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“Certified soil biodegradable plastics - From the fundamentals of biodegradability to sustainable products”

Prof. Andreas Künkel
Vice President Research Biopolymers

Recy & DepoTech; Leoben, Austria, 14th of Nov. 2024

Leoben

Agenda:“Certified soil biodegradable plastics - From the fundamentals of biodegradability to sustainable products”

1 **Introduction**

2 Certified soil biodegradable mulch film - basics

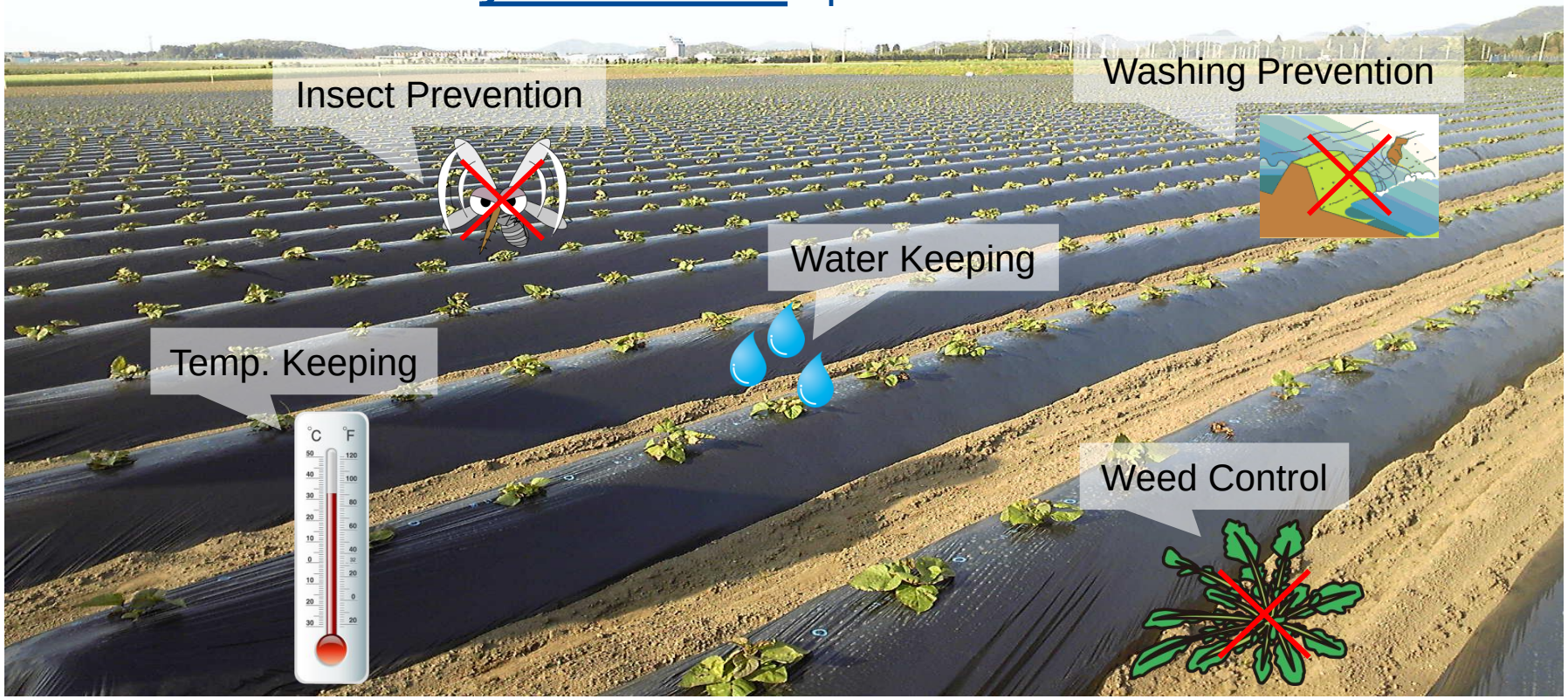
3 Implementation – Austria as case study

4 Conclusion and outlook

Agricultural mulch film

Mulch film increase crop yield via different functions

Each function leads to **yield increase** up to 50%.



➔ Mulch film is a plastic film which is specialized for different crops in agriculture.

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Agricultural mulch film

To achieve environmental performance thickness of PE film is defined by mechanical requirements for collection

- Biodegradable mulch film (BDP): ~12 µm thickness
- **Polyethylene mulch film (PE): ≥25 µm thickness needed to ensure collection**

Film Manufacturing → Carriage and Storage → Installation → Crop Development → **Plowing or Collection** → Fallow Period → Next Cropping

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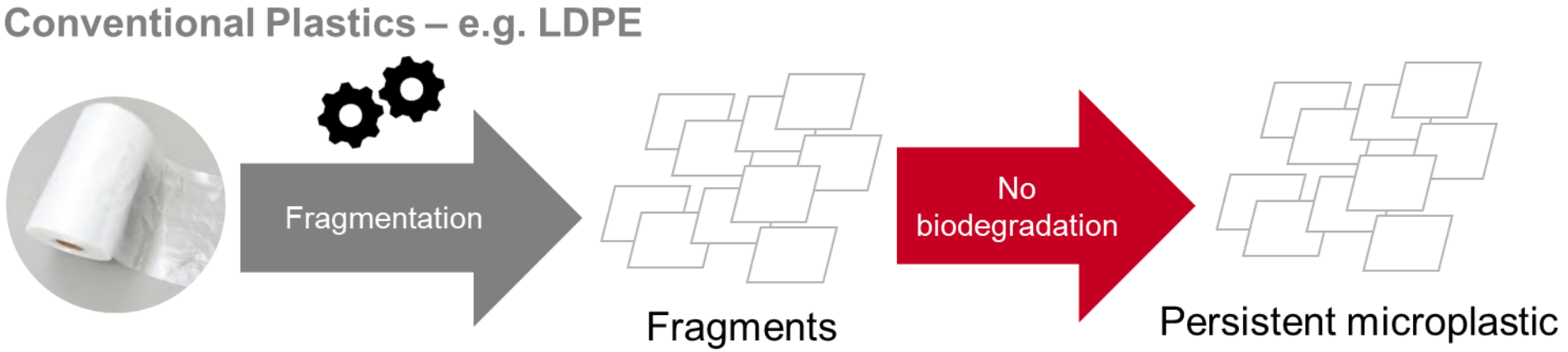
Agricultural mulch film

