3D Printing

3D-ECO

ECO technology: Educate Create Organise

Project Identifier: 2023-1-DE04-KA210-YOU-000155718

Initiative Mittel- und Osteuropa

Co-funded by the European Union

3D Printed Examples

jewelry

fashion

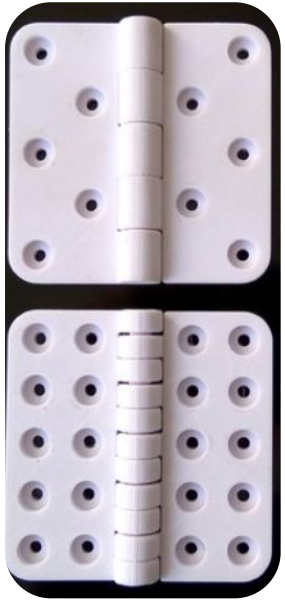
medical devices

source: Thingiverse

3D Printed Examples

stuff for home

tools



toys

source: Thingiverse

3D Printed Examples - not just plastic

metal - tool

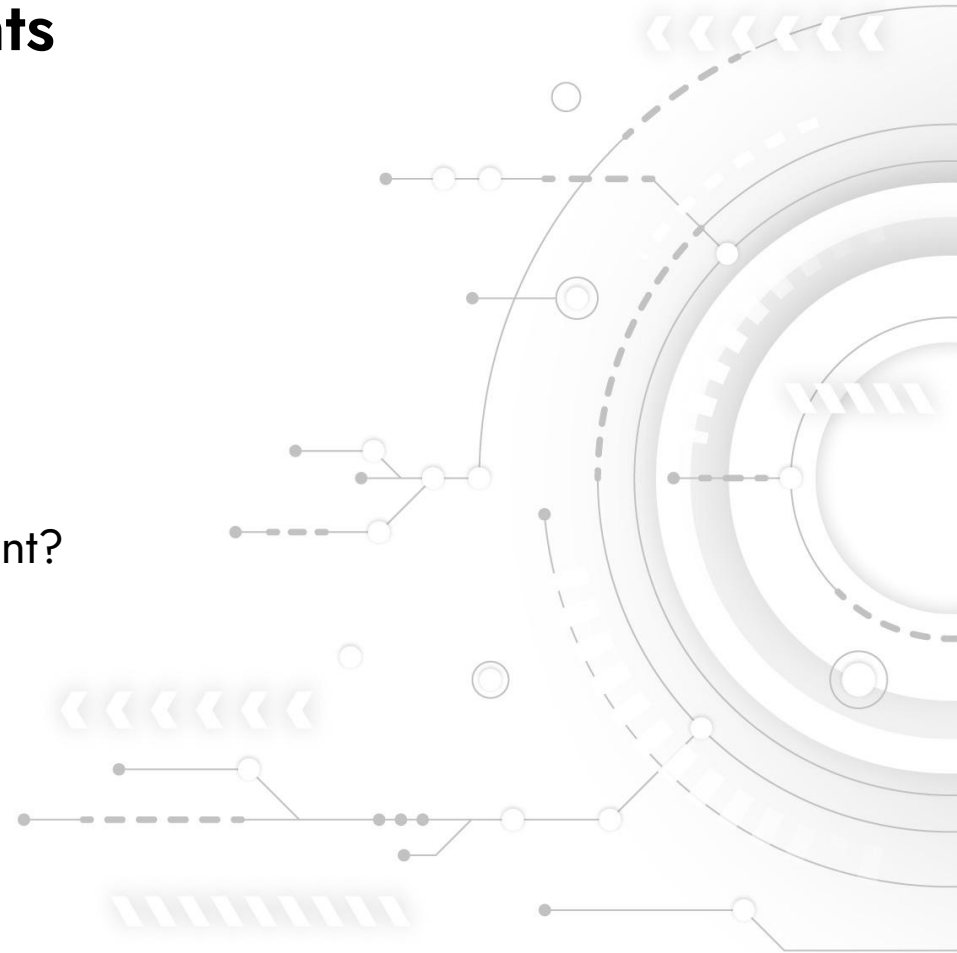
food

housing - concrete

source: Google prictures

Self Introduction of participants

- Get to know each other
- What is your motivation?
- Do you have any visions what to print?
- Who do you want to help with your print?
- What is your experience so far with 3-Printing and 3D-Modelling?



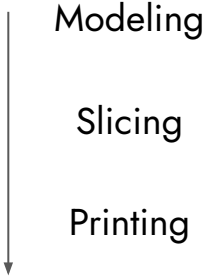
Introduction to 3D Printing

Creating 3D-objects by adding material **layer by layer** based on a **digital model**

Other term is *"Additive manufacturing"*

3D Printing process - General overview

1. Idea of desired object
2. Get or make 3D-model
3. Prepare model for the 3D-Printer
4. Prepare 3D Printer
5. Print the object
6. Post processing the object



Tinkercad

tinkercad.com

Tinkercad is an online 3D modeling software that is used to create simple 3D models primarily for hobbyist and educational purposes

It is **user-friendly** and requires no previous experience in 3D modeling

It can export files that can be printed on a 3D printer or CNC machine

Tinkercad - Practical Task

Download a shopping coin from here: https://www.thingiverse.com/thing:2539236

Import the shopping coin model to Tinkercad

Put the first letter of your first name on the coin

Export the object as .stl-file

Slicer

Slicer is a software that takes a 3D model and **converts it into a set of instructions** for a 3D printer to create a physical object.

Slicing involves **dividing the 3D model into layers** and **generating tool paths** that the 3D printer can follow to create each layer.

The slicer software allows the user to adjust various parameters such as layer height, infill density, print speed, and much more

The output of a slicer is a file in a “.G-code” or “.bg-code” format

Slicer

PrusaSlicer: PrusaSlicer is a slicing software developed by Prusa Research specifically for use with their 3D printers, but it can also be used with other printers.

Time to slice

Import the modified shopping coin model to Prusa slicer

Slice the model

Checkout the preview

Export the model as an .gcode file

Time to print

Save the .bgcode file on a SD-Card or USB-Stick

Put it in the 3D-Printer

Prepare the printer (this we do together)

Start printing

Break

10 minutes time for coffee, chats and bio

3D Printer Hardware

Frame: Frame made of aluminum extrusions and injection-molded parts.

Extruder: The extruder is responsible for melting the filament and pushing it through the nozzle. Prusa Mini+ has a direct drive extruder, which means that the motor is mounted directly on the extruder and feeds the filament into the hotend.

Hotend: The hotend is responsible for melting the filament and extruding it through the nozzle. It features a modular design, which allows for easy maintenance and upgrades.

Bed: The bed is the surface on which the printer creates the 3D object. Prusa Mini+ has a removable magnetic bed that makes it easy to remove printed objects and reduces the risk of warping.

Control board: The control board is the brain of the printer, and it controls all the printer's functions. Prusa Mini+ has a board based on the 32-bit ARM processor.

Motors: The motors are responsible for moving the printer's components, such as the extruder and the bed. Prusa Mini+ has a high-quality stepper motors that provide accurate and precise movement.

3D Printer Hardware

Original Prusa MINI+ 3D

Sensors: The Prusa MINI+ has a PINDA probe sensor for bed leveling.

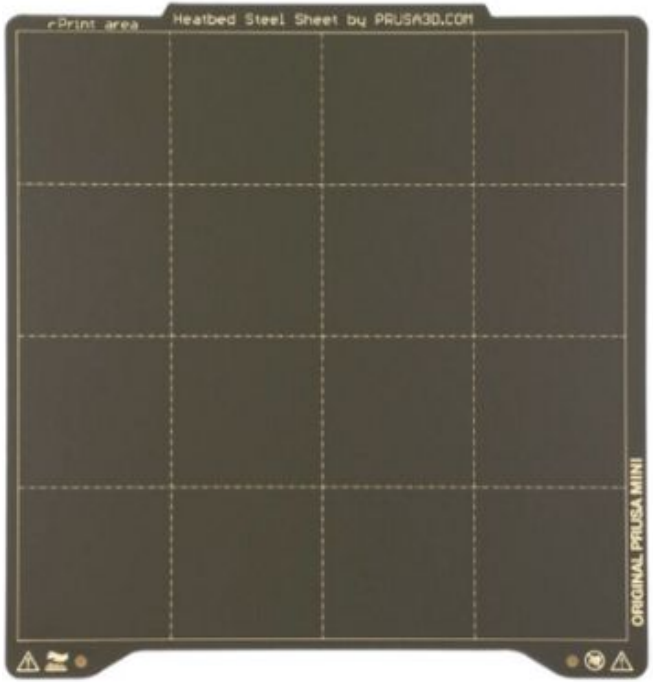
3D Printer Hardware

XZ-axis assembly

Y-axis assembly

3D Printer Hardware

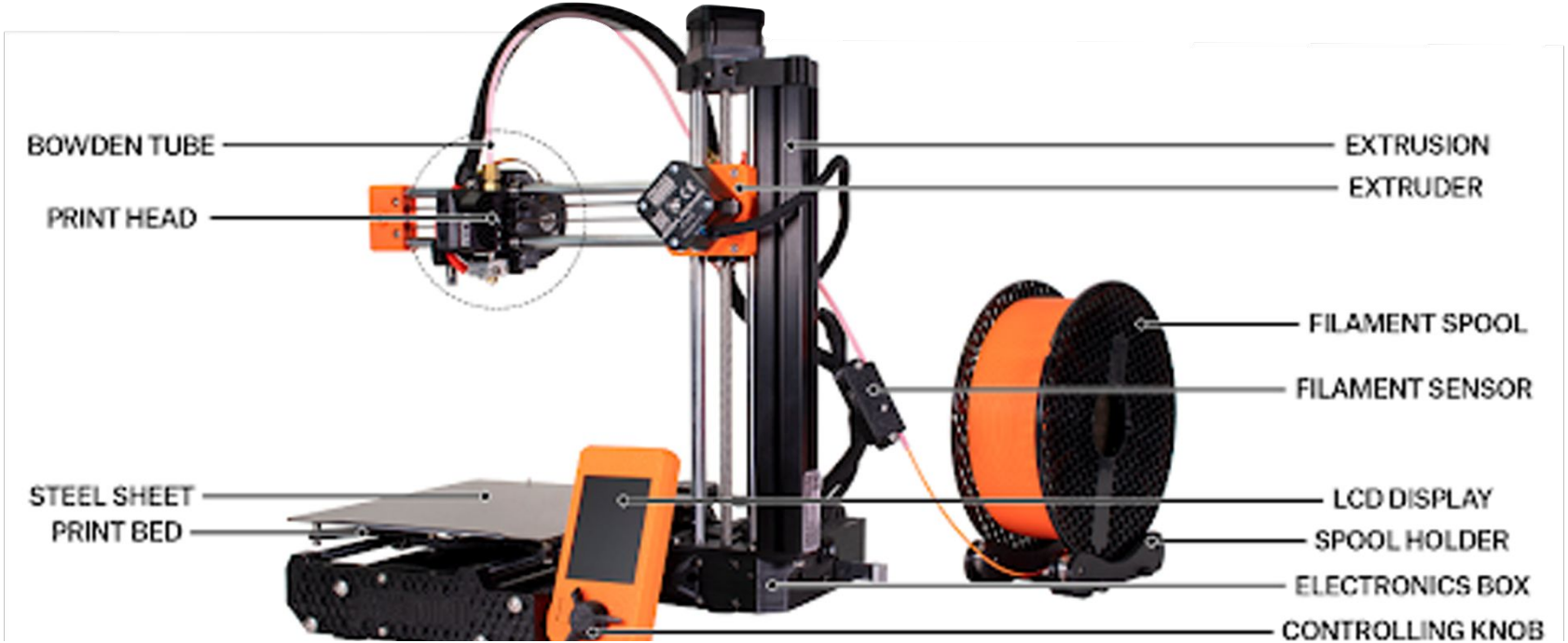
Spring steel print sheet with PEI surface



