ENVIRONMENT PARK Parco Scientifico Tecnologico per l'Ambiente

Confservizi il sindacato d'impresa per i servizi pubblici PIEMONTE - VALLE D'AOSTA

Virtualmente Torino, 18/12/2020

Impianti pilota per la riduzione dei fanghi ed il recupero di fosforo, cellulosa e altri materiali

IWA the international water association

Francesco Fatone, PhD, IWA Fellow

Water Europe Ambassador

General Secretary IWA Resource Recovery Cluster

Polytechnic University of Marche, Italy

Water Europe Technology & Innovation

SMART-Plant HYDROUSA FIT4REUSE Digital Water .City ULTIMATE

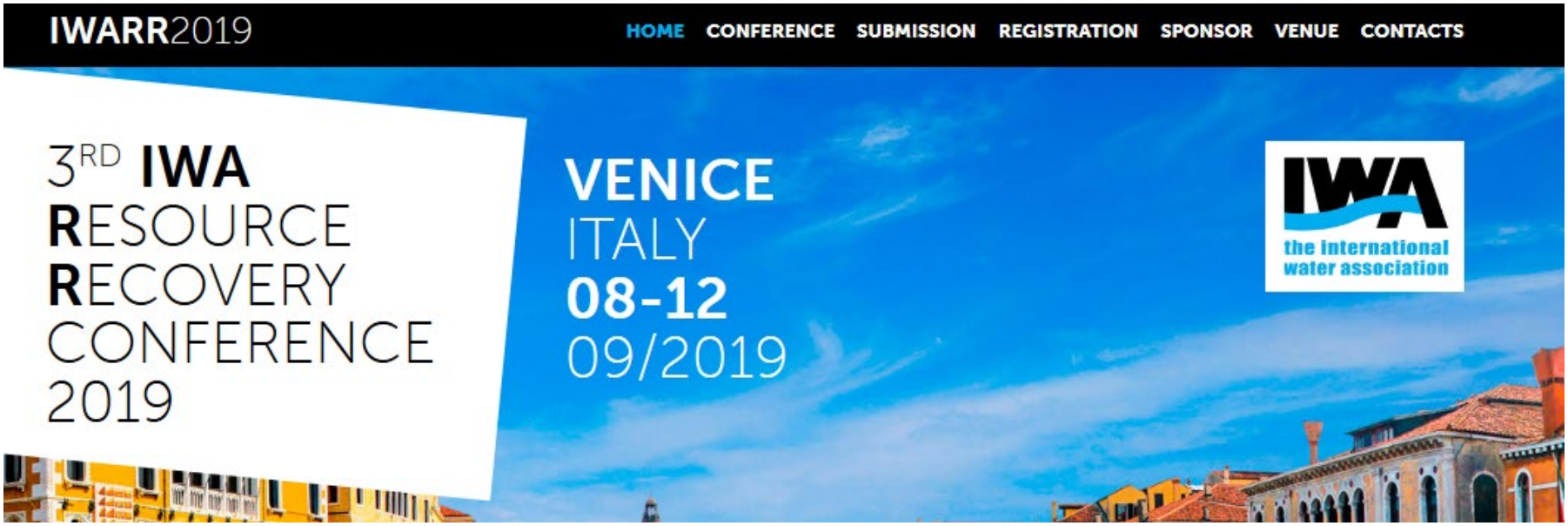
Università Politecnica delle Marche

WWEE LAB Water and Waste Enviromental Engineering

Outline

- Resource recovery from used water: from energy to higher value
- Material recovery and SMART-Plant → challenges addressed since 2016 - achievement in 2020 … and future
- SMARTechs - validated and assessed technologies to turn existing WWTPs into WRRFs
  - *Focus on cellulose and PHA recovery*
- SMART-Products – energy-efficient material recovery and safe products from municipal wastewater
  - *Focus on Nutrients*
- SMART Digital solutions - energy and carbon footprint monitor and optimization
  - *Focus on Energy and Greenhouse Gas Monitoring and control*
- Legislation and regulation: current achievements and barriers

Outcomes of the conference: following



SMART-Plant

UNIVERSITÀ POLITECNICA DELLE MARCHE

UNIVERSITÀ di VERONA

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

https://www.iwarr2019.org/

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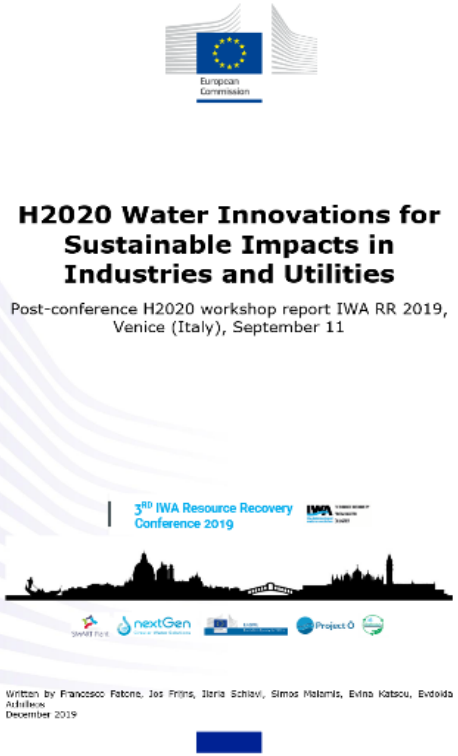
3RD IWA Resource Recovery Conference 2019

Co-organized by

EASME Executive Agency for SMEs



H2020 Water Innovations for sustainable impacts in industries and utilities

post-conference workshop @ IWA RR 2019, Venice (IT) 11/09/2019
chaired by H2020 projects SMART-Plant, Hydrousa and NextGen
co-organized by EASME

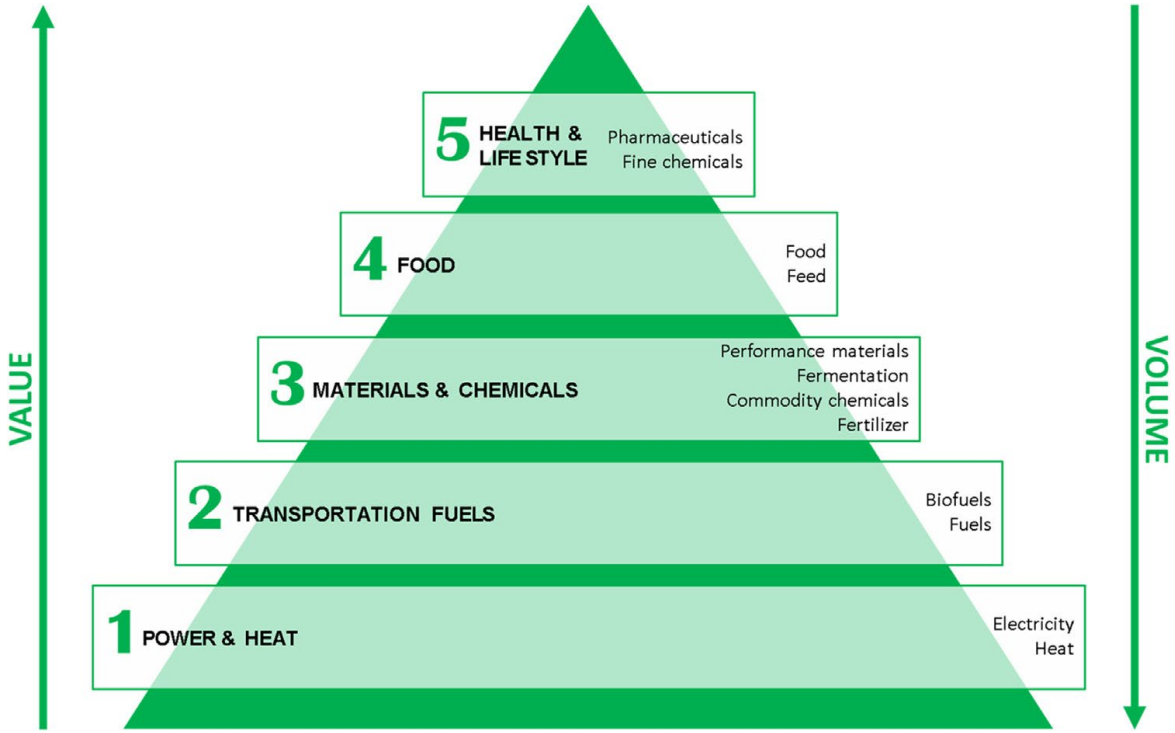
The workshop include:

- Pitch presentations showcasing the outcomes/progress of innovative H2020 projects in front of selected audience of utilities and industries for circular economy solutions in the water sector.
- Discussion with panel of experts with a strong focus on the viewpoints of the end-user / consumer and the regulator in relation with (but not limited too) water & energy, water reuse, nutrients recovery, organics recovery, C-footprint and integration in the water tariff.
- Break-out session to discuss opportunities and challenges related to the market uptake of the proposed circular economy solutions, replication and widespread adoption of resource recovery from water in urban water management.

Target participants:

We encourage researchers, utilities, water professionals, technology providers, policy makers, consultants to participate in this workshop as well as market segments and industries outside of the water sector that can valorize the recovered resources.

Water Resource Recovery Facilities must recognize the value of the materials they recover



Product market and profitable production are key requisites for a sustainable bioeconomy!

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The ENERGY PATHWAY
(to deliver circular economy)

Current TRL = 8-9

but
WATER-ENERGY-CARBON NEXUS!

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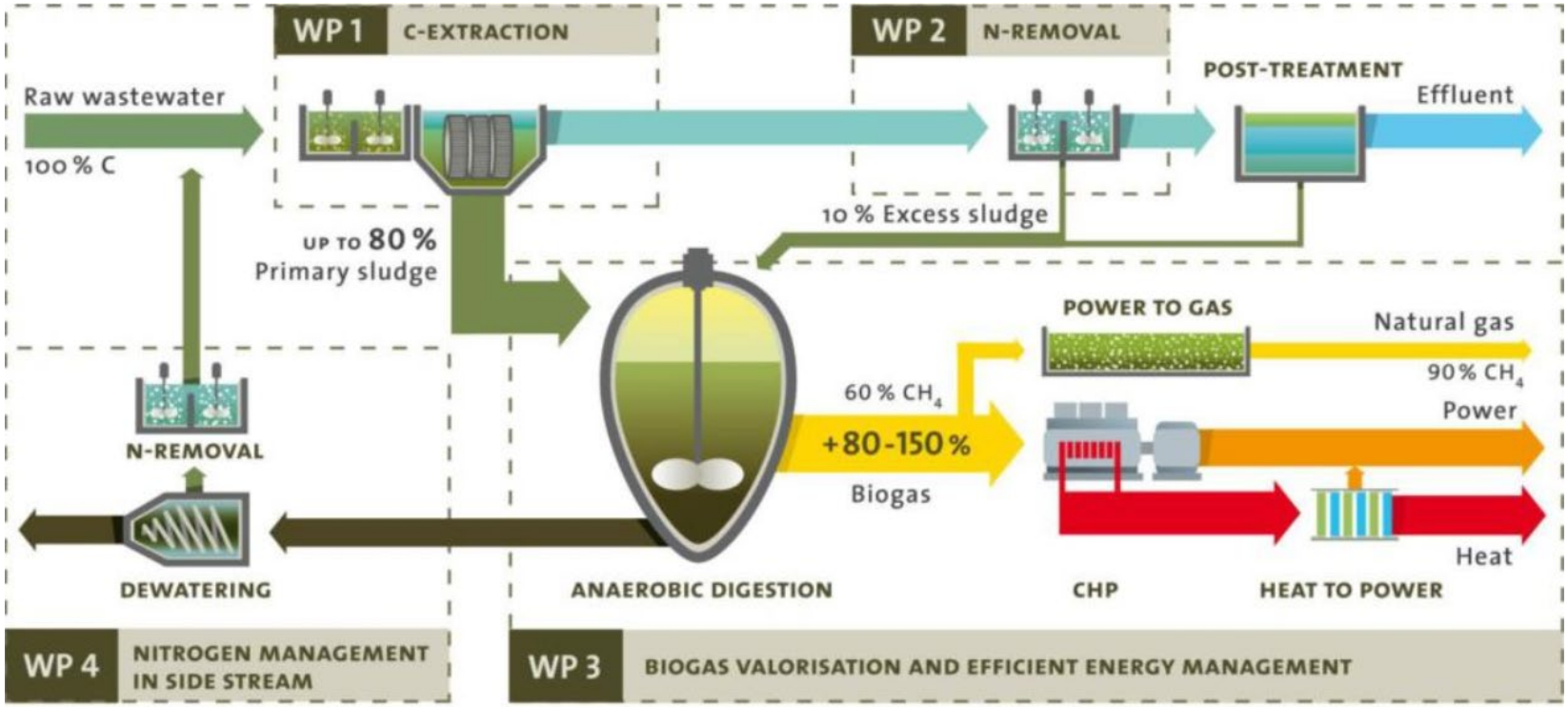
Energy positive evolution: H2020 POWERSTEP