The consequence of non-collection of PE films

- ➔ Insufficient collection of PE mulch; Soil pollution leads to reduced yield of crops
- ➔ Generation of persistent microplastic



Fragmentation occurs via external processes such as mechanical treatment and creates persistent microplastic

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Agricultural mulch film

A thinner soil biodegradable mulch film supports biodegradation performance – it goes hand in hand

➔ **Biodegradable mulch film (BDP): ~12 µm thickness**

➔ Polyethylene mulch film (PE): ≥25 µm thickness needed to ensure collection

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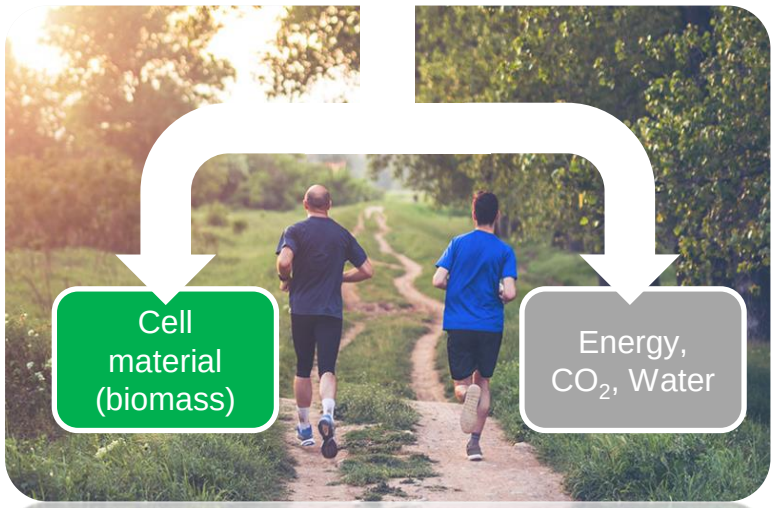
Biodegradability understanding

What is biodegradability?

Humans

Food biopolymers

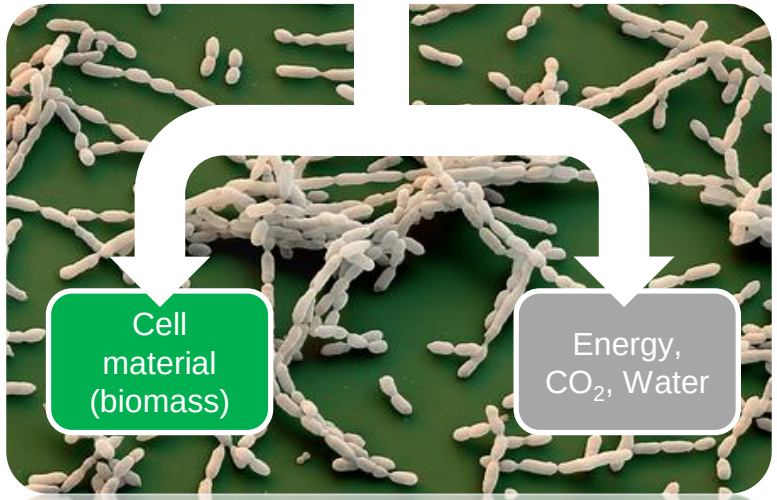
(e.g. starch, proteins)



Microorganism

„Food“ biopolymers

(e.g. starch, proteins, synth. biodegr. polymers)



Biodegradation = microorganisms metabolize the polymeric material completely to energy, CO_2, water & biomass (aerobic process)

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General mechanism of polymer biodegradation

Energy, CO_2, H_2O, biomass

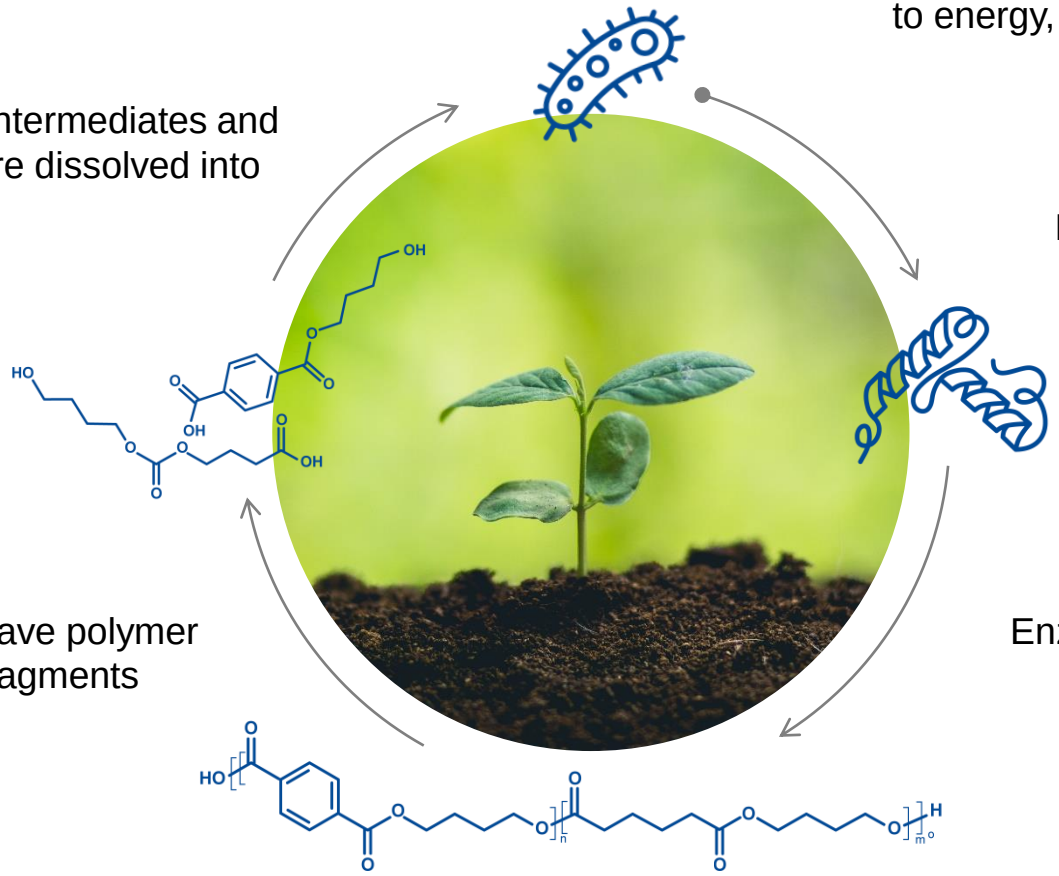
Microorganisms metabolize intermediates to energy, CO_2, H_2O and biomass

