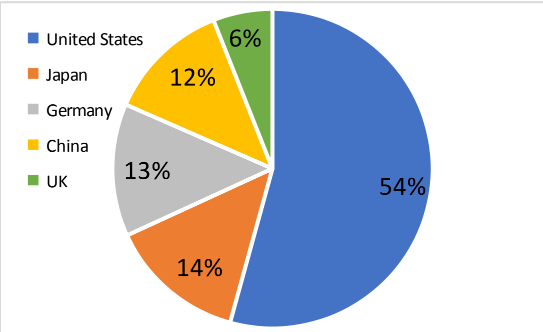

Figure 1. *Largest 3D Printing Markets*

Currently the United States has the largest market share amounting to 38%, significantly more than any other country. Behind the US are Japan, Germany, China, and the UK (Figure 1).

According to a 2015 Reuters report, the highest growth in the 3D printing market is being primarily seen in the US. Asia Pacific (APAC) and the European markets will contribute significant revenue growth over the next years.[5] However, the 3D printing revolution is not restricted to these markets: a recent report by the International Data Corporation (IDC) predicts that the spending on 3D printing in the Middle East and Africa (MEA) market will more than double over the coming years, growing to $1.3 billion by 2019.[6] IDC argues that the world's emerging markets will present a clear growth opportunity to the 3D printing industry and their hardware and services.

3.2 3D Filament Market

3D filament is the basic consumable resource for many 3D printers. The market for polymers used in 3D printing reached $310 million in 2014 and is estimated to grow to $1.4 billion by 2019.[7]

3
, accessed February 2016

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, accessed February 2016

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, accessed February 2016

A 2014 report on plastics in the 3D printing market states that a growing user base in the consumer and professional markets for high value-added plastic materials for 3D printers represents "a high-margin opportunity for materials companies, equipment manufacturers and others in the 3D printing supply chain".[8] Analysing key opportunities in the market for plastic materials used in 3D printing, the report considers novel plastics for 3D printing and assesses opportunities in newer plastic materials categories. The conclusions is that, in weight terms, three types of plastics – ABS, PLA and nylon – are expected to represent the biggest share of the 3D printed materials market accounting for more than 13,000 metric tons by 2019.

PET has become well known as a plastic from the popularity of plastic bottles. In its original state PET filament is a colourless and clear material, but when it is heated or cooled down the material changes its transparency. The material has more crystalline structure when allowed to cool down slowly after printing. The filament is fairly stiff and lightweight material, which makes it strong and impact-resistant.[9]

4. Background Recycling Filament

4.1 Process of recycling

There are six main operational stages in the process of producing and distributing 3D filament from recycled plastic, shown in Figure 2 below. The main steps are:

> **1. Collect:** good quality plastic waste is collected for example through recycling suppliers or waste pickers;