POWERSTEP modules ***www.powerstep.eu***

1- in mainline WWTP for A-stage (C extraction)

2- in mainline WWTP for B-stage (N removal)

3- reject water for N- removal or N-recovery

4- for best biogas valorisation

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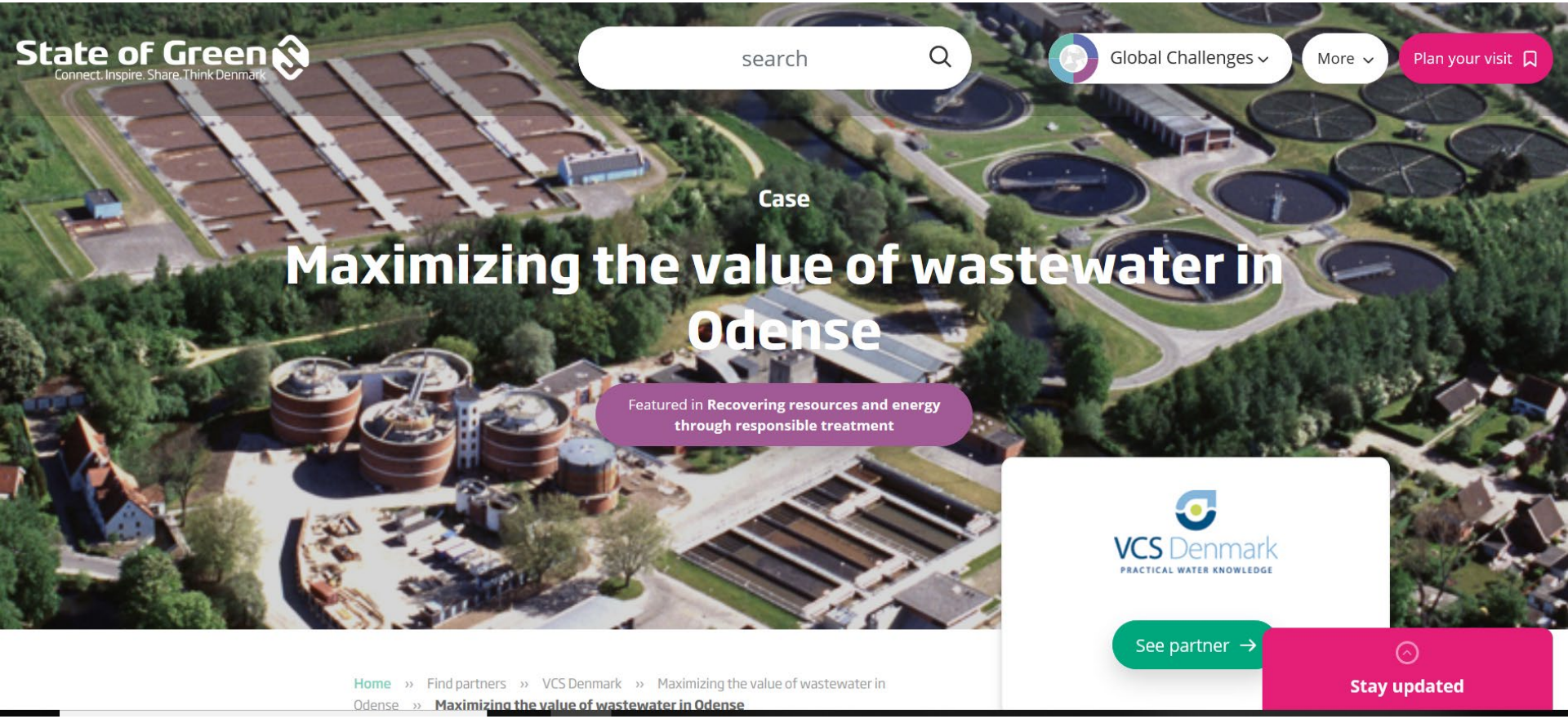
Odense WRRF >> energy positivity of 150 percent



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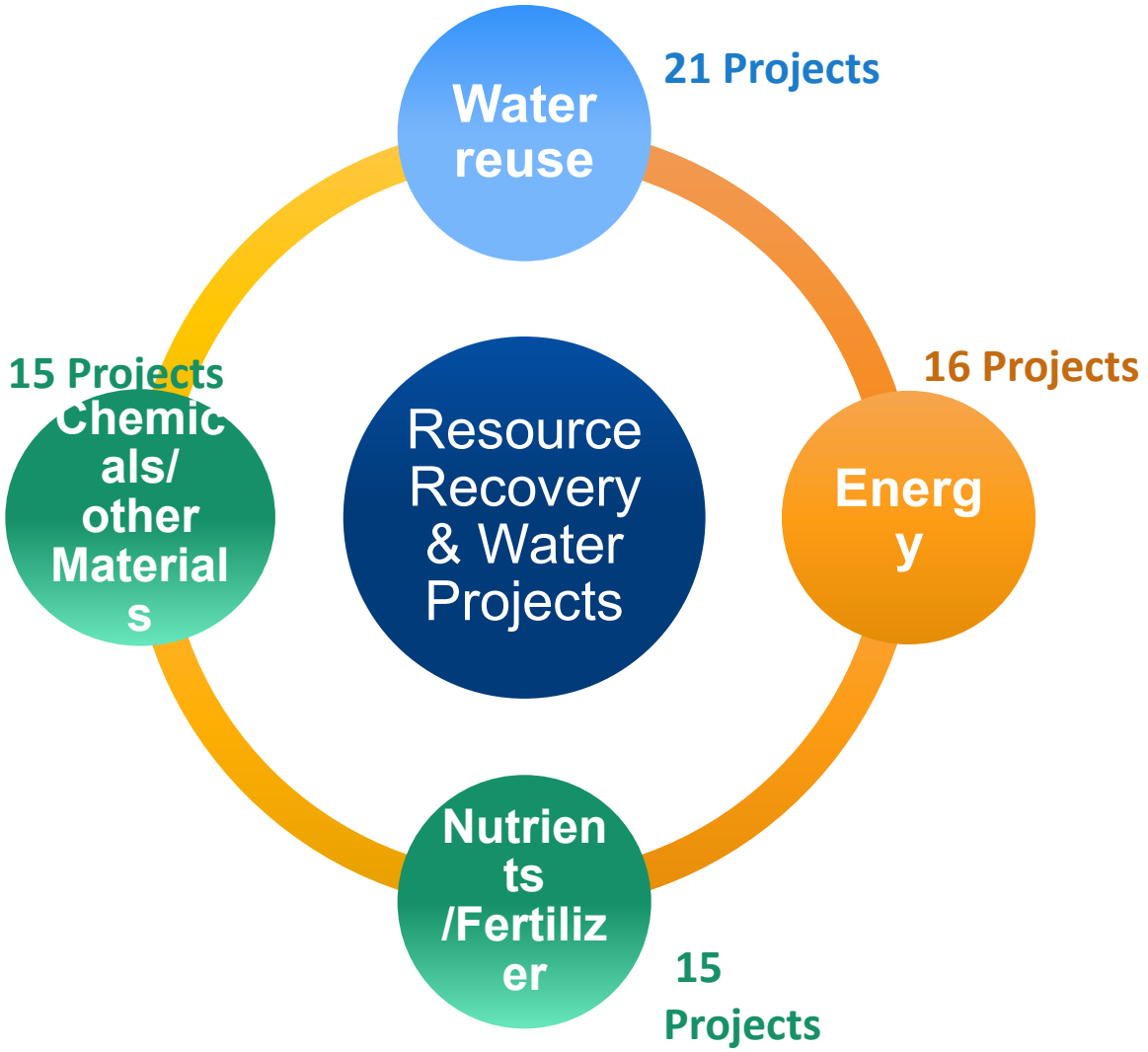
H2020 Circular Economy & Water

Carmen MENA ABELA
Head of Sector
EASME, H2020 Eco-innovation

Water Europe Innovative Water Week , Resource Recovery Group 26 June 2020

H2020 CE Water Projects from SC5
24 Projects
125 Large Demos
EU funding € 194 M



European Commission

H2020 projects related to water in the CE

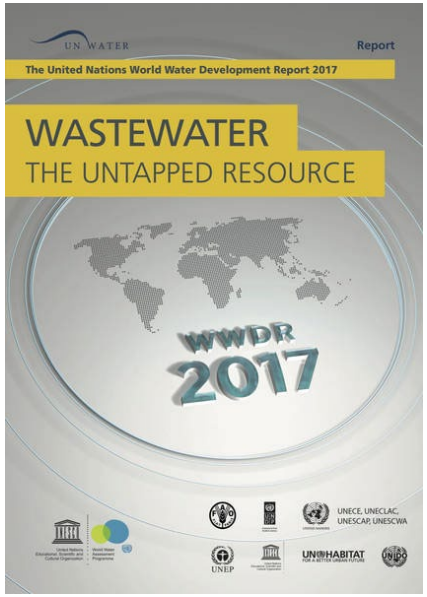
ACRONYM	COORD.	DEMOS	MATERIALS RECOVERED
SMART-Plant	**IT**	NL, UK, IL, IT(2), EL, ES	cellulose sludge/ refined, PHAs, VFAS, Nutrients (phosphates, Struvite), P-rich sludge
INCOVER	**ES**	ES, ES(2),DE	PHAs(bioplastics), citric acid, biofertilizer, nutrient
RUN4LIFE	**ES**	BE, ES, NL, SE	Struvite, Ammonium Sulfate and Nitrate, phosphoric acid, solid and liquid NPK,
Water2REturn	**ES**	ES (2) + test in SI, RO, LT	Organic source fertilizers; biostimulant products, micro-algal biomass; soluble N and P from slaughter house waste water
Project O	**IT**	IT, IL, ES, HR	recovery nutrients, saltwater reuse, fit-for purpose water
HYDROUSA	**EL**	6 demosites in 3 EL-islands	clean water via evaporation and condensation, edible salt; nutrient rich water (as fertilizer)
NextGen	**NL**	DE, ES, NL(2), CH, UK, SE, EL, UK, RO	spiruline; struvite; ammonia sulphate; NPK fertilizer; protein
SYSTEMIC	**NL**	UK, DE, NL, BE, IT + test-plant in FI	mineral nutrients, ammonium sulphate, calcium carbonate; biogas; organic soil improver, P-poor soil improver, N+K-concentrates, NPK fertilizers;
ZEROBRINE	**NL**	NL, PL, TRK, ES Replication: NL(2), PL, EL, ES	minerals (e.g. sodium chloride, sodium sulphate), regenerated acids, caustics, magnesium
SALTGAE	**ES**	SI, IT, IL	algae biomass;

H2020 new projects
"*Building a water-smart economy and society*"

ACRONYM	COORD.	DEMOS	MATERIALS RECOVERED
ULTIMATE	**NL**	ES, NL, IT, EL, UK, FR, DK, CZ, IL	Nutrients (ammonia); sulphur for sodium bisulfide; polyphenols, antioxidants; metals; copper-rich fertiliser
B-WaterSmart	**DE**		Brines/salts, energy/ biogas, nutrients (ammonia), minerals
Wider Uptake	**NO**	IT, NO, Cz, NL, Ghana,	Biocomposite materials, organic and inorganic fertilizers
WATER-MINING	**NL**	NL, ES, CY, PT, IT	Chemicals, minerals, nutrients (phosphates), fit-for-purpose water
REWAISE	**ES**	Living Labs: SE, SE, PL, ES(6), UK	Nutrients(primarily phosphorous), metals, minerals, CRM-Mg, Li; biogas; biopolymers; NPK fertilizers; struvite, vivianite

Water in the CEAP: still untapped resource?

