ATHENS2017

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"An Urban Biowaste Biorefinery: the H2020 RES URBIS project"

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THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020

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

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

Grant Agreement 730349
3-year project, started January 1°, 2017
21 partners from 8 countries.
Estimated total cost: 3,377,915.00 €
EU Grant: up to 2,996,688.75 €

Is it worth to recover carbon from urban organic waste?

Municipal wastewater contains a lot of organic matter (COD)!
Around **100-120 gCOD/(inhabitant per day)**, mostly biodegradable.
Unfortunately, it is **strongly diluted** in around 250-350 L.
Nevertheless, a major portion is concentrated in **primary and excess sludge**.

The organic fraction of municipal solid waste (OF-MSW)
A comparable amount of COD (around 30-40% more) originates from the same urban area, mostly through source-sorted collection of the organic matter (OF-MSW).
Additional COD (although less easily biodegradable) is present in urban park/garden waste

Agro- and food-industry wastewater and waste
Concentrated biodegradable COD is also present in industrial wastewater/waste from agro-industries and food-processing industries, often in proximity to urban areas

- **Although all these streams have «similar» COD composition and originates from same area, they are separately handled (with a few exceptions!):**
  - ✓ different collection systems, different technologies, separate regulations
- **COD is seldom recovered, but for**
  - ✓ carbon stabilization as compost or sludge
  - ✓ energy recovery through bioconversion into biogas (either sludge or OF-MSW)
- **However, several limitations exist, such as**
  - ✓ stringent regulation for use as soil improvers, poor quality (depending on collection or treatment for OF-MSW or sludge, respectively), low (or no) economic value

CIRC-05-2016: Unlocking the potential of urban organic waste

Challenges from the Call which RES URBIS aims at answering to

Can different organic waste streams of urban origin combined into a common valorization chain?

Can bio-based products be obtained from organic waste of urban origin with a higher economic value than compost and/or biogas?

Can both targets be fullfilled togheter?

Can both targets be fulfilled by integrating emerging technologies with existing systems for waste/wastewater management, into a new technology chains?

RES URBIS Rationale: developing an urban bio-waste biorefinery

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

RES URBIS aims to combine treatment of most relevant **bio-waste of urban origin**, e.g source-sorted of urban solid waste (**OFMSW**) and the sludge from urban wastewater treatment plants (**WWS**), also including park/garden waste, and possibly residues from food-processing industry of suitable composition.

To develop an urban bio-waste biorefinery and related bio-based products

Integrated treatment of different bio-waste is functional to implement a novel **"urban biowaste biorefinery"** aimed to converting urban bio-waste into useful **bio-based products**, especially towards **higher value products than biogas and compost** (while not disregarding them at the end of the chain).
By using an integrated approach, the minimal operating capacity of the urban bio-waste biorefinery is expected to be achievable even in smaller waste collection areas.

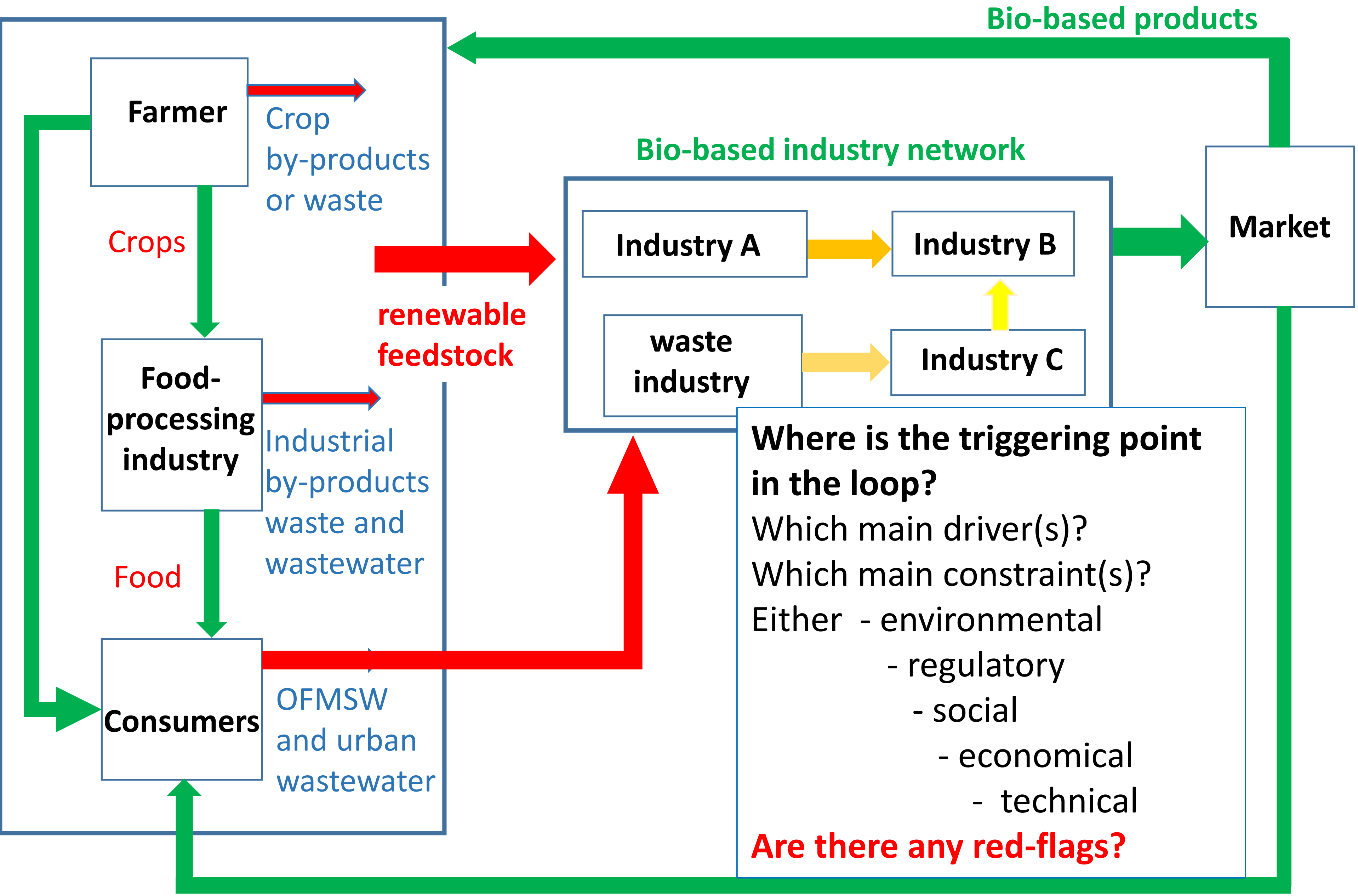
To take care of the whole technology chain and as function of territorial conditions

By converting urban biowaste into bio-products, **several industrial sectors have to be linked each other**, each one having its own business targets, needs and specifications.
Because driving forces and constraints highly depend on territorial conditions, affordable economic strategies have to be tailored with respect to autonomous **clusters**, e.g. where "waste basin" is large enough and recovery cycles are possibly closed within the cluster itself.