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, accessed February 2016

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, accessed February 2016

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, accessed March 2016

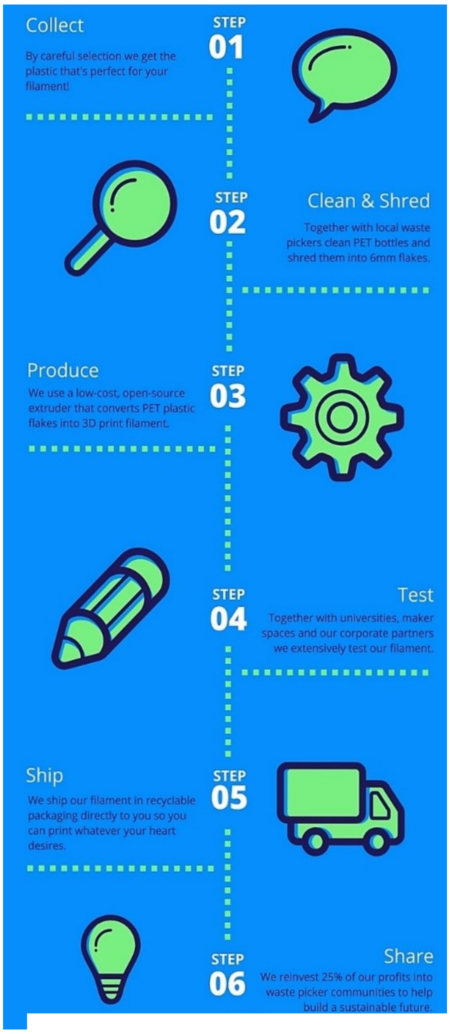

Figure 2. *Process of Recycling Filament*

2. Clean and shred: the plastic is cleaned, dried and shredded into flakes according to preferred size (commonly 6mm);
3. Produce: the filament is converted into 3D print filament through a machine called an extruder. According to the size and speed of the extruder different amounts of filament can be produced per day;
4. Test: appropriate testing with professionals in the field needs to be done to ensure quality;
5. Ship: recyclable packaging is used and the filament is ready to be sent to the final consumer;
6. Share: profits can be reinvested into local communities to help build sustainable future.

Some examples of businesses currently producing filament from waste are:

- **Dimension Polymers** (USA): Develops engineering-grade 3D printing filaments from recycled ABS plastic. Their product ensures a minimum of 95% recycled plastic;
- **Refil** (Netherlands): Refil makes fully recycled ABS filament from car dashboards (100% recycled material) and PET filament made from old PET bottles (90% recycled material);
- **B-Pet**: Recycles PET waste into fully functional 3D printing materials.

4.2 Ethical Filament

"*Ethical filament*"[10] takes one step further: it is filament which not only is produced from recycled material but which also tackles a social issue. Technology and development charity Techfortrade, social enterprise Dreambox Emergence, and Michigan Technological University together have founded the *Ethical Filament Foundation* which aims to ensure that social, economic and environmental requirements are met in the production of 3D filament. The Foundation aims to:

- **Set the benchmark** for the production of ethically produced 3D printer filament made from recycled plastic;
- **Reduce the environmental impact** of 3D printing by cutting the use of virgin plastic and encouraging that of recycled materials;
- **Provide a sustainable form of income** for waste pickers, some of the poorest global communities;
- **Encourage discussion and debate** around the use of 3D printing technology to improve the lives of those in developing nations.

10 , accessed February 20 16

4.3 Filament Cost

The cost of filament and its components are summarized in Table 1 below and are calculated based on some basic assumptions. The cost of energy is assumed to be $0.5 p/Kwh and the labour cost $2 p/hour.

Table 1. *PET Filament Cost Calculation*

Filament cost components	
Plastic buy-in	$ 0.5 p/kg
Extruder cost	$ 1500
Extruder production uptime	40 hours p/week
Extruder life span	3 years
Extruder write-off	$ 0.24 p/kg filament
Extruder filament production	1.00 kg p/hour
Labour time	0.50 hour p/kg
Labour cost	$ 1 p/kg
Production margin	1.5
Energy use	0.3 KWH
Energy cost	$ 0.15 p/kg

The filament cost price is calculated by summing the plastic buy in, extruder write-off, labour cost and energy cost and multiplying it by the product margin. Based on the assumptions above, the cost of filament is expected to be $2.84 p/kg.[11] To get the total cost of a spool of PET filament packaging costs, distribution costs and other overhead costs need to be added.

5. Market Possibilities for Filament

The filament can be sold to businesses (60% of the market), to individual consumers (40%) or to both market segments.

Business-to-**business**:

- Tech Universities and/or private high schools;
- 3D Hubs (both local and worldwide) – there are over 25,000 maker spaces and print labs worldwide;
- FabLabs;
- Local entrepreneurs looking to set up businesses in 3D printing;
- Companies selling 3D printers but who do not produce their own filament.

Business-to-**consumer**:

- 3D print enthusiasts;
- Hobby printers and home owners.

The choice of target market does not necessarily have to be business-to-business or business-to- consumer and instead it is often favourable to mix and target both markets.

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According to a recent Forbes article, a report commissioned with research agency OnePoll surveyed 1,000 U.S. consumers and found that one in three Americans would consider buying a 3D printer for their home in 2014. From this one third, 65 percent of consumers were interested in creating and printing customized items for the home.[12] However, more recent articles do not show that one in three Americans has indeed bough a 3D printer, and this case remains specific to the US.

