



Intellectual Output 4

Curricula on Recycling

Part C

RECYCLING TECHNOLOGIES

Course Outline

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1. Aim of the course

This course aims to introduce the students to the recycling technologies. Specifically, it deals with the treatment of each recyclable material and at the same time emphasizes on the contribution of recycling to the environmental protection. Additionally, the course analyzes the procedure of transforming plastic waste into filament.

2. Learning outcomes

The skills that students will be expected to acquire after the end of the course are:

- Be familiar with the different recycling technologies
- Knowledge of the economy of plastic packaging
- Be familiar with the types of plastic that can be transformed into filament
- Presentation of projects and companies which use 3D printers with plastic filament and recycled plastic

3. Teaching and Learning Methods

3.1 Teaching approach

A comprehensive transfer of knowledge and experiences to students through mental and experiential understanding of recycling technologies and how plastic can be used in 3D printers.

3.2 Delivery method

Face-to-face, distance learning and use of audiovisual material.

3.3 Sessions

1. Life cycle of plastic
2. Circular economy of plastic packaging
3. Mechanical recycling
4. Chemical recycling
5. Secondary materials and recycled products
6. Plastic to filament
7. Projects on recycling
8. Activity

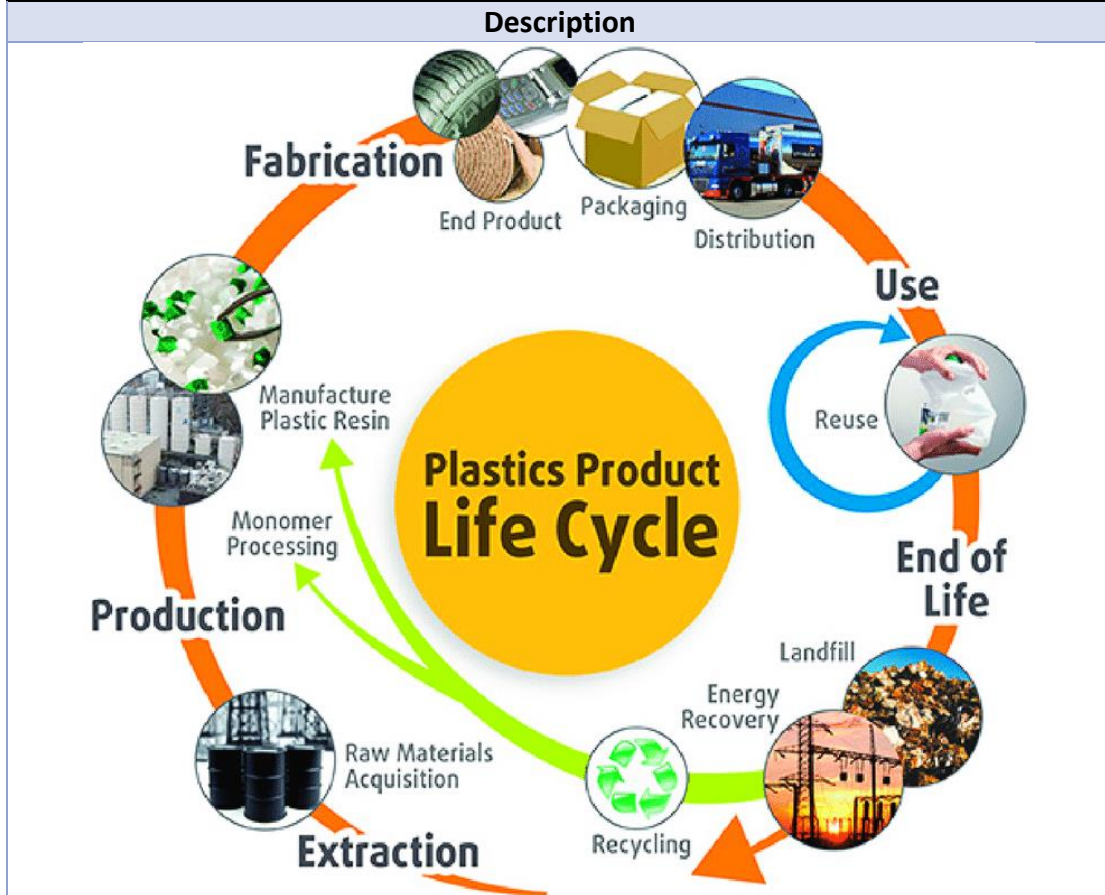


Figure 1: Plastics product life cycle

(https://www.researchgate.net/figure/Life-cycle-of-plastics-2_fig1_331249931)

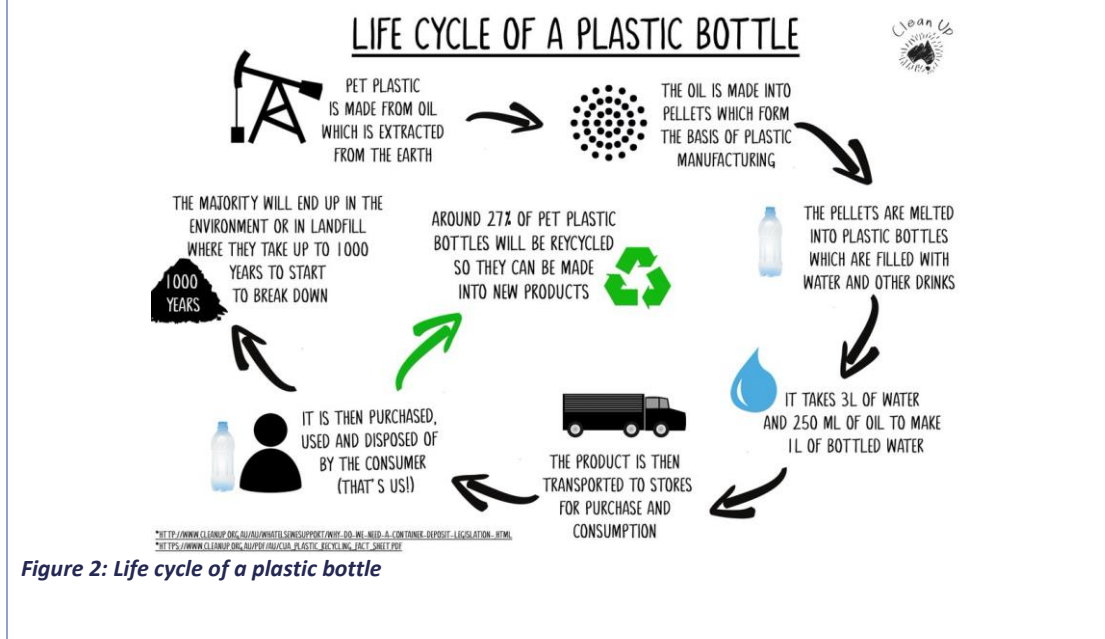


Figure 2: Life cycle of a plastic bottle

Description

A circular economy is an alternative to a traditional linear economy (make, use, dispose), where all materials are treated as precious resources, with nothing thrown away.

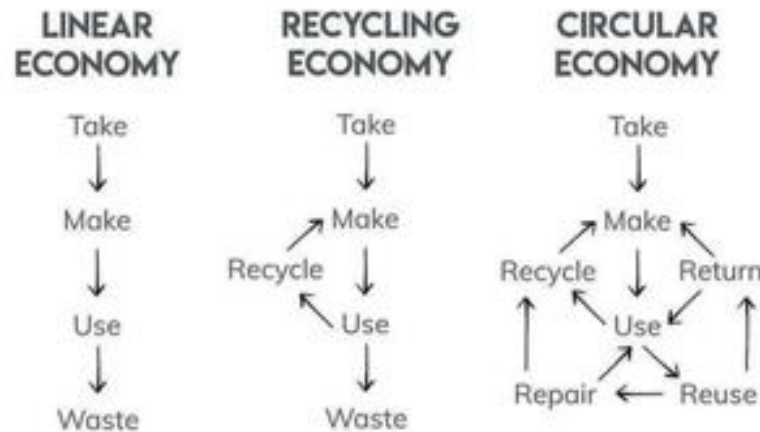


Figure 3: Different types of economy

(<https://www.cleanup.org.au/circular-economy>)

Plastics are widely recognized to have an ever-increasing importance in waste management.

