AFTERLIFE

Deliverable reference number and title:

D8.5 – Stakeholder workshop

Due date of deliverable: 31/10/2020

Actual submission date: 30/10/2020

Lead beneficiary: NOVA

nova-Institut GmbH

Industriestr.300, Huerth, Germany

www.nova-institut.eu

Responsible Author

Seena Koyadan	NOVA	seena.koyadan@nova-institut.de	+492233481479

Additional Authors

Maria Lopez	IDENER	maria.lopez@idener.es	+34954460278

Type			**Dissemination Level**		
R	Document, report	☐	**PU**	Public	☒
DEM	Demonstrator, pilot, prototype	☐	**CO**	Confidential, only for members of the consortium (including the Commission Services)	☐
DEC	Websites, patent fillings, videos, etc.	☐			
OTHER		☐			

AFTERLIFE has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No. 745737.

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Executive summary

Deliverable D8.5 describes the stakeholder workshop organised within the AFTERLIFE project. In order to ensure knowledge transfer towards the target groups, such as industrial partners and research institutions, the stakeholder workshop was coordinated by nova. Due to the current Covid19 situation, it was only possible to conduct the workshop online. The workshop was held online on 9th October 2020. The document provides the results of the stakeholder workshop. The project partners gave talks about the project results and engaged with attendees from industries worldwide.

1 Introduction

Deliverable 8.5 describes the stakeholder workshop organized with in the AFTERLIFE project. WP8 aims to promote the project and its results through various dissemination and communication channels. In this context, a stakeholder workshop was planned at the month 36 of the project. It was originally planned to organize by linking a bigger event such as Bio-Based Material conference in Cologne, Germany May 2020, but Covid19 has affected this event and the consortium decided to organize the workshop digitally.

2 Stakeholder workshop

Organization

The stakeholder workshop was coordinated by NOVA with the inputs from IDENER and the consortium. The workshop was organized online. NOVA and IDENER created the programme and NOVA implemented a registration page for the workshop (https://afterlife-project.eu/stakeholder/). The registration page includes, introduction, programme, registration and general information. The registration was designed few months ago prior to the workshop in order to communicate the event to the public.

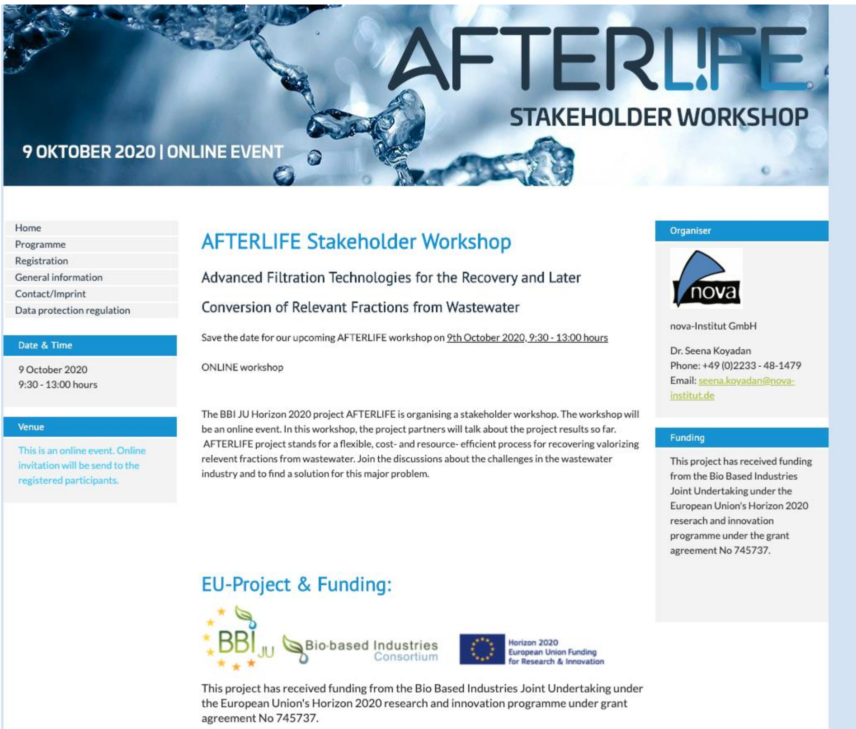


Figure 1: Workshop information and registration page

A teaser flyer for social media was created by NOVA and shared by the project partners through their networks including via Twitter and LinkedIn. The event was advertised to the EFIB 2020 attendees, more widely through the EFIB network, also through the NOVA and EuropaBio newsletters.

Figure 2: Newsletters and social media posts for the workshop

AFTERLIFE project information and registration page of the workshop was disseminated through the EFIB website (https://efibforum.com/afterlife/) to attract more attendees from their network.

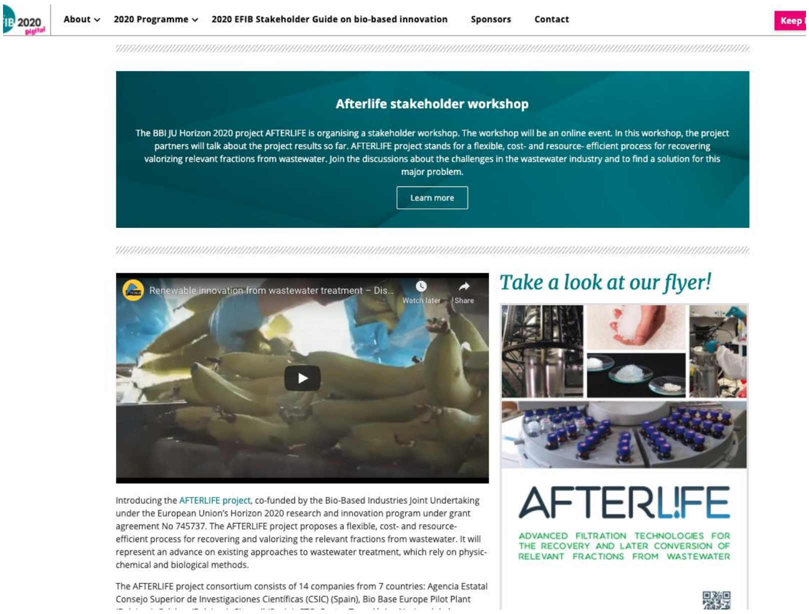


Figure 3: AFTERLIFE campaign page at EFIB

Online workshop platform

The workshop was conducted in an online webinar platform, zoom webinar, provided by NOVA. This webinar platform allows an easy access to the live session. The live link was sent to the participants prior to the workshop. The participants were allowed to ask questions and discuss with the speakers.

3 Programme

The programme was divided into three parts: Session 1- Invited talks, Session 2- Wastewater as a source of value compounds and Session 3- End products from food processing wastewater. In session 1, external speakers Prof. MSc. Jan Ravenstijn (GO!PHA) and Dr. Thomas Haas (Evonik) provided some contexts for the project. In Session 1 and Session 2, five members of the consortium presented the project results with Q&A session. A detailed programme is shown in figure. The horizon 2020 project Water2REturn project also joined in the session and gave a talk.

09:30	Introduction	
09:45	Session 1: Invited talks	
	Prof. MSc. Jan Ravenstijn (GO!PHA)	Versatile End-of-Life options for AFTERLIFE products
	Dr. Thomas Haas Evonik, Germany)	'The Rheticus Project'
10:45	Session 2: Wastewater as source of value compounds	
	Dr. Maria Lopez (Idener, Spain)	Use of circular bioeconomy approaches for the valorization of food processing residual streams.
	Dr. Antti Gronroos (VTT, Finland)	Membrane technology in valuables and water recovery from wastewaters of food industry
11:25	Break	
11:30	Session 3: End products from food processing wastewater	
	Dr. Oliver Drzyzga (CIB-CSIC, Spain)	PHA production from industrial waste streams as part of Sustainable Plastics production towards a circular plastics economy
	Dr. Nicola Frison (Innoven, Italy)	Production of bio-based Volatile Fatty Acids from organic waste as chemical building blocks
	Dr. Javier Ceras (Lurederra, Spain)	Sustainable extraction of amino acids from agro-industrial wastewater streams
	M.Sc. Maria Limongelli (ENCO S.r.l, Belgium)	Water2REturn project
12:40	Feedback and discussion / Wrap-up	
13:15	Workshop end	

Figure 4: Workshop programme

4 Results

The audience of the AFTERLIFE stakeholder workshop were an international public. 40 attendees registered from 14 countries. Most of the participants originated from the industry and academic research. The workshop provided an opportunity to disseminate projects results and discussions between partners and stakeholders. The discussions between the invited speaker, PHA expert, Jan Revenstijin and project partners gave fruitful insight of the PHA industry.

All the PowerPoint presentations from the workshop are available at the project website (https://afterlife-project.eu/workshop/) and were send to all registered attendees. Copies of the presentations are included as Appendix 1 to this report.

5 Conclusions

The AFTERLIFE stakeholder workshop was planned and delivered on time (provided Covid 19 situation) with in the project. The stakeholder workshop was successful in regard to attracting relevant attendees. The workshop was helpful for the consortium in terms of building the industry networks and to get feedback for the other tasks such socio-economic analysis.

6 Appendix 1: Presentations from the workshop

1. Versatile End-of-Life options for AFTERLIFE products_Ravenstijn (GO!PHA)
2. 'The Rheticus Project'_Thomas Haas (Evonik)
3. Advanced Filtration Technologies for the Recovery and Later conversion of relevant Fractions from wastewater_Maria Lopez (Idener)
4. Membrane technology in valuables and water recovery from wastewaters of food industry_Antti Gronroos (VTT)
5. PHA production from industrial waste streams as part of Sustainable Plastics production towards a circular plastics economy_ Oliver Drzyzga (CIB-CSIC, Spain)
6. Production of bio-based Volatile Fatty Acids from organic waste as chemical building blocks_ Nicola Frison (Innoven)
7. Sustainable extraction of amino acids from agro-industrial wastewater streams_ Javier Ceras (Lurederra)

The Rheticus Project

AFTERLIFE
Stakeholder Workshop
09.10.2020

Evonik Operations GmbH,
Dr. Thomas Haas

EVONIK
Leading Beyond Chemistry

Technical photosynthesis involving CO_2 electrolysis and fermentation

Thomas Haas, Ralf Krause, Rainer Weber, Martin Demler & Guenter Schmid

Nature Catalysis **1**, 32–39 (2018)
doi:10.1038/s41929-017-0005-1
Download Citation

Biocatalysis Electrocatalysis
Photocatalysis

Received: 05 May 2017
Accepted: 23 October 2017
Published online: 08 January 2018

https://www.nature.com/articles/s41929-017-0005-1

In addition Nature has published a video „learning from leaves“ based on the article:

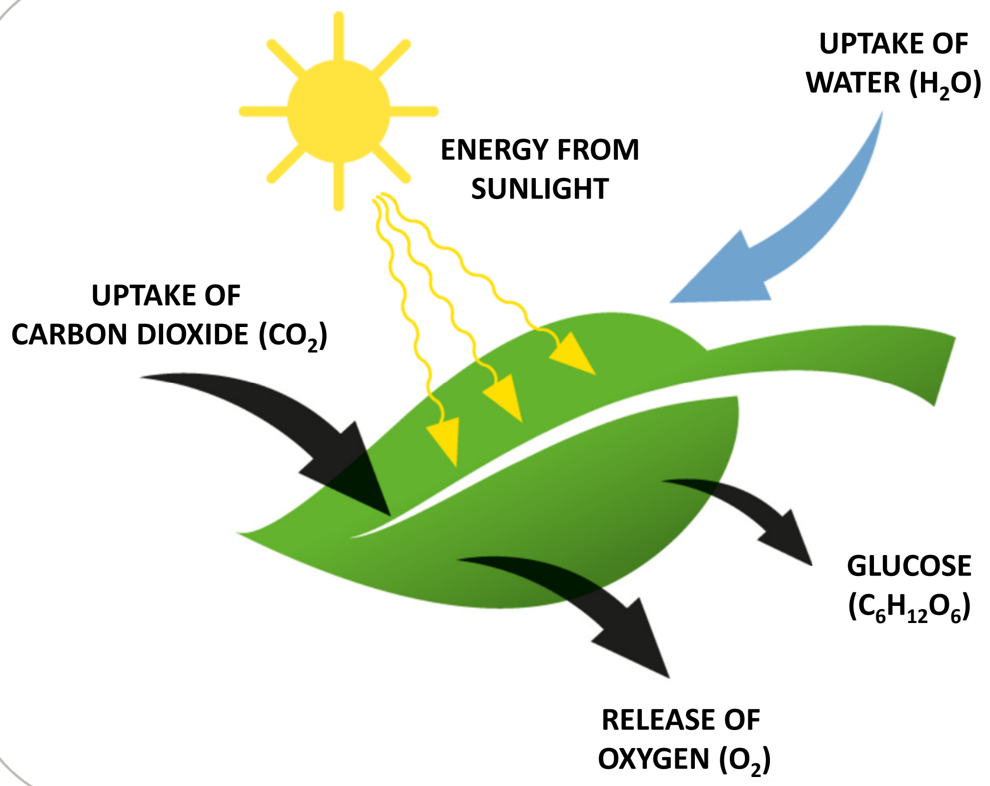
https://www.youtube.com/watch?v=VK-dULEK-rc

Leading Beyond Chemistry

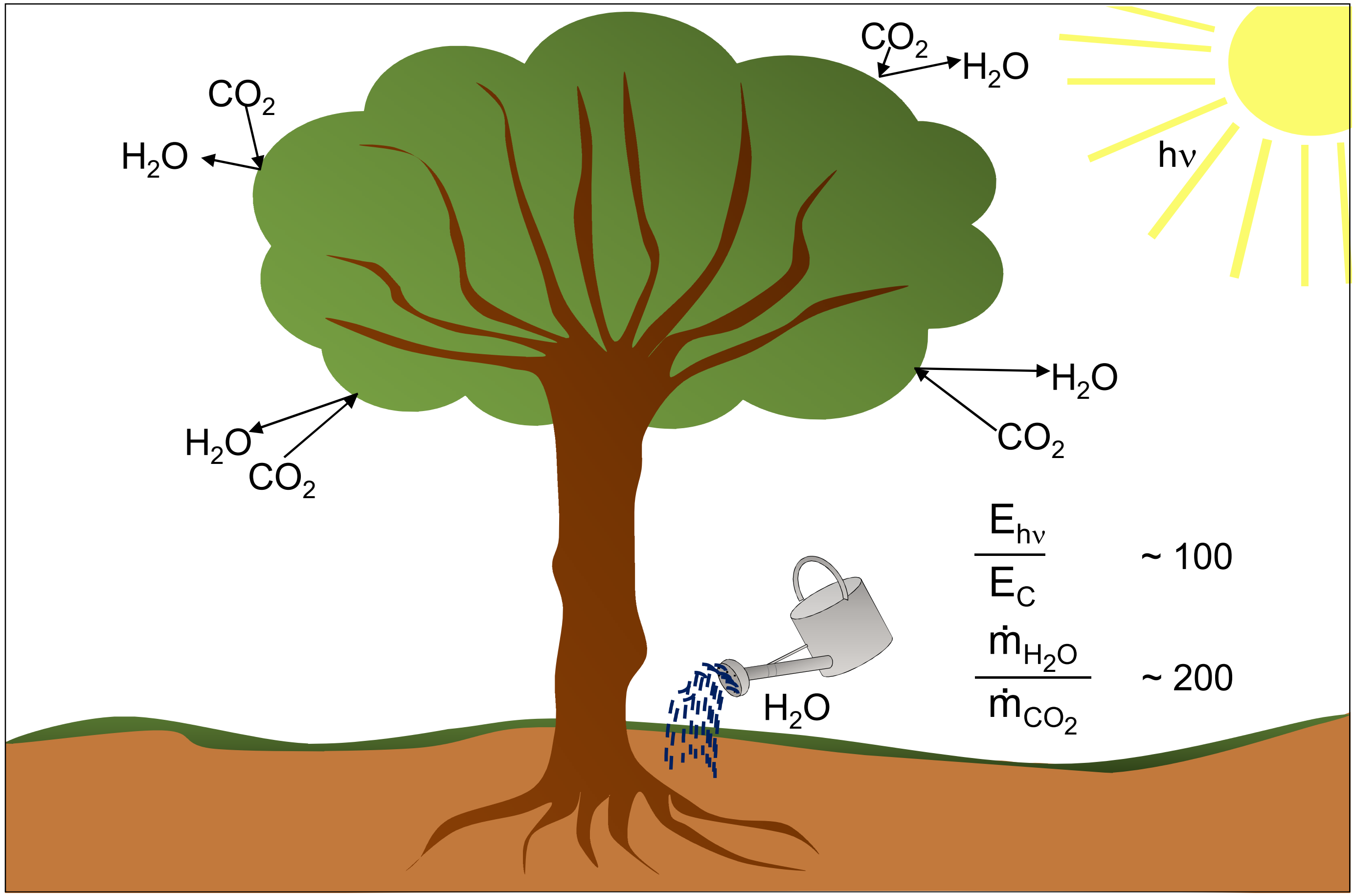
Photosynthesis – converts sunlight, water and CO_2 into organic compounds

Light/light energy is absorbed – „harvested“ (e.g. by Chlorophyll) and converted in chemical energy

Usage of the chemical energy together with CO_2 and water to build up energy rich, organic compounds (e.g. sugar, fatty acids etc.)



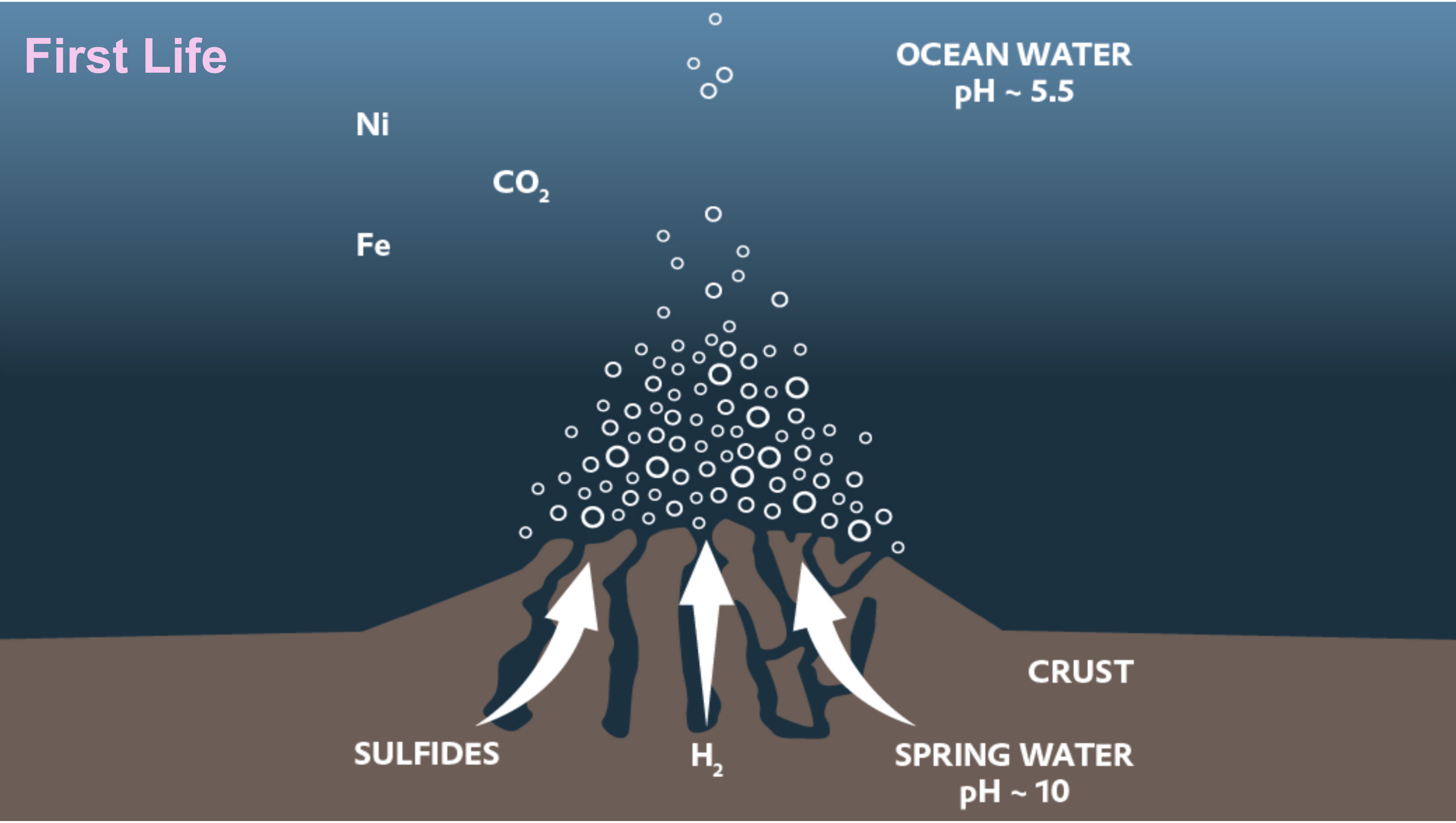
Photosynthesis – efficiencies and utilizations



Photosynthesis indicators

Artificial	Carbon Efficiency %	Energy Efficiency %	Water Utilization kg_{H_2O} / kg_{CO_2}
Natural	99.999	1	200
Sugar Cane	> 95	< 1	> 200
Artificial	> 95	>> 1	<< 100

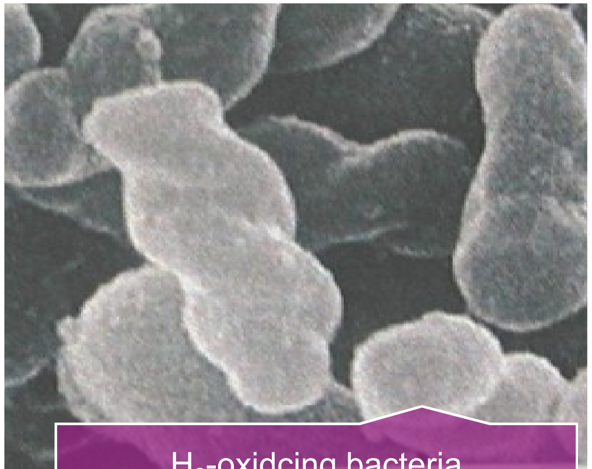
First Life



OCEAN WATER
pH ~ 5.5
Ni
CO2
Fe
CRUST
SULFIDES
H2
SPRING WATER
pH ~ 10

Nature provides gas consuming bacteria species

Methanotrophic bacteria
organisms that are able to use methane as sole carbon and energy source

