An urban biorefinery for food waste and biological sludge conversion into polyhydroxyalkanoates and biogas

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EN Horizon 2020 Work Programme 2016 - 2017
17. Cross-cutting activities - Focus Areas

CIRC-05-2016: Unlocking the potential of urban organic waste
Research and Innovation Actions (RIA)

REsources from **UR**ban **BI**o-wa**S**te
RES URBIS

(in latin: things, goods, or affairs of the city)

3-year project, started January 1°, 2017
20 partners, 8 countries

Project coordinator: M. Majone
Research Centre for Protection of Environment and Cultural Heritage
University of Rome “La Sapienza”, Italy
Website: www.resurbis.eu

SAPIENZA UNIVERSITÀ DI ROMA

Project Rationale: developing an urban bio-waste biorefinery

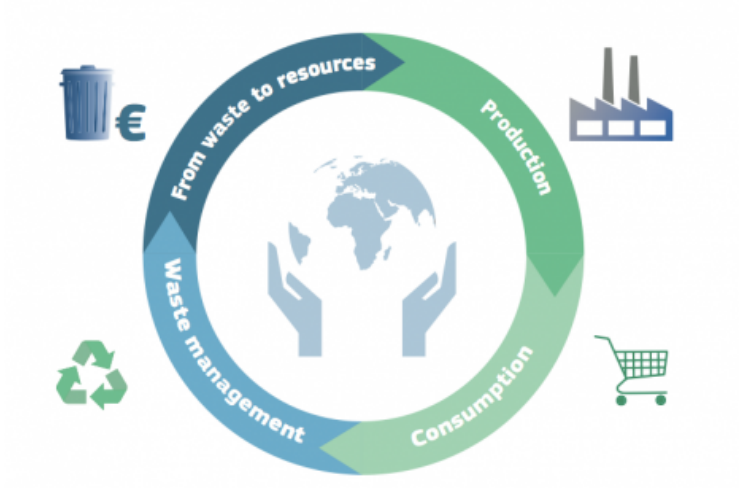
To integrate the treatment of most relevant bio-waste of urban origin

To develop an urban bio-waste biorefinery towards bio-based products

Also taking care of...

the whole technology chain	**Different industrial sectors to be linked each other**, each one having its own business targets, needs and specifications.
territorial conditions	Defining territorial **clusters**: different waste production and management systems
technical and non technical constraints	Regulatory (e.g. "**end of waste**"), environmental, and social constraints, as function of local, regional and national conditions

Circular economy: from waste to resource



Organic waste recycling in Treviso province = 85.3%
(ARPAV, 2017)

Parameter	Mean ± st.dev	Max	Min
TS (g/kg)	153 ± 52	211	33
VS (g/kg)	113 ± 44	178	25
VS/TS (%)	84 ± 3	97	75

Recovery biodegradable carbon from urban organic waste

Organic fraction of municipal solid waste (OF-MSW)
especially from source-sorted collection

Municipal wastewater
major COD portion is then concentrated in **primary and excess sludge (WWS)**

Park/garden waste
not easily biodegradable and more variable with season

Agro- and food-industry wastewater and waste
often produced in proximity to urban areas

Slurry (squeezed OFMSW- thickened sludge)

Parameter	Mean ± st.dev
TS (g/kg)	56 ± 3
VS (g/kg)	44 ± 3
COD (g/kg TS)	835 ± 24
TKN (g N/kg TS)	25 ± 3
P (g P/kg TS)	2.3 ± 0.1

Organic Urban Waste

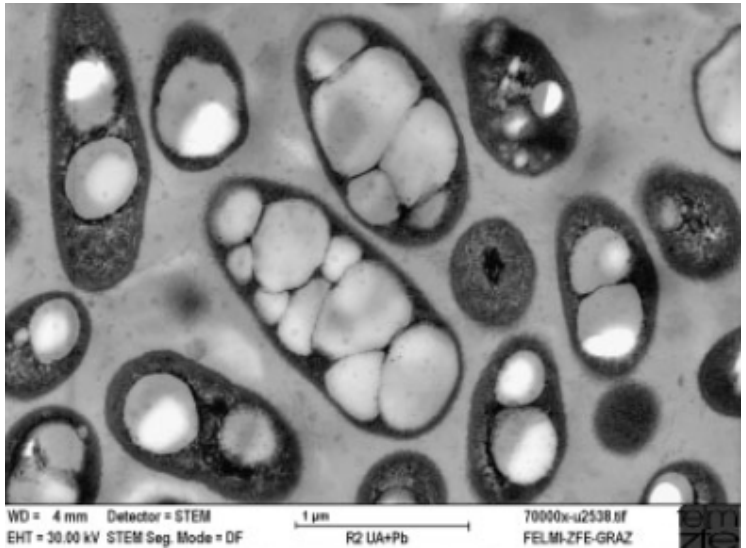
The organic fraction of municipal solid waste (OFMSW)

Primary and excess sludge from municipal wastewater treatment (WWS)

