27º Congresso Técnico AESabesp
São Paulo, Brasil, 16/August/2016

management of municipal wastewater

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Scientific Executive Board of ECOMONDO (**www.ecomo**

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Who we are and what we do

GreenAwards L'Italia che sa innovare / 10

Qui recuperiamo le risorse cadute nell'acqua sporca

Fertilizzanti, metalli, scarti chimici. Al LabICAB li tirano fuori dagli scarichi, trasformando i **depuratori** in fabbriche di sostanze riciclate

di **Micaela De Medici**

Ogni volta che tirate lo scarico in bagno, quando lavate i piatti o fate la doccia, avete mai pensato che le acque reflue potrebbero essere una miniera urbana ecosostenibile dalla quale recuperare energia, fertilizzanti, sostanze chimiche e metalli? Dovreste farlo. Perché, in effetti, le cose stanno proprio così. Di fatto, dagli scarichi di ogni persona si potrebbero recuperare acqua riutilizzabile, cellulosa, polimeri biodegradabili, fosforo, azoto, metano e fertilizzante organico. Al LabICAB, il Laboratorio di Ingegneria Chimica dell'Ambiente e dei Bioprocessi dell'Università di Verona, si lavora proprio in questa direzione: si ricercano, si sviluppano e si trasferiscono processi e impianti biotecnologici innovativi che possano rendere efficienti i depuratori di acque reflue urbane già esistenti, fino a trasformarli in "fabbriche di risorse recuperate", sostenibili dal punto di vista tecnico, economico e ambientale, con attenzione alle emissioni di gas serra (carbon footprint). Lo studio di questi temi risale agli anni Ottanta quando Franco Cecchi, professore ordinario di Impianti chimici all'Università di Verona, per primo concepisce l'idea del depuratore come "centro urbano multifunzionale", utilizzabile per trattare diversi flussi di scarto urbani, come le acque reflue e la frazione organica dei rifiuti solidi, per recuperare biogas — dunque energia —, fertilizzanti e ammendanti (cioè fertilizzanti che migliorano le caratteristiche fisiche del suolo). Sviluppando queste idee innovative si arriva, una quindicina di anni fa, all'impianto di depurazione urbano di Treviso: allora esempio pionieristico in Europa proprio per lo schema che includeva il recupero di biogas e nutrienti dalla co-digestione di fanghi e Forsu (Frazione Organica del Rifiuto Solido Urbano, cioè il materiale raccolto dalla raccolta differenziata dell'organico, altrimenti detto umido), il recupero di fosforo sotto forma di struvite e il processo biologico per produrre scarico finale a bassissimo contenuto di nutrienti. Da allora il LabICAB è cresciuto fino ad affermarsi come punto di riferimento in Italia e all'estero per il trattamento di acque reflue e di rifiuti organici. La sede del dipartimento è sempre a Verona: le ricerche hanno inizio nei laboratori, ma l'applicazione viene realizzata dove si trovano materialmente i rifiuti e gli impianti — da Treviso a Catania, da Porto Marghera alla Toscana. Non solo. Oggi Francesco Fatone e David

«La nostra è una ricerca applicata. Partiamo dagli impianti esistenti per rinnovarli e renderli efficienti, ottimizzando i consumi»

SETTEGREEN AWARDS 2015

LabICAB Verona

Green Award Winner 2015

Leading position in the EU R&I: Coordinator Horizon2020 «SMART-Plant» Innovation Action

SMART-Plant

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Our main R&D&I topics

LabICAB Verona

- Design, operation and optimization of innovative **wastewater treatment** processes directed **towards the circular economy concept**: convert waste streams into value streams
  - **Nutrients recovery**
  - **Energy production**
  - **Bioplastics production**
  - **Carbon and environmental footprint reduction**
- **Anaerobic (co)digestion of biowaste**
- **Treatment of supernatant from anaerobic digestion** for nutrients removal or recovery and bioplastics production
- Occurrence and removal of **emerging contaminants** during waste and wastewater treatment processes

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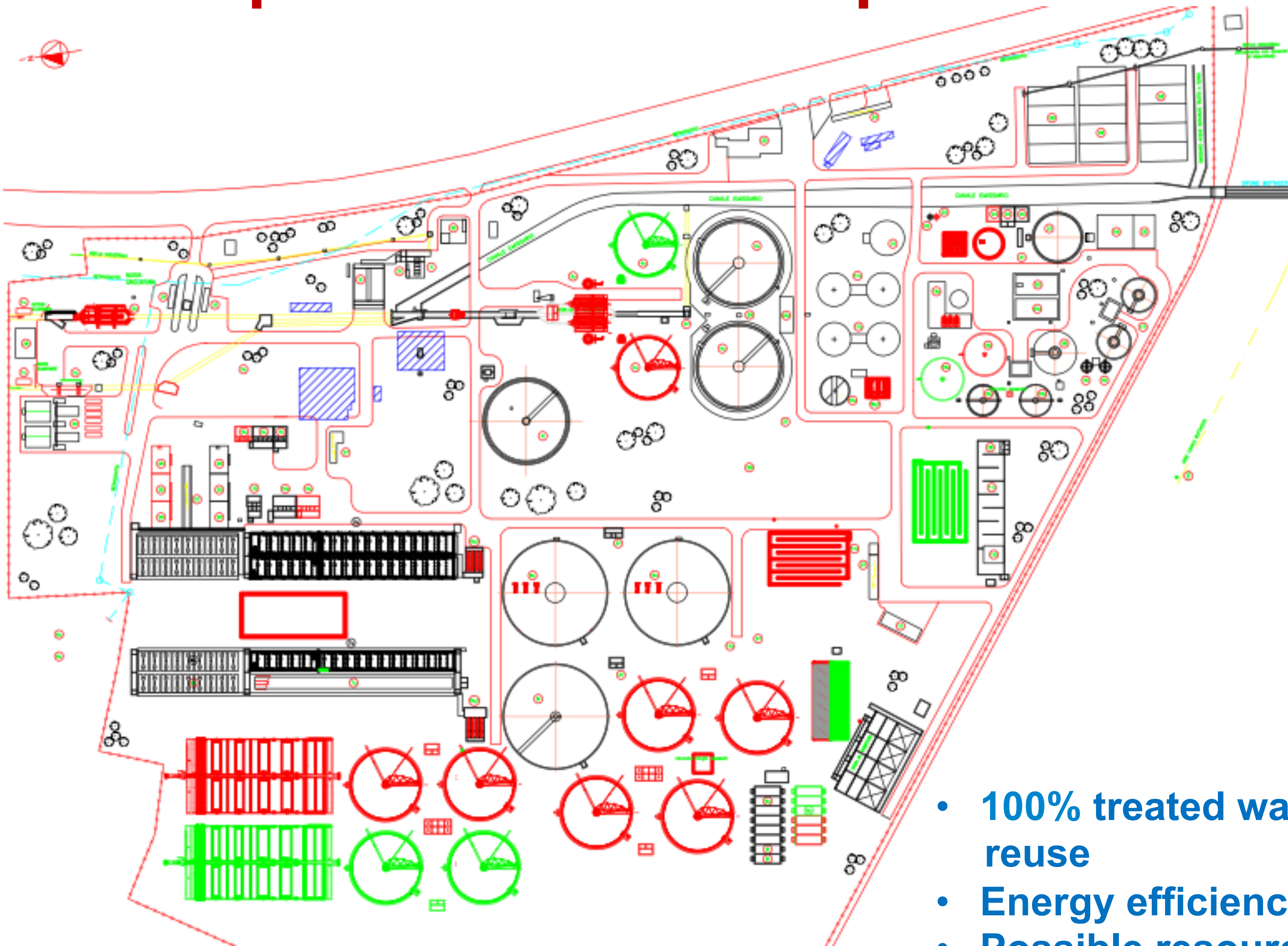
Bringing R&D&I to full scale: example of the new wwtp of Catania



- 100% treated water reuse
- Energy efficiency
- Possible resource y

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Industrial WWTP Porto Marghera, Venice, Italy (EU largest industrial Membrane BioReactor)

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Our ongoing EU R&D&I projects (within Horizon2020)

Water

EU H2020 – SMART-Plant
Scale-up of low-carbon footprint material recovery techniques in existing wastewater treatment plants

Water

EU H2020 – IntCatch
Development and application of Novel, Integrated Tools for monitoring and managing Catchments

Water

EU H2020 - ENERWATER
Standard method and online tool for assessing and improving the energy efficiency of waste water treatment plants

Water

EU Water JPI – Pioneer STP
The potential of innovative technologies to improve sustainability of sewage treatment plants

Waste

EU H2020 – RES URBIS
REsources from URban BIo-waSte

Waste

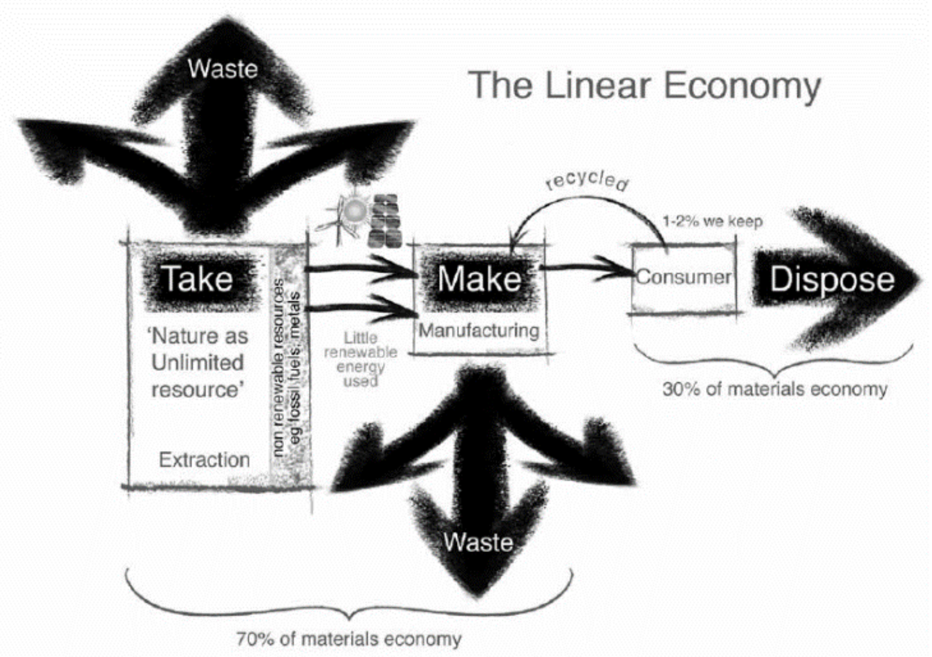
EU H2020 – NoAW
Innovative approaches to turn agricultural waste into ecological and economic assets

Contents of the presentation

1. **Linear vs Circular** Economy
2. **ECOMONDO**: #1 Italian platform for circular econo
3. **SMART-Plant**: circular management of wastewate
4. **Urban mining** by integration of organic waste treatments and municipal wastewater
5. **SP-JV** to deliver custom solutions for **valorizing recovered chemicals**

The Linear Economy

- Current economic model of 'Take-Make-Dispose'
- World as unlimited resource and waste bin;
- 65 billion tonnes of raw materials enter the economic system, p.a.;
- Around 60% of waste ends up in landfill…