To take care of all other technical and non technical constraints

Regulatory (e.g. "end of waste"), environmental, and social constraints have to be also addressed, by also taking into account local, regional and national conditions

Bioeconomy, circular economy and the business network



URBAN BIO-WASTE

In RES URBIS approach, urban biowaste includes:

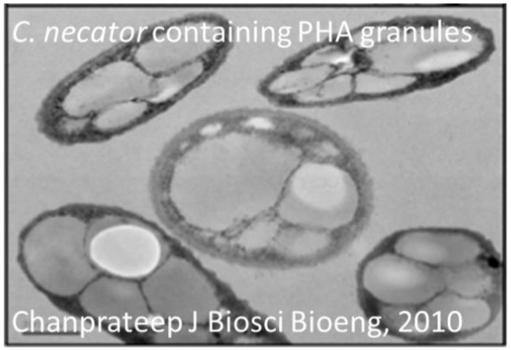
- the organic fraction from separate collection of municipal solid waste (**55 g TS/d from OFMSW**)
- **excess sludge from treatment of urban wastewater** (**39 g TS /d from WWS**), with possible further integration with wastewater treatment
- garden and parks waste
- waste from food-processing facilities (to be selected, based on similar composition)

This is coherent with proposal 2015/0275 (COD) for a Directive of the European Parliament and of The Council amending Directive 2008/98/EC on waste:
“4. "bio-waste" means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, comparable waste from food processing plants and other waste with similar biodegradability properties that is comparable in nature, composition and quantity;”

FROM URBAN BIOWASTE TO BIO-BASED PRODUCTS

The RES URBIS project is mostly focusing on

- **polyhydroxyalkanoate (PHA), a biodegradable natural biopolymer**
- related PHA-based bioplastics (e.g through blends)
- fibers (to be also used for PHA-based biocomposites).
- bio-based solvents (to be also used in PHA extraction)



Bio-based plastics and PHA

Feedstock	Synthesis	End of life	Examples
Oil	**Chemical**	Biodegradable	PCL, PBS,PBAT, PBTS
Renewable		Non biodegradable Easy to be recycled	PE, PP, PET....
Renewable		Biodegradable	PLA
Renewable	**Biological**	**Biodegradable**	**starch-based, PHA's**

2011 analysis: 3.5 Mton, 1.5% of an overall polymer production of 235 Mton.

2020 forecast: 12 Mton (3 times more), 3% of about 400 Mton

Market trends

Strongest development is foreseen for drop-in biopolymers, chemically identical to their petrochemical counterparts but at least partially derived from renewable feedstock (PET, PE and PP, e.g. bio-based on bioethanol).

However, PLA and PHA are also expected to at least quadruple the capacity between 2011 and 2020.

(http://www.bio- based.eu/market_study/).

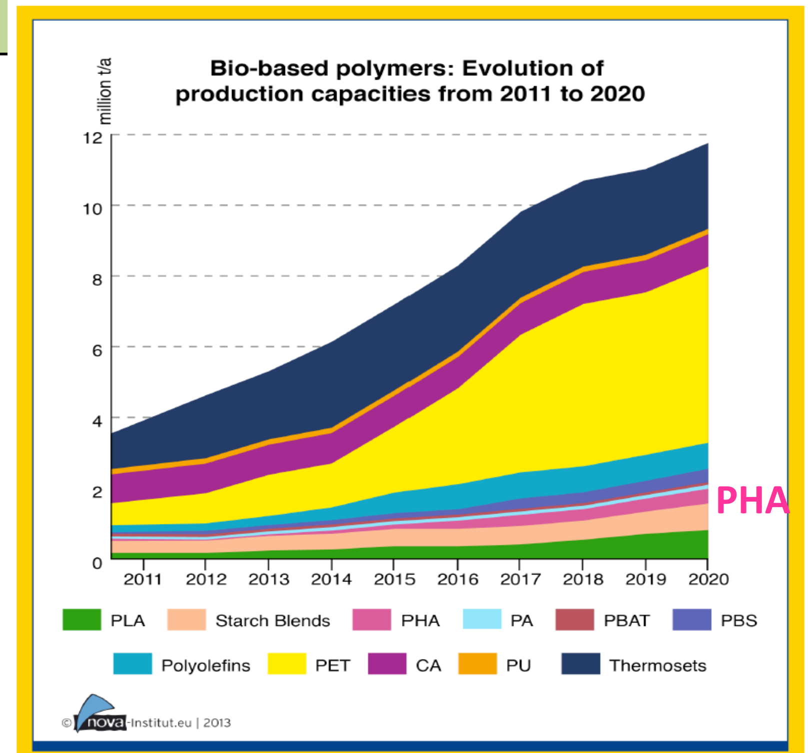
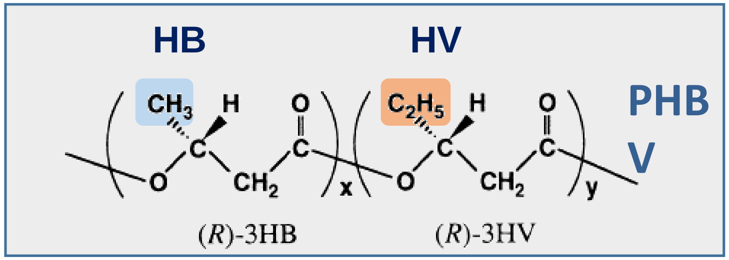


Figure 2: Bio-based polymers: Evolution of production capacities from 2011 to 2020

Why focusing on PHA?

