



**Ninth International Conference BULAQUA 2017
BLUE CIRCULAR ECONOMY**

Circular management of municipal wastewater

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Scientific Executive Board of ECOMONDO (www.ecomondo.com)



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Outline of the presentation

- Brief outline of our R&D&I activities to deliver circular economy in water and waste sectors
- Circular economy in the water sector: new key role for wastewater stakeholders and operators
- The SMART-Plant Innovation Action
 - Technologies
 - Business models
 - Market exploitation and replicability
- Wastewater treatment plant as urban biorefinery

Who we are and what we do



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 concepì l'idea del depuratore come "centro urbano multifunzionale", utilizzabile per trattare diversi flussi di scarico 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»



Green Award Winner

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

- 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

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 Blo-waSte



Waste

EU H2020 – NoAW

Innovative approaches to turn agricultural waste into ecological and economic assets



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Water Utility Pathways in a Circular Economy



Water utility pathways in the circular economy

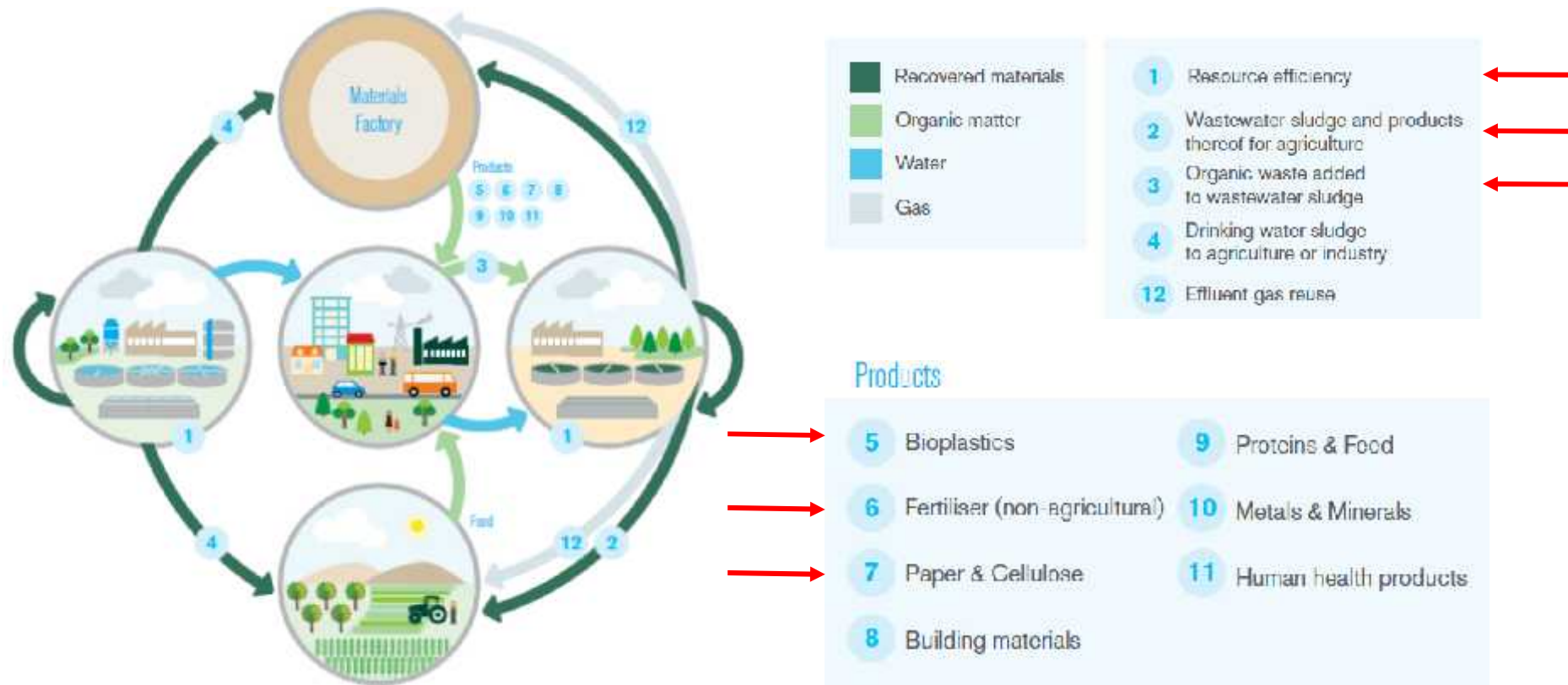
Water utilities can become engines for the circular economy by following three interrelated pathways:

- **The water pathway**
- **The material pathway**
- **The energy pathway**

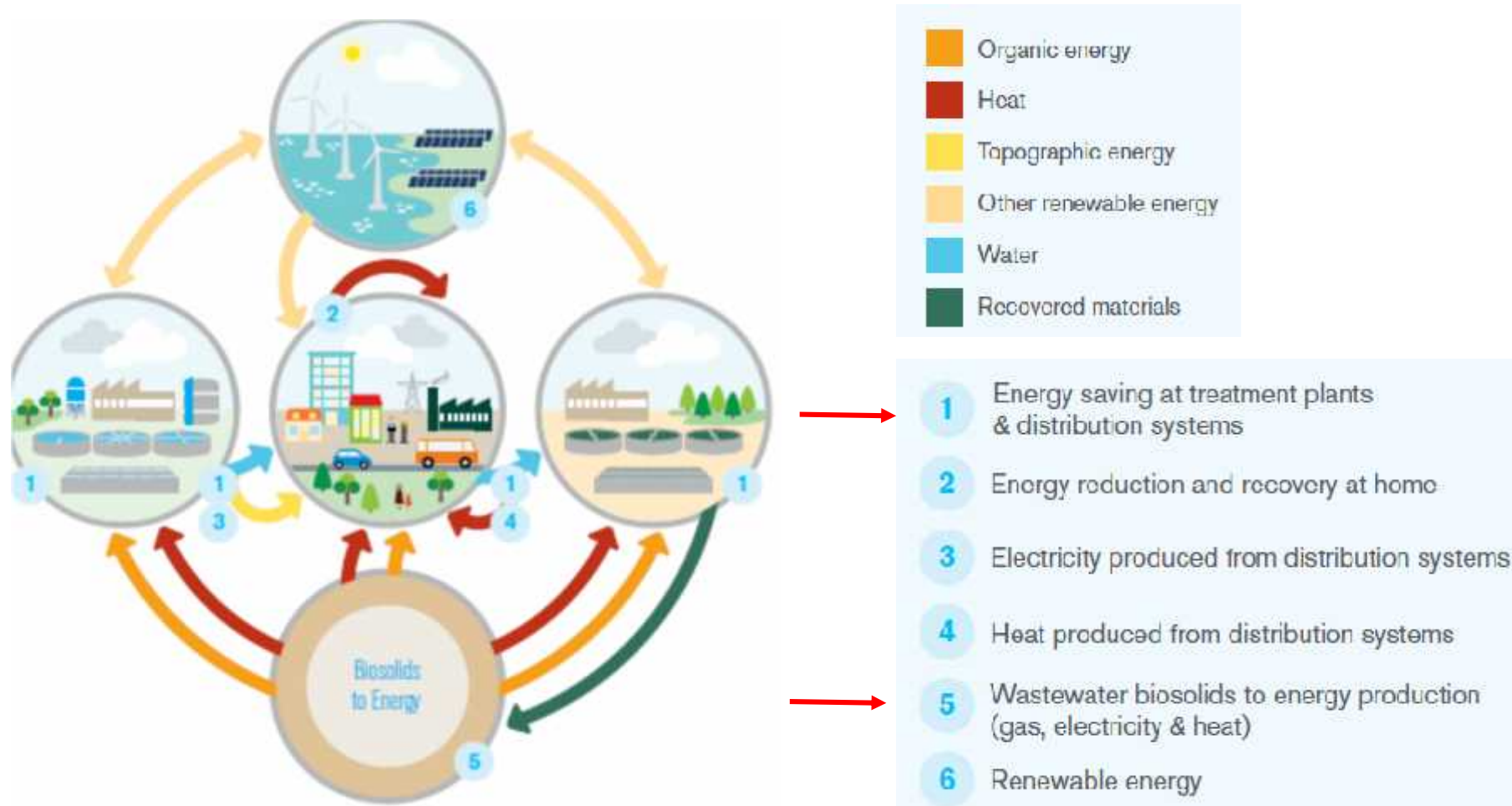
The water pathway



The materials pathway



The energy pathway



Ready-to-market circular solutions

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the green technologies expo

21th edition 7-10 November 2017 Italy - Rimini Expo Centre -220 DAYS

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GREEN & CIRCULAR ECONOMY

7TH-10TH
NOVEMBER 2017
RIMINI ITALY

21st INTERNATIONAL TRADE FAIR OF MATERIAL
& ENERGY RECOVERY AND SUSTAINABLE DEVELOPMENT

CONTEMPORARY WITH

KEY ENERGY

Water in the circular economy?

