DTU Sustain
Department of Environmental and Resource Engineering

Maastricht University

NTE-7

ESR 3- Design Plastic for Circularity:

A multiscale approach to assess Plastic Circularity

PhD candidate, Manon LISIECKI

Main supervisor: Prof. Anders Damgaard
Co-supervisor: Prof. Kim Ragaert
External co-supervisor: Prof. Thomas F. Astrup

C-PlaNeT
CIRCULAR PLASTICS NETWORK FOR TRAINING

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 859885.

'Turn off the plastics tap' by Canadian activist and artist Benjamin von Wong at the UN Environment Assembly in Nairobi, Kenya. ***Credit: UNEP/Cyril Villemain A***

Plastic Design for Circularity

Plastic

Large family of polymers, product types used in many sectors

(packaging, B&C, Agriculture, EEE, Automotive, Furniture).

Design

A concept of a system that has been intentionally created.

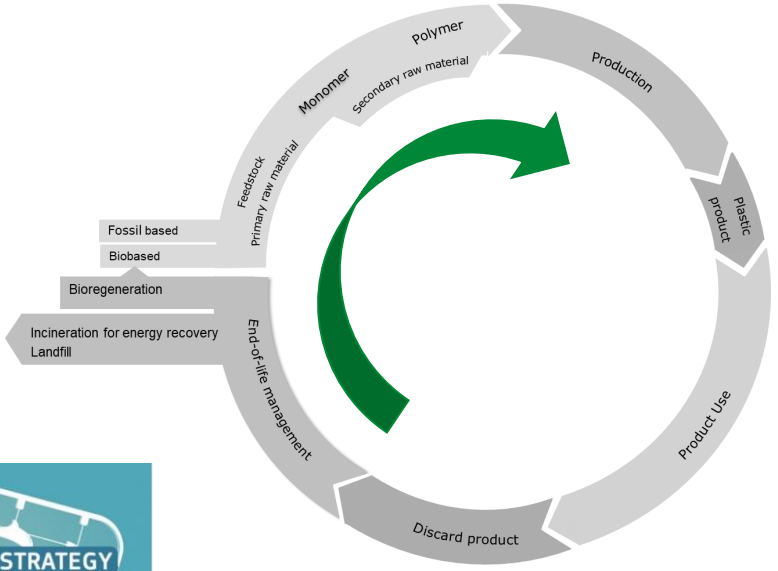
Circularity

- Protect our environment and reduce marine litter
- Reduce greenhouse gas emissions and dependence on fossil fuels
- Support more sustainable and safer consumption and production.

Circular Economy

European Green Deal

Plastic Circularity

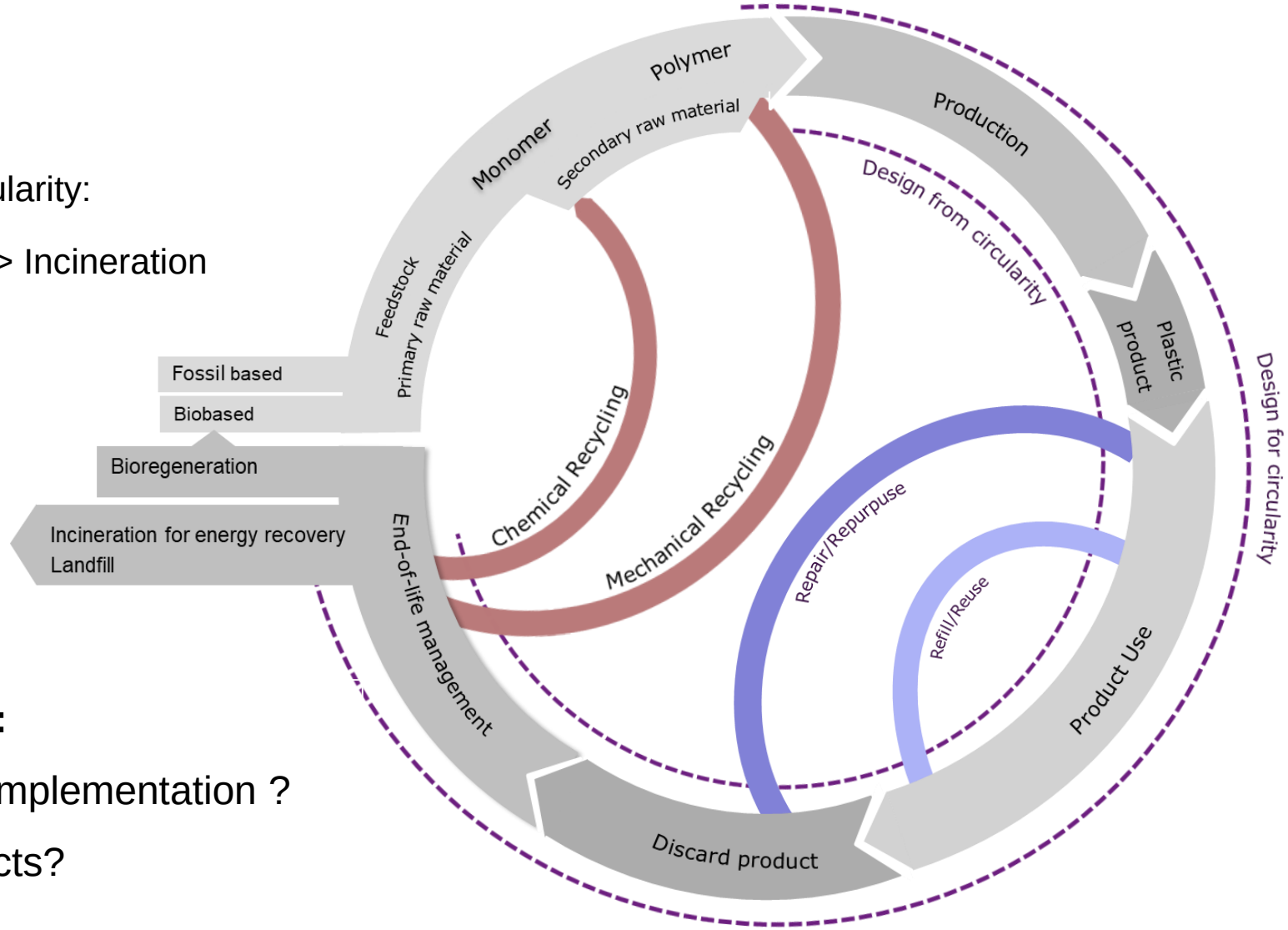


Implementing Plastic Circularity:

- Several strategies to improve Plastic Circularity:

  Prevent > Reuse > Recycling > Compost > Incineration

- Design for and from recycling



Research questions:

How to assess the Plastic Circularity implementation ?