Product related Pro’s

PHA is not a single polymer but a family of copolymers with a wide range of tunable properties,
so that, 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)
- Premium slow C release system for groundwater remediation

Production process Pro’s

- A novel PHA production process (**open microbial cultures instead of pure strains**), which can better cope with **large heterogeneity of the waste feedstock**,
- An upstream step, the **acidogenic fermentation**, which is both robust and tunable too.
- Overall, PHA production process is mostly **biological, under mild conditions and reliable**.
- Thus, the PHA-producing biowaste biorefinery is more sustainable, including an **easier integration with existing biological plants for waste and wastewater treatment**.
- Combining no-cost feedstock and novel processes, the cost of PHA can significantly decrease

Appealing: PHA is 3 times “Bio”
- Produced from renewable feestock (**but no food**)
- Produced through biological process (**but no OGM**)
- Easily and “truly” **biodegradable**

and it’s not recycled: it’s virgin material

Applications and economics

High market potential

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

Already under investigation at TRL 6

An old story: PHA is stored in activated sludge under dynamic conditions

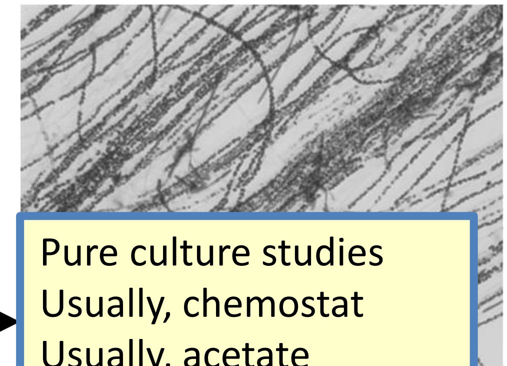
- Enhanced bio-P removal
- Bulking control

Late 80's

Time-changing conditions are imposed to the microbial consortium (non Monod-like growth)
-anaerobic/anoxic /aerobic cycles,
-and/or feast & famine

Physiological adaptation of each microbial species

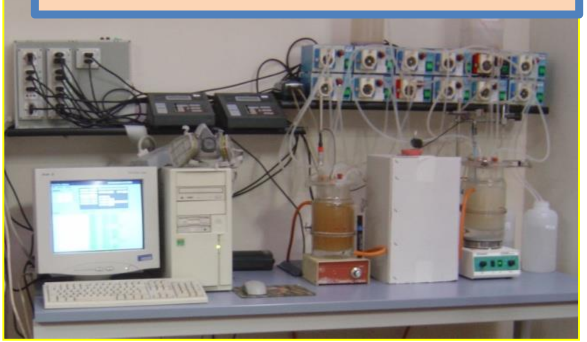
Early 90's



Pure culture studies
Usually, chemostat
Usually, acetate

Mid-90's

Mixed culture studies
Sequencing Batch Reactors
Acetate and other VFAs



Selection of species that are more adaptable to growth under changing conditions

Biomolecular tools, eg. FISH

Mid 00's

Mixed culture studies
Usually, batch reactors

Regulation towards triggering dynamic storage response

Moving to PHA production

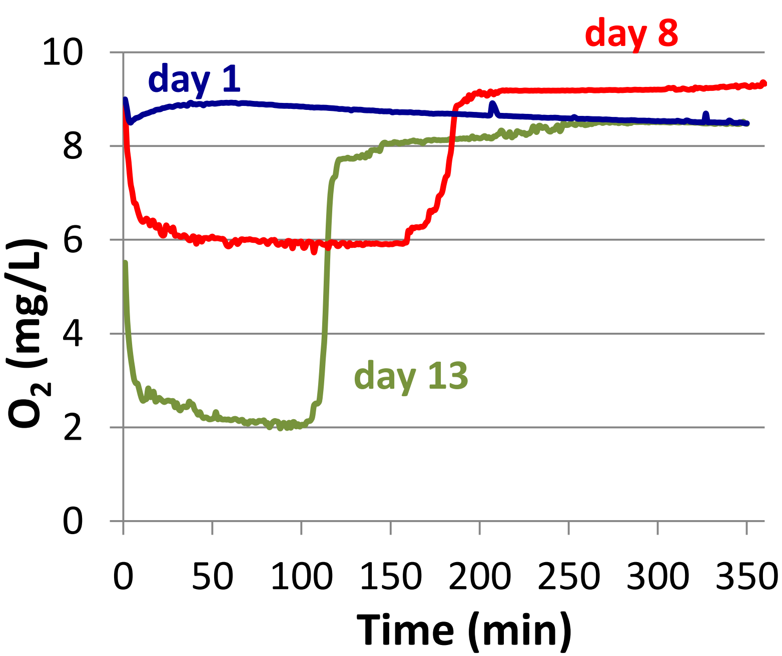
Early 00's

The key-role of the selection step

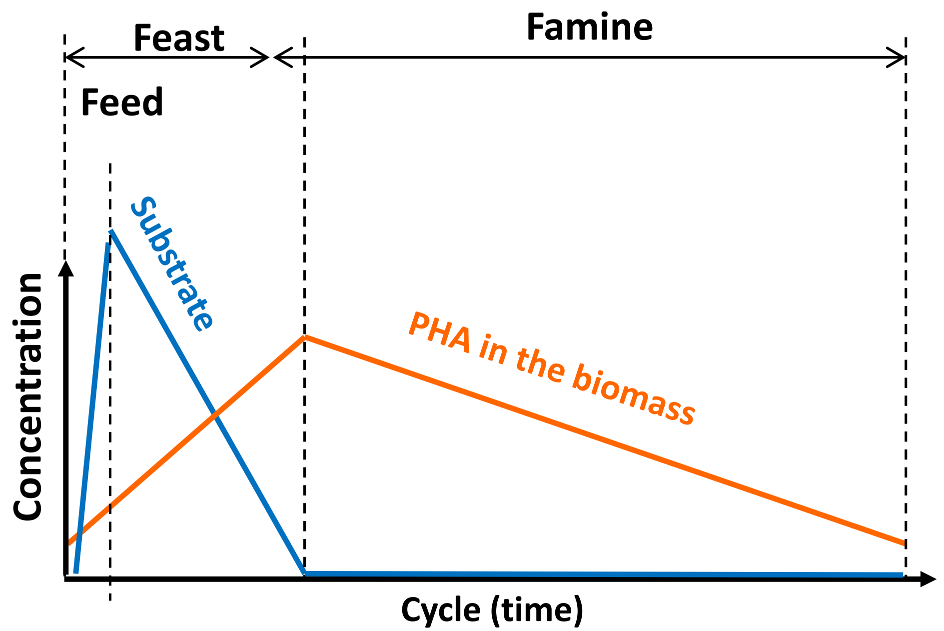
Selection of biomass with good storage properties

in order to obtain high storage performance in the accumulation step (rate, yield, PHA content)