- Plastics are often used in products with short lifespans, and pose substantial environmental problems due to the accumulation in ecosystems when disposed improperly
- EU target by 2025 → 55% increase in recycling and reduce the landfilling of packaging waste
- Plastics are one of the five priority areas in the EU action plan for the circular economy
- One of the circular economy's indicators is the recycling rate
- PET causes relatively high environmental impacts on primary production
- PET has about half the heating value compared to the other major packaging polymers

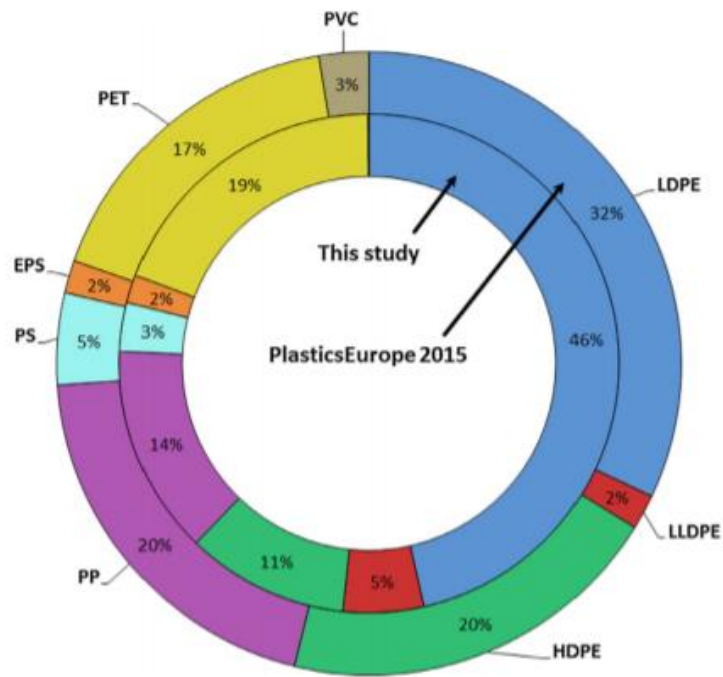
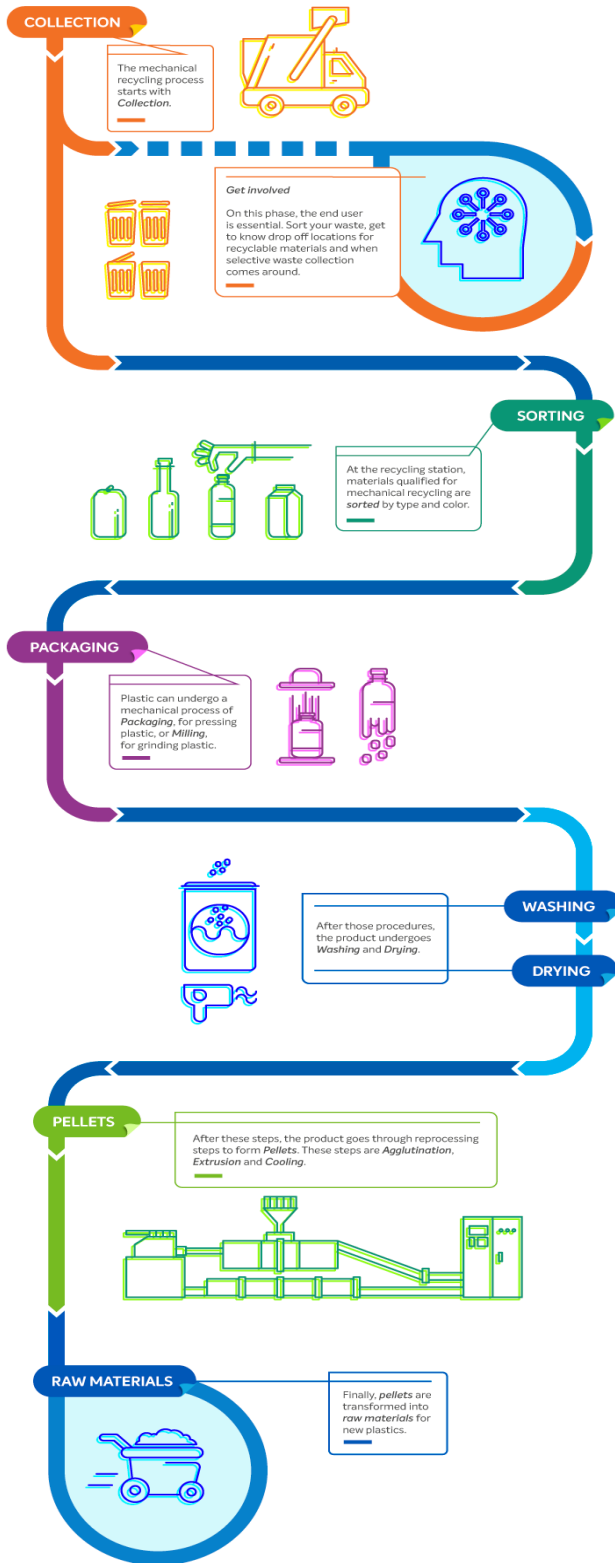