LCD display + cable

3D Printer Hardware

Main components



3D Printer Hardware

Main components

Tinkercad - Practical task

Add a hole for a chain in the shopping coin

Make a thin and small plate with the text “Berlin”

Remove the dot above the “i” and replace it with a heart shaped object

More on Slicer

Infill Density

Infill Pattern

Printing Temperature

Build Plate Temperature

Print Speed

More on Slicer - Infill Pattern

When choosing an infill pattern, these are the main **things to consider:**

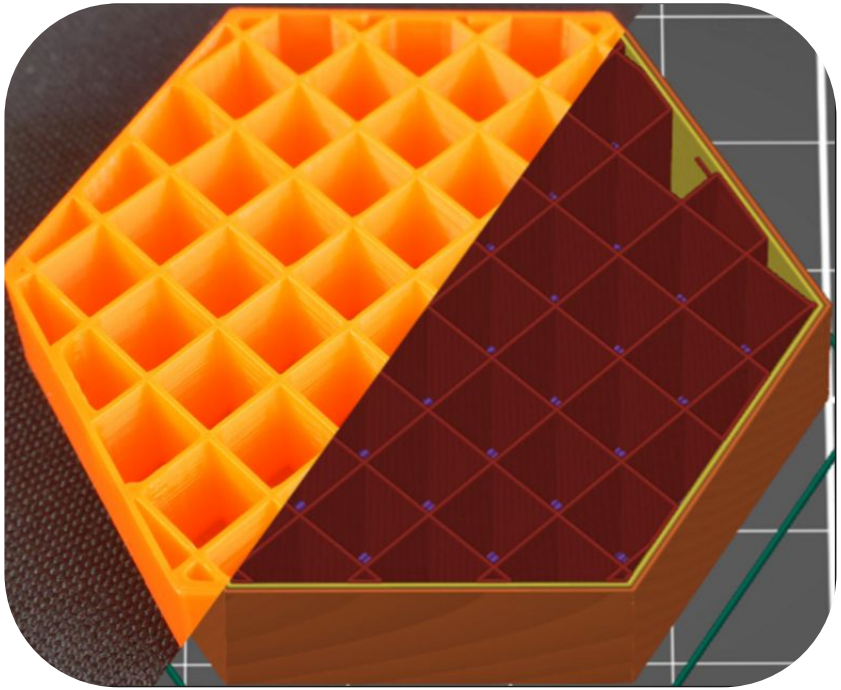
- Print speed
- Density per material used (better support for top layers with less material)
- Visuals
- Support for top layers
- Flexibility (for TPU/TPE prints)

Different infill patterns are used for some, but usually not all applications:

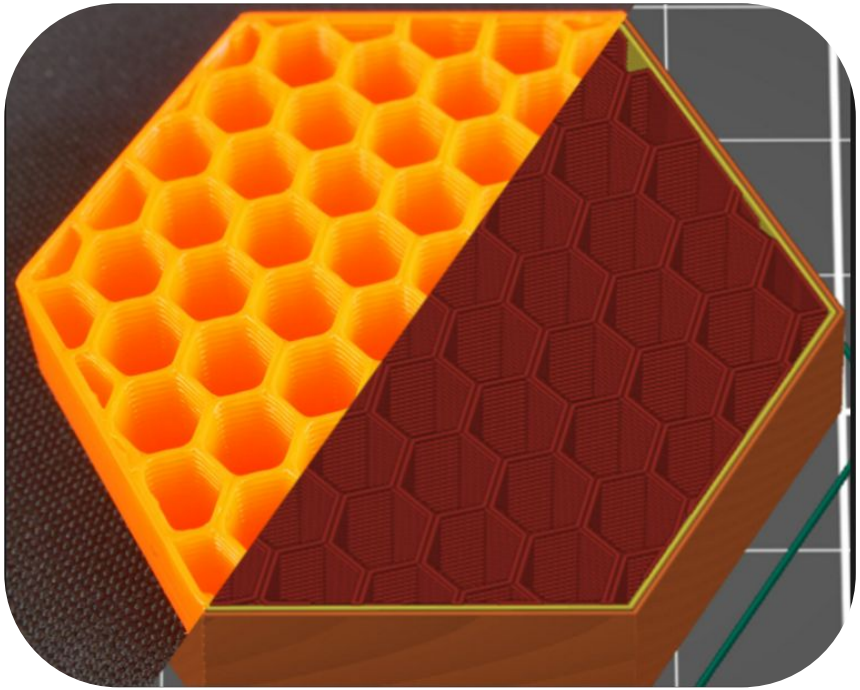
- low-density filling of the inside of a model
- filling the top layers
- filling the bottom layers
- generating support material

More on Slicer - Infill Pattern

Grid

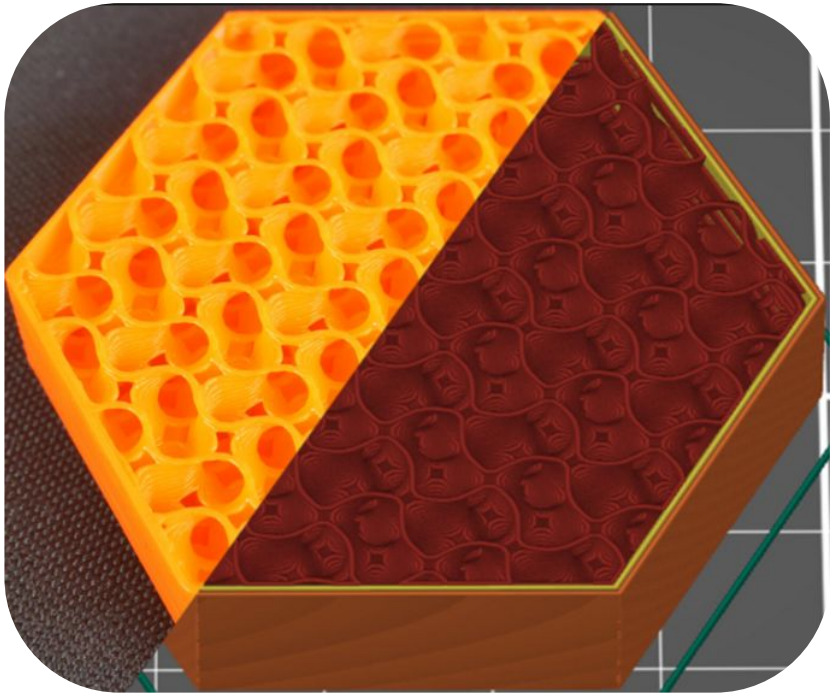


Honey comb

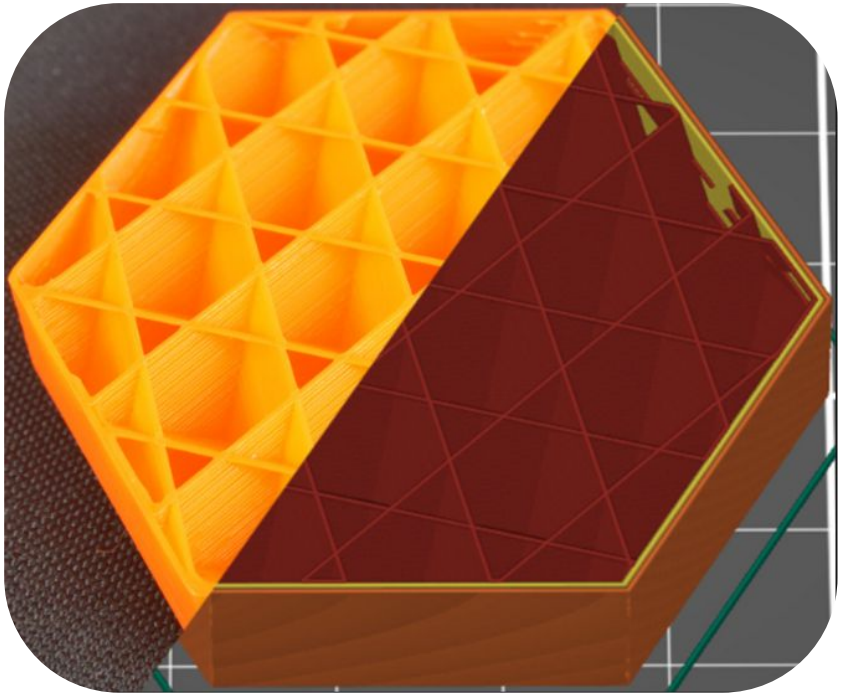


More on Slicer - Infill Pattern

Gyroid



Cubic



Time to slice and print

slice the objects you have designed in tinkercad..

Material types

Material types - PLA - Polylactid

Polylactides (PLA) belong to the polyesters

Used to make plastic that is obtained from regenerative sources (e.g.: corn starch).

PLA a biocompatible raw material.

3D printing filament is often not pure PLA, but a so-called PLA blend, whose basic structure is enriched with additives to obtain certain desired properties.

Material types - PLA - Polylactid

Low melting point, Printing temperature: 175° - 220

Low deformation, Fast printing speed, Easy to print, Suitable for small and large objects, low warpage, flame retardant

Dimensional stability is up to a maximum of 65 degrees Celsius

Weather resistance is quite high

Somewhat brittle (negative)

Break

10 minutes time for coffee, chats and bio

Project Work

- For individuals or for a group 2 - 3 people
- Brainstorm an idea
- Design it
- Print it
- Make a documentation of your work and the progress
- video, pdf, pictures
- what went well, what went wrong, lessons learned

Day closing

How do you feel?