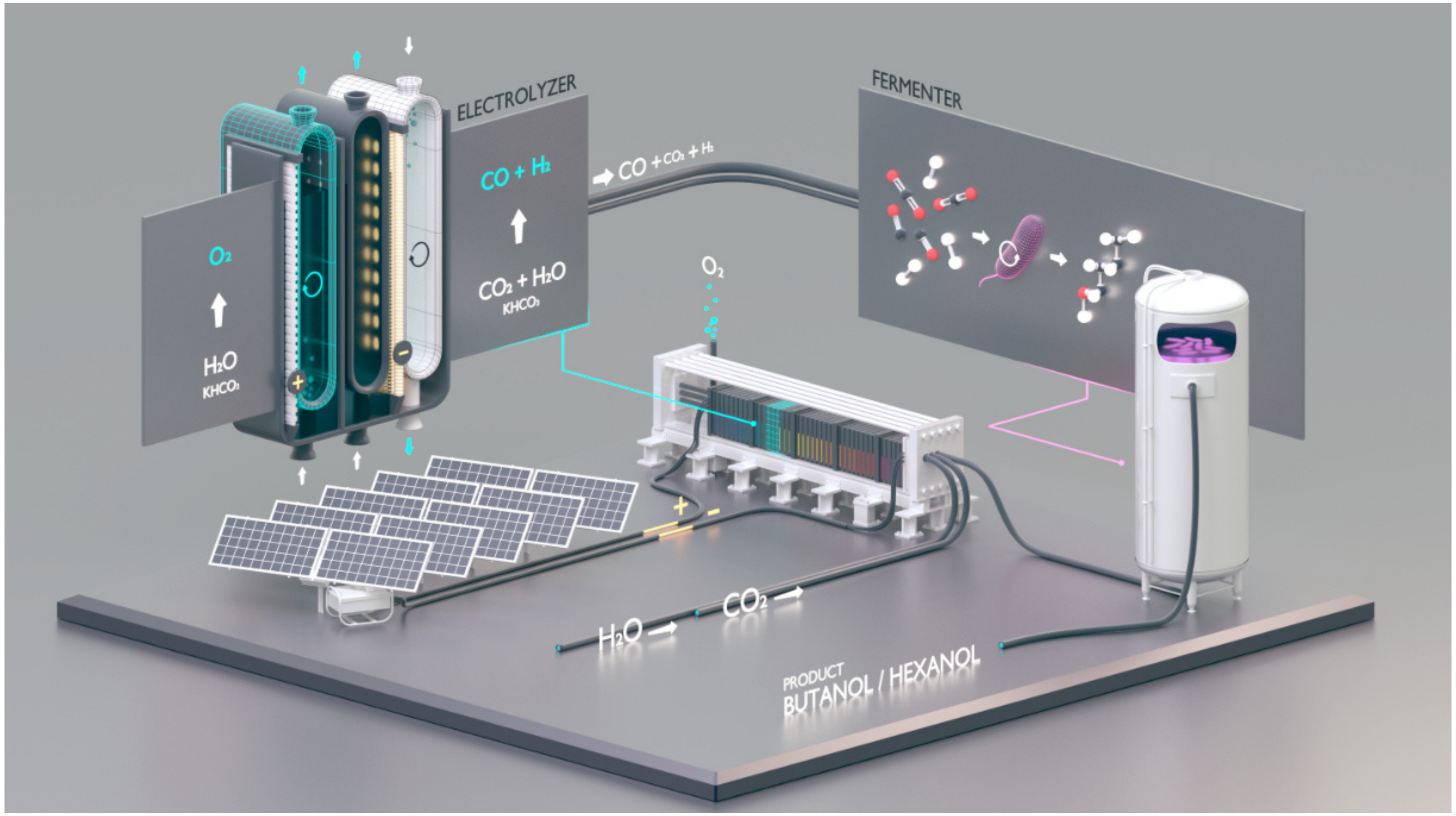


H_2-oxidcing bacteria
Assimilate $CO_2/H_2/O_2$ via Calvin-Cycle to carbonhydrates

acetogenic bacteria
convert $CO/CO_2/H_2$ to acetate

Source:
www.mpg.de/7427999/zoom.jpg
https://upload.wikimedia.org/wikipedia/commons/b/b2/Methylococcus_capsulatus.png
http://blogs.scientificamerican.com/media/inline/blog/Image/Clostridium-ljungdahlii.jpg

RHETICUS – an overview



Objectives

- Joint research project to convert carbon dioxide (CO_2) into specialty chemicals (like butanol and hexanol) using electricity from renewable sources and bacteria
- Pilot plant scheduled to start up 2020 at the Evonik facility in Marl, Germany
- Production plant with a capacity of up to 20,000 tons a year as possible target capacity

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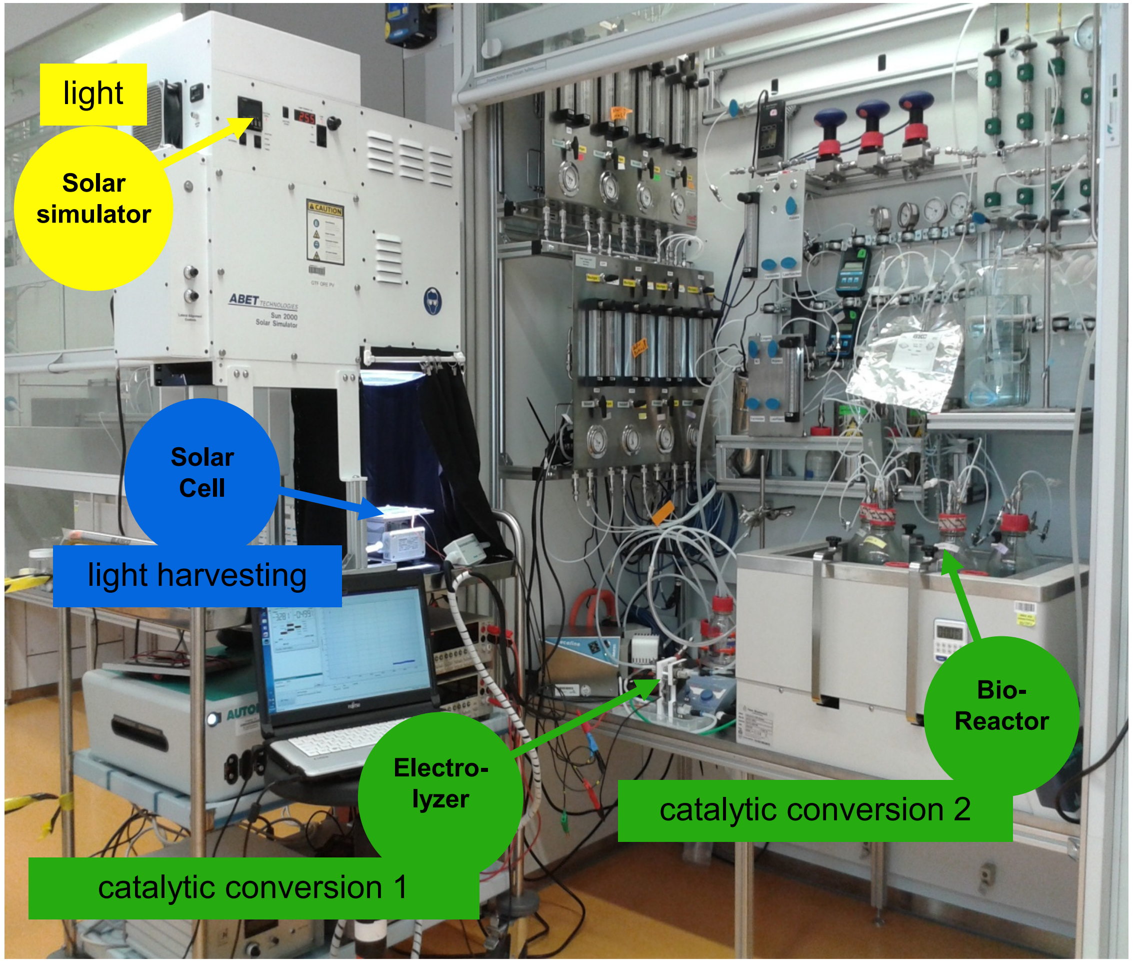
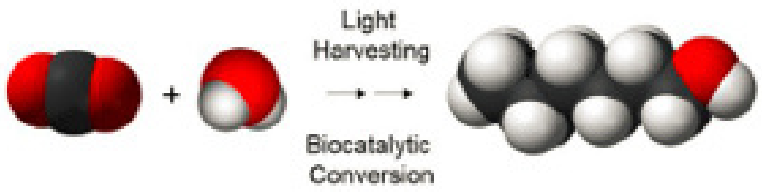
SIEMENS energy

EVONIK Leading Beyond Chemistry

Experimental set up



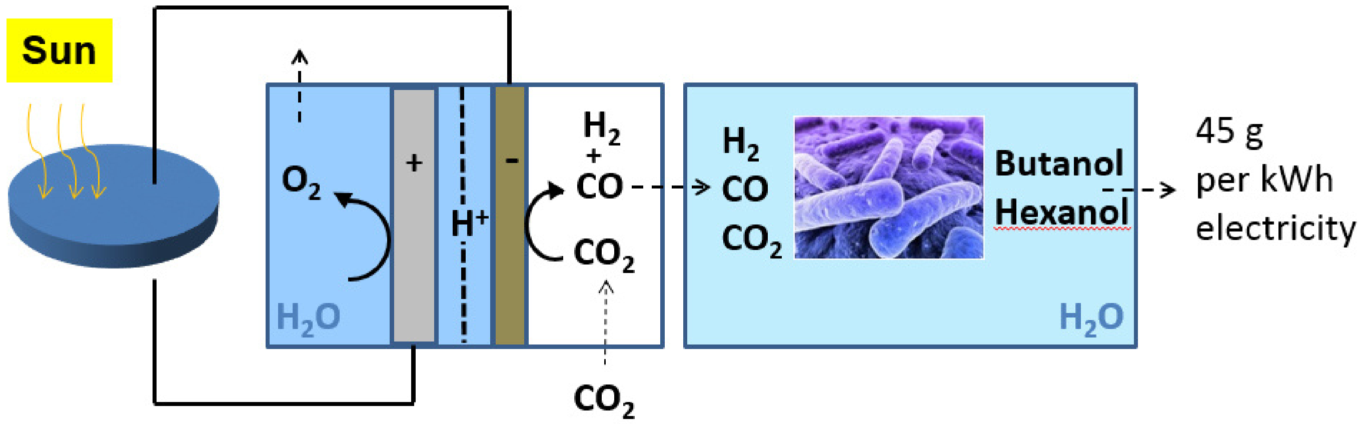


EVONIK Leading Beyond Chemistry

Experimental results

Artificial	Carbon Efficiency %	Energy Efficiency %	Water Utilization kg_{H_2O} / kg_{CO_2}
Natural	99.999	1	200
Sugar Cane	> 95	< 1	> 200
Artificial	> 95	> 5	< 50

Example: Butanol and Hexanol



PV cells	CO_2- and H_2O electrolyzer	Fermenters *Clostridium autoethanogenum* + *Clostridium kluyveri*
EE up to 20%	EE-CO up to 47%	
	EE-H_2 up to 70%	EE near 80%
	FE-CO + FE-H_2 near 100%	FE near 100%

Prize of 1 kWh PV electricity
= 2.5 cent

Prize per 45 g alcohols
= 5.4 cent

Main Cost Drivers

$$\text{Price} = f\left(\begin{matrix}\text{electricity}\\\text{price}\end{matrix}, \begin{matrix}CO_2\\\text{price}\end{matrix}\right)$$

Summary

- Artificial photosynthesis approaches present needs for

  CO_2 based synthesis of chemicals

  concepts to combat climate change

- Combined electrochemistry and biotechnology is a promising new modular concept of artificial photosynthesis

- Thank you!

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EVONIK

Leading Beyond Chemistry

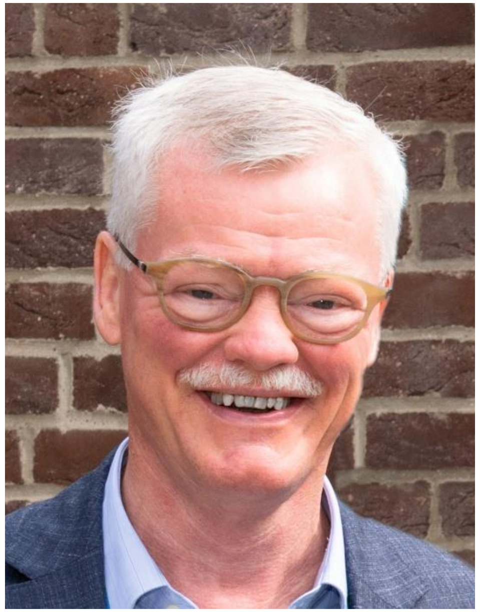
GO!PHA

Global Organization for PHA

Versatile End-of-Life options for AFTERLIFE products

9 October 2020

Introduction: Jan Ravenstijn



Experience:

- 22 years Dow Chemical
- 11 years DSM
- 27 years R&D
- 3 years Manufacturing
- 15 years global R&D director executive positions in engineering plastics, epoxies and elastomers' businesses
- 3 years USA, 4 years Germany, the rest in the Netherlands
- 3 years New Business Development → Biopolymers platform at DSM
- Contact details: Phone: +31.6.2247.8593 E-mail: j.ravenstijn@kpnmail.nl or jan.ravenstijn@gopha.org

Current & recent activities since 2008

- Visiting professor Biopolymers at Eindhoven, Tsinghua and Dublin universities
- Consultant to international (EU, US, Asian, Japan) biopolymer companies and bio-refineries
- Consultant to investment and consulting companies, SMEs and OEMs
- Completed an extensive global bioplastics review paper (January 2010)
- Co-author of a bioplastics book for SMEs (Q1 2011)
- Member of the global expert team on renewable materials of the nova Institute
- Co-author of global market studies of the nova Institute (2013, 2015, 2017, 2018, 2019, 2020)
- Member Scientific Advisory Board Aachen-Maastricht Institute for Bio-Materials (AMIBM)
- Co-organizer of the PHA-platform World Congresses
- Co-founder and Board member of the Global Organization for the PHA-platform

TOPICS

1. What is PHA?
2. Status of the PHA-platform
3. Applications
4. End-of-Life in a circular economy
5. Closing remarks

1. What is PHA? (1)

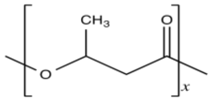
- ✓ **PHA stands for Poly-Hydroxy-Alkanoate.**
- ✓ **Theoretically there can be an infinite number of PHAs.**
- ✓ **Claiming properties for or behaviour of PHA is a non-sense exercise. Even the well known PLA also belongs to the PHA class of materials.**
- ✓ **Specific PHA-polymers, like PHB and a number of its copolymers (like PHBV, PHBH, etc.) are not “plastics”, but are natural materials that are made and found in nature, like cellulose or starch.**
- ✓ **These natural macromolecular materials are not made by polymerization, but by enzymatically controlled biochemical conversion and they all have a role to play in nature.**

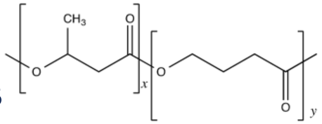
1. What is PHA? (2)

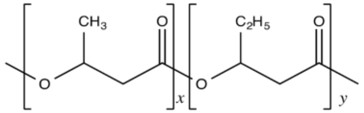
- ✓ **Of course not all natural materials biodegrade in every environment. Wood doesn't biodegrade in a marine environment, since the lignin in wood needs fungi to biodegrade and those are not present in sea water.**
- ✓ **PHB and its copolymers found in nature are part of the metabolism in all living organisms (plants, animals and humans) ever since there are living organisms on earth.**
- ✓ **Those specific PHA-materials function as nutritious and energy storage materials, so they are supposed to be used for that purpose. One can call that "biodegradation", but one could also call that "feed for living organisms in every environment".**
- ✓ **So the industrialization of the PHA-platform materials we talk about, consists of PHB and its copolymers PHBV, PHBH, PHBO, PHBD and P3HB4HB. The molecular structure of these are the same as what we find in nature.**
- ✓ **Details of these bio-benign materials, what they look like and how they perform will be covered in the next slides.**

1. The industrial PHA product platform is very diverse…

✓ scl-PHAs → P3HB, P4HB, PHBV, P3HB4HB, PHB3HV4HV.

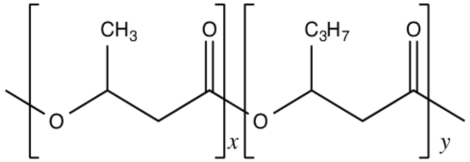
P3HB 

P3HB4HB 

PHBV 

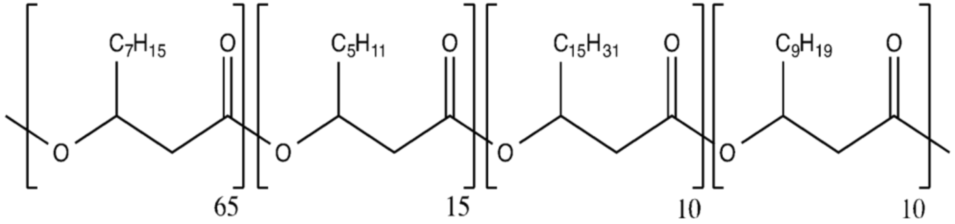
✓ mcl-PHAs → PHBH, PHBO, PHBD.

scl:	short chain length
mcl:	medium chain length
lcl:	long chain length

PHBH 

✓ lcl-PHAs → Many varieties possible.

In addition PHAs have been designed with aromatic or C=C groups in the side chain.



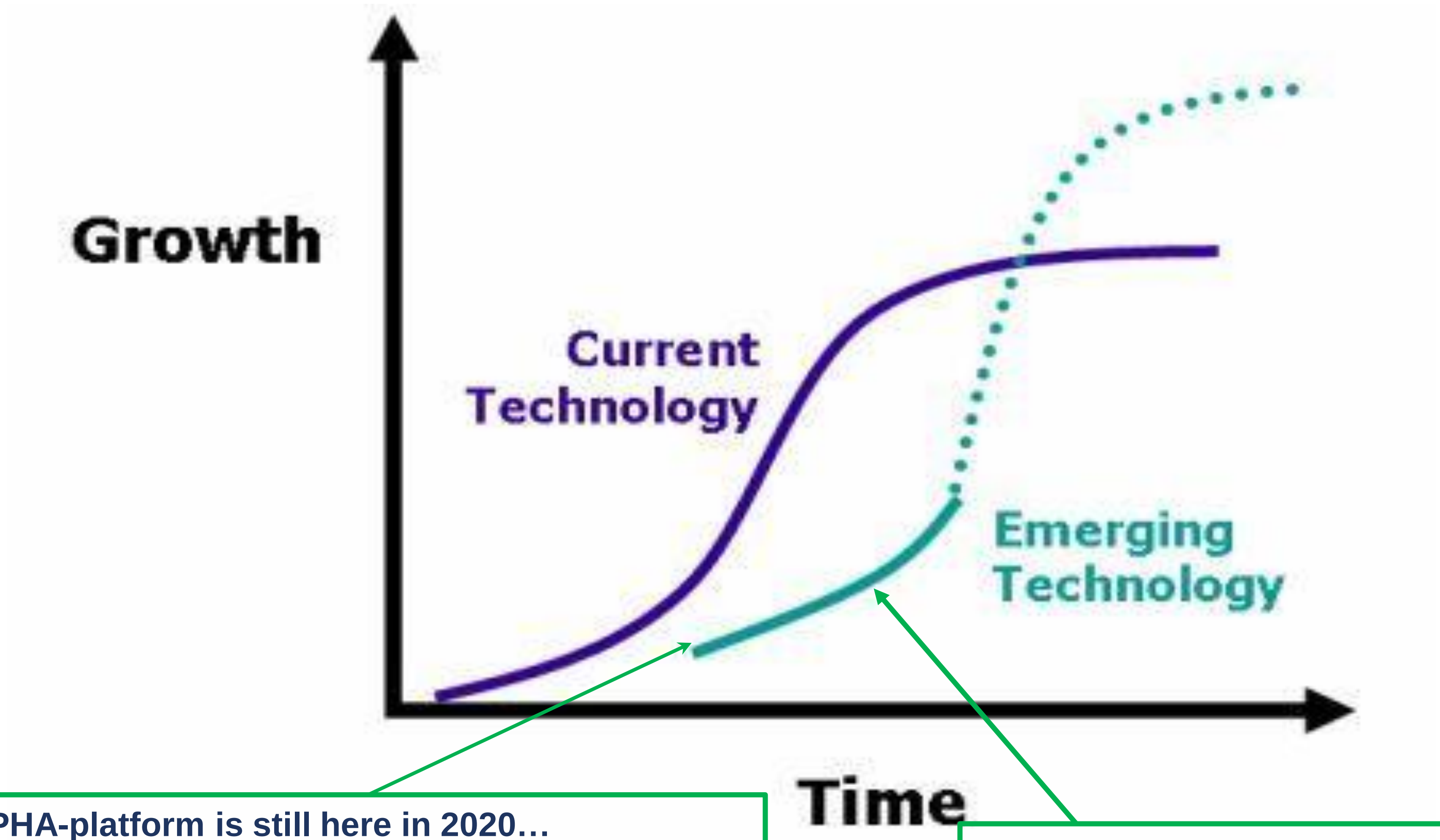
1. … so the properties vary quite a bit

Properties of PHA-platform materials										
Polymer	PHB	P3HB4HB Tianjin Green Biomaterials			PHBV Phario			PHBHx Kaneka		PHA-platform
		10% 4HB	20% 4HB	40% 4HB	20% HV	30% HV	40% HV	6% HHx	11% HHx	
Mw kD		970	810	530						300-1,000
Tmelt °C	175	127	104	59	150	125	97	145	126	60-175
Tg °C		0	-10	-21	-1	-3	-4	2	0	≤0
Tensile Modulus MPa	>3,000	955	225	4				1,820	950	<10 - >3,000
Tensile Yield MPa	45	20	8	0.4	24	20	12	36	26	<1 - 45
% Elongation	<1	180	680	1,350	20	35	>250	4	320	<1 - >1,000

→ **Chemically produced PHBV (20%) has TY of 15 and 350% E**

GO!PHA Global Organization for PHA

2. PHA-platform on the S-curve



PHA-platform is still here in 2020…

…but is expected to move to the next stage soon.

2. Many Renewable Carbon sources for PHA-polymers

- **In 2006 Metabolix announced construction of the first large scale PHA plant based on corn: 50 kt/annum.**
- **12 years ago the main feedstock sources were corn, sugar and vegetable oils.**
- **Today many PHA start-ups and SMEs are working on using flue gases, waste water streams, plastic waste, waste cooking oil and other waste streams (like from sugar, fruit & palm oil industries) as feedstock →**

  → Carbon from the biosphere, atmosphere and technosphere.
- **Most commercial PHA manufacturers also pursue the use of 2nd generation feedstock to lower the costs and to counsel issues over "competition with the food chain".**
- **They also see this as a more valuable option than using those streams for energy.**

2. Bacterial strains ←→ Feedstock & co-nutrients

- ✓ There are many different bacterial strains, both unmodified and gene-modified, that can and do make a large variety of PHA-polymers.
- ✓ Wild type bacterial strains can be and are turned into producers of multiple PHA-polymers and –copolymers which depends on the use of co-nutrients.
- ✓ Metabolic engineering of bacterial strains for production of PHA-polymers is a must nowadays to ensure process competitiveness, both from a cost as well as from a product quality and quality consistency perspective.
- ✓ Metabolic engineering also creates a new biochemical pathway for co-nutrient supply based on renewable feedstock, but they still generate PHA-polymers that also appear in nature.

2. PHA-platform challenges & status

Remaining challenges of the current commercial PHAs are:

- **Molecular chain scission above 160 °C → control processing operating window**

  Lowering T_m, low-shear screw designs, building in 4HA and/or 2HA moieties all help to open up the processing window.

- **Slow nucleation from the melt → long process cycles**

  Several effective nucleating agents have been found/developed, but this is not common knowledge yet.

- **Legislation → Threat or opportunity?**
- **Expensive!? → Starting industry at the beginning of the S-curve.**
- **Availability? → Demand exceeds supply by far in 2020.**

2. Some PHA-platform players today – October 2020

Company	Feedstock	Strain	Product	Capacity in place	Capacity planned
PHB:					
Nafigate	Waste oil - palm oil	Unmodified	PHB	Pilot	First plant in 1st half 2021
Tianan Biologic Material	Corn starch glucose	Unmodified	PHB & PHBV (2%)	2 kt/annum	Expands to 10 kt/annum
P3HB4HB:					
Bluepha	Organic waste streams	Modified	P3HB4HB (15%)	1 kt/annum	?
CheilJedang	?		P3HB4HB (50%)	Pilot	Plans next scale
PHABuilder*	?	Halomonas modified	P3HB4HB (several)	1 kt/annum	Starts 3 units of 1 kt/annum
PHBV:					
Bio-On	Glycerol, starch, sugars	?	PHB & PHBV	1 kt/annum	Company gets new owner
Full Cycle Bioplastics	Pre-consumer food waste, green bin	?	PHBV (several)	Pilot	Prepares for next scale step
Newlight Technologies	Biogas, CO2	?	PHB & PHBV (?)	5 kt/annum?	Just started a new line.
Phario	Fatty acids from waste water	Unmodified	PHBV (several)	Lab scale	Announced Pilot plant for 2021
PHBH:					
Danimer Scientific	Canola oil	Modified	PHBH (several)	2 + 8 kt/annum	+12 kt/annum in 2021
Kaneka	Palm oil, waste streams	Modified	PHBH (several)	5 kt/annum	+20 kt/annum in few years
PHABuilder*	?	Halomonas modified	PHBH (several)	1 kt/annum	Starts 3 units of 1 kt/annum
RWDC-Industries	Waste cooking oil	Modified	PHBH (several)	5 kt/annum	+25 kt/annum in 2021

3. Applications … understand USPs for the whole value chain

Most mechanical, rheological, thermal and optical property combinations offered by the new bio-based polymers are also offered by the traditional fossil-based polymers.