The wastewater treatment plant is the key enabling element of the value chain



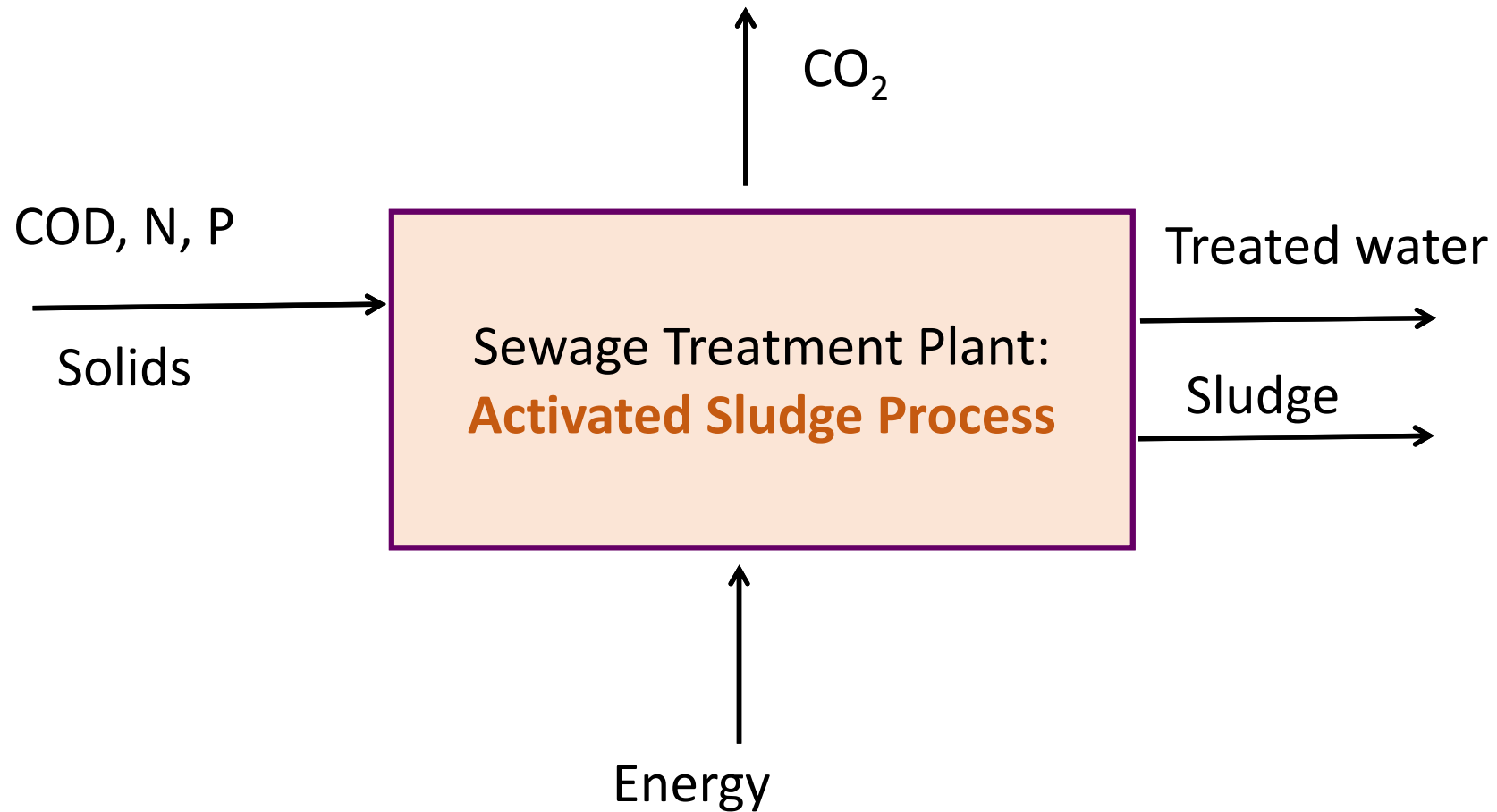
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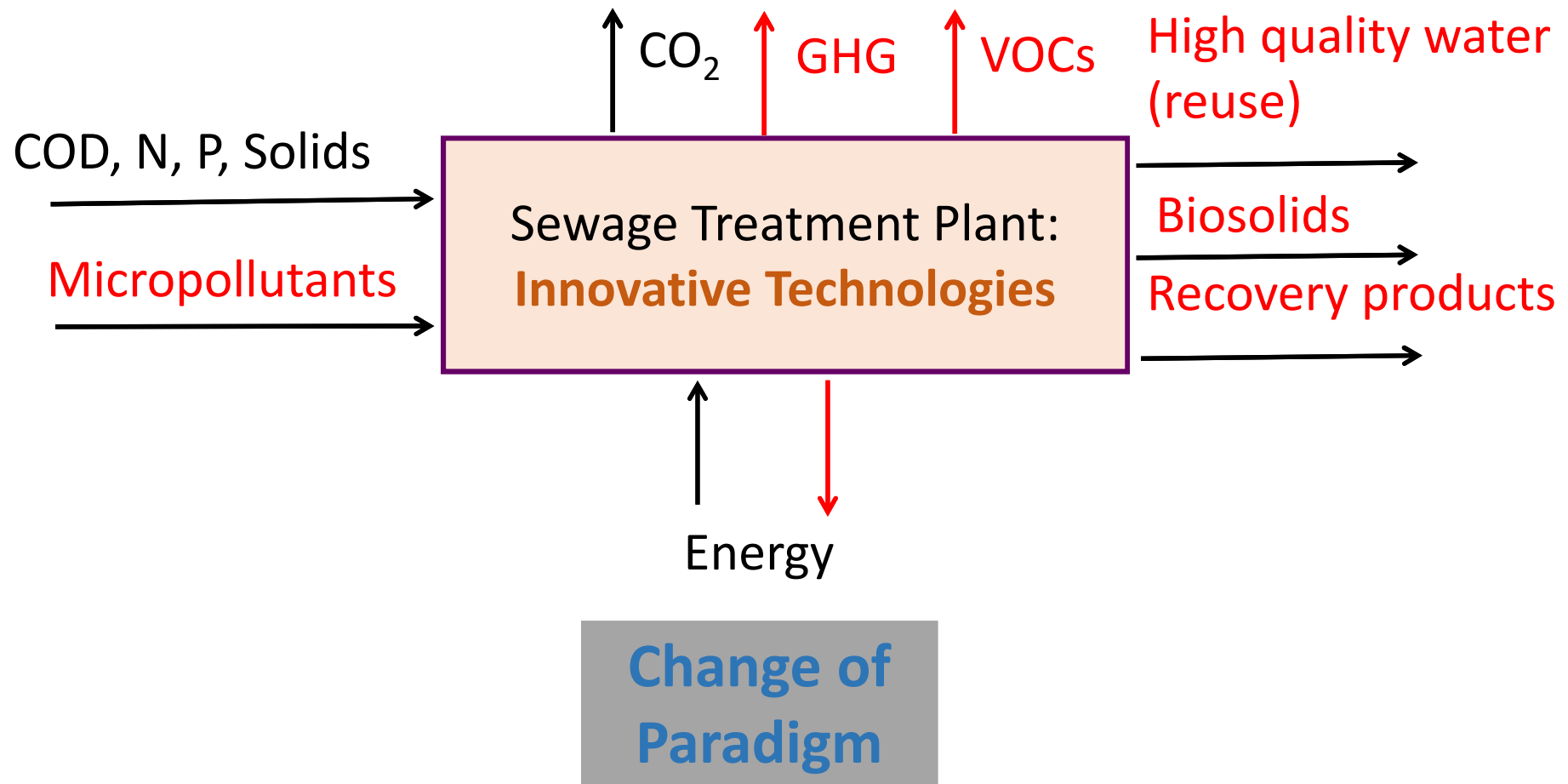
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Conventional WWTP



Advanced and circular WWTP



Resources embedded to municipal wastewater

Parameter	Value
Reusable water (m ³ /capita year)	80-100
Cellulose (kg/capita year)	5-7
Biopolymers; PHA (kg/capita year)	3-4
Phosphorus in P precursors (kg/capita year)	0,5-1
Nitrogen in N precursors (kg/capita year)	4-5
Methane (m ³ / capita year)	10-13
Organic Fertilizer (P-rich compost) (kg/capita year)	8-10

Verstraete et al. (2009) *Bioresource Technology* 100, 5537–5545

Salehizadej and van Loosdrecht (2004) *Biotechnology Advances* 22, 261–279

Key Enabling Strategy: upstream solid concentration, integration and innovation of the sewage sludge treatment

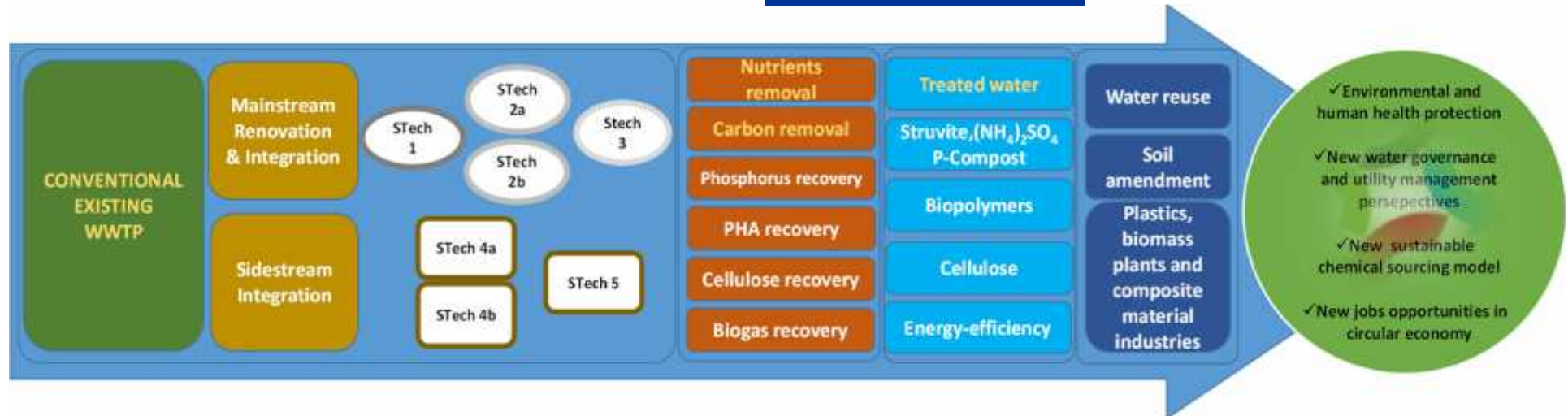


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The overall target of SMART-Plant is to validate and to address to the market a portfolio of SMARTechnologies that, singularly or combined, can **renovate and upgrade existing wastewater treatment plants** and give the added value of instigating the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

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	Aguas 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



