OMAN WASTE & ENVIRONMENTAL SERVICES EXHIBITION & CONFERENCE

ECOMONDO
the green technologies expo

Italian experience in Waste management

Muscat, Sultanate of Oman, 24/May/2016

Municipal wastewater as a Feedstock for Valuable Resources

Prof. Eng. Francesco Fatone, PhD and Dr. Olivia La Corte

University of Verona and ECOMONDO -Italy-

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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»

CORRIERE DELLA SERA SETTEGREEN AWARDS 2015

LabICAB - UniVerona: Green Award Winner 2015

Coordinator Horizon2020 «SMART-Plant» Innovation Action

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Contents

- **Linear vs Circular** Economy
- The Italian activity and the **ECOMONDO** platform of innovative solutions for circular economy
- The **SMART-Plant** to innovate municipal treatment plants towards circular wastewater management
- The integration of the municipal wastewater and organic waste treatments: towards the multipurpose site for **urban mining**

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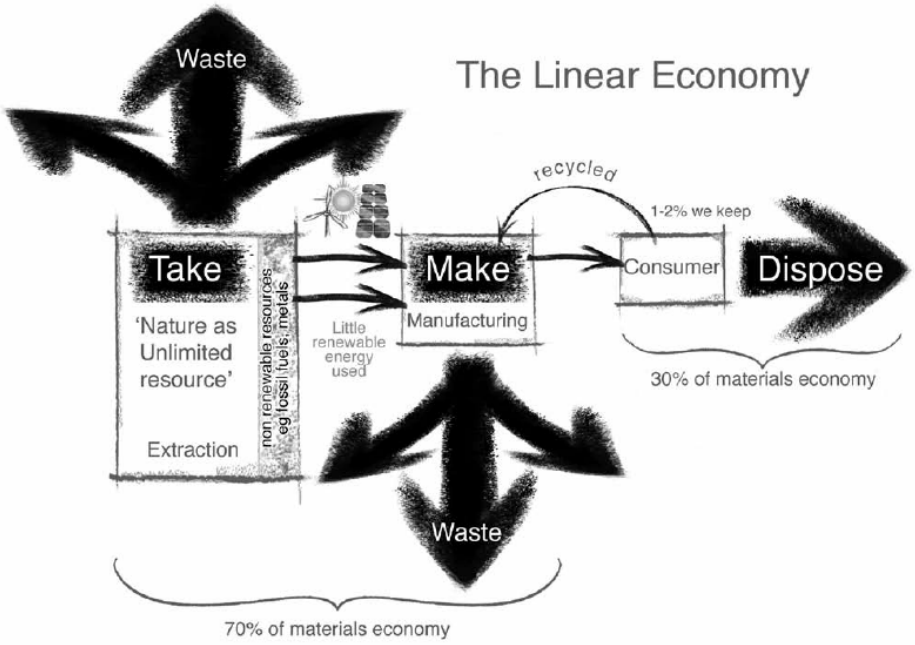
The Linear Economy

- 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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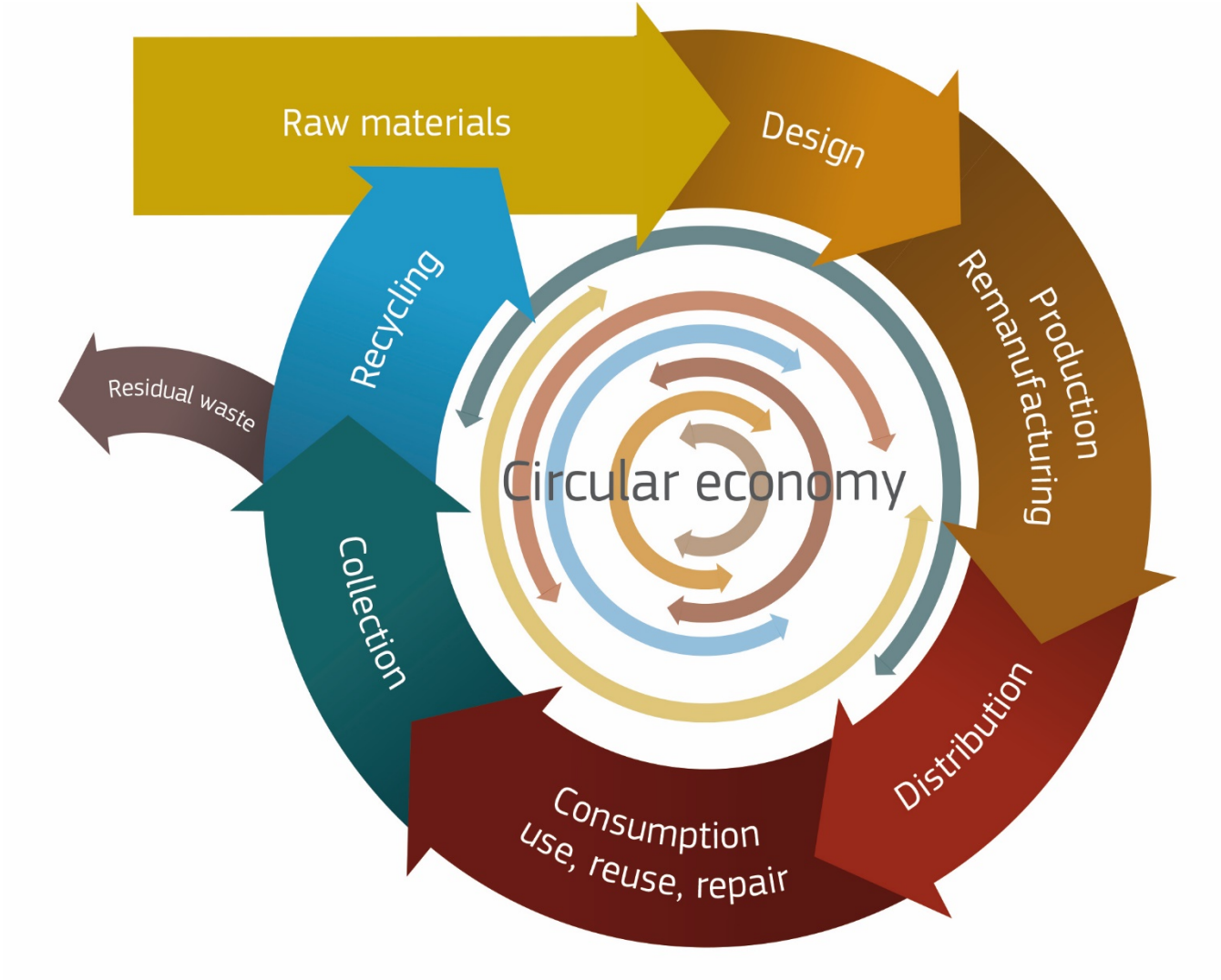
The circular economy



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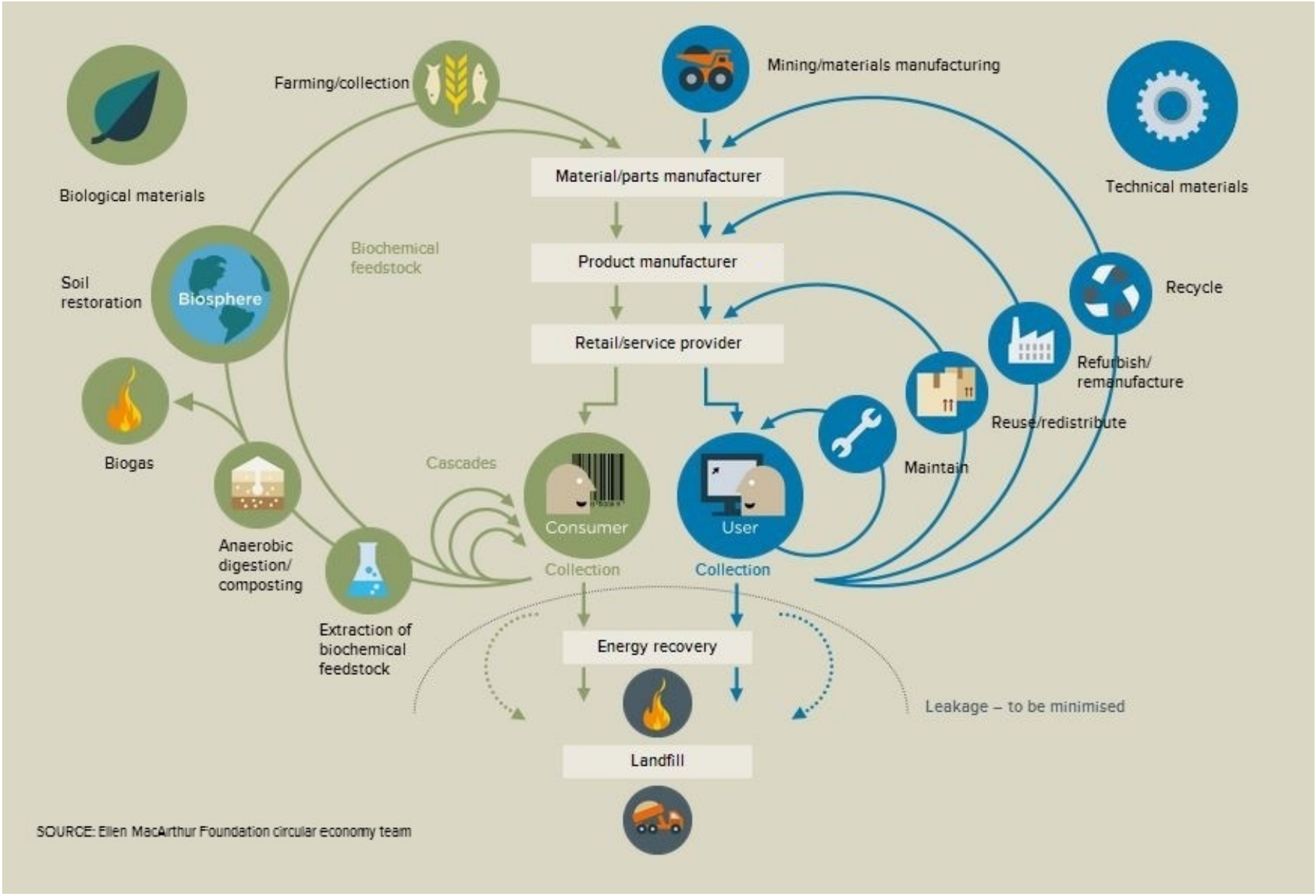

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Circular Economy: imitation of natural cycles