→ Those properties are Qualifiers, no Differentiators

However, in some cases we see some attractive new performance characteristics, like:
→ PEF for bottles shows significantly better barrier properties than PET;
→ PLA for fibers shows excellent wicking and high colour intensity upon dyeing;
→ PHA …… what about it? → haptics / soft touch / versatile biodegradability / mimicking nature;

3. Unique Selling Points of PHB and its copolymers

Although this PHA product family consists of a broad range of products, a combination of the following USPs can be applicable for different applications:

- ✓ **Boosts brand image**
  - GHG-emission
  - No competition with food chain (Wave II or GHG feedstock)
  - No GMO in feedstock
- ✓ **Very versatile biodegradability characteristics**
  - Aerobic Industrial & Home composting
  - Marine & Soil degradability
  - Anaerobic digestion
- ✓ **Compatibility - Behaviour**
  - Unique haptic properties combined with matting effect
  - No coupling agents or other expensive additives required in blends or composites
  - Excellent physico-chemical properties (printing, sealing, dyeing, barrier)
  - Forms a one-phase system with PVC as flow promotor, reinforcement of PLA
  - What about the compounds in combination with Cellulose esters or APCs?
- ✓ **Bioresorbable**
  - Watch purity
  - P3HB and P4HB

GO!PHA
Global Organization for PHA

3. Applications / market segments for PHA-polymers

- **PHA-products range from amorphous to highly crystalline, from “high strength, hard and brittle” to “low strength, soft and elastic”:**
  - → **Quite different application areas for specific types of PHA-polymer!**
  - → **Which PHA-polymer do or can you make?**

- **PHA-products cannot fully substitute any of the existent fossil-based polymers, but they can partly replace most of them:**
  - → **The accessible market for PHA-polymers is hundreds of kilotonnes/annum if the cost/performance-balance is OK.**

- **Application areas:**

  Injection moulding, sheet and film extrusion, thermoforming, foam, non-wovens, fibers, 3D-printing, paper coating, glues, binders, adhesives, additives (reinforcement, plasticization), UPR and PUR building block.

3. PHA-platform applications …… demonstrated high versatility

Possible Product Market Combinations:

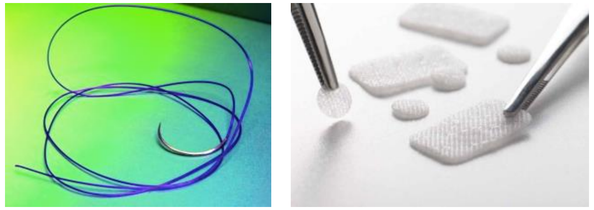
1. Feed
2. Films
3. Fibers
4. Foams
5. Furniture
6. Stationary
7. Cosmetics
8. Appliances
9. Sunscreens
10. Fishing gear
11. Chewing gum
12. Cheese coating
13. Synthetic paper
14. Animal nutrition
15. Fertilizer coating
16. Electrical switches
17. Paints and Coatings
18. Biomedical Materials
19. Cosmetic applications
20. Thermoplastic Elastomers
21. Waste-water & aquaria denitrification
22. Glues & Adhesives i.e. pressure sensitive adhesives
23. Engineering Plastics for automotive, electronics, etc.
24. Microparticles (abrasives, sunscreens, exfoliants, etc.)

One type PHA-product cannot do everything though.

Most of these applications have been demonstrated already.

3. Demonstrated PHA applications (commercial)

Spectacle case
e.g. MAIP (PHBH)



Medical and surgical applications
e.g. Tepha (P4HB)

Flexible packaging
e.g. PHBV

Sewage treatment
e.g. Tianan, Helian Polymers

Organic waste bags
e.g. Ecomann (P3HB4HB)

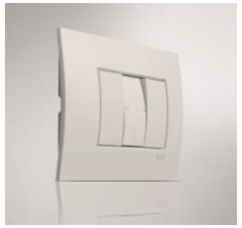
Stationary
e.g. MAIP (PHBH)

Food tray
e.g. FKuR

Exfoliating microbeads (scrub)
e.g. Orkla, Nafigate (PHB)

Organic Chair
e.g. Kartell – Sabio

Plant clip
e.g. Metabolix



Durable E&E light switch
e.g. ABB, MAIP, Kaneka partnership (PHBH)

Sea current tracking buoys
e.g. Metabolix (P3HB4HB)

Flexible packaging
e.g. PepsiCo – Danimer pre-commercial partnership (mcl-PHA)

4. Natural PHA-products fit very well with a circular economy

✓ **PHB and a large number of its copolymers are made and used in nature all the time:**

1. **They are made by bacteria from available nutrients and by enzymatic synthesis;**
2. **They are used as nutrients and energy providers by living organisms resulting in CO_2, water and biomass/compost;**

✓ **This circular system is much older than mankind.**

✓ **By using these materials for construction applications (films, parts or even glues) that circular behaviour can both be used and be extended.**

✓ **An additional advantage of these specific PHA materials is that they can fully meet a comprehensive combination of end-of-life options fitting a circular economy, very much like cellulose or starch.**

✓ **Before using them in an application one should carefully consider the "Reduce" and "Re-design" principles.**

4. End-of-Life options for natural PHA-products (1)

Polymeric materials that can fully meet a comprehensive combination of End-of-Life options include cellulose, a large number of PHA-polymers and starch, or a combination of each of these:

1. **Recycle articles to be used again:**
   → Can be done many times, but be aware of micro-plastic generation (textiles)
2. **Recycle articles back to the polymer:**
   → Can be done 2 or 3 times, so it's not a holy grail for any polymer!!!
3. **Recycle articles back to raw materials:**
   → Generates Renewable Carbon which can be used for many products

GO!PHA
Global Organization for PHA

4. End-of-Life options for natural PHA-products (2)

4. **Recycle articles to environment (home, industrial) composting:**
   → **Useful for articles that inevitably end up contaminated with organic waste**

5. **Recycle articles to energy (incineration):**
   → **Useful for bio-energy generation, but don’t forget to use the CO_2 as feedstock**

6. **Recycle to nutrients for living organisms:**
   → **All living organisms feed on nutritious materials. In addition several PHAs take care of denitrification (waste water streams, aquaria, fish ponds).**

Most current fossil-based polymers do not meet all these End-of-Life options, while they all should be required to meet them if they, intended or by accident, can end up in the environment.

All these End-of-Life options contribute to a Circular Economy.

One simply cannot avoid the necessity for any of the End-of-Life options mentioned.

4. Not all natural materials are biodegradable in all environments …

- **Starting point should be: "Materials allowed for Single Use applications should not be harmful to the environment in any way when they purposely or accidentally end up in the environment". They also need to biodegrade in a marine environment.**

- **Cellulose (paper), Starch and P3HB and its copolymers fit that description.**

- **Wood is not biodegradable in a marine environment, since lignin (50% of wood) needs fungi for biodegradation while those are not present in the marine environment.**

Biodegradable Polymers in Various Environments

NOTES

proven biodegradability

proven biodegradability under certain conditions or for certain grades

biodegradability not proven

The biodegradability of plastics derived from these biodegradable polymers can only be guaranteed if all additives and (organic) fillers are biodegradable, too. Dying and finishing of cellulosic fibres, for example, may prevent their biodegradation in the environment.

Biodegradability depends on the complex biogeochemical conditions at each testing site (e.g. temperature, available nutrients and oxygen, microbial activity, etc.). Therefore, these generalised claims about biodegradation can only serve as approximations and need to be confirmed by standardised testing under lab conditions. In-situ behaviour can vary, depending on the mentioned conditions, size of the plastic, grade of the polymer and other factors. For instance, biodegradation testing is often performed after milling, showing the inherent nature of the material to biodegrade. In reality, the same level of biodegradation will be obtained, be it possibly within a different timeframe.

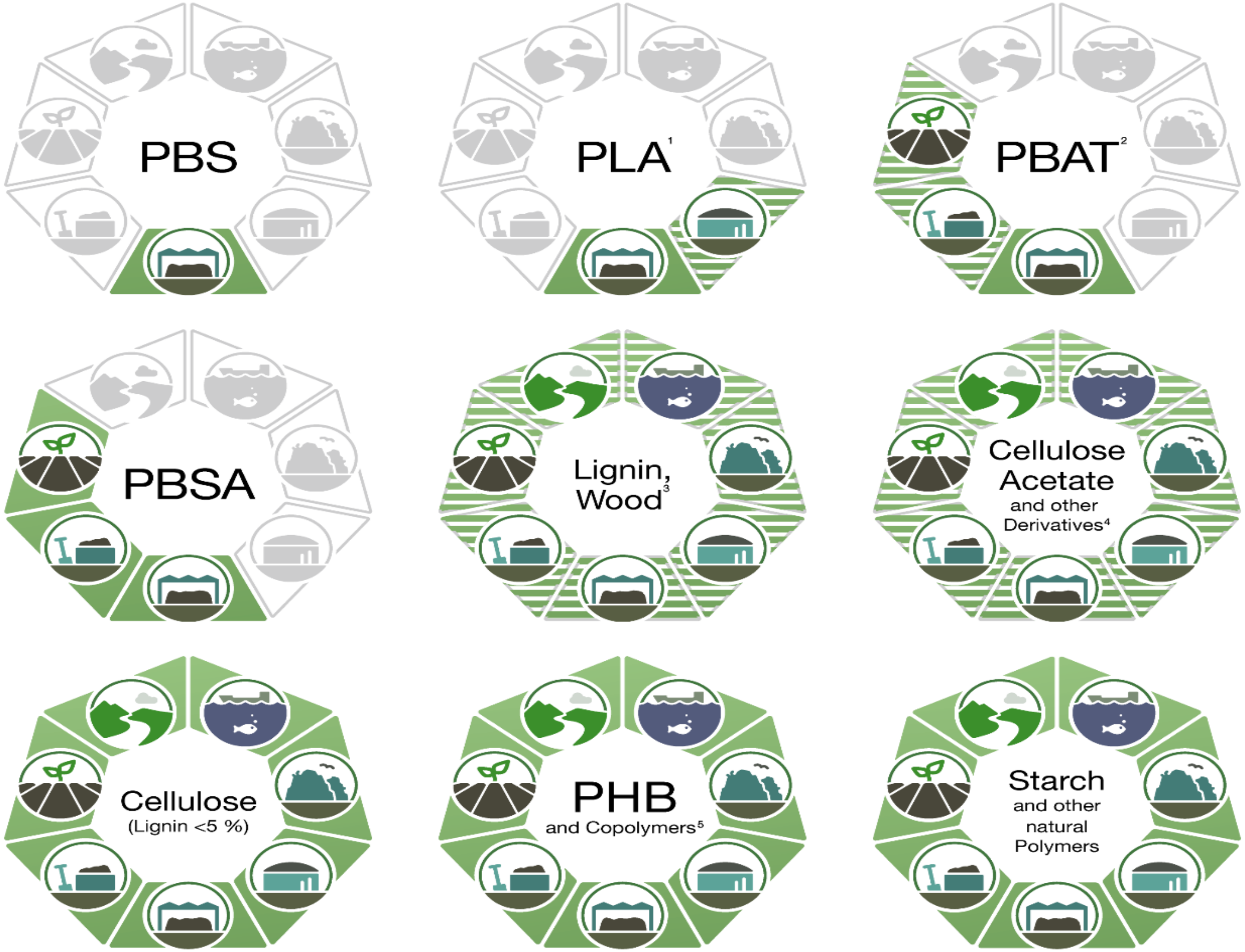
1 PLA is only likely to be biodegradable in thermophilic anaerobic digestion at temperatures of 52°C.

2 Biodegradability in home composting and in soil of PBAT is only proven for certain polymer grades.

3 Complete biodegradation of materials with a high lignin content is not easily measurable with standard biodegradation tests, but does take place (slowly). Instead of CO_2, especially humus is produced by the biodegradation of lignin-rich materials.

4 The biodegradation of CA in all environments is only proven for certain polymer grades.

5 incl. P3HB, P4HB, P3HB4HB, P3HB3HV, P3HB3HV4HV, P3HB3Hx, P3HB3HO, P3HB3HD



ENVIRONMENTS

Details on test conditions and, if available, applicable pass/fail criteria.

MARINE ENVIRONMENT
Temperature 30°C, 90% biodegradation within a maximum of 6 months (Certification: TÜV AUSTRIA OK biodegradable MARINE (ISO under preparation))

FRESH WATER
Temperature 21°C, 90% biodegradation within a maximum of 56 days (Certification: TÜV AUSTRIA OK biodegradable WATER)

SOIL
Temperature 25°C, 90% biodegradation within a maximum of 2 years (Certification: TÜV AUSTRIA OK biodegradable SOIL; DIN Certco DIN-Geprüft biodegradable in soil)

HOME COMPOSTING
Temperature 28°C, 90% biodegradation within a maximum of 12 months (Certification: TÜV AUSTRIA OK compost HOME; DIN Certco DIN-Geprüft Home Compostable)

LANDFILL
No standard specifications or certification scheme available, since this is not a preferred end-of-life option

ANAEROBIC DIGESTION
Termophilic 52°C / mesophilic 37°C; standard specification not yet available, but 90% generally considered as completely biodegradable

INDUSTRIAL COMPOSTING
Temperature 58°C, 90% biodegradation within a maximum of 6 months (Standard: EN 13432)

www.bio-based.eu

More figures available at www.bio-based.eu/graphics

Partners: IKT Kunststofftechnik Stuttgart; OWS; Marine Sciences

Sponsors: TÜVRheinland; DIN CERTCO; TÜV Austria

Your feedback is welcome: michael.carus@nova-institut.de

4. Biodegradation in deep-sea

Looking at the deep sea situation with temperatures ranging between 10 and 4 ºC we expect the following based on tests and estimations:

Material	Years to 90% degradation	Comments
Cellulose	0.5 to 1	Much faster at higher T
PHBV (17%)	4 to 7	Same order of magnitude
Wood	500 to 1,000 ?	Shipwrecks 500+ years
PP, PLA, PET	“Never”	Don’t use for SUPs

Cellulose and PHBV studied at MSU.

5. Closing remarks

- ✓ **The PHA-platform is the first polymer family produced by fermentation and is moving from the embryonic stage to the early-growth stage in 2021.**
- ✓ **Different PHA product families can be used for a broad range of applications → construction, adhesives, additives, thermosets, denitrification, coatings.**
- ✓ **New volumes built and started up and there is more to come.**
- ✓ **The mcl-PHAs currently make the main move, but scl-PHAs seem to be right behind them.**
- ✓ **Several of the old challenges (nucleation, process-ability) have been taken care of.**
- ✓ **For PHB and its copolymers all known End-of-Life options are possible and all lead to a circular economy.**
- ✓ **Main challenges now are availability and upcoming legislation to encourage this innovation.**

AFTERLIFE Stakeholder Workshop

Advanced Filtration Technologies for the Recovery and Later conversion of relevant Fractions from wastewater

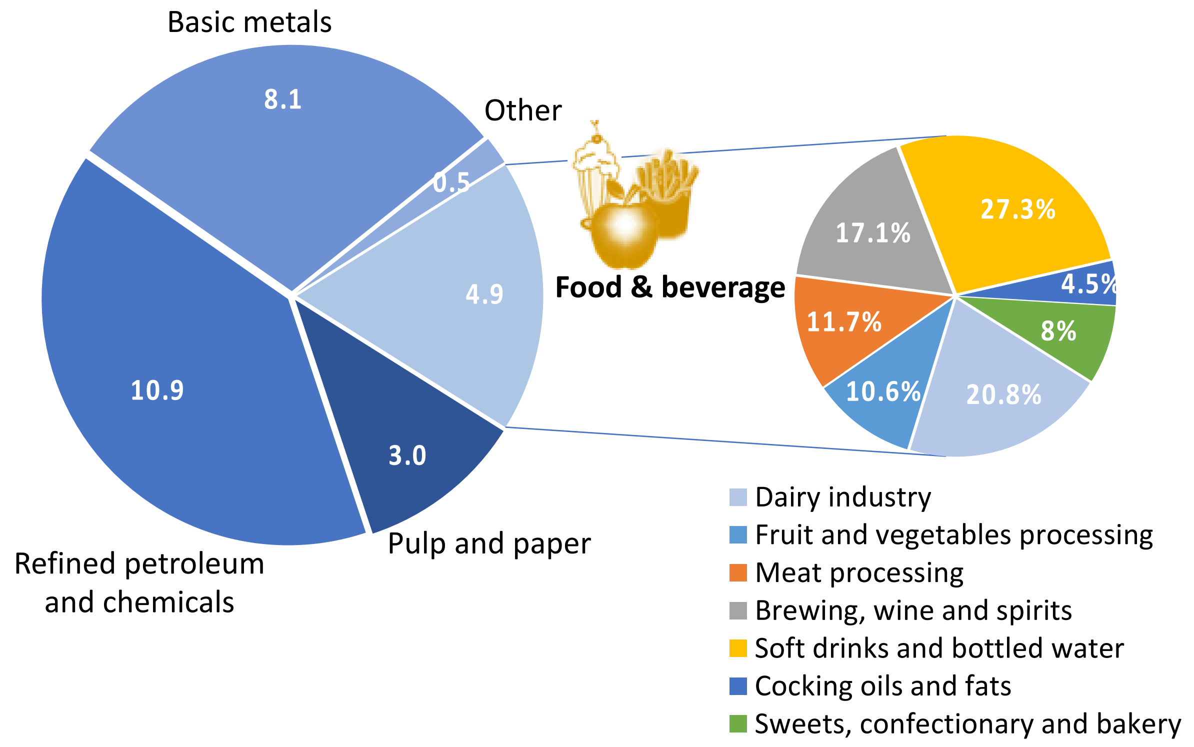
OCTOBER 9, 2020

MARÍA LÓPEZ

AFTERLIFE has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No. 745737 .

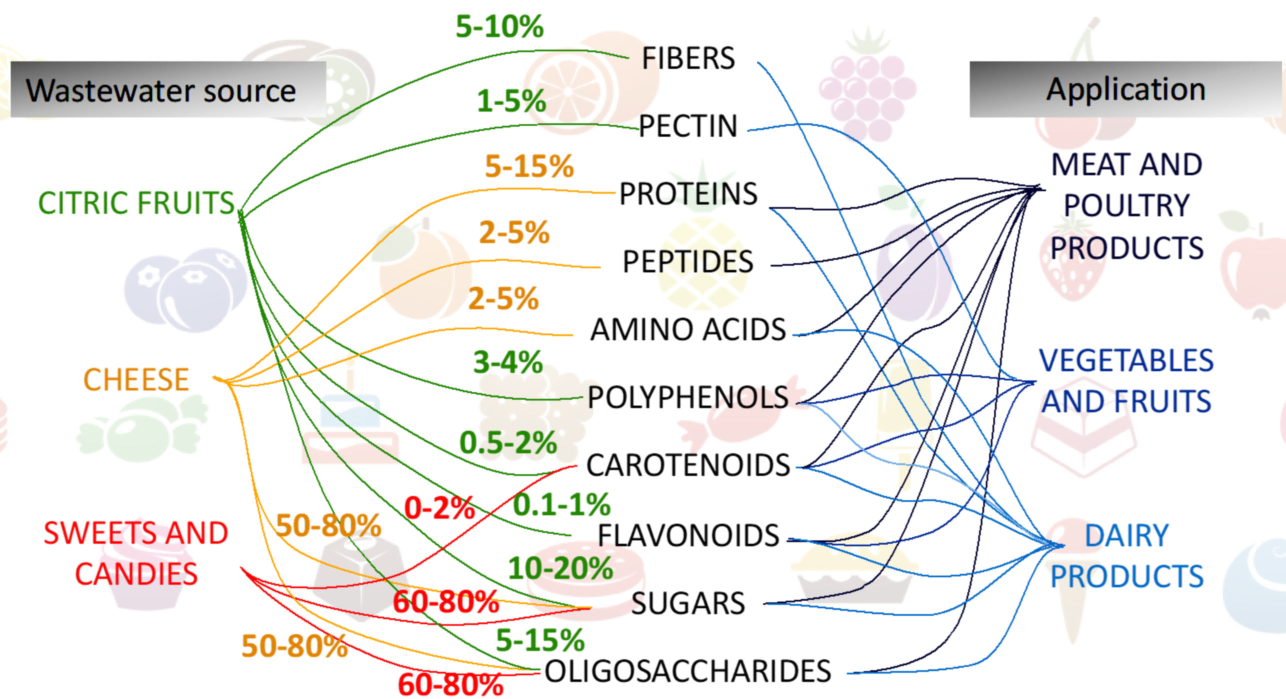
Wastewater… an abundant ~~waste~~ resource

Wastewater production in European (bio)industries

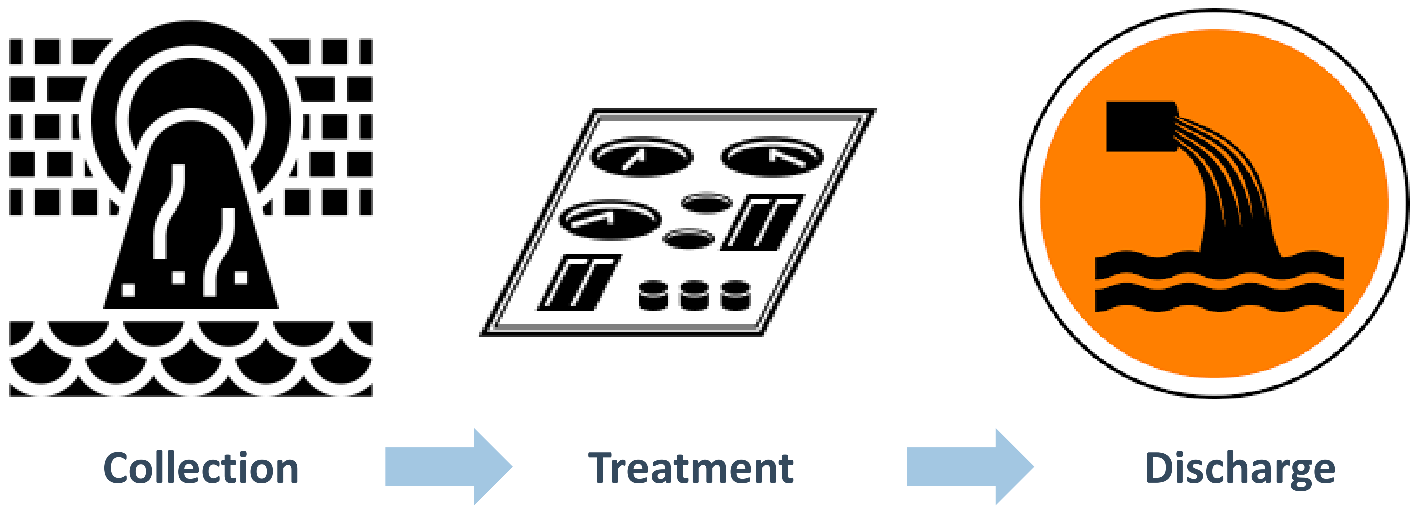


A rich source of valuable compounds

Wastewater from **food processing**: a great source of bio products!!



Current approach

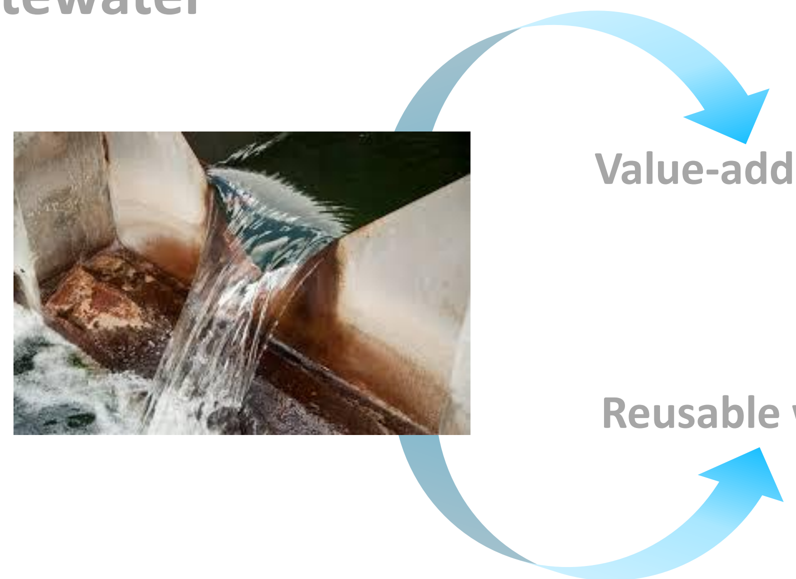


Recycling and energy aspects should be considered to develop sustainable treatment systems!