Easy monitoring, online

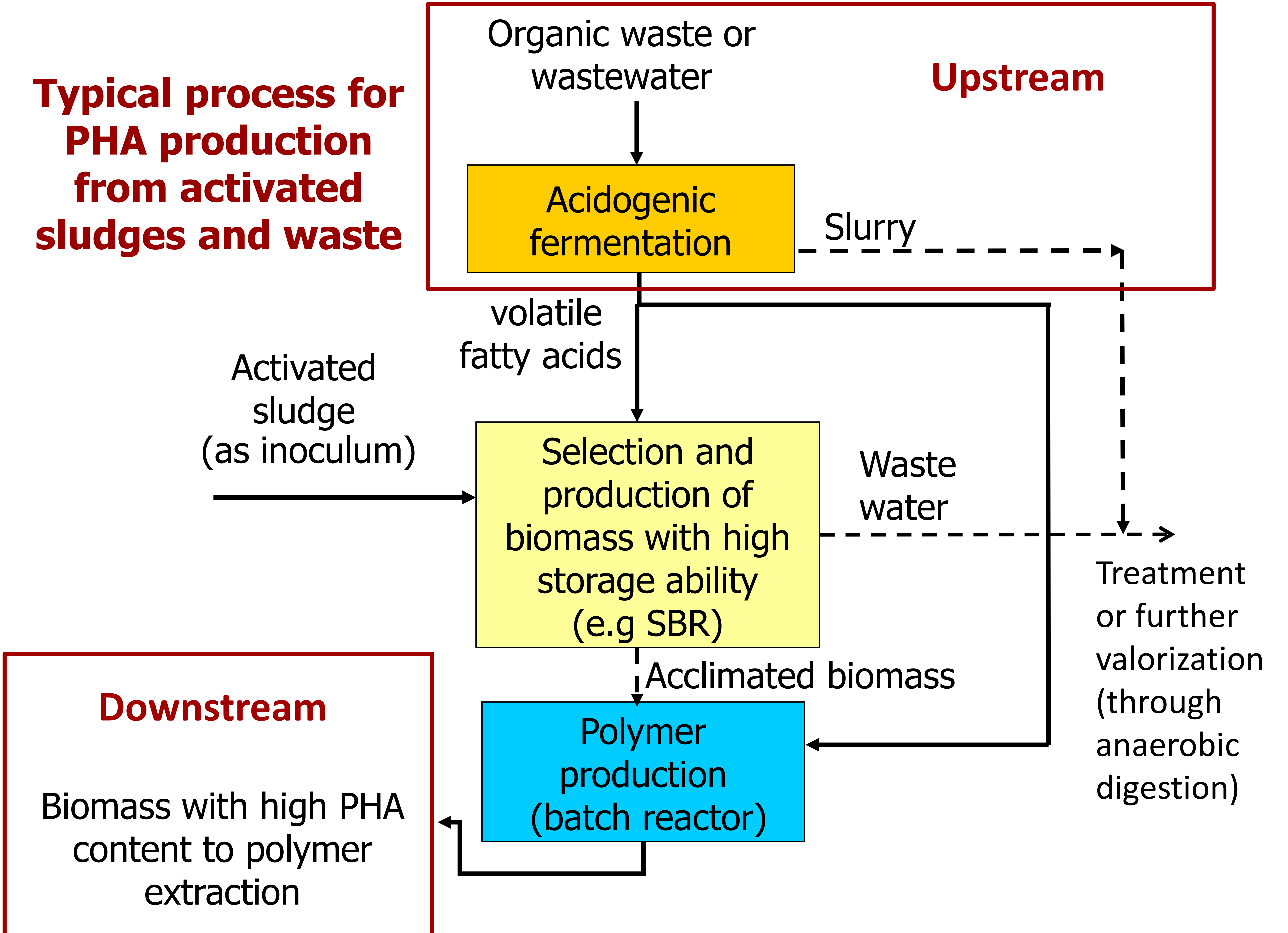


Periodic dynamic feeding in Sequencing Batch Reactor (SBR), in order to create feast-famine (F/F) conditions



- A low Feast/Famine ratio is the key-factor to trigger for PHA storing microorganisms
- Volatile fatty acids are best substrates

Typical process for PHA production from activated sludges and waste



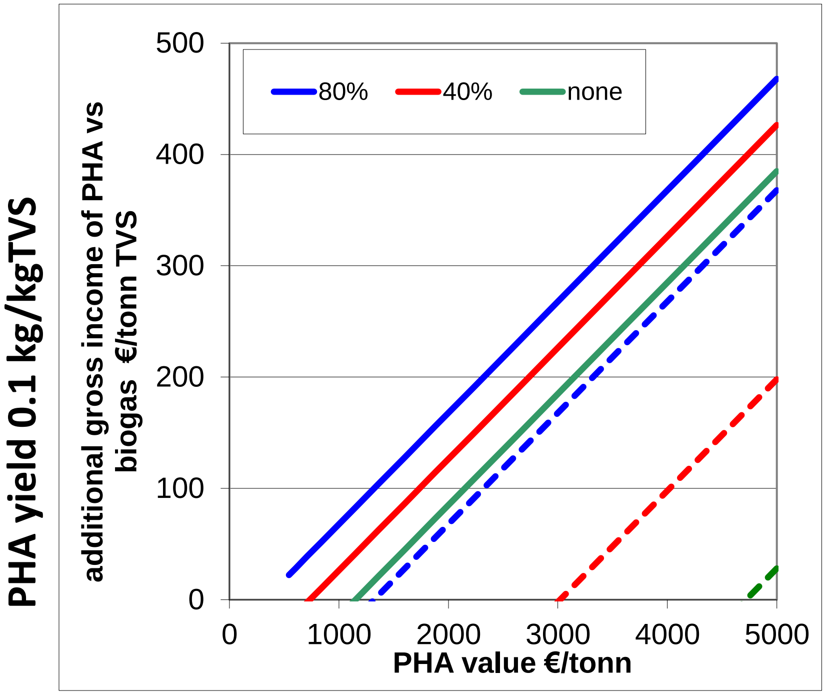
Preliminary analysis of a PHA-biogas integrated process

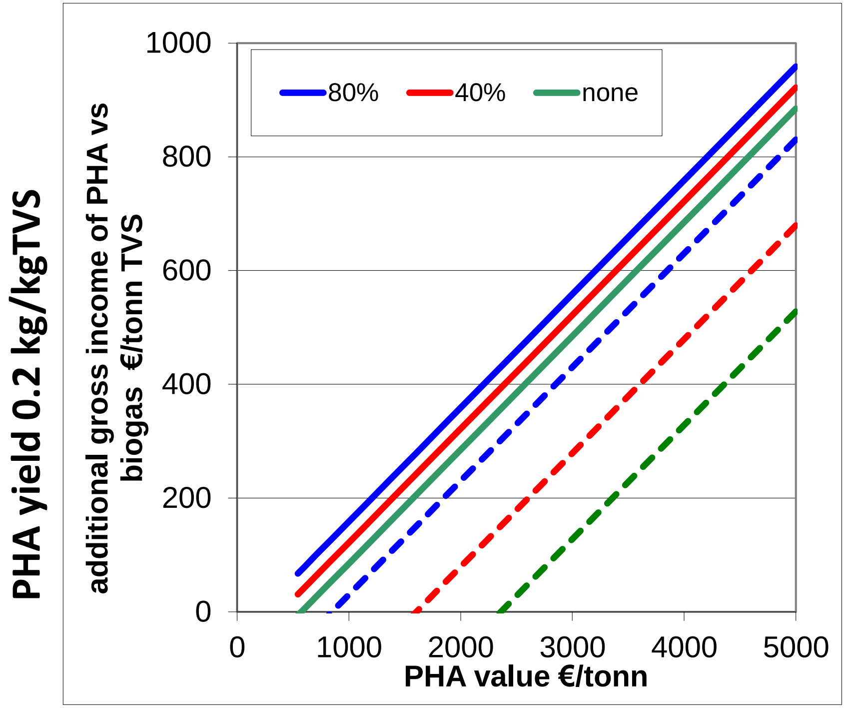
Alternative a)
Biogas only

- Biogas yield 0.75 m³/kgTVS; electric energy 2.56 kWh/m³
- EE value 60 €/MWh (no incentives) - continuous lines
  246/MWh (present italian incentives, **worst case**) - dotted lines