*"Furthermore, the Commission will develop an **Integrated Nutrient Management Plan**, with a view to ensuring more sustainable application of nutrients and stimulating the markets for recovered nutrients. The Commission will also consider **reviewing directives on wastewater treatment and sewage sludge** and will assess **natural means of nutrient removal such as algae**"*



stowa

Challenges of water authorities

2020 30% energy efficiency 2005-2020 (MJA-3)

40% self-sufficient by sustainable energy production (Climate agreement)

30% reduction of greenhouse gases 1990-2020 (Climate agreement)

€ 380 million efficiency saving in the watercycle

2025 100% energy neutral

2027 Good ecological and chemical quality surface water (WFD)

2050 CE 100%

20?? Microplastics? Drugs? Pharmaceuticals?, nanoparticles ?

antibiotic resistance ??

Source: SMART-Plant project meeting

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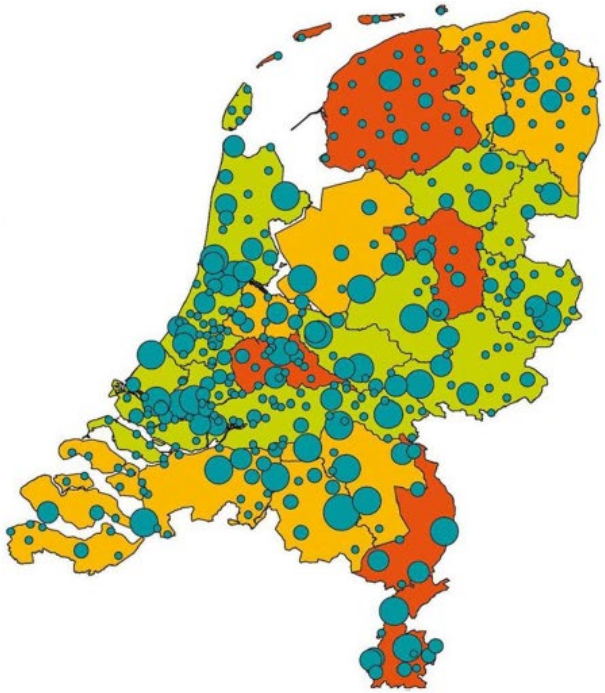
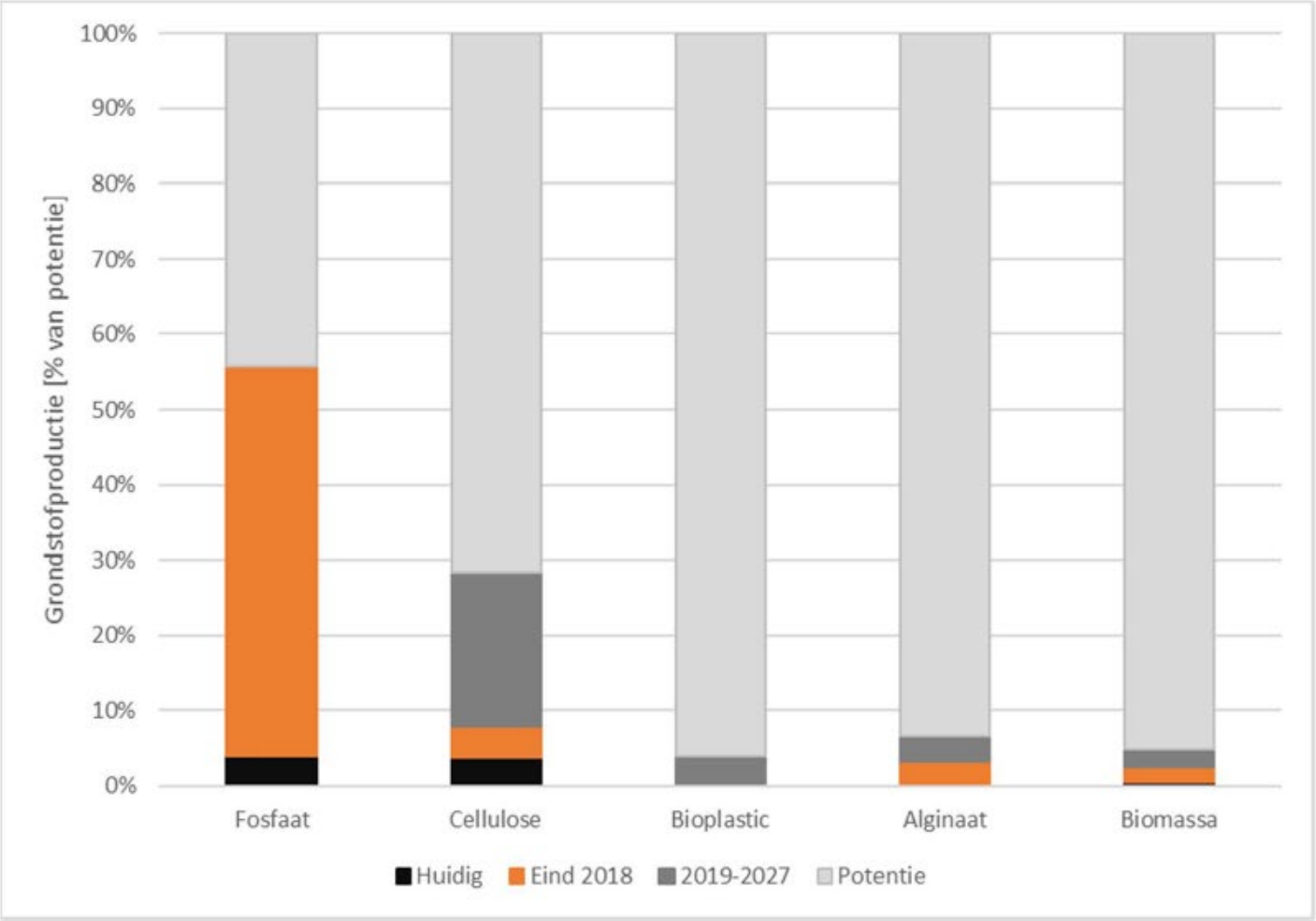
Energy and Resources



- Energy
- Cellulose
- Alginate
- Bioplastics
- Phospate
- Biomass
- Water
- ….

Fonte: SMART-Plant project meeting

Top 5 resources



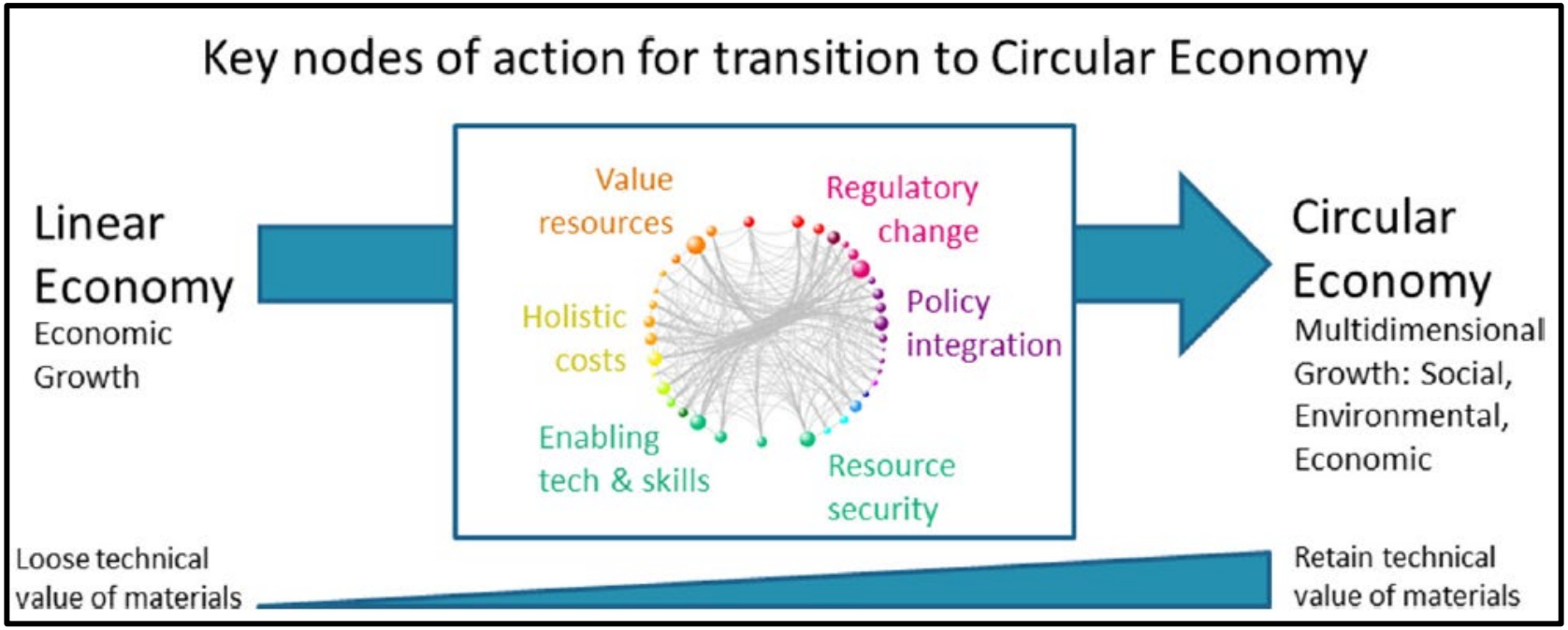
Fonte: SMART-Plant project meeting

The MATERIAL PATHWAY (to deliver circular economy)

SMART-Plant

www.smart-plant.eu


The challenges: cross-sectorial value chains, scale-up in real environment and long-term multi-dimensional validation



Source: Making the business case for resource recovery, Velenturf and Jopson, STOTEN, 2018

Scale-up of low-carbon footprint MAterial Recovery Techniques in existing wastewater treatment PLANTs

- Horizon2020 IA
- 9 demo SMARTechs
- Cross-sectorial value chain
- Innovation deal
- 26 partners
  - 19 SME or LI
  - 7 R&D Organization