Proposed approach: fitting in a circular bioeconomy

Focus on extraction and concentration techniques that will lead to the valorization of wastewater

- Green techniques
- Cost-effective
- Flexible



Application of extraction techniques in wastewater valorisation: AFTERLIFE project

- The AFTERLIFE project proposes a flexible, cost- and resource-efficient process for valorizing wastewater
- It will represent an advance on existing approaches to wastewater treatment
- It will separate out the different components of value using a series of membrane filtration units
- These will then be treated to obtain high-pure extracts and metabolites or, alternatively, to be converted into value-added biopolymers
- In addition to the value extracted from the solids, the remaining outflow of the water will be ready for re-use

AFTERLIFE project: consortium

4	3.890.000	14	7
Duration (Years)	Max. grant amount	Partners	Countries

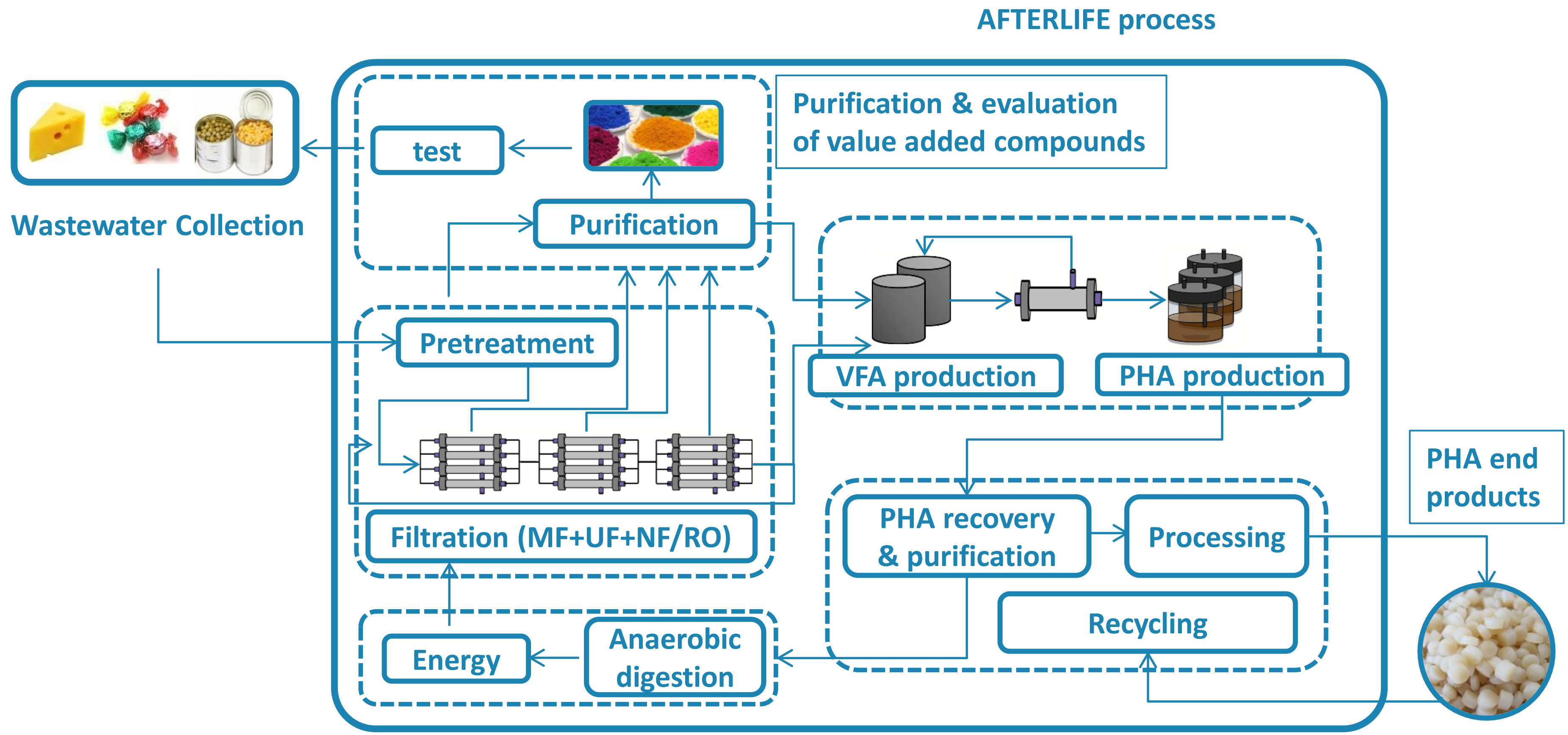
Lurederra centro tecnológico · CSIC Consejo Superior de Investigaciones Científicas · VTT · CTC Centro Tecnológico Nacional de la Conserva y Alimentación · NOVA id FCT Associação para a Inovação e Desenvolvimento da FCT

5 RTD & Non-profit org.

idener SCIENTIFIC COMPUTING · Bio Base Europe Pilot Plant · mi-plast bio-company · Jake · CITROMIL · INNOVEN INNOVATION FOR THE ENVIRONMENT · celabor · nova Institut · Herve SOCIETE

9 SMEs

AFTERLIFE project: the process



AFTERLIFE

AFTERLIFE project: wastewater

idener SCIENTIFIC COMPUTING

Wastewater Collection

Heritage-W

- **High concentrations of SS**
- Whey can be studied as a **raw material of fat, protein and lactose**

Jake-WW

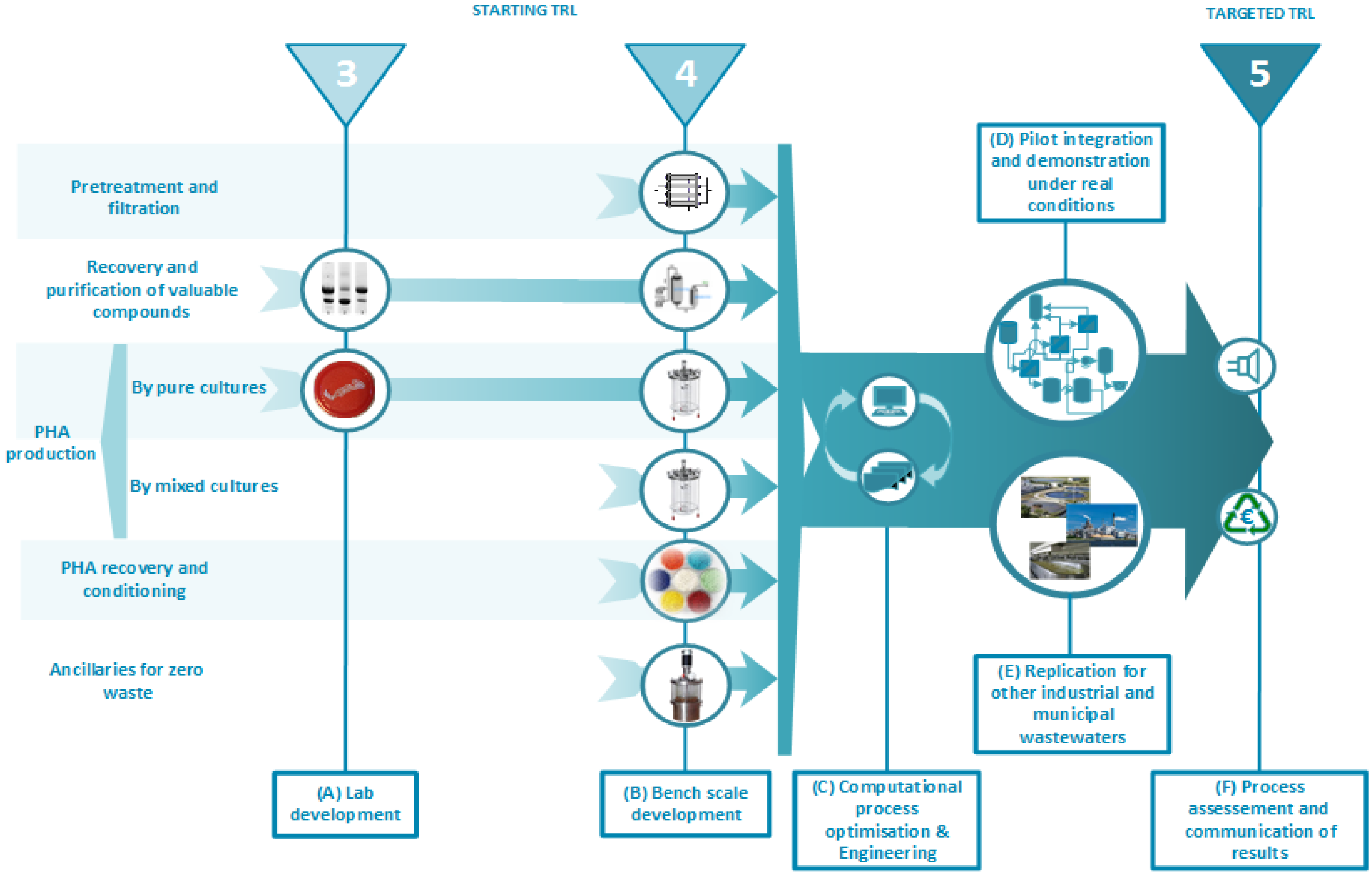
- **High concentration of SS**
- **Very high sugar content**
- Low fat and protein concentrations

Citromil-JL

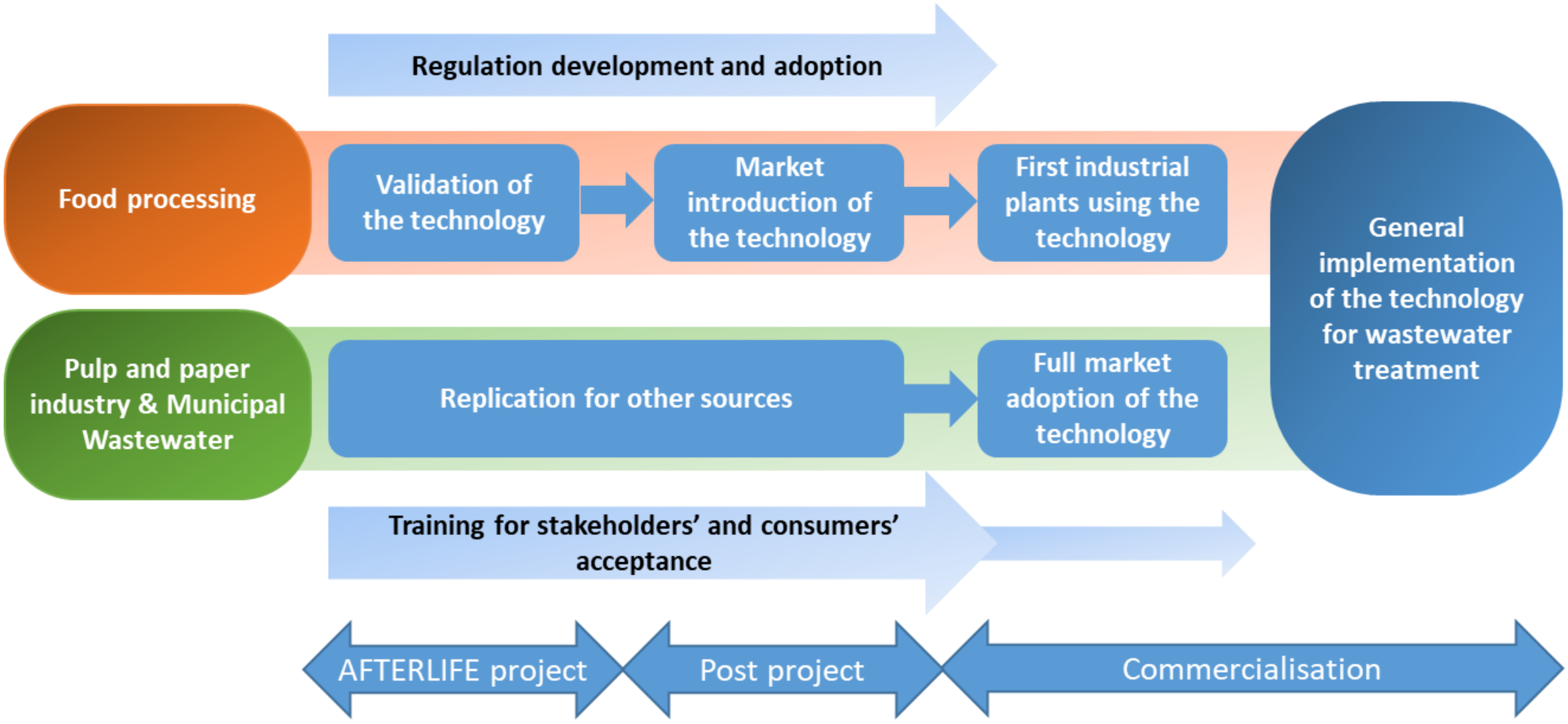
Citromil-EO

- Higher concentrations of compounds in Cit-EO than Cit-JL
- **Notable SS/pulp** concentration
- Some sugars, low fat and low protein concentrations
- **High concentrations of compounds of interest** in Citromil-EO, **such as flavonoids and limonoids, and relevant quantities of essential oils**

AFTERLIFE project: roadmap



AFTERLIFE project: roadmap



Webinar Speakers from AFTERLIFE consortium

Dr. Antti Gronroos
VTT, Finland
Membrane technology

Dr. Nicola Frison
Innoven, Italy
VFA production

Dr. Oliver Drzyzga
CSIC-CIB, Spain
PHA production

Dr. Javier Ceras
Lurederra, Spain
Extraction techniques

https://www.youtube.com/watch?v=egIUtwdFQMA

visit us at:
www.afterlife-project.eu

AFTERLIFE has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No. 745737 .

AFTERLIFE

Membrane technology in valuables and water recovery from wastewaters of food industry

RESEARCH WORK DONE IN WP1 MAINLY BY VTT, CTC, AND LUREDERRA

AFTERLIFE STAKEHOLDER WORKSHOP, OCTOBER 9TH, 2020, ANTTI GRÖNROOS AND HANNA KYLLÖNEN

BIO-BASED INDUSTRIES Public-Private Partnership

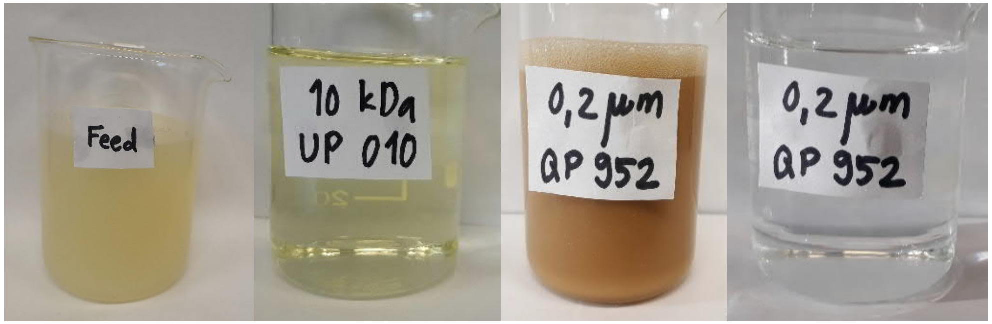
Bio·based Industries Consortium

Horizon 2020 European Union Funding for Research & Innovation

AFTERLIFE has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No. 745737 .

Content of the presentation

- ✓ Water treatment in general
- ✓ Supplying wastewater from industries representative of different food processing sectors with disparate characteristics
- ✓ Characterization of the wastewaters
- ✓ Designing the unitary operations for wastewater pretreatment according to the required characteristics for the subsequent filtration steps
- ✓ Maximizing separation for valuables and water from suspended and soluble solids, i.e. flux, water recovery (WR), concentration factor (CF), and rejection,
- ✓ Producing pure water for reuse using “fit for purpose” principle
- ✓ Conclusions



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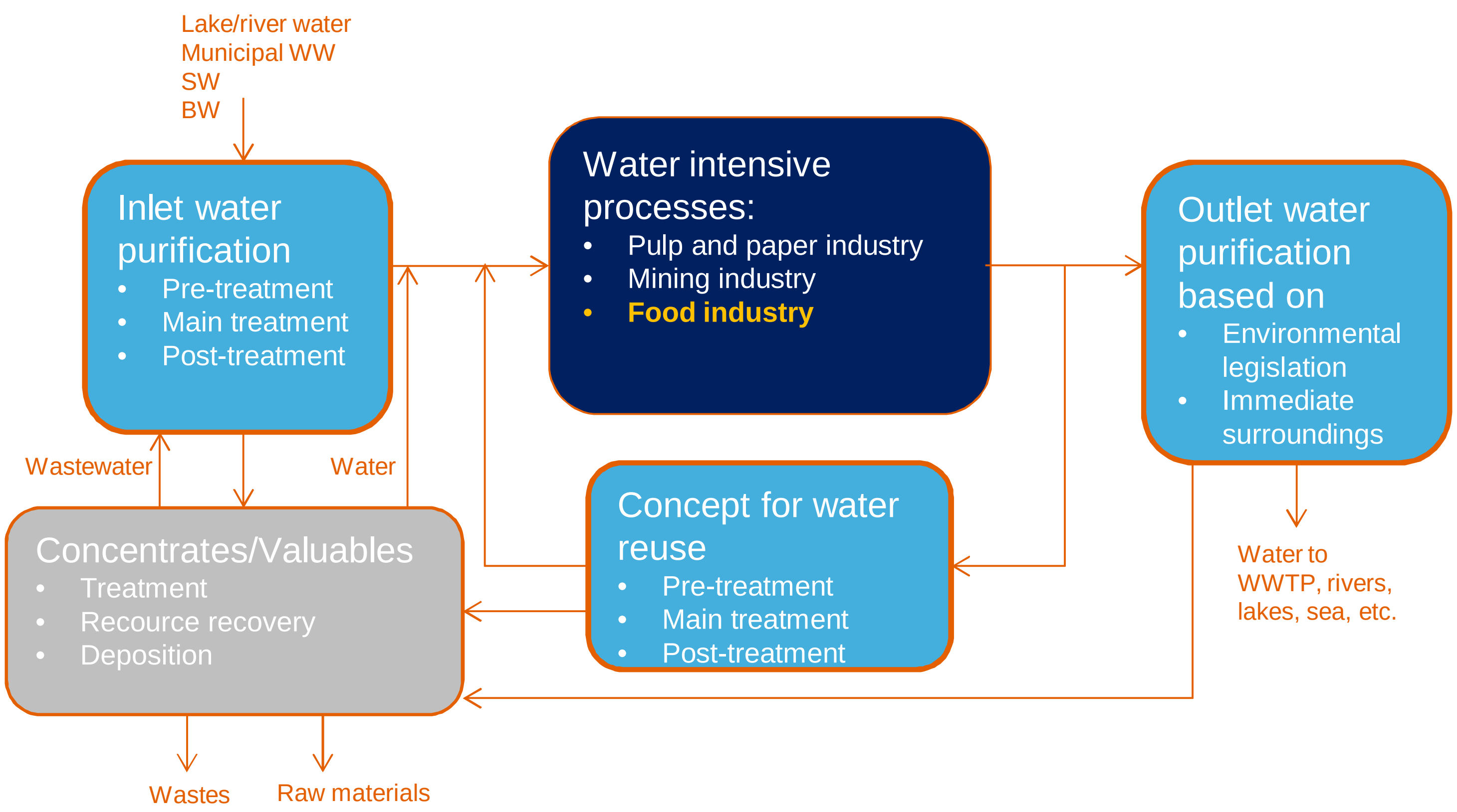
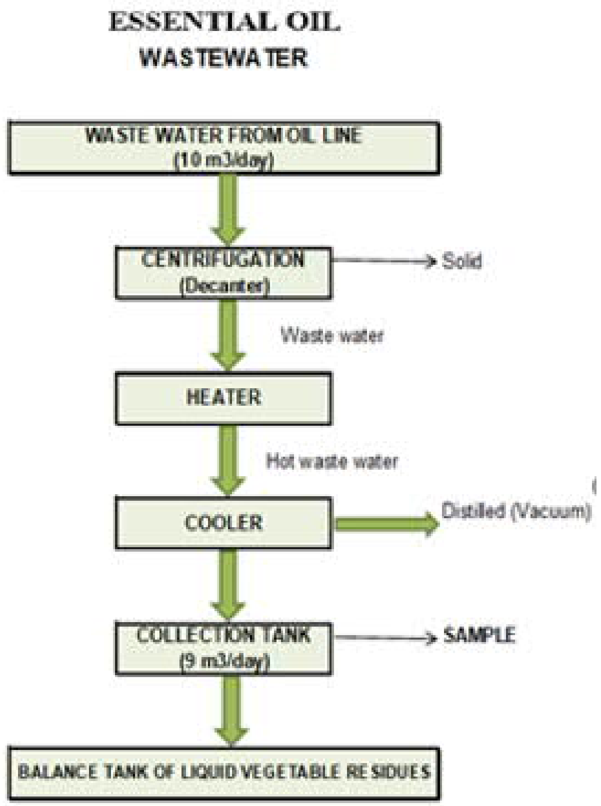
Water treatment in general



Supplying wastewater

- Wastewaters were collected from the industries representative of different food processing sectors with disparate characteristics
  - Jake wastewater (Jake-WW) from candy production, constant wastewater production
  - Citromil wastewaters from citric fruits processing, periodic production
    - Juice line wastewater (Cit-JL)
    - Essential oil line wastewater (Cit-EO)
  - Heritage wastewaters from cheese production
    - Wastewater, flocculated at site (Her-WW)
    - Whey (Her-W) simulating the highest concentrations to be recovered
- Variation of the concentrations were studied with six samples during three weeks
  - Concentrations of all wastewaters varied



Water characterisations

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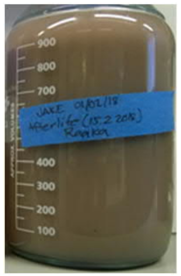
VTT

- Jake-WW contained high concentrations of SS and sugars, also pectin like organic matter. Content of vitamin C was not relevant in general but could appear sometimes in notable concentrations.
- Cit-JL and Cit-EO contained notable concentrations of compounds of interest in SS, such as hesperidin and essential oil, Cit-EO also in liquor
- Phytosanitary treatments applied to citric fruits are responsible for the presence of pesticide residues in Cit-JL and Cit-EO. Pesticides and pathogens could appear somewhat.
- Her-WW contained low amounts of valuables to be economically recovered
- Her-W was rich of proteins and lactose. Pure whey was studied to consider the most “extreme” scenario for wastewater.
- None of the wastewaters contained notable amounts of heavy metals with exceptions for boron, iron and zinc.