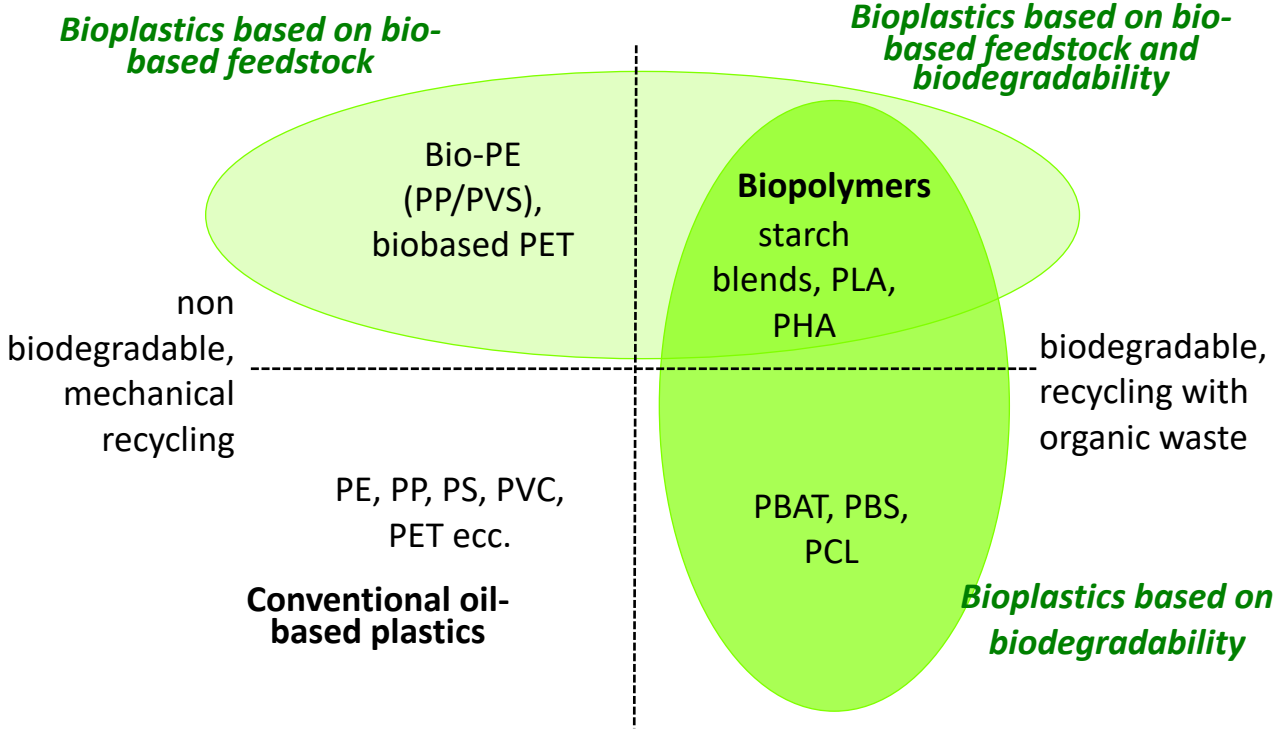
THE URBAN BIOREFINERY

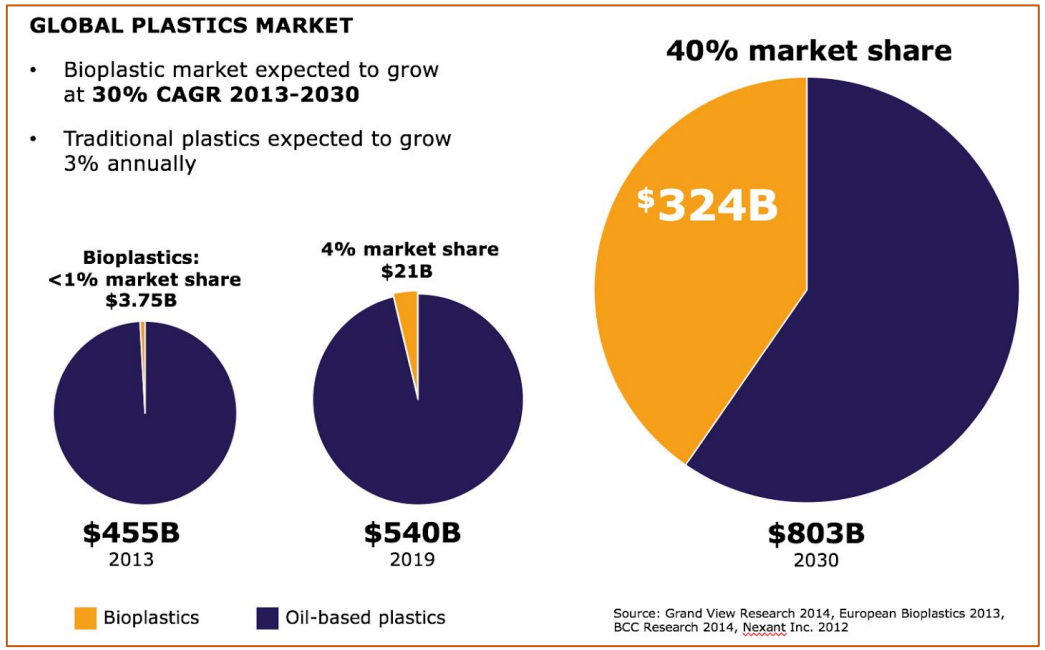
Bio-based Products

- **polyhydroxyalkanoate (PHA), biodegradable natural biopolymer**
- related PHA-based bioplastics (e.g blends)
- fibers (for PHA-based biocomposites)
- bio-based solvents (for PHA extraction)