Figure 4: Comparison of the polymer composition for the year 2013 of plastic packaging demand in Europe from PlasticsEurope (2015), and of waste plastic packaging in Austria

Session 3	Mechanical recycling
Description	
Introduction in recycling technologies. Examine one and each of them.	
<p>Mechanical recycling of plastics refers to the processing of plastics waste into secondary raw material or products without significantly changing the chemical structure of the material.</p> <p>(https://www.plasticseurope.org/en/focus-areas/circular-economy/zero-plastics-landfill/recycling-and-energy-recovery)</p> <p>(https://sustainablepackaging.org/mechanical-recycling-options/)</p>	

Mechanical Recycling



<http://www.circulareconomyasia.org/mechanical-recycling/>

Figure 5: Mechanical recycling

Benefits:

- Recycling plastic contributes to the conservation of natural resources and energy which is required to produce virgin plastic.
- When plastic is recycled, less plastic is sent to landfill and thus, less of this material takes up room in our environment for hundreds of years.
- Making new products from recycled plastic packaging materials is more than three times more efficient in terms of greenhouse gas emissions than manufacturing those same products with virgin raw materials, mainly because of the energy savings in recycled versus virgin content product manufacturing.

Challenges:

- The quality of plastics collected (the feedstock for recycling processors) is, usually, inconsistent and contaminated leading to downcycling into lower value items.
- Many plastic recycling companies have insufficient standardization, industrialization and operational excellence in their operations. This is largely due to the nature of the sector, which is characterized by small, entrepreneurial companies, with management teams that often have limited experience in the professional plastics industry.
- In fact, only a fraction of ‘recyclable’ used plastic is recycled into the products for which they were originally produced, even in the case of the most readily recyclable plastic such as PET and HDPE. The reasons are due to colorants, additives, and fillers used during plastic production, contamination from consumer use, and yield losses during the recycling process.
- Plastic recyclers tend to specialize in one or a limited number of plastic types such as HDPE, LDPE and PP, to name a few. Recyclers produce regranulates for industrial buyers, with whom they agree various quality standards around criteria such as density, melt-flow index and stability.