How to assess the impacts?

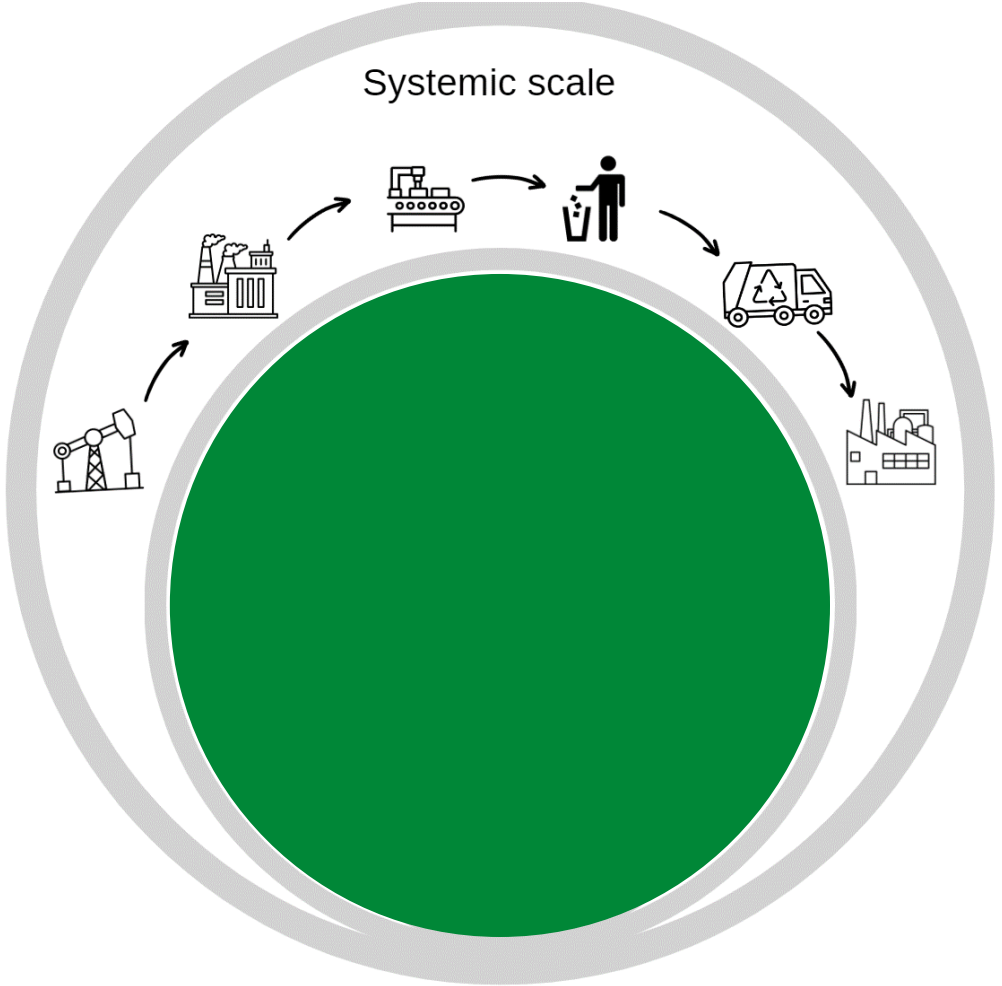
Systemic Scale

Tools

- Indicators
- Metrics

Research Gaps

- Complex value chain
- Multiples actors/stakeholders
- Different plastic types, products and sectors
- Different technologies and efficiencies



