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Life Cycle Assessment (LCA) of Chemically Recycled Polyamide Multi-Layer Packaging

By using the example of mozzarella cheese packaging

LCA of Chemically Recycled Polyamide Multi-Layer Packaging

Research Question

What are the environmental impacts of the ***packaging format*** *and the* ***type of raw material*** *in a retailed mozzarella packaging's lifecycle?*

LCA of Chemically Recycled Polyamide Multi-Layer Packaging

Scope

Comparison of the environmental performance of a **flexible mozzarella packaging** manufactured from **chemically recycled* feedstock** in contrast to flexible mozzarella packaging solutions from fossil- or bio-based* feedstock as well as a **rigid mozzarella packaging**

Flexible multi-layer packaging

Rigid tray packaging

Base Case	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Chemically recycled* PA6 + conventional** PE	Chemically recycled* PA6 + chemically recycled* PE	Biomethane-based* PA6 + conventional** PE	Conventional** PA6 + conventional** PE	Conventional** PP + multi-layer lidding film from conventional** PE / EVOH / PET

| * via mass balance approach; ** conventional = based on fossil raw materials; the pictures are illustrating the packaging format, in fact real supermarket-retailed mozzarella packagings were purchased, examined and used for this study.

LCA of Chemically Recycled Polyamide Multi-Layer Packaging

Structure and conformity with ISO standards

Panel decision: “…this LCA study followed the guidance of and is consistent with the international standards for Life Cycle Assessment (**ISO 14040:2006 and 14044:2006**) and for Carbon Footprint of Products (**ISO 14067:2018**)”

Commissioner / LCA Practitioner

Dr. Paul Neumann

Maike Horlacher

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sphera

Data provided by BASF, Sphera & SÜDPACK

Critical Review Panel

Prof. Adisa Azapagic (Panel Chair)

ETHOS Research Environment · Technology · Society

Benedikt Kauertz

ifeu INSTITUT FÜR ENERGIE- UND UMWELTFORSCHUNG HEIDELBERG

Simon Hann

eunomia

Further Information

LCA study Website (basf.com)

Films (basf.com)

Ultramid® Ccycled® (basf.com)

Ultramid® Biomass Balance (basf.com)

Chemical recycling of plastic waste (basf.com)

Life cycle assessment (LCA) for ChemCycling® (basf.com)

Südpack: Sustainability by SÜDPACK I Climate neutrality (suedpack.com)

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LCA of Chemically Recycled Polyamide Multi-Layer Packaging

Methodical approach

LCIA methodology

Environmental Footprint (EF 3.0) assessment method published by the European Commission

Packaging Formats

Flexible multi-layer packaging
(2.41 kg/FU)

PE: 71 %
PA: 29 %

Rigid tray + lid film
(7.25 kg/FU)

PP tray: 90 %
Lid film*: 10 %

Functional unit (FU)

Containing and providing packaging for 125 kg fresh mozzarella cheese (drained weight) contained in brine **(= 1,000 packages à 125 g mozzarella)**

 | * multi-layer lid film made of PET, PE and EVOH (+PU adhesive)

Why Polyamides are Used in Packaging Applications?

Mechanical Performance:

– Strength, stiffness & toughness
– High puncture resistance

Product and Packagaing Processing

– Excellent thermoformability
– Heat resistance (Sterilization, Sealing)

Barrier

– High resistance and barrier to chemicals
– Medium oxygen barrier

Others

– Compliance with food contact legislations
– High quality product presentation (high transparency)

Reduction of Packaging Waste:
Downgauging at higher protection level

Economical Packaging Solutions:
Fast Processability,
Lower Cost, Performance

Food Protection:
Prevention of Food Loss

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Polyamides are sustainable Packaging Components

PE/PA films are mechanically recyclable:

– Independent recyclability studies by cyclos-HTP
– PA-multilayer films are already recycled with PE flexibles (state of the art)

certified by Institute cyclos-HTP
recyclable

2022 Legal Acceptance in Germany

Stiftung Zentrale Stelle VERPACKUNGSREGISTER

Appendix 3: overview of packaging groups/sorts and material-specific recycling incompatibilities

Group/sort	Incompatibilities
Film and LDPE	Fibre-based labels if the cellulose share cannot be removed by means of cold washing; PA layers (excluding nylon 6 or co-polyamide 6-66 in coextruded PE/PA films without EVOH, combined with MAH-grafted PE as an adhesive promoter at a ratio of at least 0.5 g of adhesive per 1 g of PA); PE-X components; PVDC layers; other non-PE polymeric layers (excluding adhesion promoters, adhesives, PP, EVA and EVOH), non-polymeric layers (excluding SiOx/AlOx/metallisations).