Microorganisms excrete extracellular enzymes (e.g., hydrolases)

Enzymes attach to surface of polymer chains

Enzymes cleave polymer chains into fragments

Short chain intermediates and monomers are dissolved into the medium



adapted from R.J. Müller

Biodegradability 2.0

Holistic approach for biodegradability with different technologies and partnerships

Lab test systems

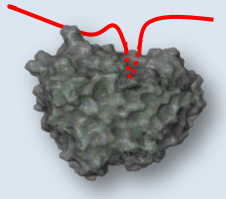
Correlation & reliability

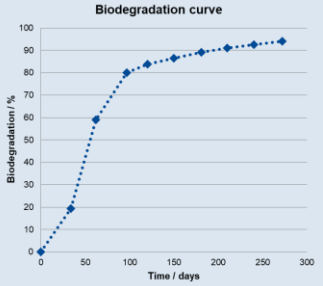
Mesocosm & field conditions

standard development and stakeholder dialogue

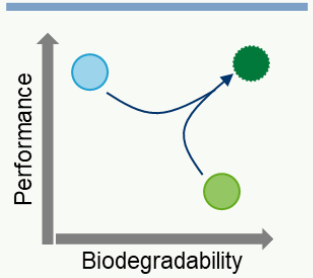
Cooperations academia & industry

Fundamental understanding of specific material biodegradation in target end of life environment





Data infrastrucure and consistency, automation & predictive modelling



material development and formulation

Microbiology & enzymes

Biodegradation pathways / fate of material

Analytical tools for complete biodegradation assessment

Biodegradation in soil

Biodegradable mulch film ecovio® M2351 mulch

End of life research

- Generate a fundamental understanding of the biodegradation process and fate of material
- Correlation of laboratory and field

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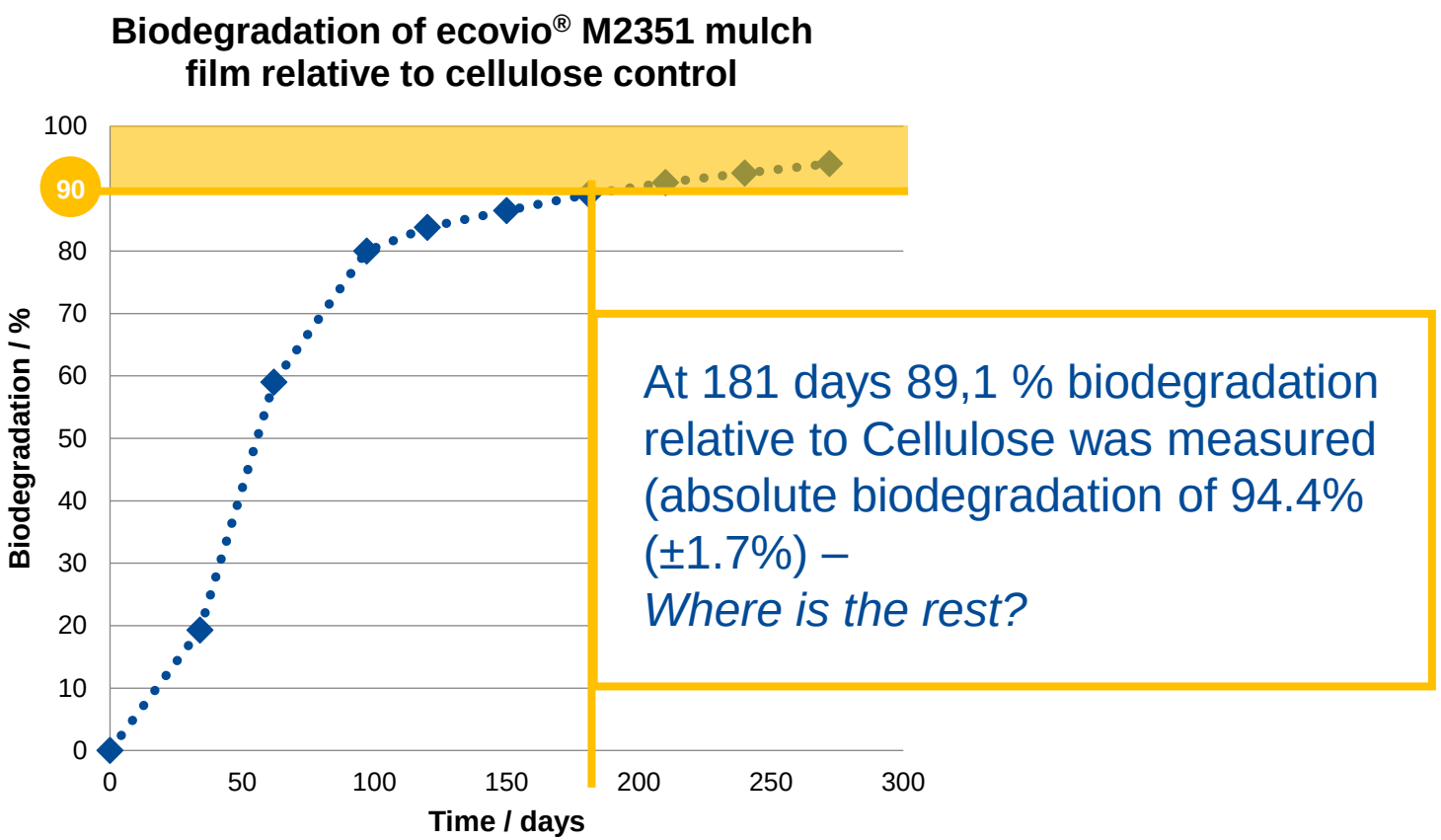
Biodegradation in soil

ecovio® M2351 mulch – Biodegradation in soil according to ISO 17556



At 181 days 89,1 % biodegradation relative to Cellulose was measured (absolute biodegradation of 94.4% (±1.7%) –
Where is the rest?