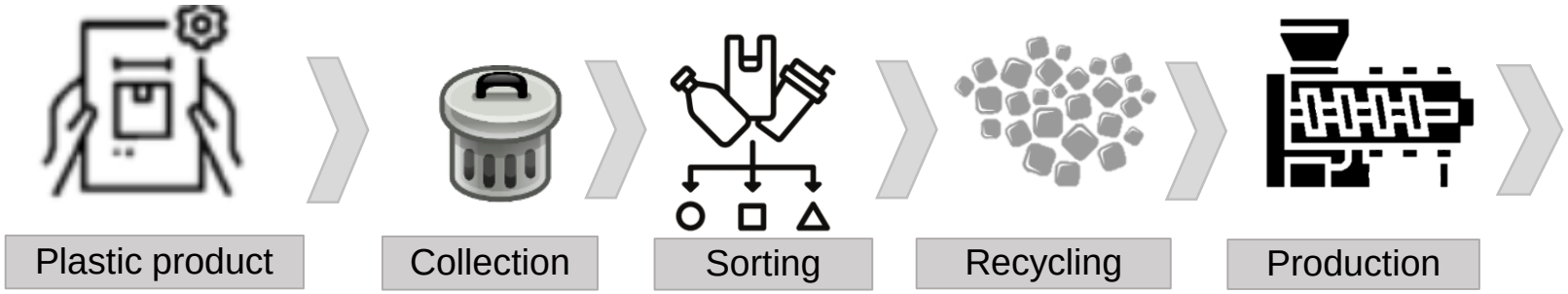
Product Scale

Tools

- Material Flow Analysis
- Life Cycle Assessment

Research Gap

- Recyclability
- Substitutability



Expected used of the recycled plastic

Component scale

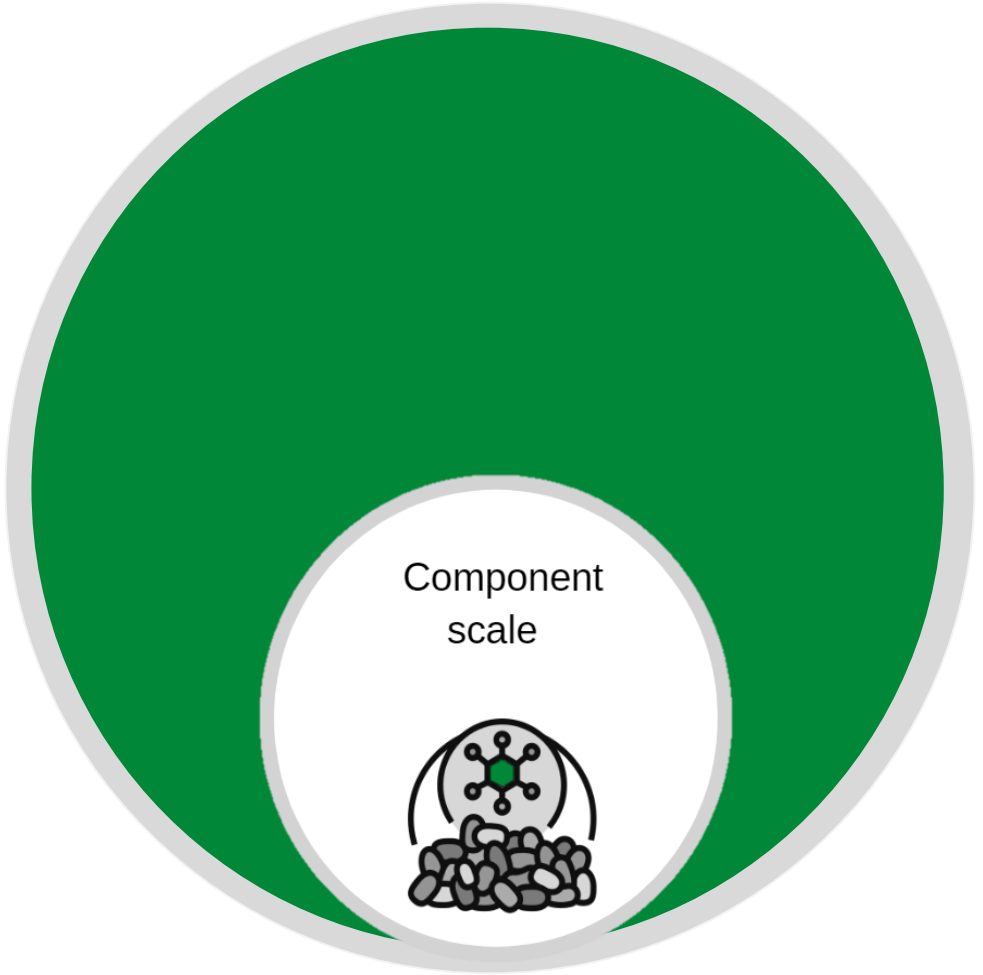
Tools

- Design guidelines
- Design for circularity
- Plastic recycling quality
- Safe and sustainable

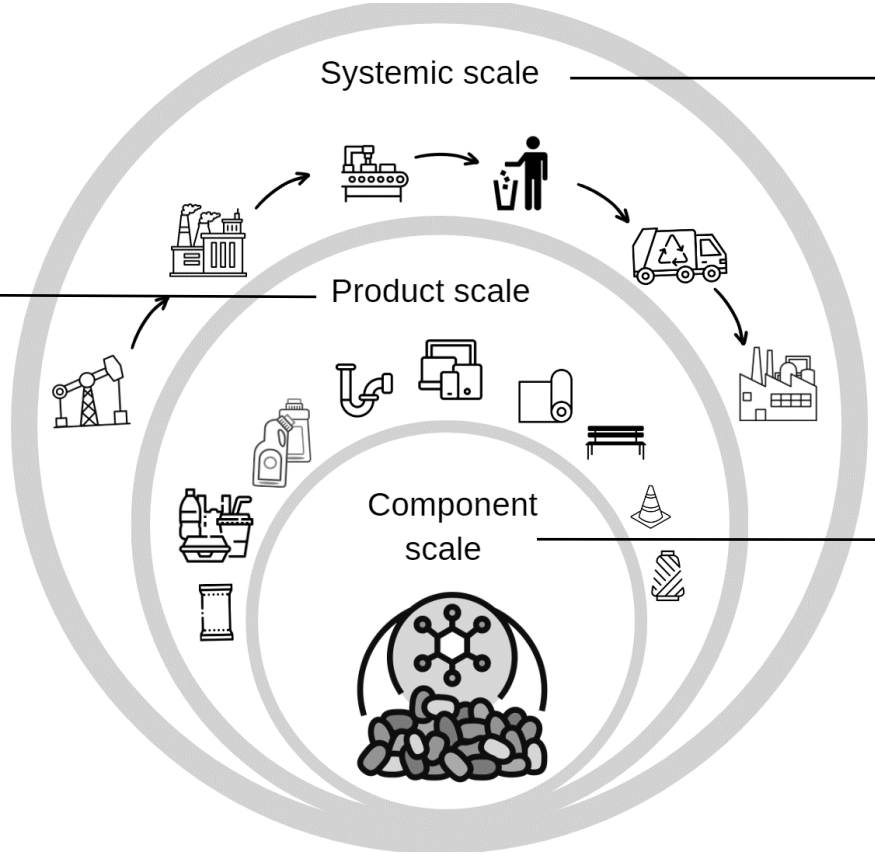
Research Gap

- Contamination
- Recycled plastic properties

Plastics in this waste transfer station in Portugal. Credit: Erica Cirino



- Provide an assessment of Plastic Circularity implementation via three different scales

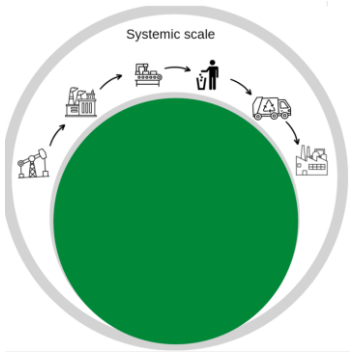


Assess the implementation of Plastic Circularity considering plastic value chain as a system

Assess the link between substitutability and waste management to evaluate Plastic Circularity of the product

Assess impact of plastic material design on circularity

- Apply assessment to a specific study case to evaluate the impacts of the Plastic Circularity implementation