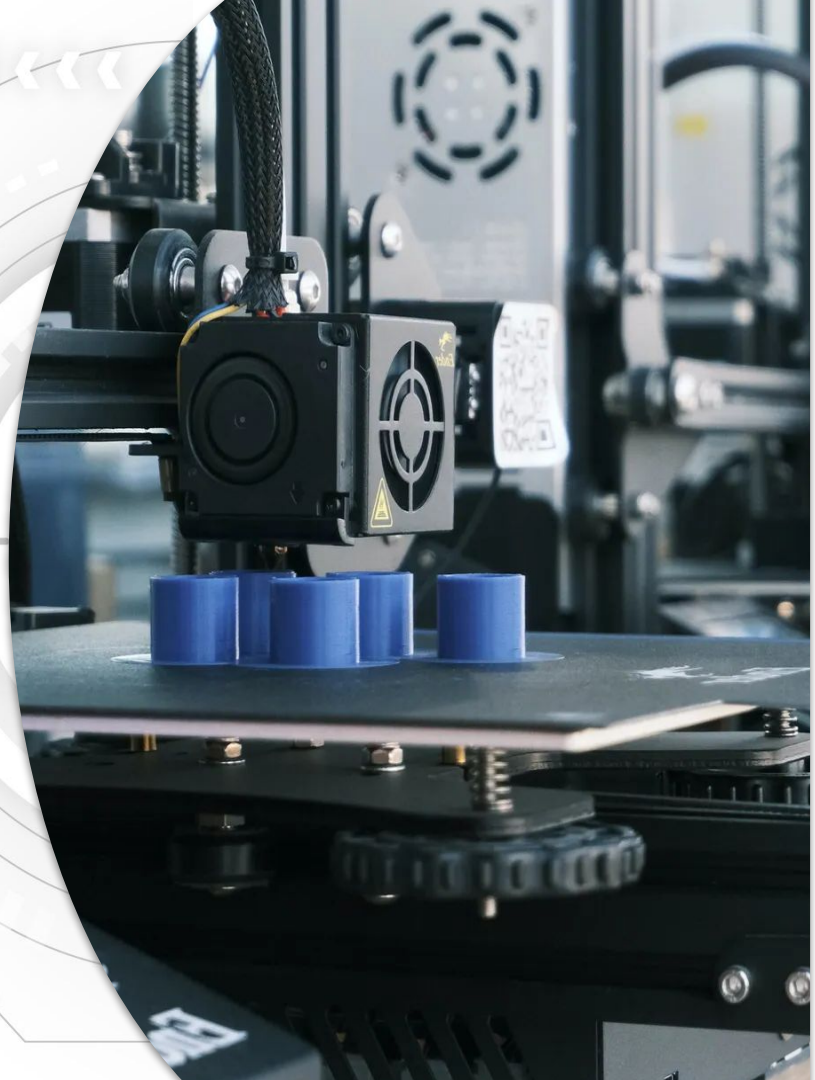
What is your motivation level right now?

Feedback?

See you soon when you start printing!

Common Plastic Types

Sustainability



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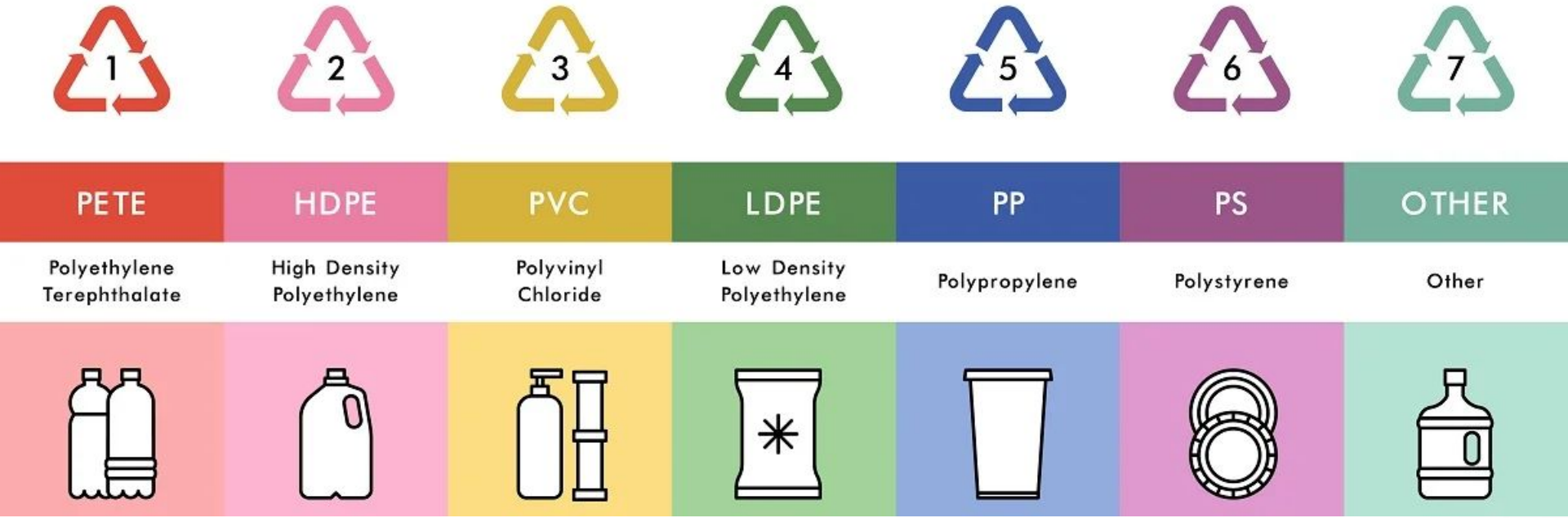
Why Knowing Different Plastic Types Matters

- **Environmental Impact -** Make eco-friendly choices, reducing environmental footprint
- **Recycling Efforts -** Better recycling, contributing to a circular economy and minimizing waste
- **Sustainable Production -** Encourages designers and manufacturer to adopt sustainable production practices, supporting a greener future
- **Consumer Empowerment -** Informed consumers can make conscious decisions, driving demand for environmentally responsible products.
- **Health and Safety** - Selecting products that meet safety standards, promoting healthier living.
- **Innovation & Alternatives** - Development and adoption of innovative, eco-friendly alternatives

Plastic categorization

Categorized according to 7 numbers known as the “Identification Number” or “Resin Identification Code”



1.PET - Polyethylene Terephtalate - Usage

- PET is typically used in water bottles, different beverage, and food containers
- When used for container and packaging applications, it is called “**PET**” or “PET resin”
- When used to produce fabric or fabric applications, it is usually referred to as “**polyester**”
- Sometimes also used for cosmetic containers, for PET-Ropes, for car parts like bumpers

1.PET - Polyethylene Terephtalate

PET as bottles

1.PET - Polyethylene Terephtalate

PET as polyester staple

PET as polyester fabric

1.PET - Properties

- High strength to weight ratio, lightweight, remains flexible and don't crack easily, even with thin walls like in water bottles. It is not porous and very resistant to moisture.
- May oxidize, that's why items which stay in a shelf for a long time can suffer from taste degradation. That's why even water bottles have an expiry date.
- Has low heat tolerance, boiling/heating the plastic results in warping.
- Not biodegradable at all. If it goes into landfills or nature, it will stay there.
- Flammable

1.PET - Recycling

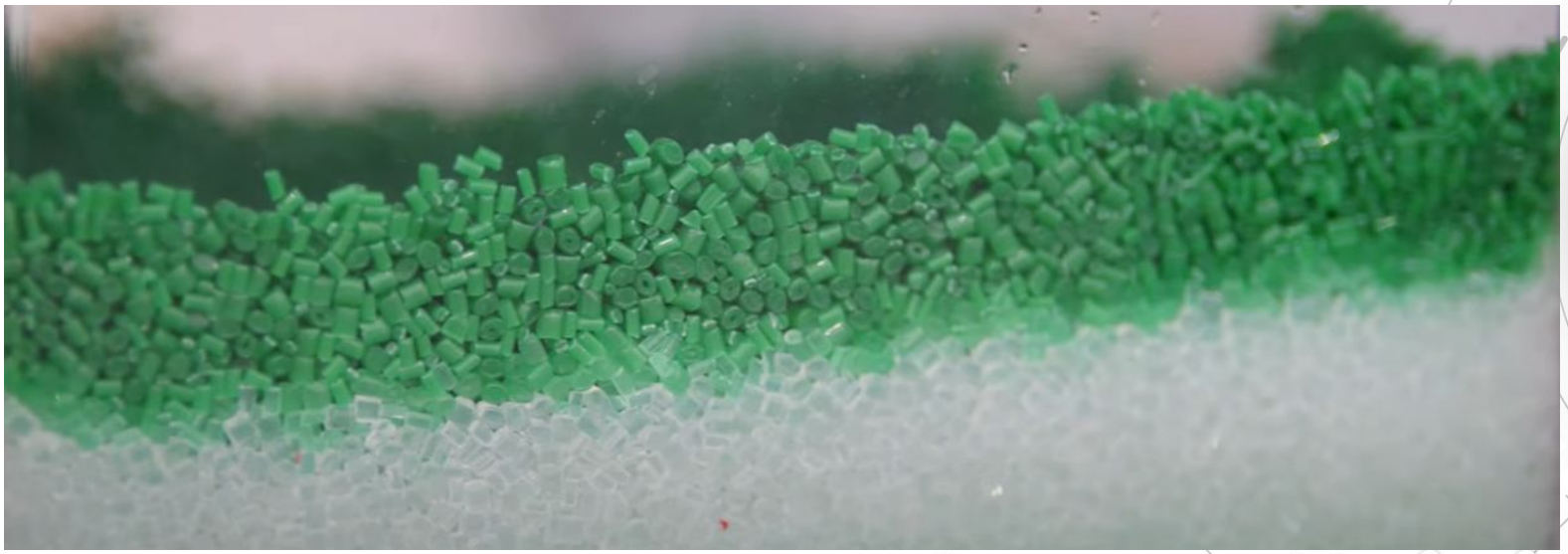
- With 30% recycling rate, it is the most recycled plastic out of all seven categories.
- It can be easily washes, broken down and turned into consistent raw materials and used very similar to the original virgin material
- Relatively easy to recycle, because all bottles are very similar by shape.
- Because so many bottle are produced and recycled every day, the stream of materials is quite consistent.
- Because it is transparent, it is especially valuable for recycling for many applications

What is Polyester - How is Polyester made?