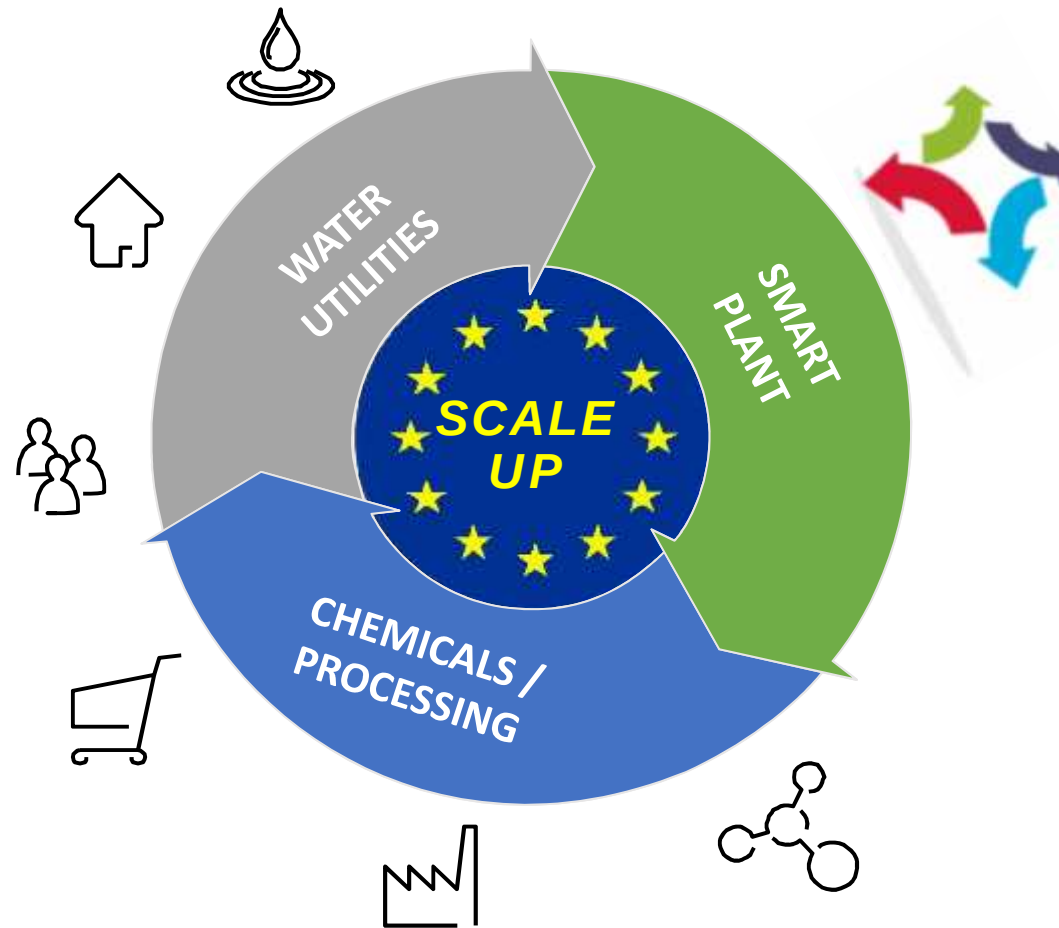


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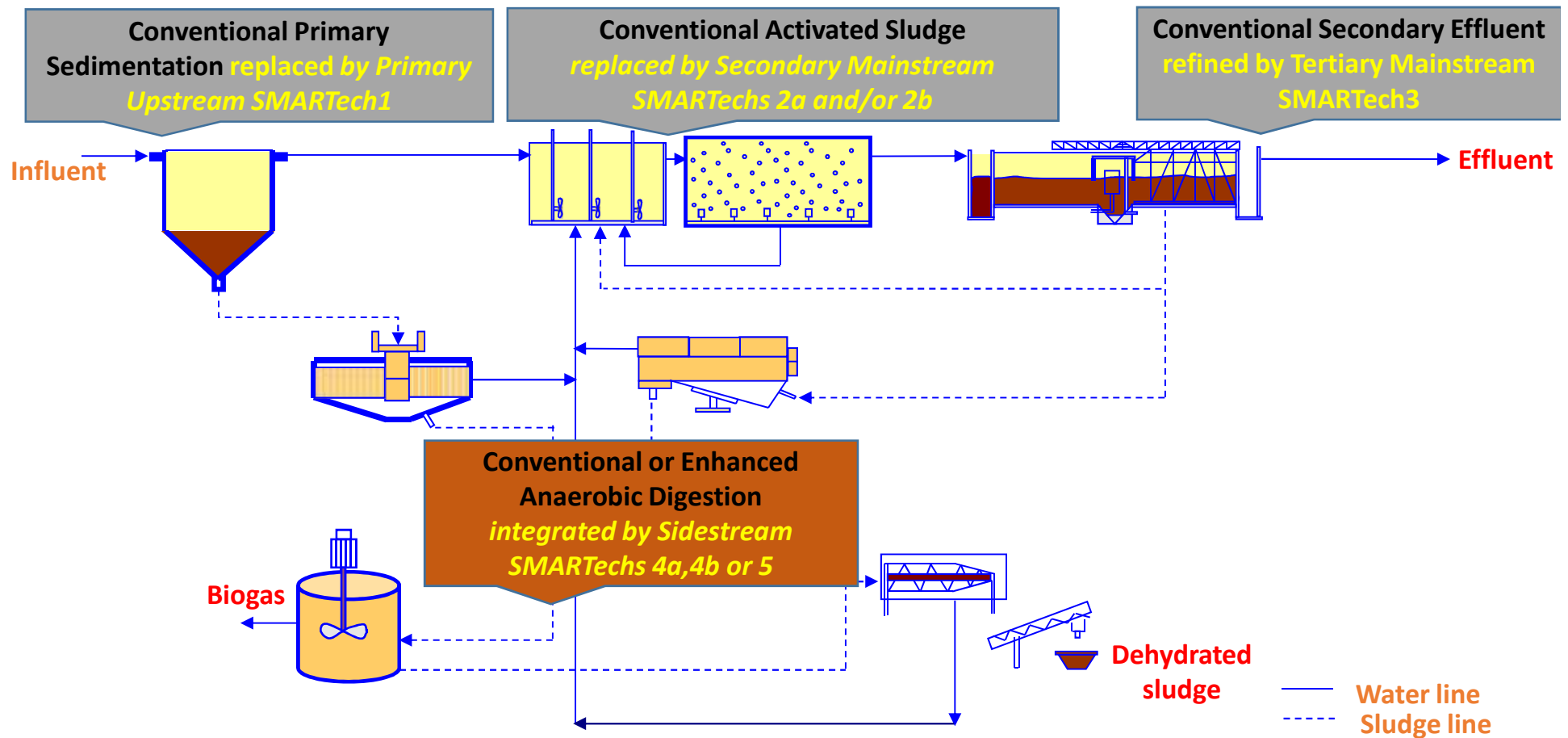


The SMART-Plant Consortium

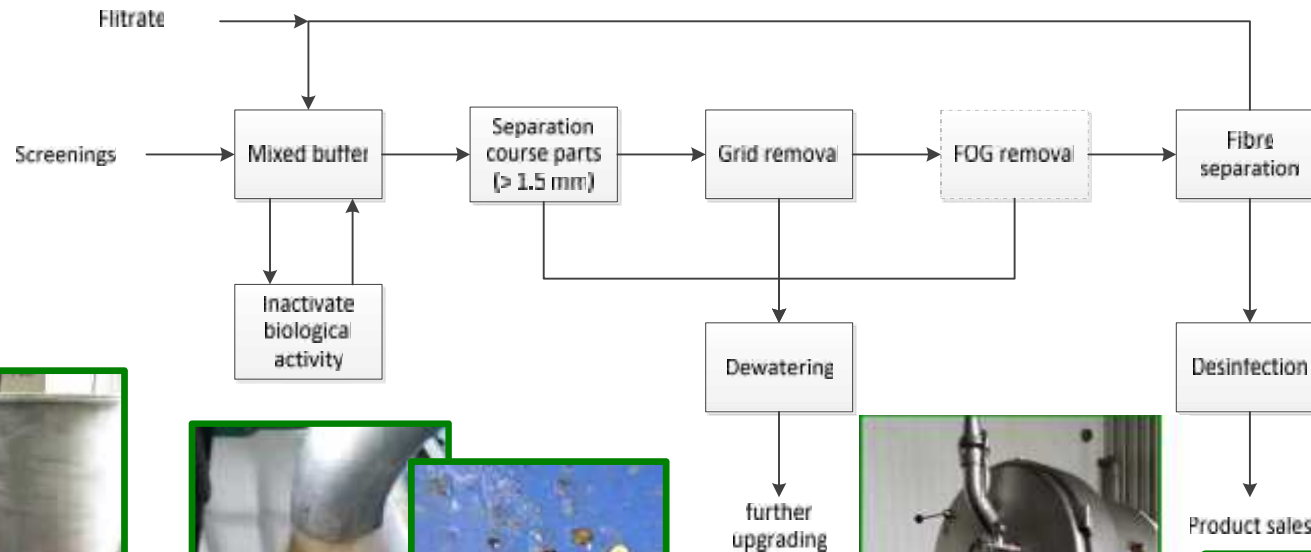
SMART-Plant open the pathway to deliver circular economy



The SMARTechnologies



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



Inactivation
biological activity



Separation course
parts



Sand-/grit removal



Fibre separation

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

Realization of a full-scale plant

- ✓ all process steps combined in one process

Optimization:

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

Market development

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



First pilot testing

SMARTech2a: Secondary mainstream biogas recovery by polyfoam biofilter

■ B1 Technical Part

1. An innovative anaerobic immobilized polymeric biofilter.
2. Reaction volume -25 m³ will be designed and installed in the WWTP of Karmiel (North of Israel)
3. Characteristics:
 - 100-120 m³/d.
 - Removal of 30-40% of COD_f
 - Additional of 25% biogas
 - Reduction of 25-30% energy consumption.
4. Operation optimization, monitoring and validation:
 - biogas yield
 - biomass activity
 - treated effluent quality