Systematic evaluation framework for comparison of plastic initiatives

- Initiatives are claims from reports, industries, NGOs, paper reviews
- European context
- Include several product types

- Based on 17 criteria and three-level likelihood ranking approach

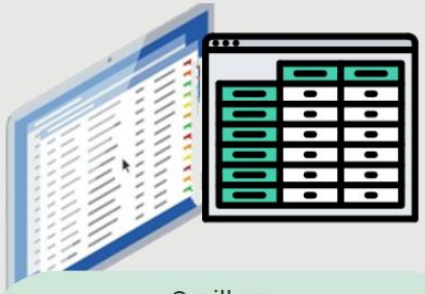
1

Screening initiatives focus on plastic circularity

54 initiaitves

2

Score initiatives with a systematic qualitative evaluation

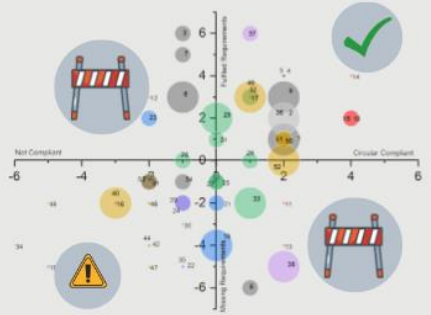


3 pillars:

- Circularity Compliance with basic Circular Economy Principle (x axis)
- Requirements needed for implementation (y axis)
- Potential contribution from a material circularity perspective (bubble size)

3

Review scoring and identify barriers and challenge to implement plastic circularity



- Plastic Circularity is not guaranteed.
- Initiatives are often co-dependent.
- Drastic changes are required to reach Plastic Circularity.

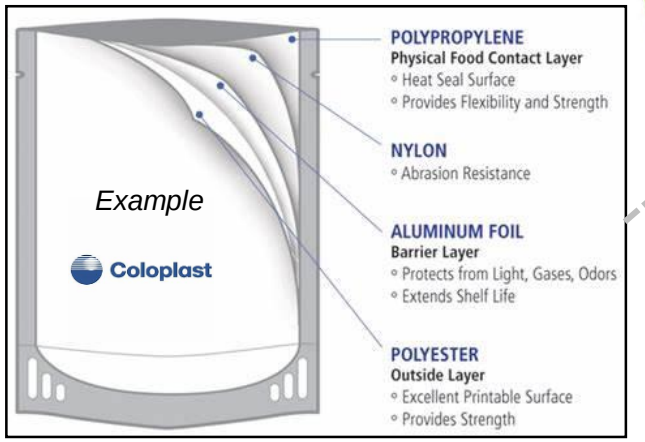
Lisiecki et al. (2023) Circular economy initiatives are no guarantee for increased plastic circularity: A framework for the systematic comparison of initiatives, Resources, Conservation and Recycling, Volume 197, 2023, 107072, ISSN 0921-3449, https://doi.org/10.1016/j.resconrec.2023.107072

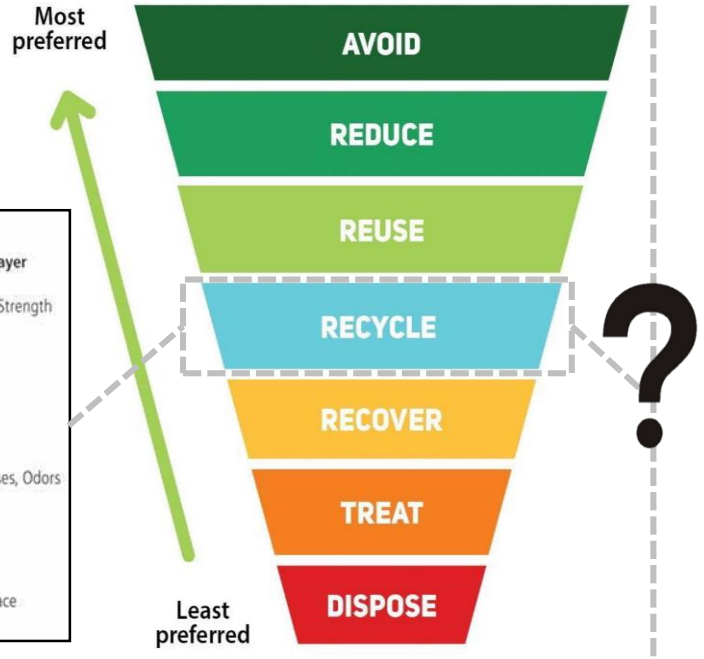
- Assess the circularity of a plastic product according its substitutability

- Assess the circularity of plastic products with a dynamic MFA for European plastic flows

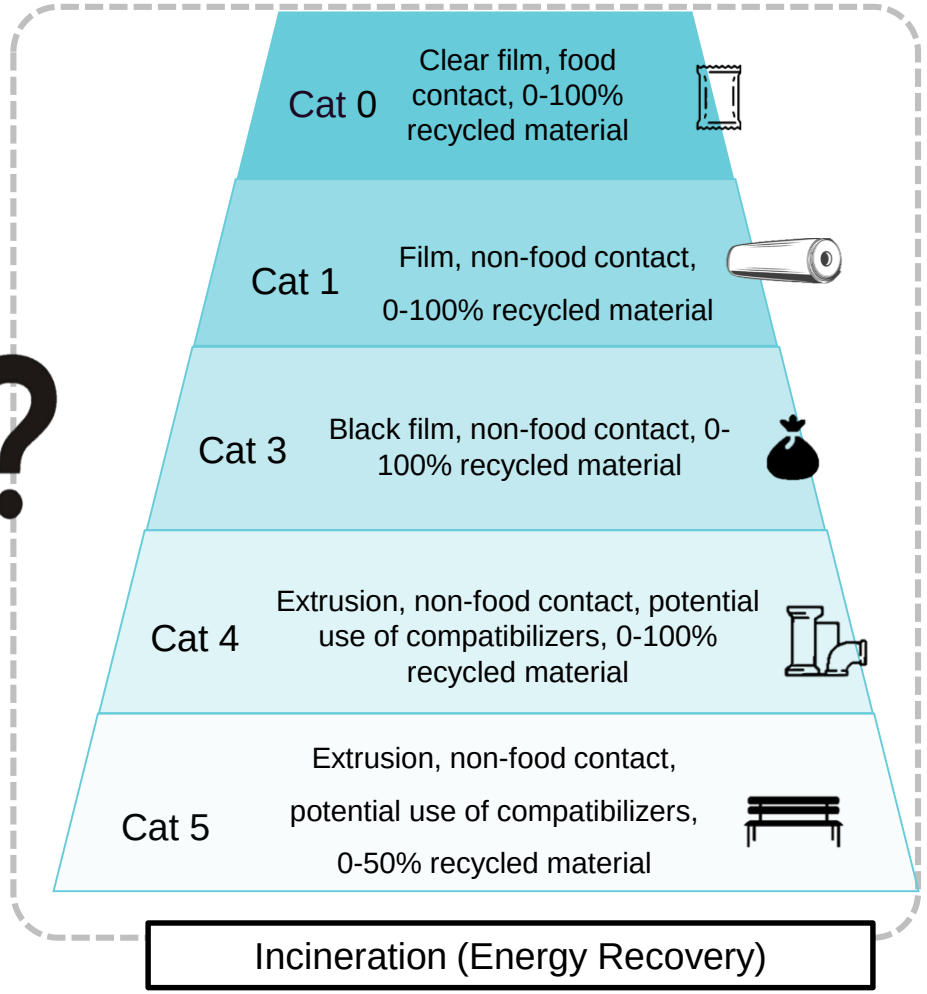
Case study 1: Evaluate the circularity of medical packaging