AIB-VINÇOTTE International s.a. / n.v.
SAFETY, QUALITY, ENVIRONMENT
Member of the Group AIB-VINÇOTTE
Head office : Boulevard A. Reyers 80 - B-1030 Brussels / Belgium

VINÇOTTE - CERTEST PRODUCTS
Everest - Leuvensesteenweg 248 / B-1800 Vilvoorde / Belgium
Tel. : +32(0)2 674.57.50 - Fax : +32(0)2 674.57.85
E-Mail : okbiodegradable@vincotte.be

SOIL — OK bio-degradable — VINÇOTTE

CERTIFICATE FOR AWARDING AND USE OF THE "OK BIODEGRADABLE SOIL" CONFORMITY MARK

No. O 14-1416-A

Issued by AIB-VINÇOTTE International

For the product(s) described hereafter :

Product Domain :	Products Biodegradable in SOIL
Product Group :	Raw materials
Product Family :	Bio material
Product Type :	In form of Resin or Granulates
Trade mark :	Ecovio M2351
Product description / Particularities :	Colour: natural white

Conformity examination applied for by :
BASF SE
G-PMPB - F206
67063 Ludwigshafen
Germany

Criteria for certification :
- AVI Test Program with ref OK 10 edition C "Bio-products – degradation in soil"

Validity of the certificate : From 25 September 2014 till 25 September 2019

Conclusions of the examination :
The products comply with the above mentioned certification criteria, as confirmed by the test report of AVI no 09 / 60159490 / 409344p.

Applicable certification system :
Type examination followed by supervision through verification tests on samples from the distributor's stocks or of the market.
The conformity of the product is guaranteed by the procedures for awarding and use of the 'OK biodegradable SOIL' conformity mark. This only applies for specimen bearing the 'OK biodegradable SOIL' mark.

This certificate is issued in English, German, Italian, French and Spanish.

Brussels, 25 September 2014

For the Certification Committee

P. MICHIELS
Contract Manager

Ph. DEWOLFS
President of the Committee

Annex : /

08-CERTOKS-c

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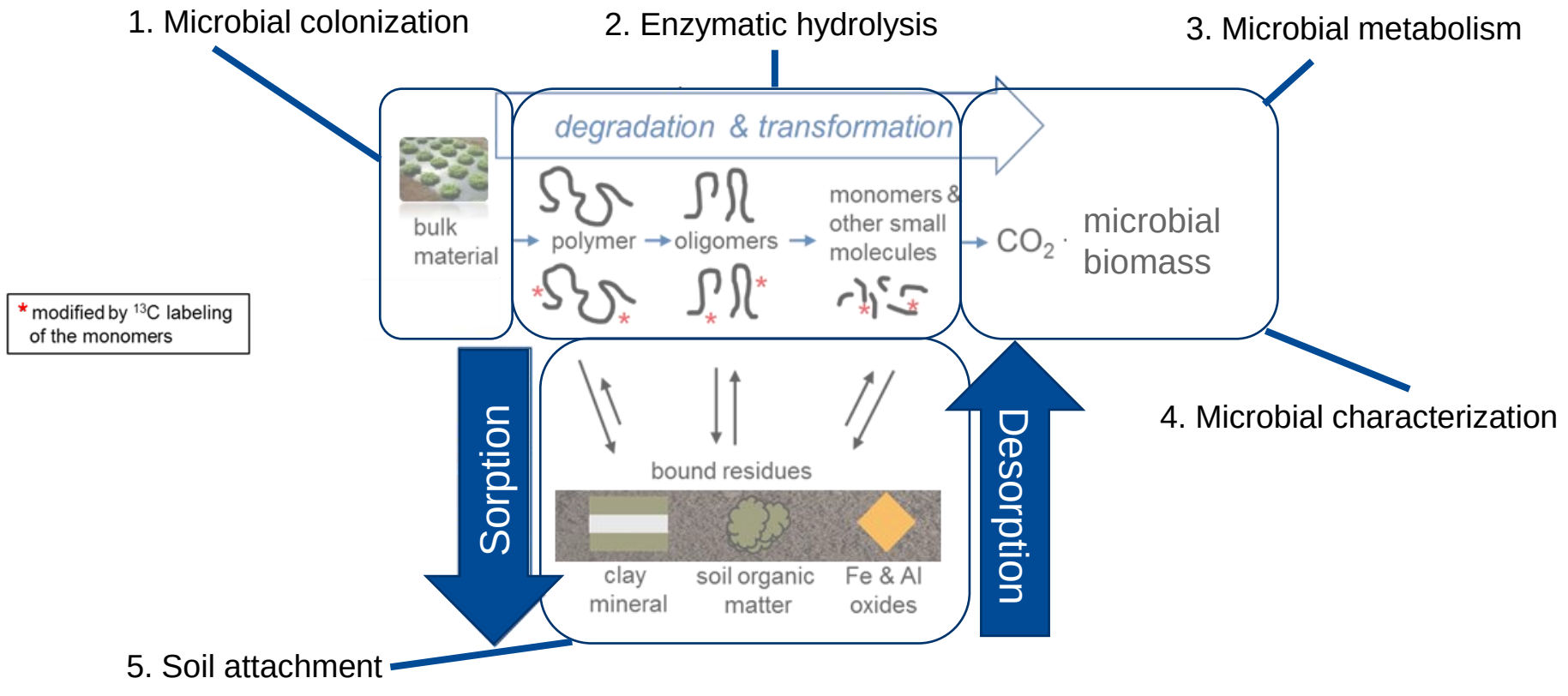
Biodegradation in soil

Decisive methods for understanding biodegradation in soil of ecovio® mulch film



Where does the polymer carbon end up?