Polyamides from renewable or chemically recycled feedstocks* enable circular recycled content in food packaging:

Ultramid® Ccycled®

Feedstock
– Pyrolysis oil from mixed plastic waste

Claims**
– “Closing the packaging loop“

Ultramid® BMB

Feedstock
– Bio-methane from bio-circular waste

Claims**
– „Saving fossil resources by using renewable feedstock”

Virgin quality, Food contact | Certified Mass Balance | 100% recycled/ renewable feedstock | reduced Fossil resources | reduced CO_2 emissions

* via certified mass balance, ** all claims subject to legal assessment by user, Multilayer packaging: innovative and sustainable (basf.com)

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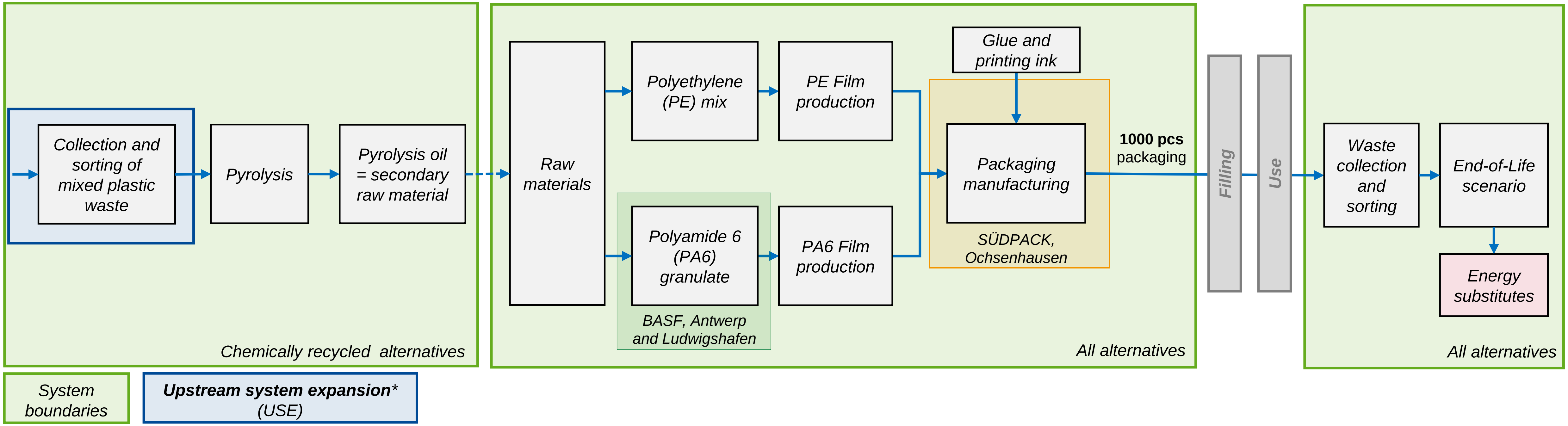
Flexible Multi-Layer Packaging

From PE + PA6 (conventional or sustainable alternatives)

System Boundaries (Cradle-to-Grave):

For models containing materials from **chemically recycled feedstock** via a **mass balance approach** an **upstream system expansion via subtraction** is applied (guideline on Product Carbon Footprinting for the Chemical Industry by Together for Sustainability, 2022)



* USE (or also differential credit/burden approach) is applied whenever chemically recycled feedstock (pyrolysis oil) was employed. Activities of prevented incineration of MPW acts as a credit onto the final results whereas prevented credits for energy and electricity act as a burden onto the final results.