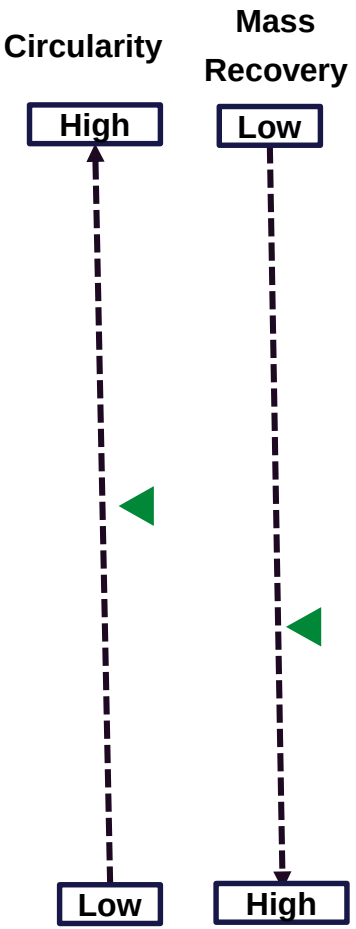
Quantification of Plastic Circularity using potential substitution





?





Example

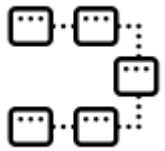
Does recycling lead to circularity, and to what degree?

Study case: Dynamic MFA of European plastic flows between 2020 and 2050

Quantification of Plastic Circularity with Material Flow Analysis

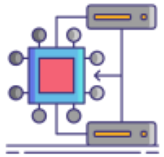
Data base

- 2020
- Plastic quantity
- Annual growth
- Lifetime
- Transfer coefficients
- Data quality assessment



MFA - Static model

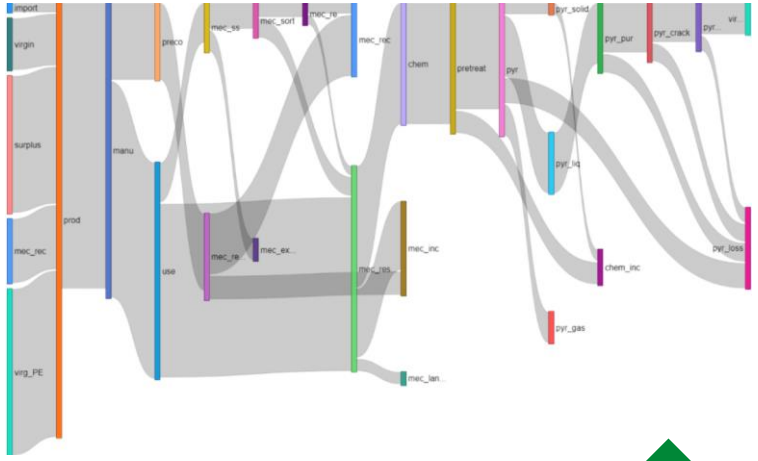
- PET, PP, PE
- 7 sectors
- Rigid, flexible, other rigids
- Mechanical recycling
- Complementary chemical recycling



MFA - Dynamic Model

- Python
- Until 2050

Example



Scenarios

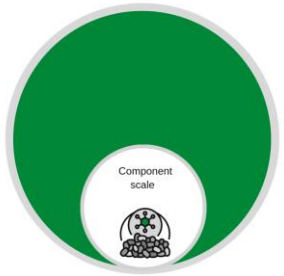
- Improve collection
- Increase reuse
- ….

Indicators

- Material circularity
- Energy recovery
- Plastic to Plastic rate

Assess plastic circularity

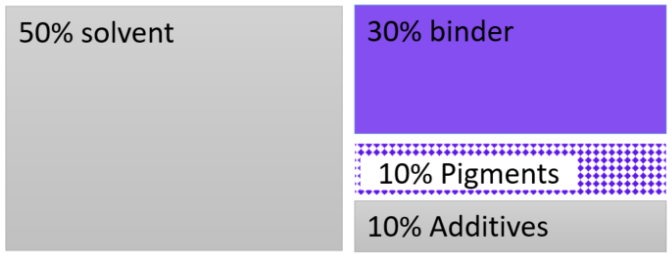
per polymer, per product, per year, per scenario



Study case: Mechanical recycling of flexible packaging with and without printing

- **Low recycling rate**: household recycling rate = 14% *(PRE, 2020)*
- **Low-value recycled material**
- **Limited uptake market**: non-food film, refuse bags, sacks in B&C and agriculture.