Consumer/Industrial Products

Struvite
Calcium-P
P-Biofertilizer

Cellulose

Bio-polymers

SMART-Plant

Energy and Carbon Efficiency

Biogas and Biomass Fuel

Water re-use and fertigation

ETV

iwater
SALÓN INTERNACIONAL DEL CICLO INTEGRAL DEL AGUA
AWARD 2018

www.smart-plant.eu Start: 01/Jun/2016 – End: 31/May/2020

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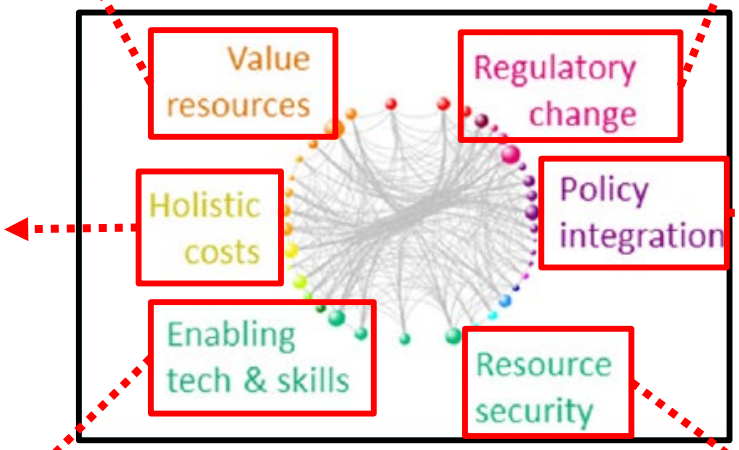
How SMART-Plant addressed the challenges

Value the resource efficiency and the recovered resources when leading to consumer/industrial products

Water tariff promotiong circular economy and measures to support PPP



Long-term measure-based quantified indicators (support by digital solutions)

Sludge and UWWTD, EU Green Deal and Circular Economy Action Plan

Long-term validation and hands-on training of water utility operators

Address the actions for resources to be priority recovered

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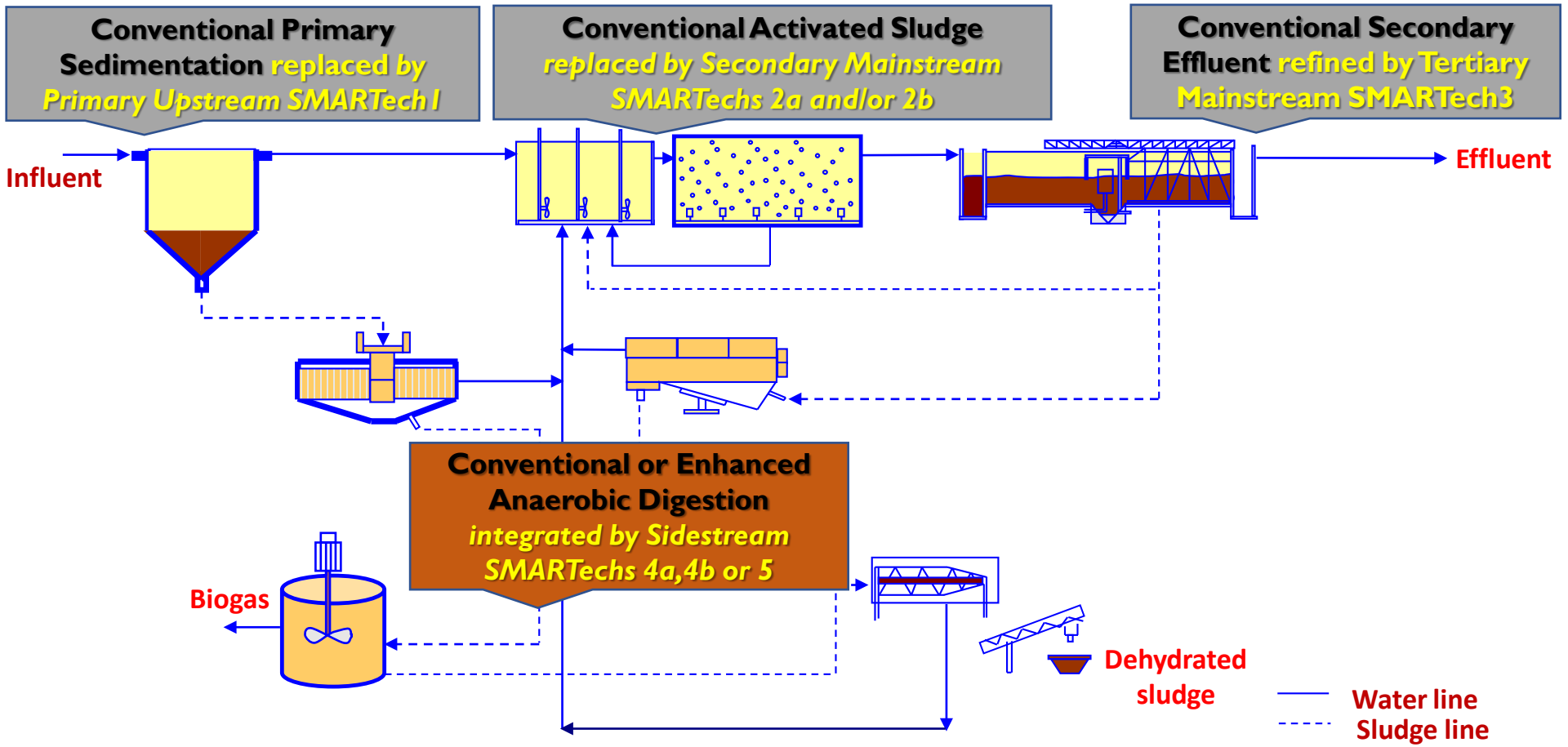
SMART-Plant approach and SMARTechs



SMART-Plant

HOME | THE PROJECT | ENE3 | MEMBERS AREA | NEWS | PARTNERS | CONTACT

Demostration Sites

ALL SITES

- Geestmerambacht
- Karmiel
- Manresa
- Cranfield
- Carbonera
- Psyttalia
- Carbonera (b)
- London
- Manresa (b)

http://smart-plant.eu/index.php/map

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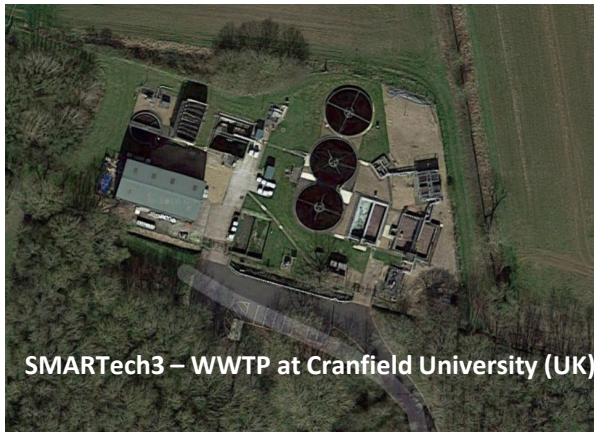
SMARTechs integrated in existing WWTPs (revamped/upgraded to WRRFs)

SMARTech2b and Downstream
SMARTech B - Manresa WWTP (Spain)



SMARTech 4b - Psyttalia WWTP (Greece)

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ACHIEVEMENTS OF SMART-PLANT

	SMARTech n.	Integrated municipal WWTP	Key enabling process(es)	SMART-product(s)
Mainstream	1	Geestmerambacht (Netherlands)	**Upstream dynamic fine-screen** and post-processing of cellulosic sludge	**Cellulosic sludge, refined clean cellulose**
Mainstream	2a ETV	Karmiel (Israel)	Mainstream polyurethane-based **anaerobic biofilter**	**Biogas, Energy-efficient water reuse**
Mainstream	2b	Manresa (Spain)	Mainstream **SCEPPHAR**	**Struvite, PHA**
Mainstream	3	Cranfield (UK)	Mainstream **tertiary hybrid ion exchange**	**Nutrients**
Sidestream	4a ETV	Carbonera (Italy)	**Sidestream SCENA**	**P-rich sludge, VFA**
Sidestream	4b	Psyttalia (Greece)	**Sidestream Thermal hydrolysis – SCENA**	**P-rich sludge**
Sidestream	5	Carbonera (Italy)	**Sidestream SCEPPHAR**	**PHA, struvite, VFA**

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Long-term *SMARTech* Evidence Based results

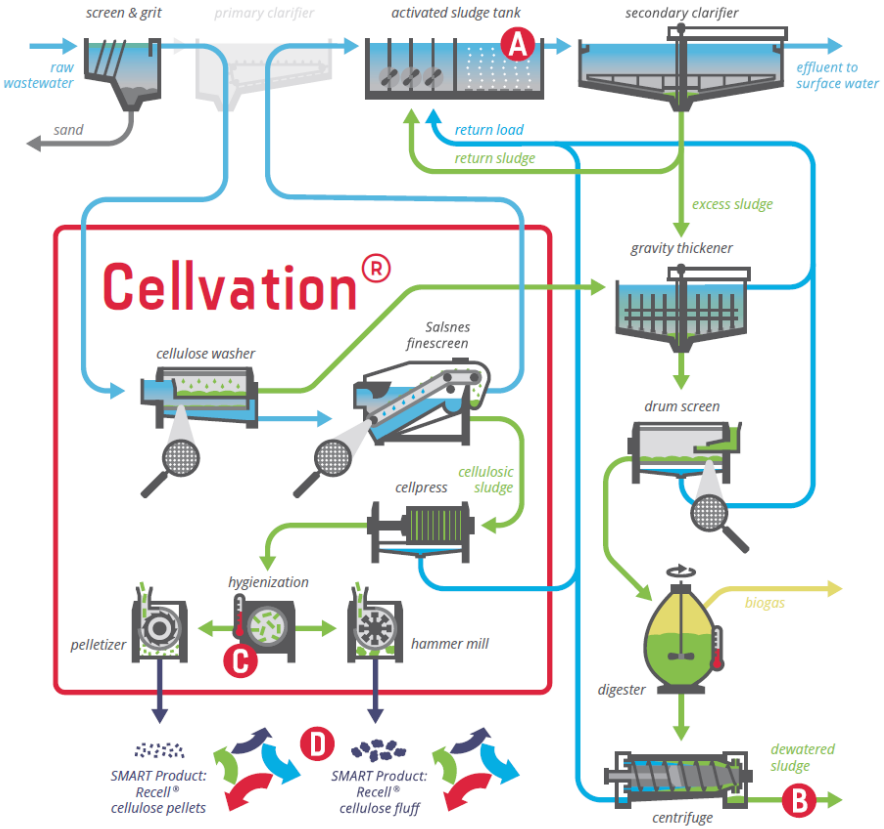
- Cellulose 2,0-7,3 kg per PE per Year
- PHA 1-1,2 kg per PE per Year
- CaP 0,4-0,8 kgP PE per Year
- Struvite 0,2-0,4 kg PE per Year
- Ammonia and ammonium sulphate 20-30 kgN PE per Year
- Spent zeolite resin (rich in K and NH3)
- Biofertilizer
- ***Energy saving 4-68 %***
- ***GHG emission reduction 1-71 %***
- ***Sludge reduction 18-30 %***

Main LCA results

Case study location	SMARTechs	Material recovered	Primary energy demand		Global warming potential		Water emissions (N, P)	
			Min	*Max*	*Min*	*Max*	*Min*	*Max*
NL	Cellvation + Biodrying	Cellulose	-4%	-23%	-2%	-19%	No effect*	
	Cellvation + Bio-composites	Cellulose	-2%	-18%	-1%	-15%	No effect*	
IL	Anaerobic biofilter	Biogas	-62%	-68%	+37%	-22%	No effect*	
ES	SCEPPHAR mainstream + PHA extraction	PHA, struvite	+6%	-18%	+8%	-12%	No effect*	
UK	Ion exchange	CaP, NH_3	+32%	-52%	+3%	-71%	-2%	-62%
IT	SCENA + Dynamic composting	P-rich compost	+8%	-2%	+1%	+4%	No effect*	
	SCEPPHAR sidestream + PHA extraction	PHA, struvite	-5%	-8%	-4%	-7%	No effect*	
GR	SCENA after TH	-	+19%	+6%	+9%	+6%	-10%	-10%

** impact on water quality could not be predicted based on the available data. Assumption: comparable effluent quality than reference WWTP*