Selling filament to businesses provides a larger customer base as it targets different institutions, networks or companies, and the volume of sales for businesses is likely to be higher.

Overall, the 3D print market is rapidly growing in both market segments and therefore sales should be targeted to both businesses and consumers.

5.1 International Market

An interesting online tool called the '3D Printing Community Map'[13] maps locations where to buy 3D printers and filament and maps maker- and market-spaces worldwide (Figure 3). It shows that overall the highest concentrations of 3D-print locations are in the US (in line with other literature), followed by Europe. The map is not comprehensive, but provides a good idea of the industry distribution. Worldwide, the biggest markets are the Netherlands, Germany, UK, USA, and China, however spending on 3D printing in the Middle East and Africa market is expected to more than double in the coming years.

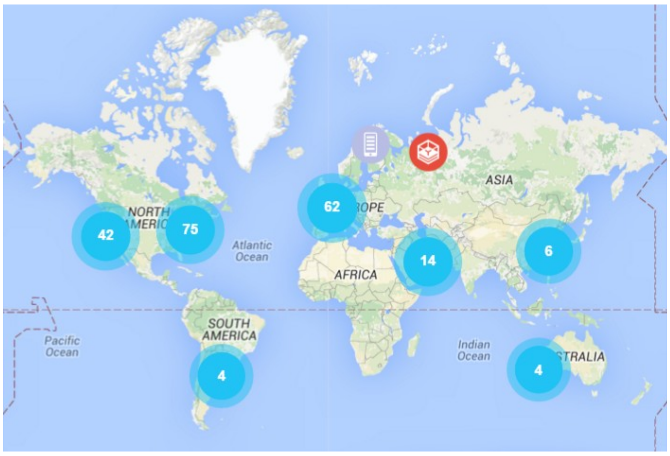


Figure 3. *3D Printing Community Map*

5.2 Comparison with International Market Prices

Worldwide prices for plastic filament range between \$19 and \$175 p/kg depending on material, diameter (mm), colour or other specific characteristics. In cases when there are high shipping costs, a kilo of filament can be as much as \$40 or \$50. This can create barriers for local communities interested in 3D printing to access the necessary supplies.

12 http://www.forbes.com/sites/tjmccue/2014/03/19/3d-printing-in-the-home-1-in-3-americans-ready-for-3d-printer/#613b82db238e, accessed March 2016

13 , accessed March 2016

The Table below provides a price comparison of filament made from different kinds of plastic in countries with a large 3D printing market. The prices compare 1kg-spools of 1.75mm natural filament.

Table 2. *Comparison of filament prices*

Company Name	Country	Type of plastic	Price/kg (USD)
	DEU	PLA/ABS	$ 41 - 59
	UK	PLA	$ 37
	USA	PLA/ABS	$ 20.99
	NL	PLA	$ 39.95
	NL	PLA	$ 21.70
	CH	PLA/ABS	$ 14 - 19
	USA	PETG	$ 38 - 55
	NL	PET (recycled)	$ 39.95
	USA	PET	$ 35
	CH	PETG	$ 25 - 35

5.3 Shipping Costs

The main challenge with international sales are logistics and distribution. The first distribution phase is shipping the filament from Tanzania to warehouses located in large markets such as Europe and the US. From these warehouses the filament can be sent in smaller amounts directly to end consumers (whether businesses or individuals).

Shipping from Tanzania is expensive, and therefore the aim is to fill a full 20- or 40Ft container. A 40ft container can contain approximately 10,500 spools of filament and a filled 20ft container contains about 5,200 spools. Shipping costs per unit are minimized when the containers are filled (unit-cost of $0.93 and $0.67 for 20ft and 40ft containers respectively). The Table below assumes Tanzania as the country of origin and provides cost estimates for different destinations. The containers are assumed to be filled to their capacity. The average cost of a 20ft container is $4,757 (min $3,420; max $6,685) and for a 40ft container $7,110 (min $5,104, max $10,078).