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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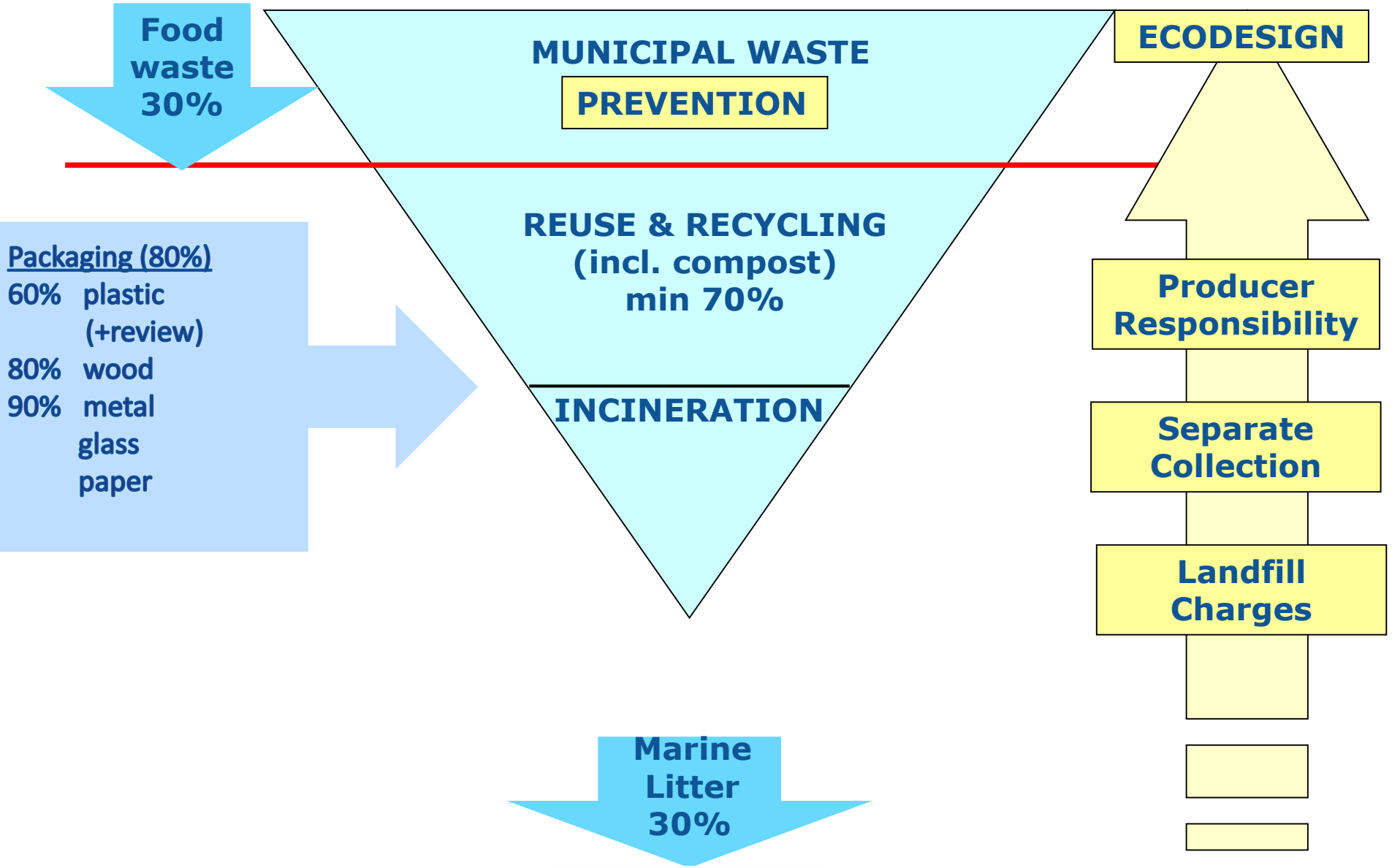
2030 – Waste Targets



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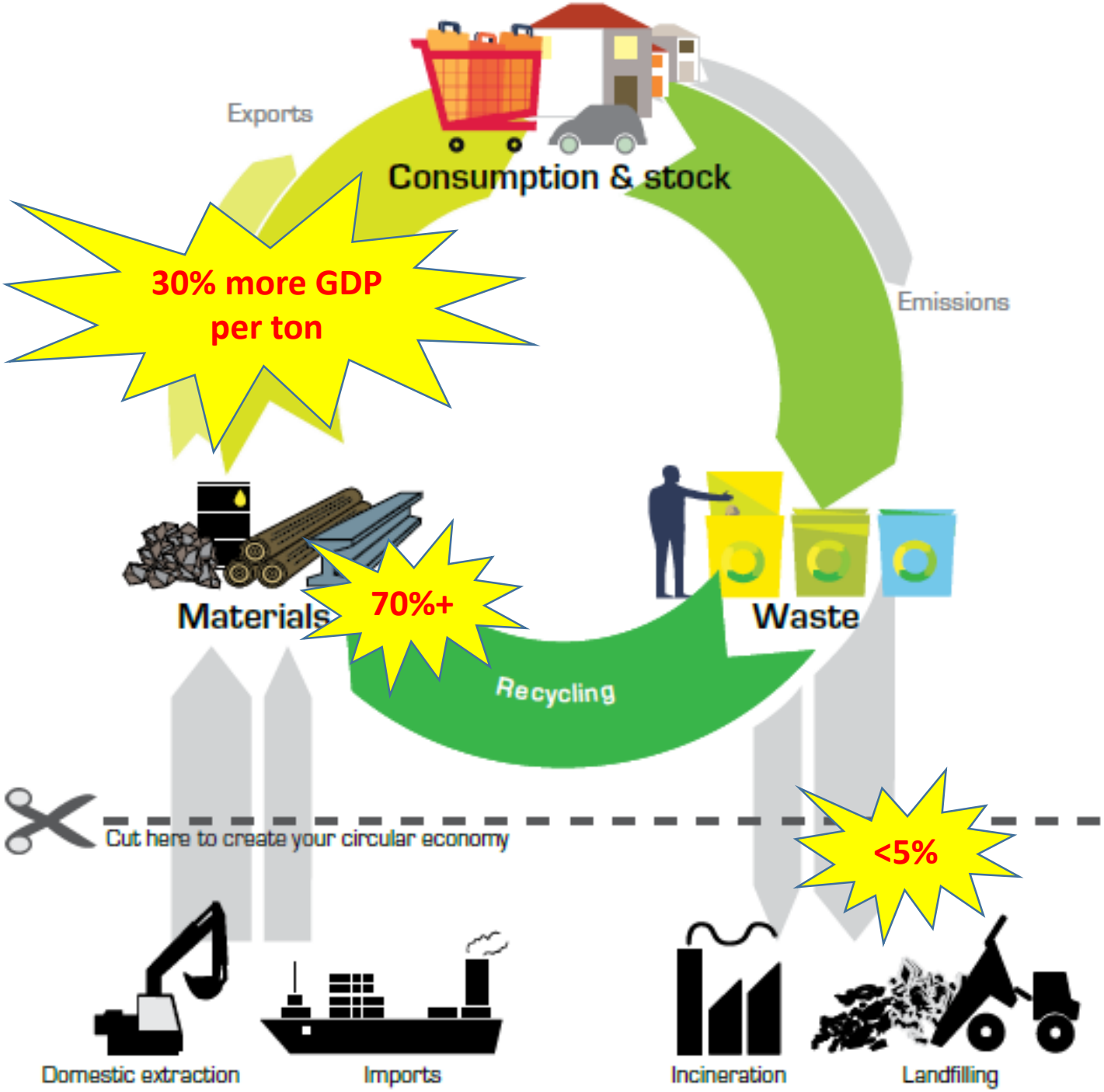
Exports
Consumption & stock
Emissions
30% more GDP per ton
Materials
70%+
Waste
Recycling
Cut here to create your circular economy
<5%
Domestic extraction
Imports
Incineration
Landfilling

ECOMONDO: the platform of the circular economy

www.ecomondo.com

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Greenrail srl

Dr. Massimiliano Russo

INNOVATIVE AND SUSTAINABLE RAILWAY SLEEPERS

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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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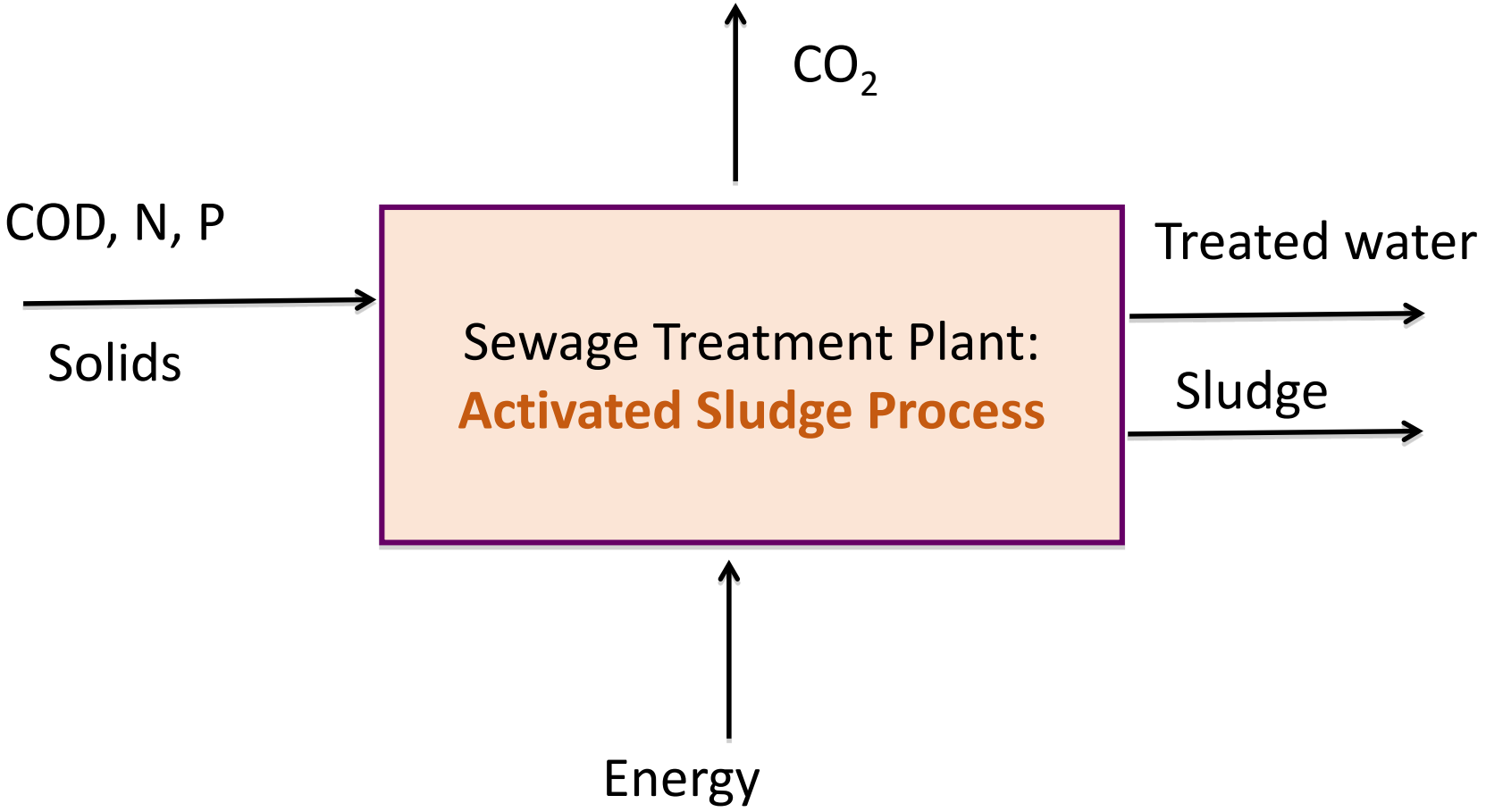
Conventional WWTP