Bioplastics portfolio





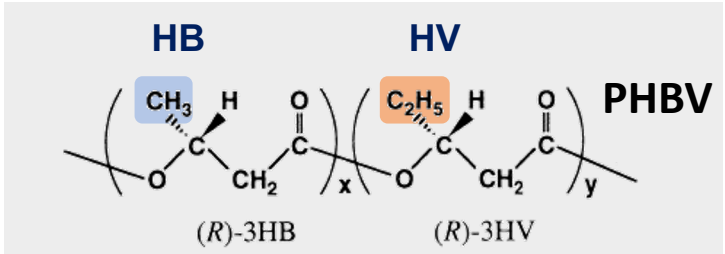
- ✓ The **European Strategy for Plastics** asks for decreasing dependency on oil-based plastics, increasing recycle
- ✓ **Bioplastic** market is still very less than oil-based plastics, but much faster growth is expected.

Why focusing on PHA?

Product related Pro's

Family of copolymers with tunable composition

PHA can be the main constituent of several bioplastics, with a wide portfolio of applications.



RES URBIS portfolio

- Biodegradable commodity film
- Packaging interlayer film
- Specialty durables (such as electronics)
- Slow C-release system for groundwater remediation

Production process Pro's

• A novel **open microbial cultures process** (not pure strains), to better cope with **large heterogeneity of the waste feedstock**;

• PHA production process is mostly **biological, under mild conditions and reliable**.

• Easier integration with existing biological plants for waste and wastewater treatment.

Appealing

- Produced from renewable feedstock (**no food**)
- Produced in biological process (**no OGM**)
- **Biodegradable**: not recycled but virgin material

Applications and economics

High market potential

As higher as more PHA cost decreases; but still higher value than biogas and compost

Under investigation at TRL 6

High Technology Readyness Level (TRL 5-6): pilot scale investigation is a key-feature of RES URBIS approach

- Working with real and representative feedstock
- Two multi-step pilot plants for production of PHA