(<http://www.circulareconomyasia.org/mechanical-recycling/>)

Session 4	Chemical recycling
Description	
Chemical recycling implies a change in the chemical structure of the material, but in such a way that the resulting chemicals can be used to produce the original material again.	
<p>The diagram illustrates the six-step process of BASF's ChemCycling™ project. It is a circular flow starting with consumers using and disposing plastic products (01), followed by waste collection and sorting (02), conversion to pyrolysis oil (03), purification of the oil (04), allocation of recycled feedstock via a mass balance approach (05), and finally, customers using these chemicals to produce their own products (06). The central text reads 'BASF's ChemCycling™ project'.</p>	
Figure 6: Chemical recycling	
<p>(https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/mass-balance-approach/chemcycling.html)</p>	

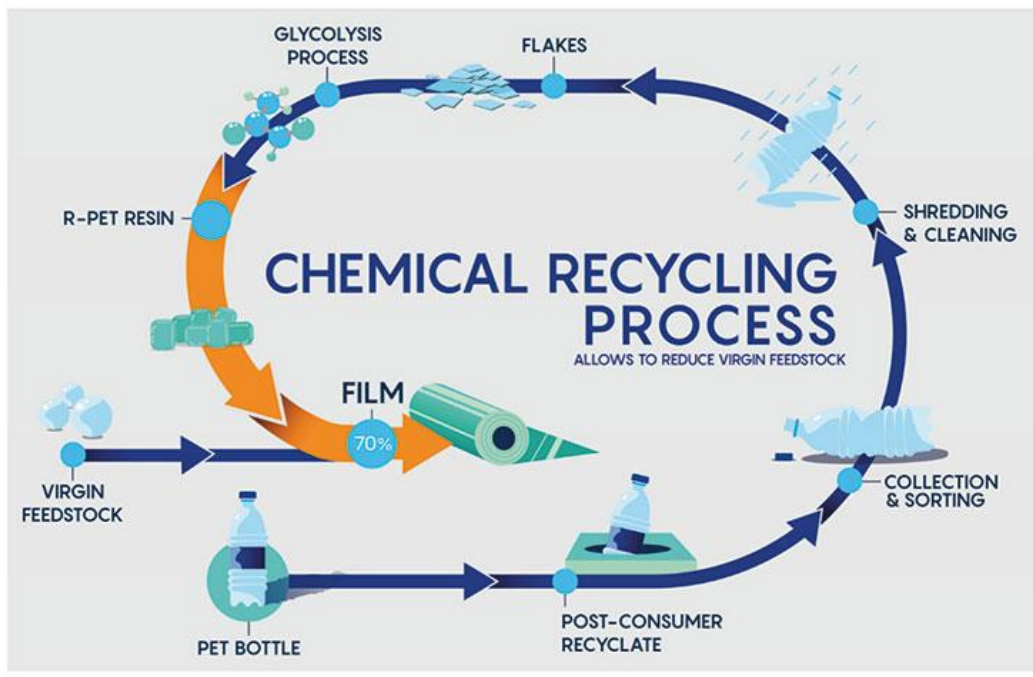


Figure 7: Chemical recycling process-Reduce virgin feedstock

(<https://www.italiaimballaggio.network/en/content/tpl-rpet-films-sustainable-solution-food-packaging>)

Benefits

- enhances circular economy and provides new means to increase recycling rates by utilizing a wider range of waste plastics than traditional, mechanical recycling
- enables production of high-quality end products – new plastics and chemicals – that can be used as drop-in solutions in all current applications of fossil-based alternatives
- decreases dependency on crude oil imports and lowers the carbon footprint of products
- supports global reduction of plastic waste and helps to eliminate landfilling
- can create new jobs in Europe and elsewhere.

(<https://www.neste.com/companies/products/plastics/combating-plastic-pollution/why-chemical-recycling>)

Fact

Chemical recycling offers a way to recover plastics that are unsuited to traditional mechanical recycling methods.