Alternative b)
PHA and biogas

- PHA yield 0.1 kg/kgTVS (**worst case**) or 0.2 (a better case);
- PHA value ranging between 500 and 5000 €/ton
- Either 0, 40, or 80 % of residual TVS are recovered into biogas



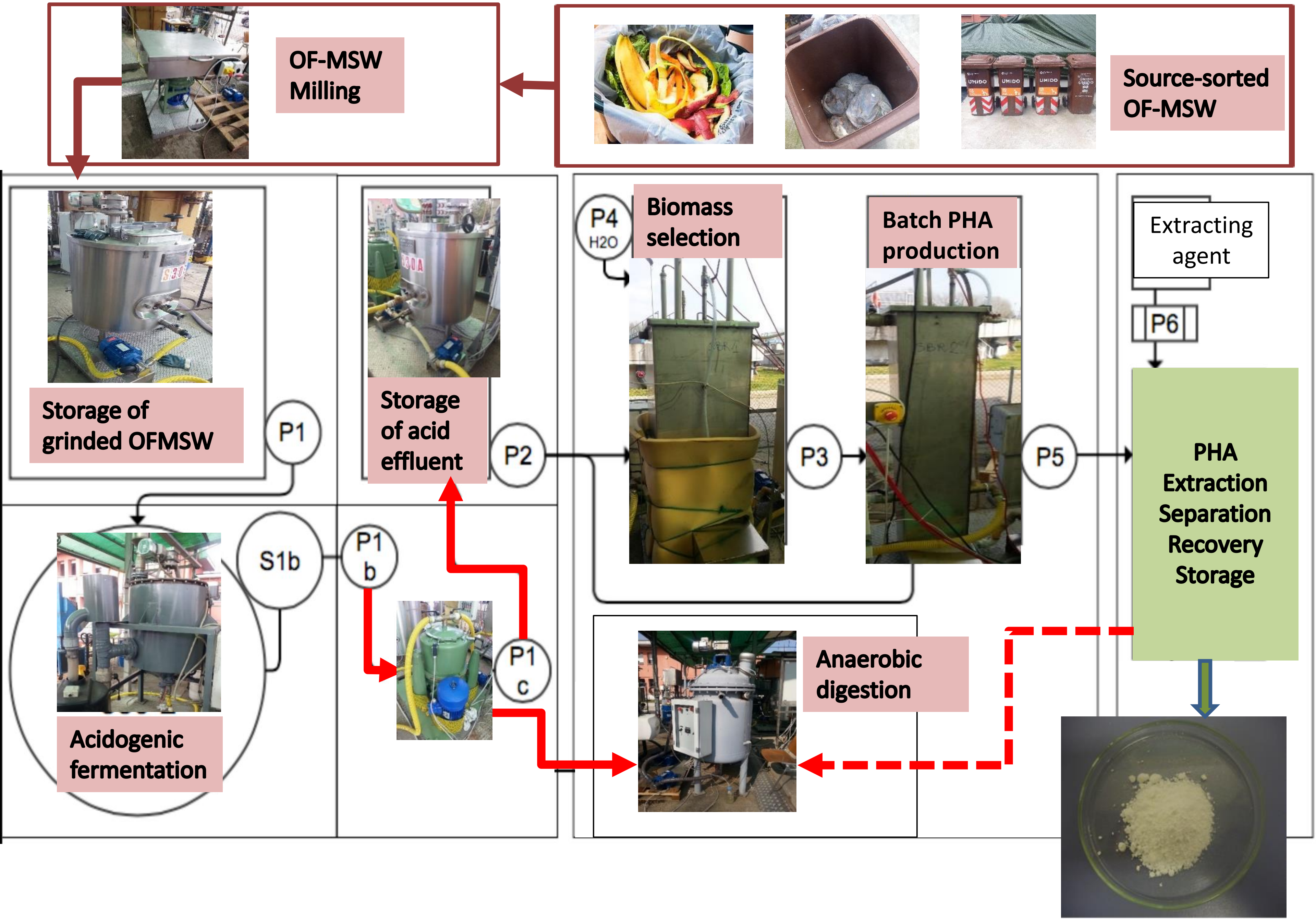


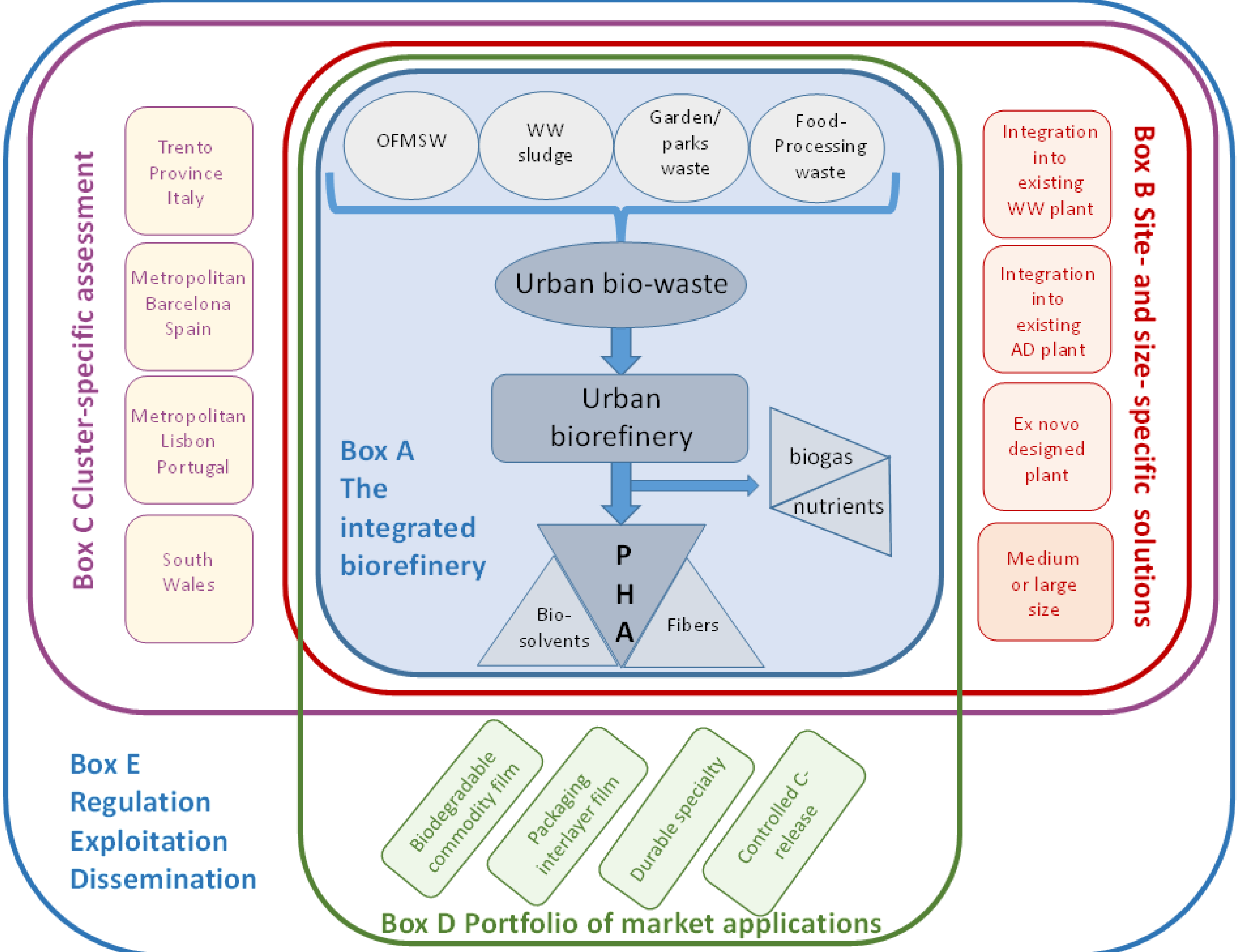
- In most conditions, PHA production offers an additional income with respect to biogas only (alternative b minus alternative a)
- The additional income can largely overcompensate the higher costs for PHA production with respect to biogas only (**pilot scale investigation is in progress**)

High TRL: pilot scale investigation is a key-feature of RES URBIS approach

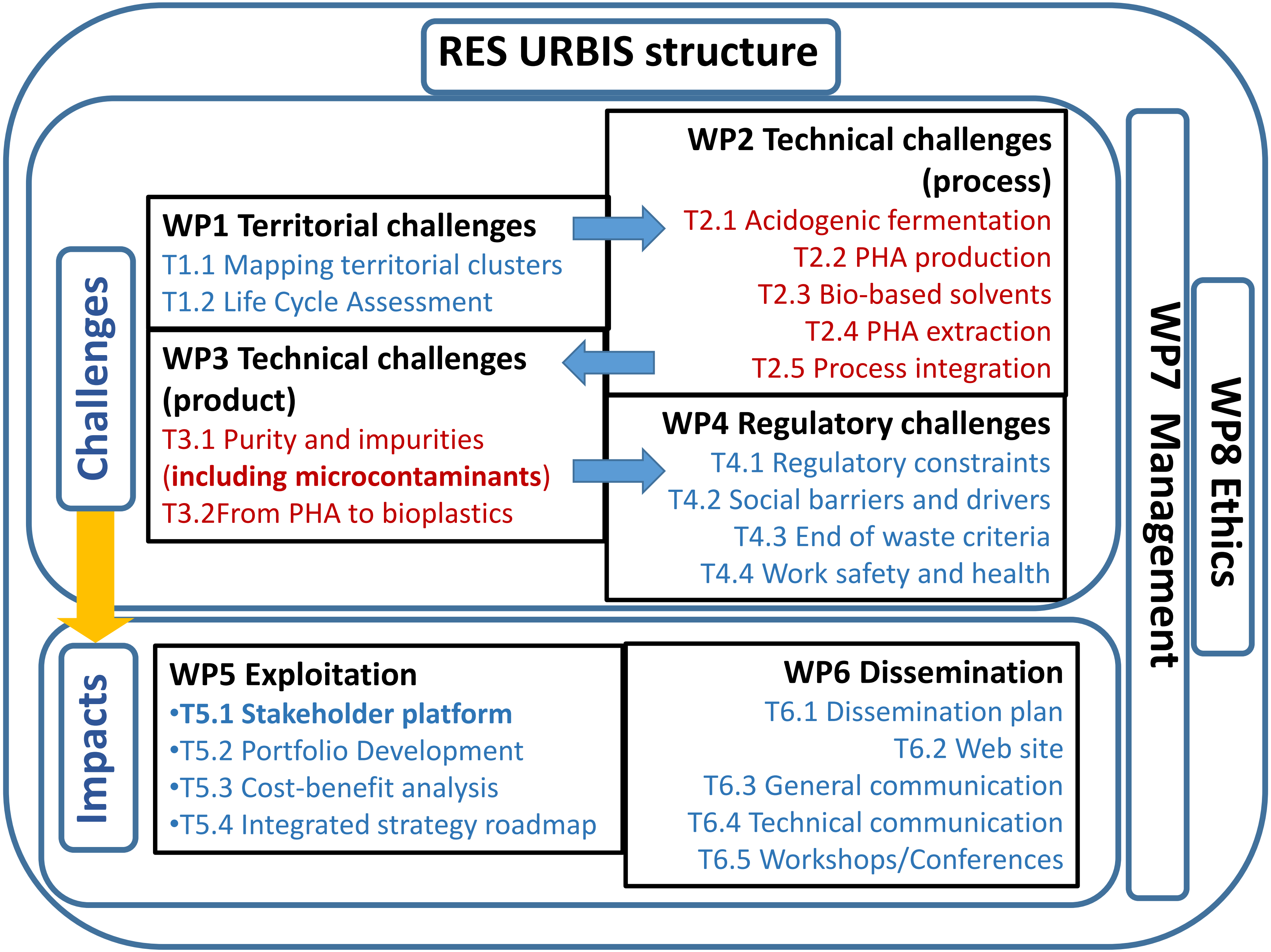
Pilot scale platform of Universities of Venice and Verona at the wastewater treatment plant of Treviso (Alto Trevigiano Servizi, ATS)

Joint PHA production pilot plant, With Rome University «Sapienza»


OF-MSW
Milling
Source-sorted
OF-MSW
UMIDO
Storage of
grinded OFMSW
P1
Storage
of acid
effluent
P2
P4
H2O
Biomass
selection
Batch PHA
production
P3
P5
Extracting
agent
P6
PHA
Extraction
Separation