NOVA id FCT
Associação para a Inovação e Desenvolvimento da FCT

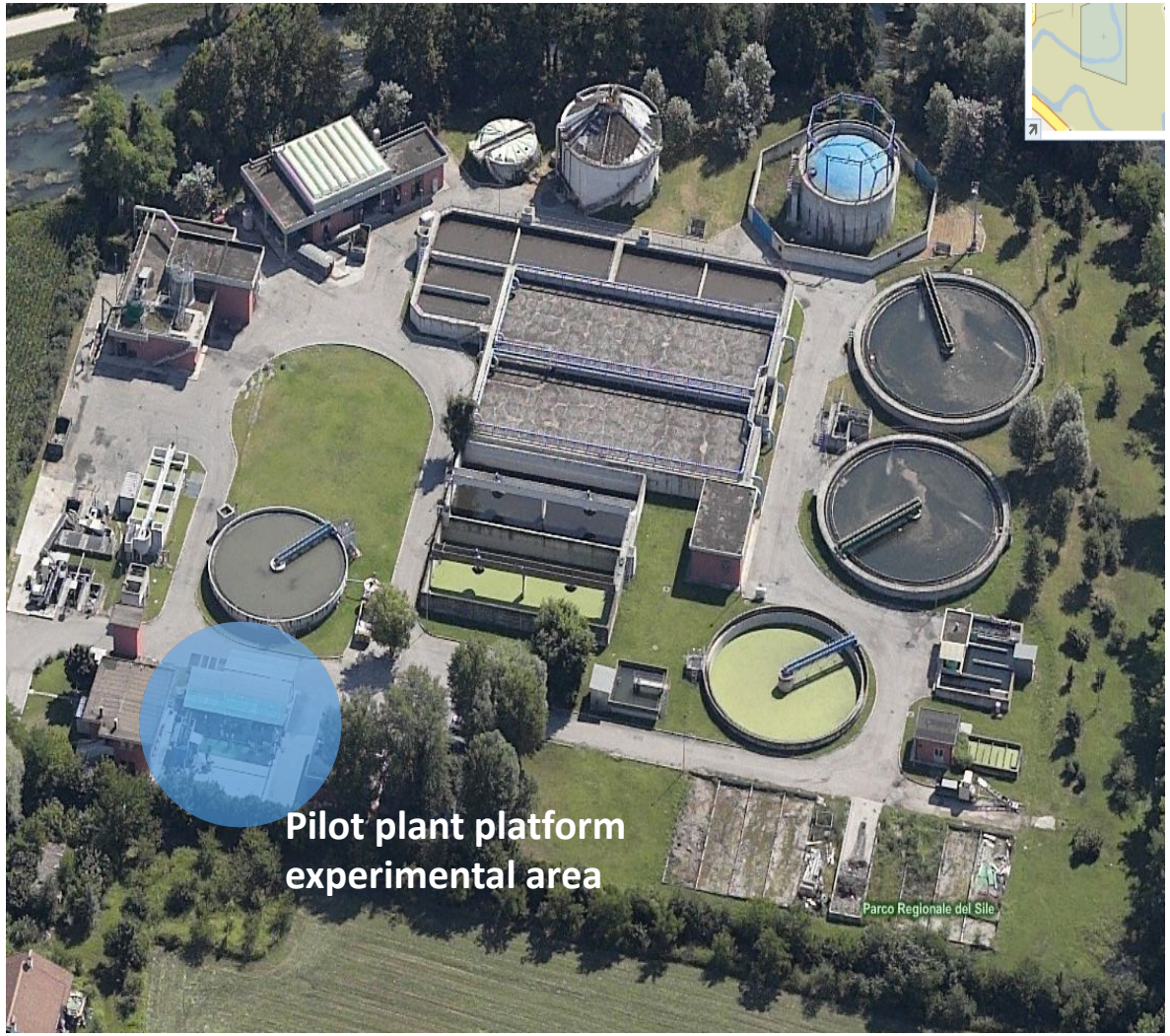
STVDIVM VRBIS

VENETIARVM VNIVERSITAS · IN DOMO FOSCARI ·

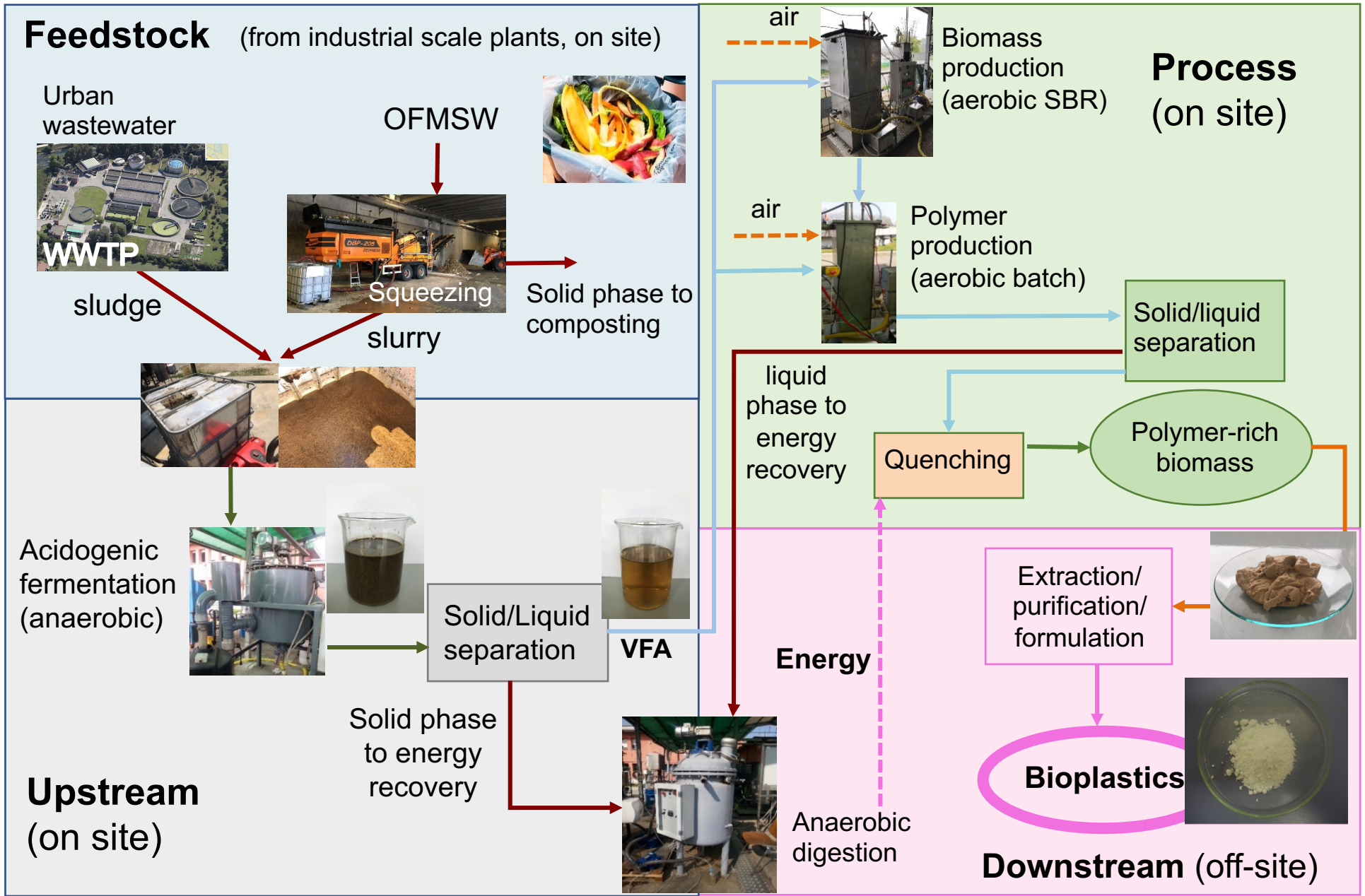
- **Treviso (TV)** WWTP ATS S.r.l.