Zumstein et al., Science Advances, 2018
Nelson et al., Nature Communications, 2022

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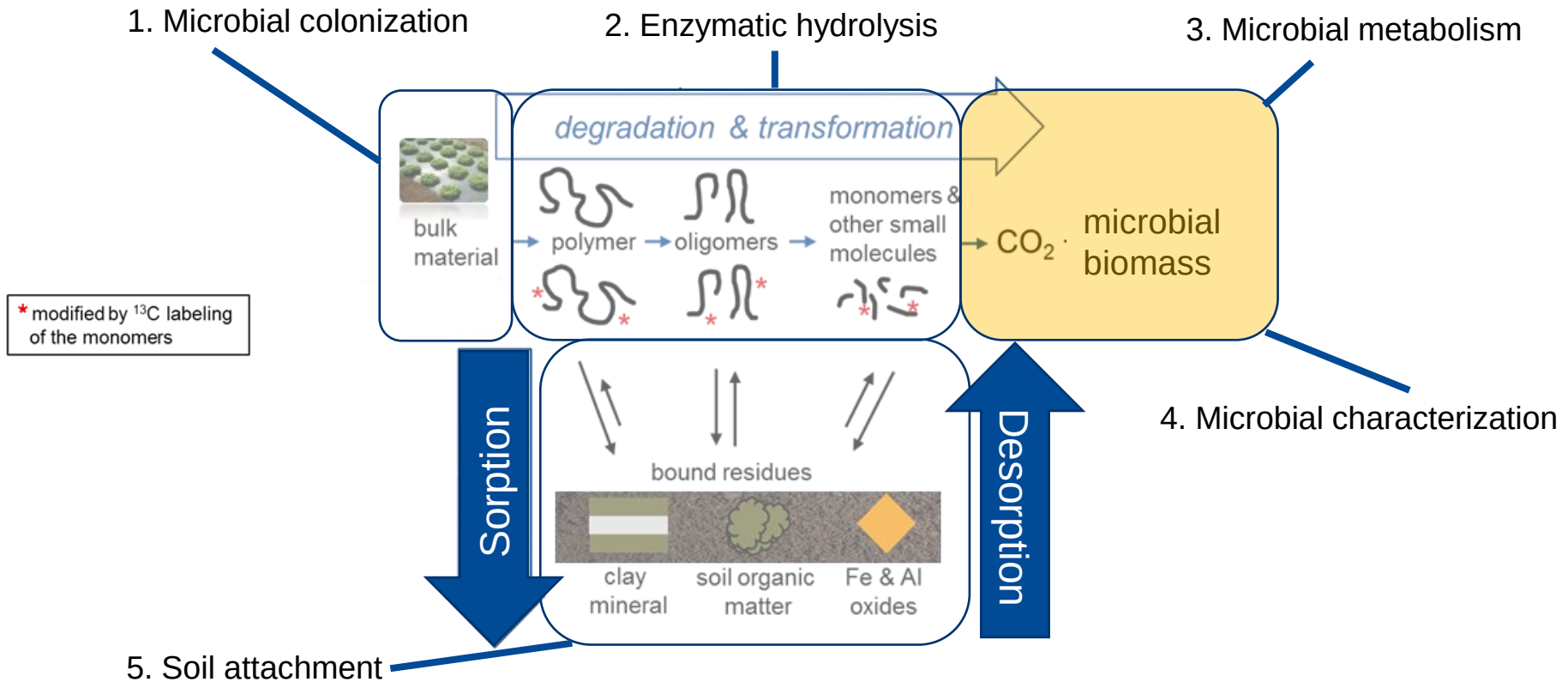
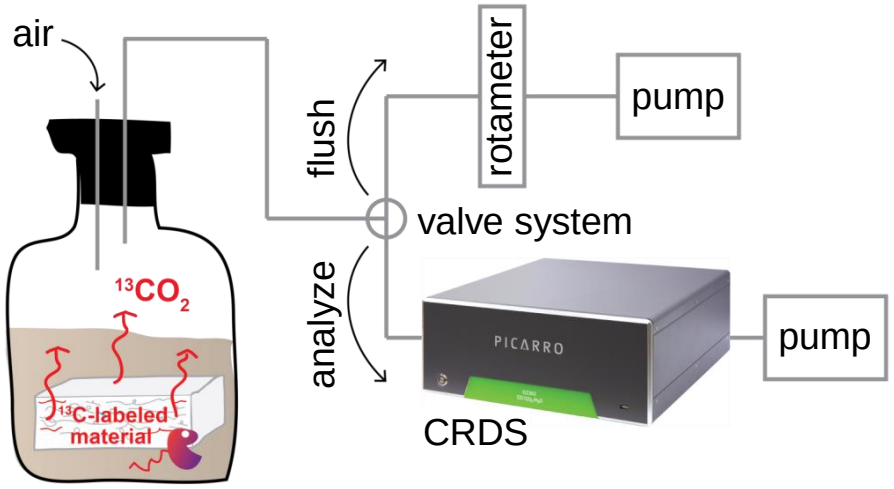
Biodegradation in soil

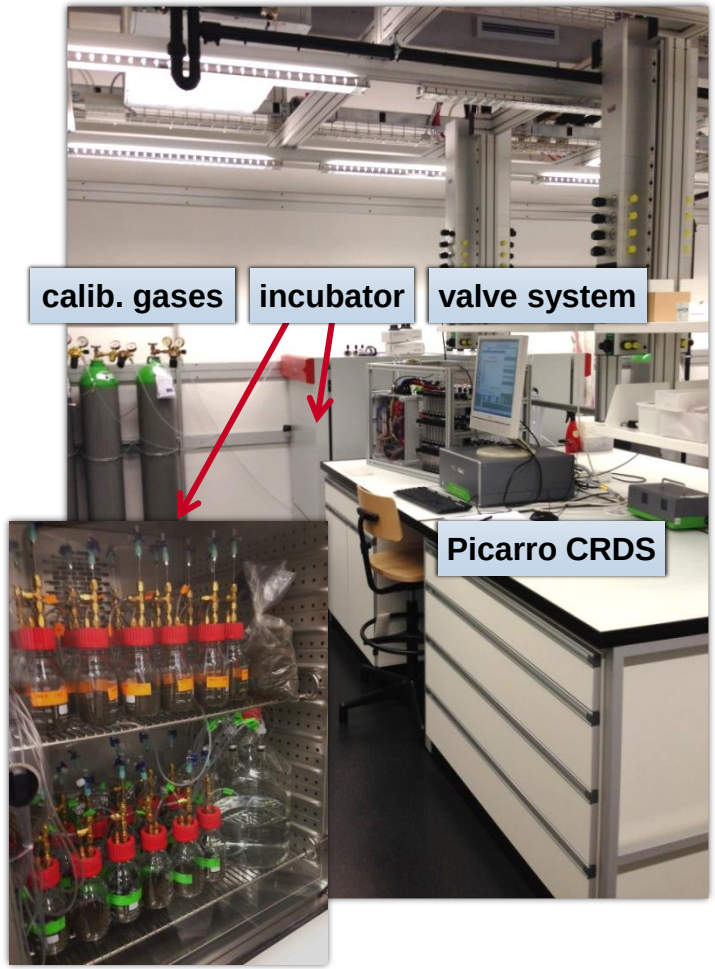
Decisive methods for understanding biodegradation in soil of ecovio® mulch film