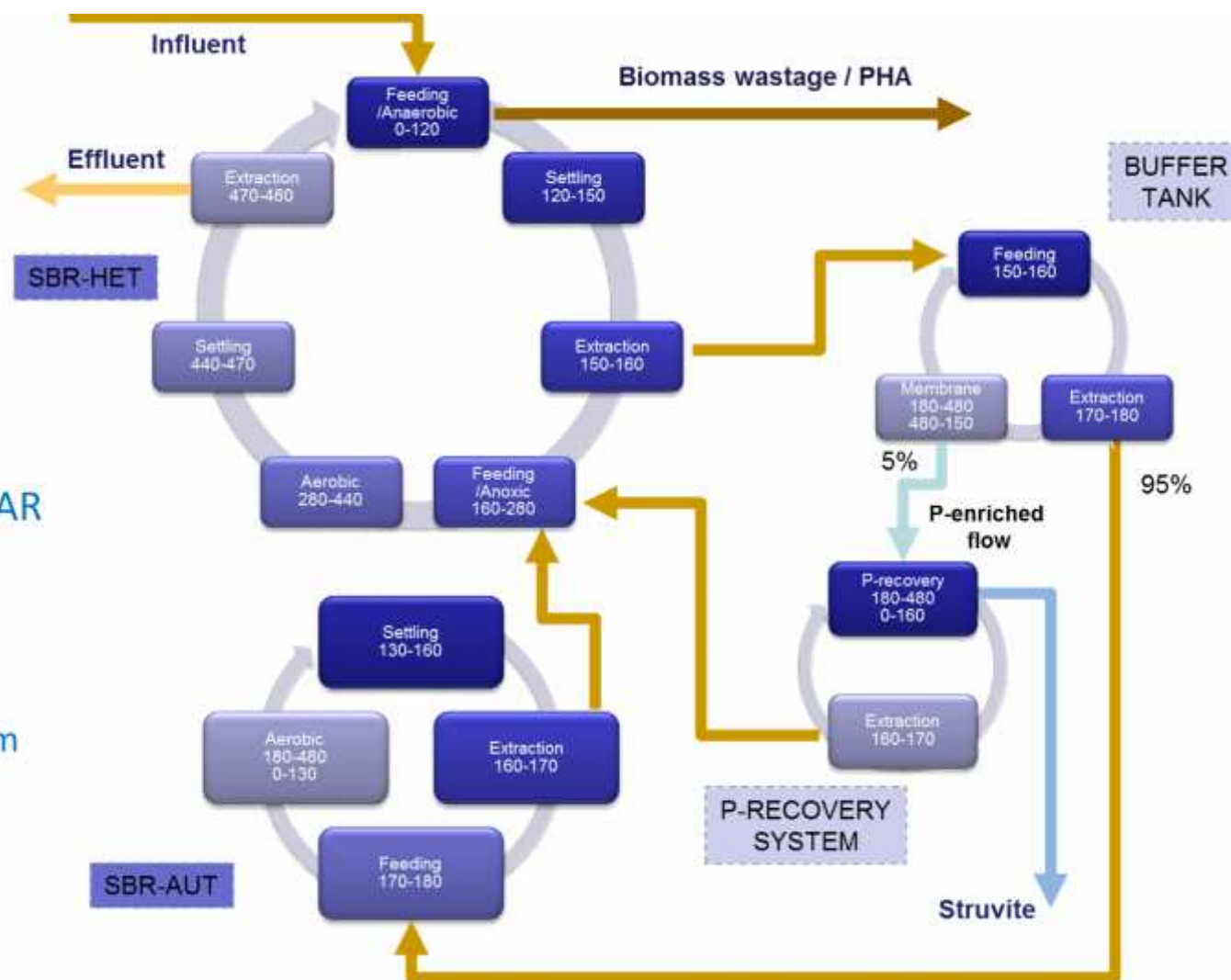


SMARTech2b: Secondary mainstream SCEPPHAR

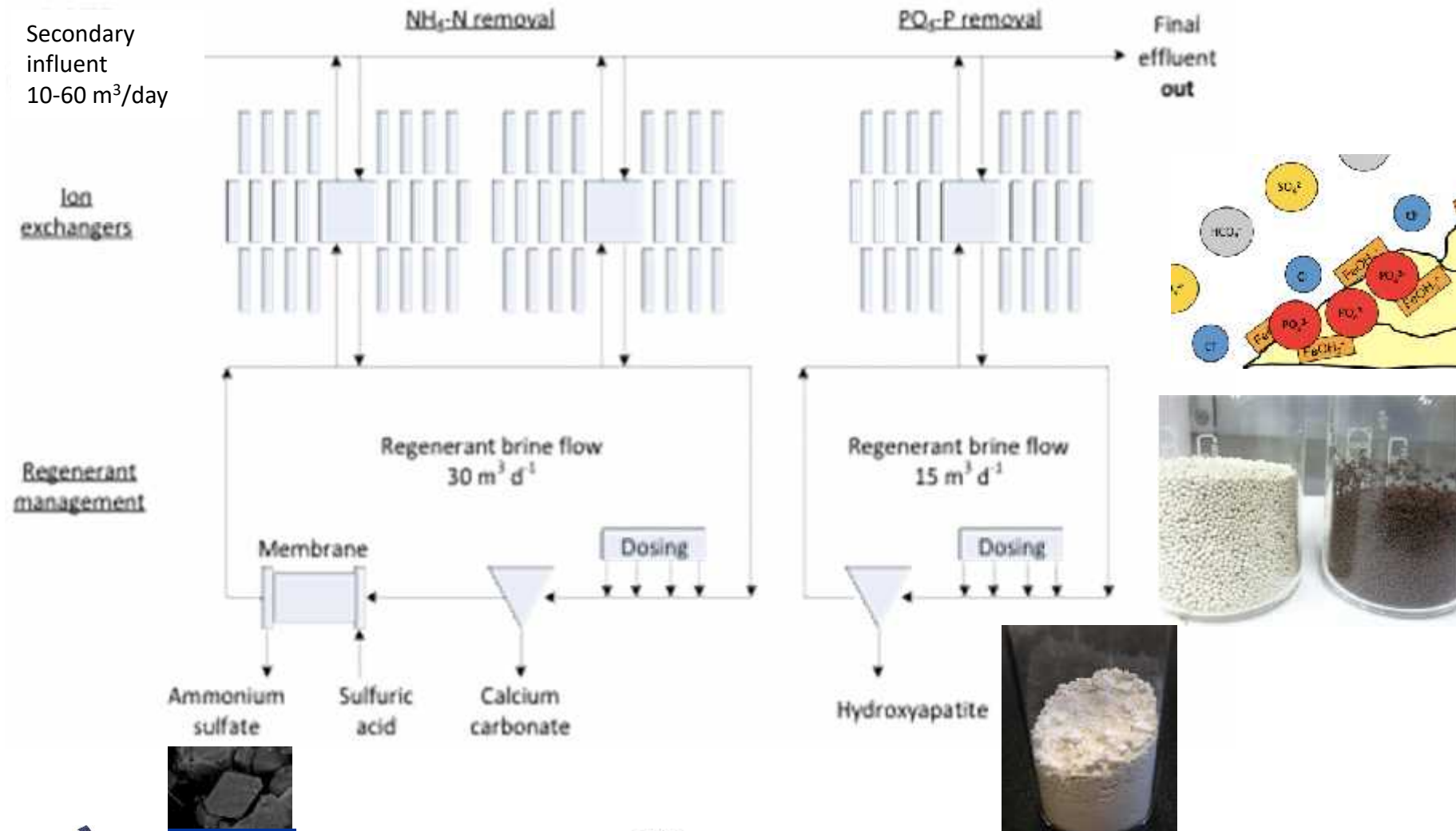
SMARTech2b

Mainstream SCEPPHAR

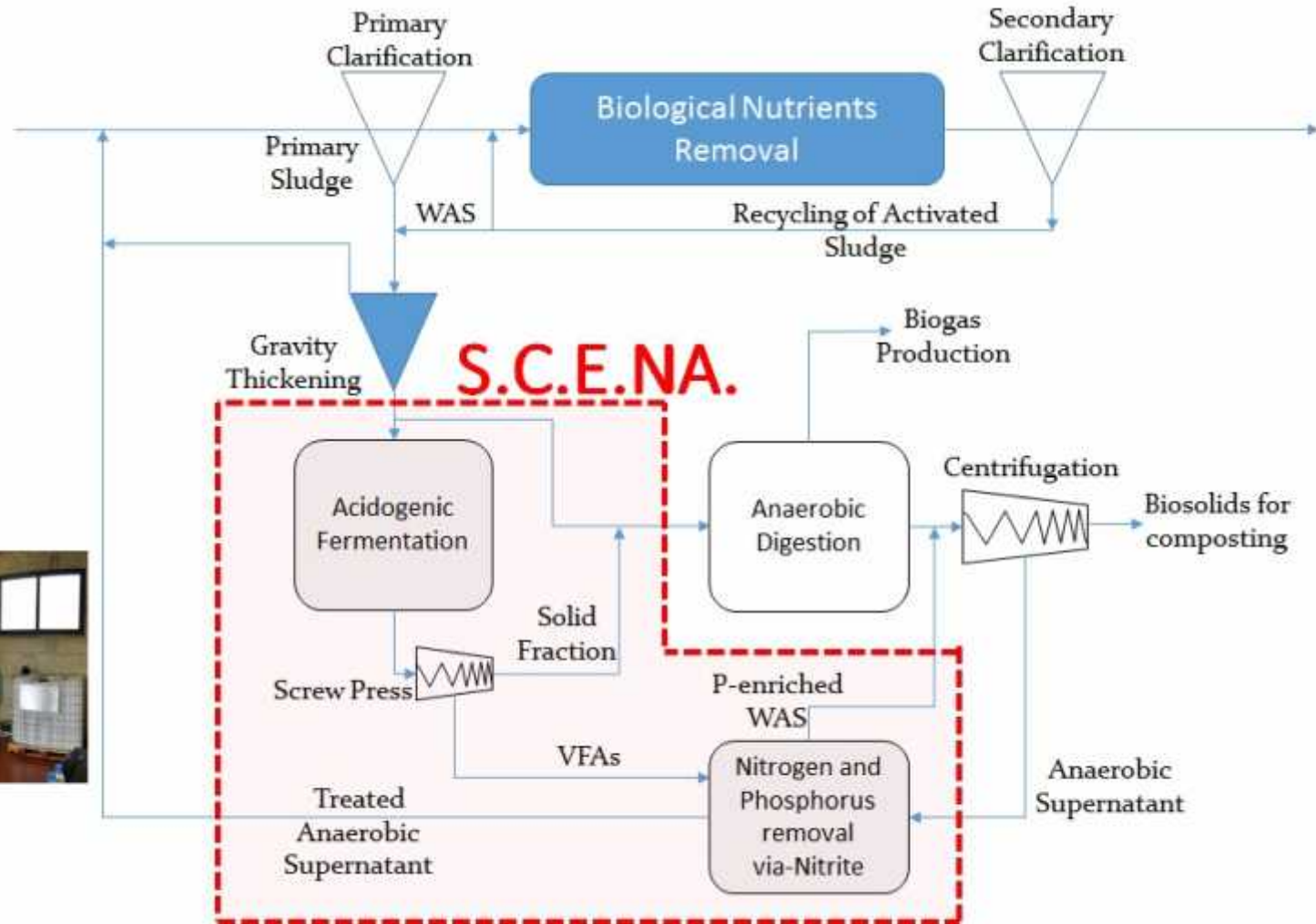
- Two SBR
- Buffer tank
- P-recovery system



SMARTech3: Tertiary nutrient recovery by mesolite and nano ion exchange



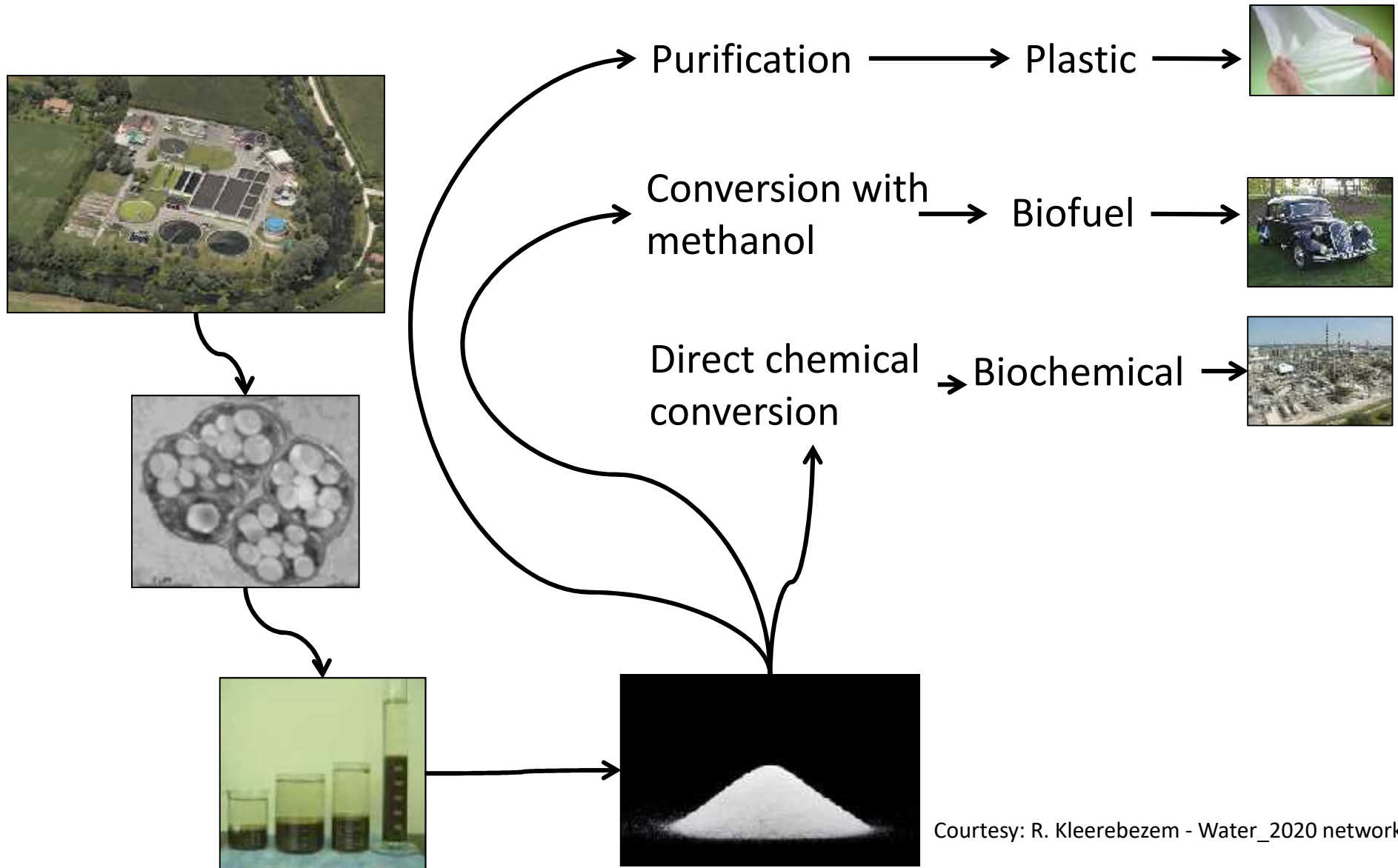
SMARTech4a/b Sidestream S.C.E.N.A.