  (Alto Trevigiano Servizi)

Biowaste-Sludge Anaerobic Codigestion	
Feed characteristics	
Flow, m^3/d	10 biowaste + 100 sludge
TVS, %TS	70
Operational parameters	
OLR, $kgVS/m^3d$	1.5
HRT, d	20-24
Temperature, °C	35-37
Yields	
Biogas, Nm^3/d	950
Methane, %	60-66
SGP, Nm^3/kg VS (% biowaste)	0.43
TS removal, %	28
VS removal, %	39



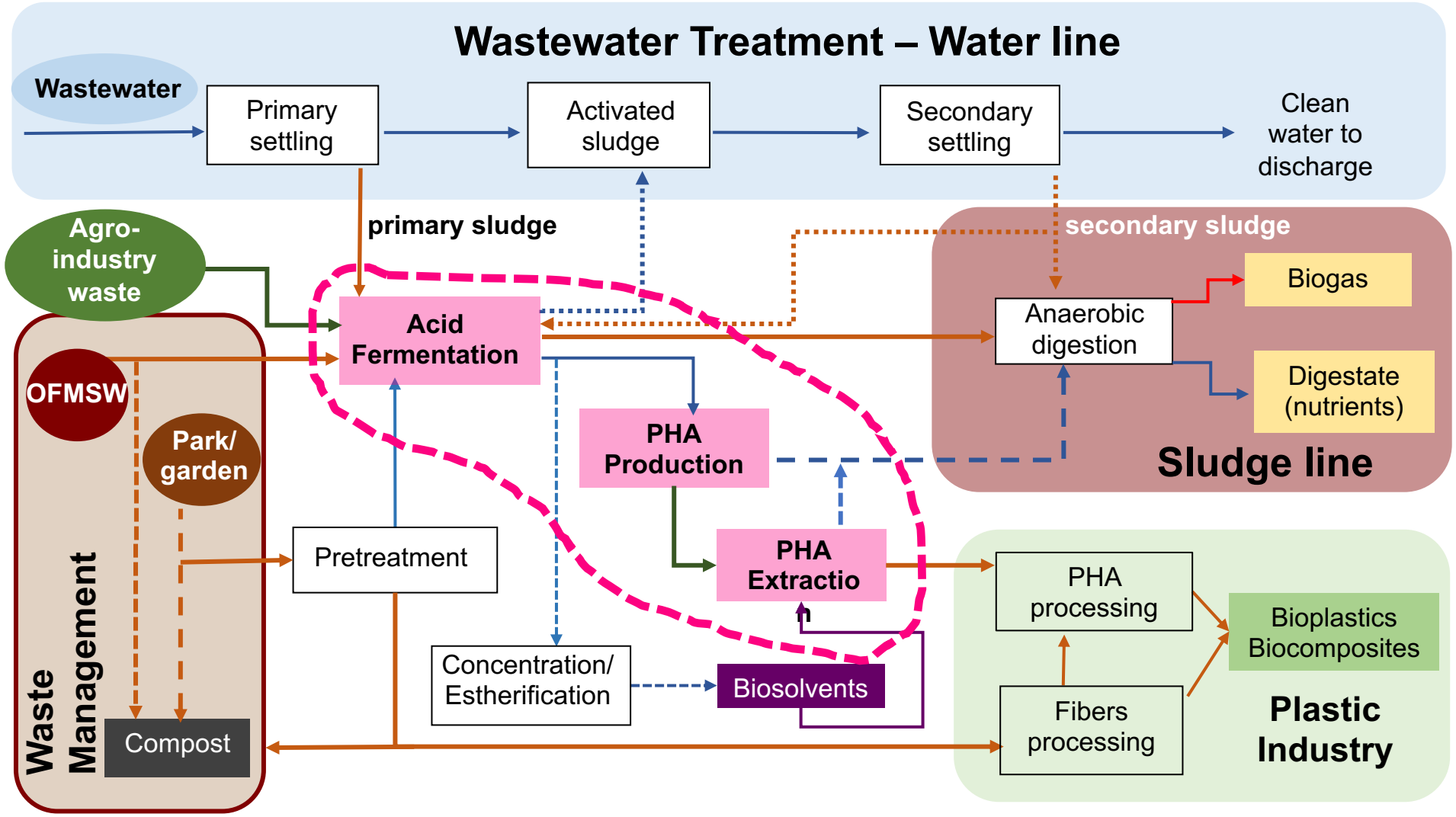
Flow-sheet of biopolymer production from urban biowaste (pilot scale plant in Treviso, Italy)