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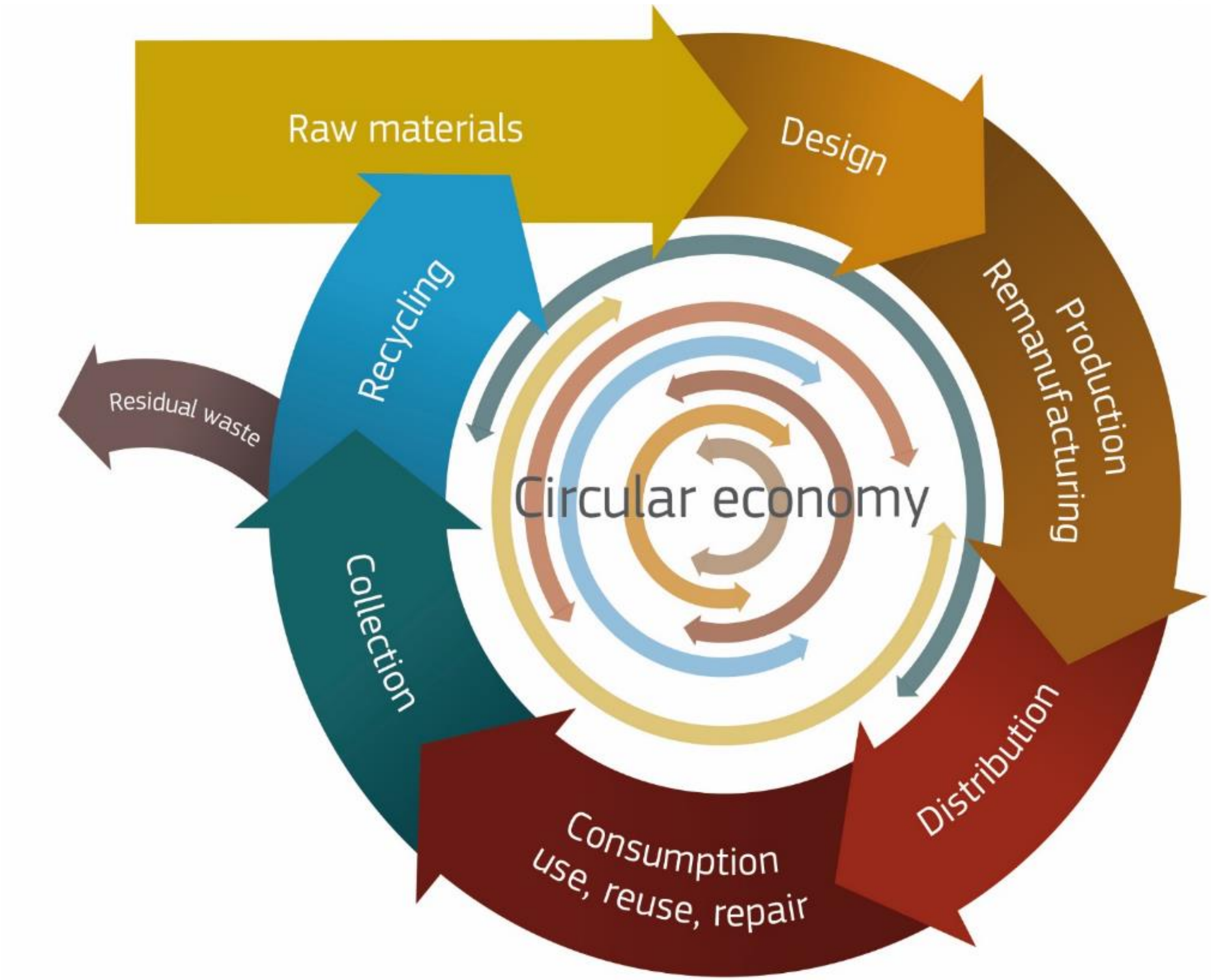
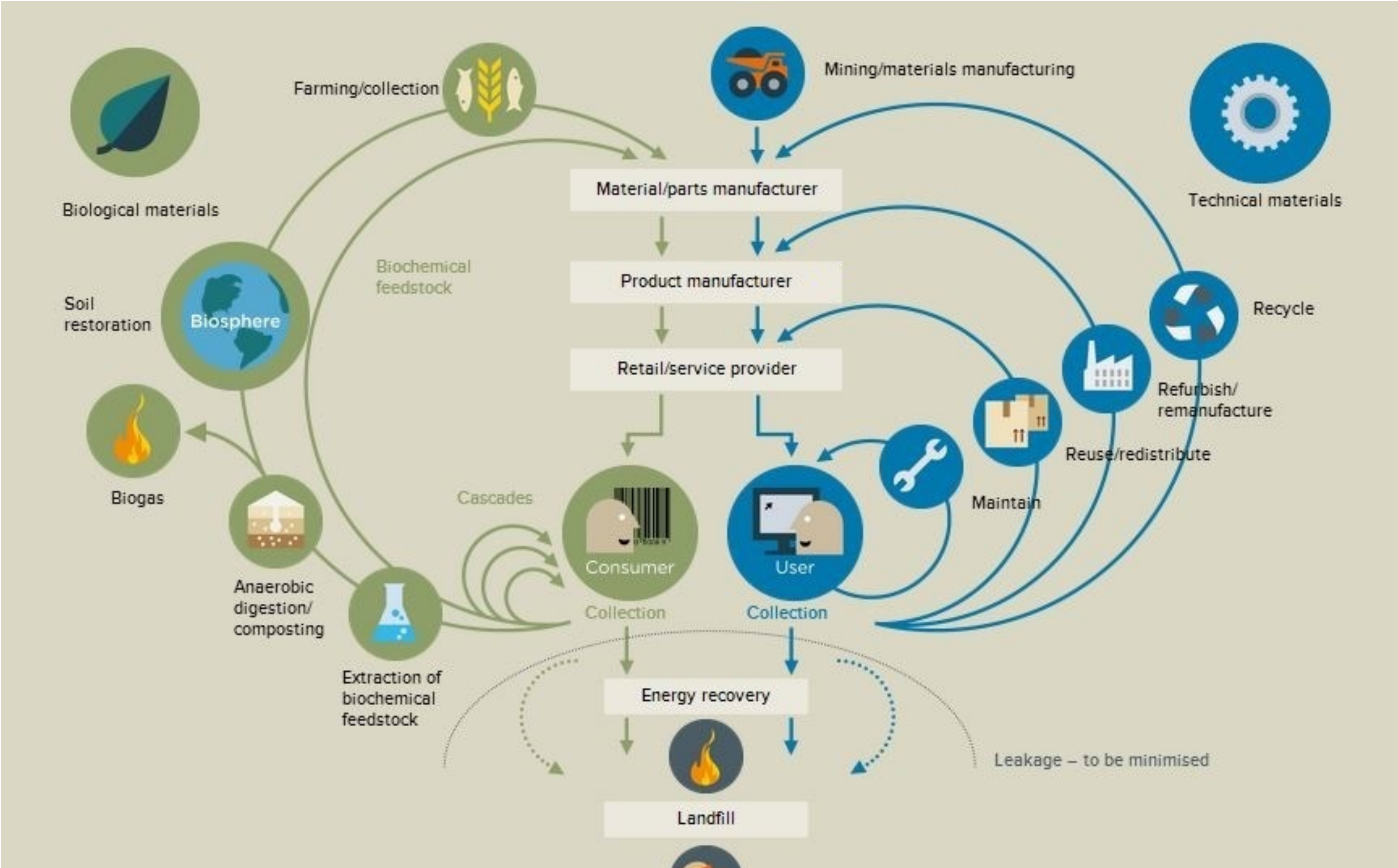
The circular economy





SOURCE: Ellen MacArthur Foundation circular economy team

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Circular Economy: imitation of natural cycles

The circular economy requires a very careful management of two material flows:

- ***biological nutrients** (biomasses) to be returned safely to the biosphere to restore the natural capital;*
- ***technical nutrients** (materials) designed to keep quality and circulate without entering back in the biosphere*

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Circular Economy: our choice

The European Commission has adopted an ambitious new Circular Economy Package to stimulate Europe's transition towards a circular economy that will boost global competitiveness, foster sustainable economic growth and generate new jobs.

This transition will be supported financially by the European Structural & Investment Funds (ESIF), which include €5.5 billion for waste management.

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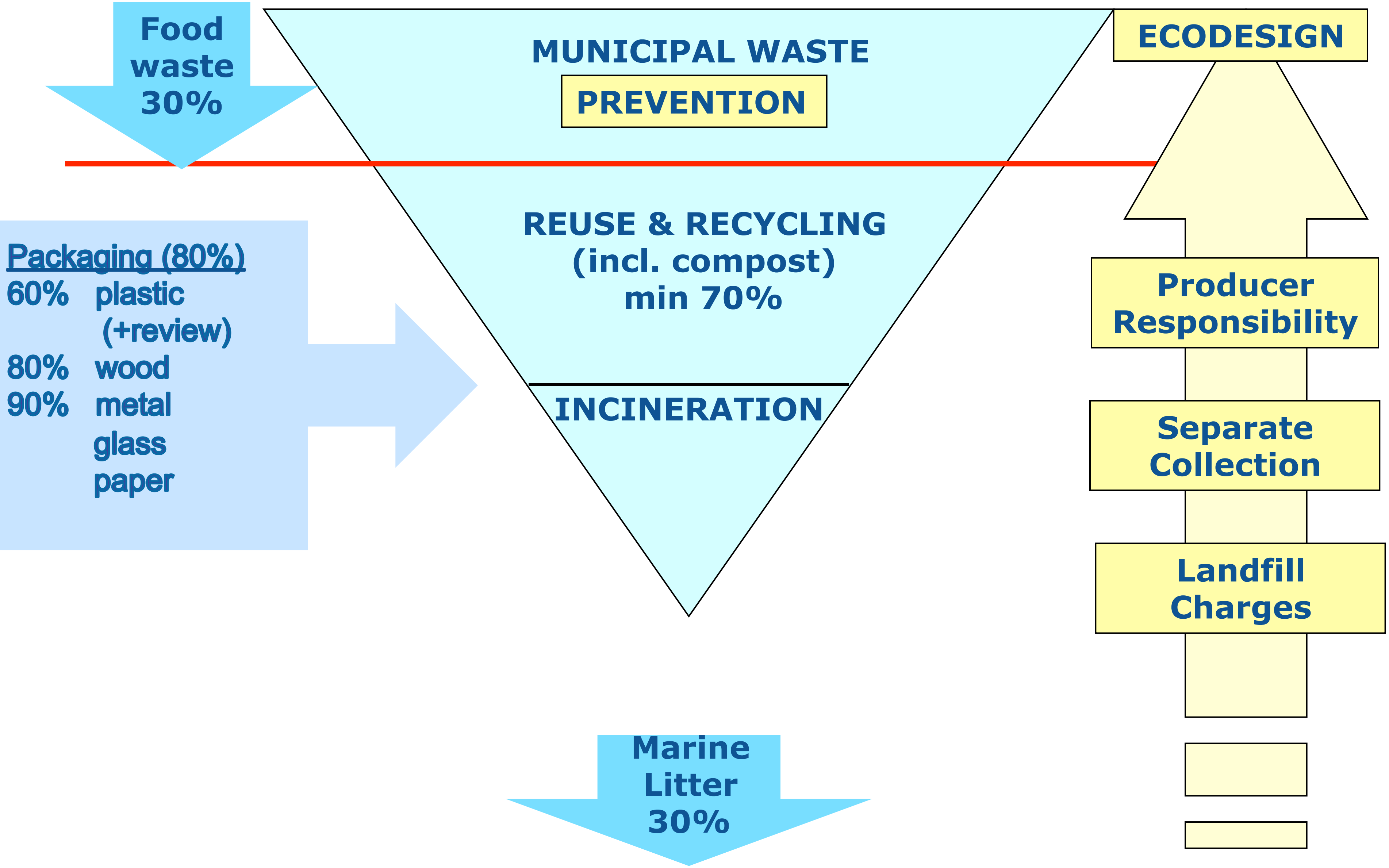
2030 – Waste Targets



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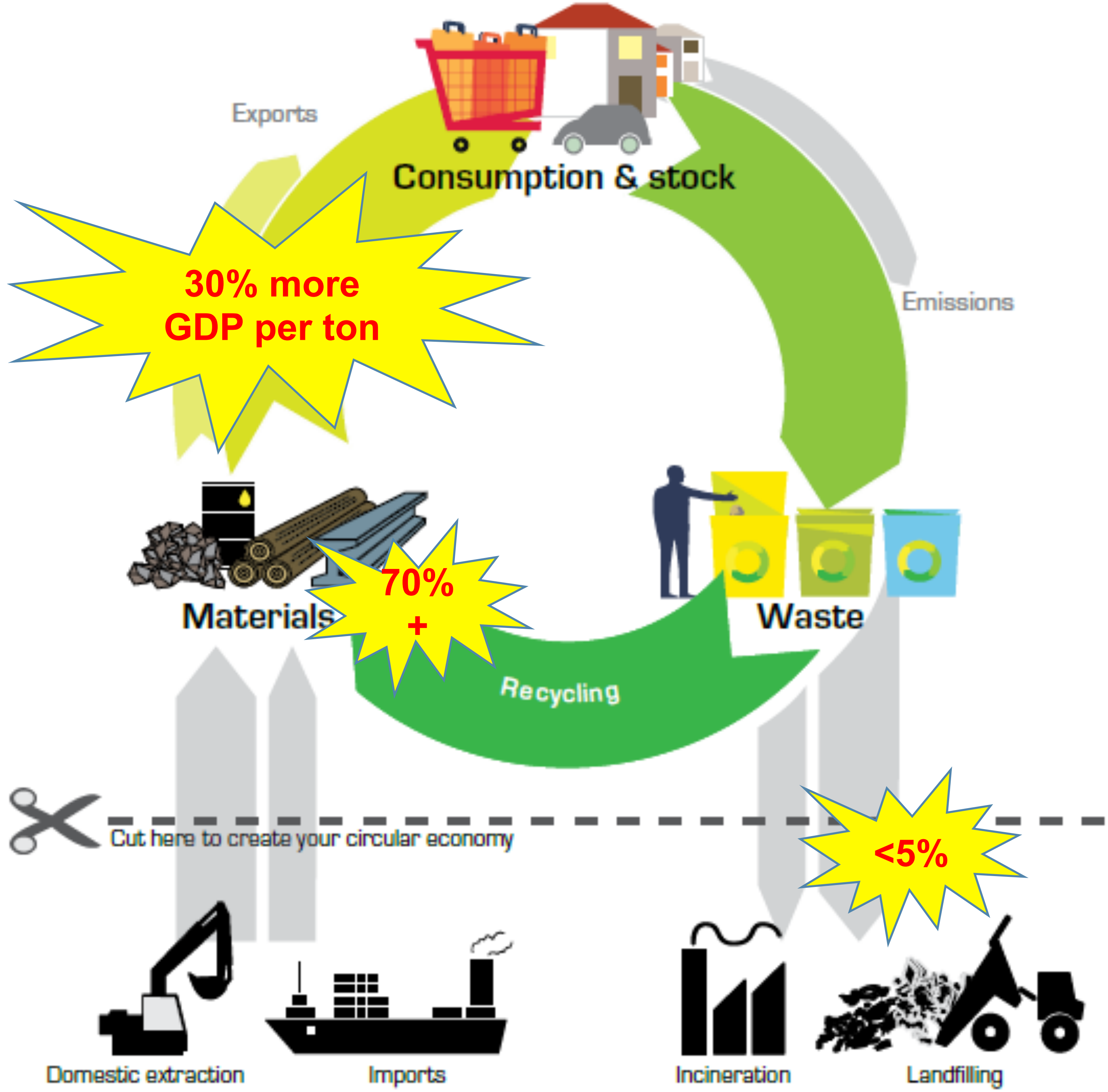

Exports
Consumption & stock
Emissions
30% more
GDP per ton
Materials
70%
+
Waste
Recycling
Cut here to create your circular economy
<5%
Domestic extraction
Imports
Incineration
Landfilling

ECOMONDO: the platform of the circular economy

www.ecomondo.com

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Water in the circular economy?
The wastewater treatment plant is the key enabling element of the value chain

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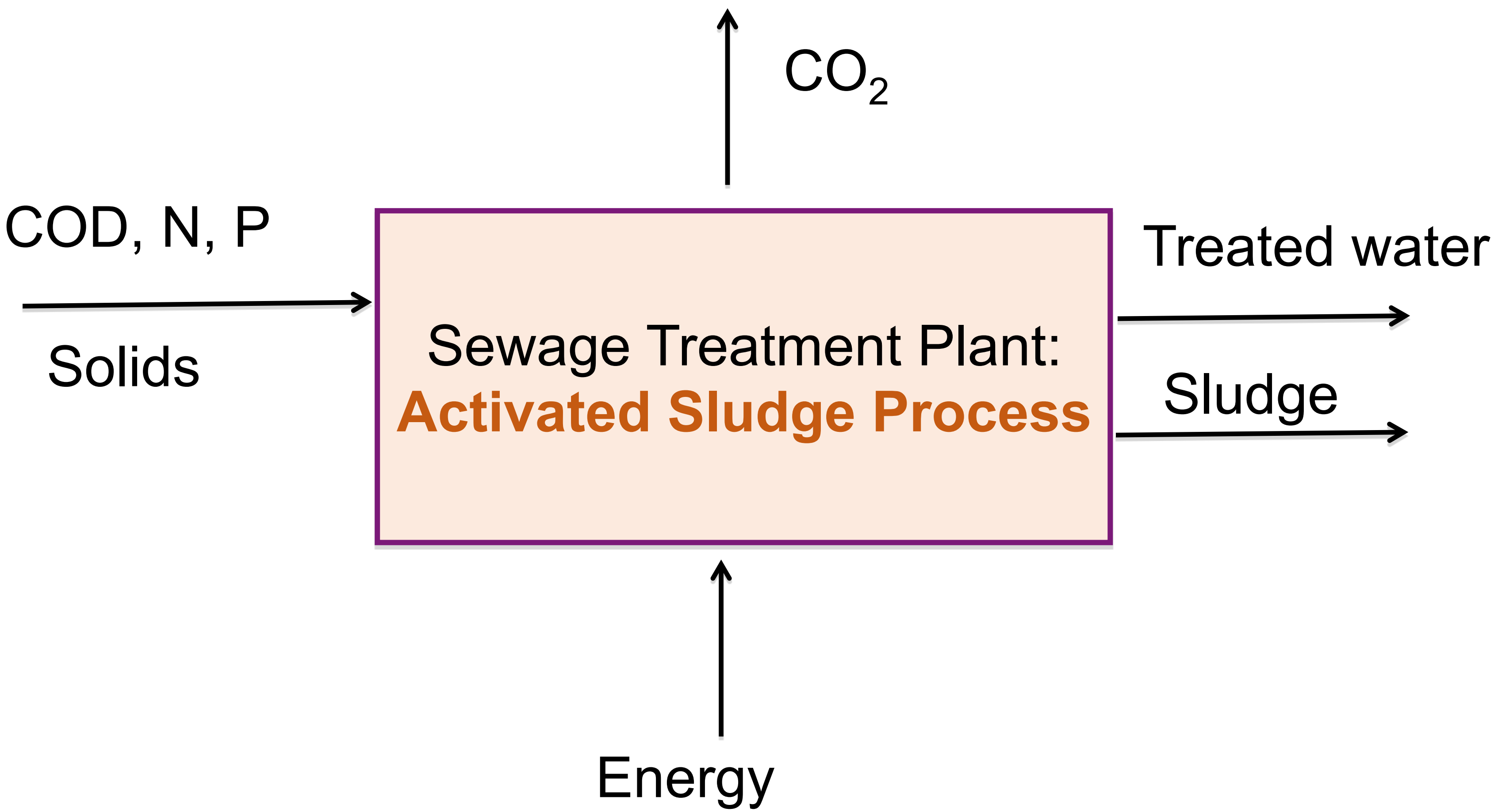
Conventional WWTP