Recovery
Storage
S1b
P1
b
P1
c
Acidogenic
fermentation
Anaerobic
digestion



The RES URBIS box-model



RES URBIS structure
WP1 Territorial challenges
T1.1 Mapping territorial clusters
T1.2 Life Cycle Assessment
WP2 Technical challenges (process)
T2.1 Acidogenic fermentation
T2.2 PHA production
T2.3 Bio-based solvents
T2.4 PHA extraction
T2.5 Process integration
WP3 Technical challenges (product)
T3.1 Purity and impurities (including microcontaminants)
T3.2From PHA to bioplastics
WP4 Regulatory challenges
T4.1 Regulatory constraints
T4.2 Social barriers and drivers
T4.3 End of waste criteria
T4.4 Work safety and health
Challenges
Impacts
WP5 Exploitation
•T5.1 Stakeholder platform
•T5.2 Portfolio Development
•T5.3 Cost-benefit analysis
•T5.4 Integrated strategy roadmap
WP6 Dissemination
T6.1 Dissemination plan
T6.2 Web site
T6.3 General communication
T6.4 Technical communication
T6.5 Workshops/Conferences
WP7 Management
WP8 Ethics

Exploring micropollutant migration and/or abatement in novel waste-to-product technologies is a "hot spot" for or full exploitation of circular economy principles.