Table 3. *Shipping Costs Calculations (from Dar Es Salaam, Tanzania), www.searates.com*

	20ft Container		40ft Container	
Destination	Transport Cost (USD)	Transport Cost per Spool (USD)	Transport Cost (USD)	Transport Cost per Spool (USD)
Rotterdam, NL	5,120	1.0	7,642	0.7
New Orleans, USA	6,685	1.3	10,078	1.0
San Francisco, USA	5,792	1.1	8,645	0.8
New York, USA	5,681	1.1	8,479	0.8
London, UK	5,142	1.0	7,675	0.7
Mumbai, India	3,420	0.7	5,104	0.5
Kolkata, India	3,645	0.7	5,440	0.5
Hamburg, Germany	5,126	1.0	7,651	0.7
Shanghai, China	3,533	0.7	5,273	0.5

Xiamen, China	3,425	0.7	5,112	0.5
Average	**4,757**	**0.93**	**7,110**	**0.67**

In Tanzania, exports are free of duty and taxes, however the process does require several documents and certifications like all other typical import/export formalities.[14] There is an Economic Partnership Agreement (EPA) between Eastern Africa and the EU, which includes immediate duty-free quota-free access to the EU market for all EAC exports.[15] Shipping to the US is slightly more complicated even though Tanzania is eligible for preferential trade benefits under the African Growth and Opportunity Act. Goods need to go through the Customs Border Protection and a series of forms are required and excise duties need to be paid.[16]

If shipping from the EU to the US or vice versa, tax and customs duties need to be paid. Table 4 summarizes the duties and tax rates for a number of countries.

Table 4. *Fees and Tariff Rates*

Country	Fee for 20Ft Container (USD)	Weighted Mean Applied Tariff Rate (%)
United States	$1,298	1.5%
United Kingdom	$1,050	1.0%
Netherlands	$975	1.0%
Canada	$1,680	1.5%

5.4 Last Mile Distribution

Tables 5 shows cost estimates of shipping one spool of filament (1.3kg / 2.9lbs) to different locations within the EU through the Dutch postal services. The prices within the EU are reasonable, while for distribution over larger distances further research is needed to find the most cost-efficient method.

Table 5. *Last Mile Distribution from the Netherlands*

Carrier: Post NL (€)	Up to 2kg	2-5kg	5-10kg	10-20kg	20-30kg
From NL to several EU countries	€13,00	€19,50	€25,00	€34,00	€45,00
Within NL	€6,95	€6.95	€6,95	€13,25	€13,25

As these estimates are for smaller quantities of filament (30kg are approximately 23 packaged spools) and therefore more likely to address the business-to-consumer market.

14 , accessed April, 2016

15 , accessed April, 2016

16 , accessed April, 2016

5.5 Domestic Market, East Africa

The domestic East African market is currently very limited. In Kenya, for instance, there are around 40 active 3D printers and that the total yearly filament market is not more than 400kg a year. However, the problems 3D printing is solving are most apparent in developing countries. Problems such as low capital for local manufacturing, relatively high transport and distribution costs and lack of products that fit specific local needs. Furthermore, in many emerging markets there are often high import tariffs which means local production is more cost-competitive.

This leads us to believe there is a large potential for growth in the 3D printing market in developing countries. By keeping the CAPEX investment of an extruder low anyone with the technical capabilities and network can create a profitable filament business quite rapidly.

5.6 Comparison with Domestic Market Prices

Currently in Tanzania, the cost of one kilogram (kg) of filament can rise to as much as $60 or even $80, including fees for shipping from China. This creates a barrier for the burgeoning local communities interested in 3D printing to access the necessary supplies. Instead, filament can be sourced directly from recycled plastic providing a valuable lower cost alternative without compromising on quality

Our cost calculations, based on an initial investment of $1,000 in extruder investment and a local sales price of $20 (Around $10 lower than market alternatives) a filament production can be profitable at 200kg of yearly sales. Detailed breakdown of these costs can be found in Annex table 2.

The technical feasibility of such a low-cost extruder to serve local markets in currently being tested in the next phase of the ReFab Dar project.

6. Plastic Collection Tanzania

The model for sourcing plastic for local filament production can be roughly divided into two models. Either work with established recycling centres or by directly sourcing plastic with waste pickers.