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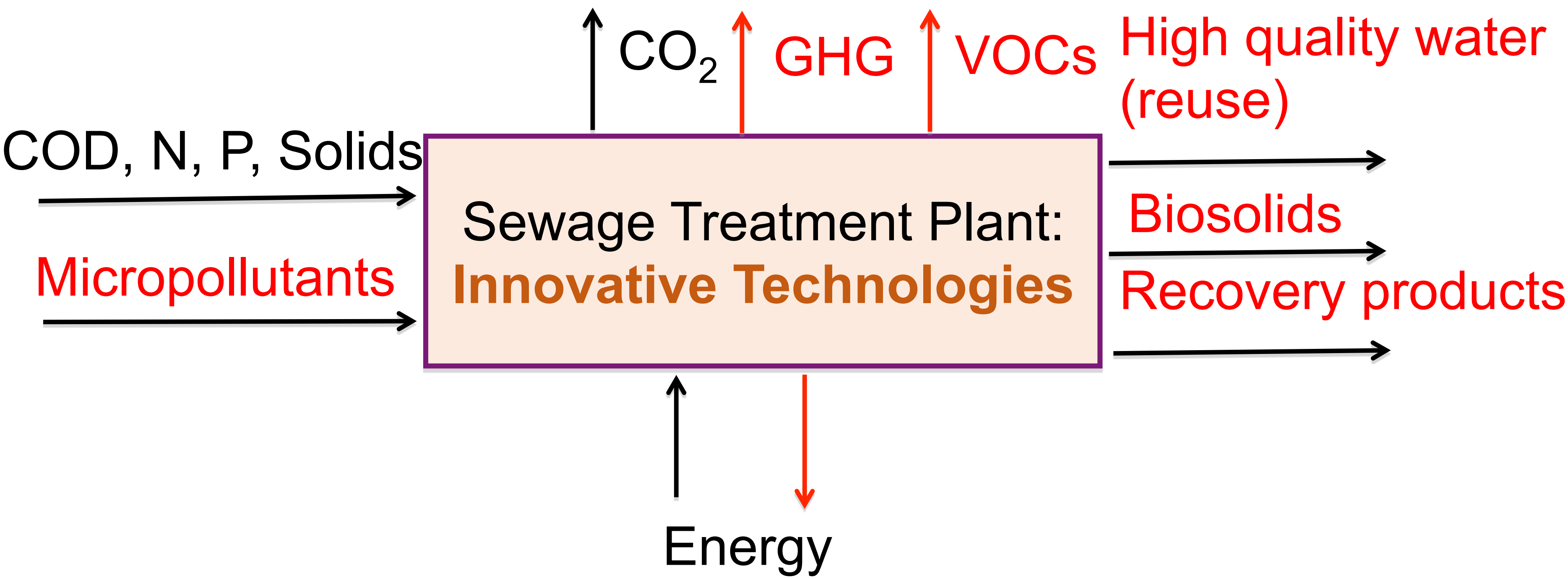
Advanced and circular WWTP



Change of Paradigm

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Resources embedded to municipal wastewater

Parameter	Value
Reusable water (m^3/capita year)	91,3
Cellulose (kg/capita year)	6,6
Biopolymers; PHA (kg/capita year)	3,3
Phosphorus in P precursors (kg/capita year)	0,9
Nitrogen in N precursors (kg/capita year)	4,6
Methane (m^3/ capita year)	12,8
Organic Fertilizer (P-rich compost) (kg/capita year)	9,1

Verstraete et al. (2009) *Bioresource Technology* 100, 5537–5545
Salehizadeh and van Loosdrecht (2004) *Biotechnology Advances* 22, 261–279

Key Enabling Strategy: upstream solid concentration, integration and innovation of the re

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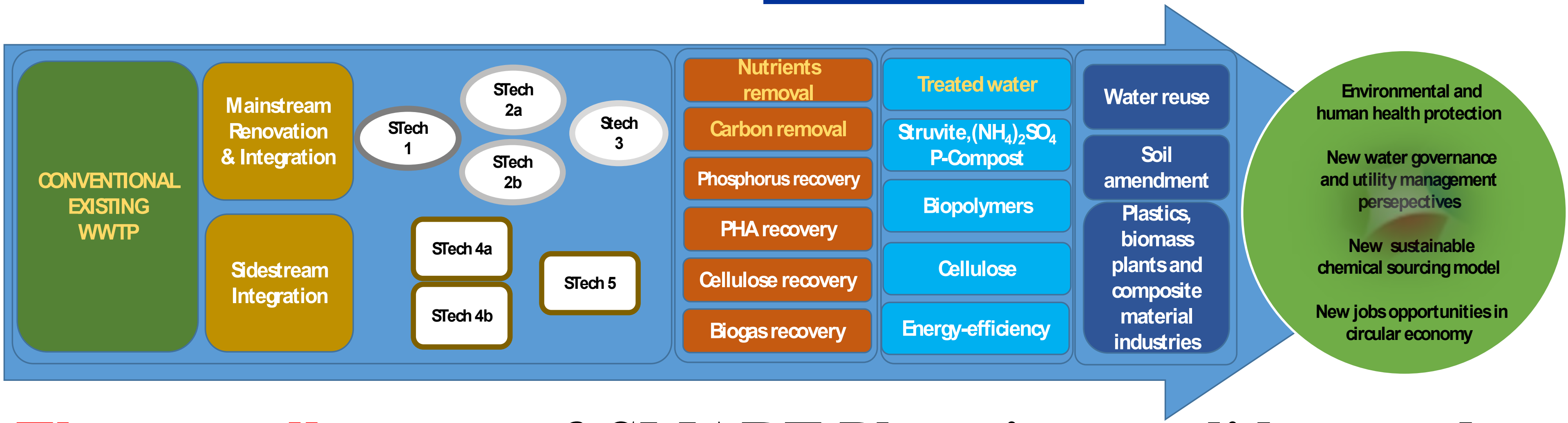

The overall target of SMART-Plant is to validate and to address to the market a portfolio of SMARTechnologies that, singularly or combined, can renovate and upgrade existing wastewater treatment plants and give the added value of instigating the paradigm change towards efficient wastewater-based bio-refineries.

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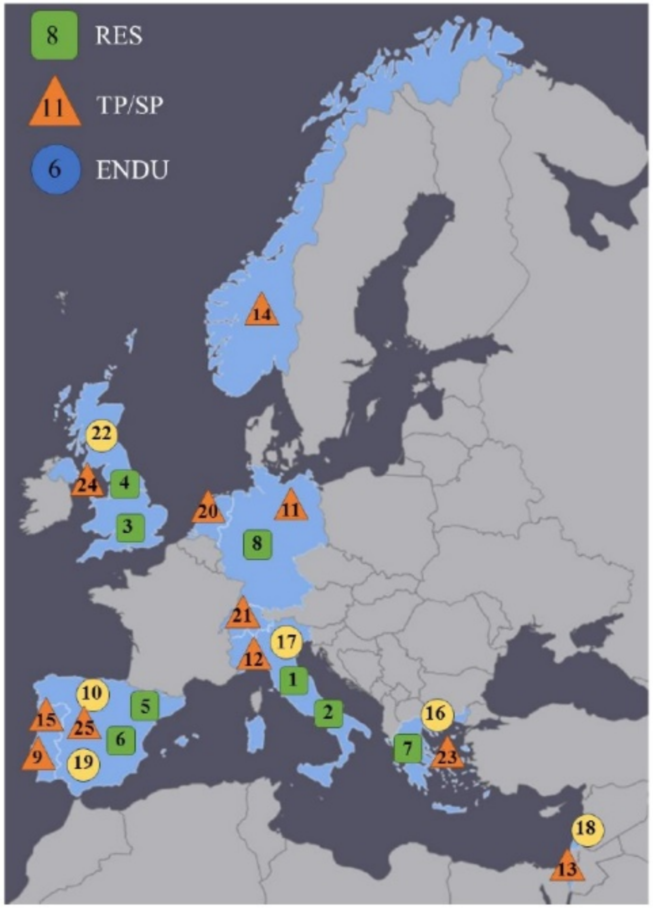
The SMART-Plant consortium

Participant No	Participant organisation name	Acronym	Type	Country
1 (Coordinator)	Università degli Studi di Verona	UNIVR	RES	Italy
2	Università di Roma La Sapienza	UR	RES	Italy
3	Brunel University	UBRUN	RES	UK
4	Cranfield University	CU	RES	UK
5	Universitat Autònoma de Barcelona	UAB	RES	Spain
6	Universitat de Vic	UVIC-UCC	RES	Spain
7	National Technical University of Athens	NTUA	RES	Greece
8	Berlin Centre of Competence for Water	KWB	RES	Germany
9	Biotrend S.A.	BIOTR	SME/TP/SP	Portugal
10	Socamex S.A.	SOC	LI/TP/ENDU	Spain
11	BYK Additives Ltd	BYK	SME/TP	Germany
12	SCAE srl	SCAE	SME/TP	Italy
13	AGROBICS Ltd	AGRB	SME/TP	Israel
14	Salsnes Filter A.S.	SALSNES	LI/TP	Norway
15	Instituto de Biologia Experimental e Tecnológica	IBET	RES/SP	Portugal
16	Athens Water Supply and Sewerage Company	EYDAP	SME/ENDU	Greece
17	Alto Trevigiano Servizi S.r.l.	ATS	SME/ENDU	Italy
18	Mekorot Water Company Ltd	MEKOROT	LI/ENDU	Israel
19	Aiguas de Manresa S.A.	AdM	SME/ENDU	Spain
20	BWA B.V.	BWA	SME/TP	Netherlands
21	Execon-Partners Gmbh	EXC	SME/SP	Switzerland
22	SEVERN TRENT WATER Ltd	STW	SME/ENDU	UK
23	JV Aktor SA and Athina SA	AKTOR	SME/TP	Greece
24	Vannplastics Ltd. (Ecodek)	ECODEK	SME/TP	UK
25	Wellness Smart Cities SLU	WSC	SME/TP/SP	Spain

RES=Research Organization; SME=Small/Medium Enterprise; LI=Large Industry; TP=Technology Provider; SP=Service Provider; ENDU=End User



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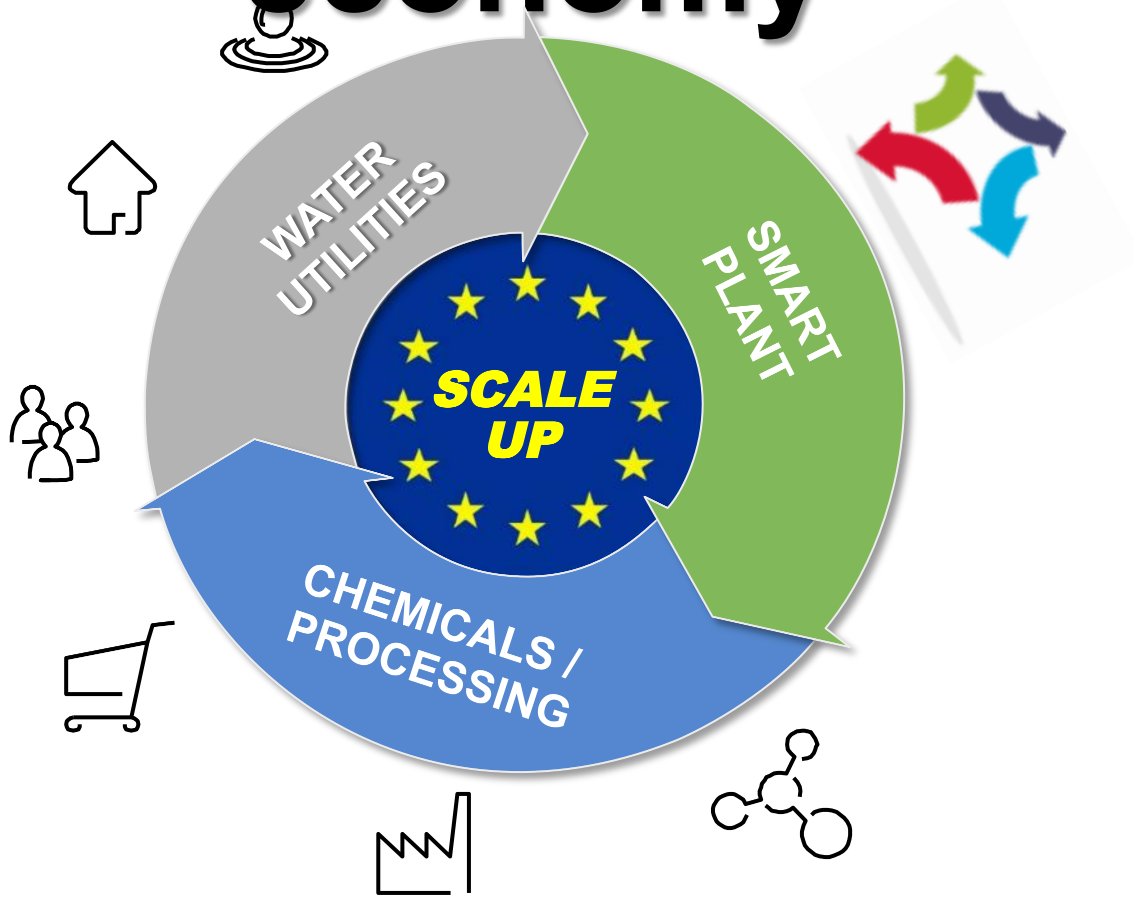
The SMART-Plant Consortium