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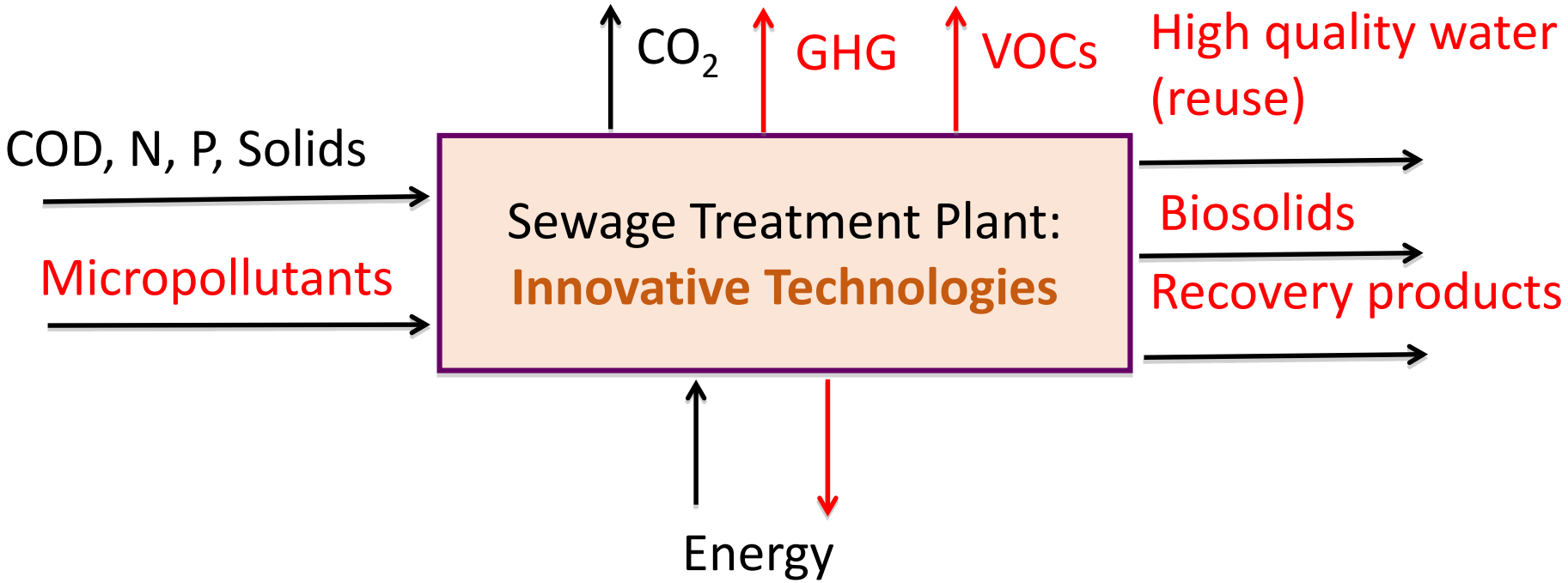
Advanced and circular WWTP



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
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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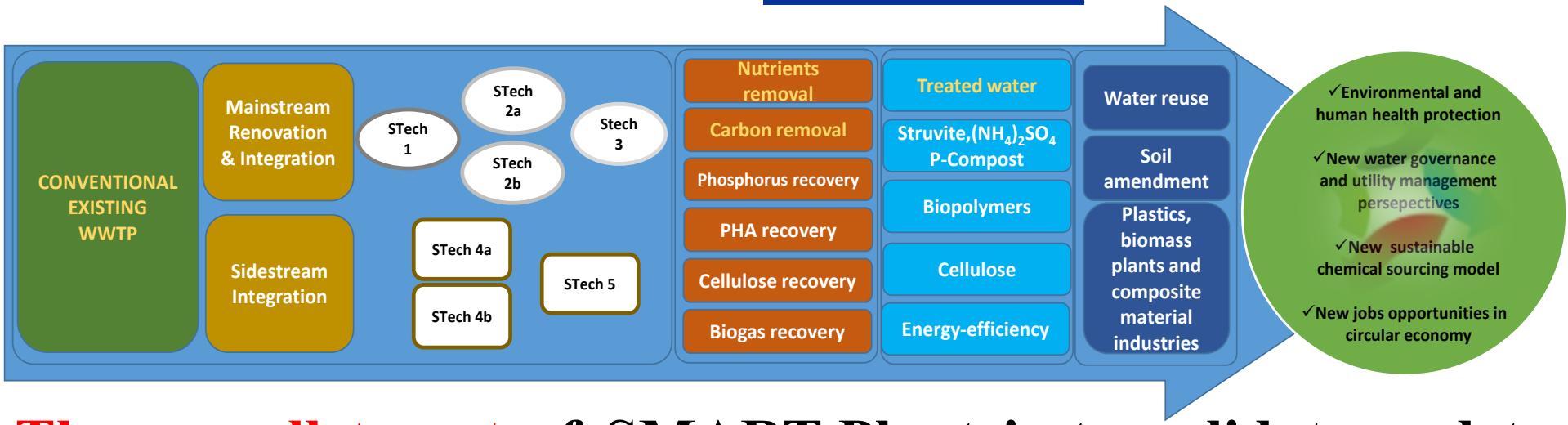

The overall target of SMART-Plant is to validate and to address to the market a portfolio of SMARTechnologies that, singularly or combined, can renovate and upgrade existing wastewater treatment plants and give the added value of instigating the paradigm change towards efficient wastewater-based bio-refineries.

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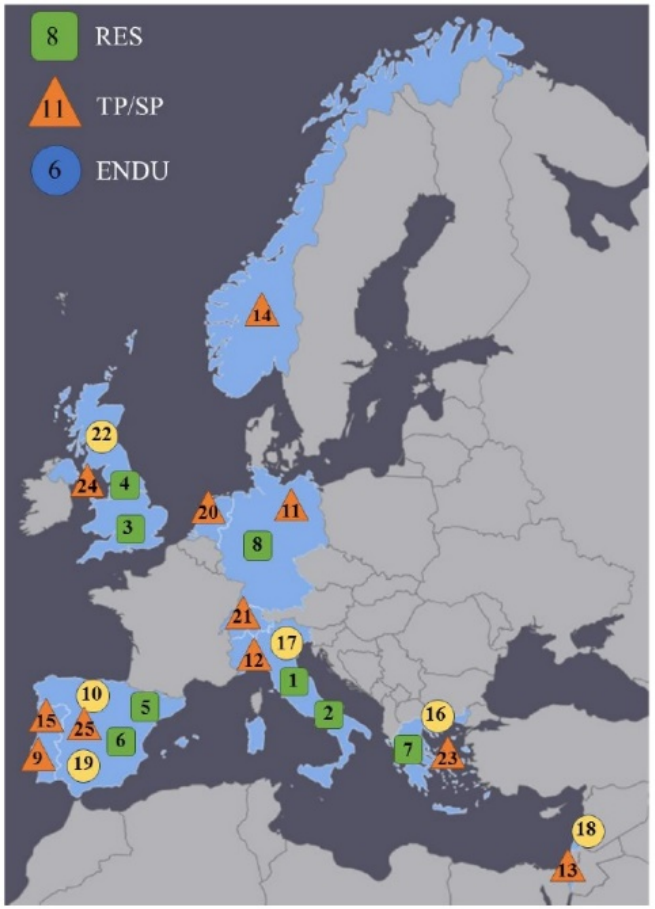
The SMART-Plant consortium