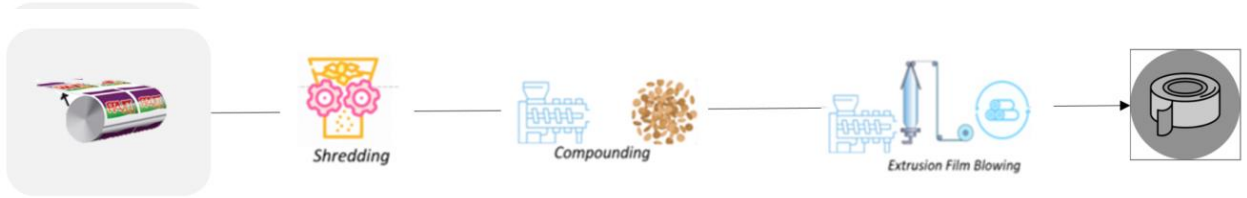
Ink = **1 - 3%** of the total weight of the packaging



Maastricht University

1. Mechanical recycling and characterization

Maastricht University



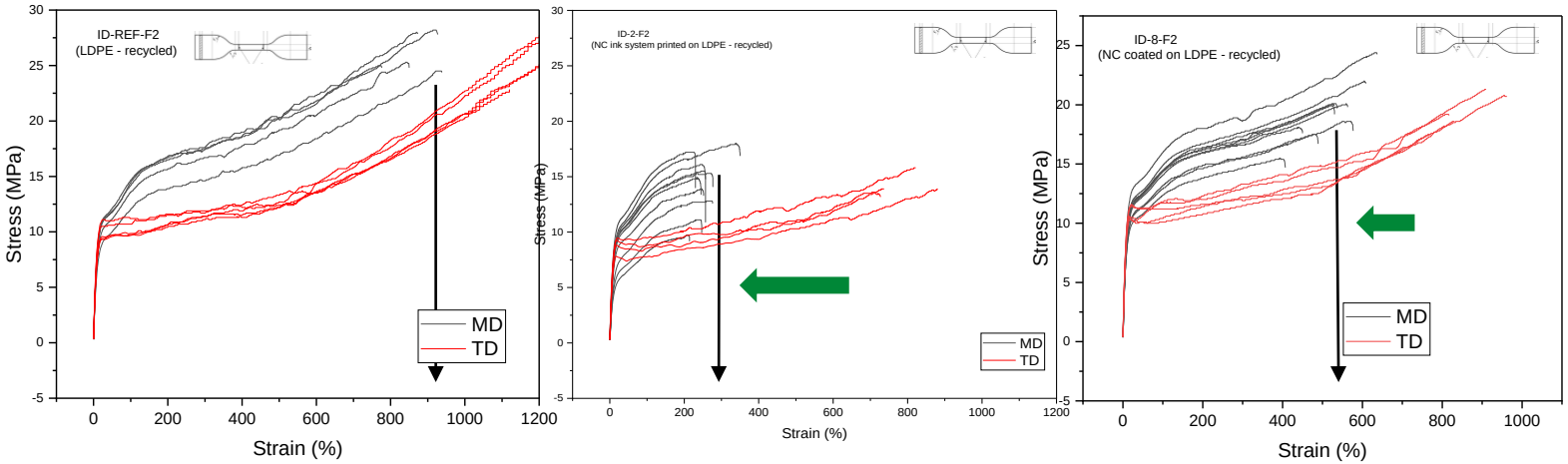
2. Thermal degradation of the components of the ink system

UNIVERSITEIT GENT

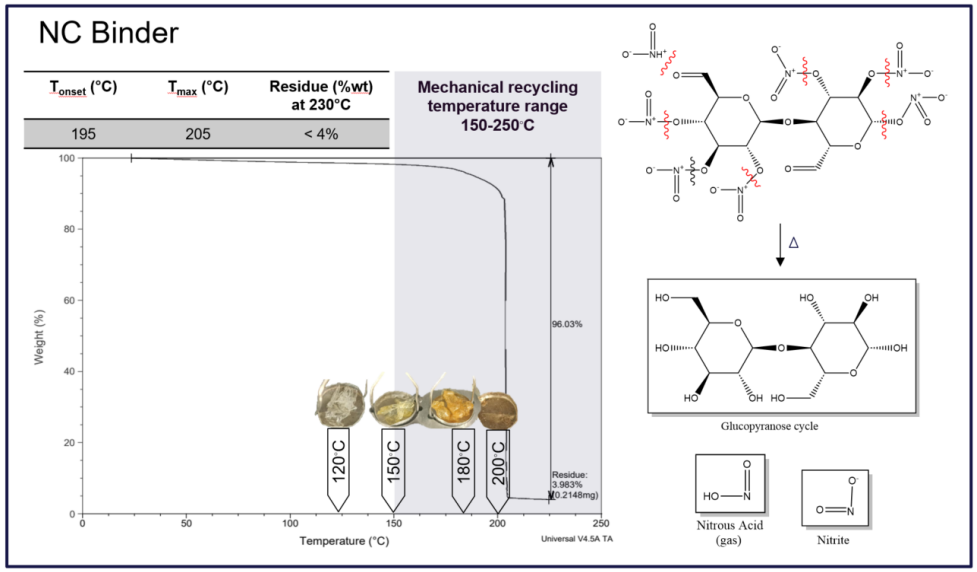
The objective is to **propose a degradation profile** of the ink components **to assess the effects of mechanical recycling** on LDPE flexible film.

Example

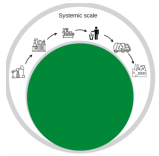
Tensile Test – comparison recycled films (reference, NC printed and NC coated)



TGA – NC binder degradation profile



Learnings



Systemic scale

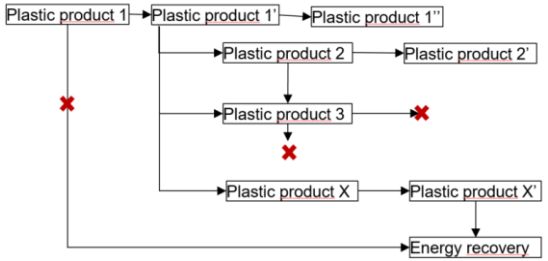
Product scale

Component scale

Design Safe and Sustainable plastic formulation.