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)

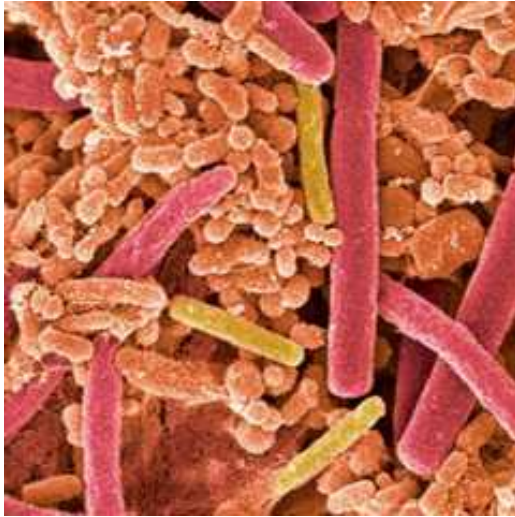
Biopolymers (PHA) recovery



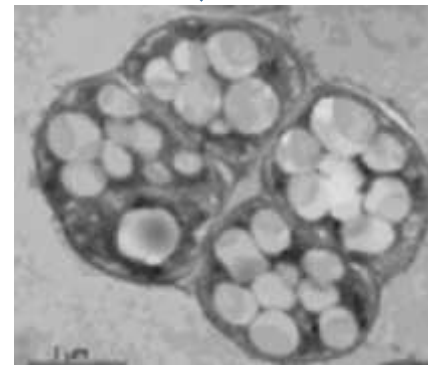
Courtesy: R. Kleerebezem - Water_2020 network

Microbial Community Engineering (MCE) for bioplastic production from wastewater

Explore natural microbial community



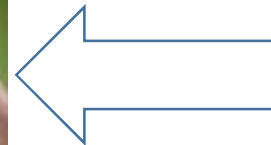
Impose selective pressure



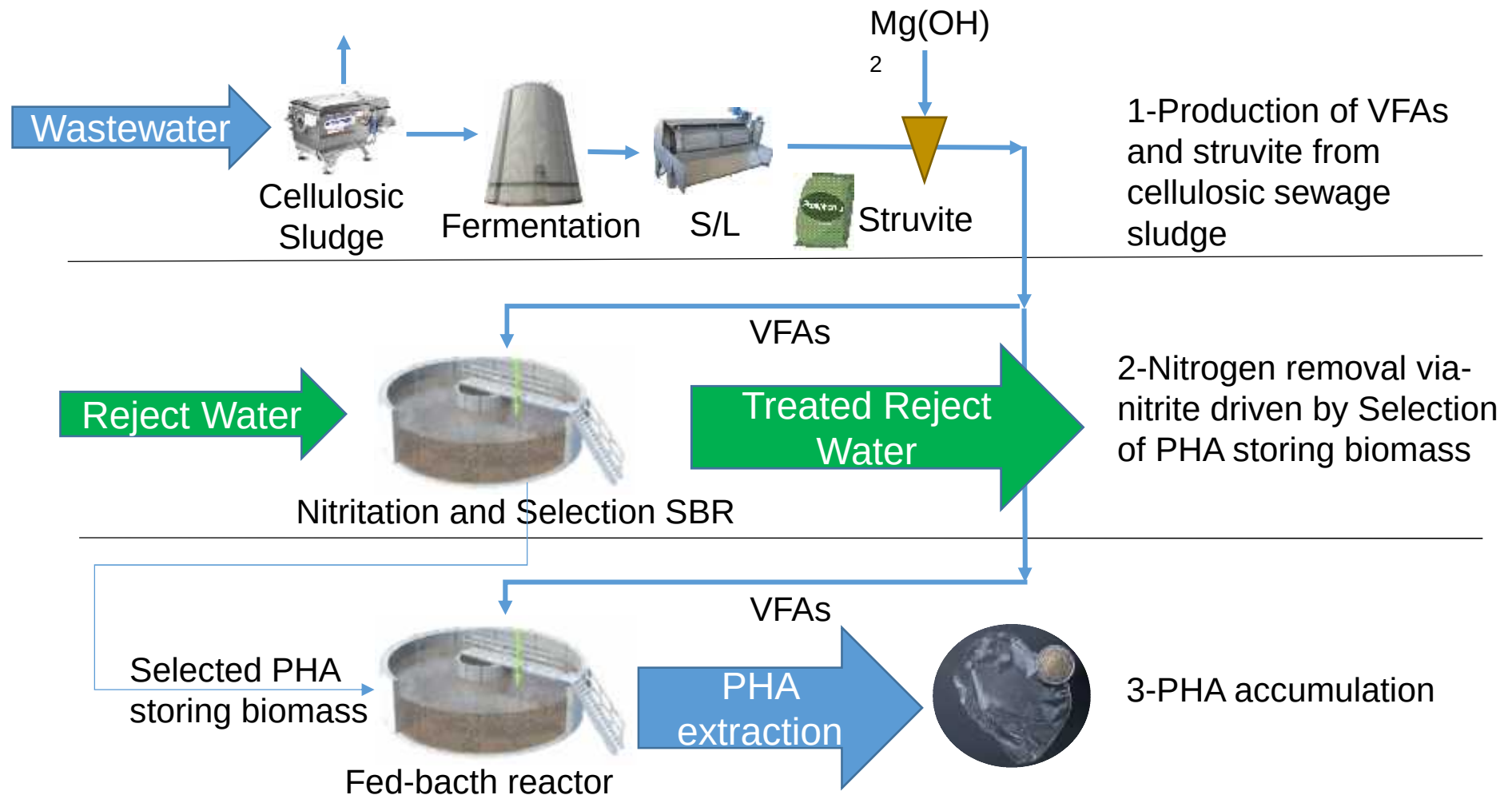
Select dominant work horse



Products and energy



SMARTech5 Sidestream SCEPPHAR



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 °C	Barrel Zones	TEMP °C
1	160	1	100
2	130	2	120
3	130	3	180
4	130	4	180
		5	170
		6	130



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

Dynamic Composting → Obtain a compost rich in nutrients from P-rich sludge

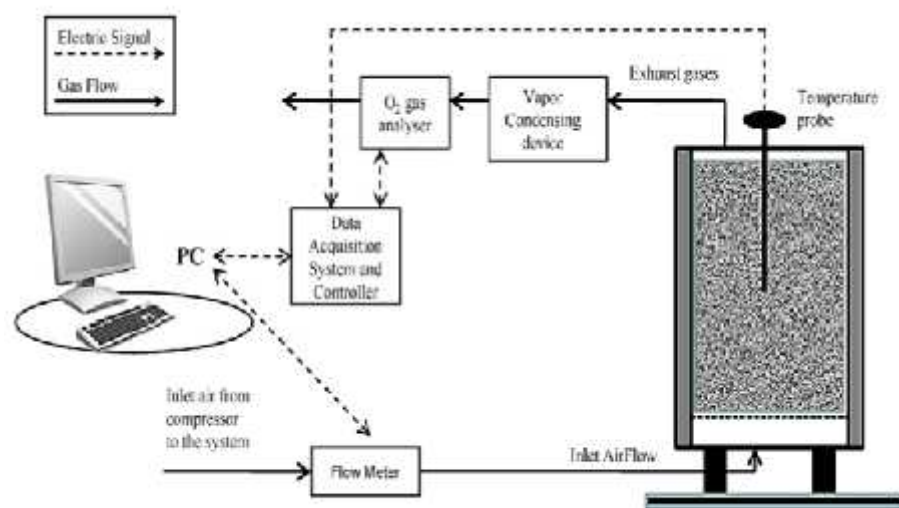
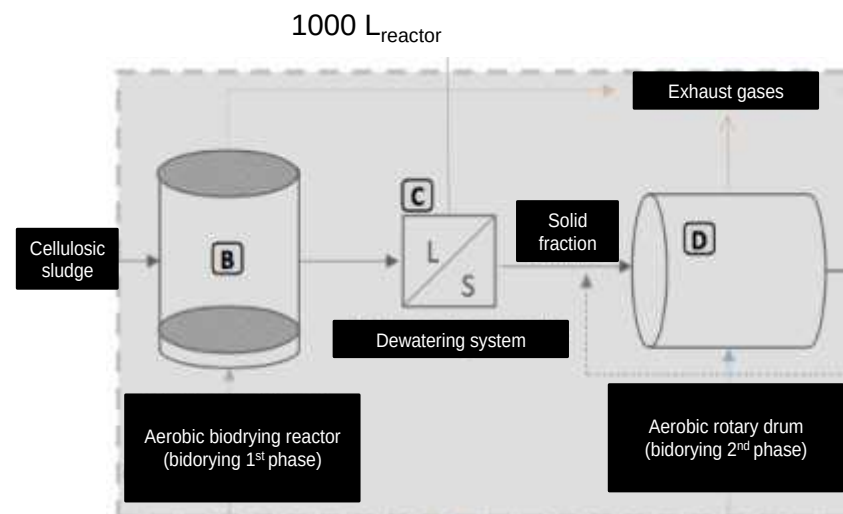


Fig. 1. Experimental set up of the composting pilot reactor. 100 -250 L_{reactor}