- Welches Wissen und welche “Messages” wollen wir den Teilnehmenden vermitteln`?
- Man-made fabric made of plastic
- p-e-t- Polyethylene terephthalate - same as for soda plastic bottles
- Polyester has many benefits, it lasts long, is very durable sweat wicking capabiltes
- It does not grab on your water and sweat as cotton would, has little pores and it can wick water away from your body, great for outdoor fashion.
- Polyester can be made from recycled or virgin material
- Vom britischen Chemiker **John Rex Whinfield und James Tennant Dickson** im Jahre 1941 entwickelt,

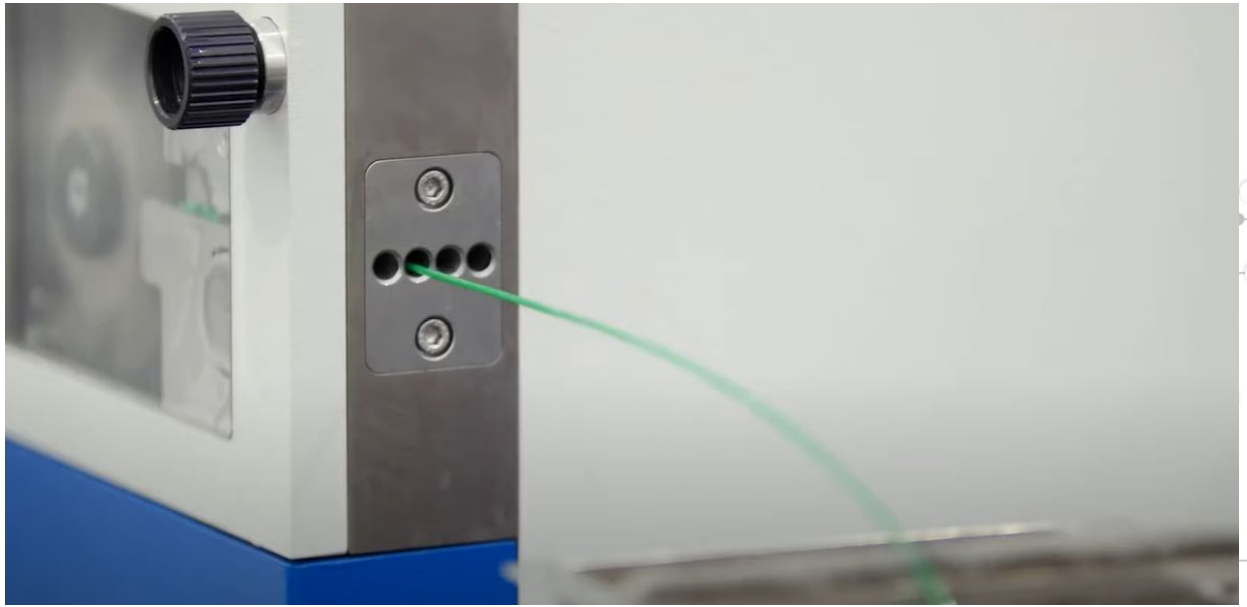
It starts with pellets

PET-Pellets are put together ..



goes to long strings

... to long strings, this is called extrusion molding



then fluffed to little threads and later to long threads

... fluffed to make little hairs/ little threads

It becomes then yarn for further processing

2.HDPE - High density polyethylene - Usage

- Often used in household chemical containers like windows spray, cleaner.
- Used outdoor like for water tanks, fuel tanks, in many containers, even car makers use it for fuel containers.
- Often used for plastic chairs, food containers, underground water systems
- Also used for shopping bags (usually bigger bag, not clear, makes crinkling sound)

2.HDPE

HDPE cans

HDPE bags

2.HDPE

HDPE pipes

2.HDPE - Properties

- Cheap to produce
- One of the most versatile plastics of the seven categories
- Has good durability, chemical resistant, does not react well with other chemicals.
- Resistant to mildew, rotting insects and different elements
- Flammable
- Practically not biodegradable or compostable

2.HDPE - Recycling

- Relatively easy to recycle in comparison to other plastics.
- It has a recycling rate of round 25%, but that depends on the country.

3.PVC - Polyvinyl chloride - Usage

- Used for plumbing supplies like piping, construction area, door frames, windows frames
- Other examples:
  - for inflatable boats
  - electric cable isolation
  - imitation leather
  - underneath the floorboards, some PVC levellers and rain gutters
  - in credit cards

3.PVC

PVC for piping

PVC Floor

PVC credit card

3.PVC - Properties

- It comes usually in flexible or rigid form
- Strong, very good for all kind of marine applications
- Relatively cheap and accessible
- Dense and resists impacts very well, high tensile strength
- Very resistant to chemicals and alkalize
- Poor heat stability, that why often additives are added in the production
- It emits very toxic fumes when it melts or subjected to fire

3.PVC - Recycling

- Rarely recycled (under 1% depends on the country)
- E.g.: pipes degrade, and it is difficult to recycle low quality plastics
- It's melting toxic properties makes it also hard to recycle
- The nature of PVC is not so good for recycling

4.LDPE - Low density polyethylene - Usage

- mostly used in polybags, zip log bag, clear grocery (often get at stores, small clear bags)
- used a lot in packaging like bubble wrap

4.LDPE

Bubble wrap

Plastic bags

4.LDPE - Properties

- Soft, flexible
- Cheap to produce
- Low melting point in comparison to HDPE

4.LDPE - Recycling

- Has a low recycling rate, many cities do not take it for recycling
- Hard to sort because e.g. HDPE and LDPE are both used for …bags, …

5.PP - Polypropylene (Polypro) - Usage

- used in wide variety of applications for example disposable containers like
  - food containers, butter tub, yogurt cup, sour cream container
- Often part of bigger objects like electronics (cameras) or in furniture
- In cosmetic application, grip strips, also in cups
- most parts that use hinges or things where a thin film of plastic directly serves as an hinge
- In car parts

5.PP

- PP for yogurt cups

PP for motor cover

5.PP - Properties

- Very strong
- good for chemical resistance against most common acids and bases
- It is not brittle, bend well and used over time and still not break, -so good for hinges
- high heat tolerance, usable for items that tend heat up (car parts)
- Also, cold temperature applications
- material is food save and can be microwaved

5.PP - Recycling

- Recycling rate is about 2-5%
- Very difficult to clean, smelly/stinky once there was food inside at is rotten, molecules stays inside and smell, very deep (molecular) cleaning needed to make a new cup out of it
- Low recycling rate, because it is inside and integrated in so many different shapes and pieces that makes it difficult to separate and recycle in a economics matter
- There is not so much infrastructure to recycle in comparison to PET bottle recycling
- In general PP is easy to recycle, still it is difficult not due to the material aspect but sorting aspect
- Potential to recycle does not mean it gets recycled to separate and recycle in a economics matter

6.PS - Polystyrene - Usage

- Can be used in a hard form for containers
- But generally know as styrofoam
- Used for cups, food container
- Packaging
- Some floating things are also made of PS

6.PS - Polystyrene - Usage

In hard form for containers

Mostly in soft form known as styrofoam

6.PS - Properties

- One of the worst plastic for environment,
- Extremely brittle
- A lot of micro plastic results from it
- Hard to clean

6.PS - Recycling

- Very hard to recycle it economically
- Needs a very special recycle facility that accepts it
- Often not recycled

7.Other: PLA - Polylactide - Usage

- Very common with 3D printing
- most of 3d printed stuff is made from PLA
- often used with various medical devices but has in general a wide variety of applications

7.Other: PLA - Properties

- Labelled as the “green alternative”, made of corn, beets or sugarcane,
- It is strong
- Can be combined with other material such as hemp
- Theoretically 100% compostable and biodegradable

7.Other: PLA - Recycling

- Recycling and compostable rate is low, because it is grouped with “other plastics” and practically gets mixed with other plastics.
- 100% biodegradable does not mean, that it happens naturally
- It needs to be heated up to a very high temperature at a special composting facility to break down, once it has broken down, bacteria can consume the PLA resulting in little byproducts.
- If your city has a proper composting facility and sorting facility, it can be properly composed. But often it is sent to “normal” recycling facilities and then it will be sent to landfill or will be burned.
- Debate, whether corn should not be better produced for consumption and not for making plastic

7.Other: ABS - Acrylnitril-Butadien-Styrol - Usage

- Most popularly used in Lego
- Used also in 3d printing, car fittings and construction

7.Other: ABS - Properties and Recycling

- It is very hard
- Scratch resistant
- Very low recycling rate (0-1%), because it is often mixed with other plastics together
- Makes toxic fumes when heated up

7.Other: Nylon - Usage

- It is used where you need strengths, resistance, flexibility and when the material is stressed the over and over again.
- Clothing: Activewear/outerwear like rain jackets. Also for hosiery and lingerie.
- Ropes and cords that need to hold up under heavy use
- Automotive parts: gears, bearings, and fuel lines.
- Military and aerospace: parachutes and aircraft parts
- Household items: carpets, cooking utensils, and toothbrushes.
- Medicine: prosthetics, …

7.Other: Nylon

7.Other: Nylon

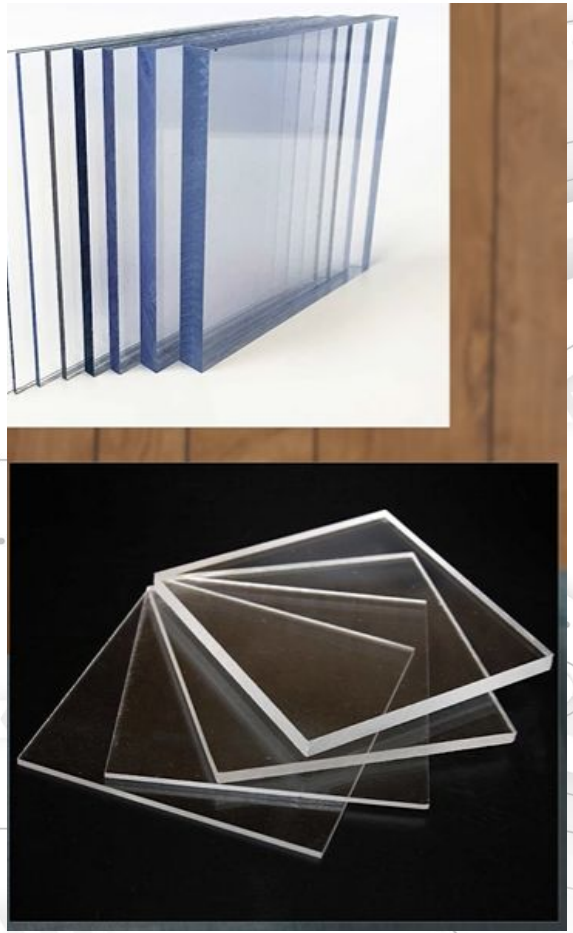
7.Other: Nylon

7.Other: Nylon - Properties - Recycling

- Stronger than polyester, more resistant
- Durable material that is resistant to wear and tear
- Low recycling rate 0-1%
- It is often mixed up with other plastics together what makes it difficult to separate.
- No standard infrastructure to recycle nylon economically, also because it is in so many different objects. That makes sorting difficult, too.
- After many years of use the nylon material quality degrades