SMART-Plant open the pathway to deliver circular economy



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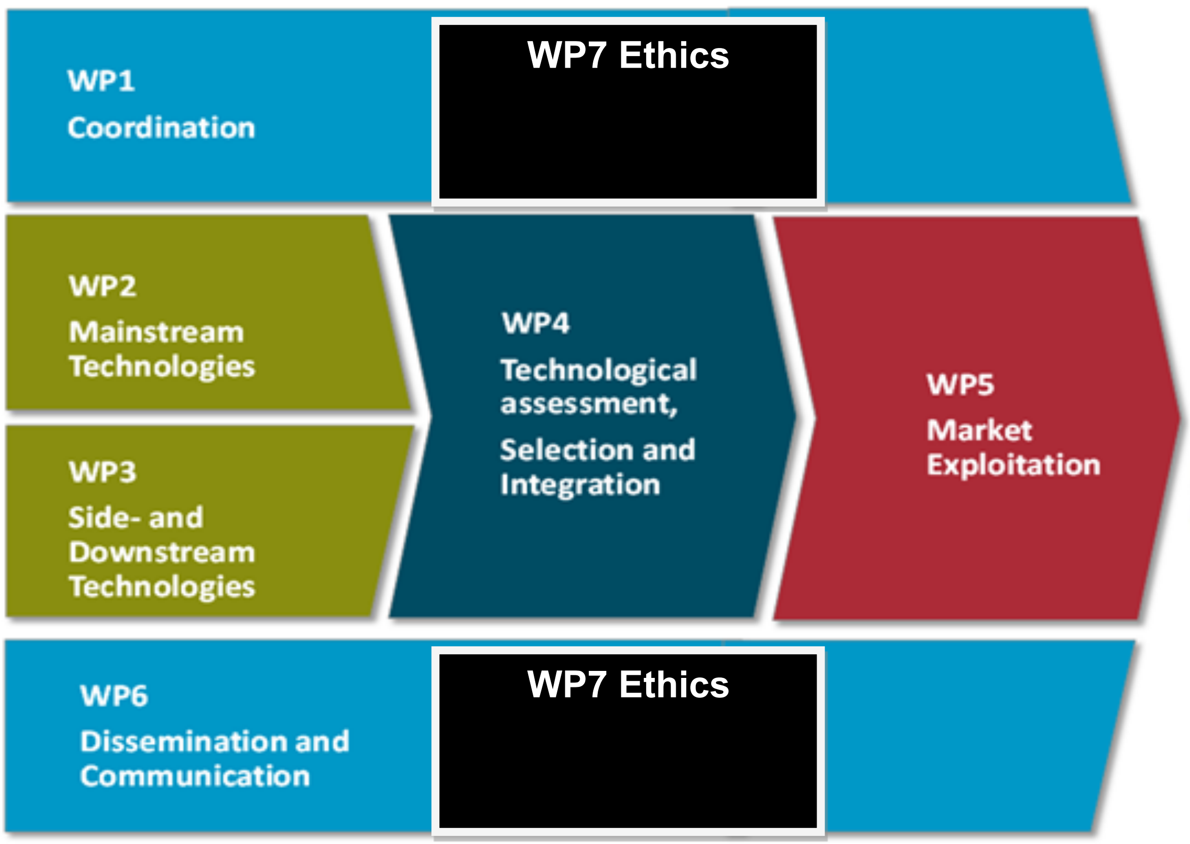
SMART-Plant workplan structure



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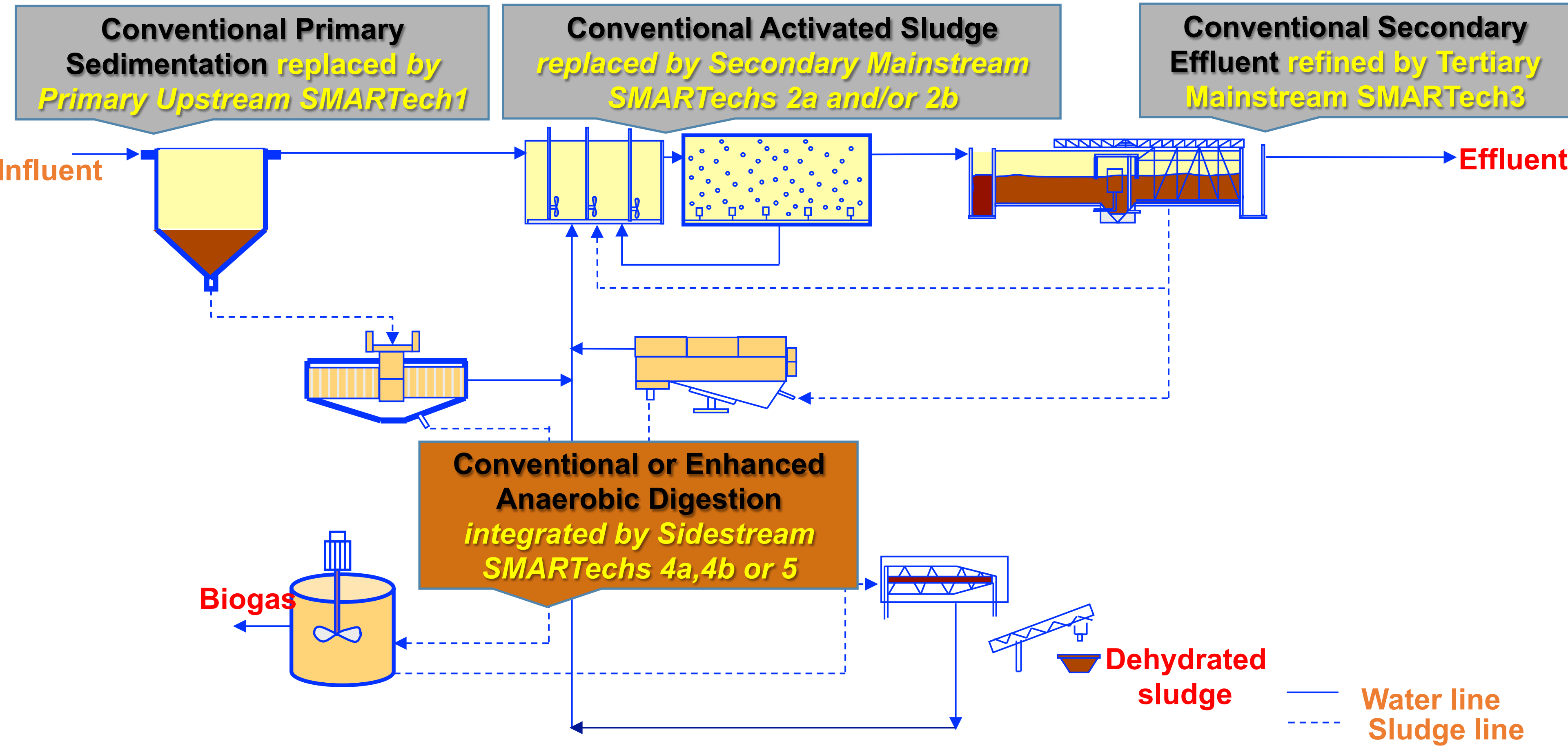
The SMARTechnologies



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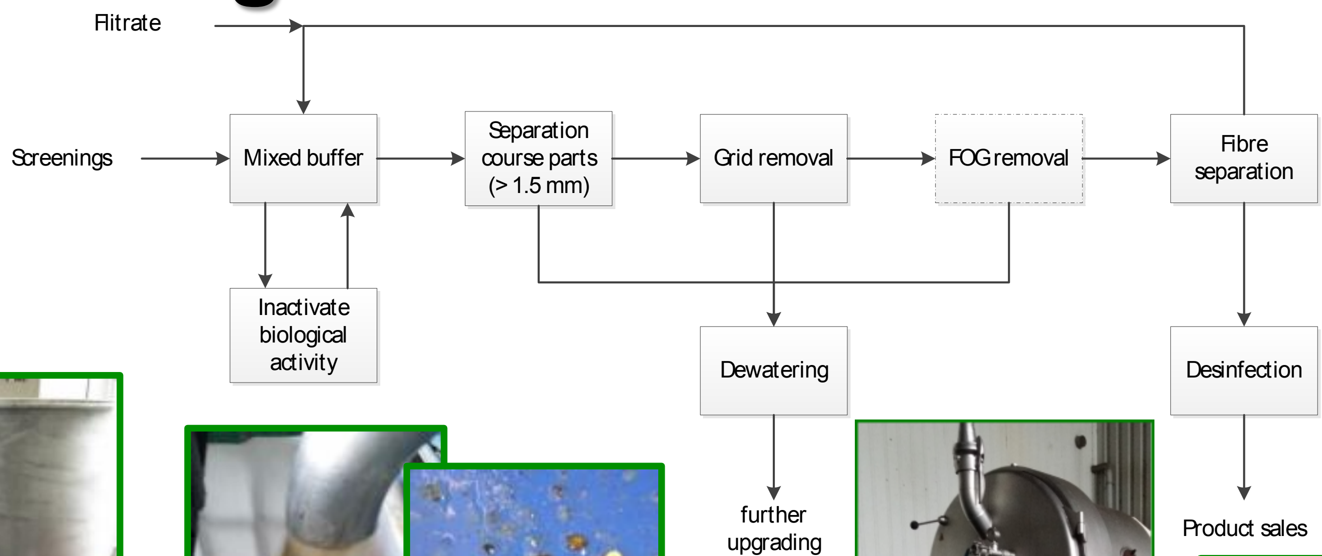
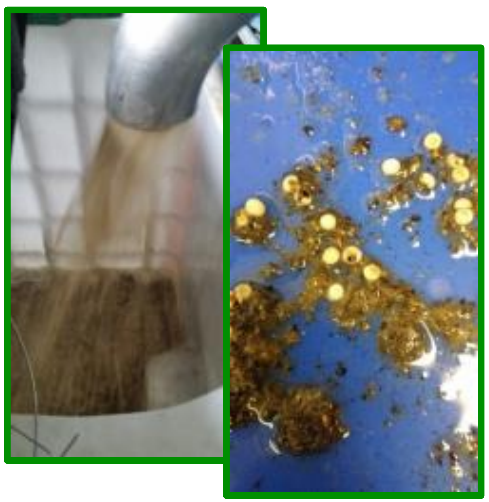
SMARTech1: Primary (upstream) dynamic sieving and clean cellulose recovery



Inactivation biological activity



Separation course parts

Sand-/grid removal

Fibre separation

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SMARTech1: Primary (upstream) dynamic sieving and clean cellulose recovery

Realization of a full-scale plant
- ü all process steps combined in one process

Optimization:
- ü Efficiencies of different process steps
- ü Energy-/chemical consumption individual process steps
- ü Quality cellulose fiber after different process steps
- ü Optimization interdependence

Market development
- ü Marketing and valorization of recovered cellulose
    - ü Reuse in asphalt
    - ü Raw material for composite (Brunel)
    - ü Insulation materials (In development, not sure yet)

First pilot testing

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SMARTech2a: Secondary mainstream biogas recovery by polyfoam biofilter

§ B1 Technical Part

1. An innovative anaerobic immobilized polymeric biofilter.
2. Reaction volume -25 m^3 will be designed and installed in the WWTP of Karmiel (North of Israel)
3. Characteristics:

- 100-120 m^3/d.
- Removal of 30-40% of CODf
- Additional of 25% biogas
- Reduction of 25-30% energy consumption.

4. Operation optimization, monitoring and validation:

- biogas yield
- biomass activity
- treated effluent quality

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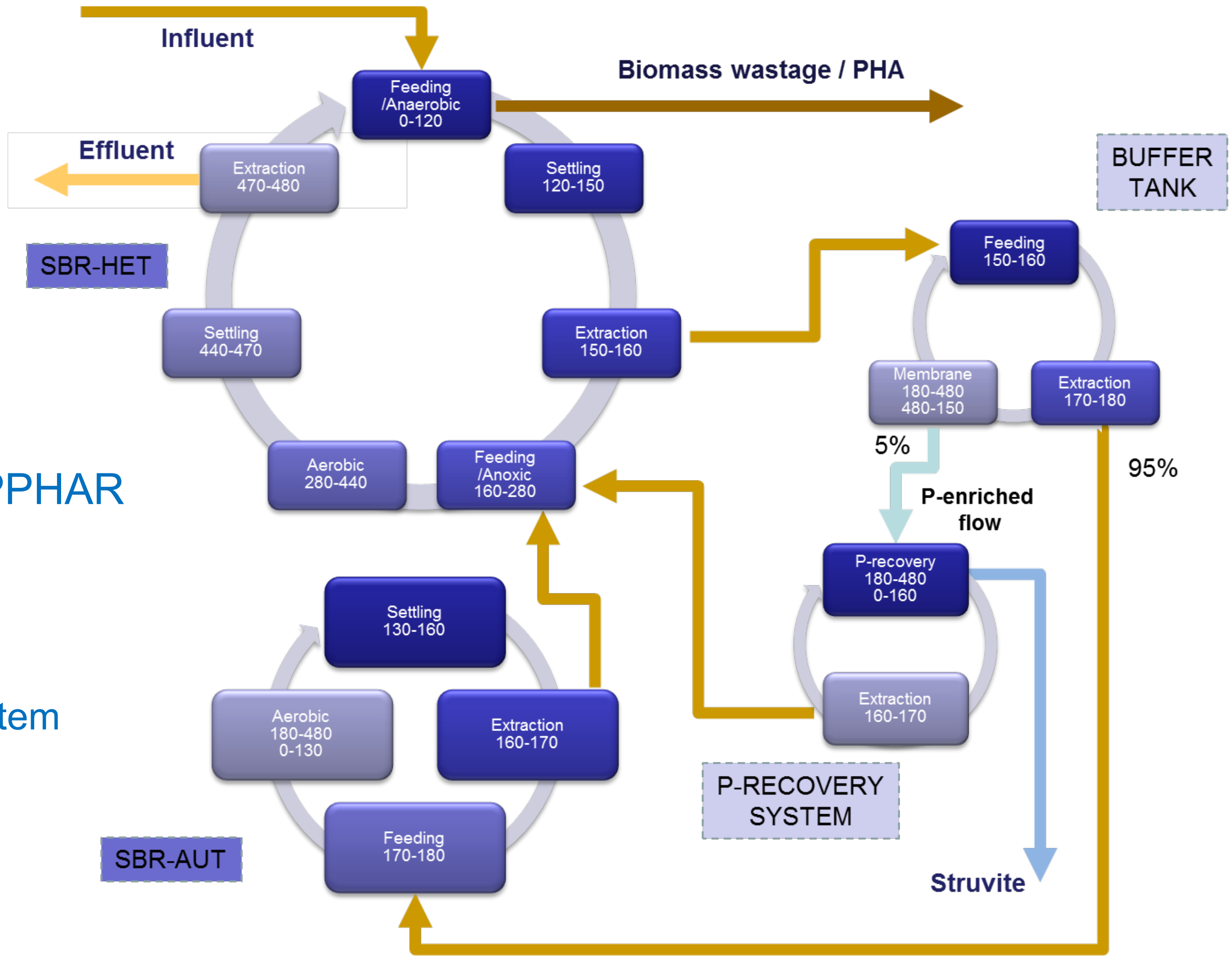
SMARTech2b: Secondary mainstream SCEPPHAR