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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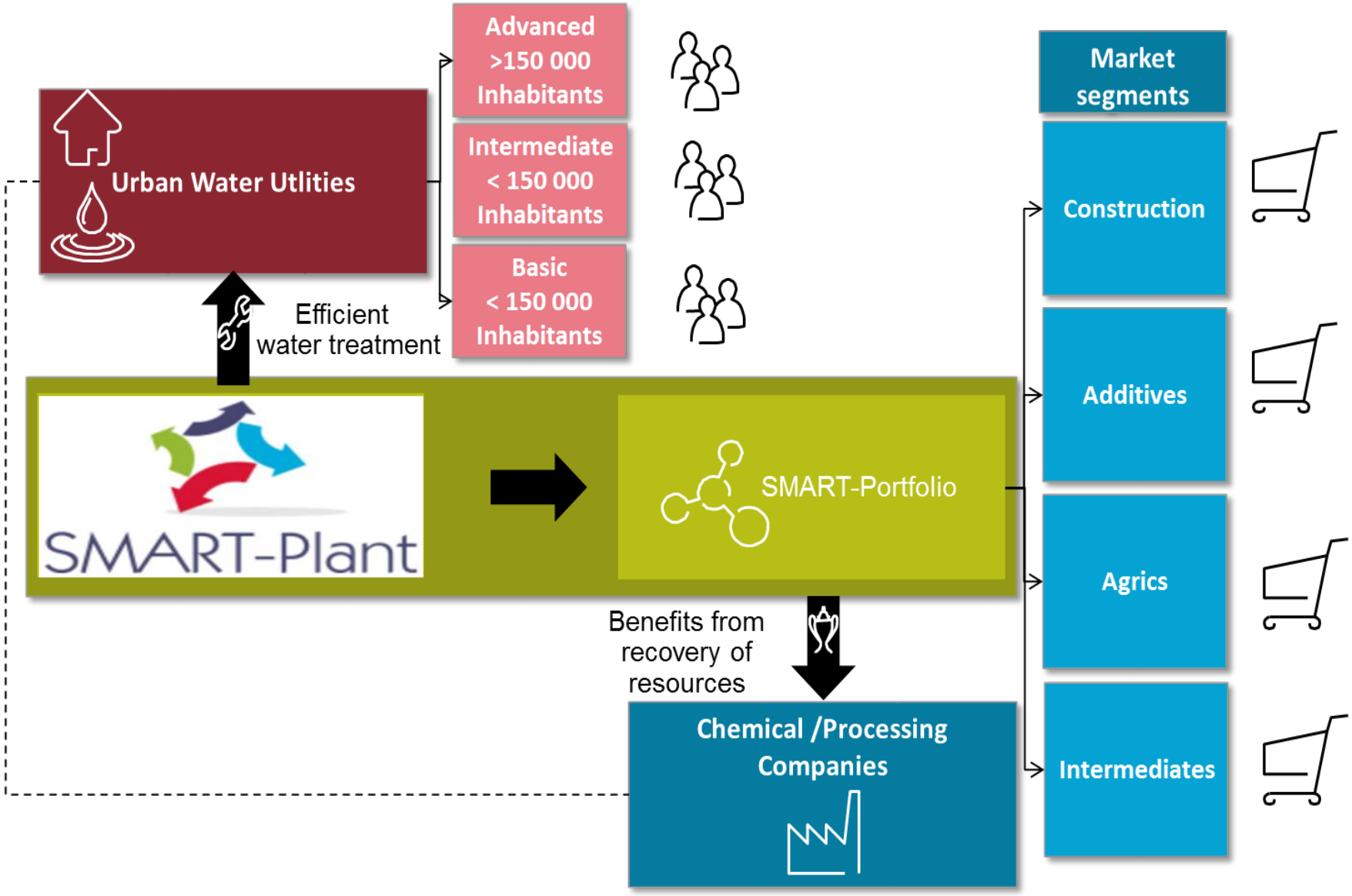
Schematic view of SMART-Plant Model



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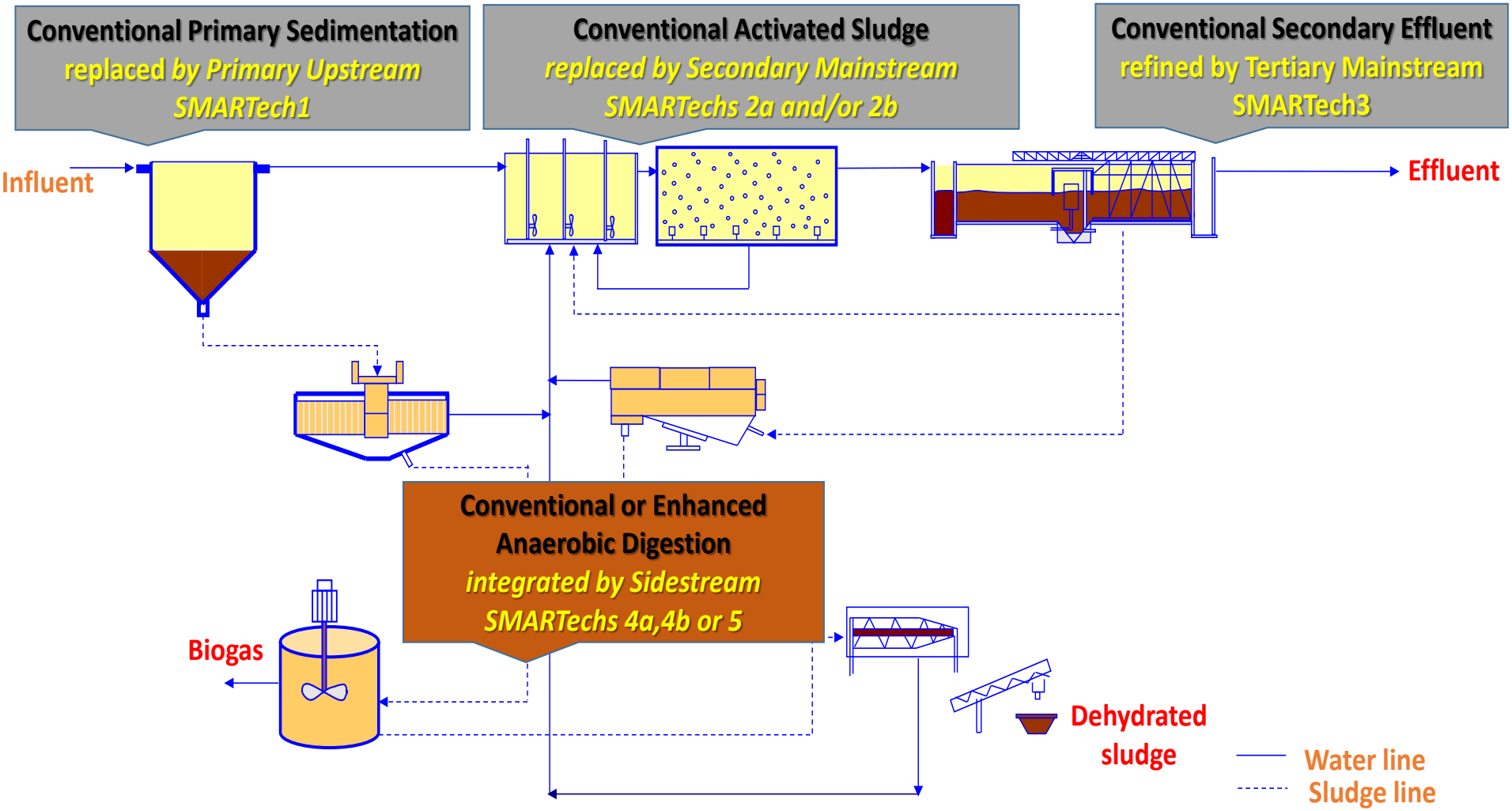
The SMARTechnologies integrated in existing wastewater treatment plants



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Wastewater treatment and reuse: Membrane Bioreactors

Presented by Mr. Mohammed Al Lawati -HAYA Water- at ECOMONDO 2015 – Rimini, Italy, November 2015

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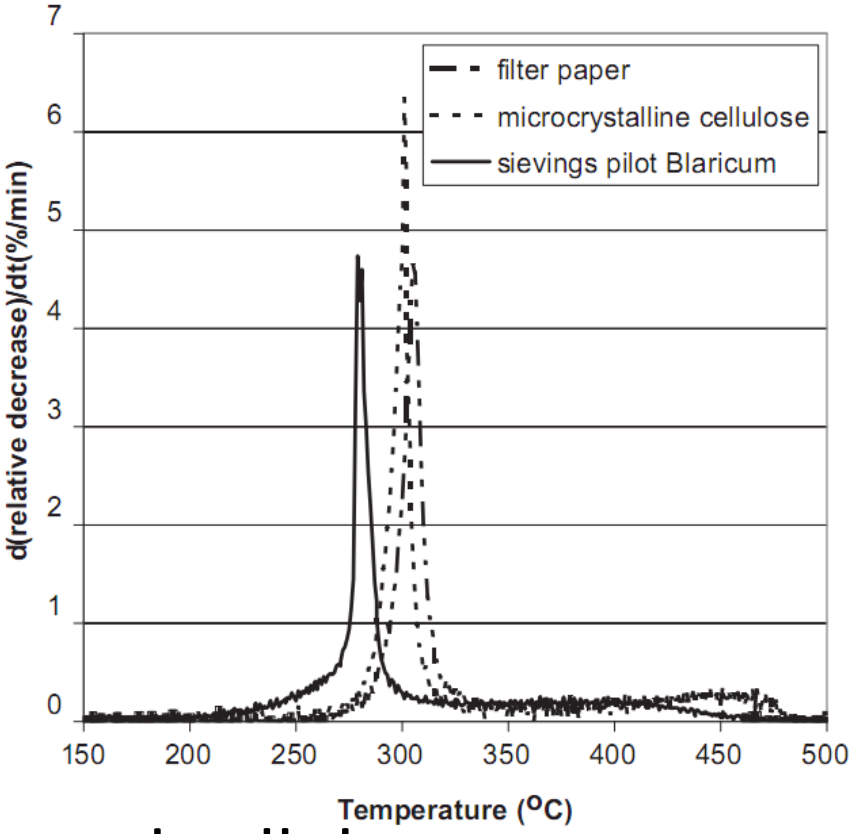
Industrial MBR Porto Marghera, Venice, Italy

Cellulose recovery



Possible use of recovered cellulose

- Bioplastics production; - 100% cellulose recovery; - Production of energy (thermal of biological processes)