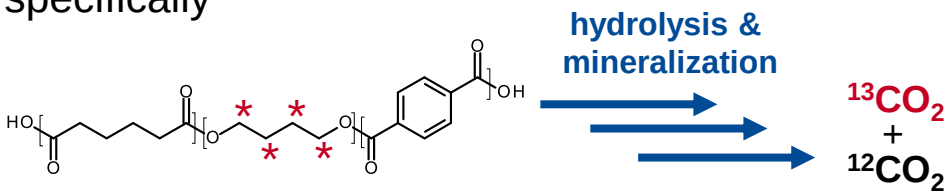
Where does the polymer carbon end up?

Microbial metabolism – CRDS technique to monitor polymer mineralization



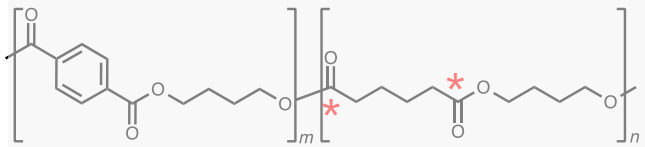


- Cavity Ring Down Spectroscopy (CRDS) method is sensitive to ^{12}C- & ^{13}C-carbon dioxide
- Mineralization of stable isotope labeled polymers can be followed very accurately & position-specifically



Biodegradation in soil

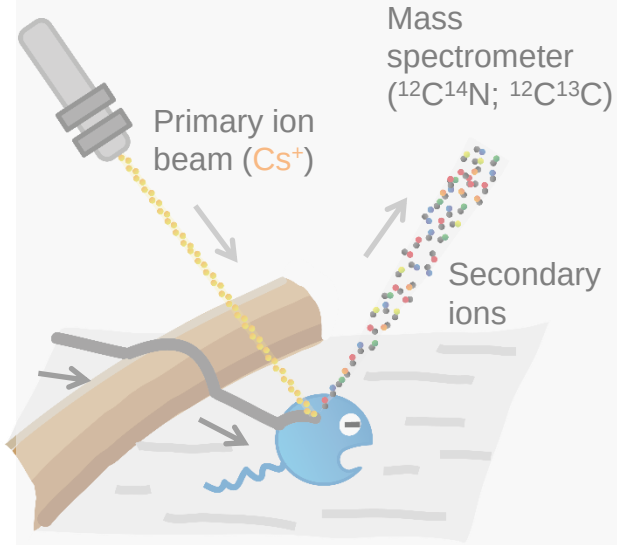
Conversion into microbial biomass

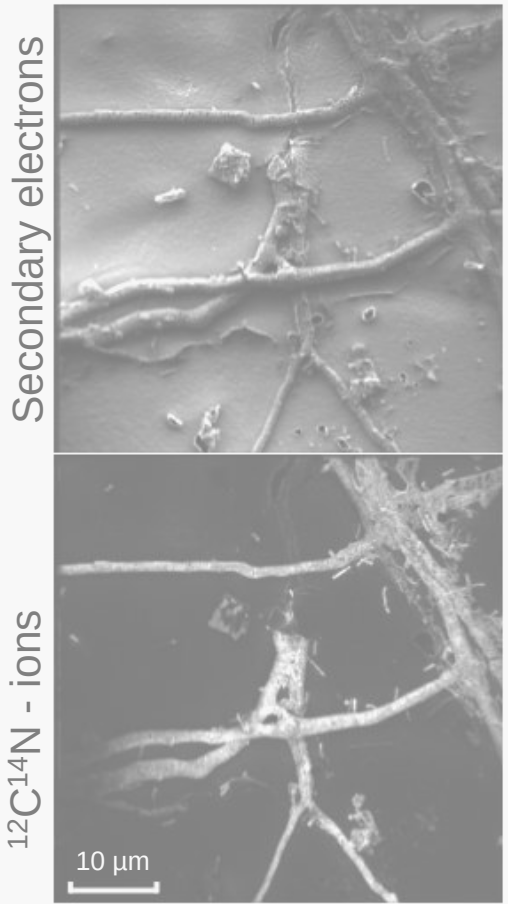


poly(butylene adipate-co-terephthalate)
PBAT: labeled in adipate

Zumstein et al.,Science Advances 2018;**4**:eaas9024

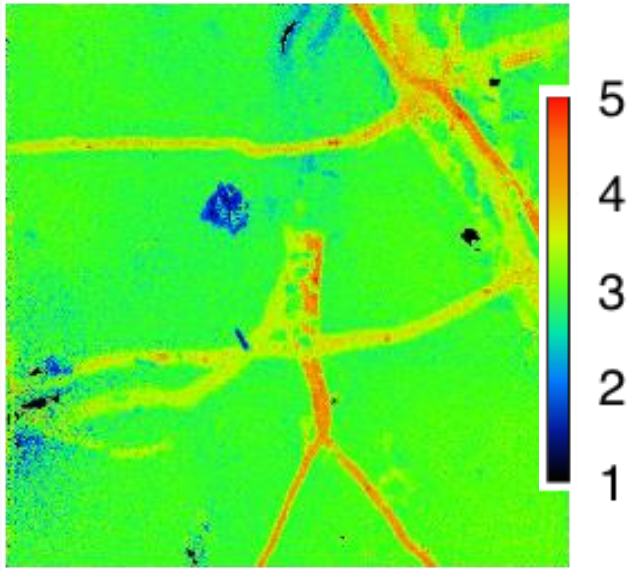
Nanoscale secondary ion mass spectrometry (NanoSIMS)