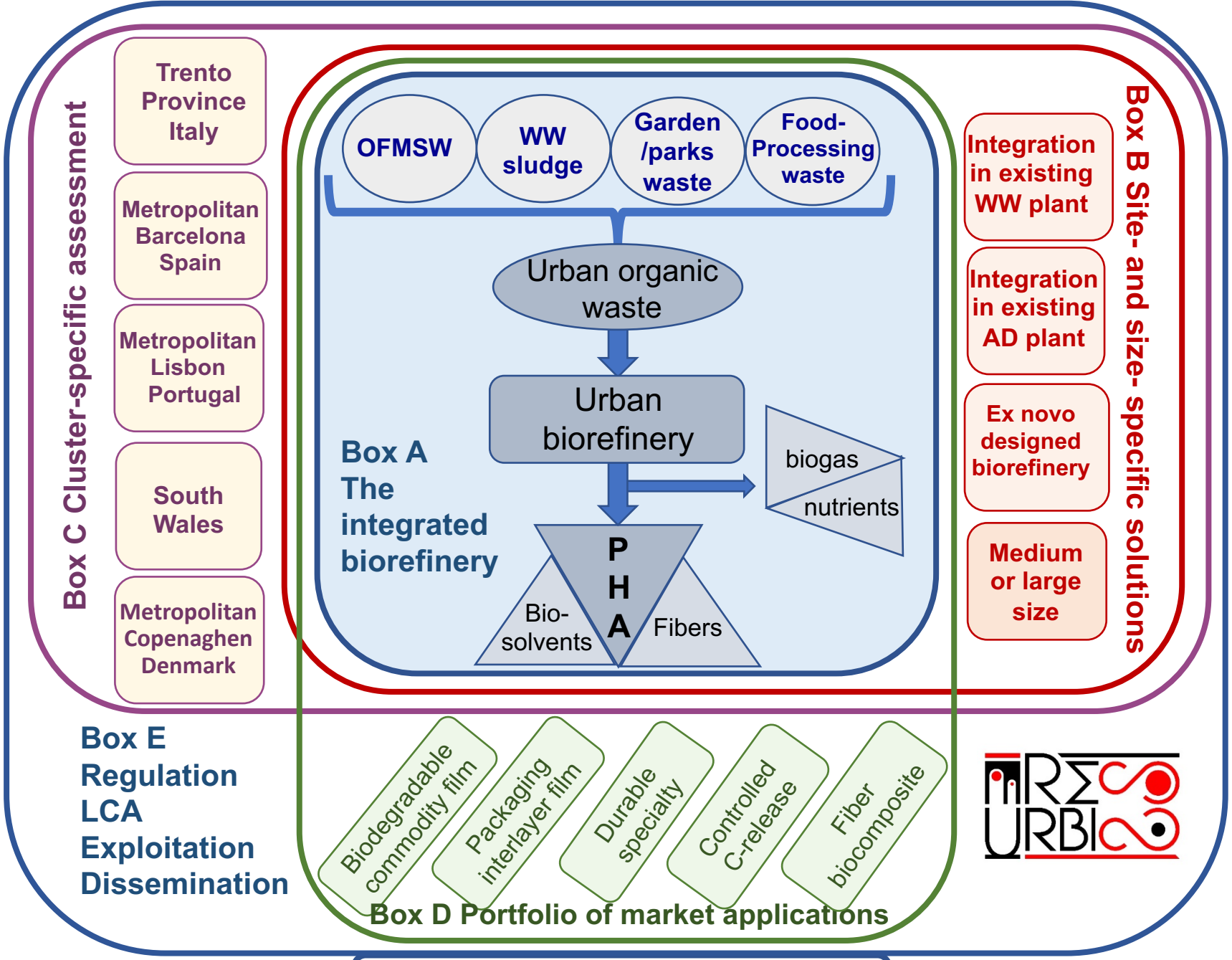


Progress of waste transformation

OFMSW	Sludge (WAS)	Cake to anaerobic digestion	Filtrate to PHA production	Aerobic biomass slurry	Cake to PHA extraction
Feedstock		**Effluent from acidogenic fermentation**		**Biomass after PHA accumulation**	