7.Other: Polycarbonate - PC - Usage

- Used for safety glasses, greenhouses, bullet proof materials
- containers, CDs and more



7.Other: PC - Properties - Recycling

- 250x stronger than glass.
- Often transparent
- It is in theory very good recyclable, near to 100%
- 0-1% recycling rate
- Mixed up with other plastics
- Objects are difficult to process, not “standard” objects
- Not a huge quantity, so not a lot get recycled

7.Other: Acrylic - Usage

- Used for display cases, nails, TVs, aquariums and more.
- Acrylic is similar to PC, used also for barriers (medical and nonmedical), furniture.
- Known for being Clear and transparent –> Plexiglas
- Uses for more static use cases and is cheaper then e.g., PC

7.Other: Acrylic - Properties - Recycling

- Stronger than glass (10-15% stronger, or more)
- Resistant to temperature change, and half the weight of glass
- Good for chemical applications as it oft does not react to many chemicals.
- Very recyclable in theory
- Objects are difficult to process, not “standard” objects
- Not a huge quantity, so not a lot get recycled
- There is not easy system to recycle nails, aquarium glasses …

Challenges in Recycling

- Complex steps to create new raw materials from old plastics: collecting, sorting, cleaning and producing
- You need to have enough amount of material coming frequently with number 7 type plastics the constant flow is difficult, as it often comes in many different pieces and is mixed.
- Poor quality plastic must be sorted out
- Different types of plastic have to be sorted correctly, which is often difficult and costly. “Same items” like Yogurt cups or shopping bags can be made from different plastics

Challenges in Recycling

- The colour also plays a role whether a plastic is recyclable / worth recycling.
- The Cleaning can be very expensive and challenging and economically not affordable.
- Many cities due not have the infrastructure (collection system, sorting system and recycling systems) for the different plastic types.
- It is often significantly cheaper to produce new “virgin” plastic than collecting, sorting, cleaning and finally producing recycled plastic. The costs for virgin plastic are more constant and easier to calculate with

Sources

What is PET Plastic? | Polyethylene Terephthalate Overview https://www.youtube.com/watch?v=N5Zkr6NDAVo
What are the Different Types of Plastics | 7 Types of Plastic and Categories https://www.youtube.com/watch?v=LPThrGVMARA
What Is HDPE Plastic? | High-Density Polyethylene https://www.youtube.com/watch?v=G8rPezOpjD0
What Is PVC Plastic? | Polyvinyl Chloride Explained https://www.youtube.com/watch?v=TomsPjfdH_U
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What is Polypropylene Plastic | Can it be recycled? https://www.youtube.com/watch?v=fmMPYnl9x7c
What is PLA Plastic? | What are the Pros and Cons of this "Green" Plastic https://www.youtube.com/watch?v=Iw191pVHnQo
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What is Polyester | How is Polyester made? Plastic or Eco-Friendly https://www.youtube.com/watch?v=inqJOVcETtA
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What is ABS Plastic? | How to use ABS Plastic. 3D Printing? Lego? https://www.youtube.com/watch?v=OsVO1h_fIBs
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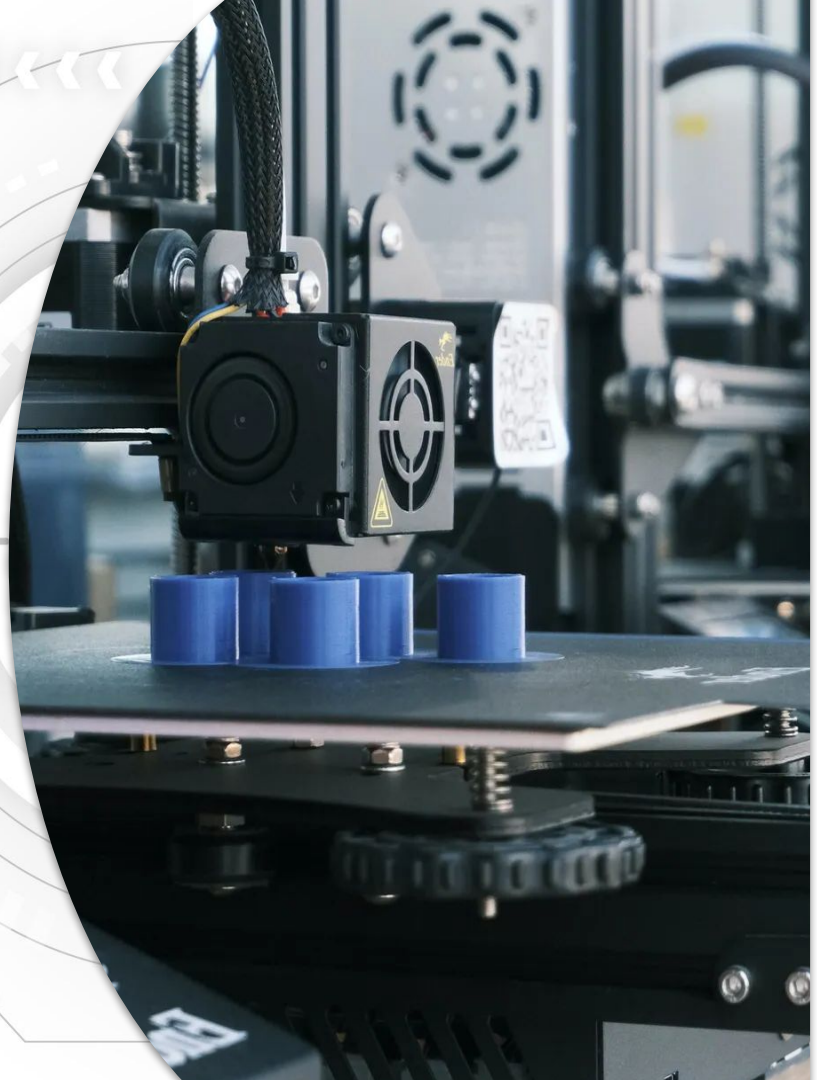
Why are Bottles and Bottles Caps Different Plastics? | Questions Answered https://www.youtube.com/watch?v=XQOQtTrgRhc
14 Easy Ways I Reduce Plastic | How to use less single use plastic https://www.youtube.com/watch?v=Cbezt8jpd8A
How Science Is Fixing Recycling's Grossest Problem https://www.youtube.com/watch?v=rQAKC870dLA

Materials for 3D Printing

3D Printing



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Rigid Filament - PLA - Examples in context of fashion

- Customized Jewelry: Design and print your own unique earrings, bracelets, or pendants.
- Buckles and Belt Accessories: Create custom belt buckles or accessories to enhance belts.
- Fashionable Buttons: Print stylish buttons for clothing like blazers or jackets.
- Shoe Accessories: Shoe clips, lace locks, shoelace Tips, or heel embellishments.
- Hair Accessories: Print hair clips, barrettes, or hair combs with intricate designs.
- Cufflinks: Design and print personalized cufflinks for a distinctive touch to formal wear.
- Printed Textiles and Fabrics: Create one-of-a-kind fabrics for clothing.

Rigid Filament - PLA - Examples in context of fashion

- Hat Accessories: Print hat bands, pins, or other accessories to personalize your hats.
- Gloves: Combine traditional materials with 3D-printed elements for unique gloves.
- Zipper Pulls: Customize your clothing by replacing standard zipper pulls with 3D-printed ones.
- Elastic Waistband Adjusters: Adjustable and personalized waistband adjusters for skirts or pants.
- Printed Bow Ties: Design and print your own bow ties with intricate patterns or shapes.
- Fashionable Brooches: Print stylish brooches to add flair to your clothing.
- Printed Collar Stays: Keep your collars sharp with 3D-printed collar stays in unique designs.

Rigid Filament - PLA - Examples in context of fashion

- [Pictures here]

PLA - 3D Printing properties

- Standard PLA is one of the most widely used materials in 3D printing and it is easy to print with
- It is usually rigid and does not bend
- Nozzle printing temperature is usually between 190°C and 220°C
- Print Bed Temperature is usually 60°C
- No enclosure needed, as PLA does not release harmful gases when it is heated up
- Not recommended for outdoor applications as it can deform, when being in the hot summer sun. PLA deforms and becomes soft when it is heated up over 60°C
- Not very recommended for mechanical pieces, as it is not very hard and it rubs off relatively easily

TPE , TPE - Flexible Filaments - Examples in context of fashion

- Customized Jewelry: Flexible Bracelets: Flexible and comfortable bracelets, soft Jewelry Elements,necklaces or earrings, wristbands ...
- Elastic Belts: Print belts with stretchable and flexible properties for a snug yet comfortable fit.
- Shoe Insoles: Design custom insoles that provide both support and flexibility.
- Headbands: Print flexible headbands with unique designs for a fashionable accessory.
- Customizable Cuffs: Create cuffs for sleeves or pants with a flexible and adjustable fit.
- Flexible Buttons: Design buttons with a soft and flexible feel for clothing closures.
- Hair Ties: Print stretchable and stylish hair ties or bands.

TPE , TPE - Flexible Filaments - Examples in context of fashion

- Comfortable Bra Straps: Create bra straps that are both flexible and comfortable.
- Soft and Flexible Hat Bands: Enhance hats with soft and flexible bands for added comfort.
- Flexible Bow Ties: Print bow ties with a flexible structure for a modern and unique look.
- Stretchable Glove Components: Incorporate flexible components into gloves for a snug fit.
- Adjustable Straps: Design clothing with adjustable and flexible straps for a customizable fit.
- Printed Textile Patterns: Experiment with 3D-printed textile patterns for clothing designs.
- Customizable Shoelaces: Print shoelaces with TPE or TPU for a comfortable and flexible alternative.