SMARTech2b

Mainstream SCEPPHAR

- Two SBR
- Buffer tank
- P-recovery system

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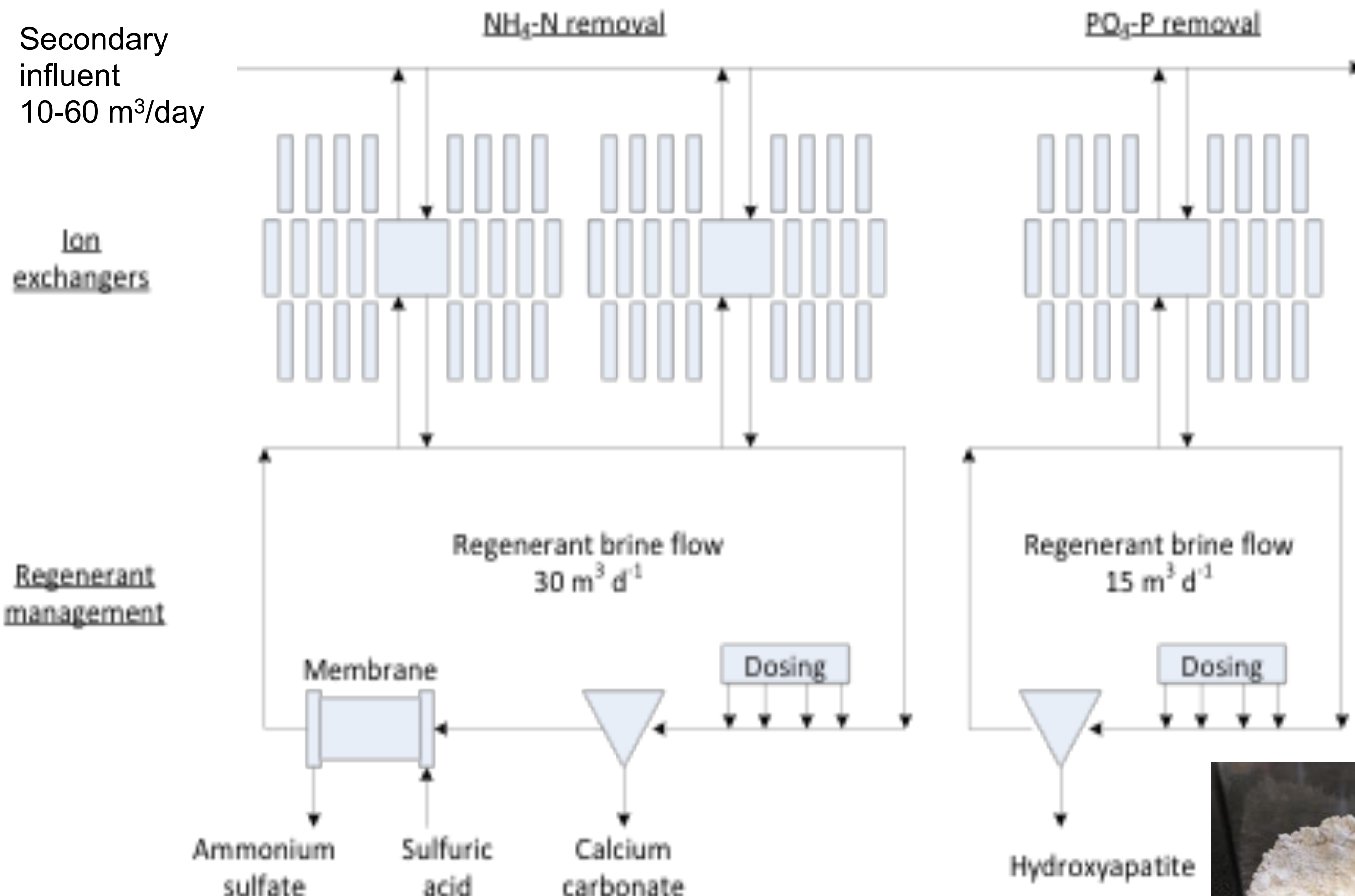
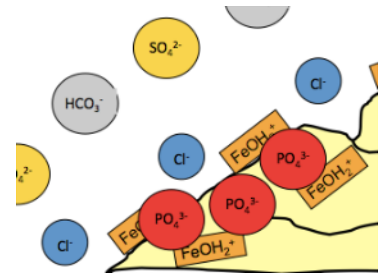
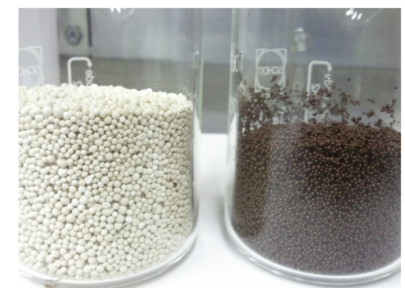
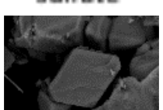
SMARTech3: Tertiary nutrient recovery by mesolite and nano ion exchange









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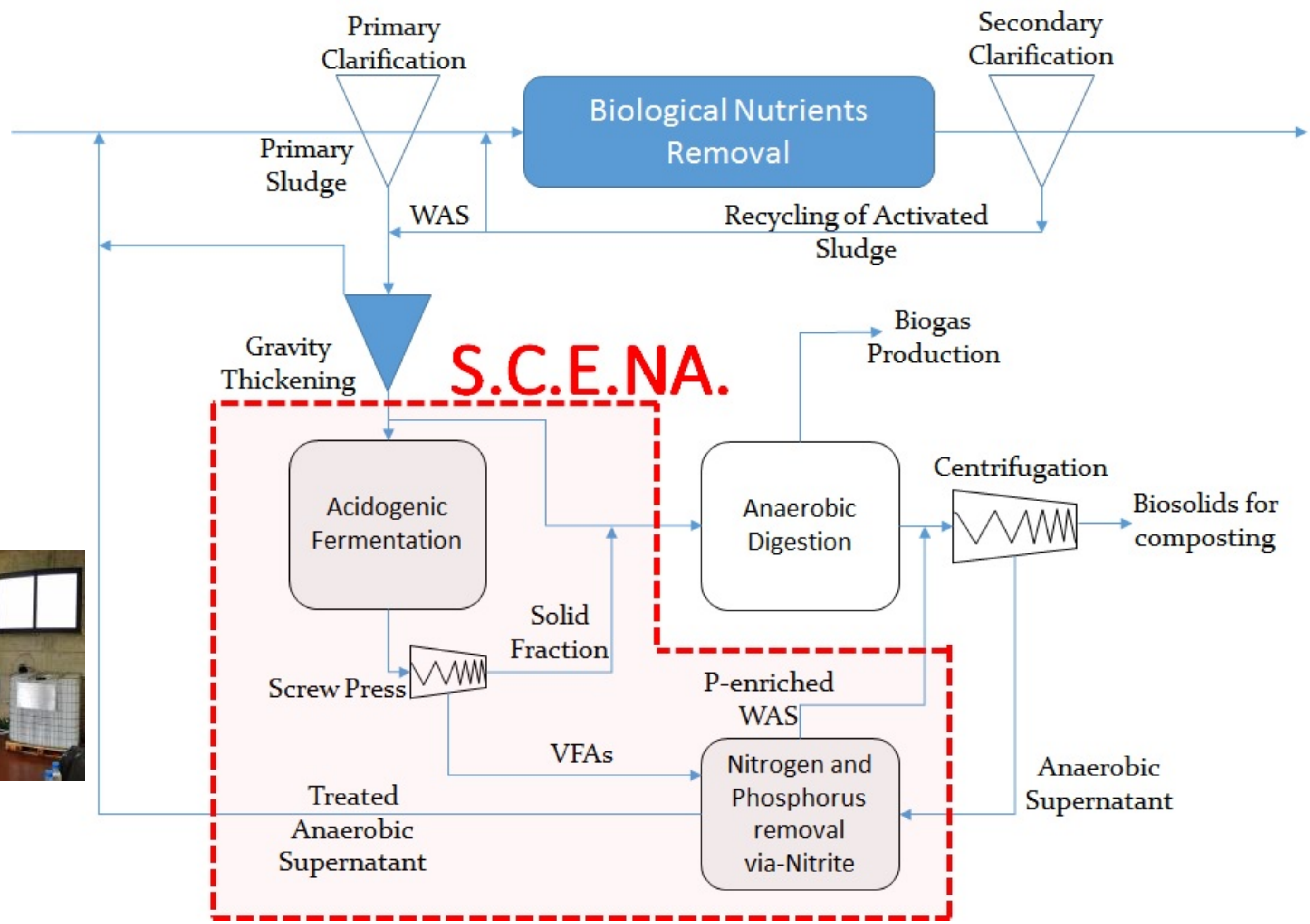
SMARTech4a/b Sidestream S.C.E.N.A



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Main features of S.C.E.N.A.

- Costs for nitrogen removal 1.1-1.6 €/kgN
- Biological rates 10-12 times higher than conventional activated sludge processes
- Enhanced Biological Phosphorus Recovery associated to the biological sludge
- Applicable on strong nitrogenous fluxes (e.g. anaerobic digestate, landfill leachate, livewaste slurries and agro-waste, etc)

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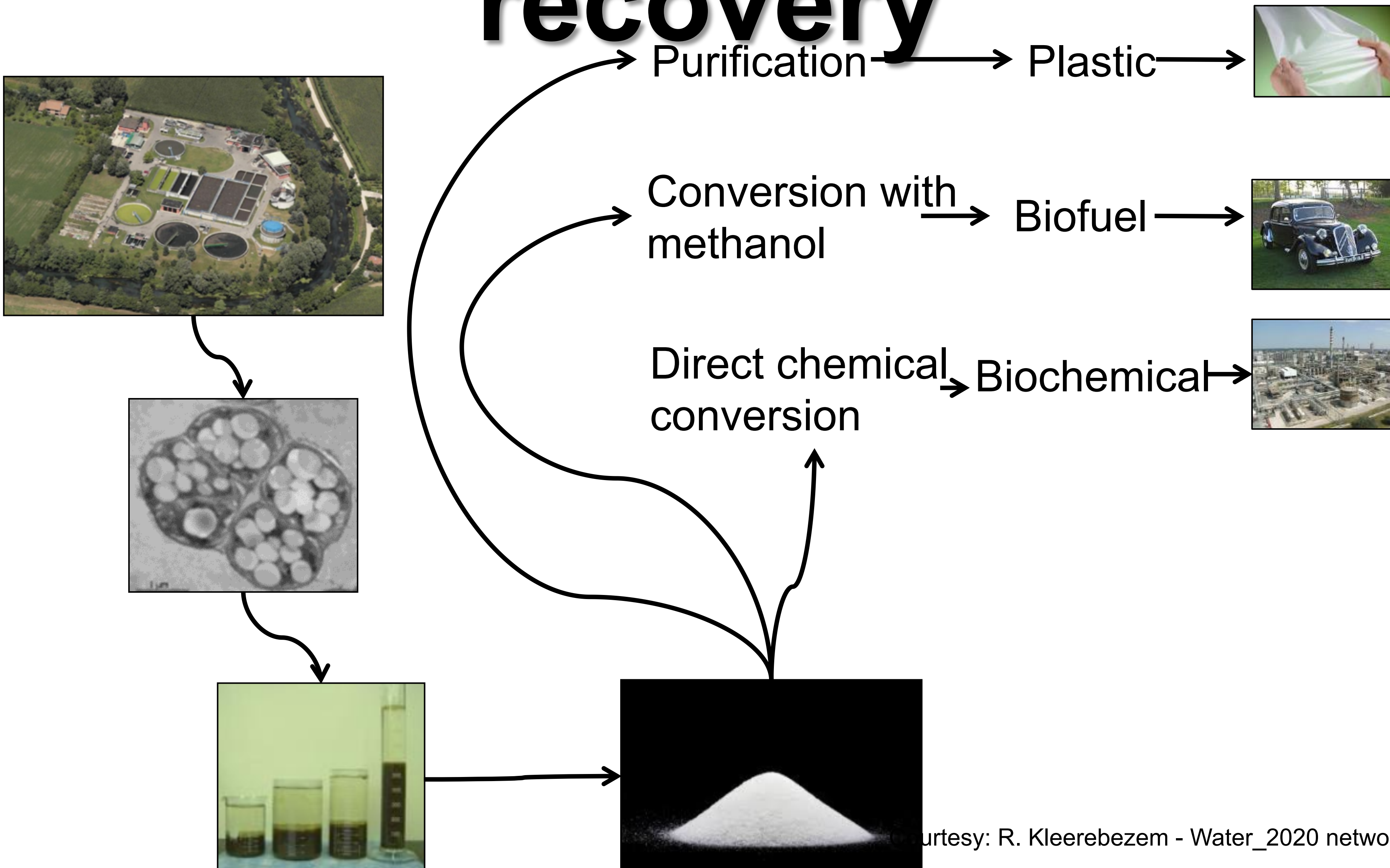
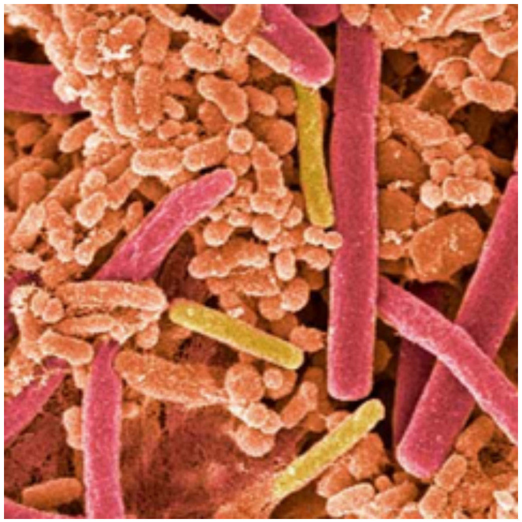
Biopolymers (PHA) recovery