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

Biodrying → Obtain a biofuel from cellulosic sludge



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

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

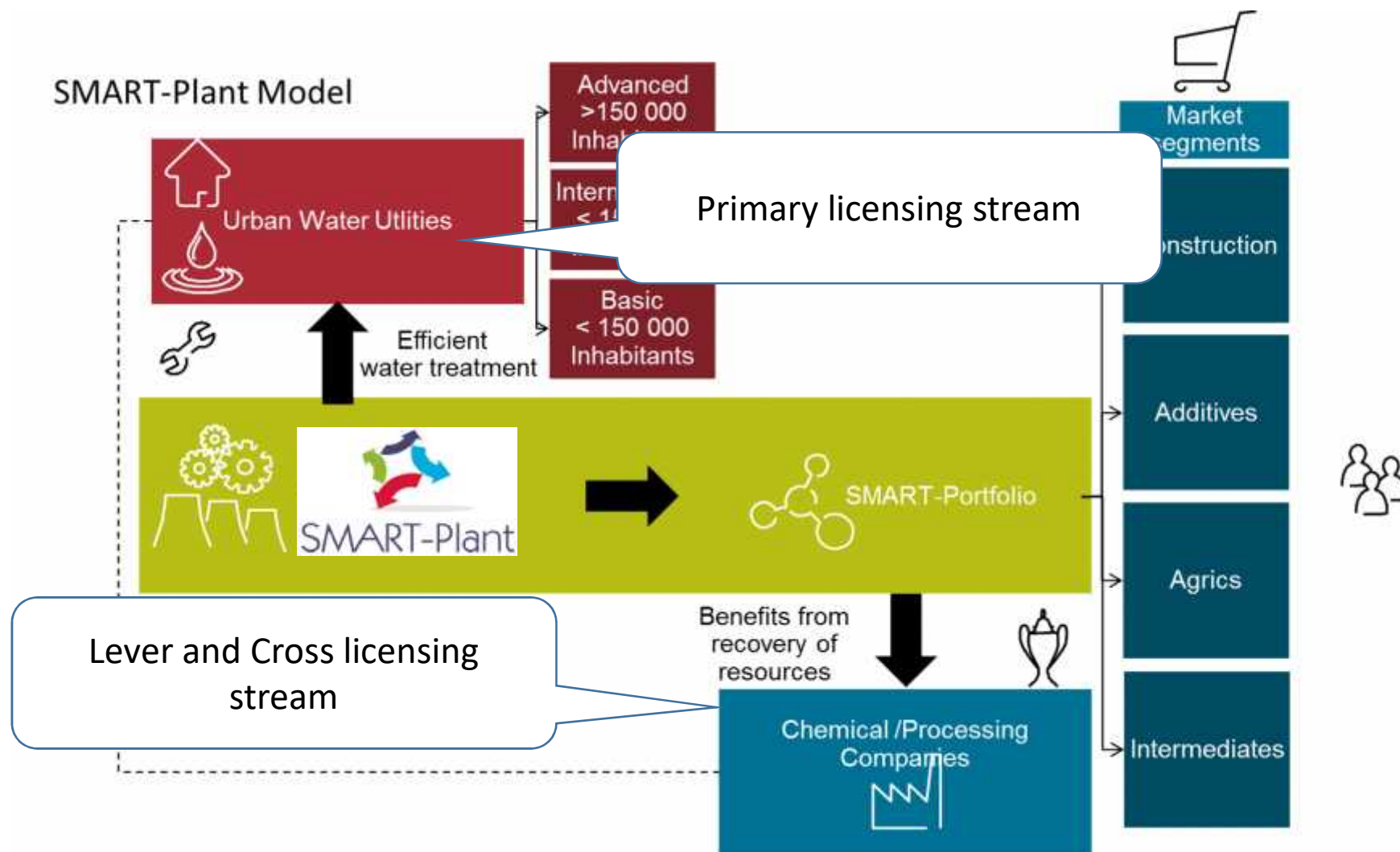
Mg: “the forgotten element”
fertilizer programs

widespread deficiency, increasingly used in

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



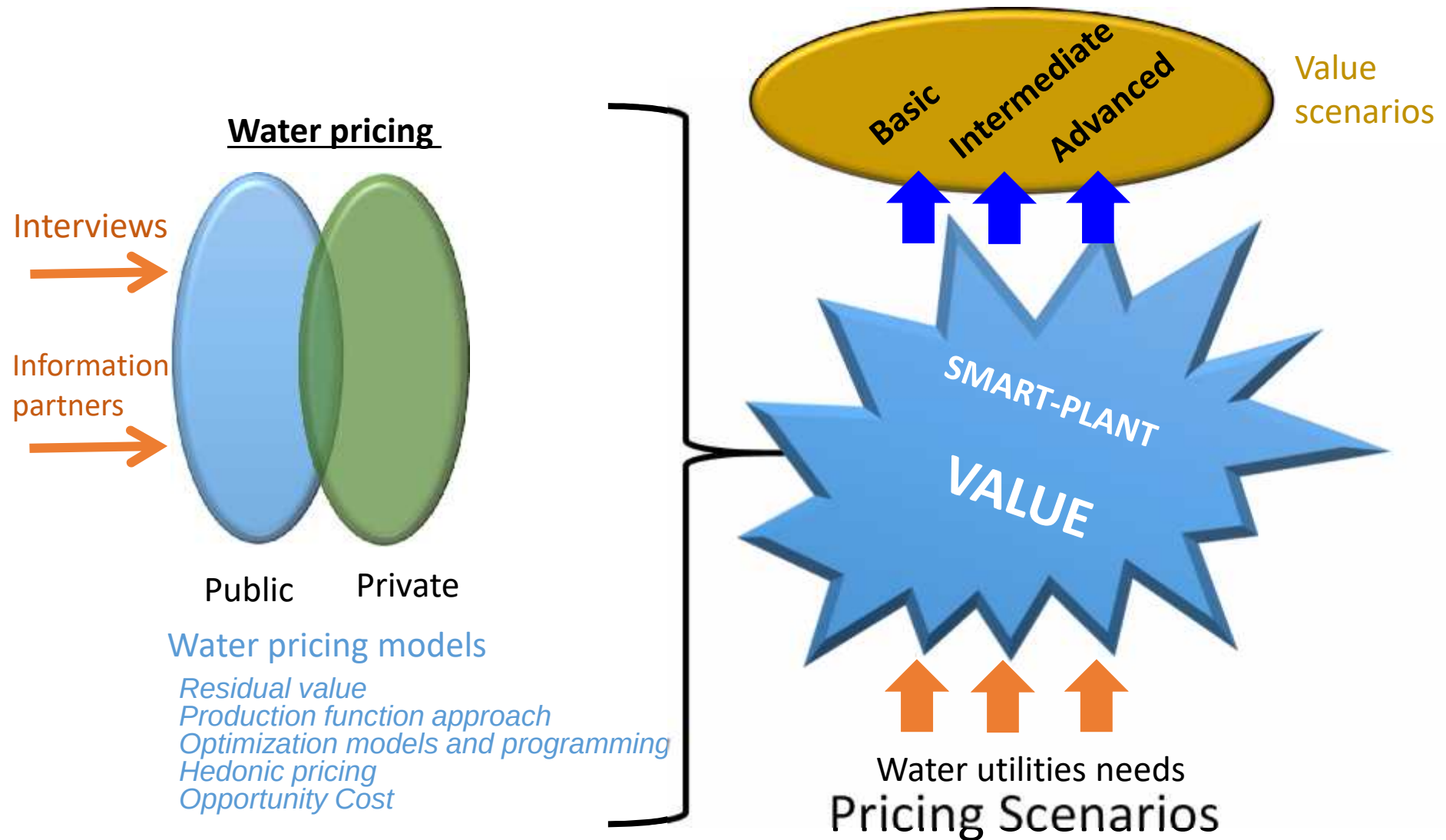
SMART-Plant Business plan and market deployment strategy



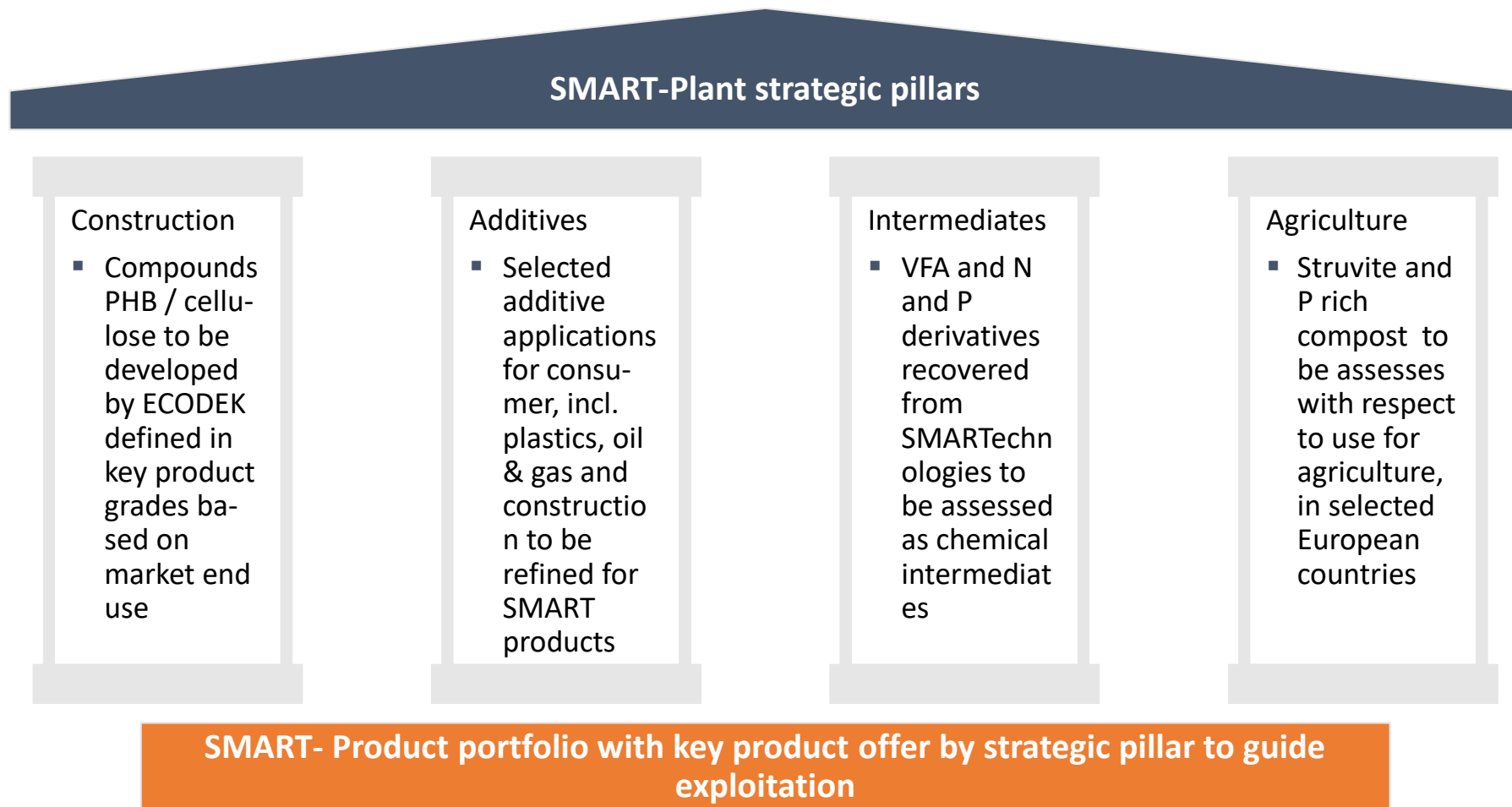
The business model is developed profiling key target groups:

- **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

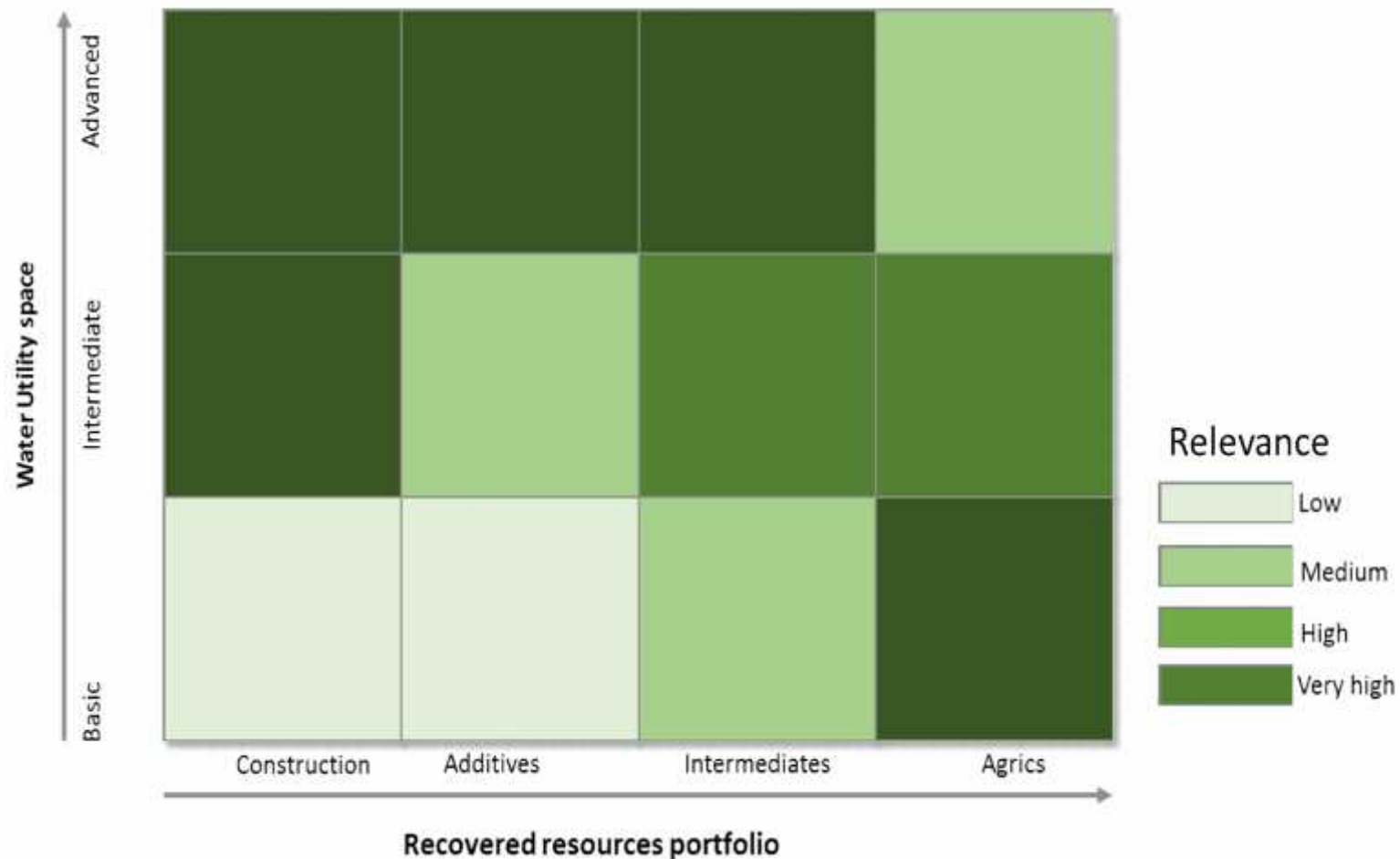
Public/private water utility management perspectives to deliver circular economy with the chemical industries



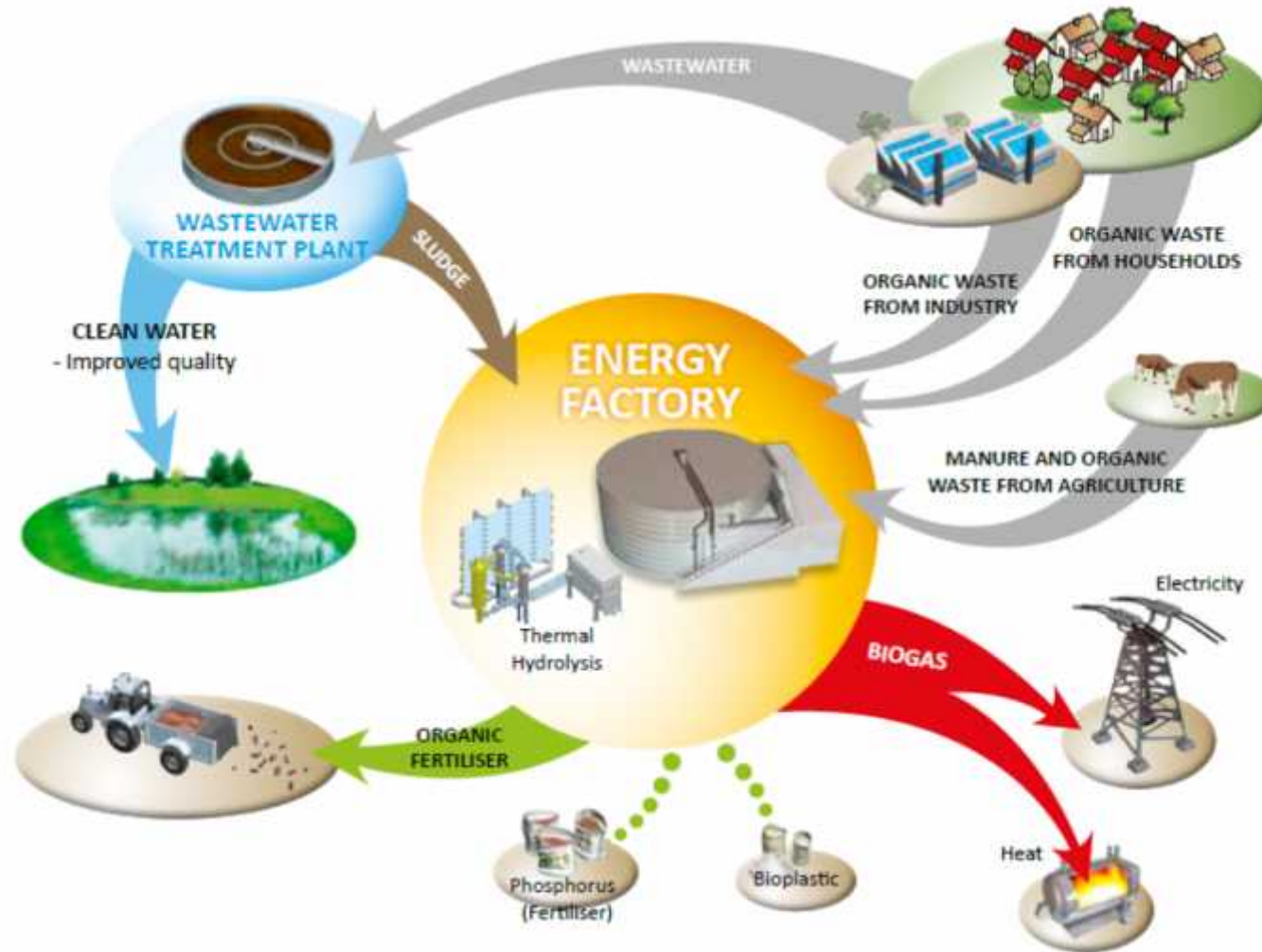
SMART-product portfolio devt. for the recovered resources



SMART-Plant exploitation matrix and heat map



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



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

TECHNOLOGIES

BIOWASTE PREPARATION AND TRANSPORT

1) Source Separate Collection



2) Under Sink Food Waste
disposer



WWTP

THE TREVISO FULL SCALE WWTP



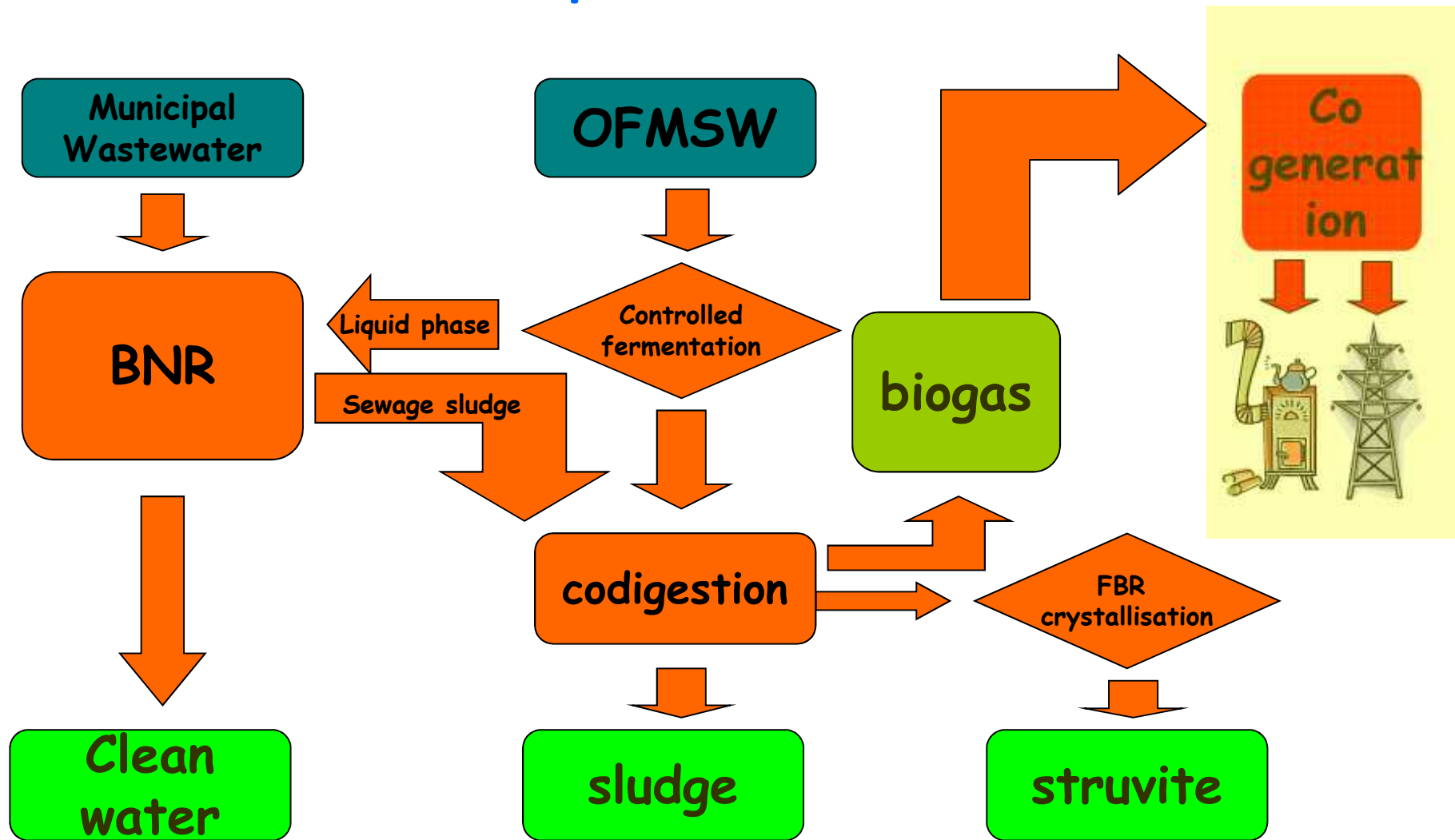
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AF-BNR-SCP: process scheme