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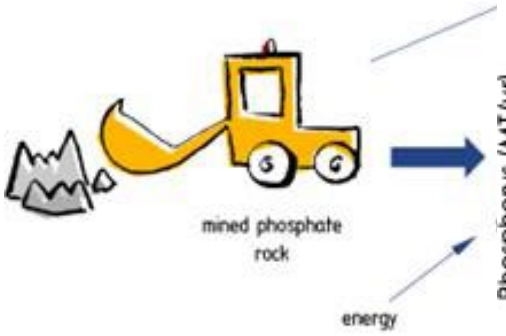
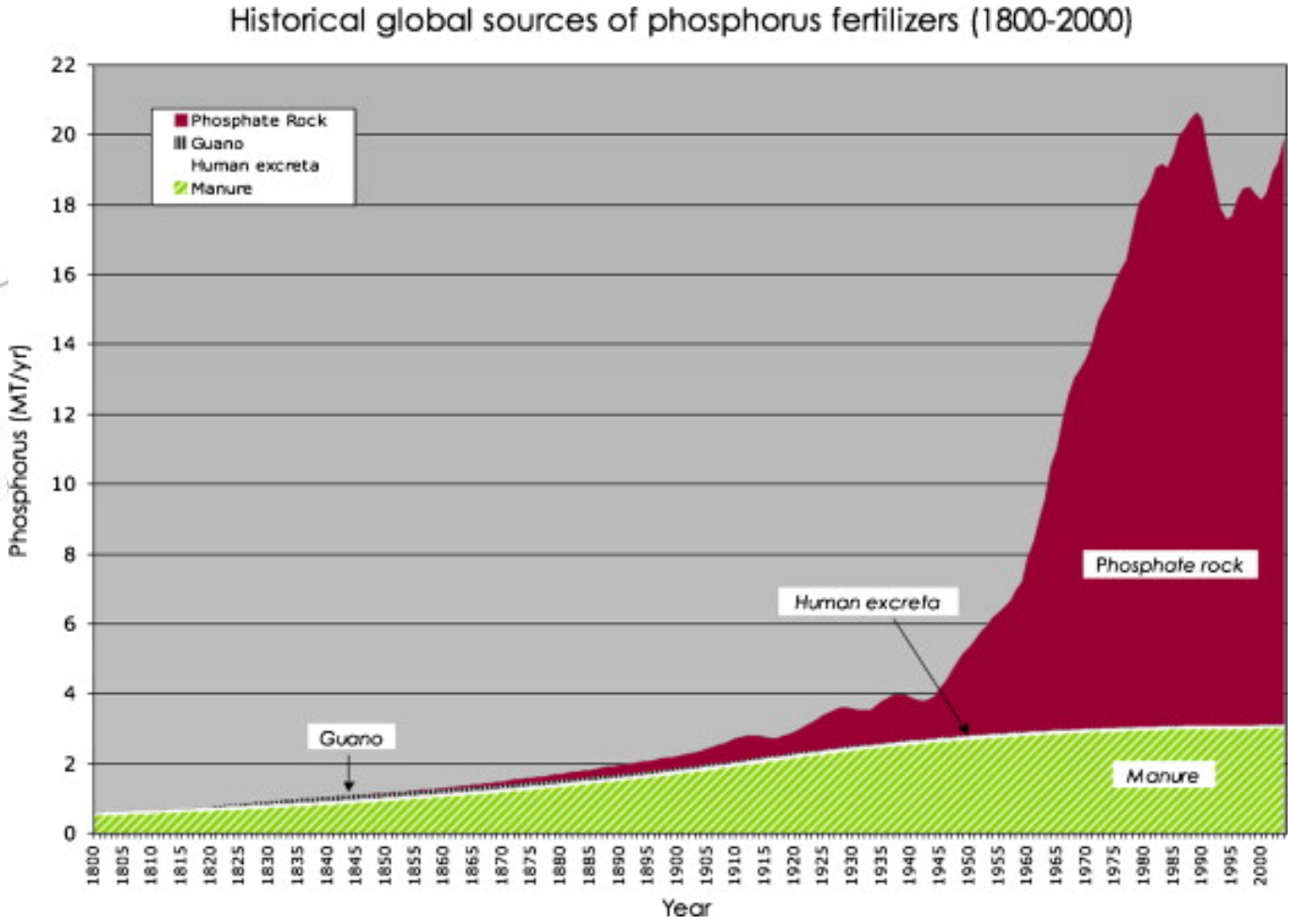
New (mine-based) phosphorus cycle





Historical sources of phosphorus for use as fertilizers(1800–2000)
Source: Cordella D. et al. (2009) doi:10.1016/j.gloenvcha.2008.10.009

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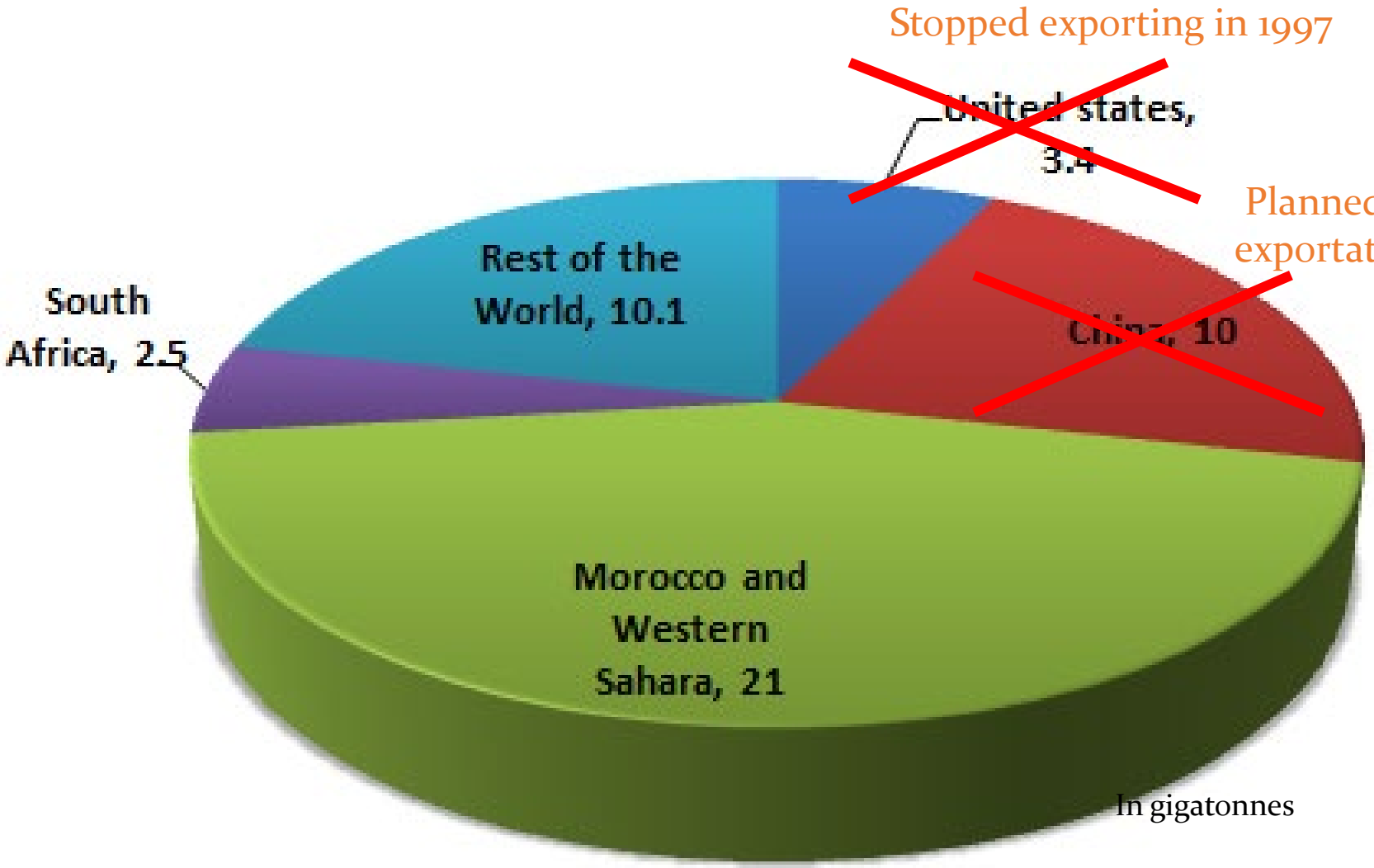
World P resources



Gilbert N: The disappearing nutrient. Nature 2009 461: 16–718

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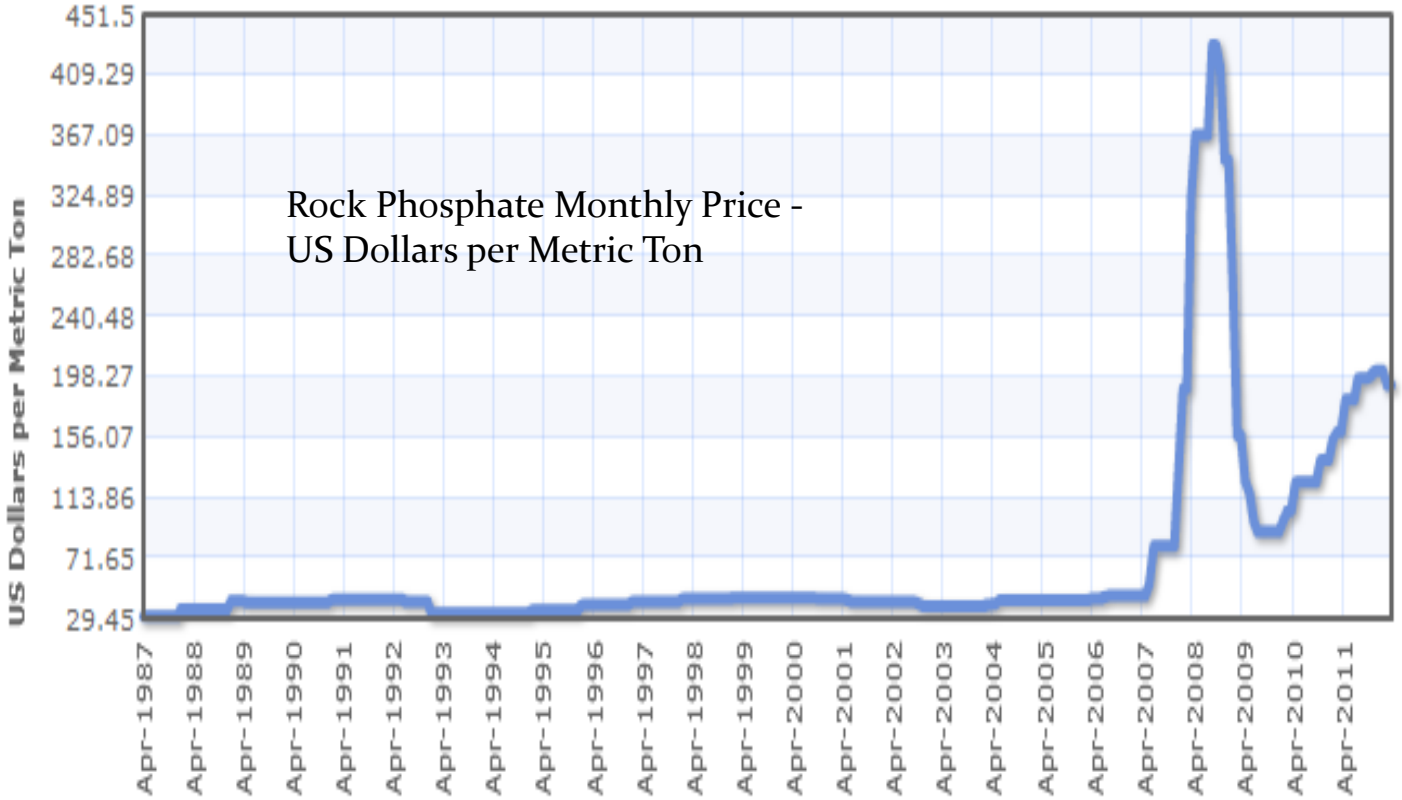
Phosphorus (volatile) price



http://www.indexmundi.com/commodities

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Our P dependency

EU is reliant on imports and, as good quality sources of phosphorus diminish, EU will become increasingly dependent on phosphorus reserves that are less accessible and more polluted with toxic elements, such as cadmium and uranium.