SMARTech 1
Cellulose Recovery with Dynamic Sieving as Primary Treatment



- Around 100-200 kg of cellulose per week
- 20% less of aeration in the aerobic basins
- 10-15% less excess sludge production
- EPA Class A rating for the cellulose product

Unique Selling Points

A Reduction of energy consumption for aeration by up to 20 % and increase of treatment capacity at the plant due to reduction of organic load in the activated sludge process

B Reduction of sludge volume which leads to lower polymer use for dewatering and lower sludge disposal costs

C Reaching EPA class A rating for the celluslose product

D Recovery of a high quality product: clean cellulose fluff or pellets for reuse in road construction (e.g. as additive in asphalt) or as a raw material for bio-composites and other buildings materials

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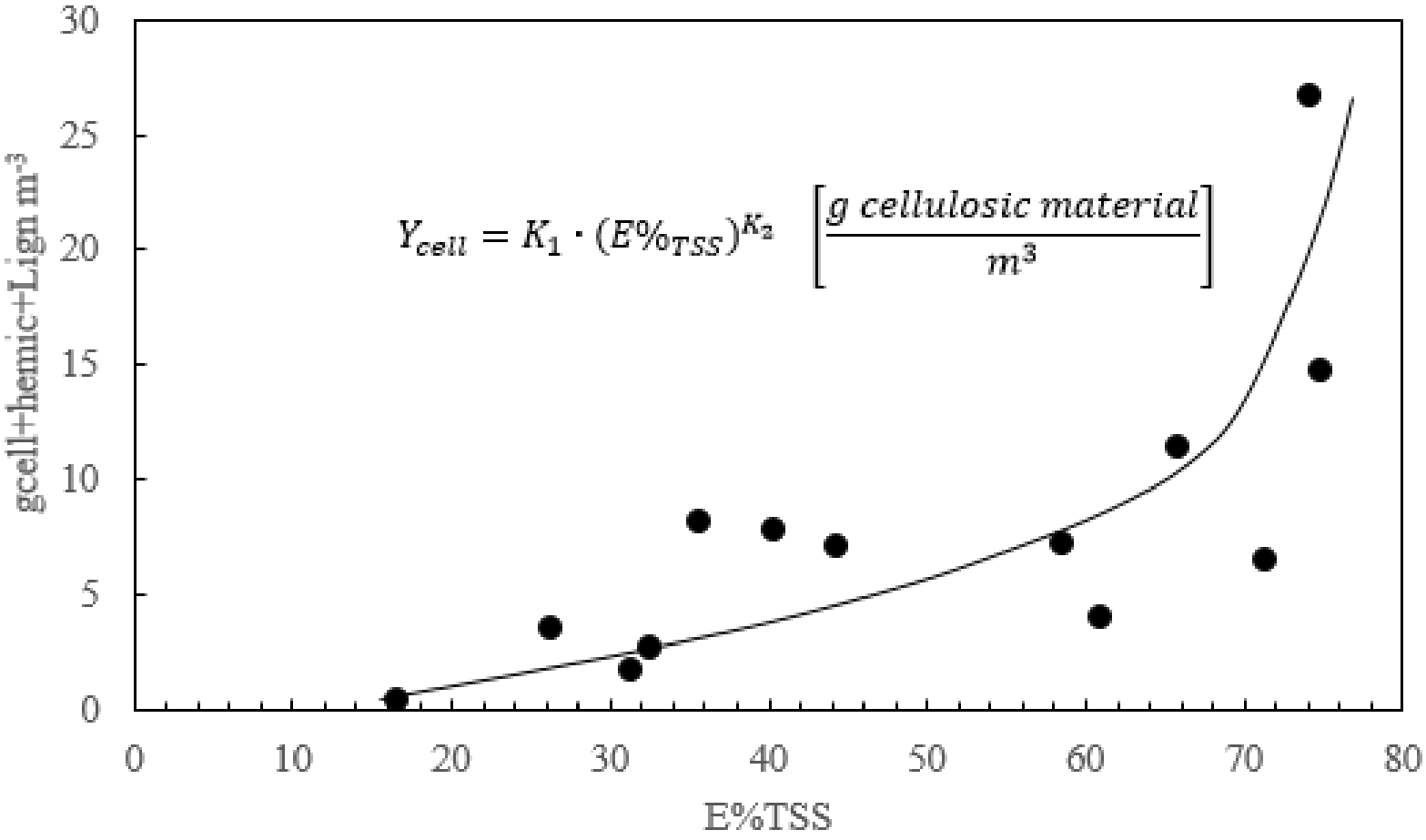

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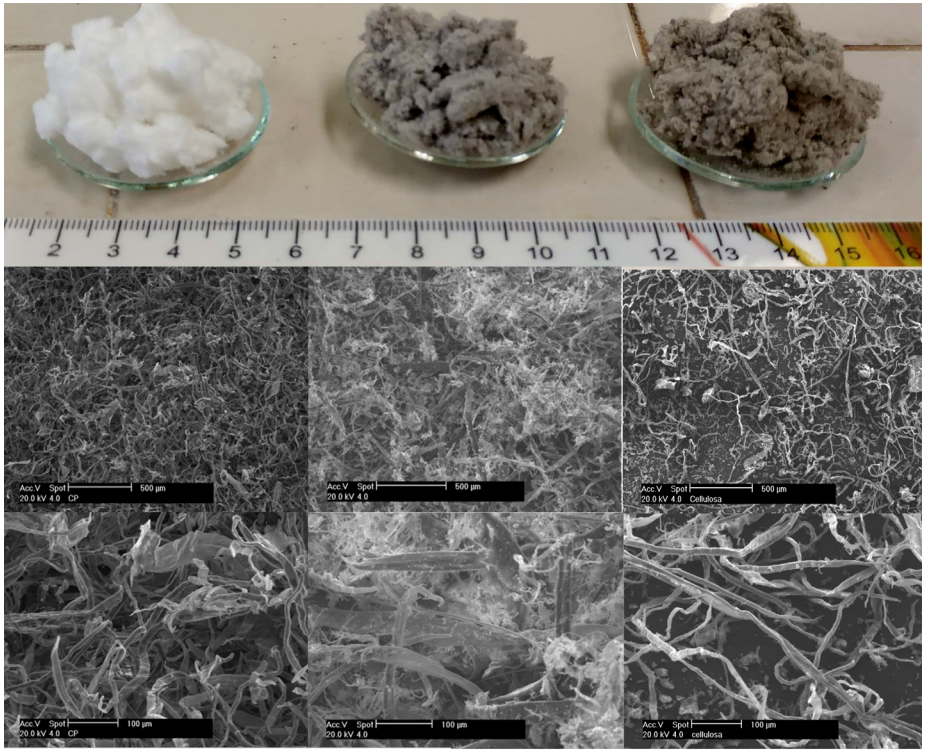

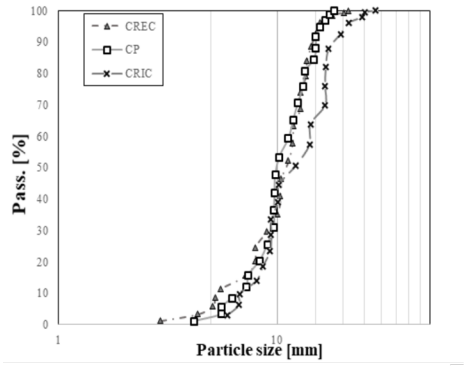

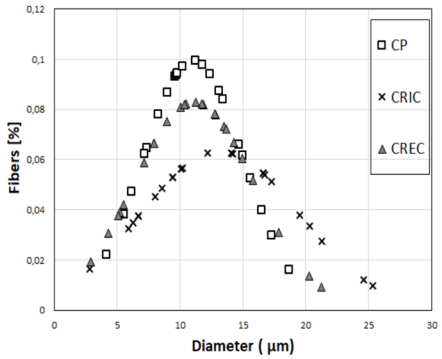

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Recell®

Product description Recell®
Tertiary cellulose fiber produced for the industry.

Safety & Health
This document provides a short view of the extended MSDS. Read the full MSDS before working with the product.

CAS-No.	9004-34-6
REACH-No.	Do not require registration
Cellulose	100% recycled product
Toxic properties	None
Fire Hazardous	Yes

Handling
Take care of dust formation when handling the dry fluff cellulose. Avoid inhaling. It is recommended to use protective measures (PBMs) for eye protection, skin protection, body protection and respiratory protection. The product is microbiologically comparable to the market product, only due to the pilot installation it cannot be guaranteed. This should be taken into account when processing the product. It is recommended to wash hands after using the product.

Shelf life: Minimum 1 year, provided the products are stored in a dry, cool and in the delivered intact packaging.

Physical properties	
Appearance	fibre fluff
Cellulose content	60 - 80 %
Hemicellulose/Lignin	10 - 15 %
Ash	5 - 15 %
Organic residue	5 - 10 %
pH	5 - 8
Dry matter	> 90%
Odour	Neutral
Colour	Light grey
Brightness	> 50%
Loose density	50 - 80 kg/m3

Number	Weight	Volume	Date production	Productionlocation	Operator

For more information:

Cellvation B.V.
Agora 4, 8934 CJ Leeuwarden
Postbus 7560, 8903 JN Leeuwarden
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Adapted from IWA RR 2019

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Public acceptance? Would you eat on your wastewater?

Eating on recovered toilet paper at the 3rd IWA Resource Recovery Conference in Venice

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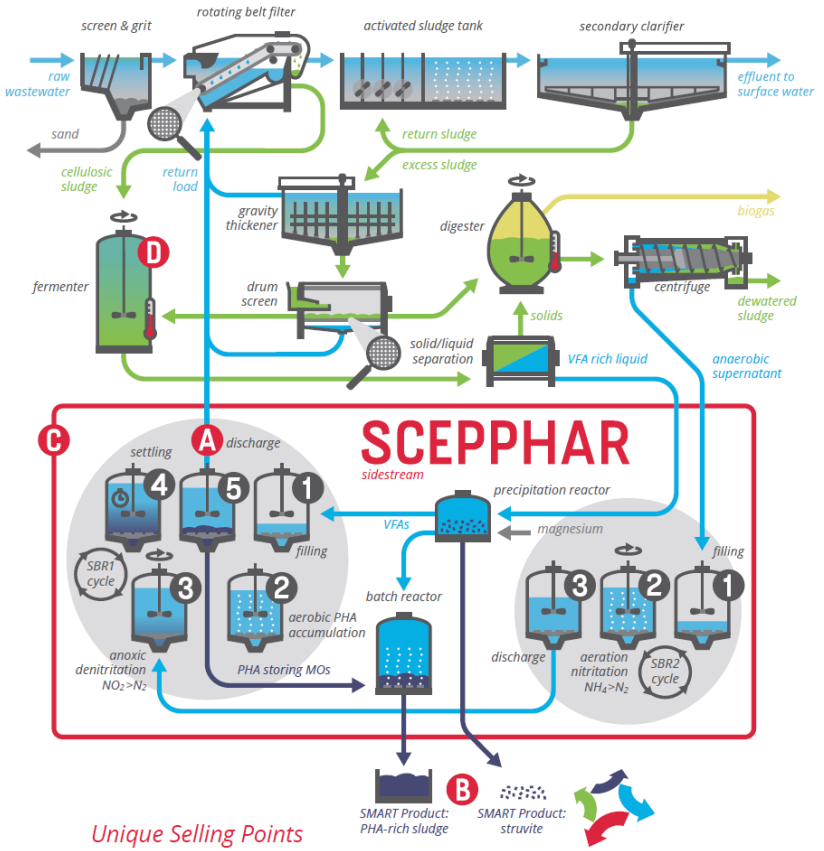
SMARTech 5
Short-Cut Enhanced Enhancved P and PHA Recovery