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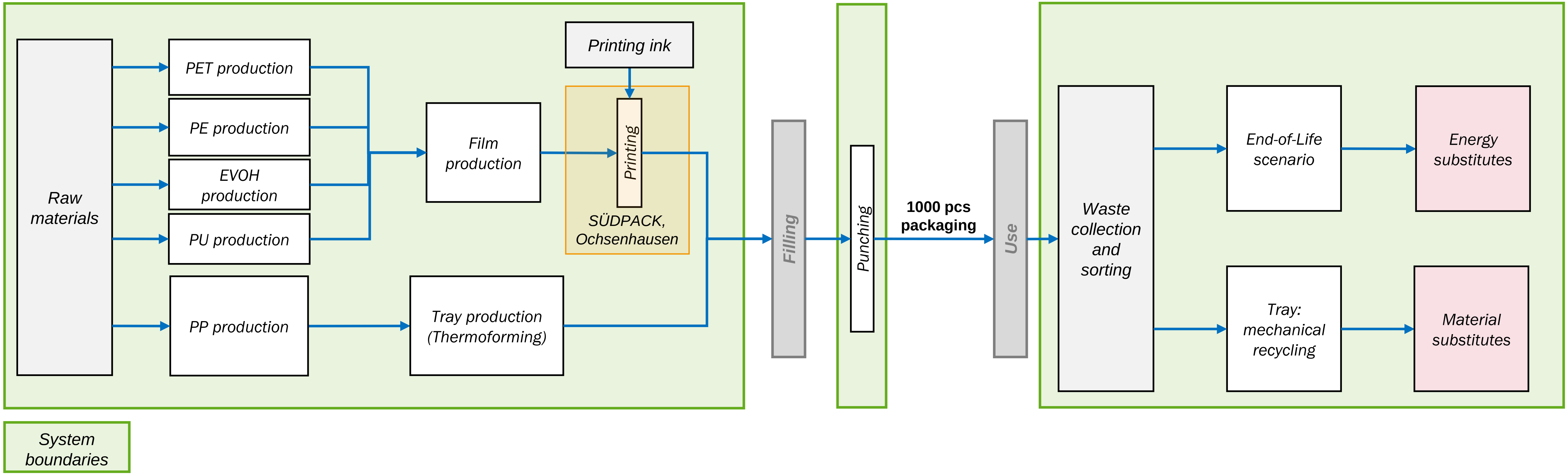
Rigid Tray Packaging

From conventional polypropylene (PP) + multi-layer lidding film from conventional PE / ethyl-vinyl-alcohol (EVOH) / polyethylene terephthalate (PET)

System boundaries (Cradle-to-Grave):



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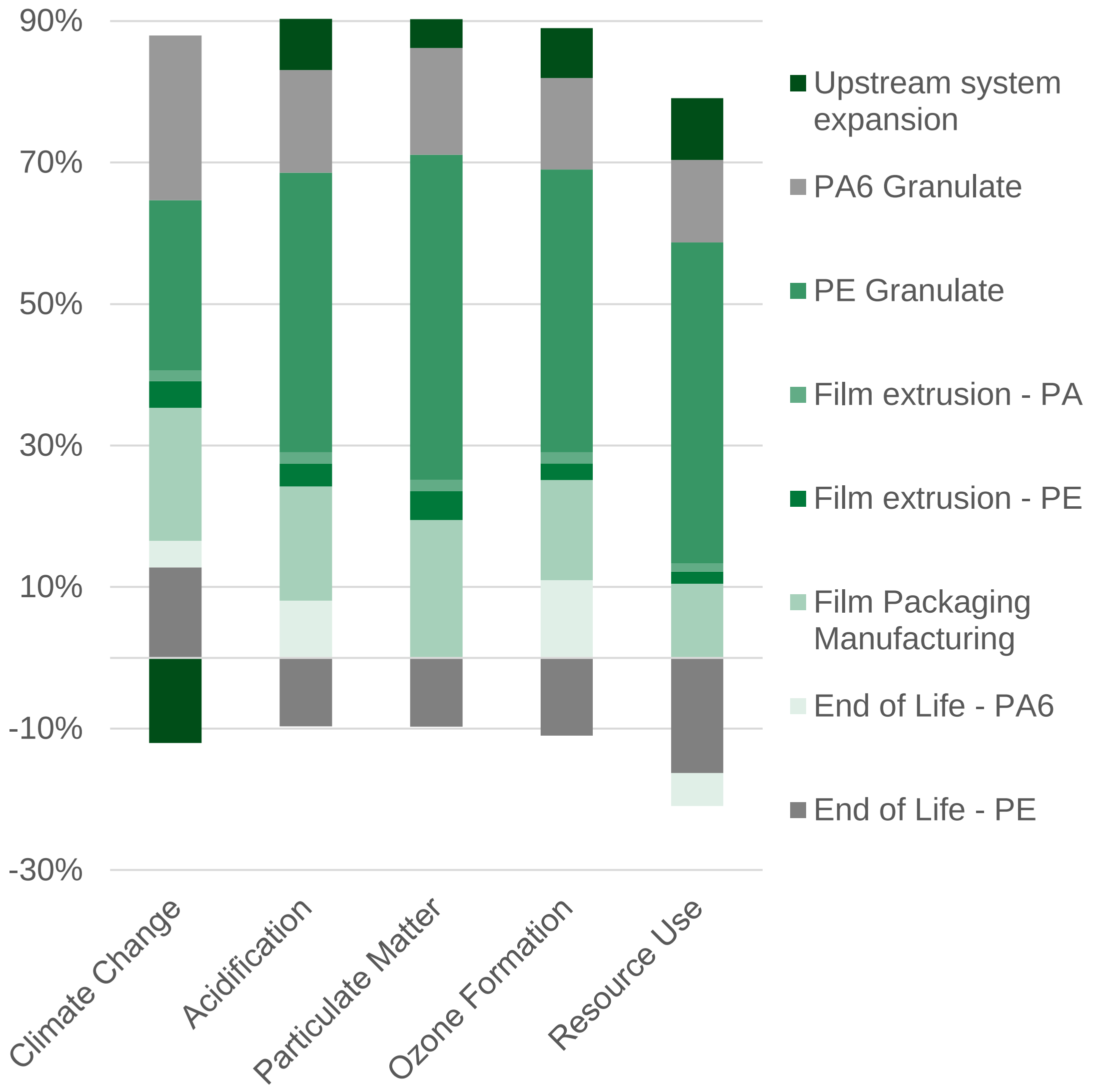
Internal