6.1 Direct Recycling with Waste Pickers

Direct recycling with waste pickers involves selecting trusted waste pickers to find high quality clean bottles. Advantages of directly working with waste pickers is that you have control of the entire plastic chain, you can easily track impact and monetary exchanges and you are not dependent on a third party. This however does mean you have to invest significant time on building up a local network, set up a tracking system for monetary exchange (for instance through mobile phone payments), rigorously control and check the plastic quality input and create clear instructions for cleaning and sorting and create your own facilities to shred the bottles and possible a washing facility.

6.2 Recycling through a Waste Recycler

Working through a waste recycler involves finding a trustworthy local partner that can deliver high quality, clean plastic for filament production. Advantages of this model are that, if you find the right partner, you have a continuous source of quality plastic with little or no effort which means you can focus on the primary production process. Disadvantages are that you are reliant on a third party for which you are often a small part of their entire production process (general recycling business processes 700,000 kgs of plastic a month, which is more than the global yearly filament sales) and you have little control over how value is redistributed to waste pickers.

7. Strengths, Weaknesses, Opportunities and Threats, Tanzania Filament

7.1 Strengths

- **Easy to scale up production** – Production can be scaled up easily with a relatively low additional capital investment (low-cost extruder machine);
- **Flexible Production** – With the low capital Expenditure production can easily be adapted to specific customer needs, for instance custom colouring, diameter sizing or scenting of the filament;
- **Cost-Competitive** – As the filament is produced locally the costs of distribution and transport are cut significantly. Furthermore local production makes sure import tariffs are avoided. Even at small scale production a filament producer would be able to be cost-competitive;
- **Sustainability –** Clear environmental sustainability incentive that ties into the overall branding of the product;
- **Material –** PET has proven to be a very viable material for 3D printing and in terms of material properties is more than competitive with ABS**.**

7.2 Weaknesses

- **Plastic Supply** – ensuring a continuous supply of clean plastic is one of the largest challenges in recycled filament production. Local recyclers either do not have the machines or the quality control systems needed for the level of quality 3D print filament needs. Furthermore, with the decline in the number of recycling businesses in Tanzania these partners are harder to find;
- **Quality and Consistency** – 3D print filament is a very specialized product, it needs to be precisely round, the diameter can only differ by 0.05 mm and any grain of sand would clog up a 3D printer. To achieve this consistent quality is harder in the low-tech small-scale setting compared to industrial processes;
- **PET 3D printing unfamiliar** – printing with PET plastic is not as established as “the famous two” - PLA and ABS;
- **Small local market** – The current 3D printing market in Tanzania is rather small, where estimates are that there are less than 50 active printers in the entire country.

Although the market has potential, especially with the start of locally made affordable 3D printers, it is still in its infancy stage.

7.3 Opportunities

- **Potential growth of local 3D printing market** - 3D printing has the potential to solve a lot of problems in developing regions around local production and import dependency. As with mobile banking the lack of local infrastructure might help leapfrog 3D print technologies in these countries;
- **Easy to scale to new markets -** Once some of the main challenges around plastic supply and extrusion are solved it is relatively easy to scale to new (fledgling) markets.

7.4 Threats

- **Changes in technology limiting the need for filament –** 3D printing technology is rapidly changing. While FDM (Fusion deposition modelling) is still the most widely uses technology, new technologies might emerge that do not use filament. One notable development is the Carbon3D, M1 Resin based 3D printer;
- **Larger international competitors entering local market at more mature stages –** If the local 3D printing market grows than international competitors will see the advantages of setting up shop locally;
- **Changes in bottle production limiting the use of PET (PEF, Avantium for example).** Companies such as Avantium are looking into ways to replace PET with a more sustainable PEF version, which is biodegradable. This might mean it is no longer suited for filament.

8. Key Takeaways and Next Steps

There is a clear business case for the production of recycled filament in developing countries. However, there were several challenges in sourcing a clean plastic supply. First of all, the low plastic prices meant a lot of local recycling partners are going out of business. Our primary partner, a social enterprise in Dar es Salaam focussed on PET recycling, shut down two months into the project.