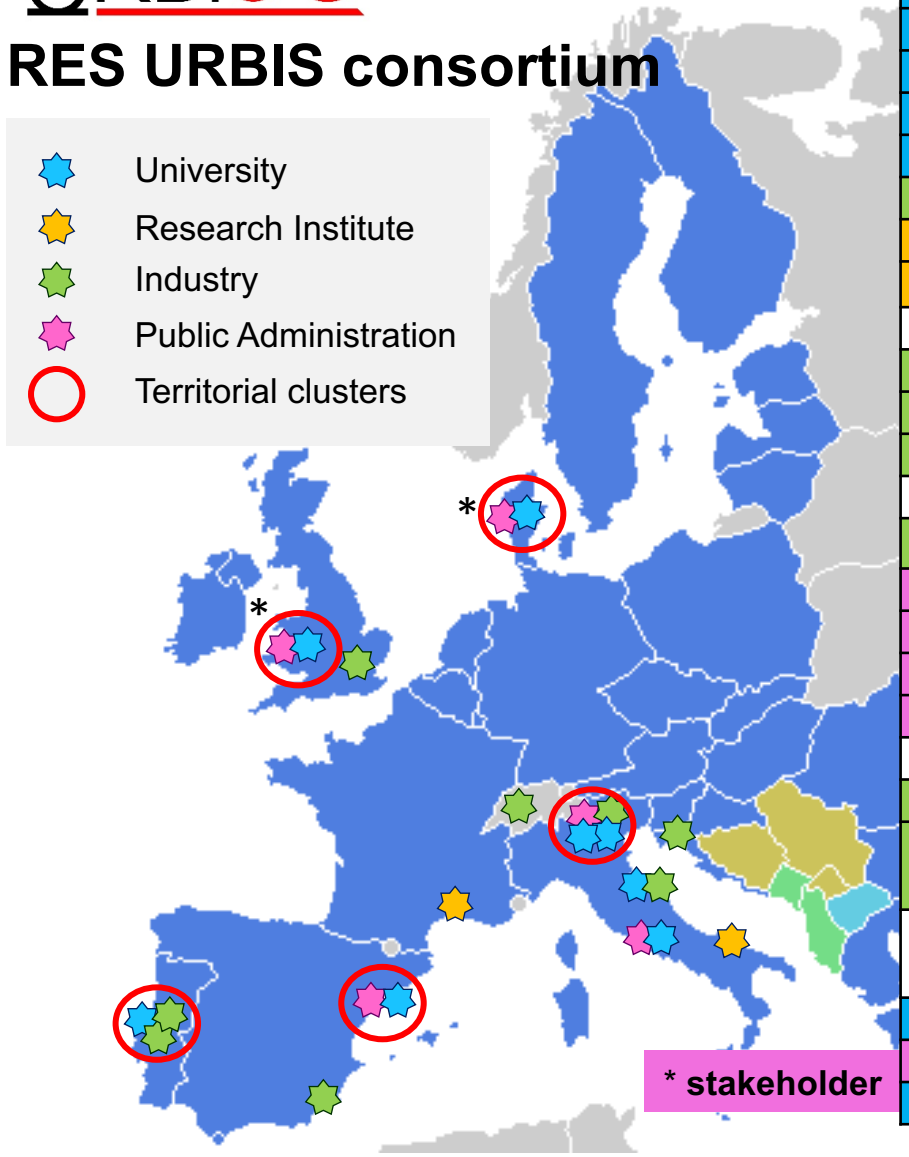
Linking the urban organic waste biorefinery with existing waste/wastewater treatment facilities and plastic industry





The RES URBIS box-model

RES URBIS consortium



Process-related challenges	
University of Roma “La Sapienza” (Italy)	WP2
New University of Lisbon (Portugal)	
University Ca Foscari of Venice (Italy)	
University of Barcelona (Spain)	
University of South Wales (UK)	
University of Bologna(Italy)	
Biotrend (Portugal)	
CNR – IRSA(Italy)	
Inst. Nat. Recherche Agronomique (France)	
Product-related challenges	
BioInicia (Spain)	WP3
Mi-Plast (Croatia)	
SABIO (Italy)	
Territorial clustering	
Aguas do Tejo Atlantico (Portugal)	WP1
Barcelona Metropolitan Area (Spain)	
Province Autonoma di Trento(Italy)	
Rhondda Cynon Taff County Council (UK) *	
City of Copenaghen (Denmark)*	
Economics and exploitation	
InnoExc (Switzerland)	WP5 WP6
Bio-Based and Biodegradable Industries Association (UK)	
Regulation, safety, environmental and social aspects	
Technical University of Denmark (Denmark)	WP4 WP1
National Institute for work safety (Italy)	
University of Verona (Italy)	

“End-of-waste” status

Article 6 of the Directive 2008/98/EC, as amended by the new Waste Directive (Brussels, 27 April 2018 (OR. en) 2015/0275 (COD) PE-CONS 11/18)

1. Member states ensure that waste which has undergone a recycling or other recovery operation is not considered a waste if it complies with:

- the substance is ~~commonly~~ **to be** used for specific purposes;
- a market or demand exists for such a substance;
- the substance *fulfills ~~the~~ technical requirements for the specific purposes* and **meets the existing legislation and standards** applicable to products;
- the use of the substance will not lead to adverse environmental/human health impacts.

in compliance to ECHA-REACH regulation

From PCB-PAH-Metals analysis, PHA from organic waste meets all conditions to cease to be a waste

provided that PHA composition is well known and PHA is not dangerous

PCB

polymers

MDPI

Article

Polychlorinated Biphenyl Profile in Polyhydroxy-alkanoates Synthetized from Urban Organic Wastes

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Abstract: The microbial synthesis of polyhydroxyalkanoates (PHA) from organic wastes is a valuable process to valorize available renewable resources, such as food wastes and biological sludge. Bioplastics find many applications in various sectors, from medical field to food industry. However, persistent organic pollutants could be transferred from wastes to the final product. The present paper demonstrates that the use of municipal wastes in PHA production is safe for the environment and human health and provides a polychlorinated biphenyl (PCB) profile in both commercial and waste-based PHA samples. PCB analysis in several PHA samples showed very low concentrations of the target analytes. Commercial PHA samples showed a similar PCB level with respect to PHA samples from municipal waste/sludge and higher than PHA samples from fruit waste. For all analyzed PCBs, detected concentrations were consistently lower than the ones reported in regulatory framework or guidelines.