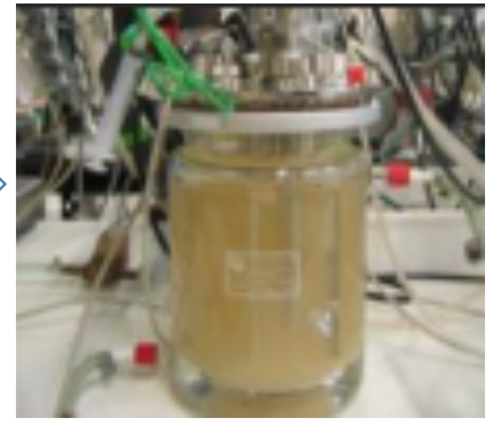
Courtesy: R. Kleerebezem - Water_2020 network

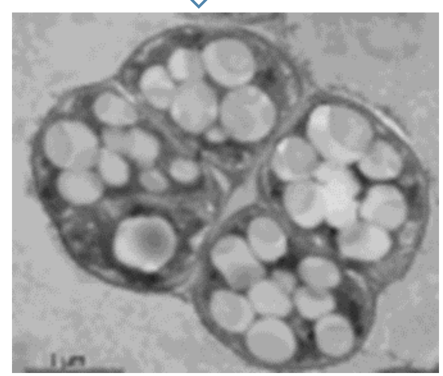
Microbial Community Engineering (MCE) for bioplastic production from wastewater

Explore natural microbial community



Impose selective pressure



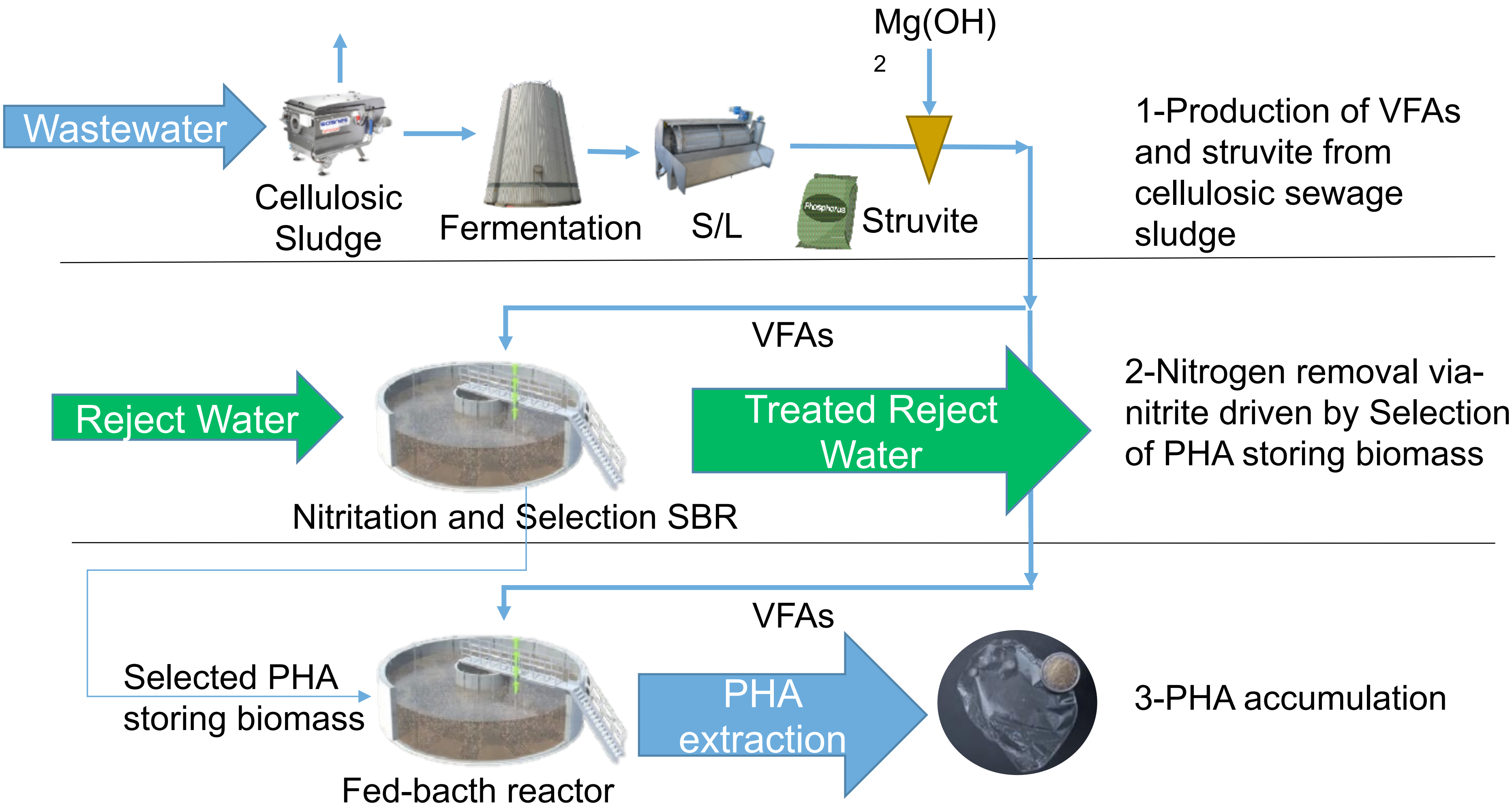


Select dominant work horse

Products and energy

Courtesy: R. Kleerebezem - Water_2020 network

SMARTech5 Sidestream SCEPPHAR



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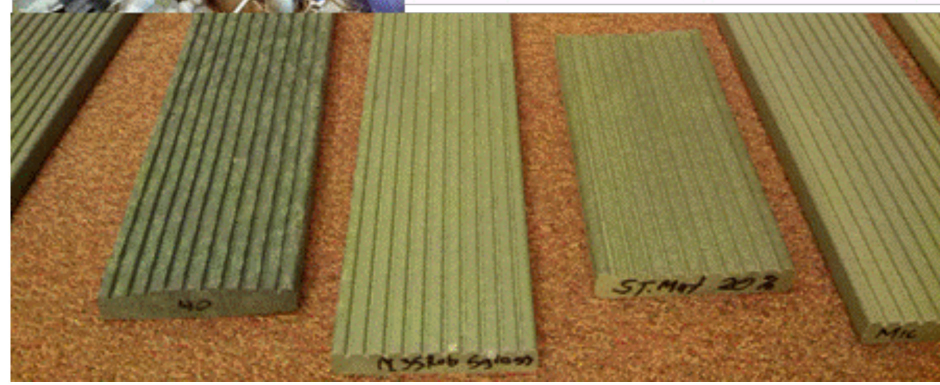
Downstream SMARTechA Post-processing of recovered cellulose and PHA for bio-composites production

- Downstream SMARTechA: Incorporation of the recovered cellulosic and PHA-rich materials as raw materials for the production of new type of sludge plastic composite (SPC);
- Processing of SPC is to be based on the modified extrusion process used for processing classical WPC;

Die Zone	TEMP ºC	Barrel Zones	TEMP ºC
1	160	1	100
2	130	2	120
3	130	3	180
4	130	4	180
		5	170
		6	130



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Downstream SMARTechB Post-processing of cellulosic and P-rich sludge

Dynamic Composting Obtain a compost rich in nutrients from P-rich sldudge

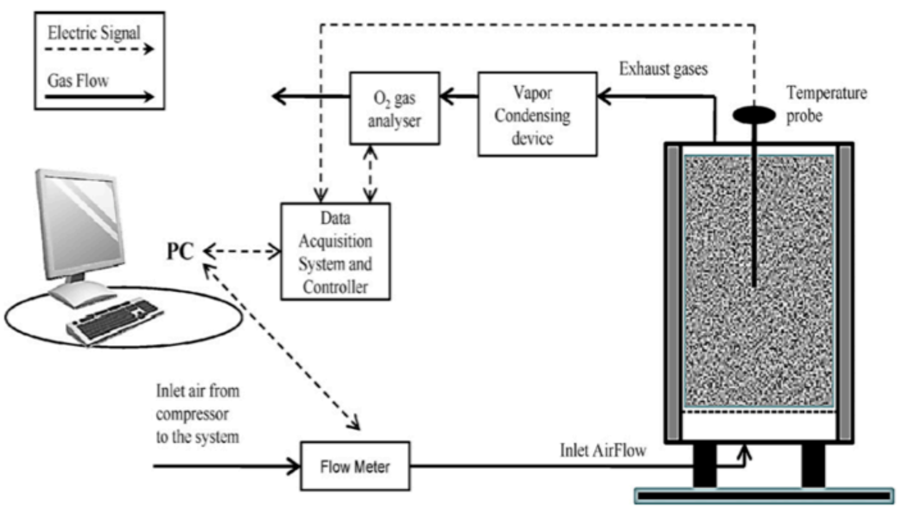


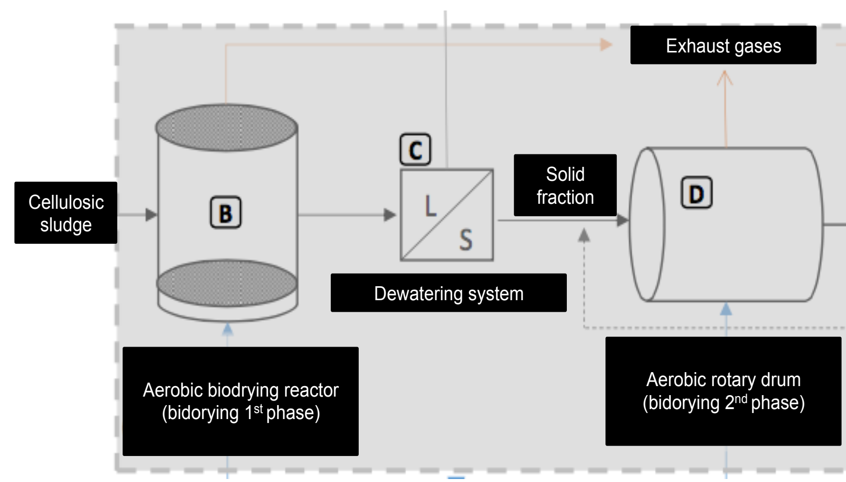
Fig. 1. Experimental set up of the composting pilot reactor.

100 -250 $L_{reactor}$

1) Mixture of bulking agent + P-rich sludge (SCENA)
2) Mixture of bulking agent + Mesolite recovered compounds + Prich sludge
3) Mixture of mesolite recovered compounds + P-rich sludge + conventional WWTP sludge

Biodrying Obtain a biofuel from cellulosic sludge

1000 $L_{reactor}$



Bio-drying is a compost-like process, however, the eventual goal of this concept is to use the metabolic heat to remove water from the cellulosic sludge at the lowest possible residence time and minimal carbon biodegradation hence preserving most of the gross calorific value of the waste matrix

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SMARTechB Post-processing of cellulosic and P-rich sludge

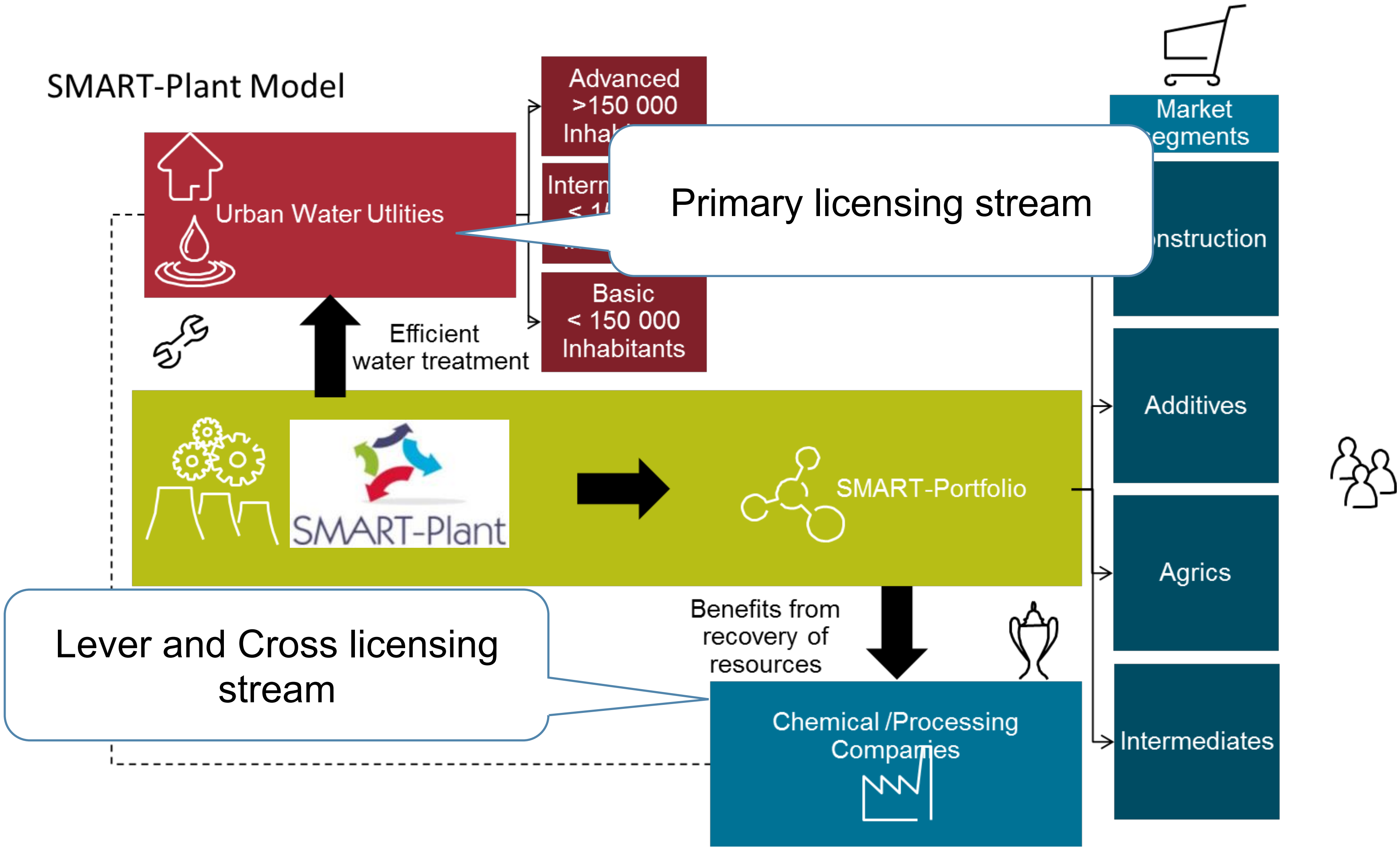
Evaluation of P fertilizing effects of P-rich sludge and struvite