TPE , TPE - Flexible Filaments - Examples in context of fashion

- [Pictures here]

TPE , TPE - 3D Printing properties

- TPE (Thermoplastic Elastomer) combines the properties of plastic and rubber
- TPU (Thermoplastic Polyurethane) is a subset of TPE and has often a rubber-like finish
- TPU and TPE are flexible 3D printing materials
- They come in different range of hardness/softness and flexibility
- Nozzle printing temperature is usually around 215-255°C
- Print Bed Temperature is usually between 0 - 60°C

PET and PETG - 3D Printing properties

- PET (Polyethylene Terephthalate) and PETG (Polyethylene Terephthalate Glycol) are two variations of the same polymer, with some key differences in terms of their properties and applications:
- PET is a clear, transparent, colorless, and rigid plastic
- PET more challenging to 3D print, it needs a higher melting temperature and adhesion can be an issue.
- PETG contains the addition of glycol and makes PETG more flexible and less brittle compared to PET.
- PETG is naturally transparent but may have a slightly milky appearance. It is available in various colors
- PETG is more popular for 3D printing due to its lower melting temperature and better adhesion properties. Adheres well to a variety of surfaces, including a non-heated print bed.

PETG - 3D Printing properties

- Especially suitable for mechanical parts and both indoor & outdoor use.
- Nozzle printing temperature is usually around 220 - 260°C
- Print Bed Temperature is usually 60°C - 90°C
- No enclosure needed, as PETG does not release harmful gases when it is heated up

PET and PETG - 3D Printing properties

- [Pictures here]

ABS - 3D Printing properties

- [Pictures here]

PC - 3D Printing properties

Additives and special 3D printing filaments

- PLA, TPE/ TPU/, PETG and all other regular plastic types used in 3d printing can be combined with various additives.
- Additives give filaments special functional properties or optical properties
- It may influence the recyclability
- Additives can be “organic” and non organic
- Every few month new types of filaments appears on the market
- There is a lot of research taking place on this topic

Filaments with special visual appearance

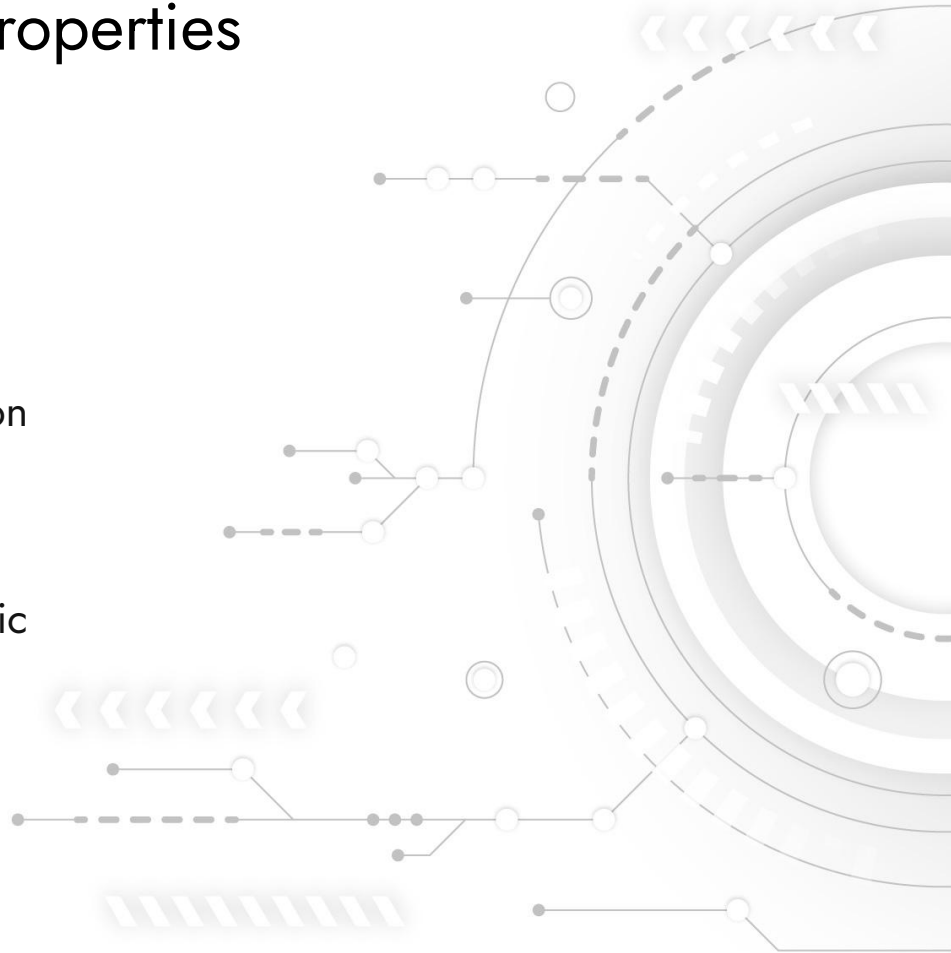
- Additives to change the visual appearance
- wooden style, stone style, metalic style, …
- shiny silky or glitter
- - glow in the dark with UV light

Filaments with special functional properties

- ...make filament conductive
- - make filament harder, softer, more dureable, more flexible
- - make filement change color if certaine temperature is reached
- - give filament anti bacterial properties
- - give filament a special scent
- - give filament air purifying attributes
- - give filament magnetic properties
- give filament light reflecting ability

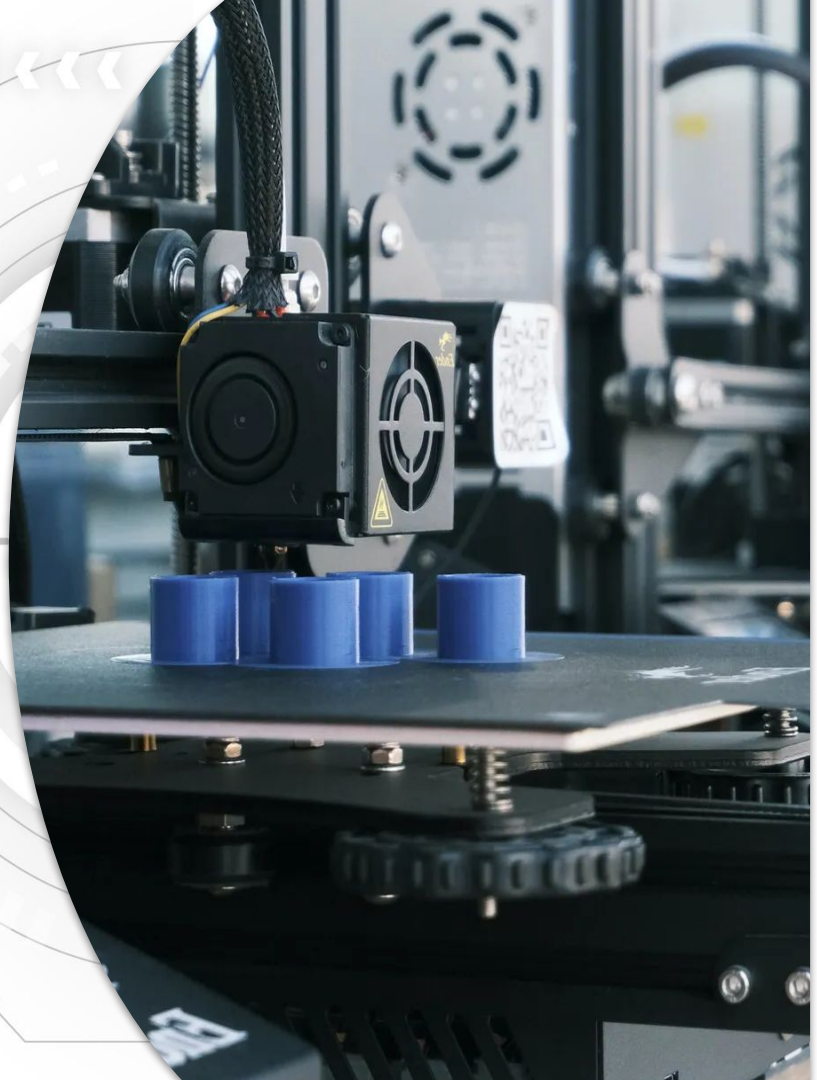
Filaments with “reduce” waste properties

- …filament made out of waste from olive pits
- - made from coffee
- - made from waste from austers consumption
- - made from mussel shells
- - filament made from plastic waste, old plastic



Recycling in the context of 3D printing

Sustainability



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Recycling with 3D printing and the circular economy approach

- In 3D printing and especially in the context of fashion, the adoption of a circular economy approach should be prioritized already at the design phase. Cleverly done, the 3D printing technology
  - can contribute to waste reduction and saving resources and CO2 emissions
  - can enhance recycling, upcycling, and downcycling of already produced materials
  - can give previously valueless materials a new greater appreciated value
- On the other hand, using 3D printing the wrong way, will rather increase the waist of resources

Recycling with 3D printing and the circular economy approach

The circular economy approach can be implemented in the context of 3D printing with the following measures:

- Design your objects so that as little plastic as possible is used
- Try to design your objects in such a way that no additional screws or glue is needed
- design your objects so that they are made of the same type of plastic wherever possible
- If different types of plastic are required for an object, design the object parts in such a way that they can be easily separated later on
- Consider whether recycled filament is an option for your objects
- Try to minimize waste during prototype development
- Try to recycle your own 3D printed objects

3D printed leftovers

1. Try and Error while prototyping

3D printing works iteratively and according to a "try and error" principle.

- You create a new model on the computer and then try printing it for the first time. Once you have the printed model in your hand for the first time, you often see room for improvement.
- You adjust the model or the print settings and print the model again.
- This continues until you are satisfied with the print.