Phosphorus rock was declared a critical raw material by the EC in 2014

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Main techniques and processes to recover phosphorus from wastewater

- ***Small-scale decentralised***. to separate urine, faeces and flush water so that recycling can be achieved more effectively.
- ***Large-scale centralized***
  - Biological Uptake (Enhanced Biological Phosphorus Removal EBPR)
  - Precipitation (e.g. struvite recovery)
  - Adsorption
  - Ion exchange: more selective than adsorption

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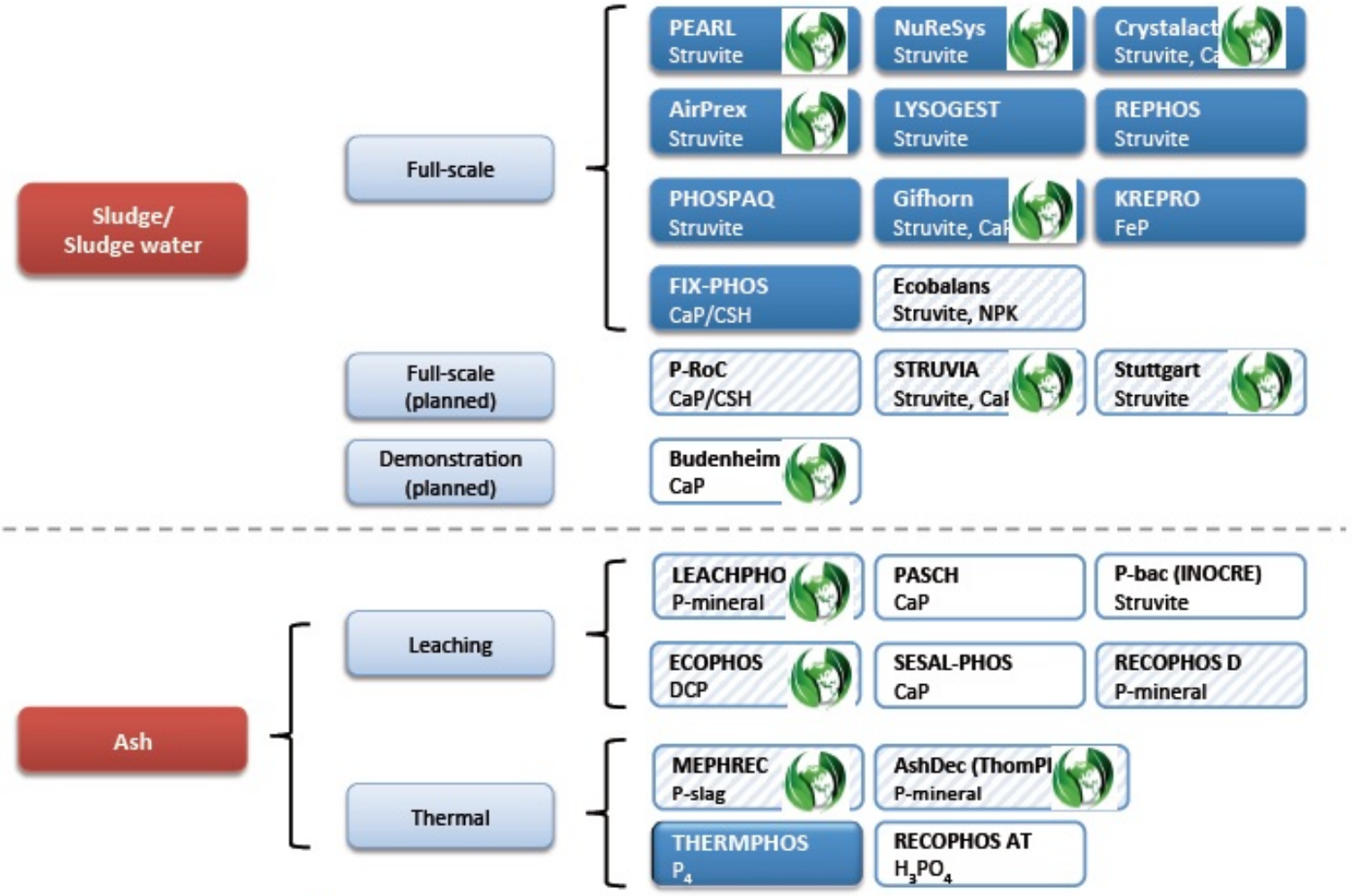
Overview of P-recovery processes in Europe

P-REX-



KOMPETENZZENTRUM WasserBerlin

Full-scale | Demo | Lab/pilot

www.p-rex.eu

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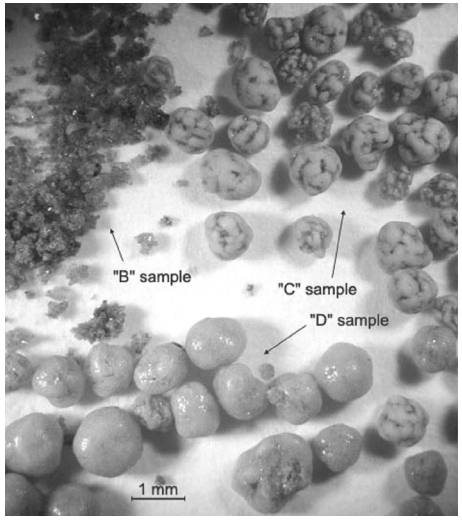
The Struvite Cristallization Plant at the Treviso WWTP

Struvite Crystallization Plant

The Struvite

N-P low release fertilizer



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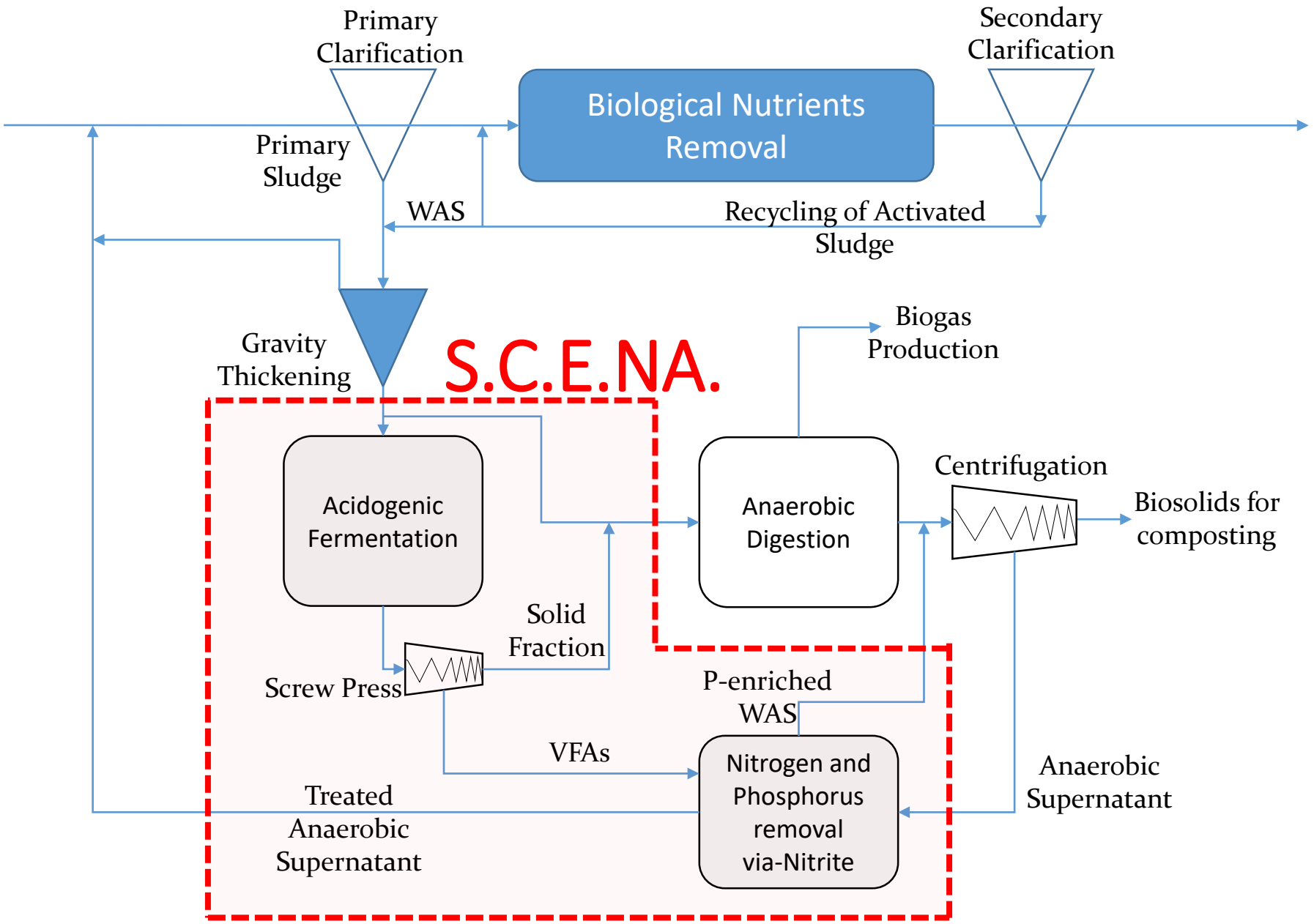
Short-Cut Enhanced Nutrient Abatement



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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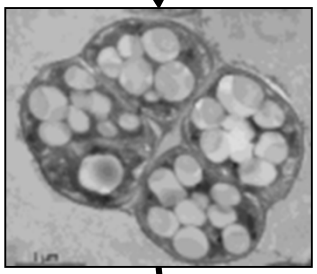
Biopolymers (PHA) recovery



Purification → Plastic →

Conversion with methanol → Biofuel →

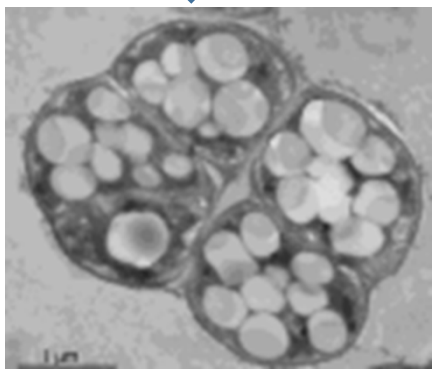
Direct chemical conversion → Biochemical →