Second, there are very little to none operational hot wash systems in Tanzania to generate the clean plastic we need for production. To test the technical feasibility, we imported post-industrial plastic from Nairobi. In terms of cleanliness this seems promising but the plastic also had fine plastic dust causing technical challenges with extrusion, which we are currently solving. An alternative we will be exploring in the coming months is to work directly with waste pickers to hand pick clean bottles and find a small scale shredder to create production ready plastic.

Third, the current 3D print market is relatively small and the 3D printing ecosystem needs to overcome certain challenges for it to be viable (technical schooling, local 3D printer manufacturing, local use-cases). Last of all, technical challenges around filament extrusion

(Water, dust, roundness, diameter consistency) need to be solved before the product is market ready.

The next steps to create a viable local filament business are:

- Perfect the extruder design so that it is ready to produce consumer ready filament;
- Create local network of plastic collectors that can supply high quality PET plastic on a continuous basis;
- Establish production site, ideally close to collection point, that can consistently produce small amounts of filament for the local market;
- Set up the impact framework for redistribution of profits back to waste pickers;
- Partner with local 3D printing partners trying to establish a 3D printing ecosystem.

9. Annex

Table 1. *Full Calculation of Shipping Costs from Dar Es Salaam, Tanzania*

Destination Port	Mode of Transport	Number of Spools	Container Size	Cargo Weight (1 packed spool = 1.3kg)	Transport Cost (USD)	Transport Cost per spool (USD)	Total Cost per Spool (USD)	Profit per Spool (USD)
Rotterdam, NL	Air	10	Carton	13	186	18.6	30	0
Rotterdam, NL	Sea	100	Partly filled container	130	556	5.6	16.9	13.1
Rotterdam, NL	Sea	500	Partly filled container	650	1,778	3.6	14.9	15.1
Rotterdam, NL	Sea	1,000	Partly filled container	1300	3,556	3.6	14.9	15.1
Rotterdam, NL	Sea	5,200	20 Ft	6760	5,120	1	12.4	17.6
Rotterdam, NL	Sea	10,500	40 Ft	13650	7,642	0.7	12.1	17.9
New Orleans, USA	Sea	5,200	20 Ft	6760	6,685	1.3	12.7	17.3
New Orleans, USA	Sea	10,500	40 Ft	13650	10,078	1	12.3	17.7
San Francisco, USA	Sea	5,200	20 Ft	6760	5,792.32	1.1	12.5	17.5
San Francisco, USA	Sea	10,500	40 Ft	13650	8,645	0.8	12.2	17.8
New York, USA	Sea	5,200	20 Ft	6760	5,681.26	1.1	12.5	17.5
New York, USA	Sea	10,500	40 Ft	13650	8,479	0.8	12.2	17.8
London, UK	Sea	5,200	20 Ft	6760	5,142	1	12.4	17.6
London, UK	Sea	10,500	40 Ft	13650	7,675.10	0.7	12.1	17.9
Mumbai, India	Sea	5,200	20 Ft	6760	3,419.98	0.7	12	18
Mumbai, India	Sea	10,500	40 Ft	13650	5,104	0.5	11.9	18.1
Kolkata, India	Sea	5,200	20 Ft	6760	3,645	0.7	12.1	17.9
Kolkata, India	Sea	10,500	40 Ft	13650	5,440	0.5	11.9	18.1
Hamburg, Germany	Sea	5,200	20 Ft	6760	5,126	1	12.4	17.6
Hamburg, Germany	Sea	10,500	40 Ft	13650	7,651	0.7	12.1	17.9
Shanghai, China	Sea	5,200	20 Ft	6760	3,533	0.7	12.1	17.9
Shanghai, China	Sea	10,500	40 Ft	13650	5,273	0.5	11.9	18.1
Xiamen, China	Sea	5,200	20 Ft	6760	3,425	0.7	12	18
Xiamen, China	Sea	10,500	40 Ft	13650	5,112	0.5	11.9	18.1

Found at:

Table 2. *Financial Plan Local Filament Production*

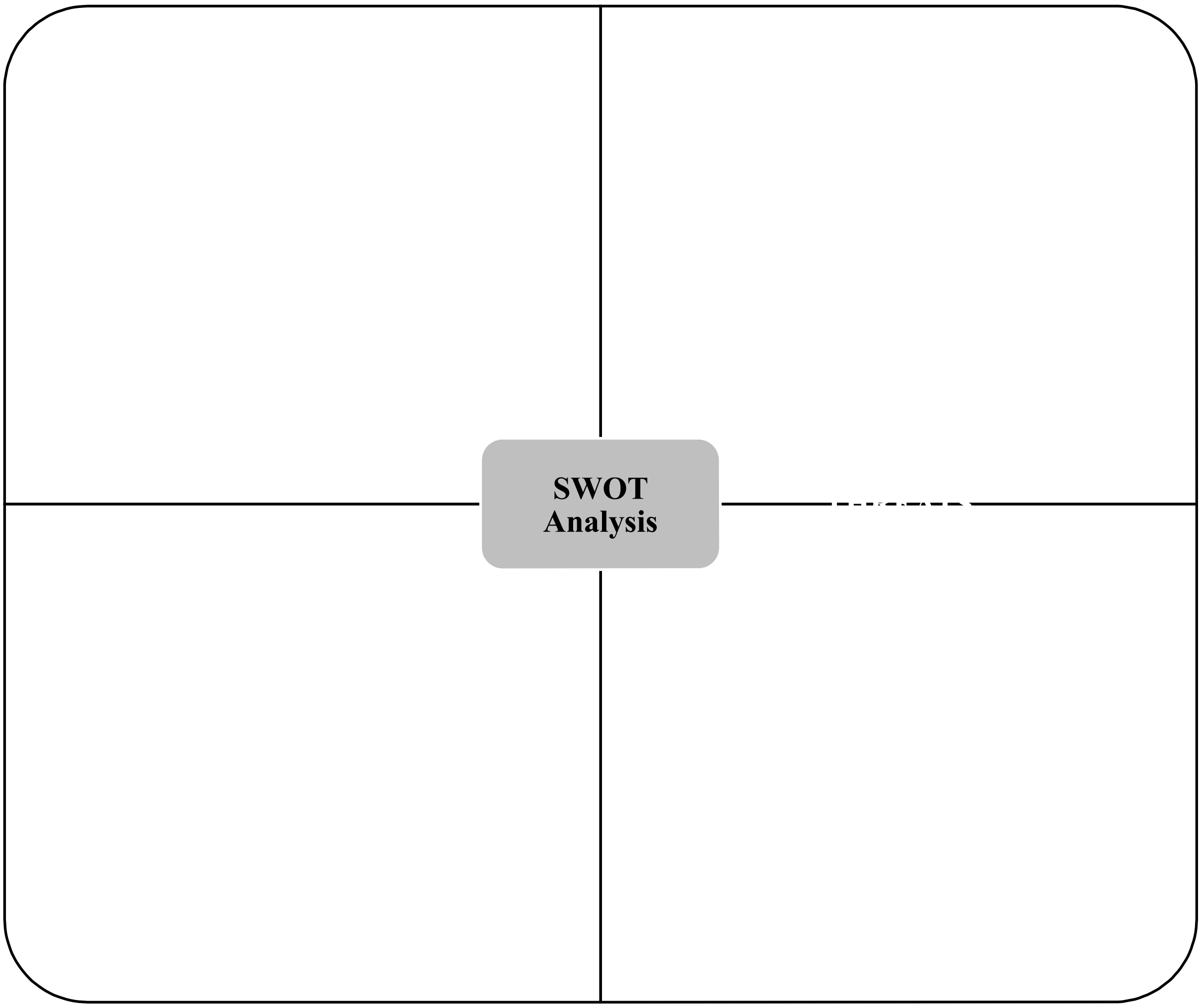
				Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Shilling - EURO conversion rate*		0.0005	Tanzanian shilling to Euro						
Extruder Efficiency		1	kg filament per hour						
Extruder Working Hours		40	per week						
		2	kg of waste buy in per kilo filament						
Labour Costs	Low skilled (non-production - factory)	2,000	Tanzanian shilling per hour	2,000	2,200	2420	2662	2928	3221
	Medium skilled	5,000	Tanzanian shilling per hour	5,000	5,500	6050	6655	7321	8053
	High skilled (production)	10,000	Tanzanian shilling per hour	10,000	11,000	12,100	13,310	14641	16105
Average filament purchase Household Customer		2	kg per year						
Average filament purchase Professional Customer		80	kg per year						
Energy consumption		2,000	KWH/H per year per extruder						
Sale Price (50% of market rate)		25	Euro/kilo						
Inflation Tanzania		7%							
Salary Raise (year on year)		10%							
Plastic Preparation Worker Efficiency		4	kilo per hour						
Number of working weeks per year		50							
Number of Extruders				1	2	3	6	11	32
Cost of Extruder		2000	Euro/piece						
Cost of Laptop/Computer		1000	Euro/piece						
Number of Computers				1	2	3	6	11	32
Cost of Training per extruder		5000	Euro/extruder						
Increase in the number of extruders				1	1	1	3	5	21
Marketing Costs		8000	Euro/extruder						
Annual Maintenance Charges		2200	Euro/extruder	2200	2354	2519	2695	2884	3086
Rent per Extruder		3000	Euro	1000	1070	1145	1225	1311	1403
Cost of Energy		500	Shilling/KWh						
Cost of Energy (EUR)		0.250	Euro/KWh	0.250	0.268	0.286	0.306	0.328	0.351
Waste recycling price (normal)		0.150	Euro/Kilo						
Waste Buy-In (with redistribution)		3	Euro/kilo						
Filament waste kg needed per kilo		1.5							
Distribution Cost (packaging, shipping)		3	Euro/kilo						
Yearly Tax Rate		30%							