Identify the impact of contamination

Product Circularity



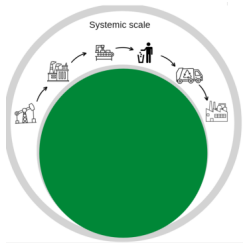
Waste as a valuable material

Assessing Plastic Circularity considering **material science and waste management** is necessary

Plastic value chain contribution to Plastic Circularity

Identify **levers and barriers** toward Plastic Circularity implementation

Delivrables



Systemic Scale

Resources, Conservation & Recycling 197 (2023) 107072

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

journal homepage: www.elsevier.com/locate/resconrec

Circular economy initiatives are no guarantee for increased plastic circularity: A framework for the systematic comparison of initiatives

M. Lisiecki [a,b,*], A. Damgaard [a], K. Ragaert [b], T.F. Astrup [a]

[a] Department of Environmental and Resource Engineering, Technical University of Denmark, Bygningstorvet, Building 115, 2800 Kgs. Lyngby, Denmark
[b] Circular Plastics, Department of Circular Chemical Engineering, Faculty of Science and Engineering, Maastricht University, Urmonderbaan 22, 6162 Geleen, The Netherlands

ARTICLE INFO

Keywords:
Circular economy
Plastic circularity
Waste management
Recycling
Plastic
Initiative

ABSTRACT

Plastic plays a prominent role within circular economy, with many stakeholders promoting initiatives to increase plastic circularity during the manufacturing, use and end-of-life phases. Despite well-meant intentions, many initiatives are characterized by a lack of compliance with basic circular economy principles, implementation barriers, and limited effects on the intended long-term plastic circularity. This study provides a systematic evaluation framework for comparison of plastic initiatives, based on 17 criteria addressing key aspects of plastic circularity. A three-level likelihood ranking approach is applied to analyse the impact of 54 initiatives targeting plastic circularity in a European context. It was found that relatively few of these initiatives were readily implementable without considerable investments, e.g. in new waste management and recycling technologies, and changes in plastic production and product design. The results clearly suggest that current suggestions for circular economy initiatives targeting plastic may have limited effect and not lead to the intended impacts without the support of new regulations and change in plastic demand and consumption. The study stresses the importance of synergies and cooperation between stakeholders across the value chain to reach plastic circularity. The framework offers a consistent basis for decision-makers to identify critical barriers and enablers in relation to plastic circularity characteristics, but the approach may also be applied to other topic areas.

1. Introduction

The circular economy (CE) is a prominent strategy in the European transition toward a more sustainable society. To support this transition, and as part of the European Green Deal (EC, 2019), the European Union (EU) has launched a range of strategic roadmaps, including the Circular Economy Action Plan (EC, 2020). The implementation of a circular economy has received considerable attention in the literature (e.g. Sitadevi et al., 2021), as well as from policymakers, governments and intergovernmental agencies at the local, regional, national and international levels (Ghisellini et al., 2016; Liefer and Rashid, 2016; Kirchherr et al., 2017; Geissdoerfer et al., 2017). Several studies have stressed the need to measure progress toward the circular economy (Jocken et al., 2017; Borrello et al., 2020), and many attempts have been made to measure circularity, such as reviews of circularity indicators (Moraga et al., 2019; Kristensen and Mosgaard, 2020; de Oliveira et al., 2021; dos Santos Gonçalves and Campos, 2022), assessments of circularity metrics (Sassanelli et al., 2019; Kamp Alhaek et al., 2020), the development of circularity performance indicators (Huysman et al., 2017; Saidani et al., 2019) and reviews of comparison methods (Saidani et al., 2017; Parchomenko et al., 2019; Nizo and Kalbar, 2019).

Plastic plays a prominent role in circular transition by representing numerous applications (Reichel et al., 2021) and holding the potential for reducing environmental impacts based on waste generation and raw material dependency and efficiency (EC, 2018). Circular economy may also be enabling the United Nations (UN) Sustainable Development Goals (SDGs) (Velenturf and Purnell, 2021). Plastic circularity is thus interlinked with the 2030 Agenda and SDG targets, such as responsible production and consumption (SDG 12) and prevention of climate change (SDG 13). Ideally, plastic circularity should contribute to increasing the resource value of plastic materials, minimizing climate impacts, reducing pollution and littering and ensuring overall resource efficiency (Geyer et al., 2017). Very little is known, however, about plastic circularity implementation, the requirements for this implementation and the potential for increasing plastic circularity falling within the circular economy principles (Kazeyilan et al., 2021). While circularity metrics

* Corresponding author.
E-mail address: mails@dtu.dk (M. Lisiecki).

https://doi.org/10.1016/j.resconrec.2023.107072
Received 22 February 2023; Received in revised form 12 May 2023; Accepted 31 May 2023
Available online 10 June 2023
0921-3449/© 2023 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

https://doi.org/10.1016/j.resconrec.2023.107072

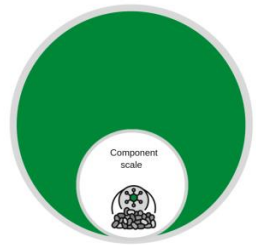
Product Scale

- Industrial partnership, external stay (4months, Sept 2023 – Dec 2023)

Coloplast

Lisiecki et al. (tbc) How to assess medical packaging Plastic Circularity?

Lodato & Lisiecki et al. (tbc) – Assessing European Plastic Circularity with a dynamic MFA



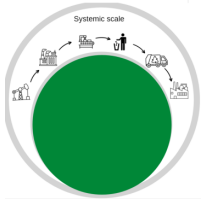
Component scale

- External Research stay (6months, Nov 2022 – April 2023)

Maastricht University

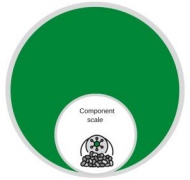
Lisiecki et al. (tbc) Fate of ink during mechanical recycling, applied to printed LDPE flexible packaging