Contribution Analysis: Base Case

Flexible multi-layer packaging with chemically recycled* PA6 + conventional PE

The most relevant life cycle impact categories were identified, their individual contributions are illustrated based on normalization.

- **Results:**
  - **Polymer granulate production** steps are the most significant process steps in all examined environmental impact categories
  - **Film packaging manufacturing** steps and the **upstream system expansion** contribute significantly to the selected environmental impact categories
  - **Film extrusion** processes only show minor influence on all environmental impact categories



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* via mass balance approach

Contribution Analysis

Comparison of all examined packaging formats

Packaging Format / Impact Category	Flexible multi-layer packaging				Rigid tray
	Base Case Chemically recycled* PA6 + conventional PE	**Alternative 1** Chemically recycled* PA6 + chemically recycled* PE	**Alternative 2** Biomethane-based* PA6 + conventional PE	**Alternative 3** Conventional PA6 + conventional PE	**Alternative 4** Conventional PP + multi-layer lidding film from conventional PE / EVOH / PET
Climate Change	0	++	0	–	– –
Acidification	0	0	0	0	–
Particulate Matter	0	0	–	0	– –
Ozone Formation	0	0	0	0	0
Resource Use	0	++	0	0	– –

++ Very positive compared to Base Case (< -25%)
\+ Positive compared to Base Case (-10% - -25%)
– – Very negative compared to Base Case (> +25%)
– Negative compared to Base Case (+10% - +25%)

- **Results vs. Base Case:**
  - The rigid tray (**Alternative 4**) shows very **negative impacts** in almost all categories
  - **Alternative 1** is leading to **significant reductions** in Climate Change as well as Resource Use