P: “the disappearing nutrient” → find new sources

Mg: “the forgotten element” → widespread deficiency,increasingly used in fertilizer programs

Plant species: monocots (maize) and dicots (grapevine)

SMART-Plant Business plan and market deployment strategy



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The business model is developed profiling key target groups:

- **Water utilities**: grouped into basic, intermediate and advanced clusters
- **Chemical and downstream processing industries**: related to the four main strategic pillars: Construction, additive, Agrics and Intermediates

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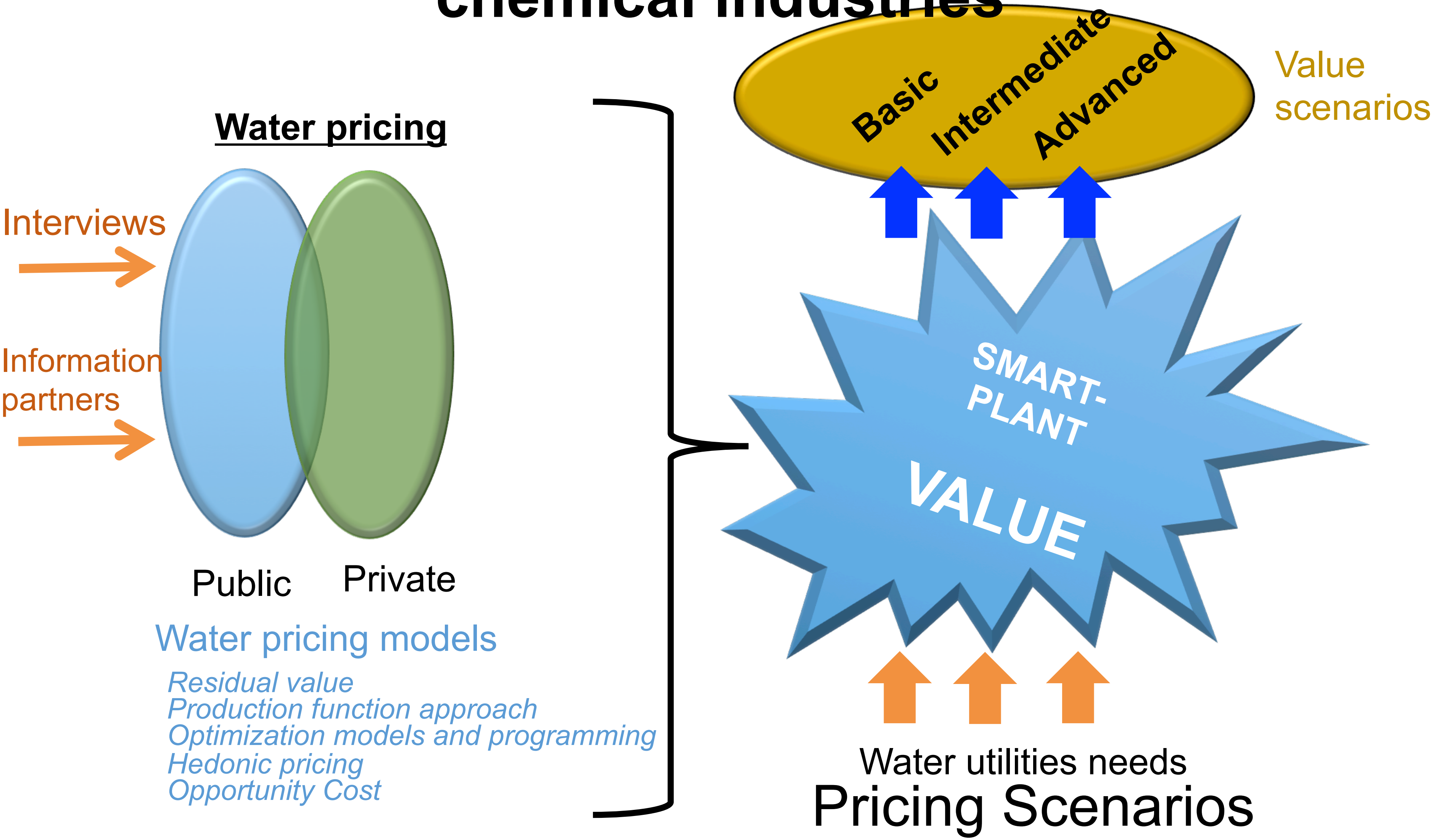
Public/private water utility management perspectives to deliver circular economy with the chemical industries



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SMART-product portfolio dvt. for the recovered resources

SMART-Plant strategic pillars

Construction
- Compound s PHB / cellu-lose to be developed by ECODEK defined in key product grades ba-sed on use

Additives
- Selected additive application s for consu-mer, incl. plastics, oil & gas and constructio n to be refined for SMART

Intermediates
- VFA and N and P derivatives recovered from SMARTech nologies to be assessed as chemical intermediat

Agriculture
- Struvite and P rich compost to be assesses with respect to use for agriculture, in selected European countries

SMART- Product portfolio with key product offer by strategic pillar to guide exploitation

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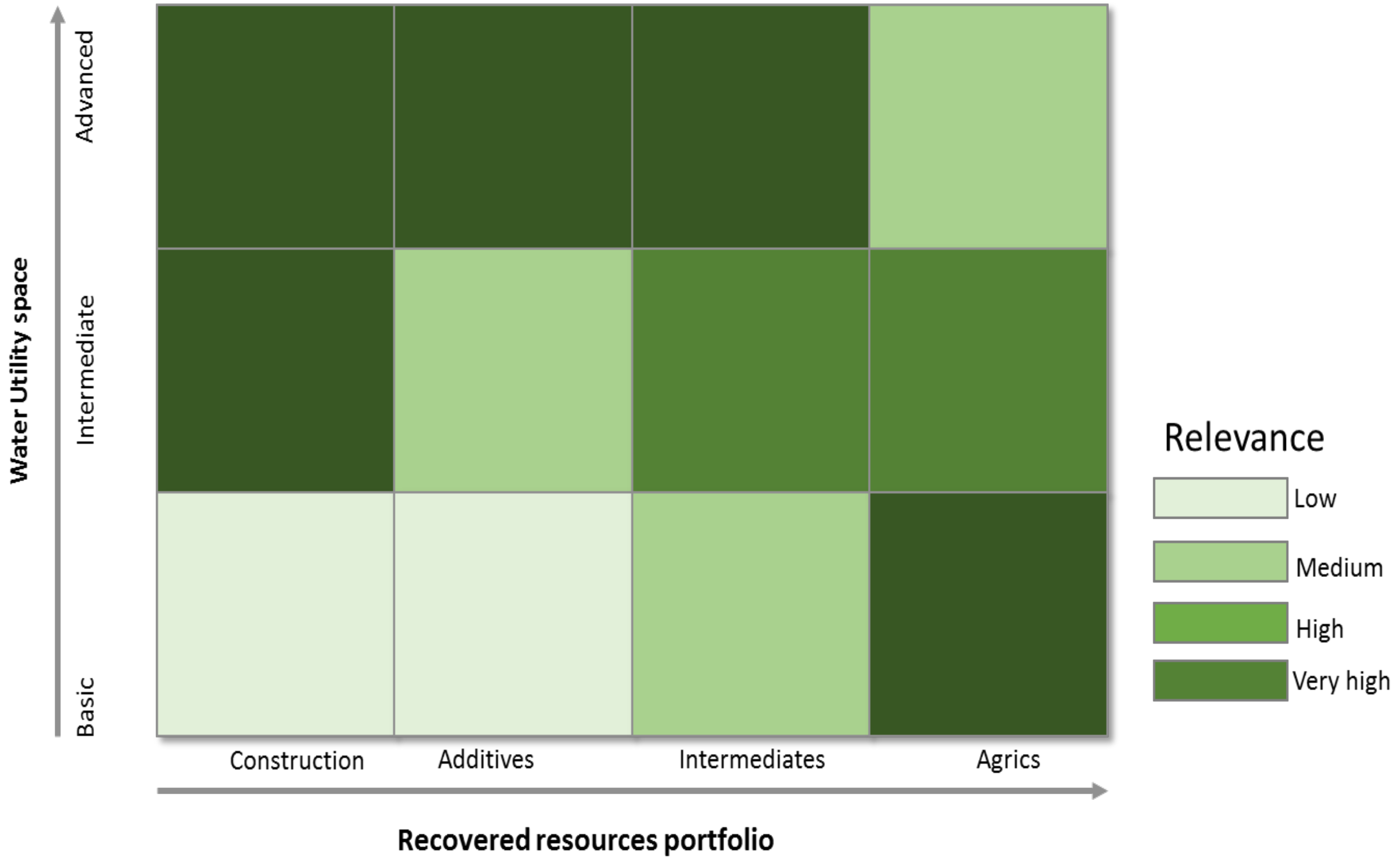
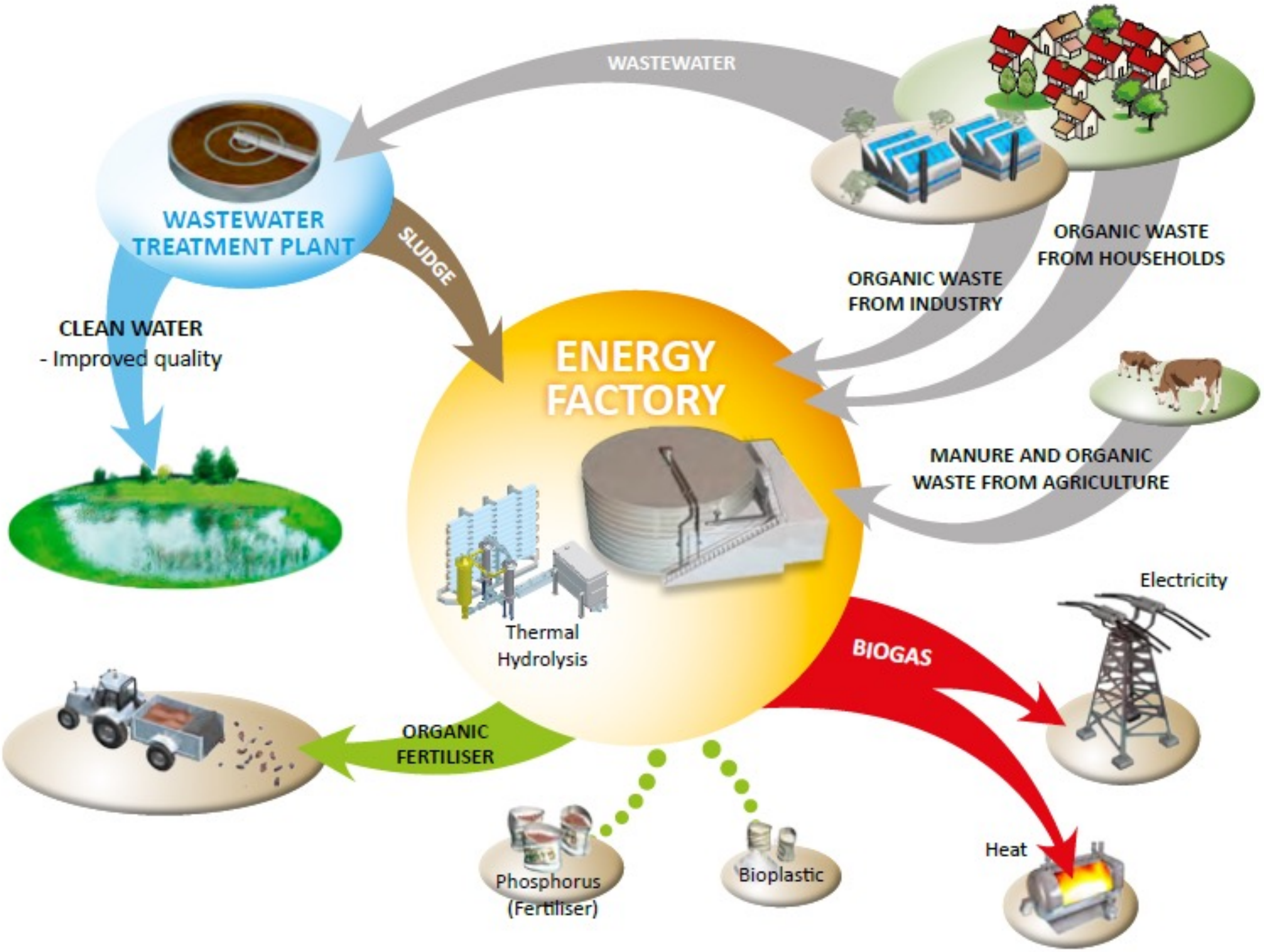
SMART-Plant exploitation matrix and heat map



Only municipal wastewater? The WWTP can be the urban biorefinery!