Metals

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Elemental concentration and migratability in bioplastics derived from organic waste

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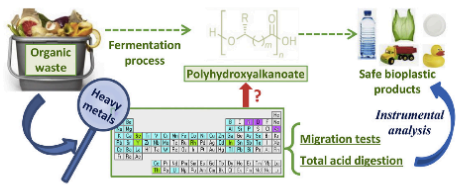
HIGHLIGHTS

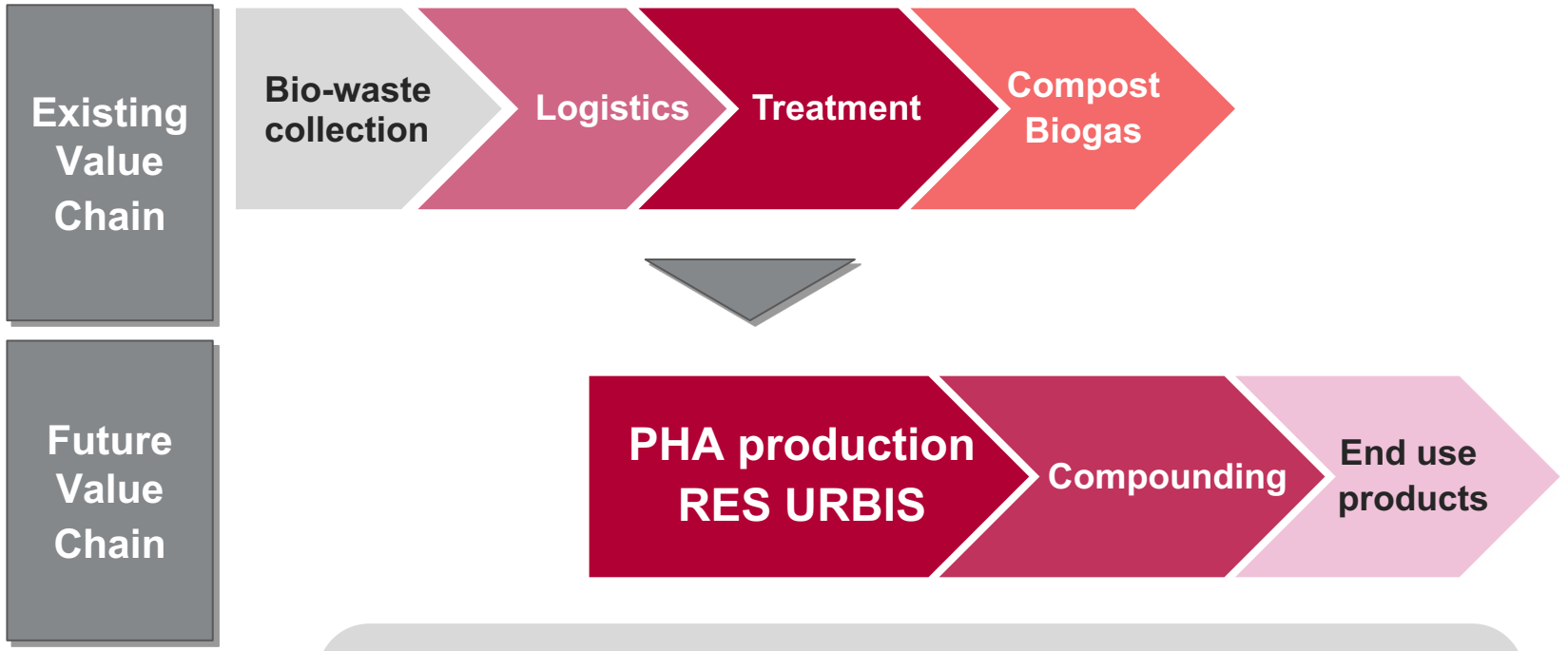
- Elemental composition of a new PHA derived from organic waste is reported.
- Feedstock type and production process affect the element levels of PHA.
- Migratability is evaluated using different solutions and conditions.
- Migratability increases under simulated acidic conditions and with heating.
- Possible use of PHA was evaluated by comparison with regulations and guidelines.

GRAPHICAL ABSTRACT



RES URBIS value chain innovation

A key question is where RES URBIS value chain is positioned and who are the potential investors interested in its scale up



RES URBIS technology provides for possible treatment for biowaste, complementary to composting and biogas production.
Both vertical integration in Municipal Waste Companies and non-integrated 3rd party service model are possible scenarios.

The products portfolio and perspectives of the market uptake

Application:

- **Interlayer film**, total market value € 2-3 billion (PHA used as pure component through electrospinning).
- **Adjacent adhesive market** (bio substitutes of polyether polyurethanes) market value approximately € 35 billion.
- **Packaging film** up to 25% of PHA content in the formulation; market value € 20 billion.
- **Durables**, e.g. flexible handles, interior furniture: up to 60% in the formulation, total market value € 1-2 billion (flexible handles realized).
- **Environmental remediation** total market value up to € 1 billion. This is a niche application in which PHA has shown good performances.

Overall the size of the accessible market is approximately **€ 60 billion**, large enough for **RES URBIS** to establish its product lines in the market.