* via mass balance approach

Packaging Format Perspective

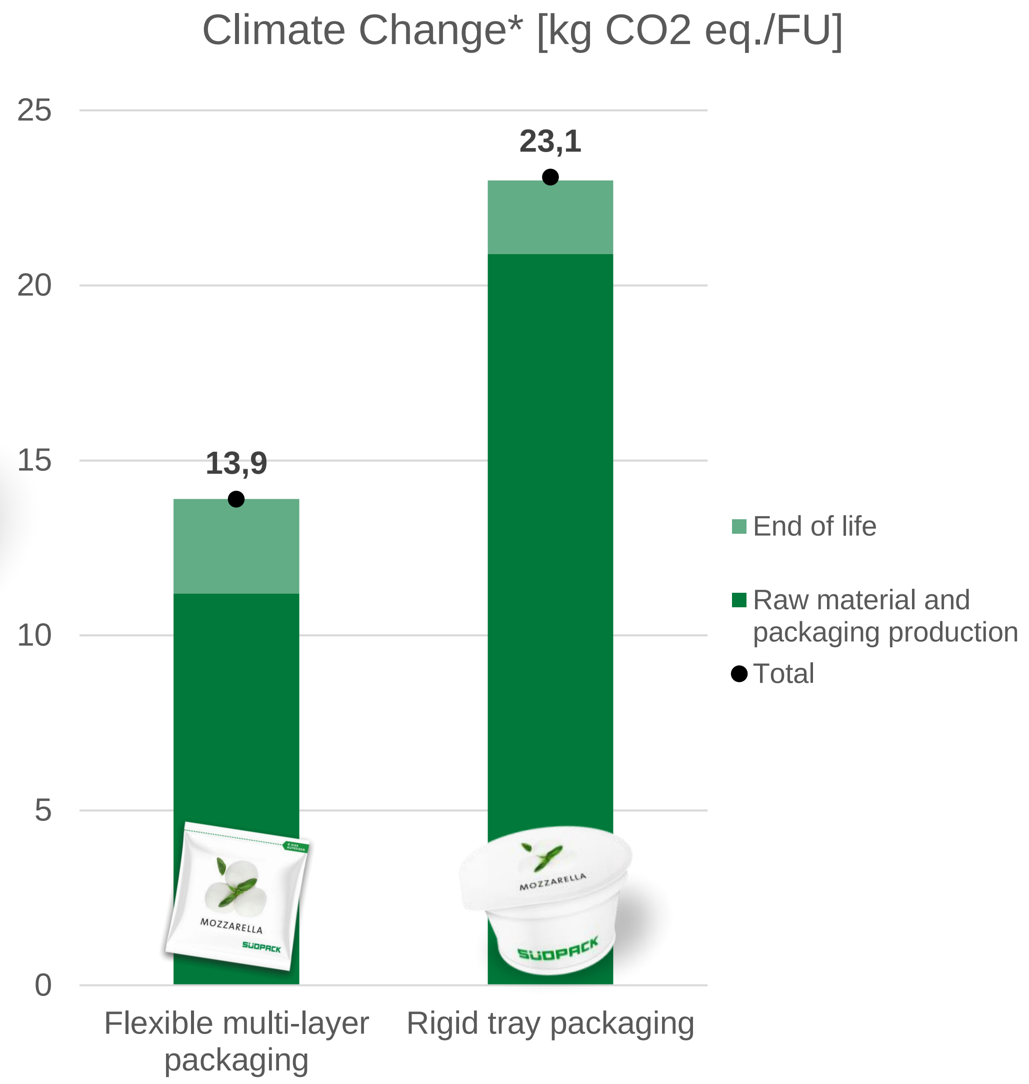
Flexible multi-layer vs. rigid tray packaging

Packaging Format Perspective

Flexible multi-layer vs. rigid tray packaging from conventional feedstock

Two retailed mozzarella packagings were compared according to their climate change impacts.

- **Results:**
  - The **rigid tray** packaging system shows the **highest potential environmental impacts in all categories**
- **Explanations:**
  - Nearly **3-fold use of raw materials** in the production of the rigid tray packaging (2.41 kg/FU for flexible vs. 7.25 kg/FU for rigid packaging)



* Climate change impact category assessed based on the IPCC characterisation factors taken from the 5th Assessment Report for a 100-year timeframe (incl biogenic CO_2, incl Land Use Change)