^{13}C atom percent

^{13}C / (^{12}C + ^{13}C) (%)

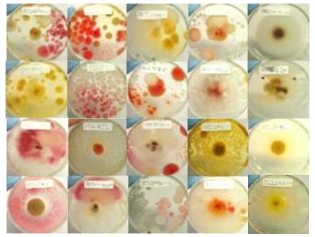


Biodegradation in soil

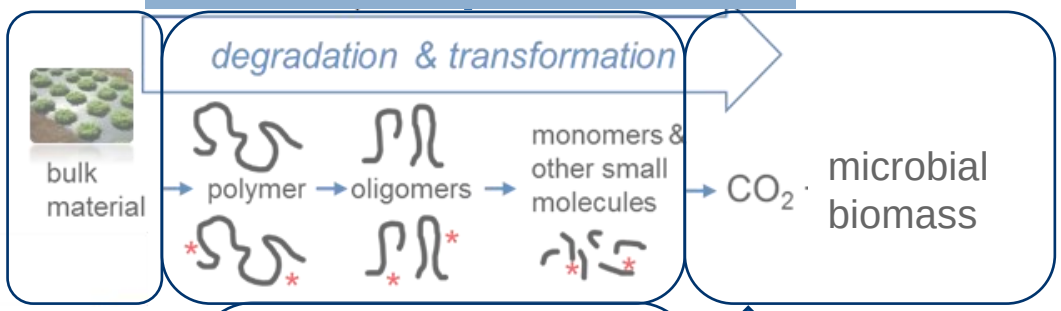
Decisive methods for understanding biodegradation in soil of ecovio® mulch film are established

UV weathering followed by biodegradation test and structural polymer analytics

Microorganisms & enzymes



700 organism identified

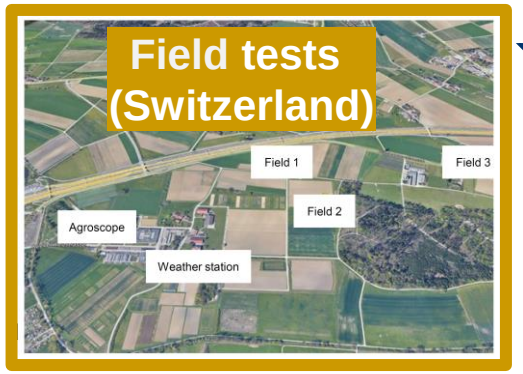


Nanoscale Secondary Ion Mass Spectrometry (NanoSIMS)

Respirometric measurements (O_2 demand, CO_2 evolution)

Cavity ring down spectroscopy (CRDS)

60 soils investigated



Soil extraction and (trace) analytics

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For the first time fate of polymer from soil biodegradable mulch film can be followed

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Biodegradability 2.0

Holistic approach for biodegradability with different technologies and partnerships

Lab test systems

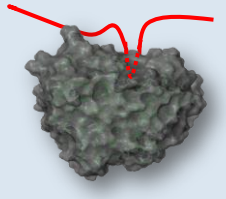
Correlation & reliability

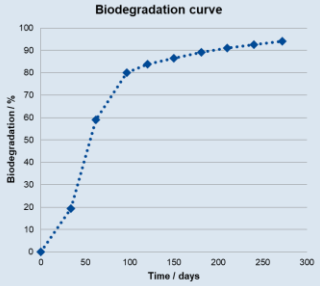
Mesocosm & field conditions

standard development and stakeholder dialogue

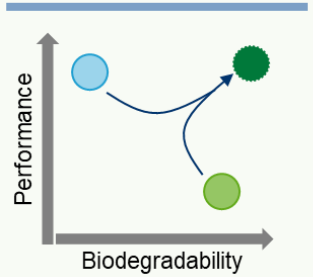
Cooperations academia & industry

Fundamental understanding of specific material biodegradation in target end of life environment





Data infrastrucure and consistency, automation & predictive modelling



material development and formulation

Microbiology & enzymes

Biodegradation pathways / fate of material

Analytical tools for complete biodegradation assessment

Biodegradability 2.0

Holistic approach for biodegradability with different technologies and partnerships

Lab test systems

60 soils investigated

Correlation & reliability

Mesocosm & field conditions

field trial in Switzerland

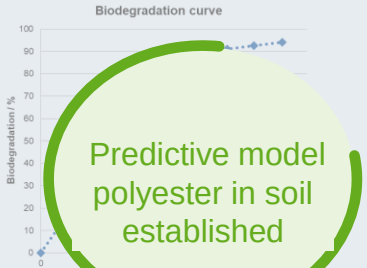
EN 17033

Austria case study constructive dialogue

Cooperations academia & industry

6 publications in high impact journals

derstanding of specific material biodegradation
target end of life environment



Predictive model polyester in soil established

Data infrastructure and consistency, automation & predictive modelling

eocio film tested for different crops

material development and formulation

700 microbes indentified

Microbiology & enzymes

Biodegradation pathways / fate of material

Analytical tools for complete biodegradation assessment

CRDS, NanoSIMS, solvent extraction established

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Film Manufacturing → Carriage and Storage → Installation → Crop Development → Plowing or Collection → Fallow Period → Next Cropping

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Certified biodegradable materials: requirements for implementation

- Reliable test methods (lab & environment)
- Biological and analytical tools for elucidation of biodegradation pathways (no persistent microplastic)
- Digital tools (data management, prediction)

Case studies for microplastic reduction

Austria as example for constructive discussion catalyzed by „Bündnis Mikroplatistikfrei Österreich“ appointed by ministery for environment

Fact based disucssion

UBA Austria microplastic event, Vienna 2022

Dialogue

Dialogue with stakeholders, moderation „Bündnis Mikroplastikfrei“ (Daniel Steinitz)