Integrated nutrient management

1,0-1,2 kgPHA per PE per year;

Around 0,2-0,4 kg struvite PE per year



Unique Selling Points

- **A** High effluent quality due to effective N and P removal from sludge liquor
- **B** Recovery of valuable products (PHA, struvite)
- **C** Reduction of energy and operational costs
- **D** Carbon source (VFA) for PHA production is gained in the process

	conventional treatment	SCEPPHAR
P Removal	Chemical	Biological
N Removal	Nitrification + Denitrification with external C Source	Nitritation + Denitritation
Products	None	Struvite + PHA-rich Sludge

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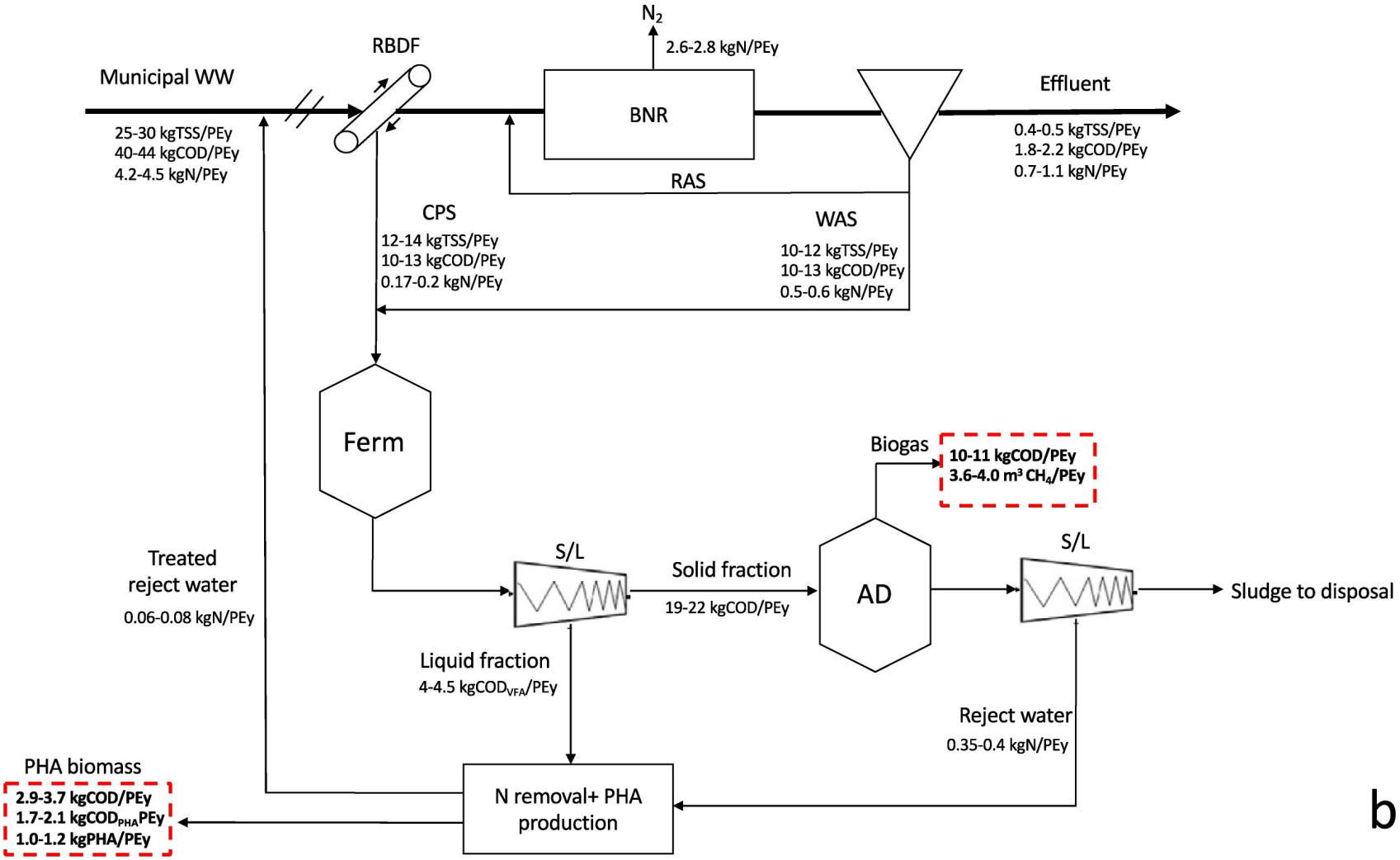
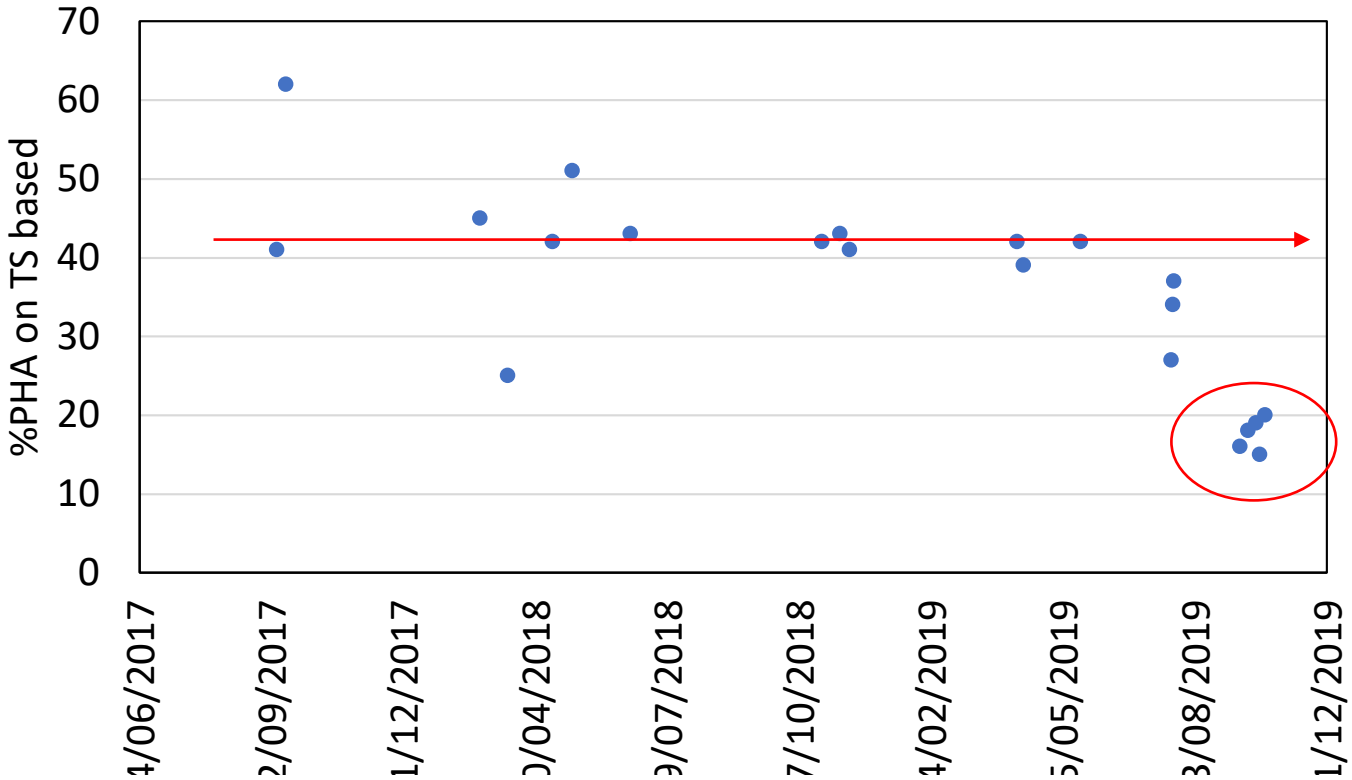
Mass balance of the SMARTech 5



Conca et al., Chem Eng. J., 2020

Long-term PHA concentration



%PHA: 40-45%

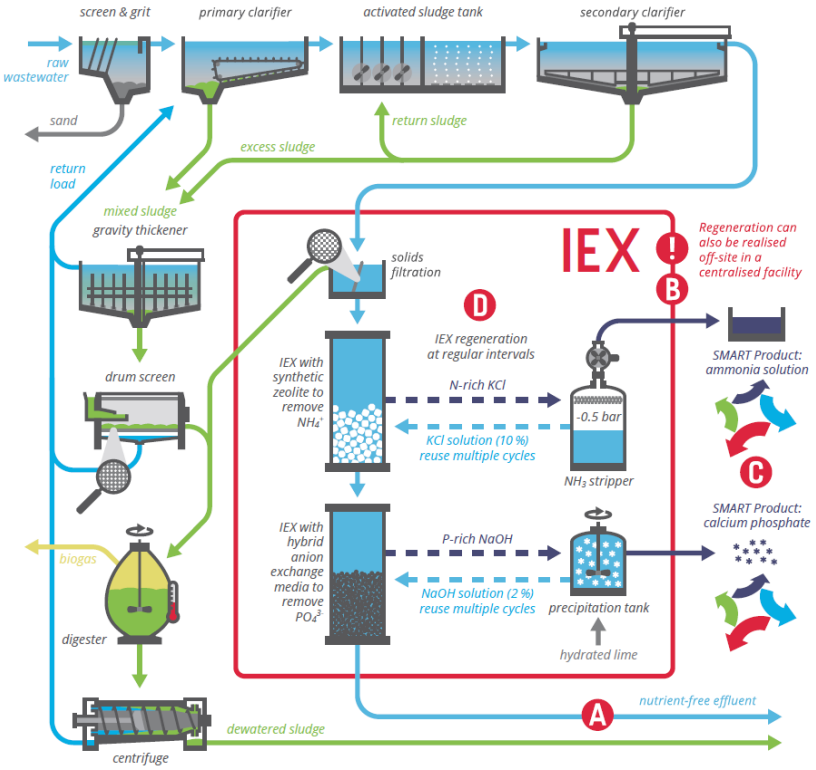
- HB: HV = 60:40

No heat from anaerobic reject water

- Low temperature

150 kgPHA/mese

SMARTech 3
Mineral fertilizer precursor recovery



- 95% of P recovered as $CaPO_4$ from the tertiary treatment;
- Low P and N limit value can be achieved