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Raw Material Perspective

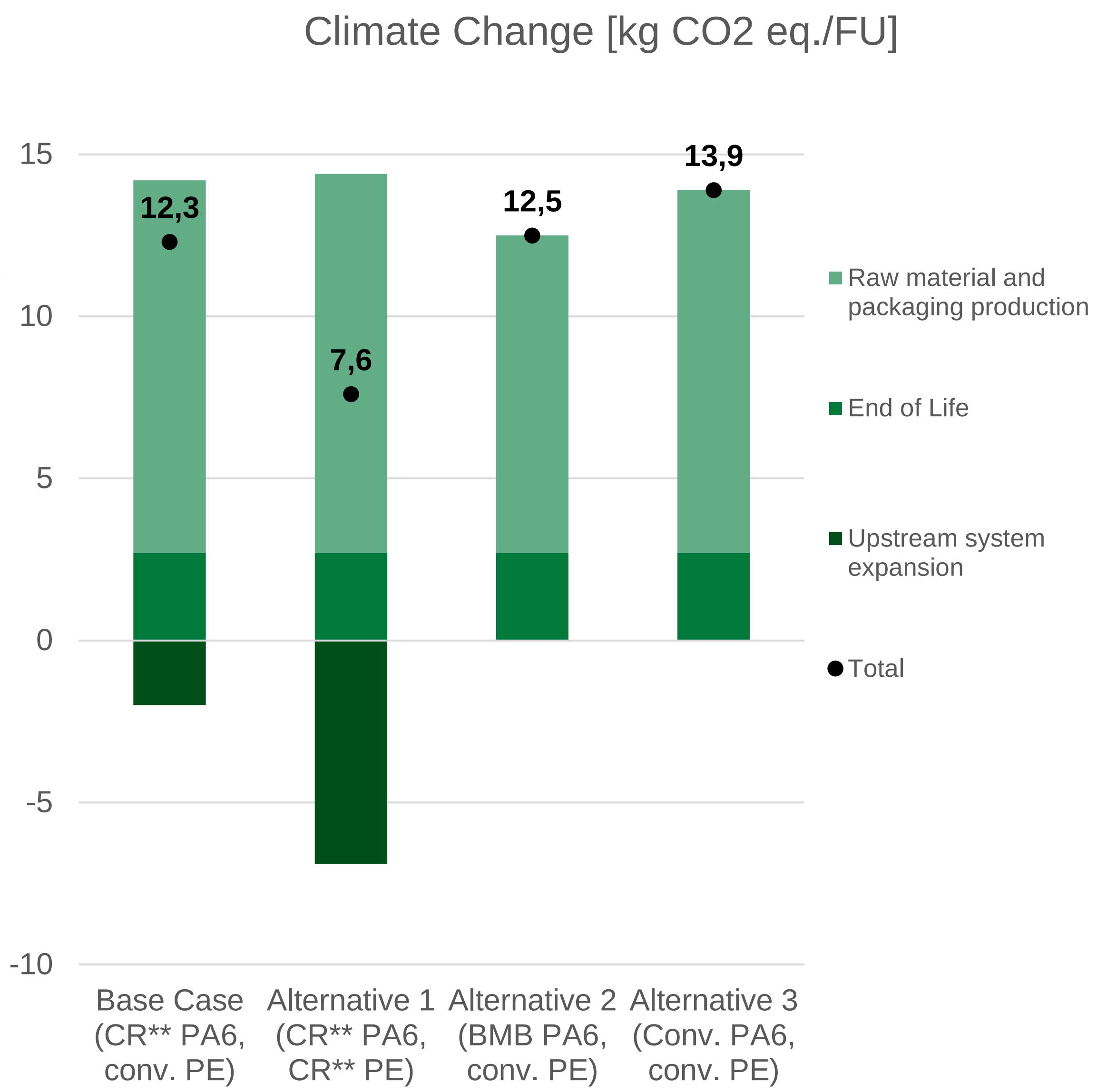
Flexible multi-layer packaging from conventional vs. sustainable raw materials

Raw Material Perspective

Flexible multi-layer packaging from conventional vs. sustainable raw materials

The flexible multi-layer mozzarella packaging was assessed according to the climate change impact of different raw material sources.

- **Results:**
  - The **conventional packaging** (Alternative 3) shows a significantly **higher climate change impact vs.** packaging containing **chemically recycled* PA6** (Base Case)
  - Increasingly lower environmental impacts can be achieved using flexible multi-layer packaging with a **high share of chemically recycled* raw materials** (Alternative 1)
  - **Climate change impact reductions** for packaging containing chemically recycled* raw materials are mainly **caused by the upstream system expansion**



* via mass balance approach

** chemically recycled; conv. = conventional

Additional scenarios

The following scenarios were analyzed for the impact category **climate change**:

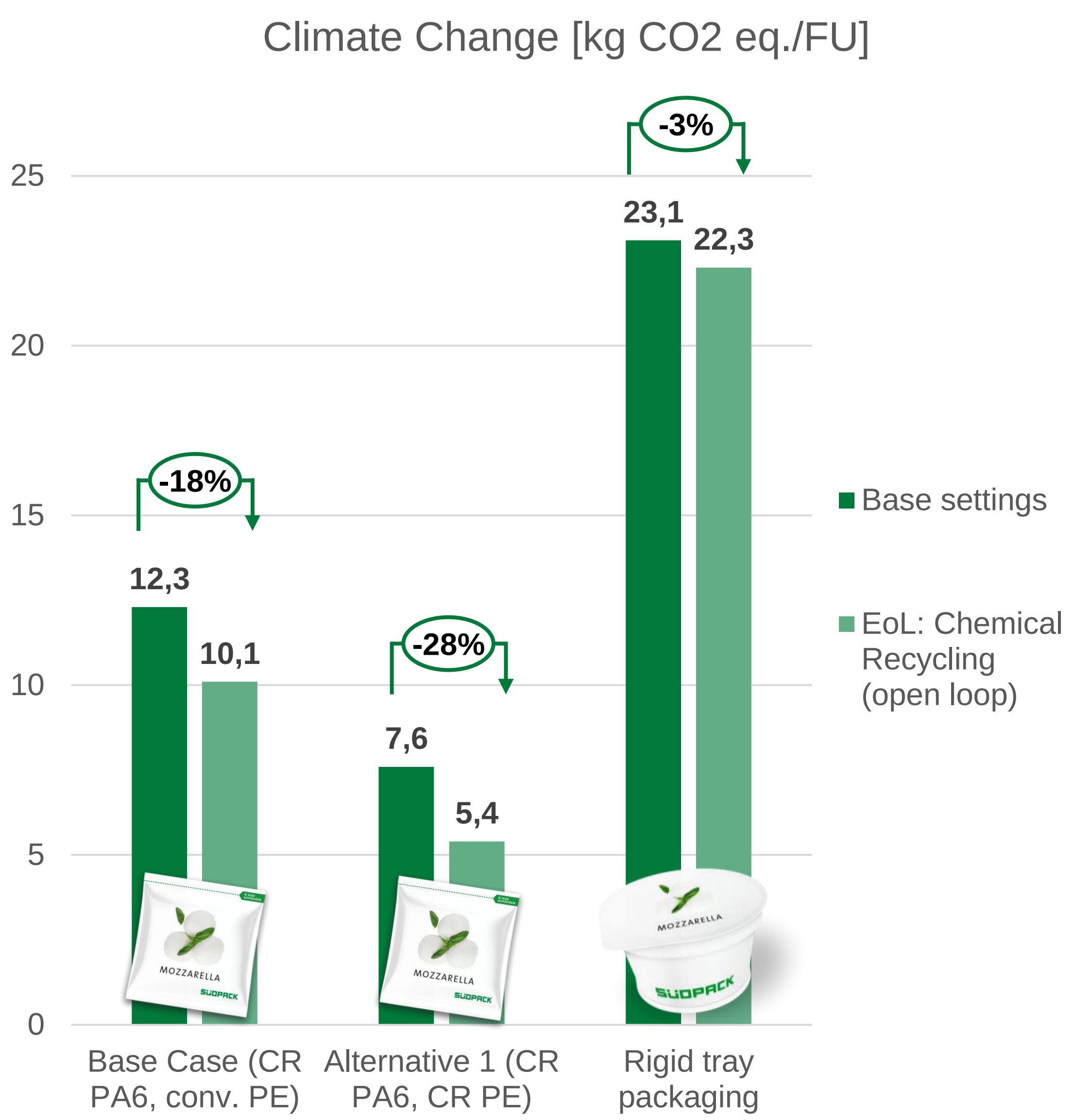
Green Electricity	1. Use of green electricity for the production of PA6
Pyrolysis	2. Additional purification step in the production of pyrolysis oil 3. Optimization of pyrolysis process
End-of-Life	**4. Chemical recycling at End-of-Life (open loop) instead of incineration** 5. Chemical recycling at End-of-Life (closed loop) instead of incineration **6. Mechanical recycling at End-of-Life instead of incineration** 7. 100% recycling rate of tray
Methodology	8. Cut-off-approach as End-of-Life methodology 9. System expansion by addition

Additional scenarios

Spotlight: End-of-Life

4. Chemical recycling* of multi-layer film at End-of-Life (open loop) instead of incineration

- **Results:**
  - **Pyrolysis** of multi-layer films **significantly reduces climate change** impacts
  - Rigid **tray packaging** shows **very low climate change reduction** as the multi-layer lidding film which is subjected to pyrolysis only adds up to 10% of the overall packaging weight