Jake-WW


Citromil-EO

Citromil-JL

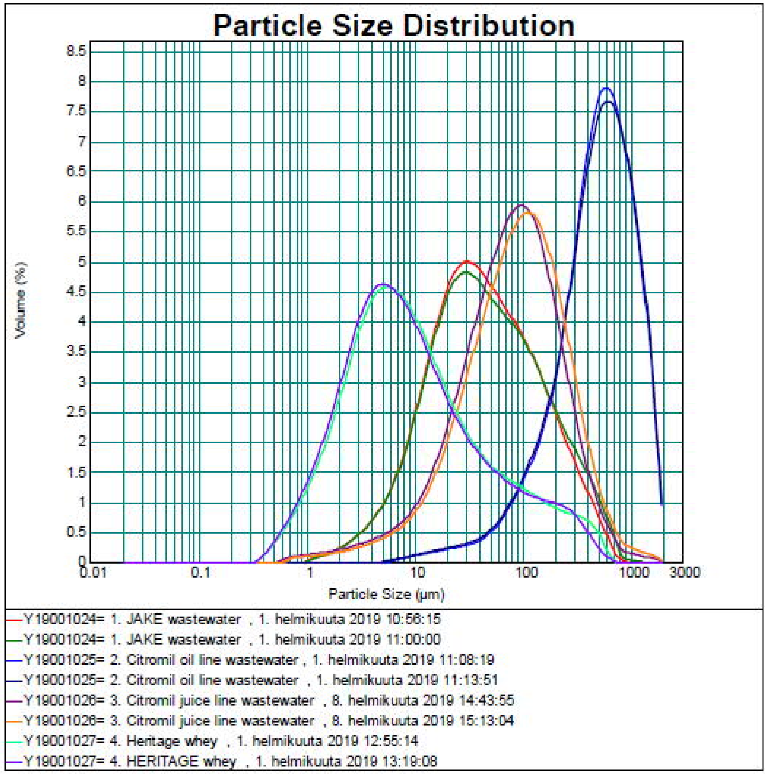
Heritage-W

Reuse ideas based on characteristics

AFTERL!FE

VTT

- Jake-WW:
  - High sugar concentration enables it to be used at fermentation in WP3 as such or after SS removal
  - Pure water production is possible after fermentation
  - Recovery of sugars can be carried out from wastewater as such
- Cit-EO:
  - Suitable for the recovery of valuables from SS or liquid phase to be valorised in WP2
- Cit-JL:
  - Suitable for reuse water production directing SS and concentrates to WP2
- Her-WW:
  - Pure water production can be carried out after flocculation and separation at site
  - Her-W suitable for proteins and lactose recovery after FOG removal



AFTERLIFE

Design of pretreatment

- There were two main issues addressed: relatively high viscosity and potential membrane fouling owing to the very high content of total SS
  - Viscosity decrease was enabled by the use of different surfactants.
  - MF was selected as the pretreatment option to tackle the removal of SS. It was expected to yield also significant viscosity decrease. The potentially beneficial combination of surfactant and MF pretreatments was also explored.
  - Coagulation and flocculation procedures was found an option to help MF of some wastewaters
- No reduced microbial activity from imazalil for polyhydroxyalkanoates (PHA) production was found in WP3.
- The removal of fat, oil, and grease (FOG) by elastomeric materials with sponge-mimicking behavior was proposed for pretreatment

Flocculation and MF

Pretreatment in lab

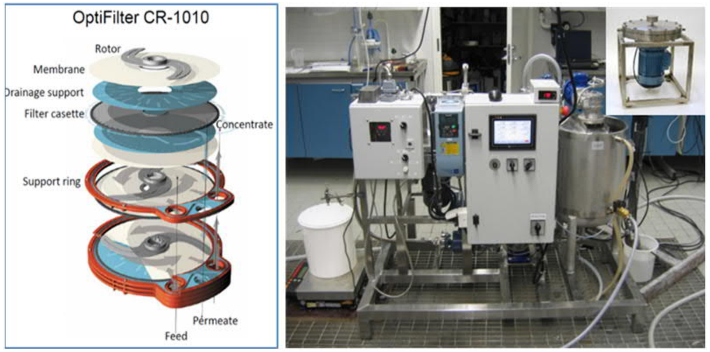
- MF was part of the proposed workflow along with the use of surfactants to address viscosity of wastewaters.
- Viscosity decrease enabled by sodium dodecylbenzenesulfonate (SDBS, 0.4 mM) was successfully achieved with Jake-WW after MF
- Streams of valorizable material were obtained from Cit-EO wastewater. Pretreatment operations for this wastewater was proposed: filtration with 150 µm sieve, followed by fat-oil-grease (FOG) adsorption, and then coagulation/flocculation to further removal of suspended solids.
- FOG removal with a 50% reduction was carried out with Cit-EO, and also with Her-W

FOG removal

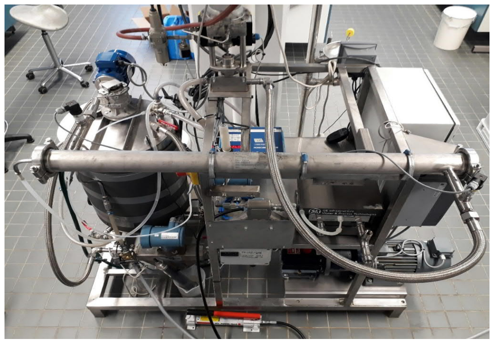
Developing of filtration steps

- SS removal was studied using flocculation, belt filtration and press filtering
- Suitability of MF using bag or cartridge filtration were tested as a clarification filtration for RO
  - Low fouling ultrasound aided MF was also an option. However, commercially available ultrasound aided MF was found unsuitable for organics containing wastewaters.
  - Cartridge filter was capable to remove FOG but it was not suitable for recovering
- UF using spiral wound and low fouling cross-rotational options were tested
- RO, either brackish or sea water membranes, or membrane distillation (MD) were found good as a last filtration step. MD especially was found good for samples having high osmotic pressure.

Cross-rotational UF



Spiral wound UF



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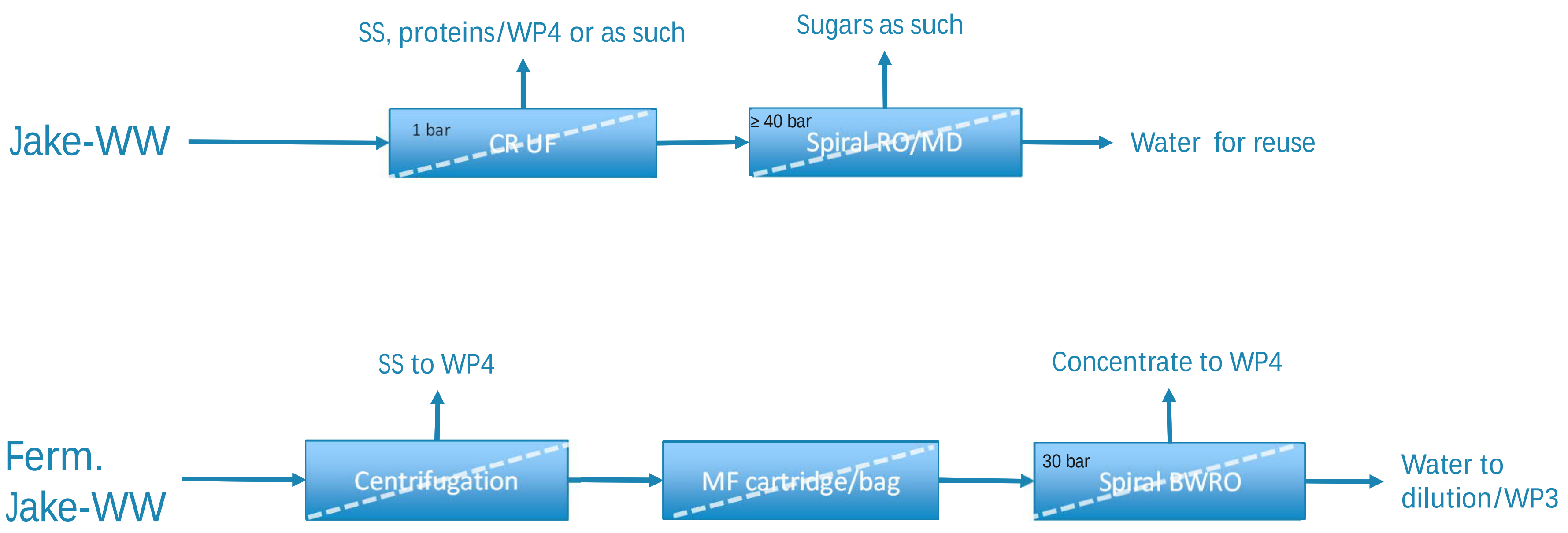
VTT

Performance of filtration

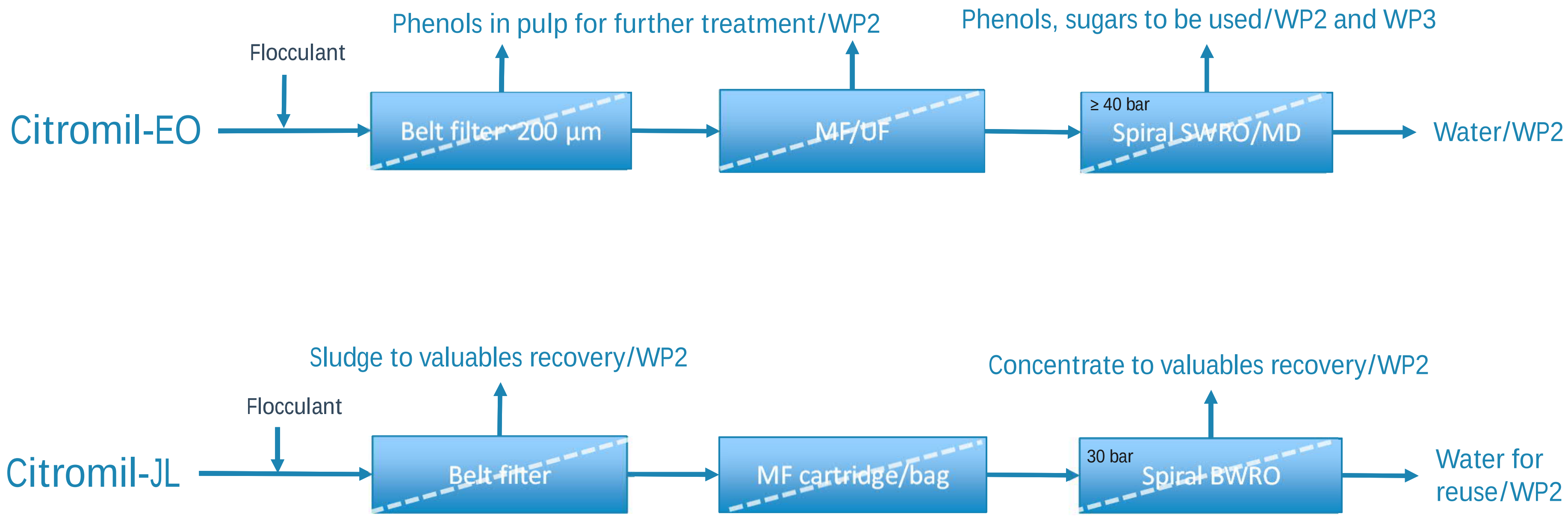
Technique	Jake-WW	Ferm. Jake-WW	Cit-JL	Cit-EO	Her-WW	Her-W
Coagulation and flocculation	✓ (red)		✓	✓	✓	-
Belt filter	✓ (red)		✓	✓		-
FOG removal	-	-	-	✓	-	✓
Clarification MF	-	✓	✓	✓	✓	✓
Spiral wound UF	✓ (red)	✓	-	✓	✓	✓
Cross-rotational UF	✓	-	-	-	-	-
Reverse osmosis	✓	✓	✓	✓	✓	✓
Membrane distillation	✓	-	-	-	-	✓

✓ (green) Workable technique ✓ (red) Not workable technique – Technique not relevant

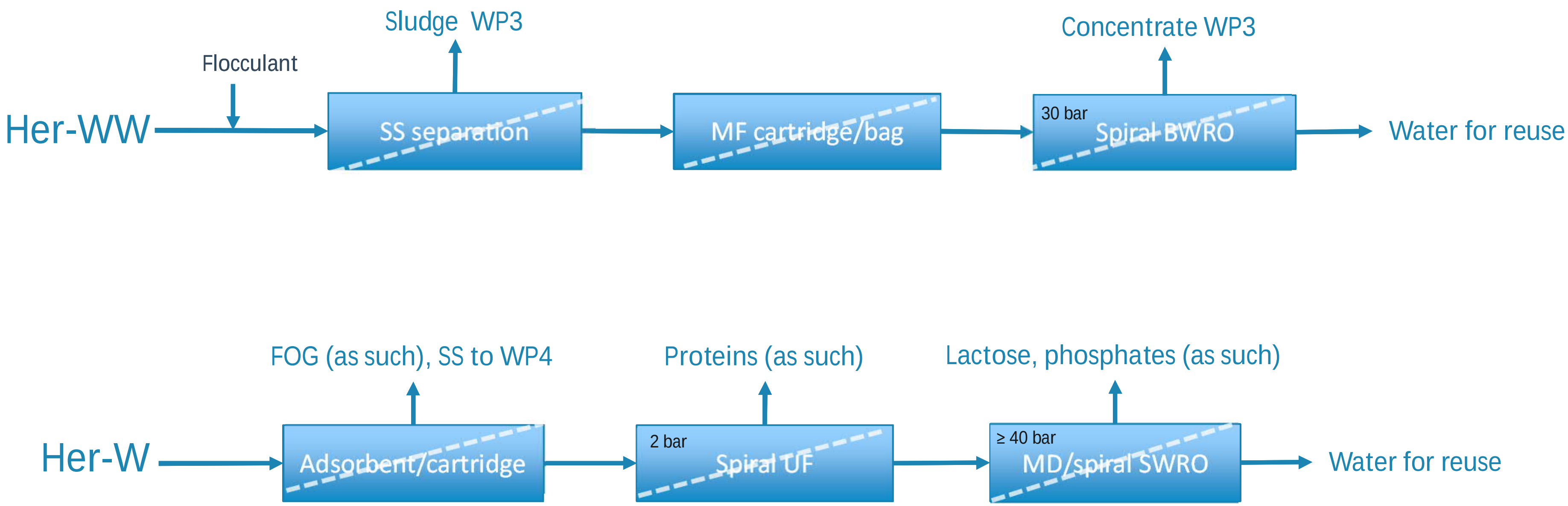
Concepts, Jake



Concepts, Citromil



Concepts, Heritage



RO-water quality

Sample	Jake-WW	PHA ferm Jake-WW	Cit-EO	Cit-JL	Her-WW	Her-W
pH	3.3	7.7	3.2	4.8	7.0	3.5
Conductivity, mS/cm	0.17	0.47	0.3	0.04	0.35	0.20
COD, mg/l	180	890	100	340	33	290
P total, mg/l	<1	<1	<1	<1	<1	<1
N total, mg/l	<1	<1	5.7	<1	<1	3.1
Cr, mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0013
Cu, mg/l	0.28	0.022	0.021	0.0041	0.0034	0.0088
Ni, mg/l	<0.0005	0.00051	<0.0005	<0.0005	0.0012	<0.0005
Zn, mg/l	0.016	0.024	0.008	0.005	0.004	0.004
Pb, mg/l	0.0031	0.00038	0.00034	0.00021	<0.0001	0.00023
As, µg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cd, µg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sb, µg/l	0.49	0.29	0.19	<0.1	<0.1	0.22
Hg, µg/l	0.4	<0.02	<0.02	<0.02	<0.02	<0.02
Fe, mg/l	0.010	0.006	0.048	0	0.61	0.014
B, mg/l	0.036	1.08	0.026	0.064	0.15	0.010

Conclusions

- Planned key exploitable results
  - Development of a cost-effective cascade of membrane filtration units for the separation and concentration of wastewater
- Realized results
  - Filtration concepts made for valuables recovery and water reuse with 70% water recovery, considering
    - Availability in large scale
    - Low-fouling technologies
    - Maximum cost-efficiency: high flux, high water recovery, concentration factor
    - Good quality water for reuse with “fit for purpose” principle

Thank you!

Antti.Gronroos@vtt.fi

Hanna.Kyllonen@vtt.fi

INNOVEN
INNOVATION FOR THE ENVIRONMENT

AFTERLIFE

Production of bio-based Volatile Fatty Acids from organic waste as chemical building blocks

Stakeholder Workshop - 9th Oct 2020

AFTERLIFE has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No. 745737 .

Outline

- What are VFAs building blocks?
- Where and how are bio-based VFAs/bioplastics considered at EU level?
- Configuration strategies for VFAs production within the AFTERLIFE project;
- Conclusion

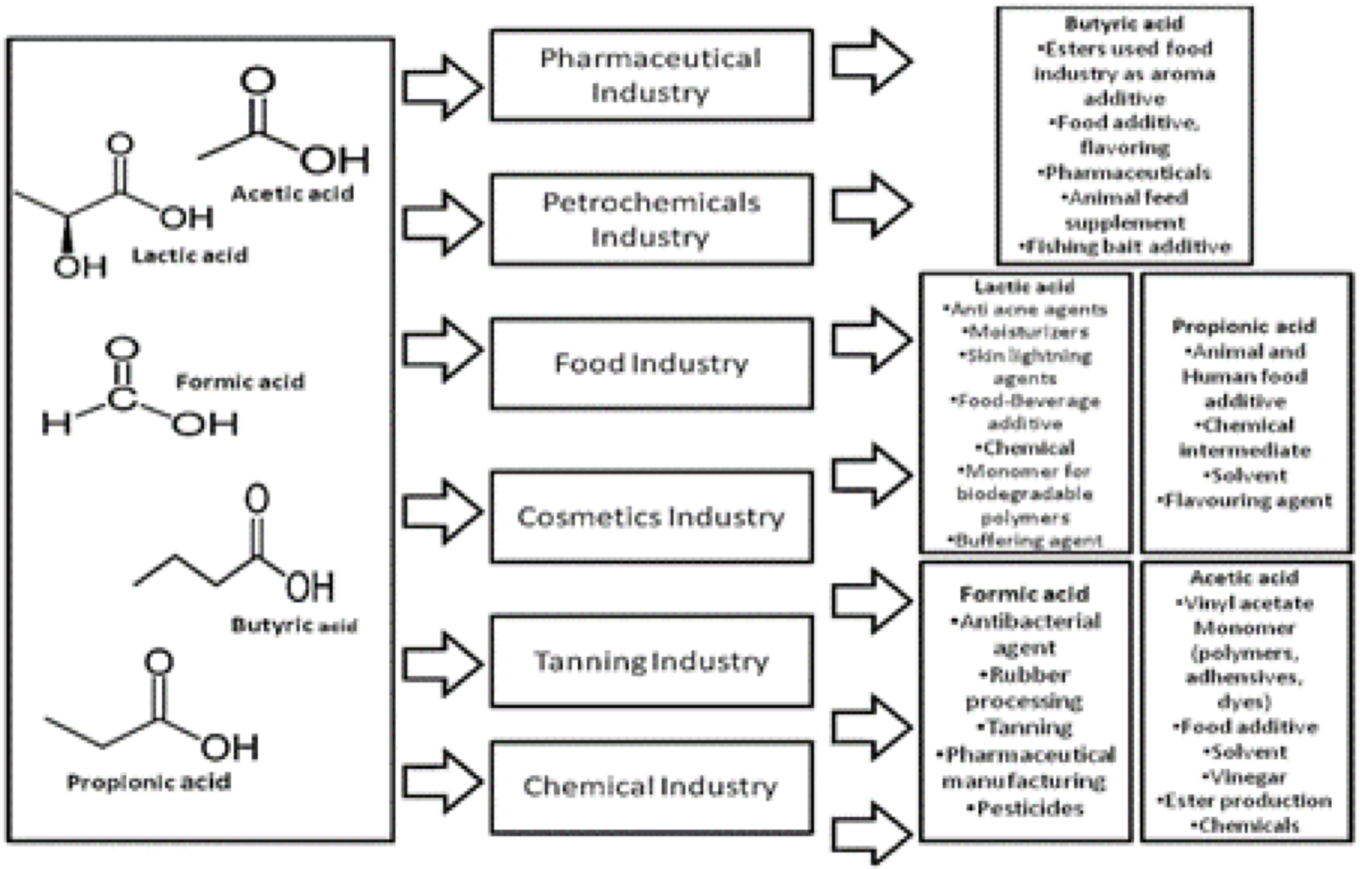
VFAs as buidling blocks

Industrial applications

VFAs applications:

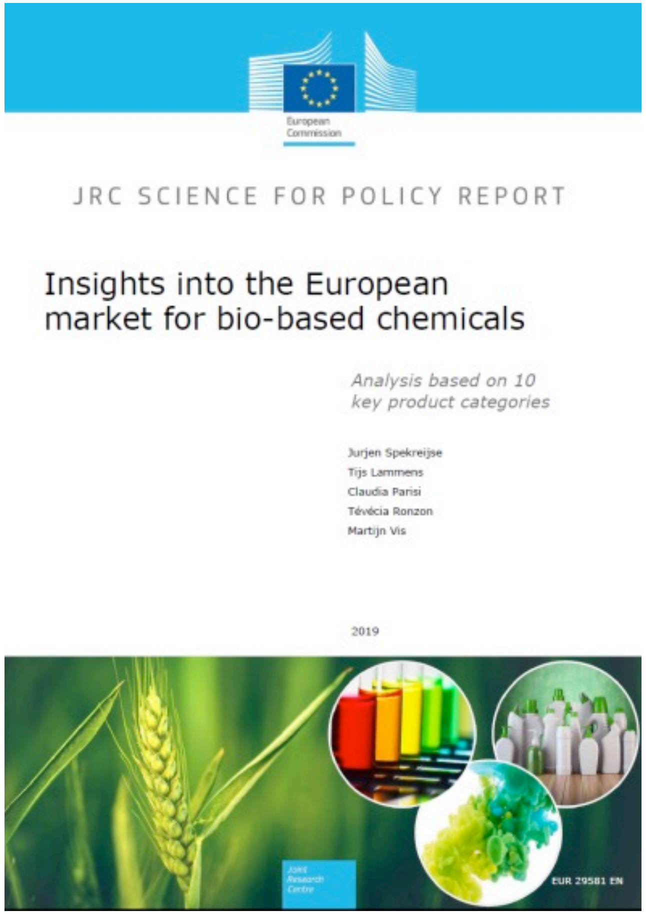
- Pharamaceutics
- Food/Feed additives
- Chemicals
- Petrolchemical industry

…



VFAs as bio-based molecules

in the EU scenario


European Commission

JRC SCIENCE FOR POLICY REPORT

Insights into the European market for bio-based chemicals

Analysis based on 10 key product categories

Jurjen Spekreijse
Tijs Lammens
Claudia Parisi
Tévécia Ronzon
Martijn Vis

2019

EUR 29581 EN

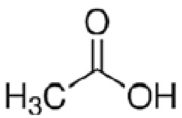
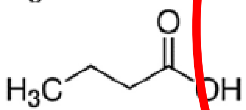
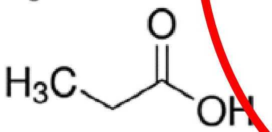
New databases of interesting and innovative bio-based compounds for EU open new market opportunities

The **European Green Deal** would accelerate the industry transition to a more sustainable model, supporting the **circular design** of all products by prioritising the reduction and reutilisation of materials before recycling. (European Green Deal 2019).

Most interesting bio-based chemicals and polymers for plastics

Platform chemicals

- Ethylene
- Ethylene glycol
- Propylene glycol (1,2-propanediol)
- 1,3-Propanediol
- Acetic acid
- Acetic anhydride
- Sebacic acid
- Lactic acid
- Epichlorohydrin

VFAs	Chemical formula	Market size (kton/year)	Market price (€/ton)	Usage/application	Production methods	References
Acetic acid		14000–17000	400–800	Vinyl acetate monomer (polymers, adhesives, dyes), Food additive, Solvent, Vinegar, Ester production, Chemicals	Chemical synthesis (carboxylation of methanol) and microbial fermentation (oxidative and anaerobic)	Bhatia and Yang (2017))
Butyric acid		90–105	1500–1650	Animal and human food additive, Chemical intermediate, Solvent, Flavouring agent	Chemical synthesis (oxidation of butyraldehyde), Extraction from butter, microbial fermentation	Zigová and Šturdík (2000)
Propionic acid		350–470	2000–2500	Esters used food industry as aroma additive, Food additive, flavoring, Pharmaceuticals, Animal feed supplement, Fishing bait additive	Chemical Synthesis (ethylene hydro formylation, carboxylation of ethylene, direct oxidation of hydrocarbons), by product of acetic acid manufacturing, microbial fermentation	Cheryan (2009)

Share of bio-based chemicals

in the EU scenario

Product category	EU bio-based production (kt/a)	Total EU production (kt/a)	EU bio-based production share (%)	EU bio-based consumption (kt/a)
Platform chemicals	181	60,791	0.3	197
Solvents	75	5,000	1.5	107
Polymers for plastics	268	60,000	0.4	247
Paints, coatings, inks and dyes ([a])	1,002	10,340	12.5	1,293
Surfactants	1,500	3,000	50.0	1,800
Cosmetics and personal care products ([a])	558	1,263	44.0	558
Adhesives ([a])	237	2,680	9.0	320
Lubricants ([a])	237	6,764	3.5	220
Plasticisers ([a])	67	1,300	9.0	117
Man-made fibres	600	4,500	13.0	630
Total	4,725	155,639	3.0	5,489

([a]) No total EU production data were found; it has been assumed that total EU production (fossil- and bio-based) equals the total EU market (fossil- and bio-based consumption).