Concrete proposal

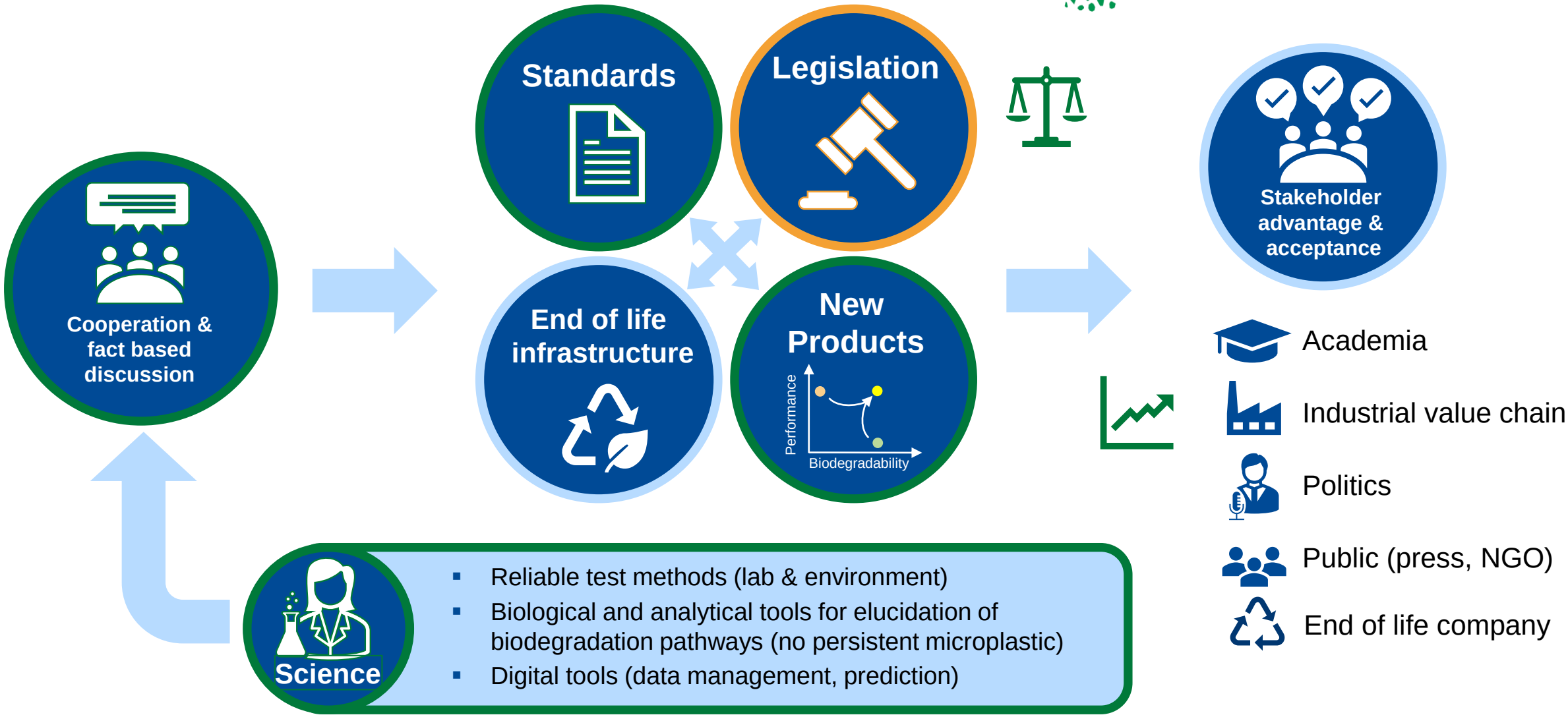
Walter Hauer (President Bündnis Mikroplastikfrei) and Leonore Gewessler (Federal Minister for Climate Action, Environment, Energy, Mobility, Innovation and Technology)

Proposal: Mulch film <25µm = certified soil biodegradable mulch film (no recollection possible → biological recycling); >25µm = PE mulch film (recollection → technical recycling)

Case studies for microplastic reduction

Biodegradable materials in agriculture and forestry

bündnis mikroplastik frei



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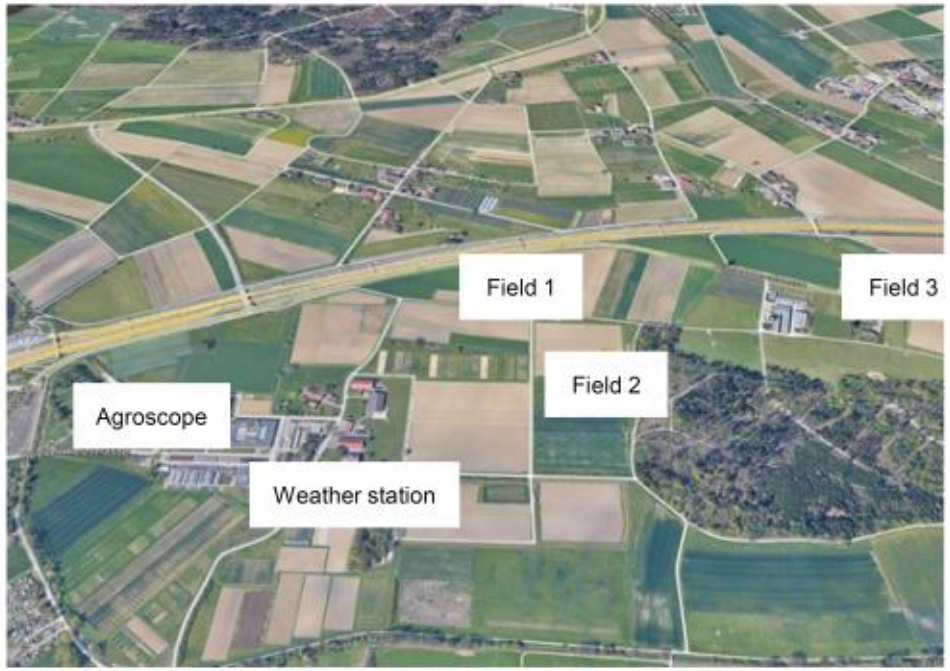
Biodegradation in soil

ecovio lab/field tests in different soils (ETH Zürich, Agroscope) 2020 - 2023

Background and experimental set-up

- Comparability of mulch film biodegradation in lab & field
- ecovio M2351 film samples used for studies
- Extraction-based biodegradation studies and DNA-extraction
- Respirometric/CO_2-evolution biodegradation studies and DNA extraction
- Sampling at different timepoints or at different level of biodegradation



- **Soil 1**: from a “Öko-Ausgleichsfläche”
- **Soil 2**: from a manure treated grassland
- **Soil 3**: from a normally treated agricultural field which just came off crop rotation