TECHNOLOGIES

Biowaste pre-treatments: Case Studies

Treviso (Italy)

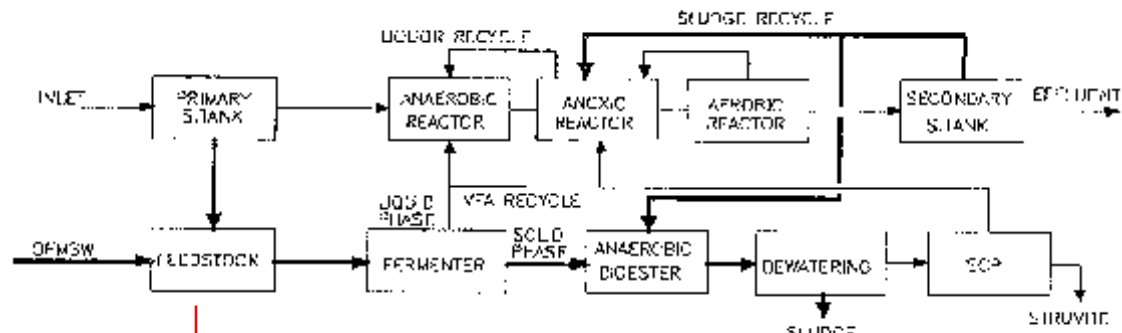


Fig. 1. Flow-sheet of the integrated AF-BNR-SCP process.

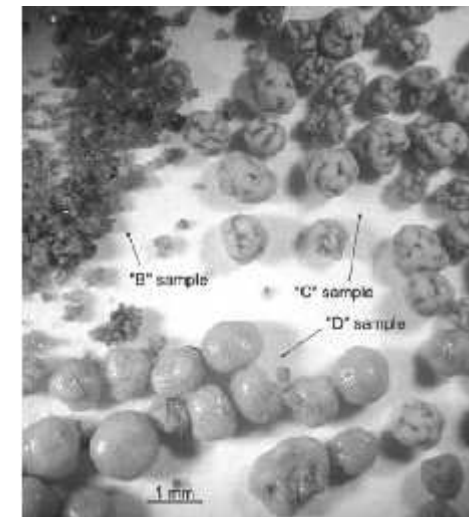


The Struvite Crystallization Plant at the Treviso WWTP



The Struvite

N-P low release
fertilizer



Struvite Crystallization Plant

TECHNOLOGIES

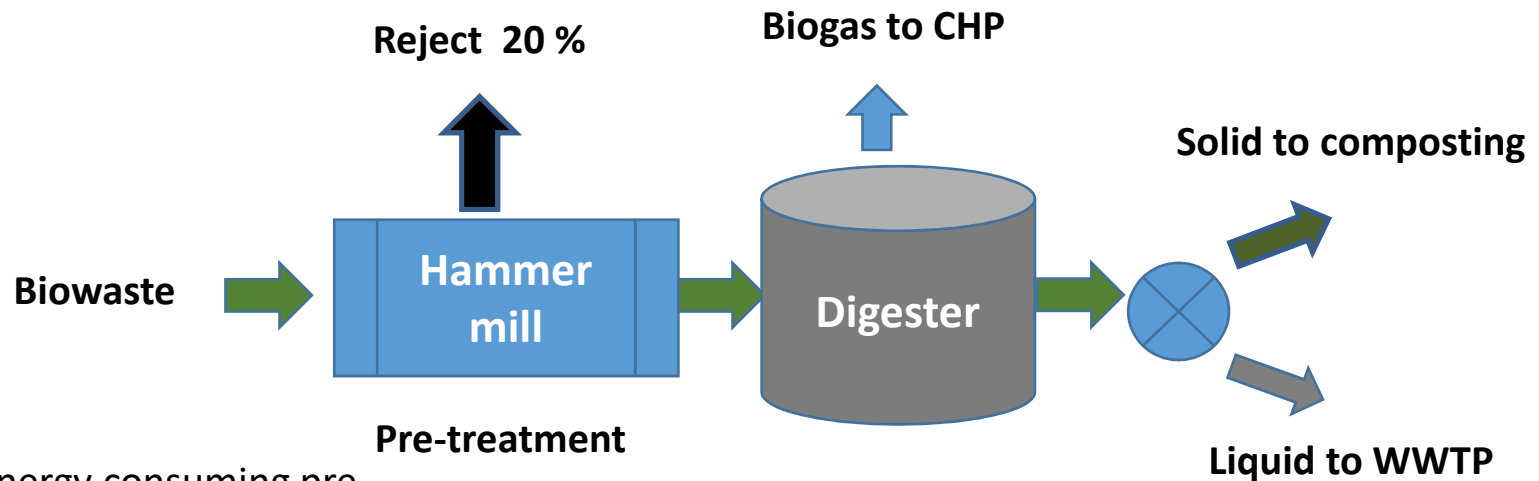
Biowaste pre-treatments: Case Studies

Rovereto (TN, Italy)

Hammer Mill



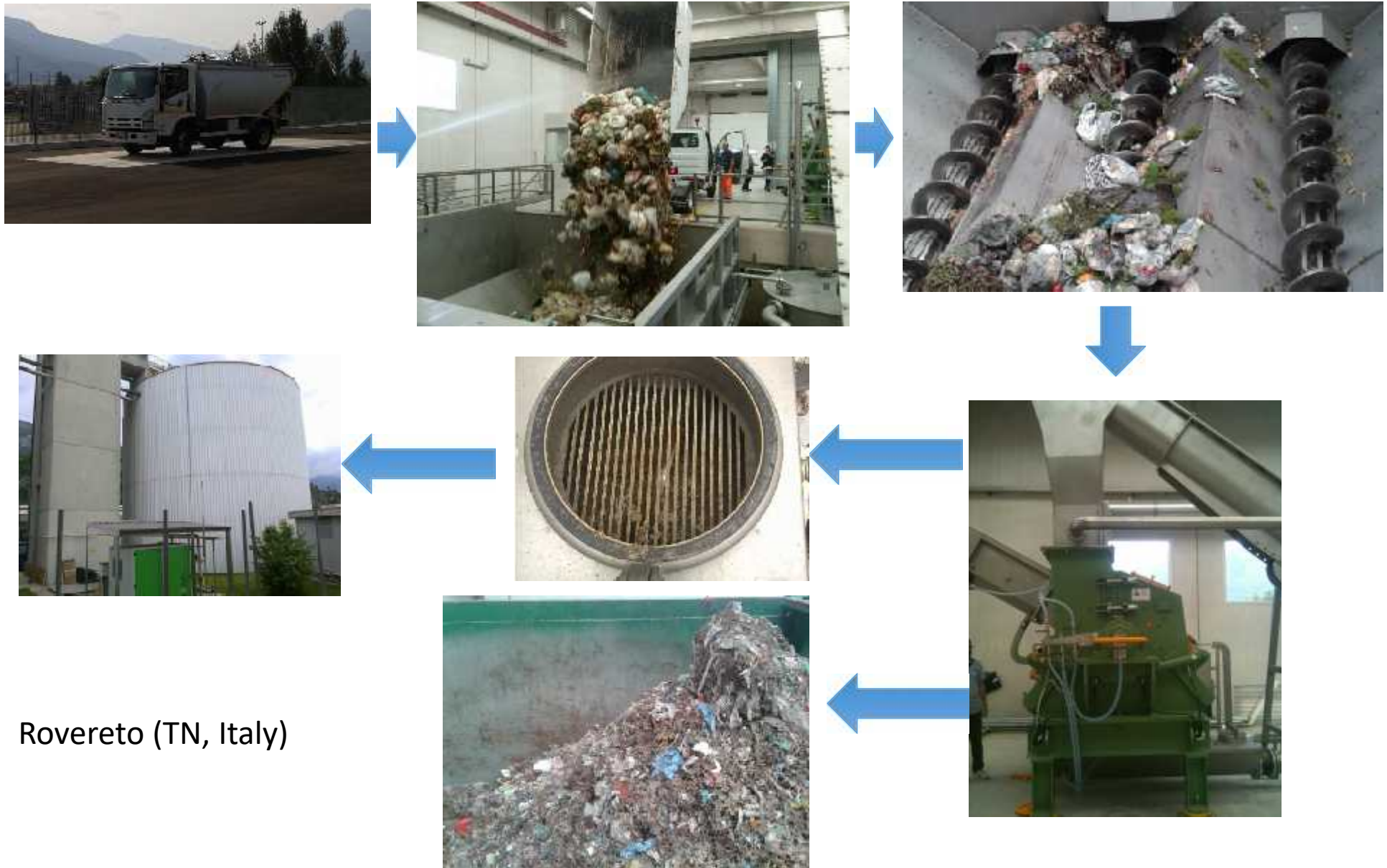
Design capacity, t/y	5.000 SS-biowaste 110.000 sludge (5% TS)
Actual Capacity, t/y	3.000 SS-biowaste 70.000 sludge (x% TS)
Process	Wet
Reactors	2 x 2.500 m ³
Temperature	Mesophilic



“MEDIUM” energy consuming pre-treatment

TECHNOLOGIES

Biowaste pre-treatments: Case Studies



Rovereto (TN, Italy)

Thank you for your
attention and... see you
in ECOMONDO 2017



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