Price of bio-based chemicals

in the EU scenario

Product category	Price (EUR/kg)	Turnover (EUR million/a)
Platform chemicals	1.48	268
Solvents	1.01	76
Polymers for plastics	2.98	799
Paints, coatings, inks and dyes	1.62	1,623
Surfactants	1.65	2,475
Cosmetics and personal care products	2.07	1,155
Adhesives	1.65	391
Lubricants	2.33	552
Plasticisers	3.60	241
Man-made fibres	2.65	1,590
Total	1.94	9,167

Product category	CAPEX	Replacement investments		Expansion investments		Total private investment	
	Million EUR/kt	Million EUR/a	Million EUR 2018-2025	Million EUR/a	Million EUR 2018-2025	Million EUR/a	Million EUR 2018-2025
Platform chemicals	3	54	380	74	515	128	896
Solvents	1.9	14	100	1	10	16	110
Polymers for plastics	3.7	99	694	45	313	144	1,007
Paints, coatings, inks and dyes	3.6	361	2,525	77	536	437	3,061
Surfactants	3.7	555	3,885	250	1,753	805	5,638
Cosmetics and personal care products	4.7	262	1,837	86	603	349	2,440
Adhesives	3.5	83	581	112	787	195	1,368
Lubricants	2.4	57	398	6	41	63	439
Plasticisers	5.8	39	273	13	90	52	363
Man-made fibres	6.2	372	2,604	122	855	494	3,459
Total		1,897	13,277	786	5,505	2,683	18,782

AFTERLIFE

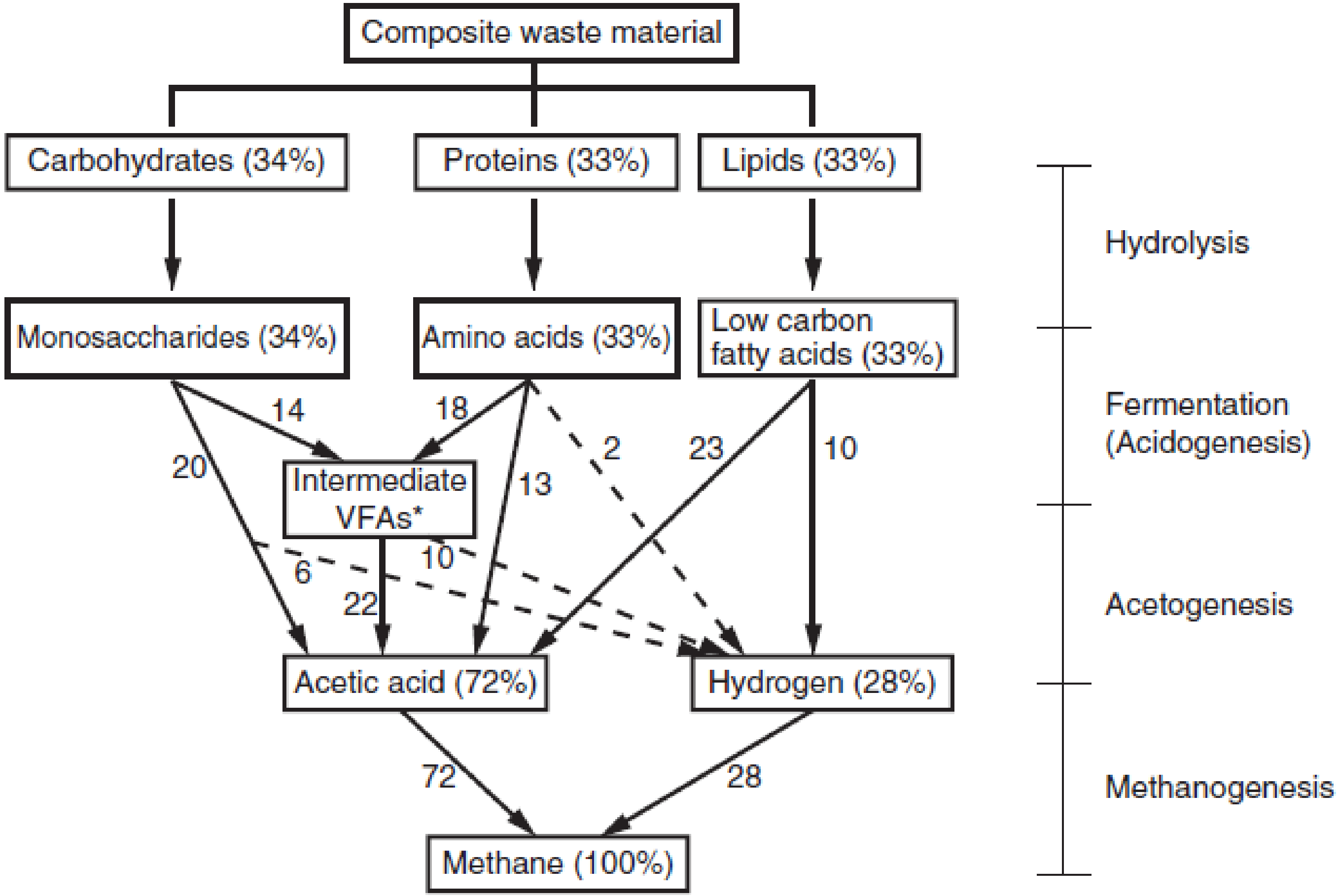
VFAs production

From waste raw materials to VFAs

INNOVEN INNOVATION FOR THE ENVIRONMENT





* Propionate, butyrate, valerate

The **feeding** affects the metabolic pathway

Max theoretical yield of Acetic Acid production: **72%**

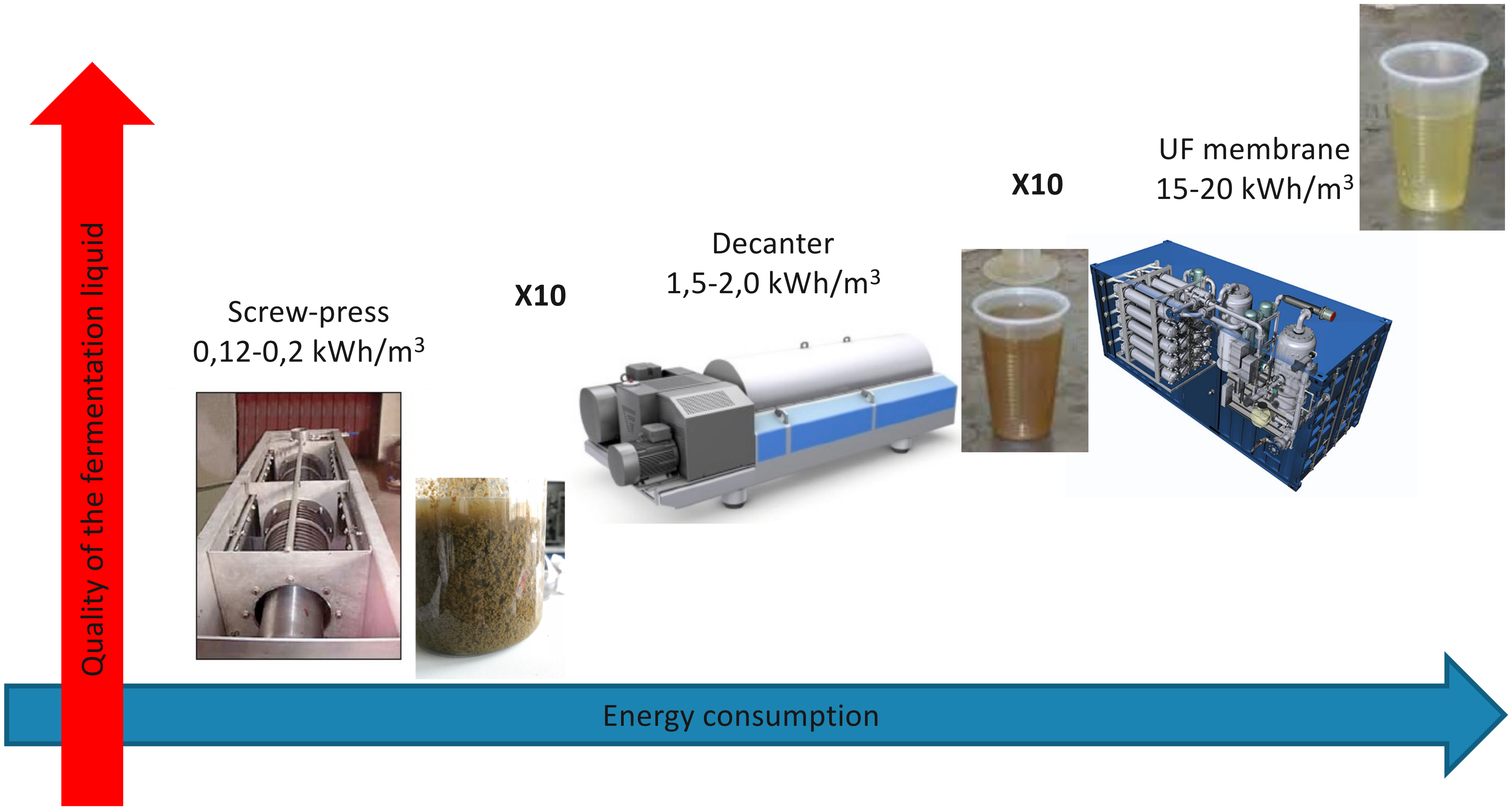
Acidogenesis and **Acetogenesis** should be balanced to optimze the production and composition of the VFAs

Solid/liquid separation

VFAs recovery

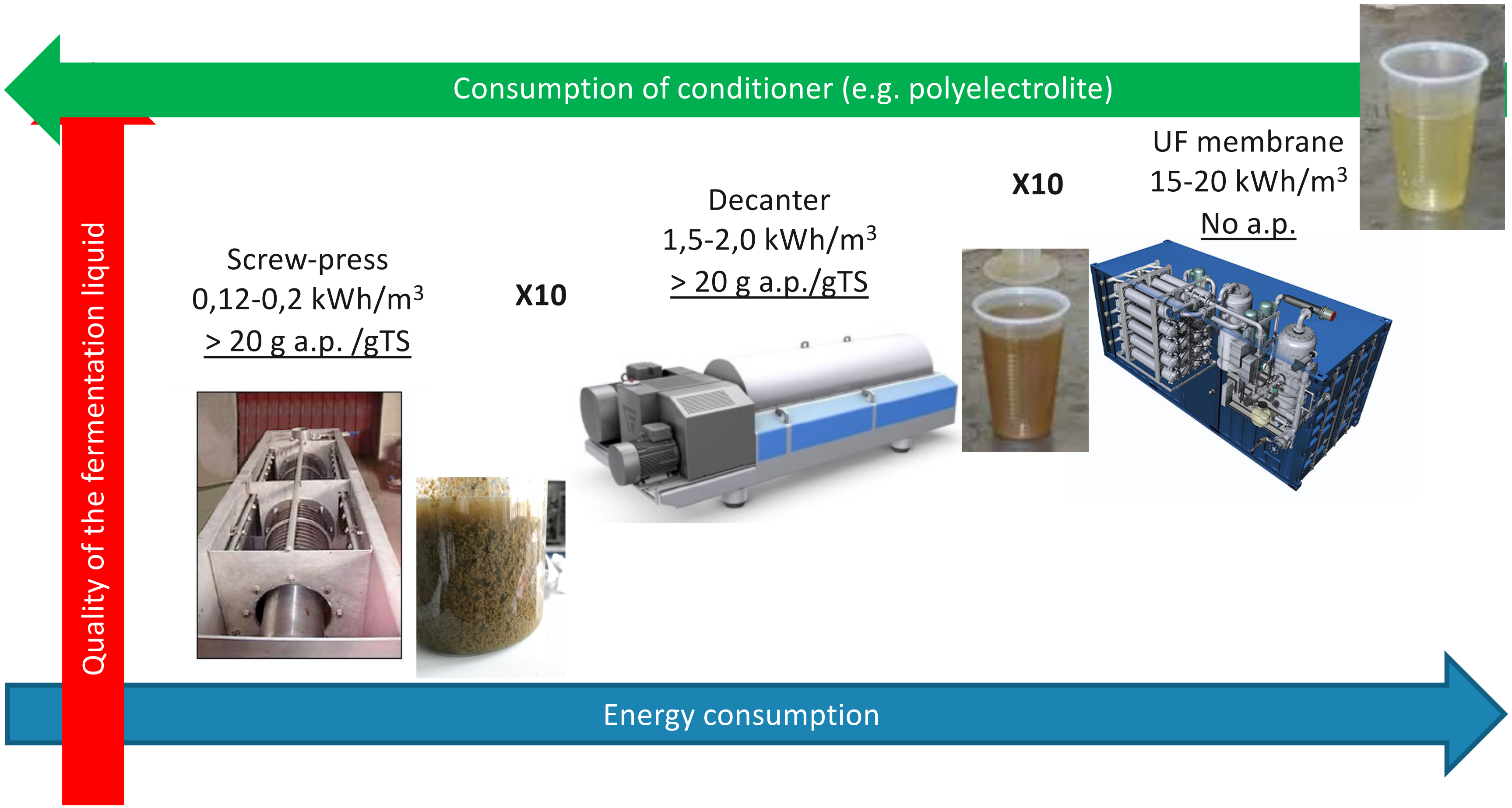
Solid/liquid separation

VFAs recovery



Solid/liquid separation

VFAs recovery

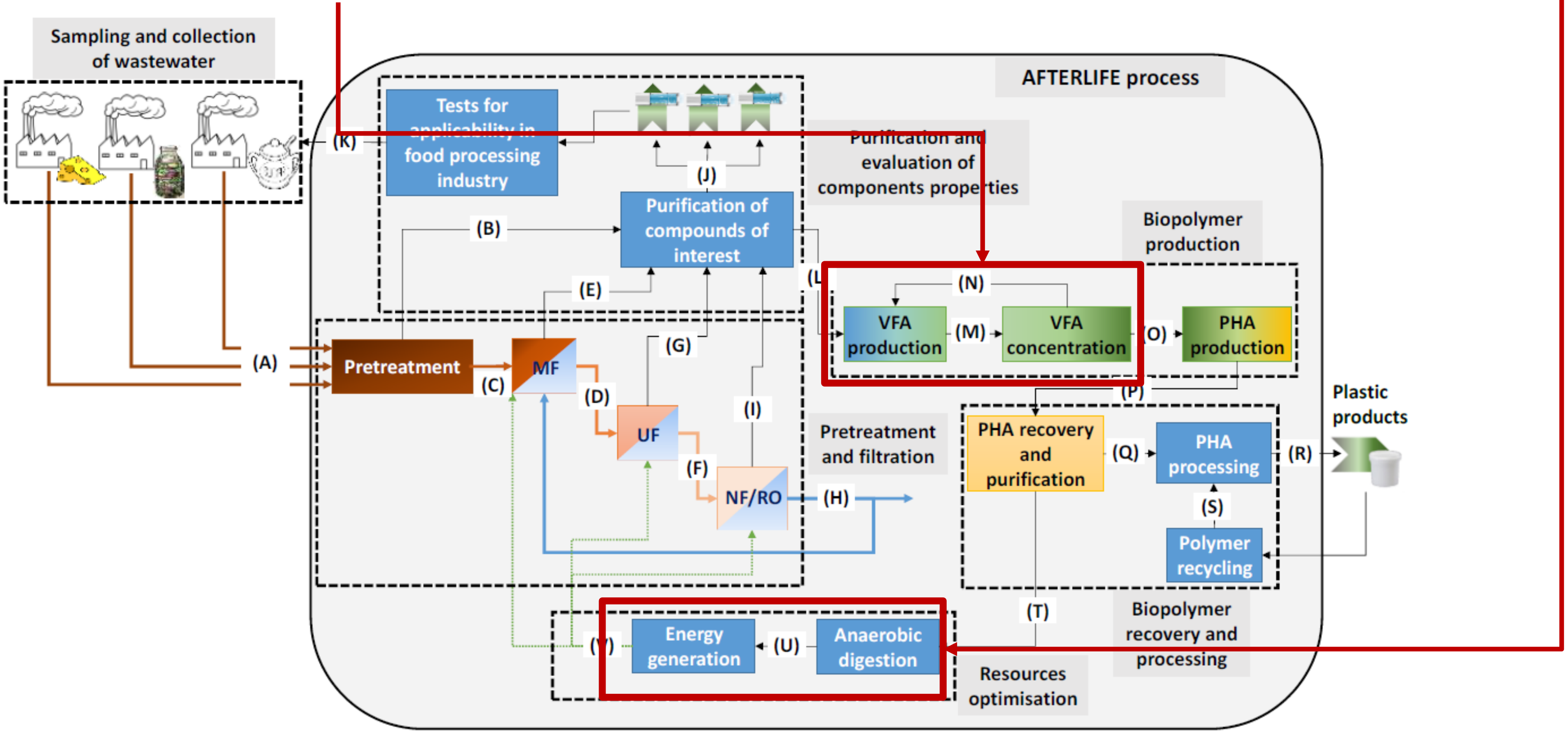


Afterlife purpose

VFAs production from 3 food industrial wastewaters

Volatile fatty acids (VFA) production, concentration and purification

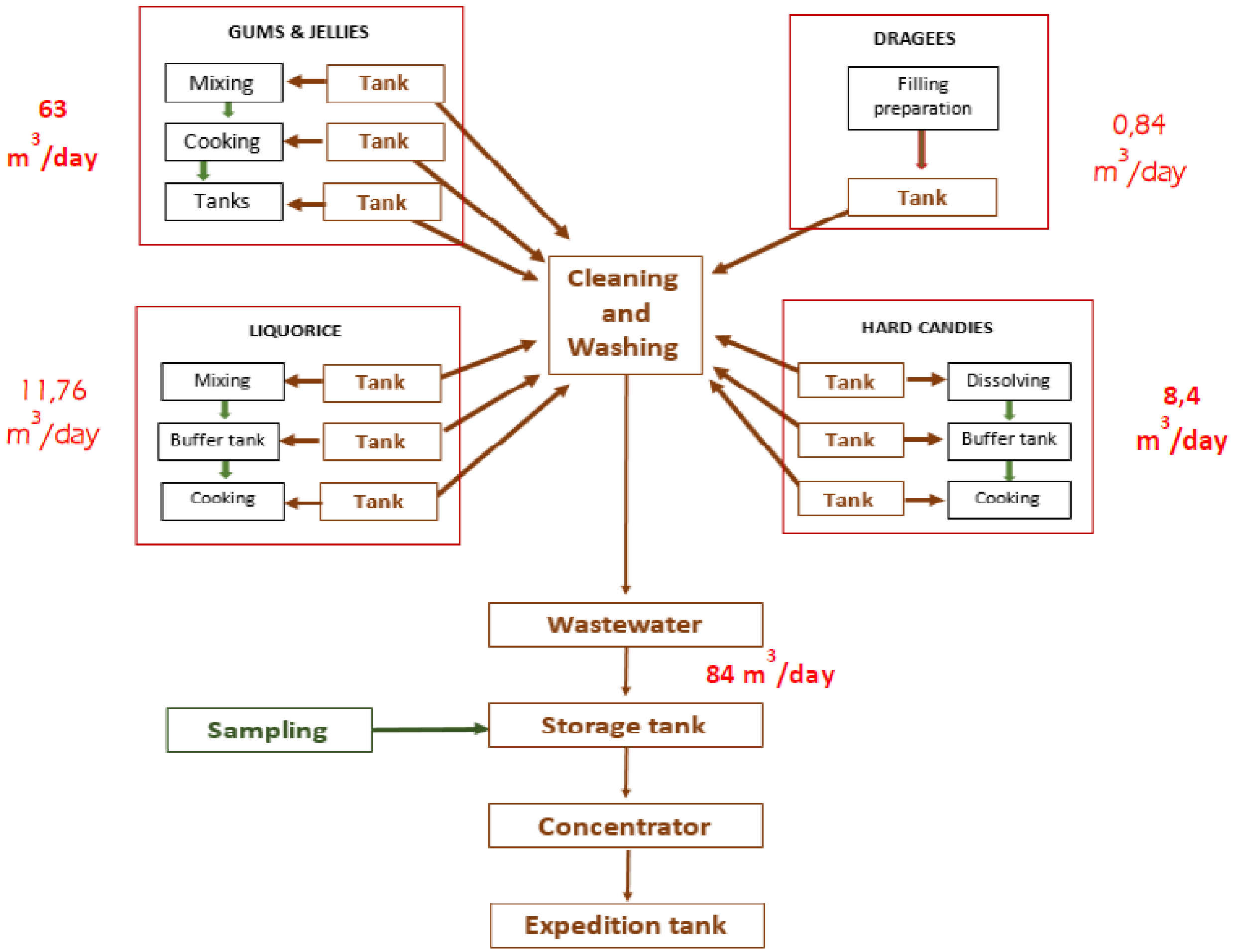
Anaerobic digestion of the solid residues from the process