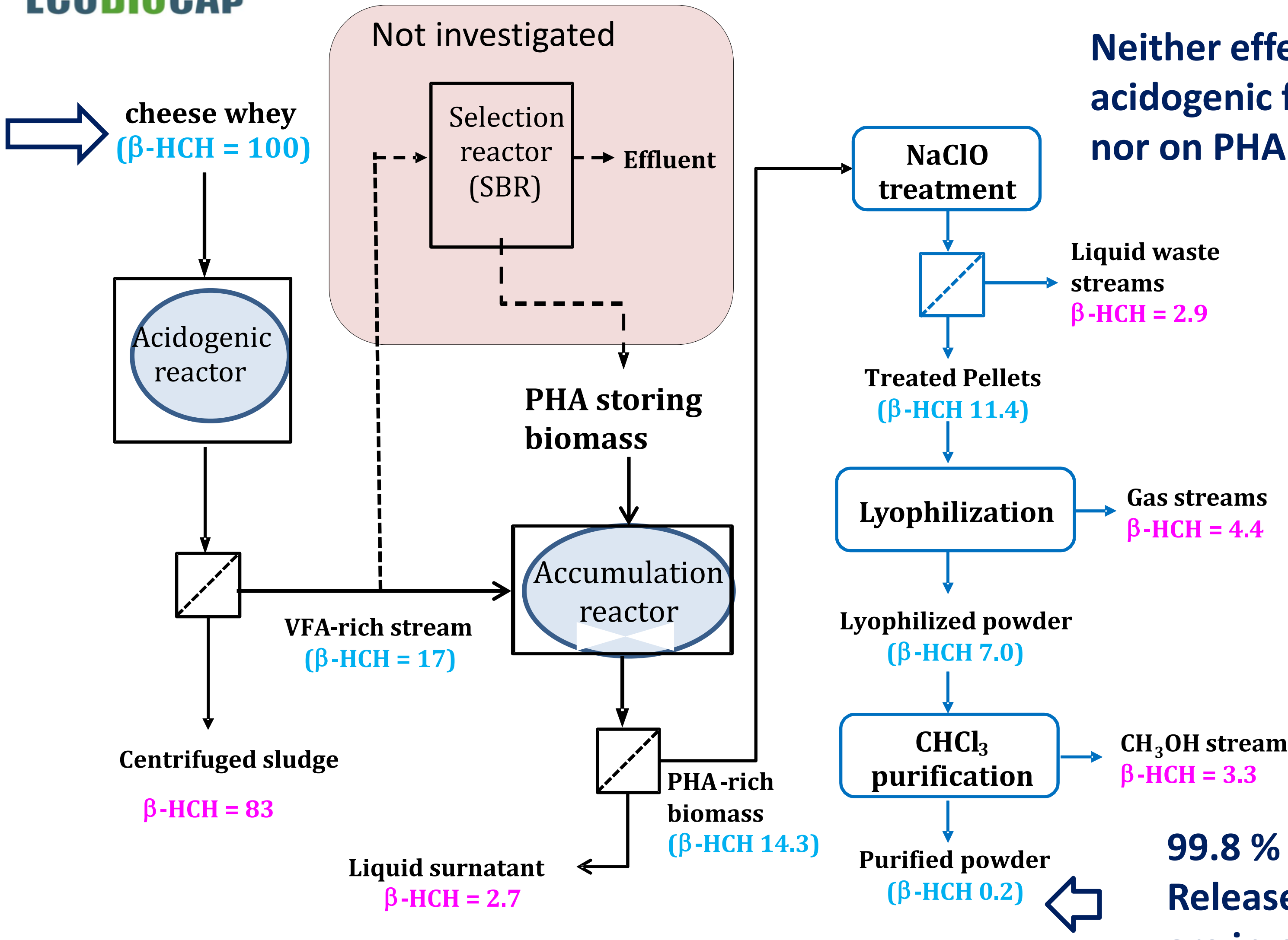
- When reusing or recovering waste, the environmental spreading of pollutants is a matter of scientific debate and a controversy at regulatory and social level
- Even the agronomic reuse of **compost, sludge and/or anaerobic digestate** as soil improvers is subjected to severe limitations by environmental regulation but also social concern
- But, **emerging technology chains** to obtain **novel products** are completely changing this scenario and require to reconsider contaminant migration in a different way than in waste "recycling" (i.e. not only based on selected origin and no-mixing principle)
- Hence, strong research effort has to be dedicated to
    1. describe migration/transformation/abatement of relevant contaminants along novel and different technology chains.
    2. monitor possible presence of contaminants in bio-based products **with specific reference to their final use**.
    3. based on novel knowledge, to refine "end of waste" criteria in order to ensure protection of public health while not hindering exploitation of novel technology chains "ab initio".
    4. Based on novel knowledge, eventually update the European regulatory frame
    5. disseminate such a novel knowledge to verify social acceptance and eventually promote public procurement.

By solving open issues about contaminant migration from waste into end products, their market exploitation would be enormously facilitated and public health and environment protection would be warranted

Can contaminant migrate from bio-waste to bio-based products?