3D printed leftovers

2. Leftovers during the print process

There are almost always some leftovers during the print process. The usually occur when:

- the printer warms up,
- the printer calibrates itself before printing,
- printing in multiple colours,
- the colour has to be changed
- supporting material is needed

3D printed leftovers

3. Errors during the print process

If you print a lot, for example you need to print 50 same items, 1 - 3 parts may go bad despite a good model and printer settings. Possible reasons for this:

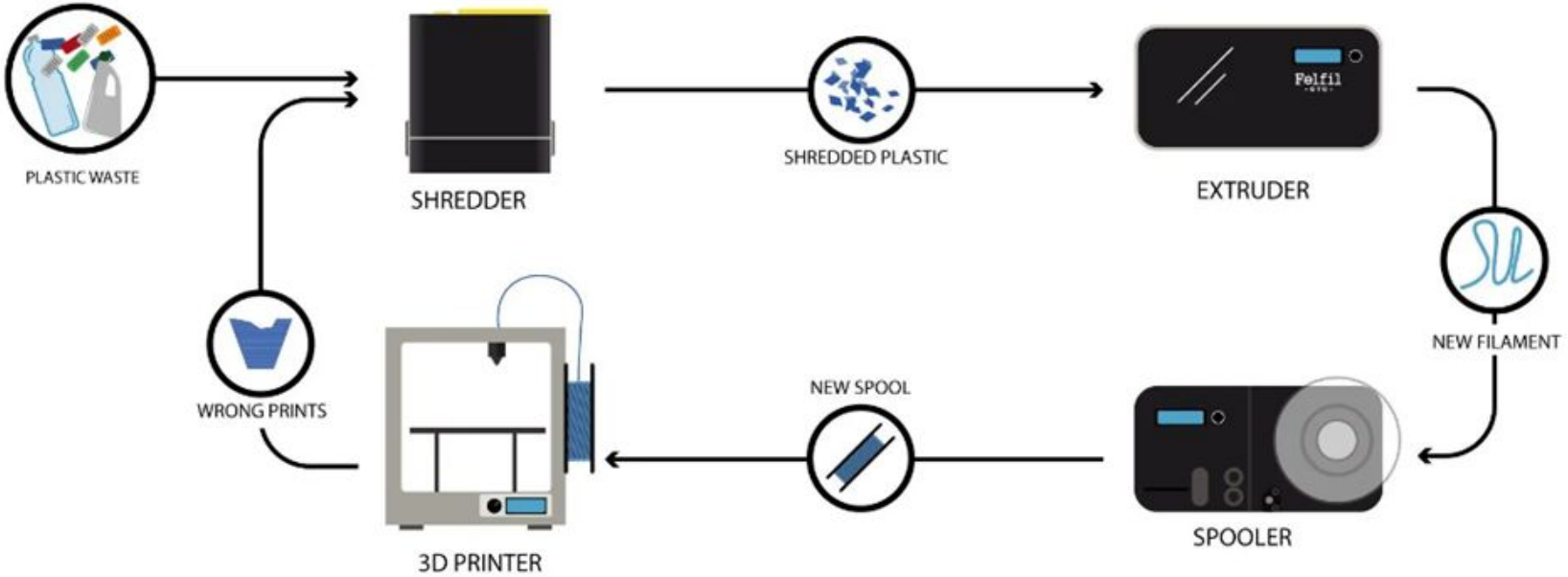
- Power failure during the print,
- The spool runs out of filament during the print,
- The filament knots somehow unfavourably and the print stops,
- An individual part in the printer breaks,
- Larger visible dirt particles or residues from the old filament of a different colour get into the print and it makes the result looking bad
- Accidentally cutting away too much with a knife or break the model during post-processing

Recycling with 3D printing and the circular economy approach

In the context of 3D printing, the general circular approach is as follows:

1. Collect recyclable plastic
2. Shred the plastic into small pieces
3. Put the plastic parts into the extruder and get filament
4. Roll the filament into a spool
5. Print something useful with the filament

Recycling with 3D printing and the circular economy approach



1. Collecting plastics for recycling

1. Collecting plastics for recycling

- When collecting the leftovers form 3D printing and plastics in general, it is important not to mix different materials.
- PLA should be collected with PLA, PET with PET, PETG with PETG, etc.
- Different plastics have different mechanic and chemical attributes and different melting points.
- Mixing different plastics together for recycling can result in a very inconsistent polymer of very bad quality and inconsistent properties
- It will make it hard or impossible to process it and recycle it for a new product.

1. Collecting plastics for recycling

2. If colour matters - same colour to same colour

- If the colour is important, you should also separate the plastics by colour
- If you put different coloured plastic parts into the extruder, usually a brownish colour results
- In general, white and transparent and light coloured plastic has an higher value, because you can later make product with these colours again or mix it easily with other colours.
- Black and dark coloured plastics have a lower value, because you can only make black or dark coloured products later with it

1. Collecting plastics for recycling

3. Garbage in, garbage out

- Parts should be pure, it means there shouldn't be any paints, glues or screws. Otherwise, it can
  - damage the shredder (e,g. when trying to shred a screw) or damage the extruder
  - or in general lower the mechanic properties of the resulting filament
- Plastic is often dirty and needs to be washed, if not, it will be at the end in the recycling machines and in the final result, harming the mechanical properties and esthetical view.
- The quality of the plastic item matters. If the item was outside for a longer period of time, e.g. a PET bottle floating in the sea or a pipe in the earth, it may absorb moisture and even rotten.
- The polymer quality can degrade and destroy its original properties, especially when heated up again.
- If you don't have the right technical infrastructure, then rotten plastics or other bad quality plastics should not be or at least only very carefully used for recycling

2. Shredding plastics

1. Shredder plastic to get plastic flakes

- Once the leftovers have been sorted, they can be shredded.
- Ideally, you get “plastic flakes” with a diameter of 3 - 4 millimetres.
- [picture of shredder here]

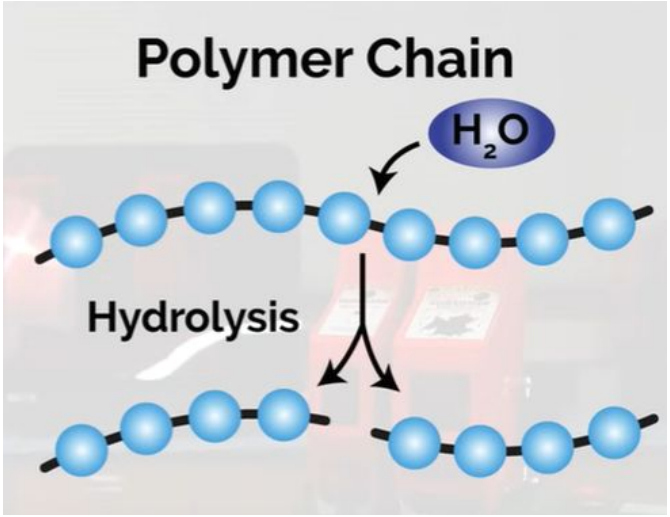
2. Shredding plastics

2. Dry the shredded plastic flakes

- Plastic can generally absorb moisture.
- In flake form, the surface area of the plastic is larger and can absorb more moisture.
- The moisture in the plastic flakes can cause problems.
- Plastics can degrade when heated above their melting temperatures in the presence of water
- It is known as hydrolysis.

Hydrolysis and Polymer Chains and Degradation

- Hydrolysis causes parts, that are printed from degraded filament to be brittle and weak
- It makes the polymer chains shorter, degradates mechanical properties and makes it more difficult to extrude
- Also, it can cause voice and bubble in the filament, reducing the final print quality.

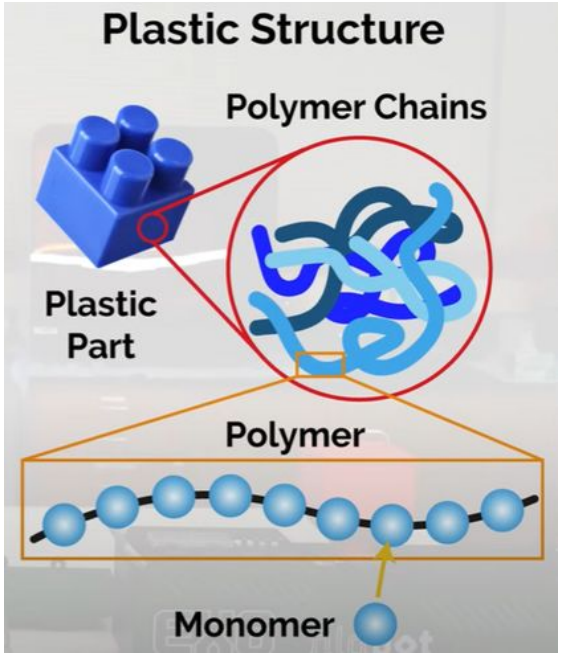


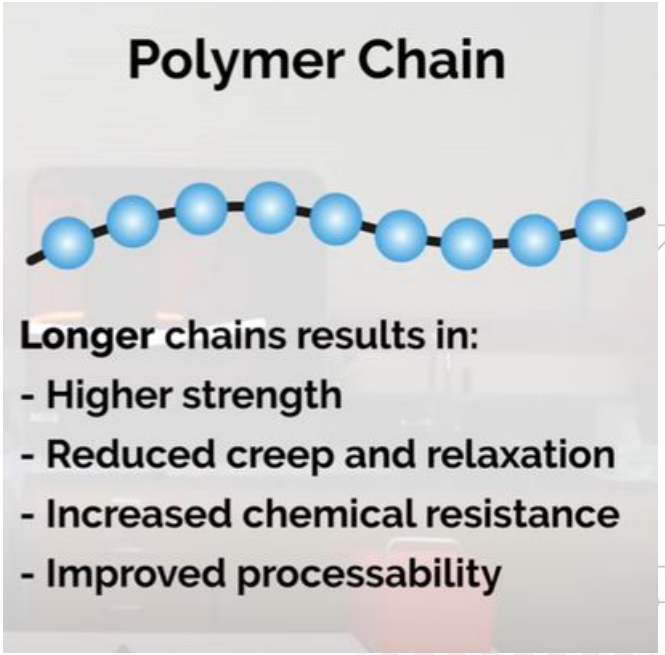
Thermal history and Degradation

- The more time plastic has processed with high temperatures, the less it will be like new material.
- Keeping track of how often plastic has been heated is called “thermal history”.
- Some plastics like PET and polystyrene can withstand a longer thermal history without a significant change in mechanic properties. These plastics are considered as highly recyclable.
- Actually, PLA is not very recyclable because of its tendency to degrade in.
- In practise recycled PLA means often that old PLA was combined with new “virgin” PLA to prevent severe loss in mechanical properties in the final product.

Polymer Chain

- About plastics you can usually say, the longer the polymer chains the better..