Afterlife substrates for VFAs production

Food Industry Feedstocks

Jake wastewater



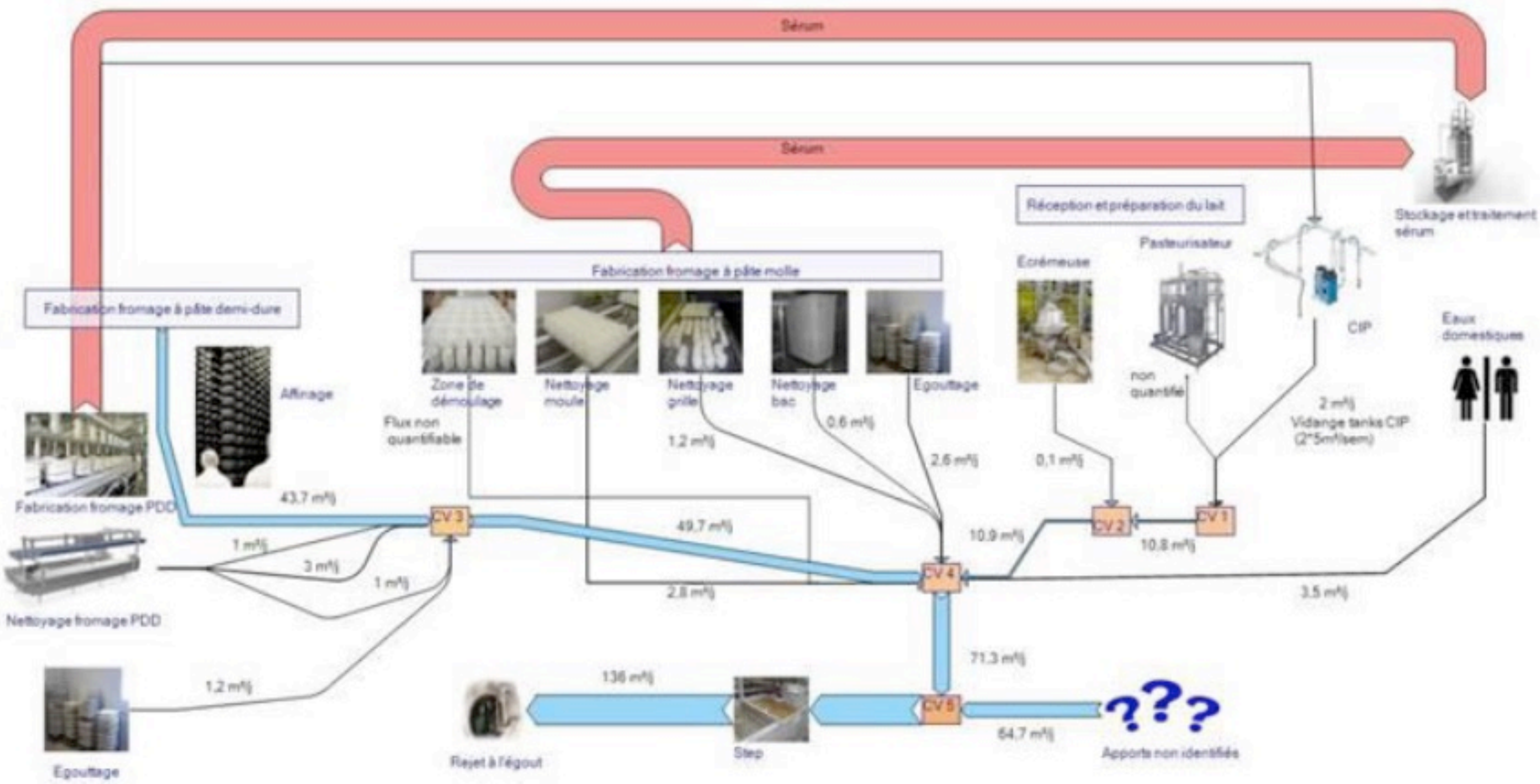
AFTERLIFE

INNOVEN
INNOVATION FOR THE ENVIRONMENT

Afterlife substrates for VFAs production

Food Industry Feedstocks

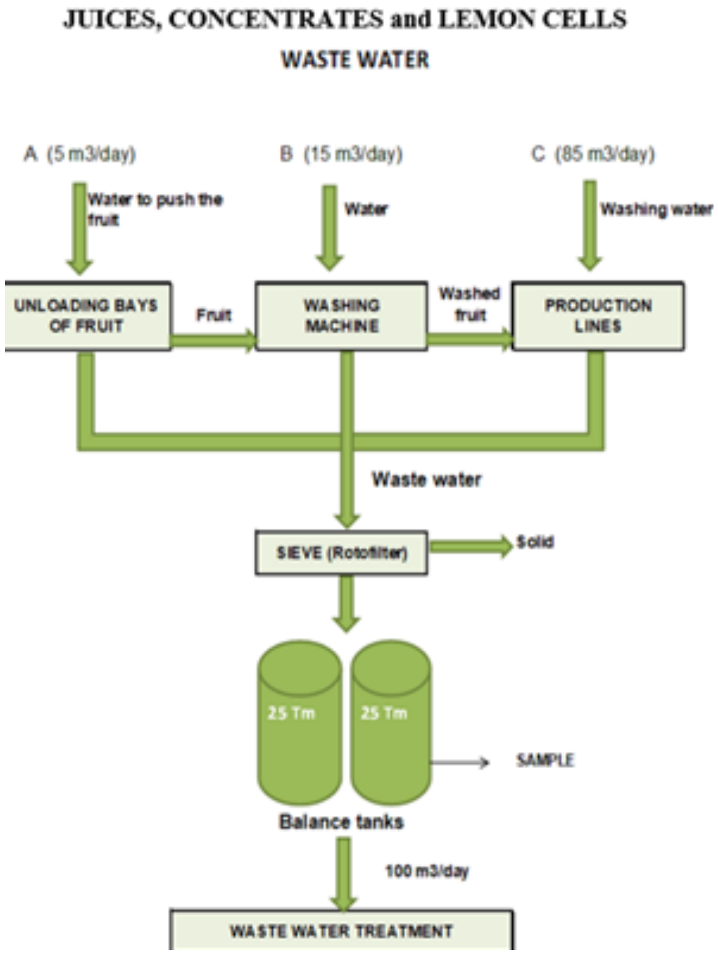
Heritage wastewater

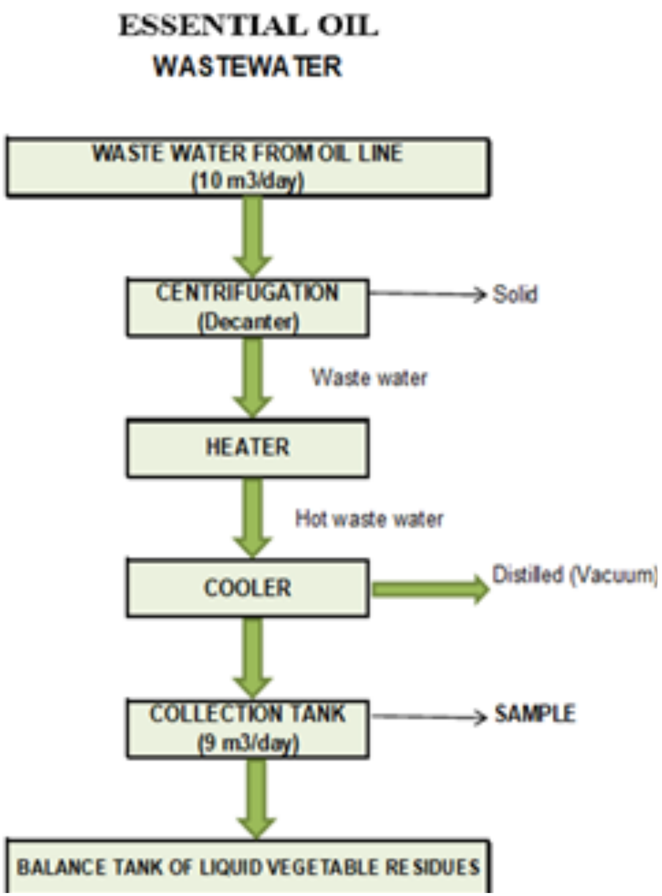


Afterlife substrates for VFAs production

Food Industry Feedstocks

Citromil wastewater





AFTERLIFE

INNOVEN INNOVATION FOR THE ENVIRONMENT

Afterlife substrates for VFAs production

Food Industry Feedstocks

Substrates characterization for anaerobic fermentation

Parameter	Unit	Jake ww	Heritage ww	Citromil JL	Citromil EOL
TS	%	7,9	4,4	18,5	4,1
TVS/TS	%	96	89	88	31
tCOD	gCOD/L	97,4	61,6	36,8	2,5
sCOD	gCOD/L	88,2	52,6	23,1	2,1
TKN	mgN/gTS	23,2	31,3	7,3	4,4
NH4-N	mgN/L	0,9	0,9	0,4	3,5
TP	mgP/gTS	2,9	10,8	1,7	0,7

AFTERLIFE

Afterlife process

VFAs production

INNOVEN
INNOVATION FOR THE ENVIRONMENT

Membrane filtration
Recovery ofVFAs-rich liquid fraction

VFAs

Jake ww
27,9 ton/d

Liquid fraction
23,7 ton/d

Influent WW → Acidogenic fermentation → Centrifuge → Ultrafiltration → PHAs production

Solid fraction
4,2 ton/d (15%)

Solid fraction

Anaerobic digestion

Biogas

Valorization of the solid fraction for biogas production at pilot scale

Bioreactors used for the VFAs production

under semi-continuous conditions

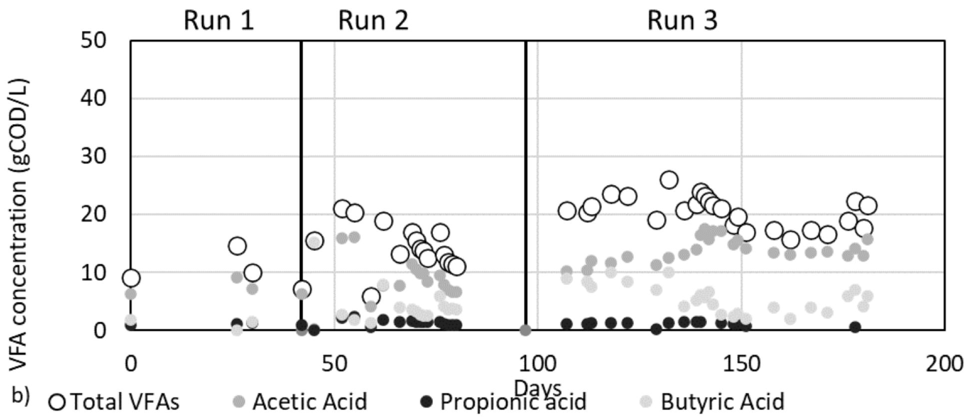
Acidogenic fermentation units

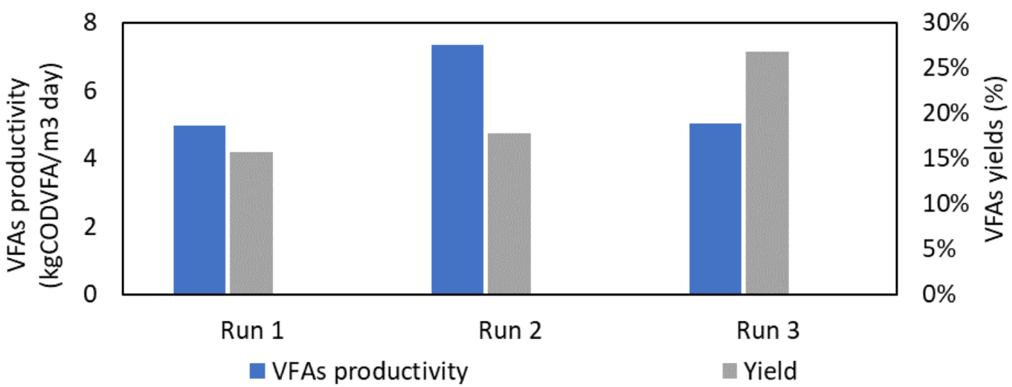
- 5 and 10 L auto-feeding
- Automatic mixing
- Heating jacket
- Automatic digestate outflow removal

VFAs production

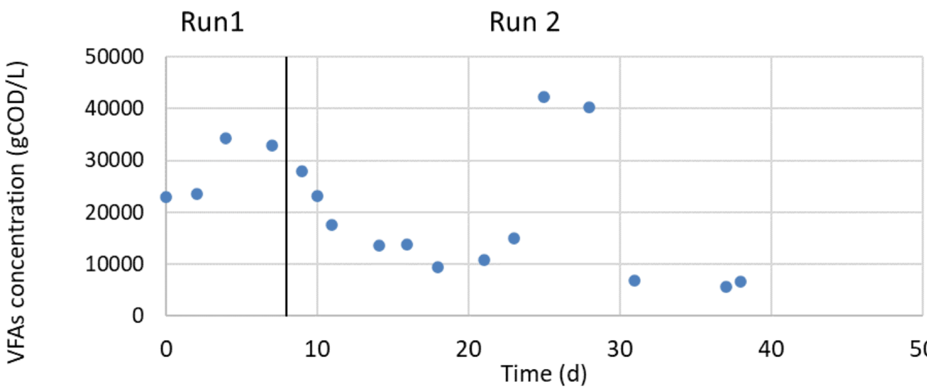
VFAs amount and yields for Jake and Heritage ww

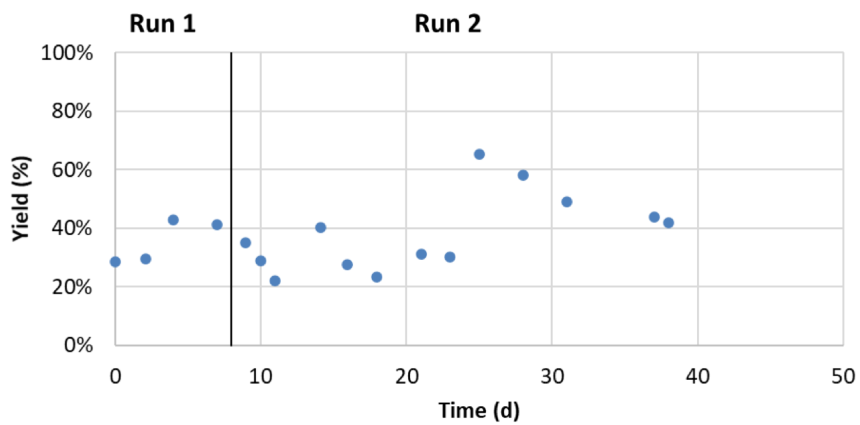
Jake ww fermentation





Heritage ww fermentation





Conclusions

- VFAs are bio-based molecules suitable for different **industrial applications**

- VFAs can be produced from different **raw materials**, allowing **industrial waste valorization**

- VFAs production, in the Afterlife scenario, was succesfully performed using **anaerobic fermentation**:
  - Jake ww: 27% COD converted to VFAs (20gCOD/L)
  - Heritage ww: 20-40% COD converted to VFAs (10gCOD/L)
  - Citromil ww: 40% COD converted to VFAs (7-20 gCOD/L)

- **Solid/liquid separation** of the fermentation effluent was succesfully performed:
  - The VFAs-rich liquid fraction was used for PHAs production
  - The solid fraction was employed for biogas and fertilizers production

Thank you for your attention

AFTERLIFE

PHA production from industrial waste streams as part of sustainable plastics production towards a circular plastics economy

OCTOBER, 9TH 2020 (AFTERLIFE ONLINE WORKSHOP)

BY: OLIVER DRZYZGA (EU PROJECT & SUSPLAST PLATFORM MANAGER AT CIB-CSIC, MADRID, SPAIN)

Margarita Salas

BIO-BASED INDUSTRIES Public-Private Partnership

Bio-based Industries Consortium

Horizon 2020 European Union Funding for Research & Innovation

AFTERLIFE has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No. 745737 .

Interdisciplinary Thematic Platforms of CSIC
(*Plataformas Temáticas Interdisciplinares*, PTI)

- Joining the knowledge of CSIC expert groups with other groups from companies, universities, public research bodies, administration, and social agents
- Addressing well defined challenges, within specific deadlines, with clear milestones

Connecting with the **"Global Challenges"**

One of the novel CSIC PTIs is SusPlast:

"Interdisciplinary Platform for Sustainable Plastics towards a Circular Economy"

Interdisciplinary Platform for Sustainable Plastics towards a Circular Economy

Our "plastic" mission:

*SusPlast aims to develop research and innovation activities, including socio-educational strategies, aimed at plastic production processes and their recycling, **through mechanical, chemical and biotechnological strategies** to meet the necessary requirements to implement plastics management based on a circular economy.*

SusPlast
Interdisciplinary Platform for Sustainable Plastics towards a Circular Economy

14 SusPlast CSIC partner institutes in Spain

Private partners supporting SusPlast

- RÖCHLING STIFTUNG – Konsequent in Verantwortung
- aitiip centro tecnológico
- REPSOL
- Ercros
- RECIAMBIENTE
- ainia
- EvoEnzyme – Customized Biocatalysts
- Hispanagar – Oceans of Experience
- Ocenic resins
- AIMPLAS – Instituto Tecnológico del Plástico
- DARWIN – Bioprospecting Excellence
- INNOVAMED
- PYRATES smart fabrics
- ecoembes
- Ingénica
- Viscofan – The casing company
- Biopolis – Tailor-made Biotechnology
- ECONWARD TECH
- Centro Tecnológico ITENE
- solteco madera plástica
- PlasticsEurope – Productores de Materias Plásticas
- Agromark – Fresh produce from Spain
- tecnalia – Corporación Tecnológica
- ZOITECH lab

Current projects on polymers, plastic & bioplastic issues and their focus areas that are part of SusPlast platform:

H2020 – NMBP
- MIX-UP
- SinFonia
- engicoin
- DAFIA

H2020 – BBI
- BIZENTE
- SUSBIND
- URBIOFIN
- WOODZYMES
- AFTERLIFE
- REFUCOAT

H2020 – CE/CIRC
- BLACK CYCLE
- CarE-Service

H2020 - SPIRE
- iCAREPLAST

H2020-INFRAIA
- IBISBA

H2020 – ERA
- MIPLACE
- MiLiMo
- BIOCARB-4-FOOD

SusPlast

Interdisciplinary Platform for Sustainable Plastics towards a Circular Economy

Find us at:

www.susplast-csic.org

Biological Research Center (CIB-CSIC), Madrid (Spain)

Dr Oliver Drzyzga: EU Project manager & SusPlast platform manager (www.susplast-csic.org)

Polymer Biotechnology Group: Prof Auxiliadora Prieto

Results: MSc Natalia Hernández Herrero

AFTERLIFE

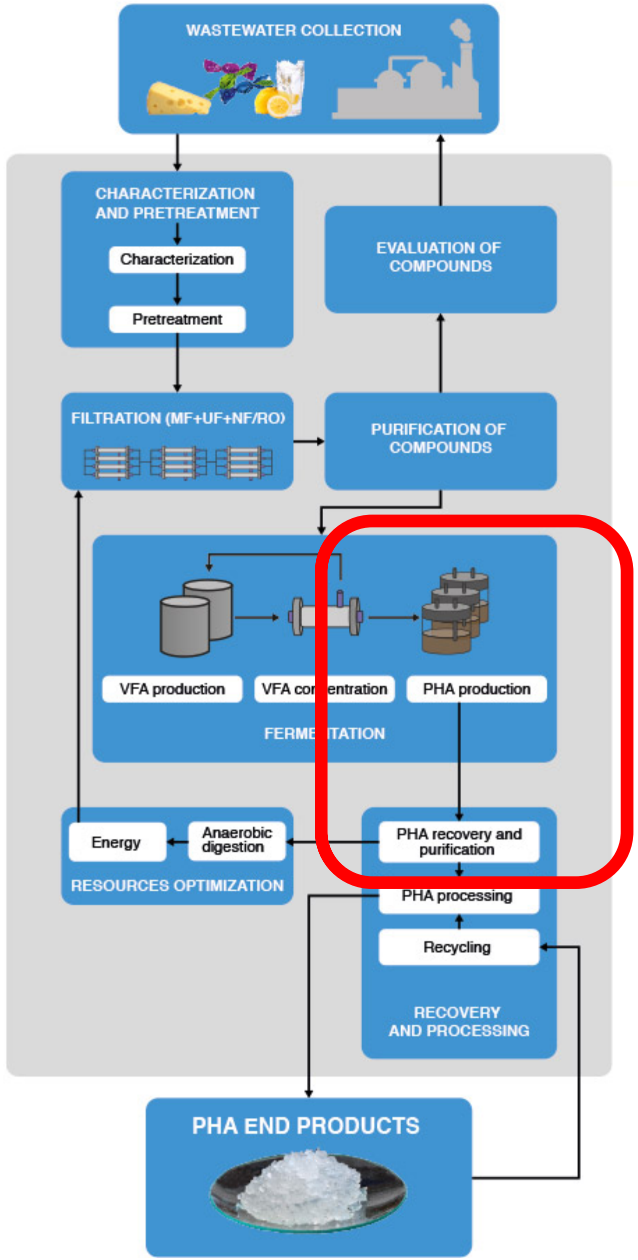
AFTERLIFE – **A**dvanced **F**iltration **TE**chnologies for the **R**ecovery and **L**ater conversIon of releVant Fractions from wastEwater

Sweets manufacturer

Lemons, oranges and mandarins processing

Cheese manufacturer

THE PROCESS



Margarita Salas

WP3 - PHA production and processing

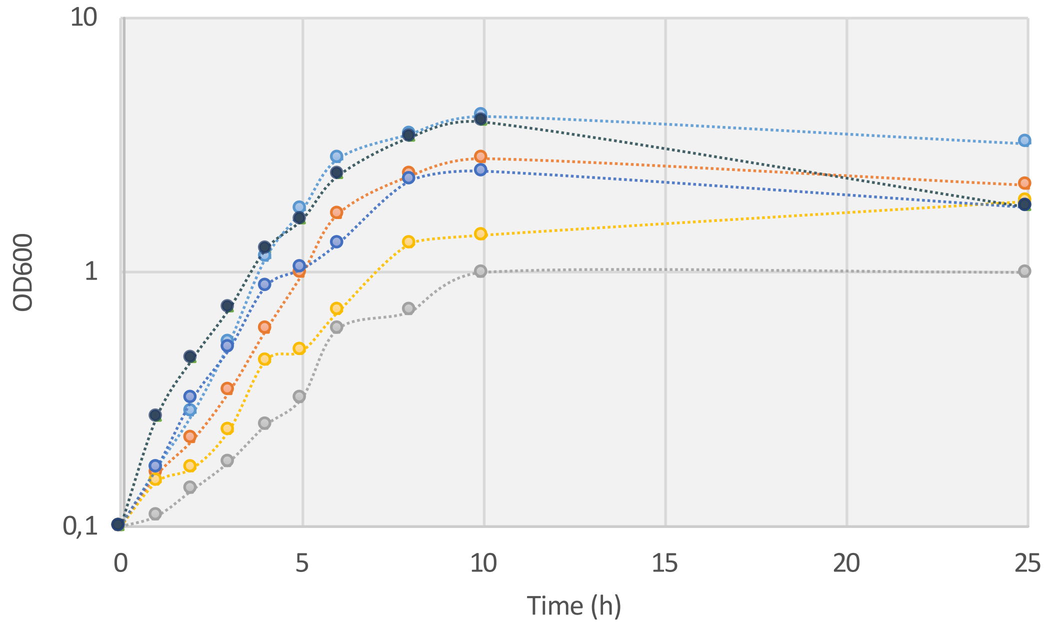
AFTERLIFE

Margarita Salas

Selection of a bacterial strain for the conversion of VFA into PHA

Candidate strains provided by ADM, Biopolis (Tailor-made Biotechnology) → **VFAs-consuming** / **PHA producers**

Rich media (Nutrient Broth)



	μ (h^{-1})	OD max.
A. latus	**0.41**	**4.1**
P. hydrogenovora	**0.35**	**2.8**
C. segnis	0.25	1
B. megaterium DSM 90	0.28	1.9
B. megaterium ATCC 13632	**0.35**	**2.5**
C. necator	**0.39**	**3.9**

AFTERLIFE

Selection of a bacterial strain for the conversion of VFA into PHA

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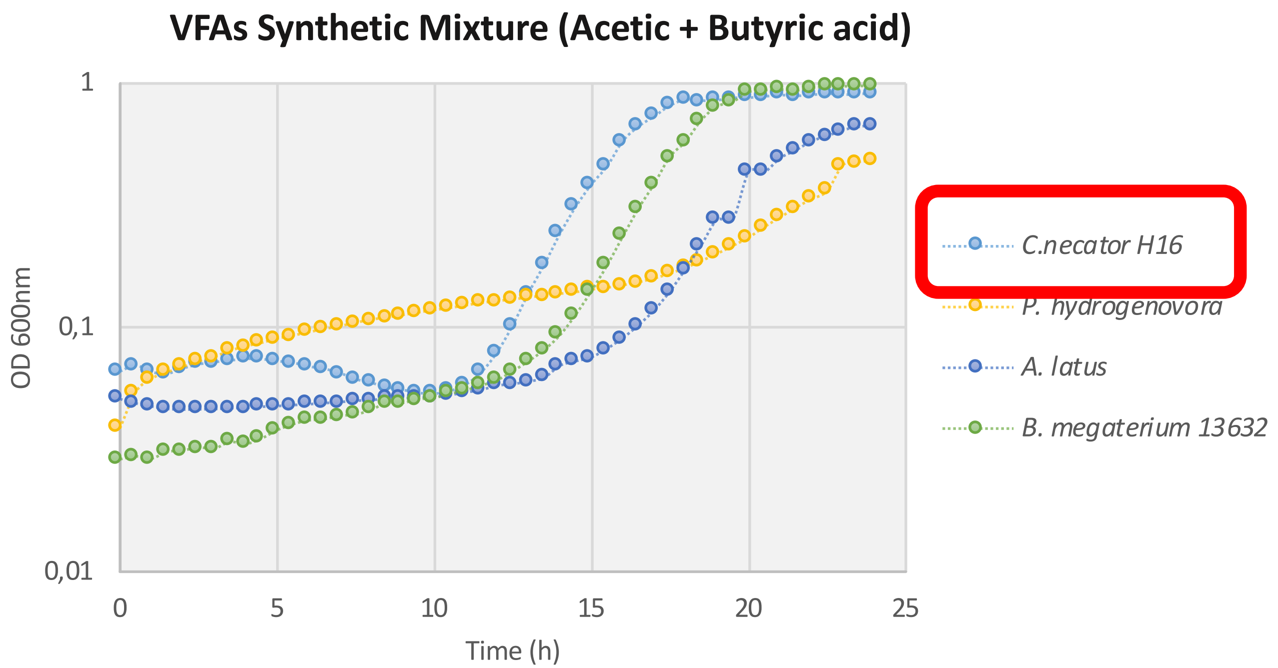
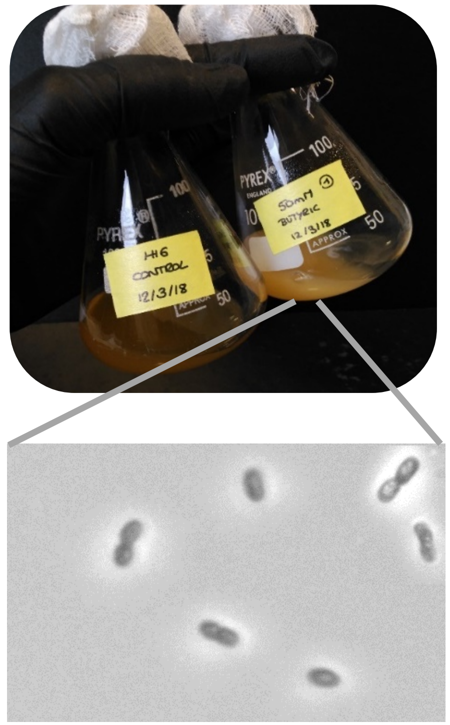
Candidate strains provided by ADM BIOPOLIS Tailor-made Biotechnology → **VFAs-consuming** **PHA producers**





C. necator H16 cells

- *C. necator* H16 was selected as the best candidate for the Afterlife project

AFTERLIFE

Synthesis of biopolymer at laboratory scale using the selected strain

Cupriavidus necator H16 → PHA production

Samples	Type of Sample	Shipment from	Data of receipt	Quantity of sample receipt (L)
JAKE	Raw WW. Centrifuge and ultrafiltration (0,2 µm)	INN	January 2019 June 2019 September 2019	5 L 10 L 25 L
Heritage 1466	Cheese Whey	INN	November 2019	3 L
Citromil	Essential oil WW	INN	December 2019	10 L

AFTERLIFE

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Synthesis of biopolymer at laboratory scale using the selected strain