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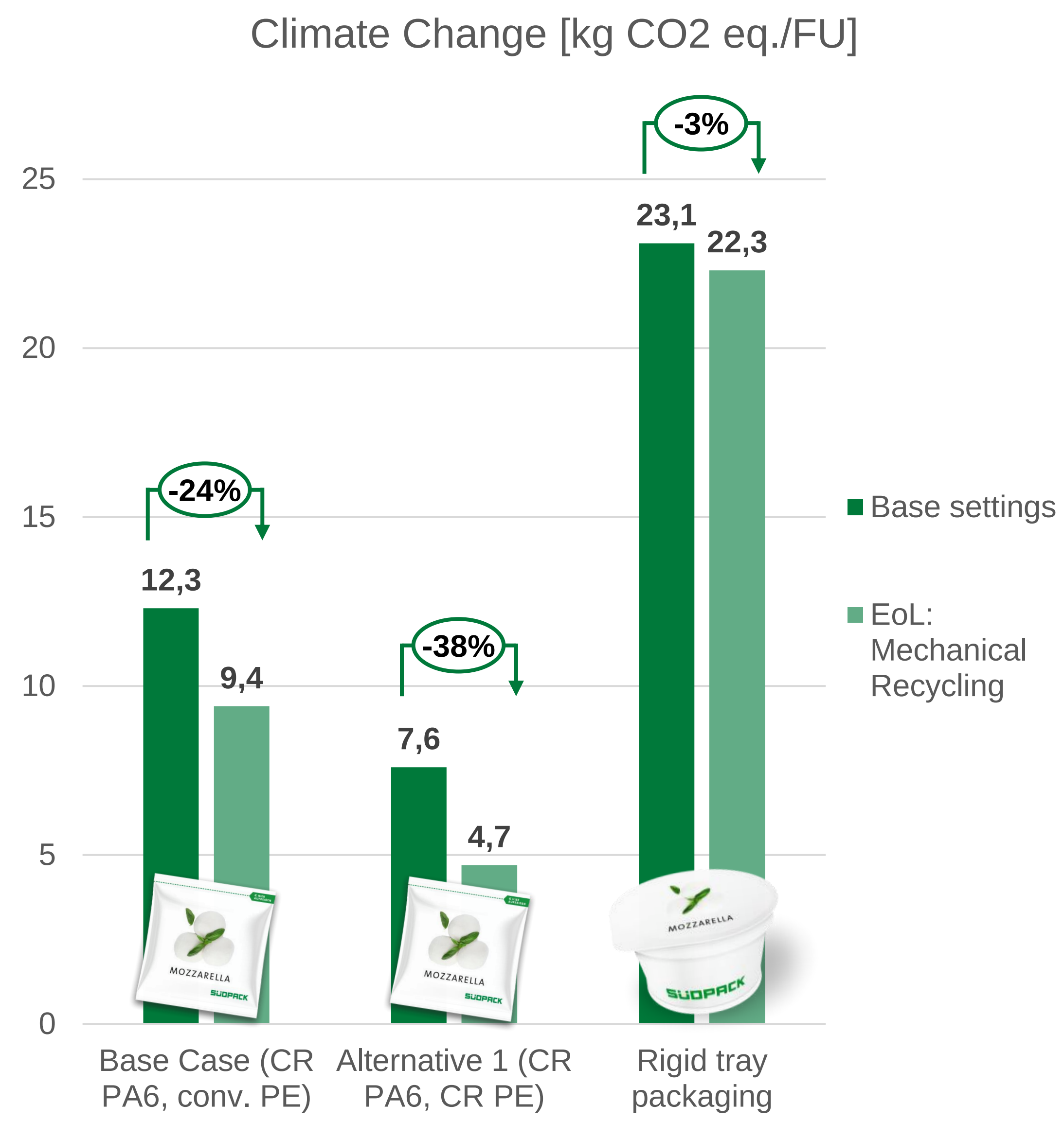
* via mass balance approach

Additional scenarios

Spotlight: End-of-Life

6. Mechanical recycling of multi-layer film at End-of-Life instead of incineration

- **Results:**
  - **Significantly lower climate change** impacts for all **flexible packaging formats**
  - In the **rigid packaging** the reduction is **not significant** because the End-of-Life scenario "mechanical recycling of multi-layer film" is applied to the **lidding film** that only makes up 10% of the overall packaging



* via mass balance approach

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