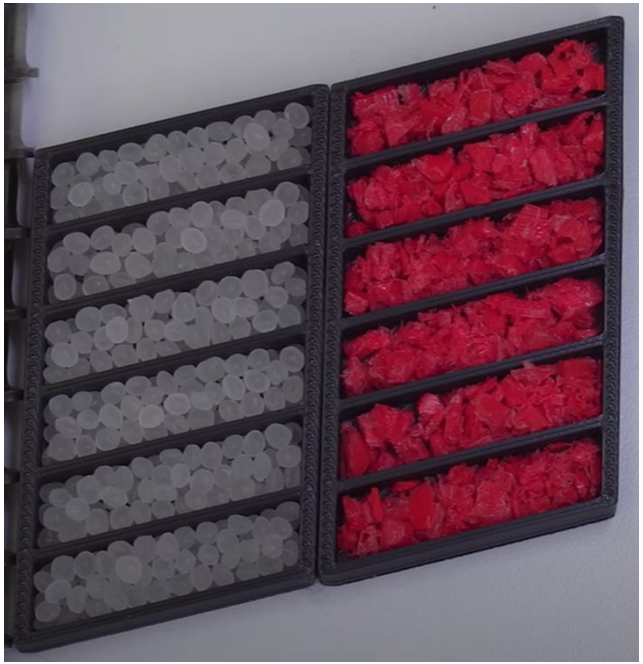
2. Shredding plastics

3. Remove plastic powder

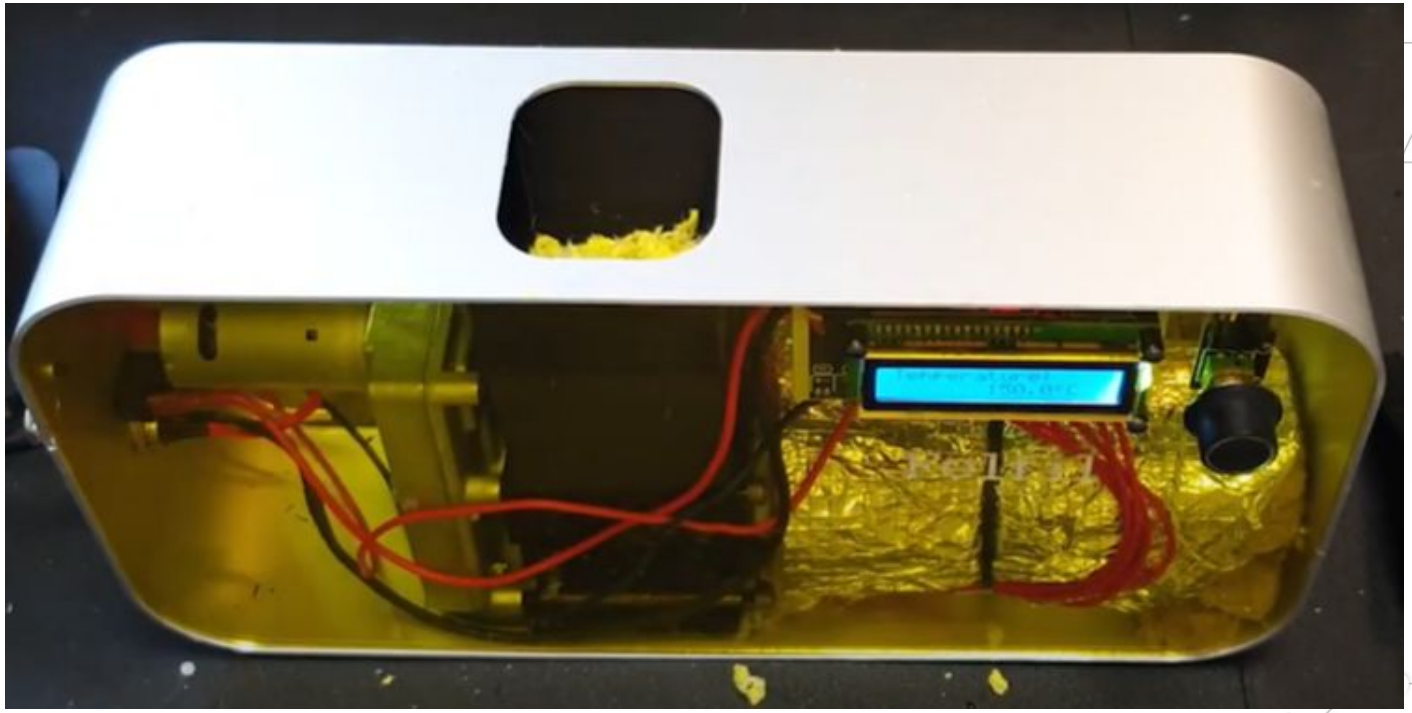
- Remove plastic powder (over granulated plastic) as it can behave strangely in the extruder and is difficult to process. In general, the plastic flakes should not be too small and not too thick

3. Extruding the flakes to filament

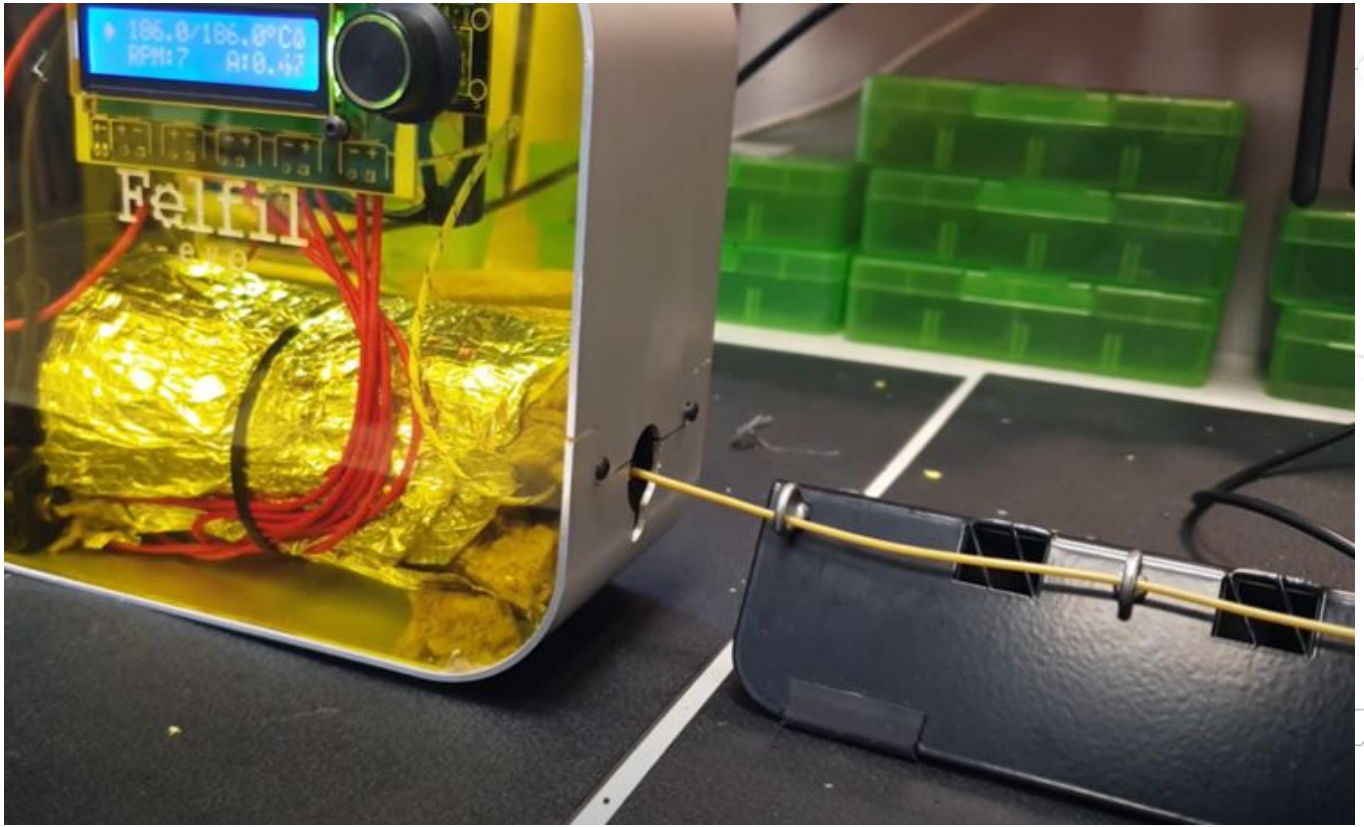
- Put the flakes into the extruder, it will create a thin plastic string, usually around 1.75mm thick.
- For these you might want or need to mix the shredded plastic flakes with virgin material



3. Extruding the flakes to filament

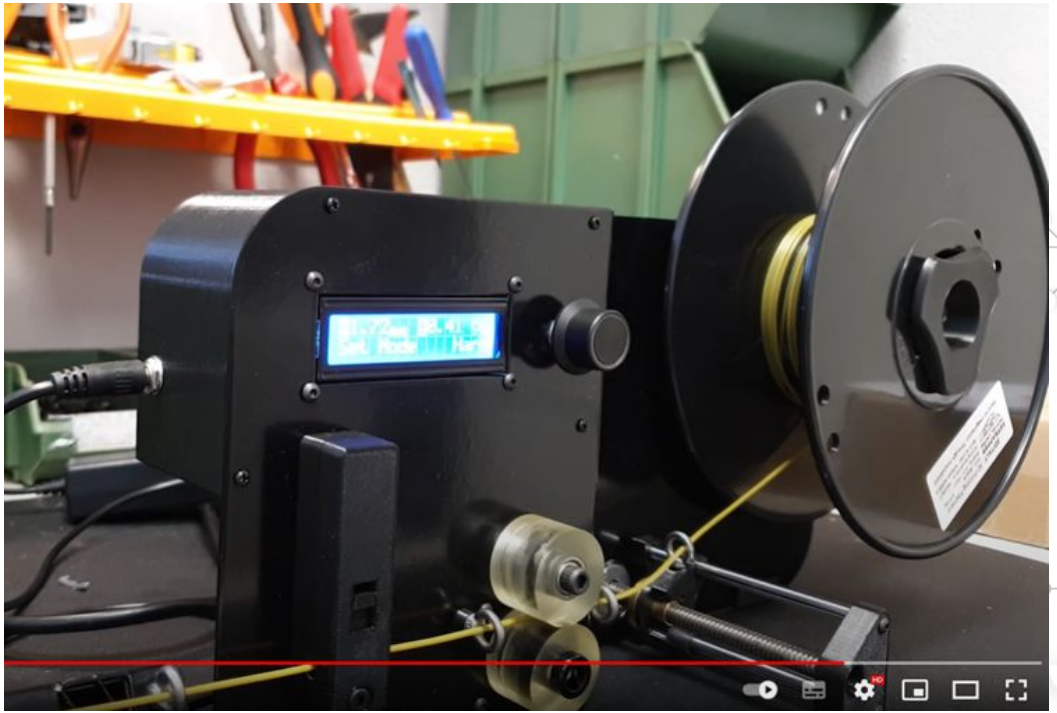


3. Extruding the flakes to filament



4. Roll the filament into a spool

- The outcome from the extruder process should be rolled around a spooler



5. Print something useful with the filament

- [Picture here]

Sources

How to Extrude 3D Printer Filament (Basics of Screw Extrusion):
https://www.youtube.com/watch?v=cIh0n2zOCfM
Recycling 3D Prints and Waste Plastic into Filament (PET & PLA):
https://www.youtube.com/watch?v=jXY1EygE4R8
Recycling 3D Printer Poop into New Filament:
https://www.youtube.com/watch?v=O6d1RKYapFI
Some useful links: https://felfil.com/sustainability/?v=5ea34fa833a1
Short Video: https://www.youtube.com/watch?v=tWviePTiAXY
Longer Video: https://www.youtube.com/watch?v=bzK86U-dBNw
Felfil: https://felfil.com/educational-recycling-project/?v=5ea34fa833a1