(<https://www.recyclingtoday.com/article/the-promise-of-plastics-chemical-recycling/>)

Material

This video shows the first prototype of chemical recycling

https://www.youtube.com/watch?time_continue=69&v=lgeCyrK9yiA&feature=emb_lo
go

Description

Secondary Materials are defined as materials that have been used, recycled and sold for use in manufacturing. These products allow for less reliance on the search for new raw resources for items such as paper, aluminum, and plastic. It is advantageous in the sustainable use of resources so that these materials can be maintained for longer periods. (<https://www.buschsystems.com/resource-center/knowledgeBase/glossary/what-are-secondary-materials>)



Figure 8: Plastics storage

(<https://www.fcc-group.eu/en/hungary/technologies/other-services/secondary-raw-materials.html>)

Description

Definition of filament and its benefits.

Filaments used in 3D printing are *thermoplastics*, which are plastics (polymers) that melt rather than burn when heated, can be shaped and molded, and solidify when cooled.

(<https://www.pcmag.com/how-to/3d-printer-filaments-explained>)



Figure 9: Filament sample

Types of plastic being used

- ABS
- PLA
- ASA
- PET
- PETG
- PC (Polycarbonate)
- High Performance Polymers
- Polypropylene
- Nylon
- Composites
- Hybrid Materials
- Alumide
- Soluble Materials
- Flexible Materials
- Resins



Figure 10: PET filament

(<https://www.3dnatives.com/en/plastics-used-3d-printing110420174/#!>)

Material

<https://www.youtube.com/watch?v=qJxT1hEb6Mk> (Recycling plastic into 3D Filaments)

Session 7	Projects on recycling
Description	
<ul style="list-style-type: none"> • Coca cola project https://www.coca-cola.gr/zero-waste-future/print-your-city-mporoun-ta-plastika-pou-petame-na-omorfinoun-tis-poleis-mas https://www.dezeen.com/2014/07/02/coca-cola-will-i-am-3d-printer-recycled-plastic-bottles/ • Blue Circle https://bluecycle.com/bluecycle-lab/ • Coronavirus: 3D printers save hospital with valves (Italian company) https://www.bbc.com/news/technology-51911070 • Marchesini Group https://www.3dprintingmedia.network/italy-marchesini-group-3d-printing/ • Make it precious 	

<https://preciousplastic.com/?fbclid=IwAR0d0A-6U40aMCDgsA33DBrtSO9U4uFQVP-szp8D24omPpnSwwemg5ZIHgM>

Session 8

Activity

Description

➤ <https://www.youtube.com/watch?v=4IG27xnh0oA> (Design Thinking for Schools)



Figure 11: Kids play with 3D printer

Discussion

Description

Discuss with kids what they learn after all sessions

4. Educational material (materials / sources / resources required to complete the course)

- ❖ Websites
- ❖ Course material

The reference material, the literature review, the proposed supplementary literature and everything else concerning the educational material will be uploaded on the platform and will be available to the public.

4.1 Keywords

Recycling technologies, plastic, economy, filament, 3D printer

4.2 "Flow Chart of Teaching"

In order to evaluate teaching, trainers should take into account the relevance of the goals they have set with the available time dedicated for the completion of the lessons.

They are called, in a limited time, to balance between the teaching objectives that the curricula require and the pupils' educational needs. In order to respond to this double obligation, it is necessary to make a planning of the steps they intend to follow in teaching.

In any case, the "Flow Chart of Teaching" is presented below:

Life cycle of plastic → Which is the life cycle of plastic material?

Circular economy of plastic packaging → What circular economy means?

Mechanical recycling → Technology

Chemical recycling → Technology

Secondary materials and recycled products → What are they and which are their use?

Plastic to filament → Definition & how it is made

Projects/Companies → What has already been done?

Activity → Through the activity, theory will be more understandable and practical and encouraging to an environmentally friendly technology

Discussion → Assessment of teaching