Just one example: main steps of the PHA production from cheese whey were investigated in the presence of a pesticide (HexaChloroCycloExane, HCH)

ECOBIOCAP



Neither effect on acidogenic fermentation nor on PHA accumulation

99.8 % removal
Release tests from PHA are in progress

Valentino et al., 2015

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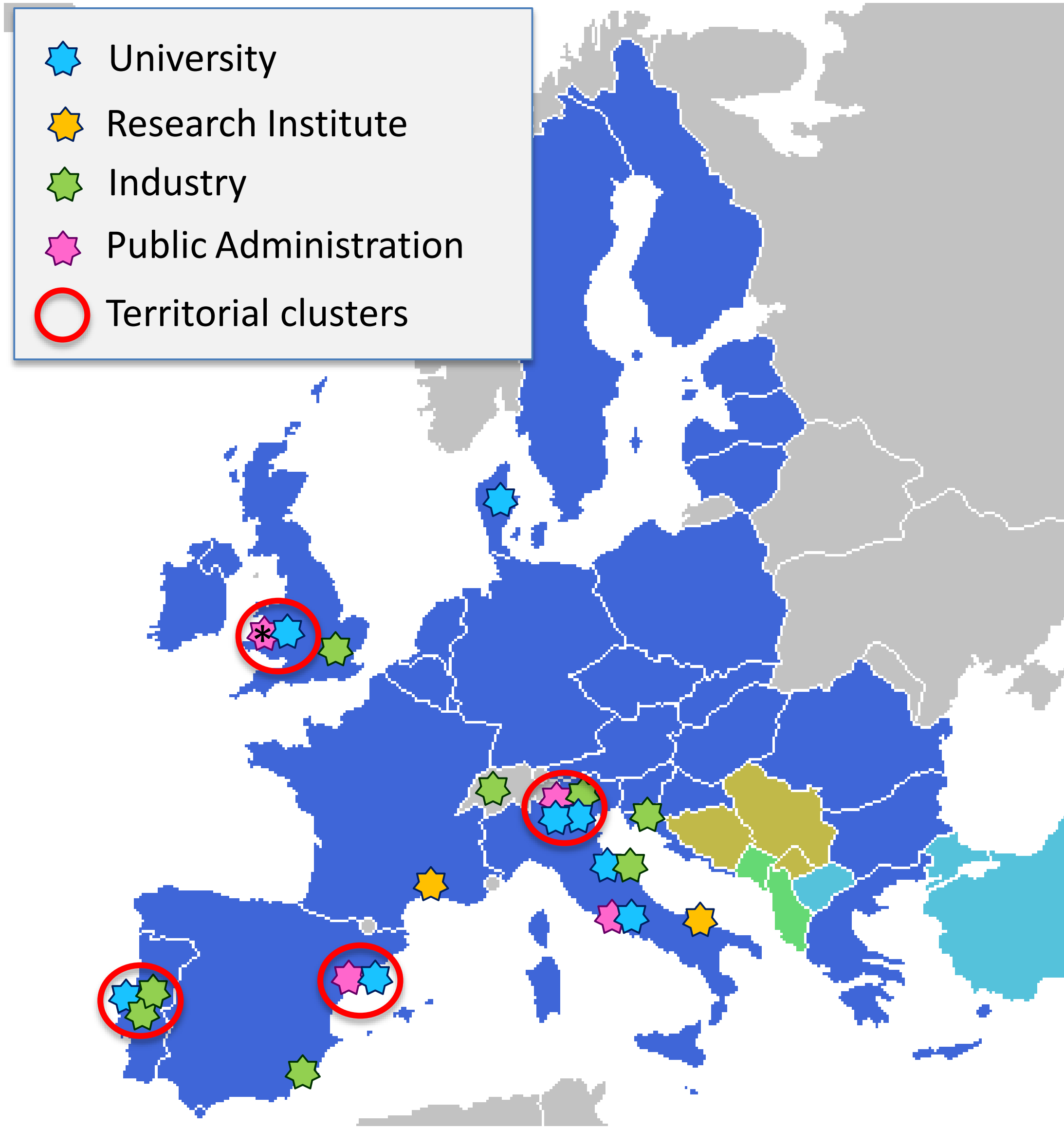
RES URBIS consortium



*** stakeholder**

Process-related challenges
University of Roma “La Sapienza” (Italy)
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)
Physis (Italy)
CNR – IRSA(Italy)
Inst. Nat. Recherche Agronomique (France)
Product-related challenges
BioInicia (Spain)
Mi-Plast (Croatia)
Softer/Sabio (Italy)
Territorial clustering
Empresa das Águas Livres (Portugal)
Barcelona Metropolitan Area (Spain)
Province Autonoma di Trento(Italy)
Rhondda Cynon Taff County Council (UK) *
Economics and exploitation
Inno-EXC (Switzerland)
Bio-Based and Biodegradable Industries Association (UK)
Regulation, safety, environmental and social aspects
Technical University of Denmark (Denmark)
National Institute for work safety (Italy)
University of Verona (Italy)

An additional high-value «partner»: the Stakeholder Platform

Stakeholder	Type	Activity
Rhondda Cynon Taff County Council (RCT)	Public Authority	Collection and management of municipal waste in Rhondda Cynon Taf (Wales)
AMA Roma	Company	Collection and management of municipal waste in Rome, Italy
Ecoparc del Mediterrani SA	Company	Collection and management of municipal waste in Barcelona, Spain
MWE - Municipal Waste Europe	Platform	The European association representing municipalities responsible for waste management and their publicly owned waste management companies
Waste and Resources Action Programme (WRAP)	Charity	Helping individuals, businesses and local authorities to reduce waste, recycle and use recycled content material
WssTP - European Technology Platform for Water	Platform	Water Supply and Sanitation Technology Platform, for research and development aimed at providing safe, clean and affordable water services while protecting nature.
Euraqua - European Network of Freshwater Research Organisations.	Research Association	The aim of EurAqua is to give significant input on the development of the scientific and economic basis of European water management.
ASOBIOCOMP	Association	Spanish association of bioplastic industries.
ASSOBIOPLASTICHE	Association	Italian association of bioplastic industries.
more coming soon……..	…………	…………………

Is it worthwhile to put all this effort together?

Let's go to estimate potential impacts

Based on a preliminary mass balance of the new technology chain, an **OFMSW collection area of about 3,000,000 inhabitants** might guarantee the throughput of ~ **8 Kton PHA/year**.

Co-treatment with other urban biowaste (excess sludge, markets and park/garden waste) from the same area can increase the production capacity to ~ **20 kton PHA/year**.

This PHA production capacity would result into revenues of **~ 80 million EUR per year**, margins of **~** 40% and the creation of **~** 100 new jobs for the cluster.

Under assumption of co-treatment, sustainable operative margins can be achieved even at smaller size, e.g from **500.000 inhabitants**. This is the smallest cluster being considered in the RES URBIS (Province of Trento).

According to population distribution in Europe (BBSR 2011), there are **115 Metropolitan Areas** which have more than **500.000 inhabitants** each and an average size of 3 million.

Thus, **~ 343 million people live in metropolitan areas** that have a suitable size to exploit the RES URBIS approach, which means a potential of producing **2,2 million ton PHA per year** (excluding food-processing waste), 8.8 billion € and **~** 10 000 new green jobs in Europe.

This PHA production is ~ 10 times more than present PHA production capacity worldwide but still less than 10% of present consumption of oil-based plastics in Europe.

Thanks for your attention

For more information on RES URBIS project:

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