Courtesy: R. Kleerebezem - Water_2020 network

Microbial Community Engineering (MCE) for bioplastic production from wastewater

Explore natural microbial community

Impose selective pressure

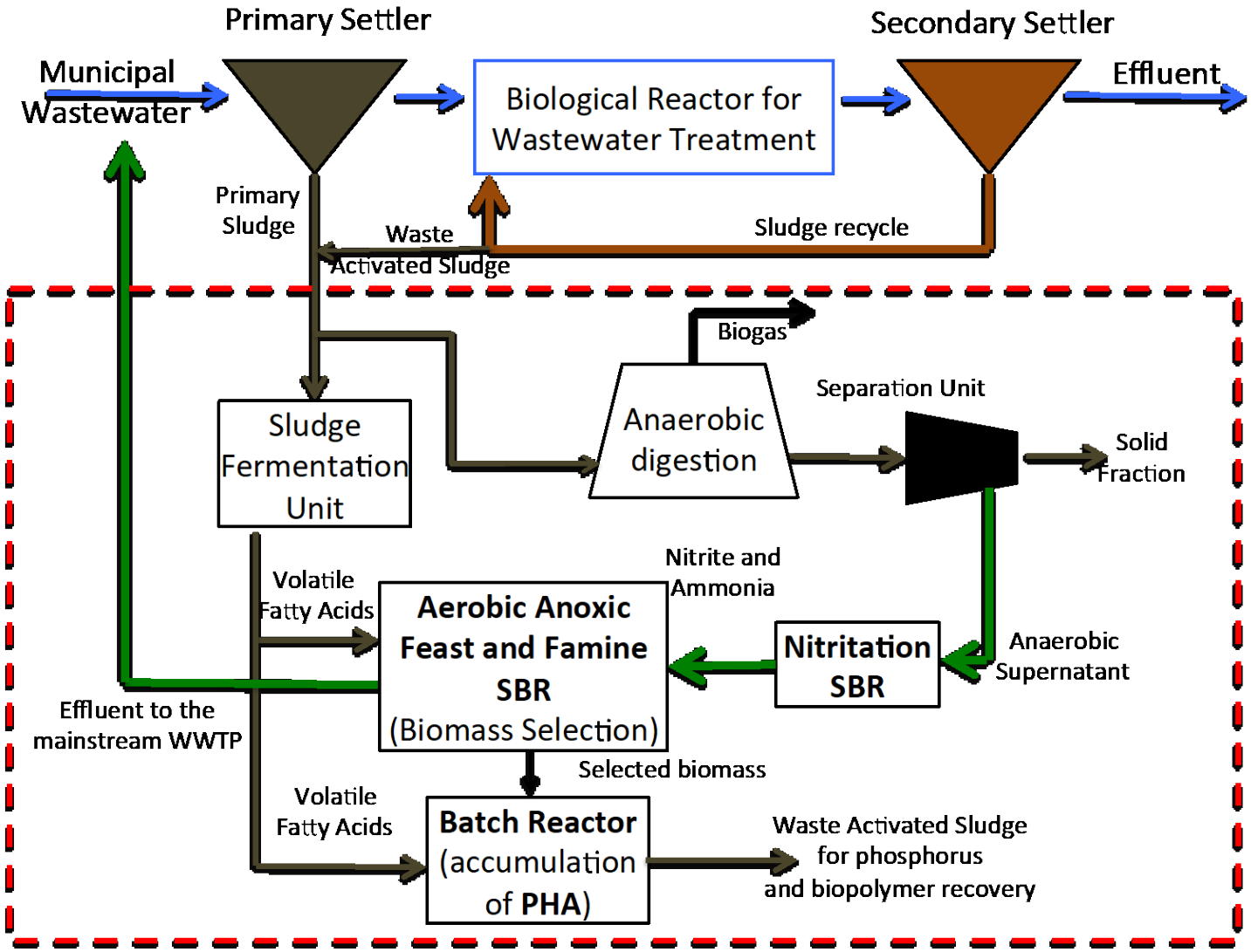


Select dominant work horse

Products and energy

Courtesy: R. Kleerebezem - Water_2020 network

Short-Cut Enhanced PHA Recovery



Frison et al., Environmental Science and Technology, 2015

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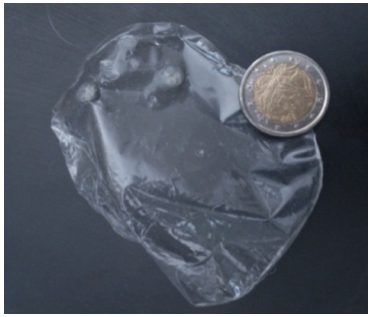
Main properties of the revovered biopolymers

Carbon source	M_w (g/mol)	PDI (Mw/Mn)	T_g (°C)	T_{m1} (°C)	T_{m2} (°C)	ΔHm (J/g)	$T_{d\text{-}trans}$ (°C)
Synthetic mixture of VFA	$6.2x10^5$	1.30	-1.1	138	147	21	267
SFL	$6.5x10^5$	1.29	-0.5	136	144	24	275
WSFL	$7.4x10^5$	1.25	-1.6	141	153	27	276

M_w: average molecular weight, PDI: polydispersity index; M_n: molar number; $T_{d\text{-}trans}$: decomposition temperature (DSC analyses); T_g: glass-transition temperature; $T_{m1,2}$: melting temperature; ΔH_m: melting enthalpy.



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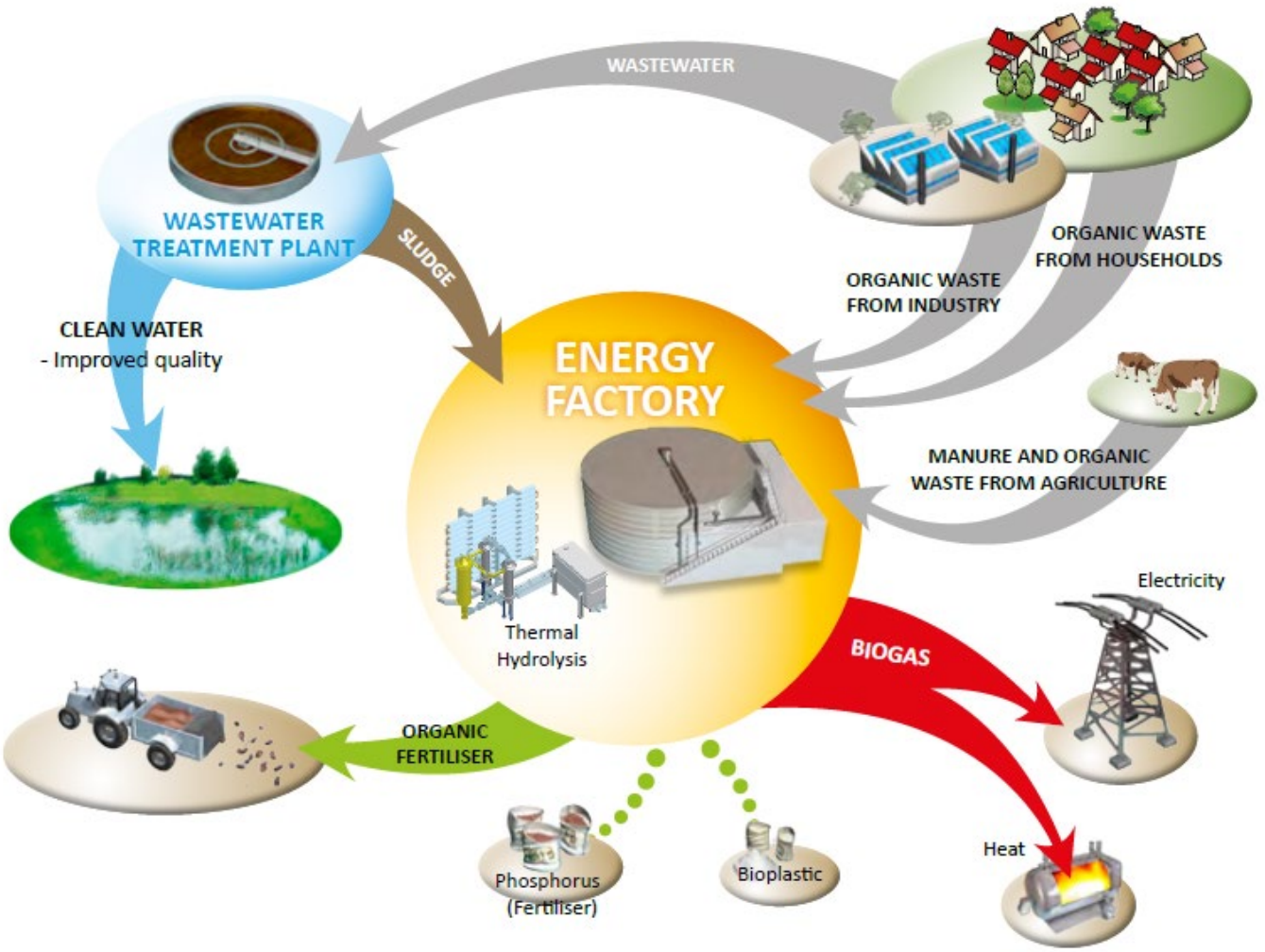
Only municipal wastewater? The WWTP can be the urban biorefinery!