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Integration of municipal wastewater and organic waste treatment

First reported in 1988, a pioneering study of co-digestion by Cecchi et al.
at Treviso WWTP

Mata-Alvarez J, Dosta J, Macé S, Astals S (2011), Crit. Rev. Biotechnol. 31:99-111

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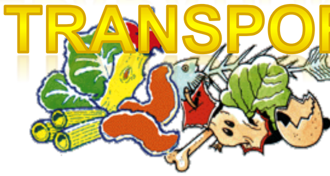
TECHNOLOGIES

BIOWASTE PREPARATION AND TRANSPORT



1) Source Separate Collection

2) Under Sink Food Waste disposer

WWTP

THE TREVISO FULL SCALE WWTP

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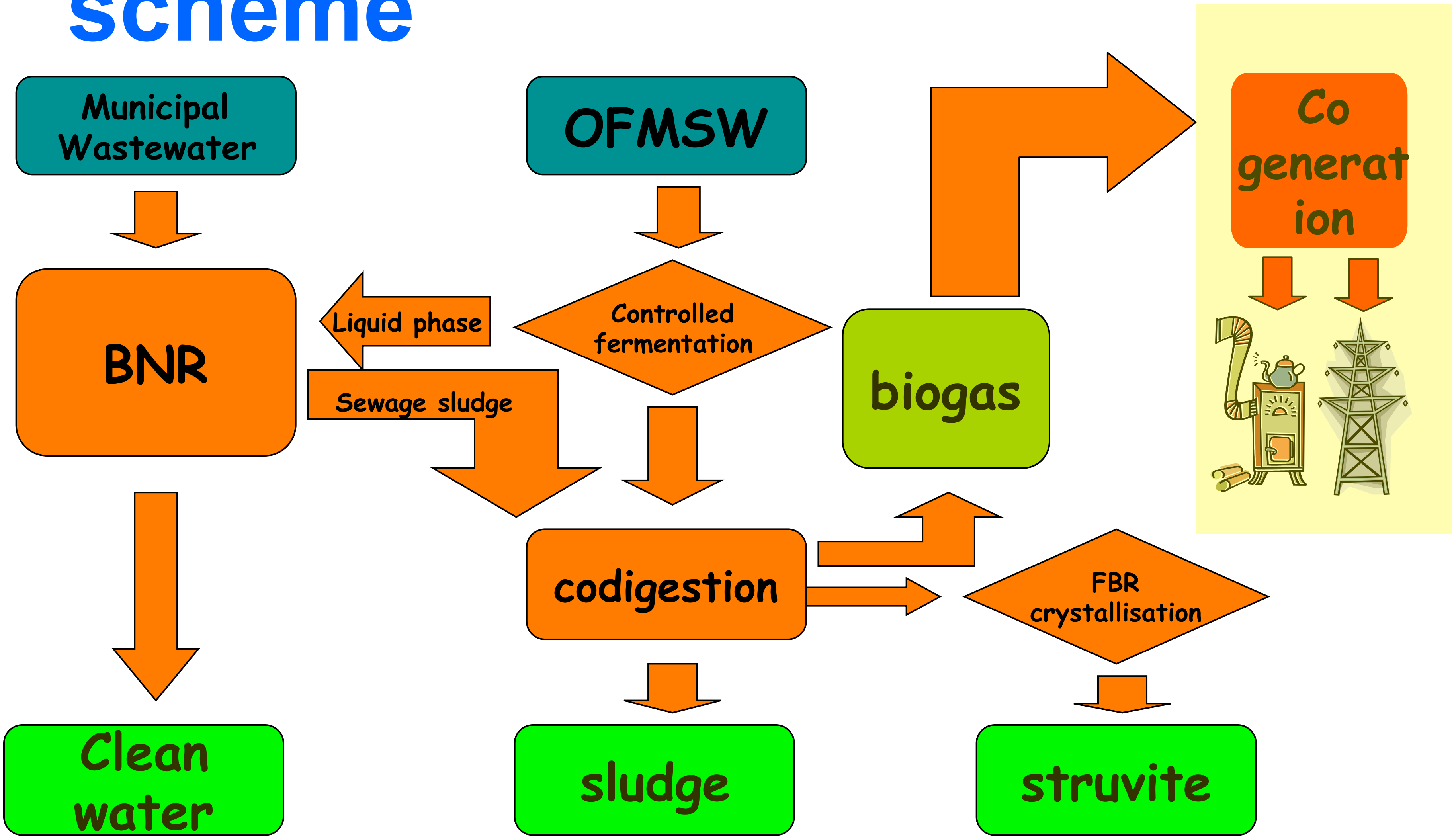
AF-BNR-SCP: process scheme



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Biowaste pre-treatments: Case Studies

Treviso (Italy)

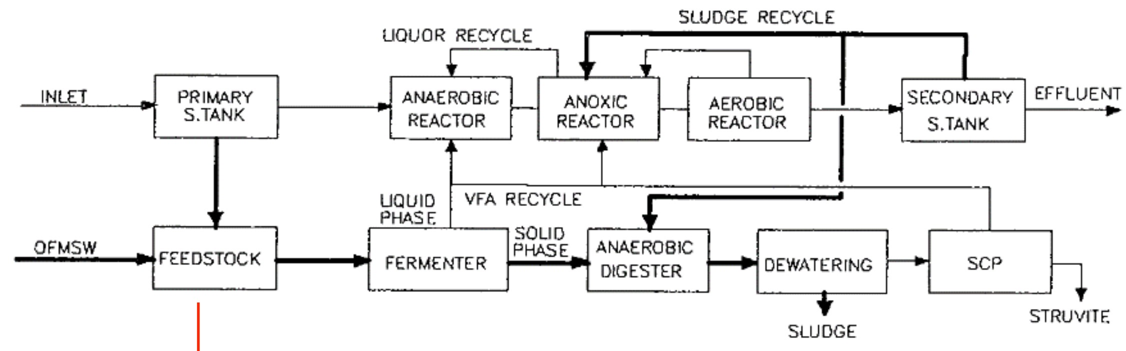

Fig. 1. Flow-sheet of the integrated AF-BNR-SCP process.

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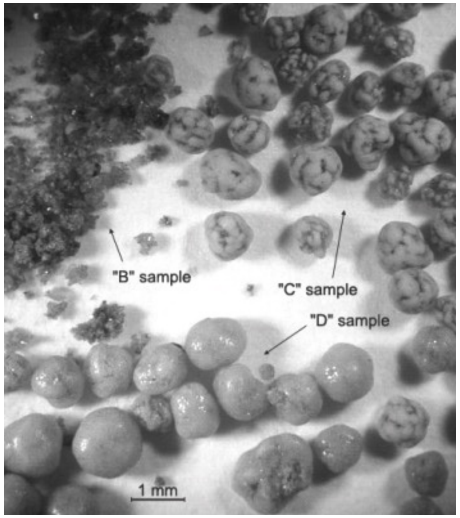
The Struvite Cristallization Plant at the Treviso WWTP

Struvite Crystallization Plant

The Struvite

N-P low release fertilizer



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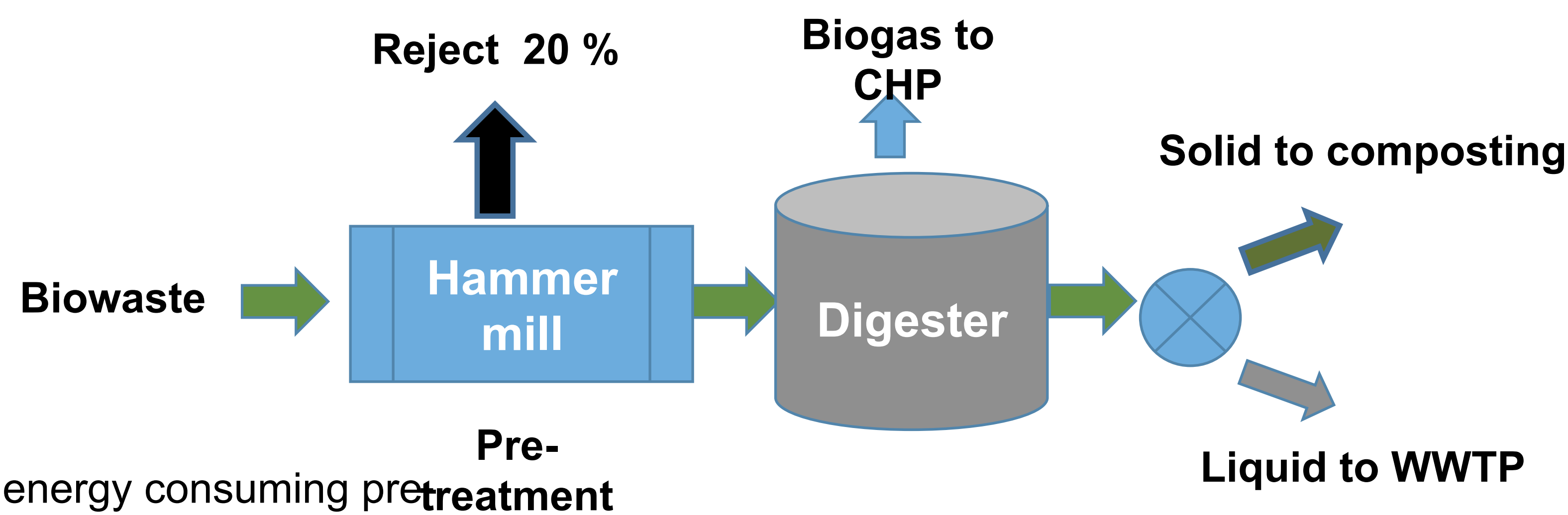
TECHNOLOGIES

Biowaste pre-treatments: Case Studies

Rovereto (TN, Italy)

Hammer Mill

Design capacity, t/y	5.000 SS-biowaste 110.000 sludge (5% TS)
Actual Capacity, t/y	3.000 SS-biowaste 70.000 sludge (x% TS)
Process	Wet
Reactors	2 x 2.500 m^3
Temperature	Mesophilic



“MEDIUM” energy consuming pre-treatment

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TECHNOLOGIES

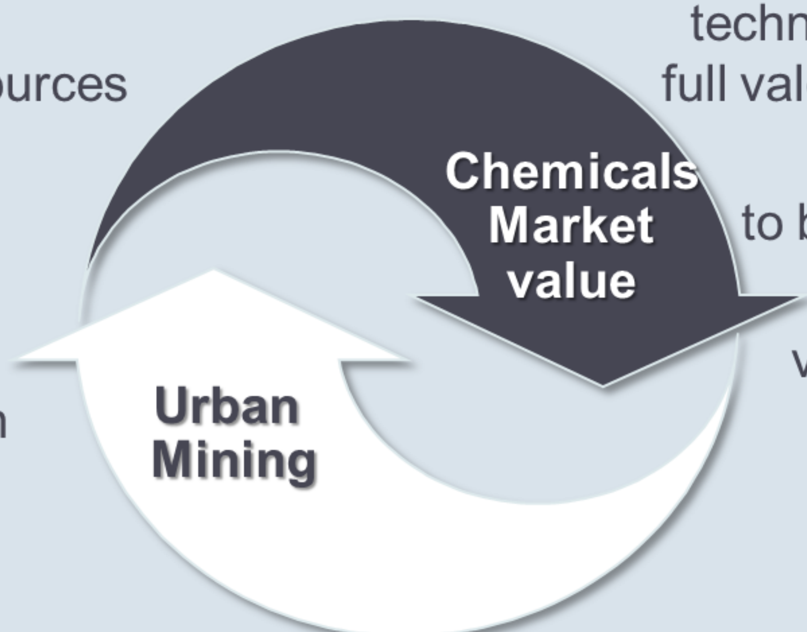
Biowaste pre-treatments: Case Studies

Rovereto (TN, Italy)

market?
The SMART-Plant Joint

From Chemicals from Natural Resources to Urban Mining

- SP JV vision is to disrupt the linear model of chemical sourcing, moving to circular economy with full valorization of chemicals, by Urban Mining through watertreatment technologies and chemical recovered resources full valorization
- Chemical sourcing to be a fully closed loop
- Chemicals to be fully valorized, disregardless their origin



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SMART-Plant Joint Venture

Mission Statement

- To enable full transition to Urban Mining

Through:

- Delivering to wastewater treatment plants custom solutions for resources recovery
- Supporting in full valorization of chemicals for relevant end use

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SMART-Plant JV will support in

1

Identify

- Key resources to recover
- Technology upgrade reqquired

2

Exploitation of Chemicals (getting full value of Urban Mining)

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Target is to use full value from Urban Mining

Realization

- Market introduction of Chemicals
- Derive full value of Urban Mining
- Close the loop of circular economy in wastewater treatment plants

Implementation

- Upgrade and resource recovery
- Chemicals application dvt. to match unmet market need

Concept

- Technology upgrade roadmap
- Recovered resources plan / to match local demand

SMART-Plant Exploitation Manager: InnoEXC

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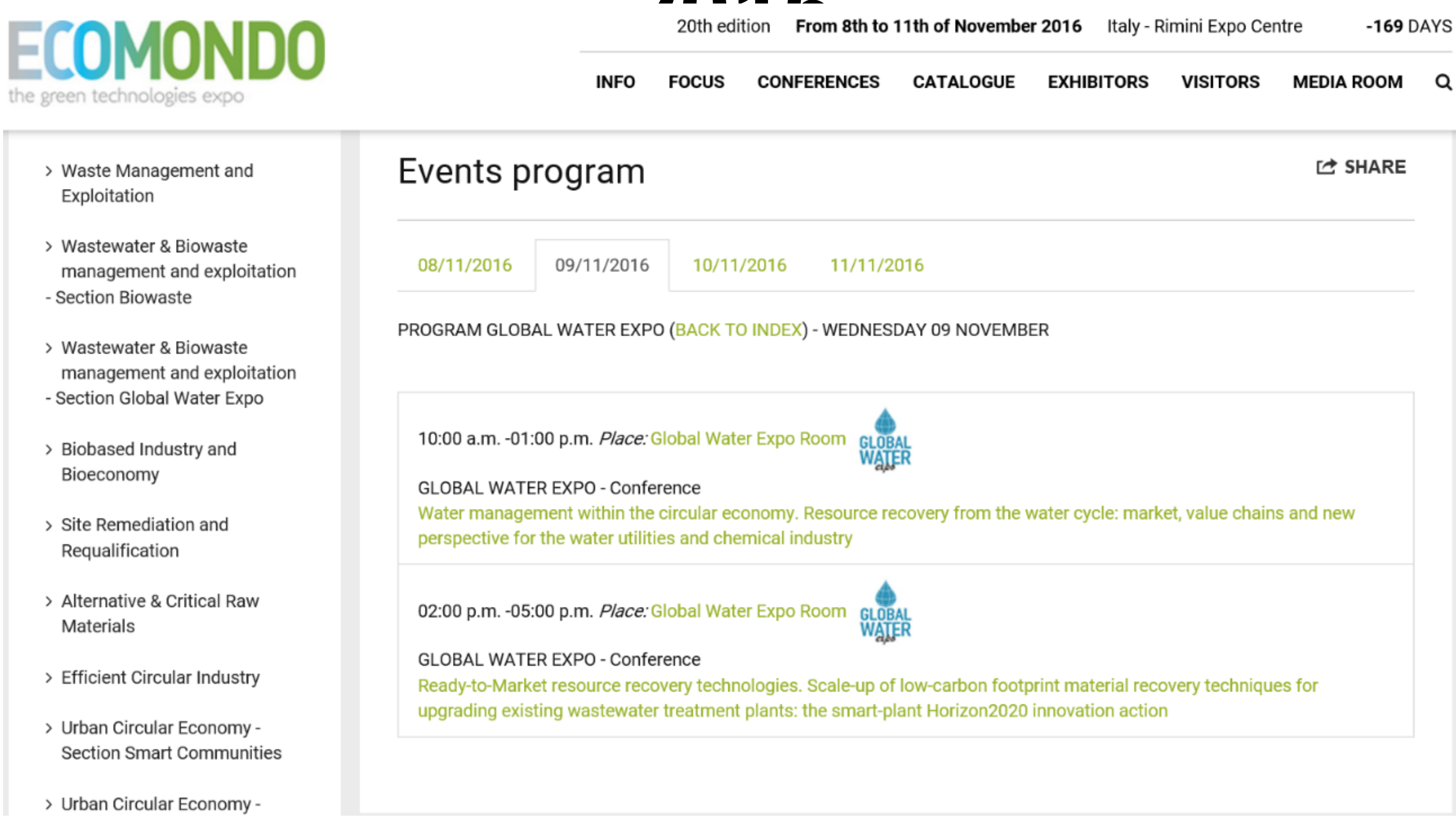
Thank you for your attention and… see you in **ECOMONDO 2016**



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