Unique Selling Points

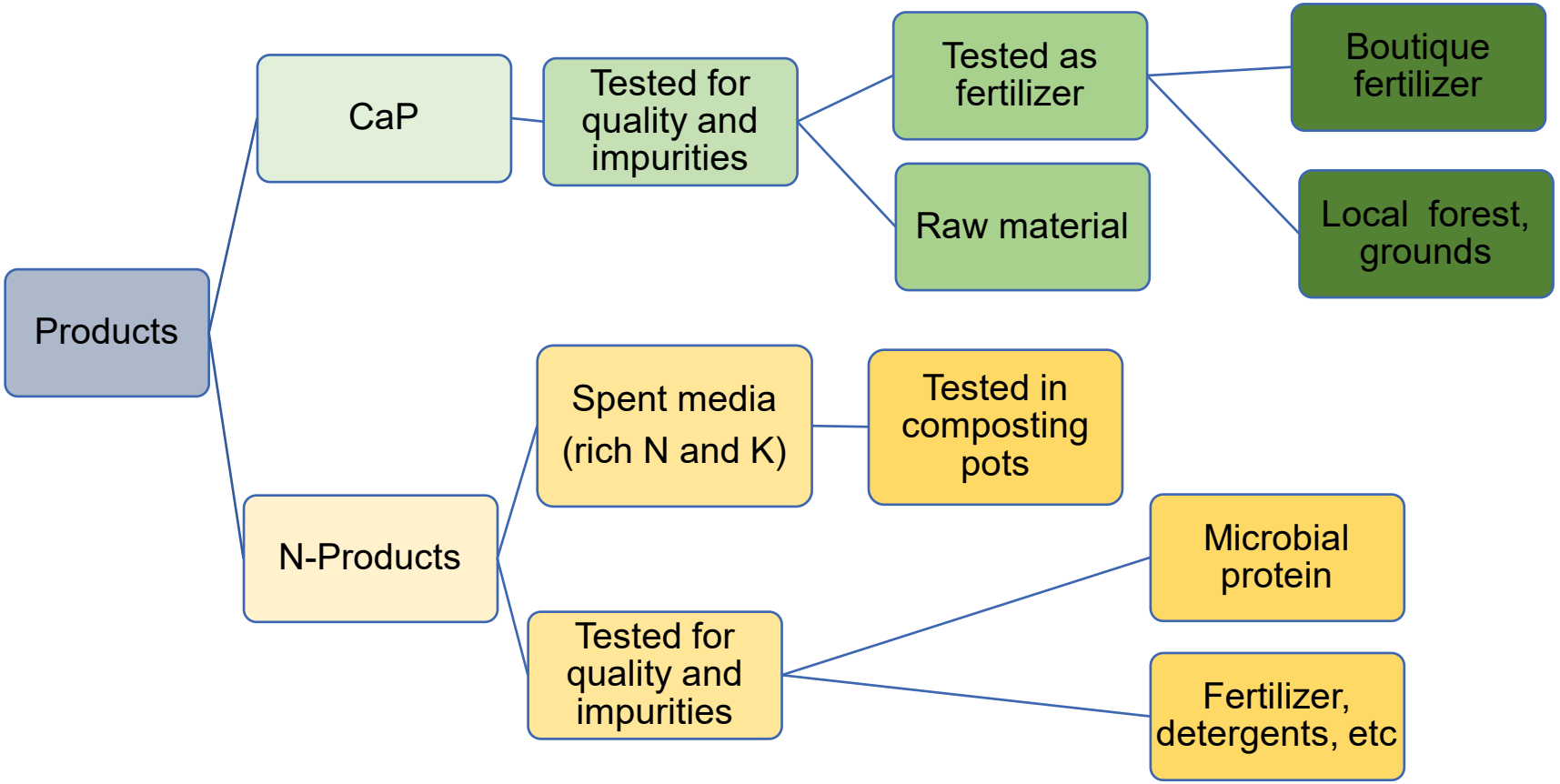
A Achieves tight nutrient discharge limits by removing NH_4^+ and PO_4^{3-} to very low concentrations (< 1-5 mg N/L and < 0.5-1 mg P/L)

B High recovery rates: up to 97 % of ammonia and 95 % of phosphorus

C High quality products which can be used in the chemical and fertilizer industry

D Multiple use and recovery of regenerants leading to an economic application of IEX processes in the wastewater sector

SMARTech 3
Value of the resource



Downstream SMARTech B: adv. Composting of P rich sludge

Improved compared to literature:

- Up to 3%N and 2.5%P typically found (dry basis)

	SMART biofertilizer	Compost from conventional sludge	Compost from MSW	Manure compost
NPK	Up to 5%N Up to 4%P >1%K All nutrients are given in dry basis	1.4-2.7%N 0.4-0.9% P 2 (d.b)	1.5- 2.1%N 0.6-0.9%P 3 (d.b)	2- 2.5%N 2-2.5%P 2-2.5%K 5 (d.b)
consumption	100- 160 kwh/t_{sludge} [1]		160-250 kwh/t_{OFMSW} [4]	
emissions	4.2E-06 $kgCO_2eq$ tTS^{-1} 0.001-2.7 $kgNH_3$ tTS^{-1} 0.008-0.48 kgC-VOC tTS^{-1}	27-130 $kgCO_2eq$ tTS^{-1} 0.6-11 $kgNH_3$ tTS^{-1} 0.6-1.6 kgC-VOC tTS^{-1} 6	4.2-204.1$kgCO_2eq$ $tOFMSW^{-1}$ 0.7-8.6 $kgNH_3$ $tOFMSW^{-1}$ 4;7	
price	40-80€/tn	11-23 €/tn	20-35 €/tn	19-28 €/tn

[1]Estimated for full scale (with blowers);[2]Grigatti et al., 2017; 2019; [3]Awasthi et al., 2015; Vázquez & Soto, 2017; [4]Colon et al., 2015; [5]Puyuelo et al., 2019; [6] Yuan et al., 2016; Han et al., 2018; González et al., 2020; [7]Puyuelo et al., 2015

- **Suitable for agricultural use: HM complying with relevant regulatory limits (Spanish Royal Decree 503/2013; Com Decision 2015/2099 of eco-labelling of growing media and soil improvers)**
- **Effective P source for plants according to agricultural tests**

Toxic and emerging comounds: Heavy metals, pesticides and emerging compounds

SLUDGE SAMPLES

1. N and P salts as produced by Cranfield (SMARTech3) Batch 1
2. N and P salts as produced by Cranfield (SMARTech3) Batch 2
3. N and P salts as produced by Cranfield (SMARTech3) Batch 3
4. P-rich sludge produced by SCEPPHAR Carbonera (SMARTech4.2)
5. P salts produced by Carbonera
6. Excess sludge produced by SCEPPHAR Manresa
7. Excess sludge by TH-SCENA Athenes
8. P-rich compost produced by downstream (SMARTechB)

REST OF THE SAMPLES

9. PHA as extracted by Biotrend
10. PHA-rich biomass (SMARTech5)
11. Final cellulose from Cirtec (SMARTech1)
12. ET100
13. ET50
14. WPC
15. SPC

→ Biocomposite produced by downstream SMARTechA

Benedetti et al., Microchemical Journal, 2020

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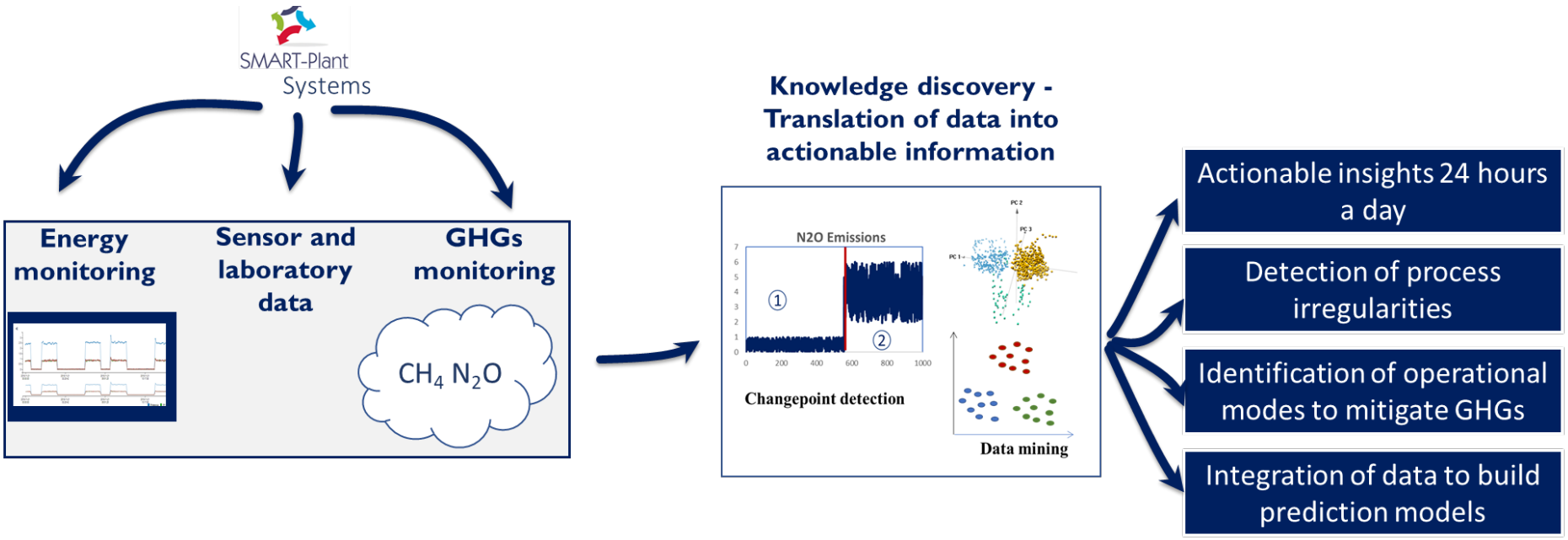
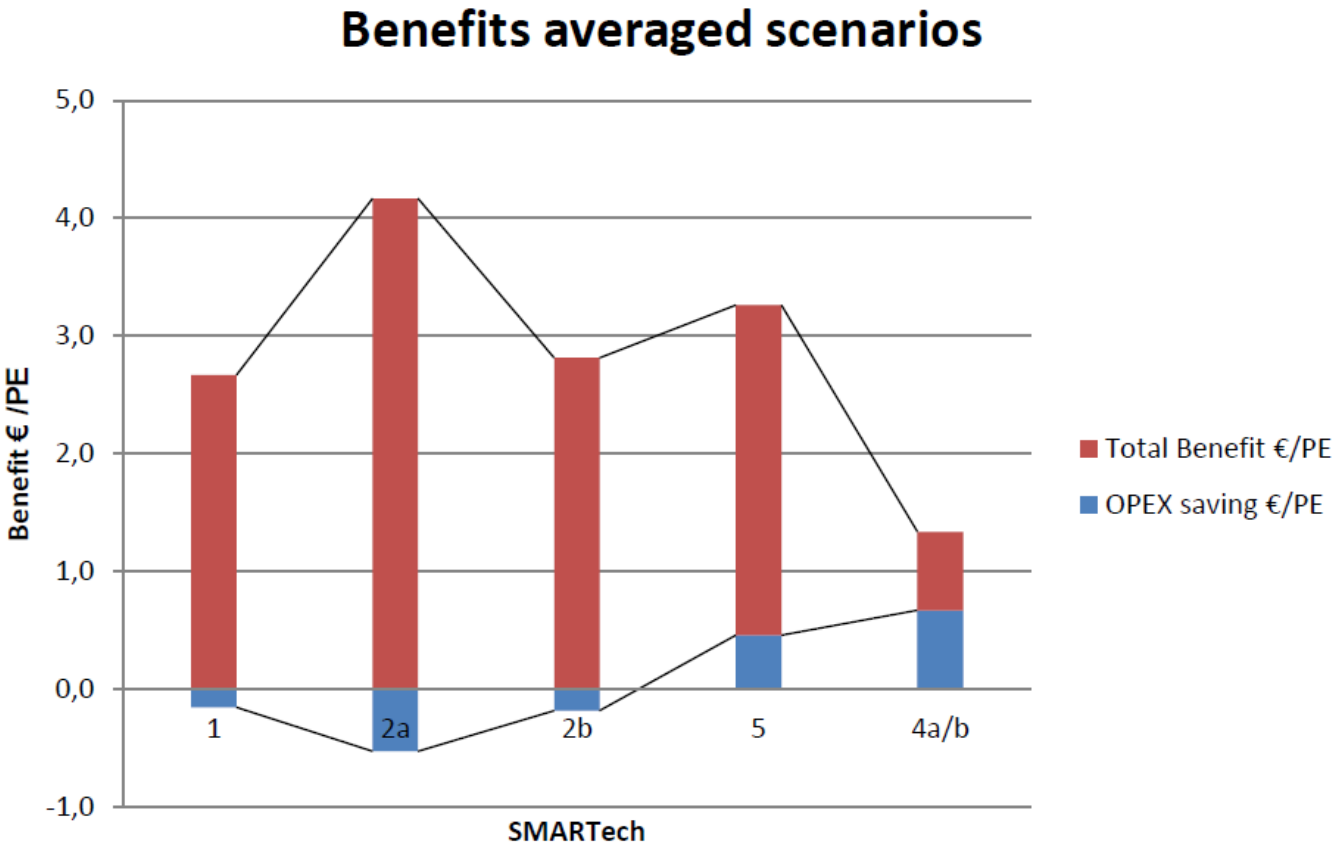
Development of GHG prediction models and control algorithms