Production worker time	0.1	hour per kg						
Extruder production costs	1500	Euro/extruder						
Number of waste pickers collecting one local person can manage	20	per person						
Waste pickers pick up rate	10	kg per day						
Number of waste pickers needed			1	1	1	1	1	2
Mobile tracking cost	10	$ per waste picker						
Transport cost	0.05	$ per kg						

Table 3. *Financial Plan for Local Filament Production*

All Figures in EURO	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
REVENUES						
Number of Home customers	**50**	**100**	**200**	**300**	**500**	**500**
Number of Professional Customers	**0**	**0**	**1**	**3**	**5**	**10**
Filament Sold (kilos)	100	200	480	840	1400	1800
Revenue from Filament Sold (EUR)	**2,500**	**5,000**	**12,000**	**21,000**	**35,000**	**45,000**
COSTS						
Personnel Costs						
Salary Local: Low Skilled Labour (Production)	1,000	2,000	2,000	2,000	2,000	2,000
Salary Local: Low Skilled Labour (Plastic Preparation)	500	2,200	2,420	2,662	2,928	3,221
Total Personnel Costs	**1,500**	**4,200**	**4,420**	**4,662**	**4,928**	**5,221**
Rent & office						
Factory - Rent	-	1,070	1,145	1,225	1,311	1,403
Total Rent Costs	**-**	**1,070**	**1,145**	**1,225**	**1,311**	**1,403**
Cost of Goods Sold						
Raw Material (Waste Buy-In)	450	900	2,160	3,780	6,300	8,100
Distribution & Packaging	300	600	1,440	2,520	4,200	5,400
Total Cost of Goods Sold	**750**	**1,500**	**3,600**	**6,300**	**10,500**	**13,500**
Marketing & Customer Acquisition	-	-	500	1,000	2,000	4,000
Total Operating Costs	**2,250**	**6,770**	**9,665**	**13,187**	**18,739**	**24,124**
Operating Profit (EUR)	250	- 1,770	2,335	7,813	16,261	20,876
Tax (@ 30%)			701	2,344	4,878	6,263
Net Profit (EUR)	*250*	*- 1,770*	*1,635*	*5,469*	*11,383*	*14,613*
Total Number of Extruders	**1**	**1**	**1**	**1**	**1**	**1**
Capex extruder	1500	0	0	0	1500	0
Computers / Laptops	1,000	-	-	-	1,000	-
Total Capex Costs	**2,500**	**-**	**-**	**-**	**2,500**	**-**
Net Earnings	***- 2,250***	***- 1,770***	***1,635***	***5,469***	***8,883***	***14,613***

Figure 1. *SWOT Analysis for Production of Recycled Filament*


SWOT
Analysis