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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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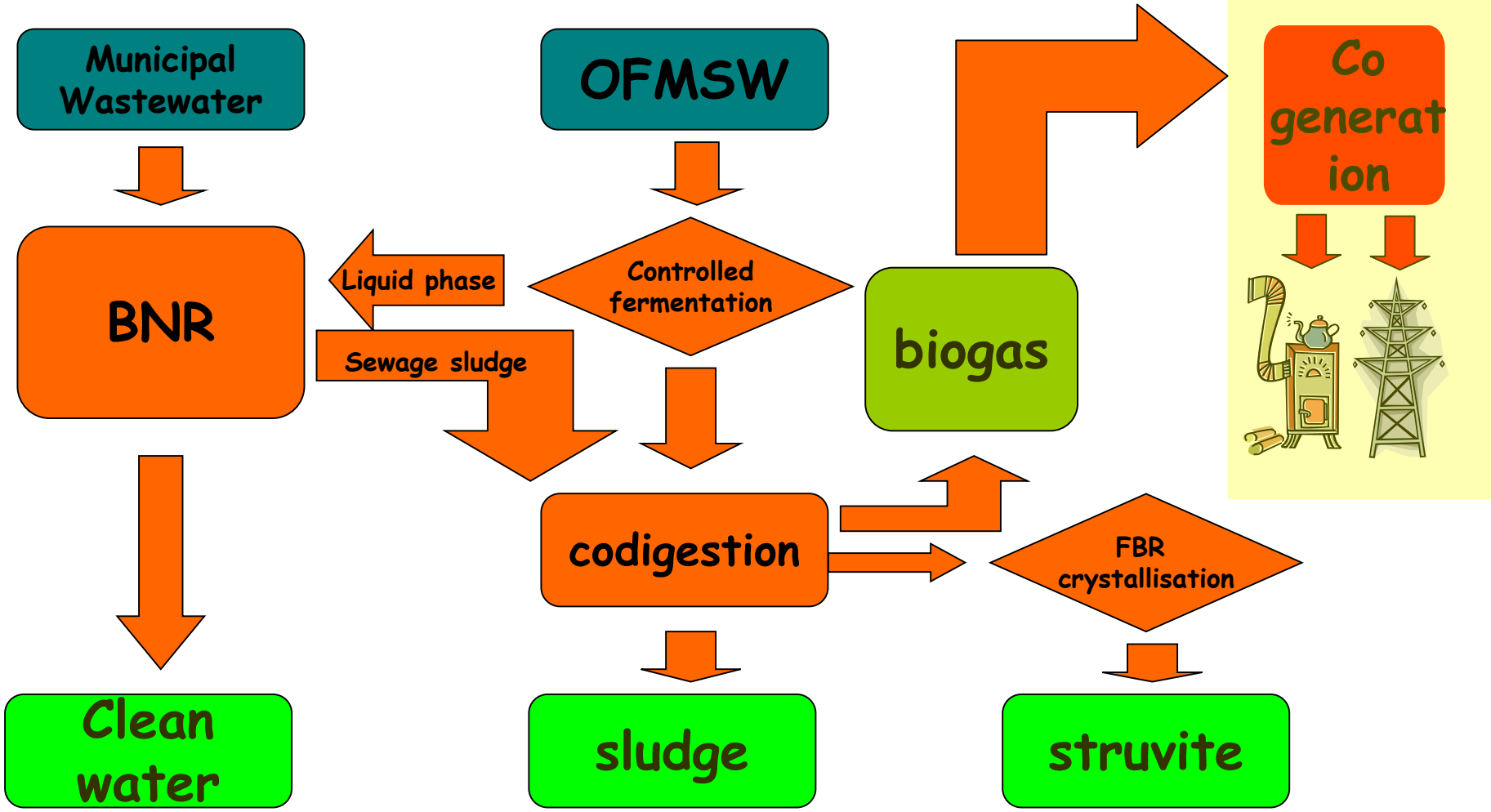
AF-BNR-SCP: process scheme



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Biowaste pre-treatments: Case Studies

Treviso (Italy)

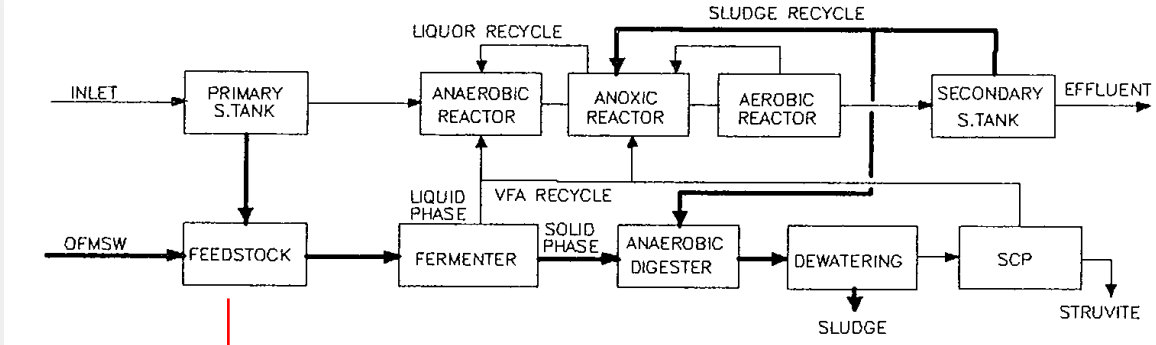

Fig. 1. Flow-sheet of the integrated AF-BNR-SCP process.

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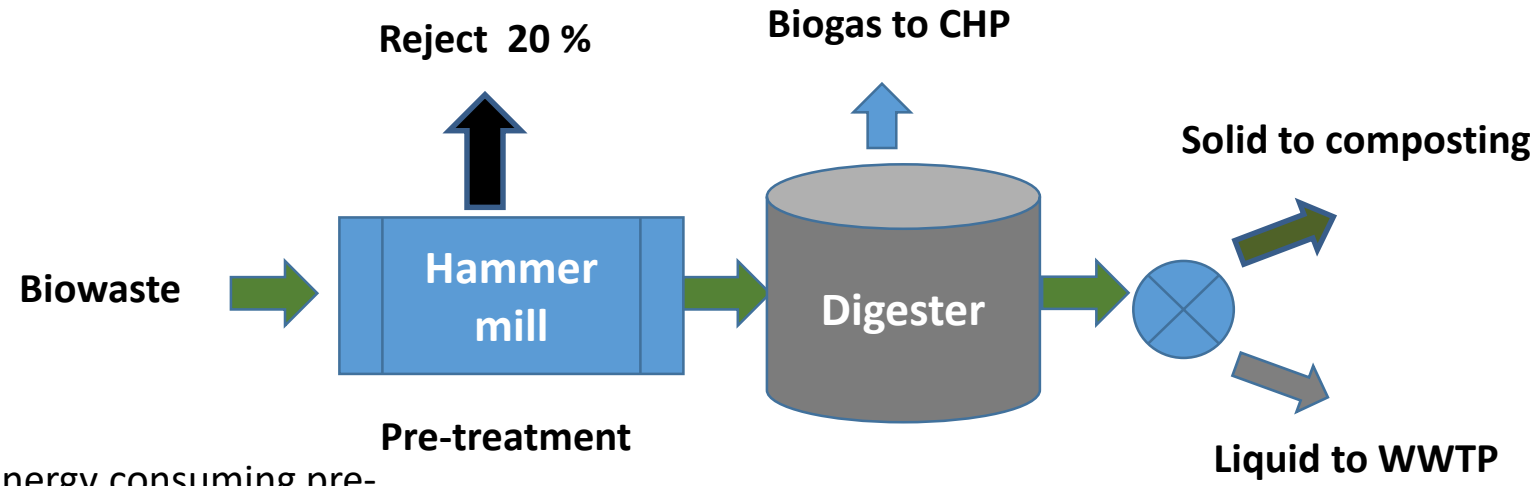
Biowaste pre-treatments: Case Studies

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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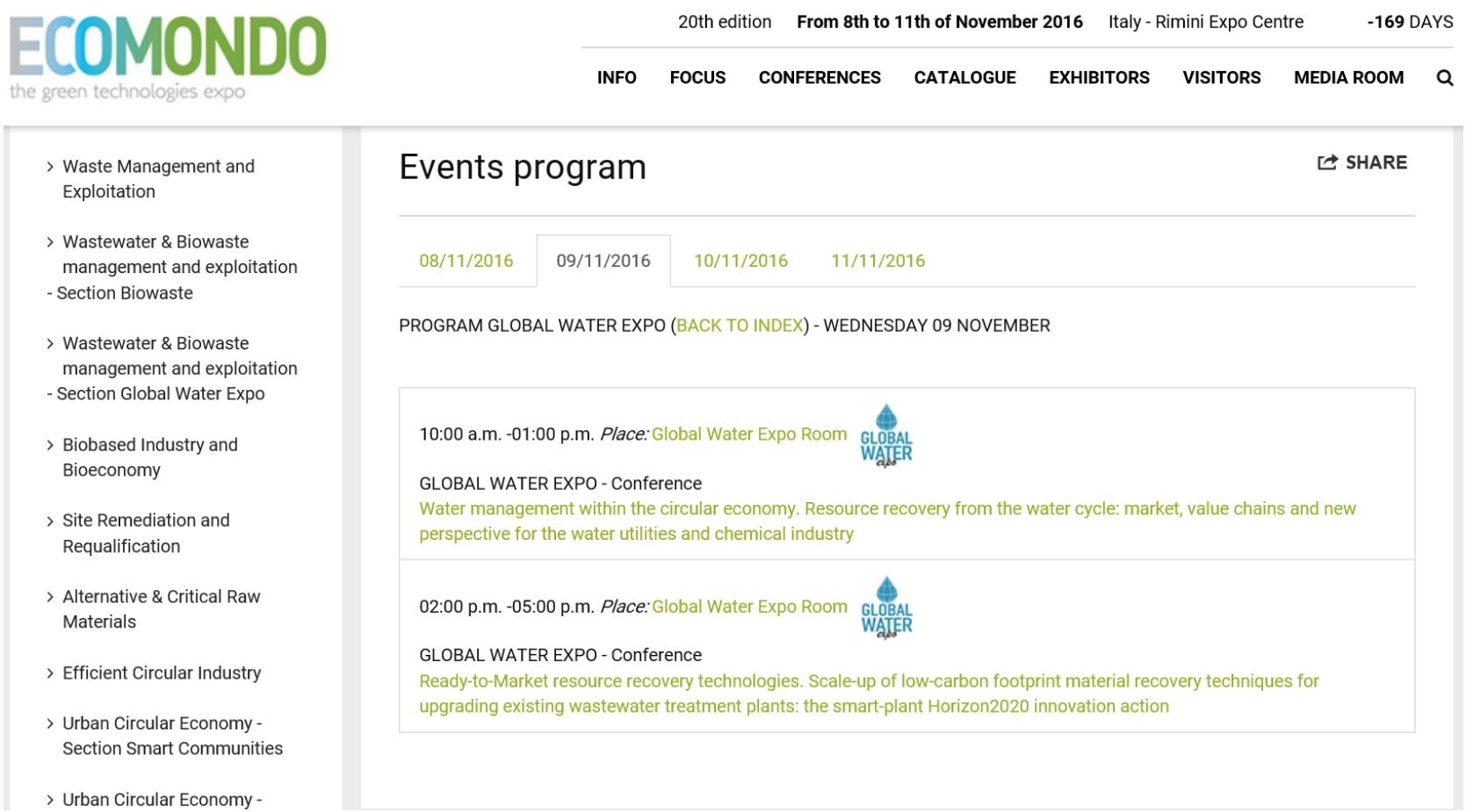
TECHNOLOGIES

Biowaste pre-treatments: Case Studies

Rovereto (TN, Italy)

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



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