Contributions to C-PlaNeT project's objectives

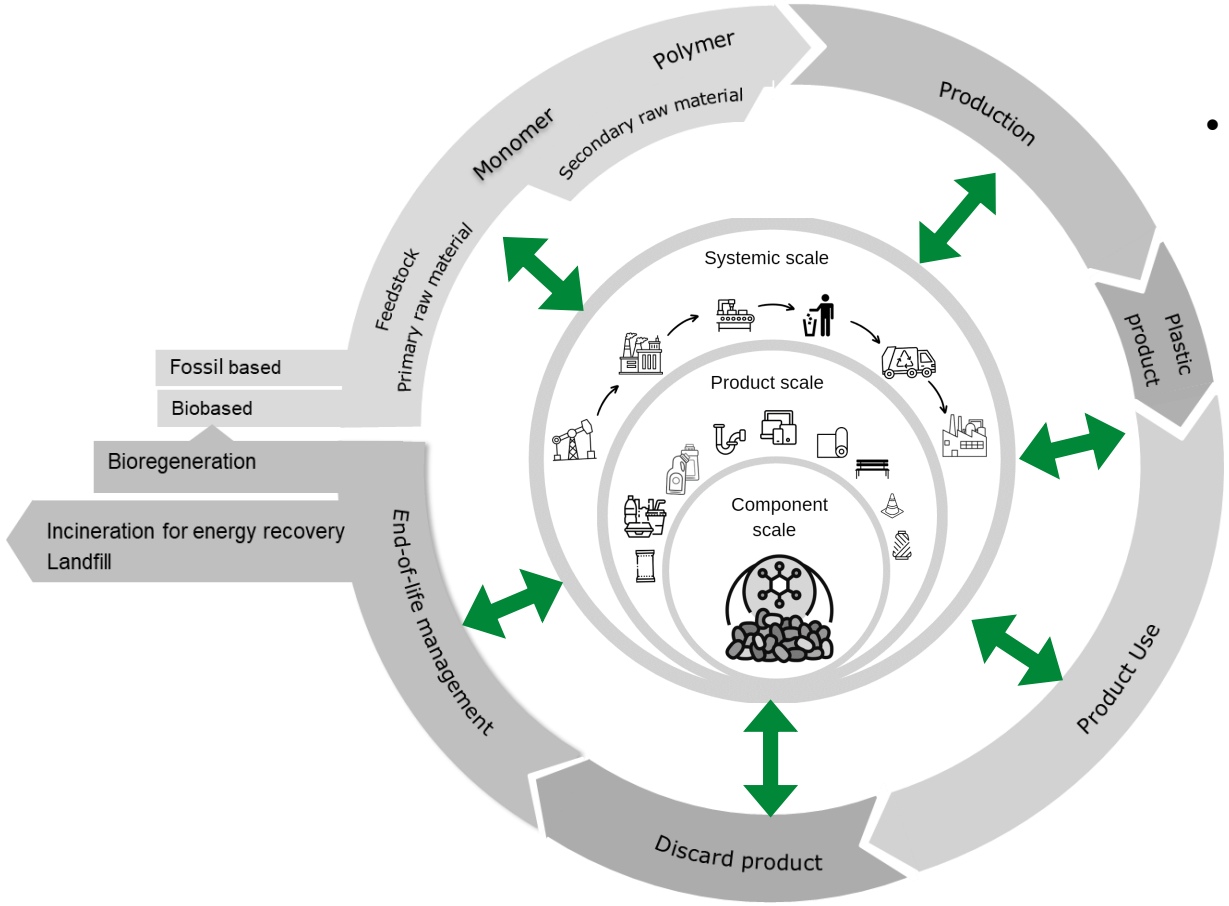


- **Systemic 'design for circularity' support decision-makers to identify critical barriers and enablers** in relation to Plastic Circularity implementation.

- **Assessing substitutability** of plastic product provide a **tool for industries** focusing on **material science and waste management.**
- **Quantifying the circularity of plastic product is insightful** for **life cycle inventory**.
- **Reporting Plastic Circularity** is providing **data base** for future research.

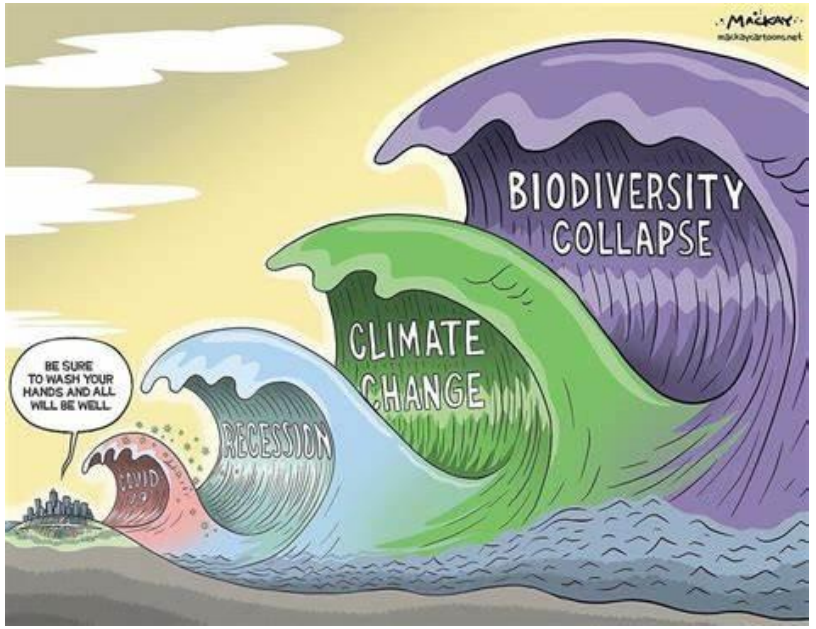


- **Experimental work** about components provides **preliminary study for future plastic design guidelines**.



- Recycling is one of the strategies but not the only
- Assess socio-economic, environmental impacts,…
- Extend to other regions
- How to challenge the plastics value chain?

Thank for your attention



Manon Lisiecki

malis@dtu.dk

PhD Candidate | Early Stage Researcher (ESR 3)

Supervisor – Prof. Anders Damgaard

Co-Supervisor – Prof. Thomas F. Astrup

Circular Environmental Impact

Danmarks Tekniske Universitet

DTU Sustain

Bygningstorvet 115, 2800 Kgs. Lyngby

Co-Supervior – Prof. Kim Ragaert

Circular Plastics

Department of Circular Chemical Engineering (CCE), Faculty of Science and Engineering, Maastricht University, Urmonderbaan 22, Geleen, 6162, nld

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 859885.