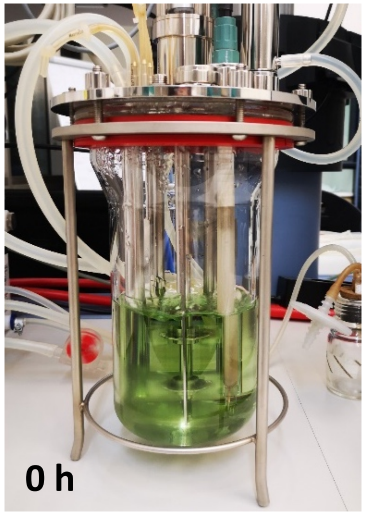
Jake fermented WW

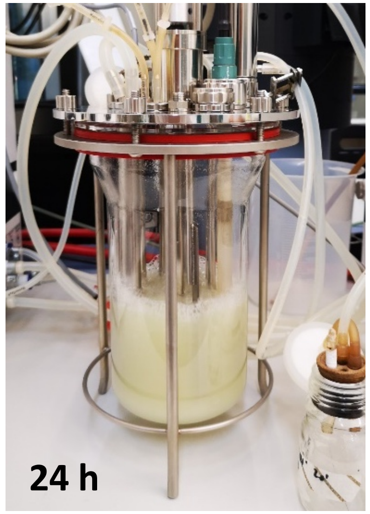
Lactic 45% | Acetic 36% | Ethanol 11% | Butyric 9%

→ VFAs: 13.40 g/L
Total: 37.05 g/L

SUMMARY

- Selected strain
  - *Cupriavidus necator* H16
- Substrate concentration and feeding policy
  - 2.5 g/L of VFAs as initial concentration (6.7 g/L in total)
  - Fed-batch: Flow rate 30 mL/h
  - More than 5 g/L of VFAs delay bacterial growth (13.40 g / L in total)





Time (h)	CDW (g/L)	PHA (g/L)	PHA (%)	Productivity (g PHA/L/h)
30	11.66	2.95	80	0.094

AFTERLIFE

Synthesis of biopolymer at laboratory scale using the selected strain

Margarita Salas

Heritage fermented WW

Lactic 57%	Acetic 12%	Ethanol 22%	Butyric 5%

→ VFAs: 5.06 g/L
Total: 31.66 g/L

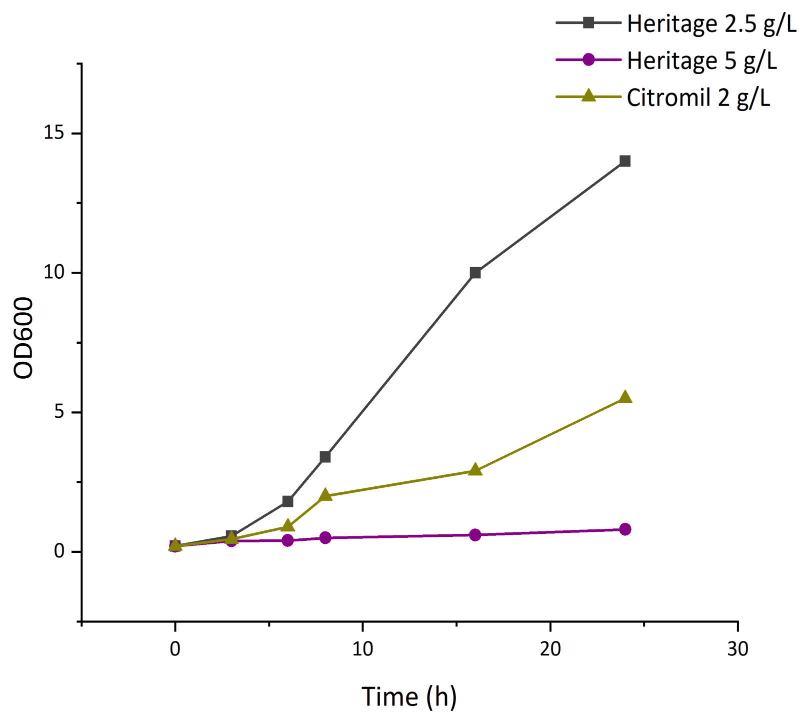
Citromil fermented WW

Lactic 60%	Acetic 40%

→ VFAs: 2.33 g/L
Total: 7.75 g/L

Results from flask scale

Stream	VFAs	Biomass 16 h	Biomass 24 h	% PHA 16 h	% PHA 24 h
Heritage 1466	2.5 g/L	2.7 g/L	3.69 g/L	56,89± 0.94	59,97± 1.88
Citromil	2 g/L	1.35 g/L	1.85 g/L	6.97± 0.93	14,62± 1.25



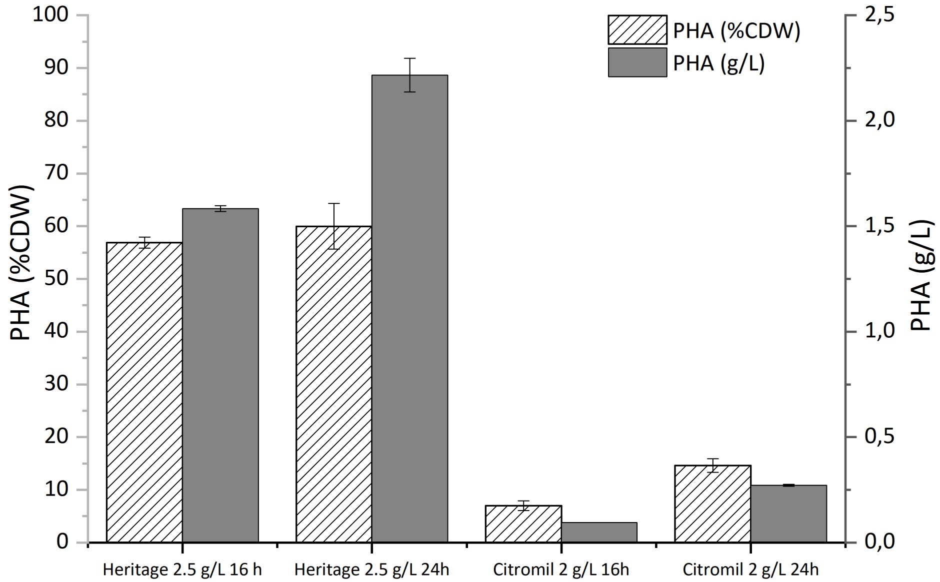
AFTERLIFE

Margarita Salas

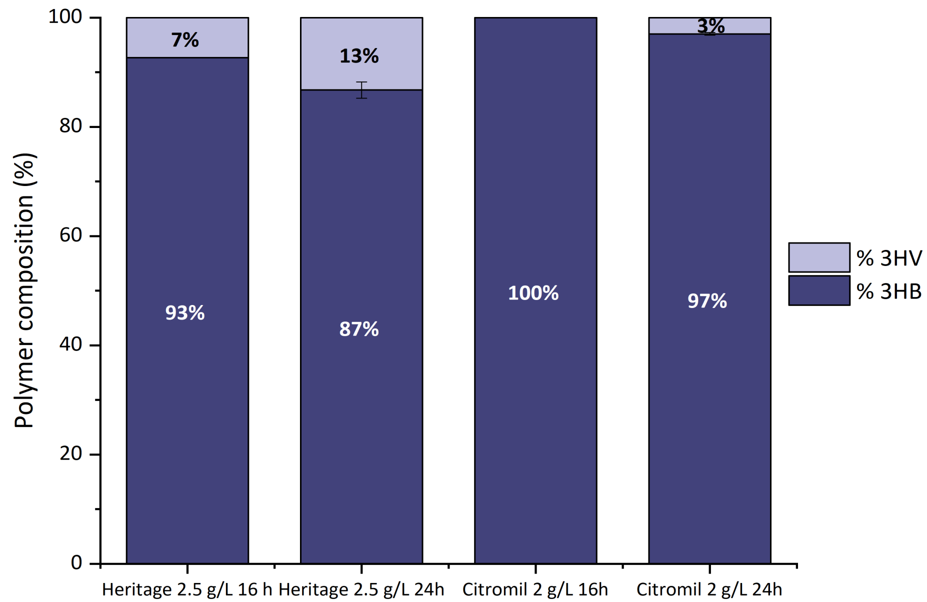
Synthesis of biopolymer at laboratory scale using the selected strain

Heritage fermented WW **Citromil fermented WW**

PHA production



Polymer composition



- *C. necator* H16 was able to obtain a PHA production of 60% using 2.5 g/L as a substrate (Heritage).
- The yield of the PHA production under batch conditions was 0.88 g PHA/g VFA (Heritage).
- The produced polymer from was composed by 3HB and 3HV units (Heritage).

AFTERLIFE

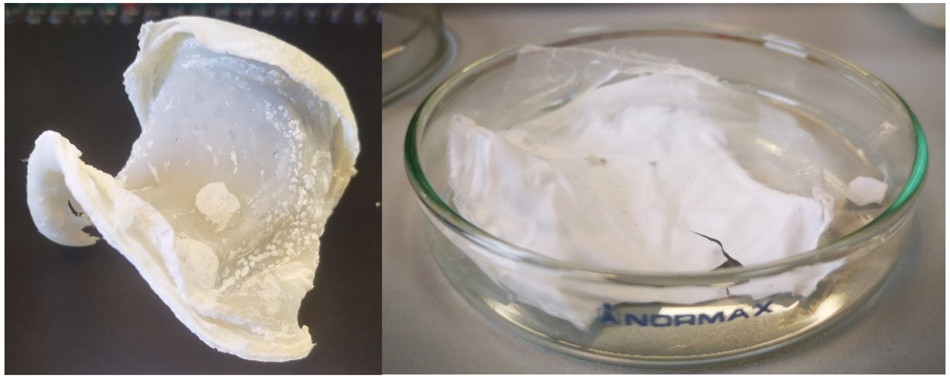
Synthesis of biopolymer at laboratory scale using the selected strain

Margarita Salas

Summary

Stream	VFAs stream concentration (g/L)	Dilution for PHA production	Initial OD	Final OD	Type of polymer	PHA 24h (%)	PHA 24h (g/L)	g PHA/g VFA
Jake*	13.82	1:5	0.2	11.65	PHB	57.21	1.19	0.52
Heritage	5.06	1:2	0.2	14.2	PHBV	59.97	2.21	0.88
Citromil	2.33	Only pH adjusted	0.2	1.8	PHBV	14.62	0.27	0.11

*Bioreactor scale 1L



PHB from Jake WW fermentation using *C. necator* H16

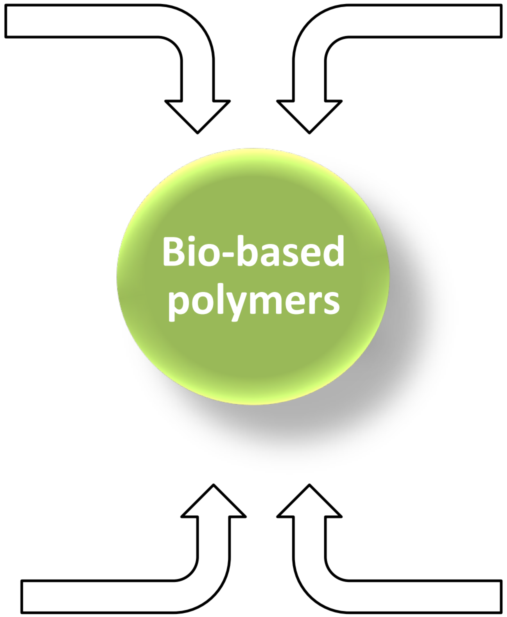
Future tasks

- Heritage 1466 WW scale-up optimization
- Polymer characterization (by NovaID partner)

Use of other carbon waste streams for PHA production:

Use of other industrial waste streams for PHA production:

Food industry



More details at:
www.refucoat.eu

RefuCoat - Full recyclable food package with enhanced gas barrier properties and new functionalities by the use of high performance coatings

Use of other industrial waste streams for PHA production:

More details at:
www.synpol.org

SYNPOL – Biopolymers from syngas fermentation

Bio-based polymers

The municipal and commercial wastes

Sludge

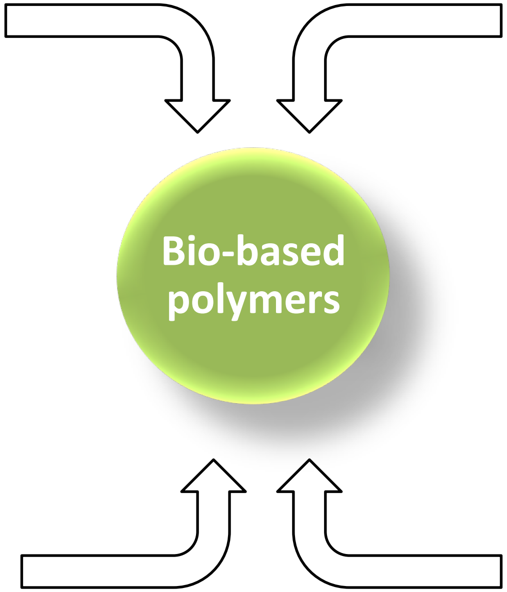
Agriculture

Use of other industrial waste streams for PHA production:

Gases (CO_2)

More details at:
www.celbicon.org

CELBICON - Cost-effective CO_2 conversion into chemicals via combination of **C**apture, **EL**ectrochemical and **BI**ochemical **CON**version technologies



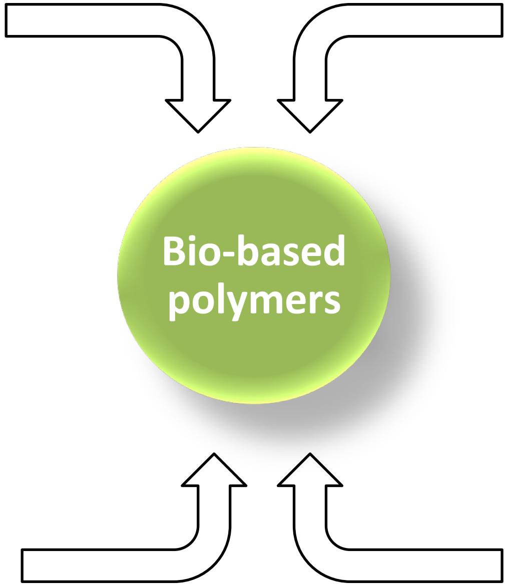
More details at:
www.engicoin.eu

ENGICOIN - **Engi**neered microbial factories for $\mathbf{CO_2}$ exploitation in an **in**tegrated waste treatment platform

Use of other industrial waste streams for PHA production:

More details at:
www.p4sb.eu

P4BS - From Plastic waste to Plastic value using Pseudomonas putida Synthetic Biology



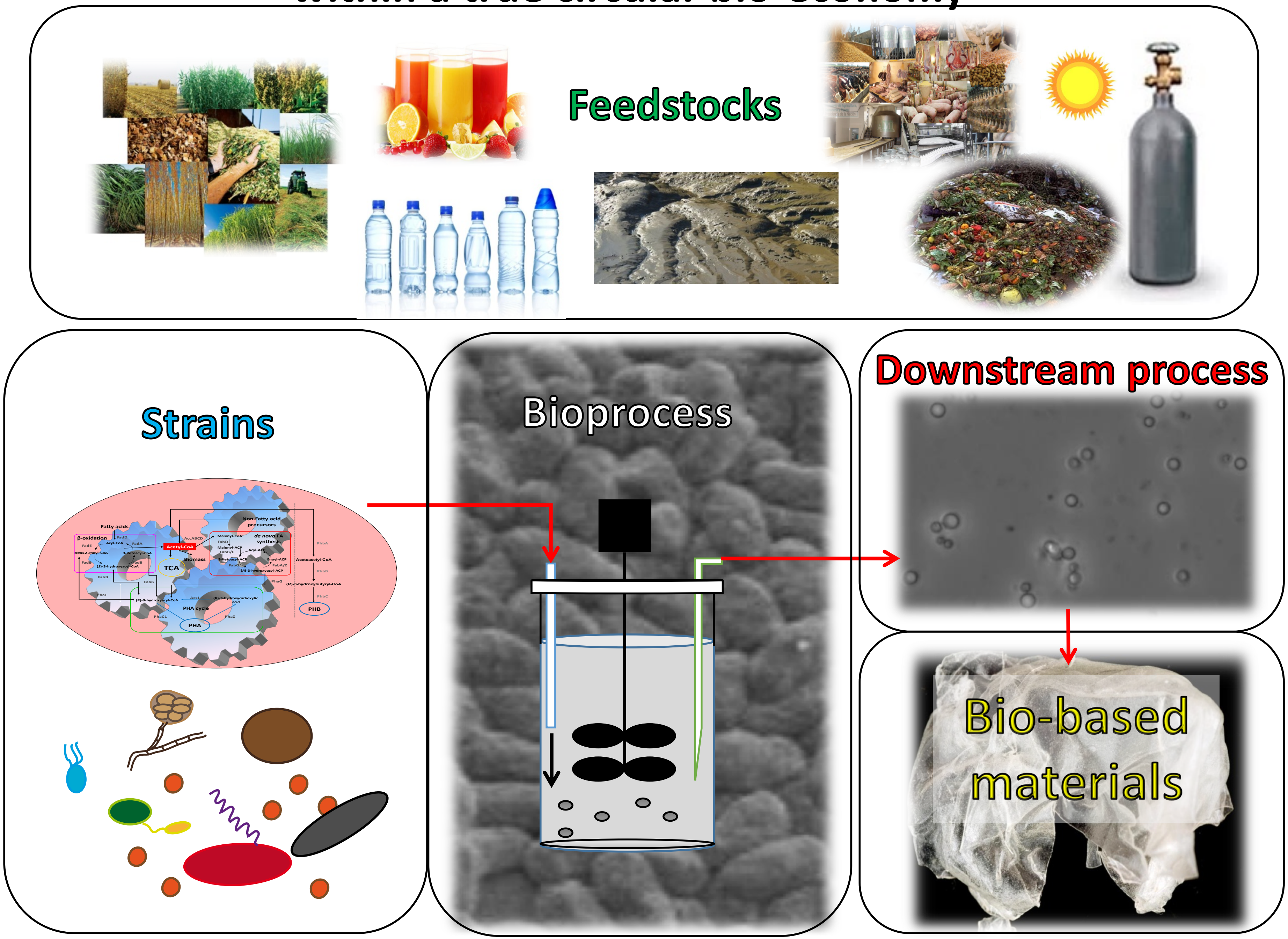
Plastic waste

mixed plastics biodegradation and upcycling using microbial communities

More details at:
www.mix-up.eu

Mix-Up - MIXed plastics biodegradation and UPcycling using microbial communities

"Towards microbial cell factories for bio-based polymer production within a true circular bio-economy"



Thank you!

Interdisciplinary Platform for Sustainable Plastics towards a Circular Economy

AFTERLIFE

WORKSHOP - Advanced Filtration Technologies for the Recovery and Later conversion of relevant Fractions from wastewater

OCTOBER 09, 2020

SUSTAINABLE EXTRACTION OF AMINO ACIDS FROM AGRO-INDUSTRIAL WASTEWATER STREAMS

BBI JU

Lurederra centro tecnológico

Dr. Javier Ceras

Bio-based Industries Consortium

Horizon 2020 European Union Funding for Research & Innovation

AFTERLIFE has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No. 745737 .

Agri-Food Industry Wastes

- **What**

  Wastewaters (AFTERLIFE) & other sources/materials

  By-products: considered wastes in most cases

- **Why**

  Huge amount of material

  Important source of high added value compounds

  Existing technologies are able to recover these valuables

  ✓

- **But…**

  Lab scale

  Marketable products are still rare

  ✗

Amino Acids

What are they

Important biological building blocks: PROTEINS

Alpha aminoacids; L-isomer

Essential aminoacids: must be supplied by diet

Commercial Applications

Food Industry

- Flavour enhancers
- Sweeteners
- antioxidants

Nutraceutical Industry

- Administration in post-operative treatment
- Feed supplements
- N-acyl derivatives in cosmetics

Chemical Industry

- Fertilizers
- Synthetic polymers
- General building blocks

Raw Material for Free Amino Acid Obtention

- Protein-Rich Streams

From Crops
Rendering (animal protein)
Other sources: algae, whey, etc.

- AFTERLIFE: Citromill Essential Oil Line Wastewaters

Essential Oils

Pectins

Polyphenols

Raw Material for Free Amino Acid Obtention

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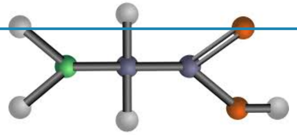
Amino Acids



Analysis by HPLC

30% of aminoacids (dry weight)

>50% essential AA

➢WP2: Protein Hydrolysis and isolation of free AminoAcids

AminoAcid*	AMINOGRAM (% of each AA)	% of AA, dry weight basis
Aspartic Acid	7,7%	2,32%
Glutamic Acid	6,3%	1,89%
Serine	2,6%	0,78%
Glycine	1,2%	0,36%
Histidine	3,4%	1,01%
Arginine	7,4%	2,22%
Threonine	21,1%	6,34%
Alanine	ND	0,00%
Proline	9,2%	2,77%
Tyrosine	2,7%	0,81%
Valine	1,8%	0,53%
Methionine	3,3%	0,98%
Cystine	ND	0,00%
Isoleucine	2,7%	0,82%
Leucine	4,4%	1,32%
Phenylalanine	2,8%	0,85%
Lysine	23,3%	7,00%
Total AA	**100%**	**30,0%**
Essential AA	**62,8%**	**18,9%**

Chemical Hydrolysis of proteins:

• Analysis: harsh conditions (6N HCl, 110ºC@24 h)

100% hydrolysis: all protein converted into free AA (with some exceptions)

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- Mild Conditions for pilot plant:

-Alkaline medium:

-Citric Acid

-Phosphoric Acid

Low Yields

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-Citric Acid

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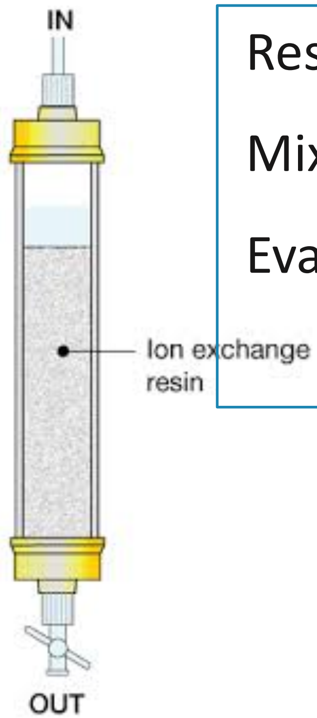
-Oxalic Acid: ✓

WP2: Protein Hydrolysis and isolation of free AminoAcids

Work-up



Resin purification and concentration

Mixed mode resin: Reverse Phase & Cation Exchange

Evaporation of MetOH elution solvent: AA recovery as solid

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➢ Alternative, Sustainable Obtention of Amino Acids

➢ Chemical Extraction

Well-known method
Good and consistent results, with limitations
Scalability
Aminoacids can be degraded by conditions
Standard Equipment and low cost

➢Alternative, Sustainable Obtention of Amino Acids

➢Sub-Critical Water Extraction

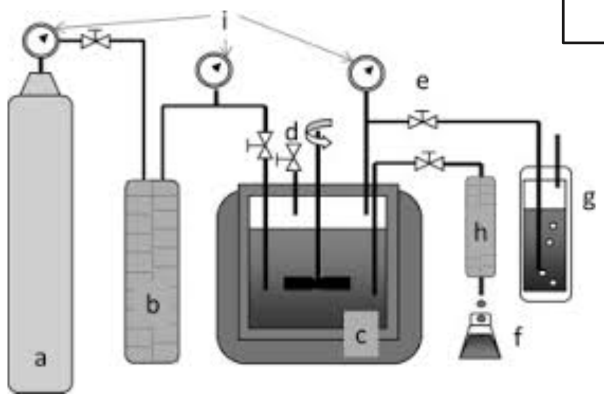
Solvent is just water

Sub.critical water shows interesting properties

More reactive as an acid or base like catalyst

Aminoacids can be degraded by hight temp.

Equipment and operational cost is high



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➢ Alternative, Sustainable Obtention of Amino Acids

➢ Enzymatic Extraction

Solvent is just water
Enzymes are very selective
No degradation of aminoacids
Expensive chemicals
Exhaustive control of medium conditions

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PERSPECTIVES

Bio-refinery Concept	Development of techniques to improve yields and economics	Innovation in the Isolation Process

↓

Sub Critical Water	**Enzymatic**
-Improve operational parameters	-Immobilization of enzymes -Chemical modification

THANK YOU !!

Lurederra@Lurederra.es

Javier.ceras@Lurederra.es