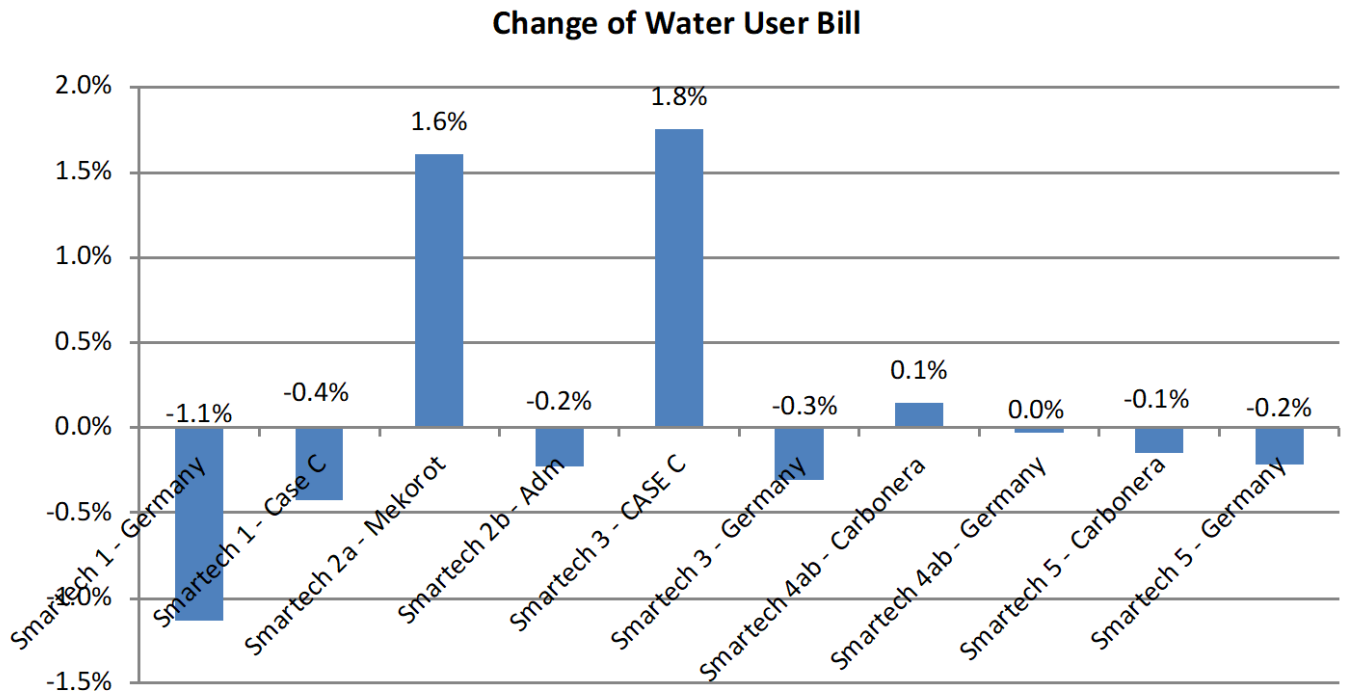


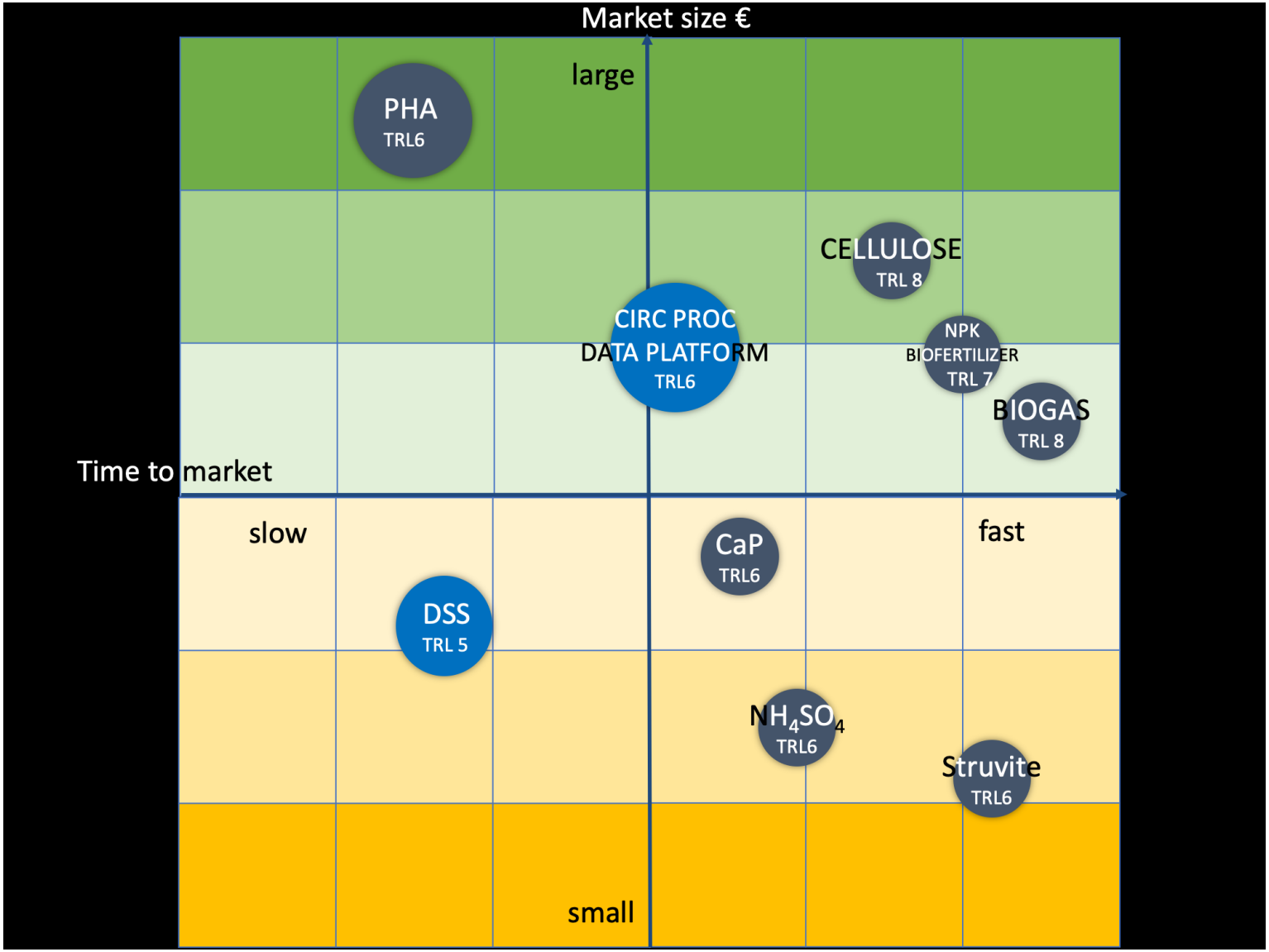
- Application of data-mining techniques in Waste-Water Treatment to understand the patterns and minimize carbon footprint
- Detection of abnormal events, pattern recognition, classification and regression techniques to model and predict carbon footprint of treatment processes
- Knowledge-based direct GHGs sampling that can minimize GHG sampling requirements without compromising the reliability of emissions estimates.
- Support WWTP operation and facilitate the integration of sustainability metrics in the decision making.

Breakdown of benefits for the SMARTechs averaged scenarios



Benefit for end users: SMART-Plant success will have no negative impact on water bill for citizens




Market size €
large
small
Time to market
slow
fast
PHA
TRL6
CELLULOSE
TRL 8
CIRC PROC
DATA PLATFORM
TRL6
NPK
BIOFERTILIZER
TRL 7
BIOGAS
TRL 8
CaP
TRL6
DSS
TRL 5
NH_4SO_4
TRL6
Struvite
TRL6

REPLICATION AND FULL SCALE-UP OF THE SMARTechs

Stage 1: integration into existing plants. **Stage 2**: inclusion in the design of new plants.

SMARTech 1	Pilot with Cap and Aqualia groups. Full scale plants in NL in 2021.
SMARTech 2a	Bennet Environmental Inc.: pilot 7/2020; full scale 5/2021.
SMARTech 2b	Current discussions with AdM for full scale-up.
SMARTech 3	Demonstration stage in various WWTPs.
SMARTech 4a/b	Possible full scale in Psytalia after 2021. Designed in 2 WWTPs and 1 sludge center.
SMARTech 5	Feasibility studies in 8 WWTPs.
SMARTech A	Feasibility analysis in progress. Draft stage in UK.
SMARTech B	Implemented in pig slurry valorization and in diary companies.
Dig. footprint & assess	Draft stage in UK funded programs.

Policy and barriers

- European policies, regulations and directives
  - Circular Economy Package
  - Proposed new Common Agricultural Policies (CAP)
  - New Fertilising Products Regulation (FPR)
- **Remaining barriers**
  - **No (apparent) willingness of customers to accept a premium for sustainability**
  - **Possible customer reluctance if sewage-originated raw materials are declared**
  - **Public procurement focusing on low cost instead of closed loops**
  - **Except for Fertilising Products Regulation, harmonized European regulatory framework missing**

Source: IWA Resource Recovery Conference and SMART-Plant final event – Venice (Italy) 2019

More direct Support Needed

- **Governance of Water-Energy-Food-Carbon nexus** by quantified evidence and metrics
- Targeted Circular Economy Directives with **clear targets** comparable to energy directives (REDII)
- Simplification and harmonization of End-of-Waste
- More **harmonisation of regulation** in the EU
    - Free trade of secondary resources for recycling with tracing and tracking system and obligatory, proven recycling
- **Cross-sector collaboration and industrial symbiosis** encouraged by ad-hoc regulatory framework that supports **long-term binding agreements** with industry and stable **public-private partnerships**

Adapted from IWA Resource Recovery Conference and SMART-Plant final event – Venice (Italy) 2019

Still a long way to go after H2020 projects? Example of support from EU-H2020 to MS … to the EU policy…

D.Lgs. xxx

Disciplina della gestione dei fanghi di depurazione delle acque reflue e attuazione della direttiva 86/278/CEE concernente la protezione dell'ambiente, in particolare del suolo, nell'utilizzazione dei fanghi di depurazione in agricoltura

e) promuove il recupero ed il riciclo di altre risorse di valore (biopolimeri, cellulosa, nutrienti) da fanghi e a tal fine entro 5 anni dall'entrata in vigore del presente decreto valuta l'opportunità di modificarlo al fine di inserirvi disposizioni specifiche per incentivare il succitato recupero sostenibile ed il riciclo in sicurezza di altre risorse di valore

METODO TARIFFARIO IDRICO PER IL TERZO PERIODO REGOLATORIO (MTI-3)
Inquadramento generale e linee d'intervento

5 Promozione di misure per la sostenibilità energetica e ambientale del servizio idrico integrato 36

5.4 Alla luce di tali premesse, l'Autorità è orientata a valorizzare misure innovative che possano comportare benefici in termini di contenimento dei costi complessivi, coniugando obiettivi di tutela ambientale e di recupero efficiente di risorse pregiate ed energia (ad esempio quelli finalizzati al recupero di materia - nutrienti, quali Azoto e Fosforo, cellulosa, biopolimeri, ammendanti organici - ed energia dai fanghi di depurazione).

In ITALY

Legislation: sludge management decree – draft – promotion of sustainable materials recovery

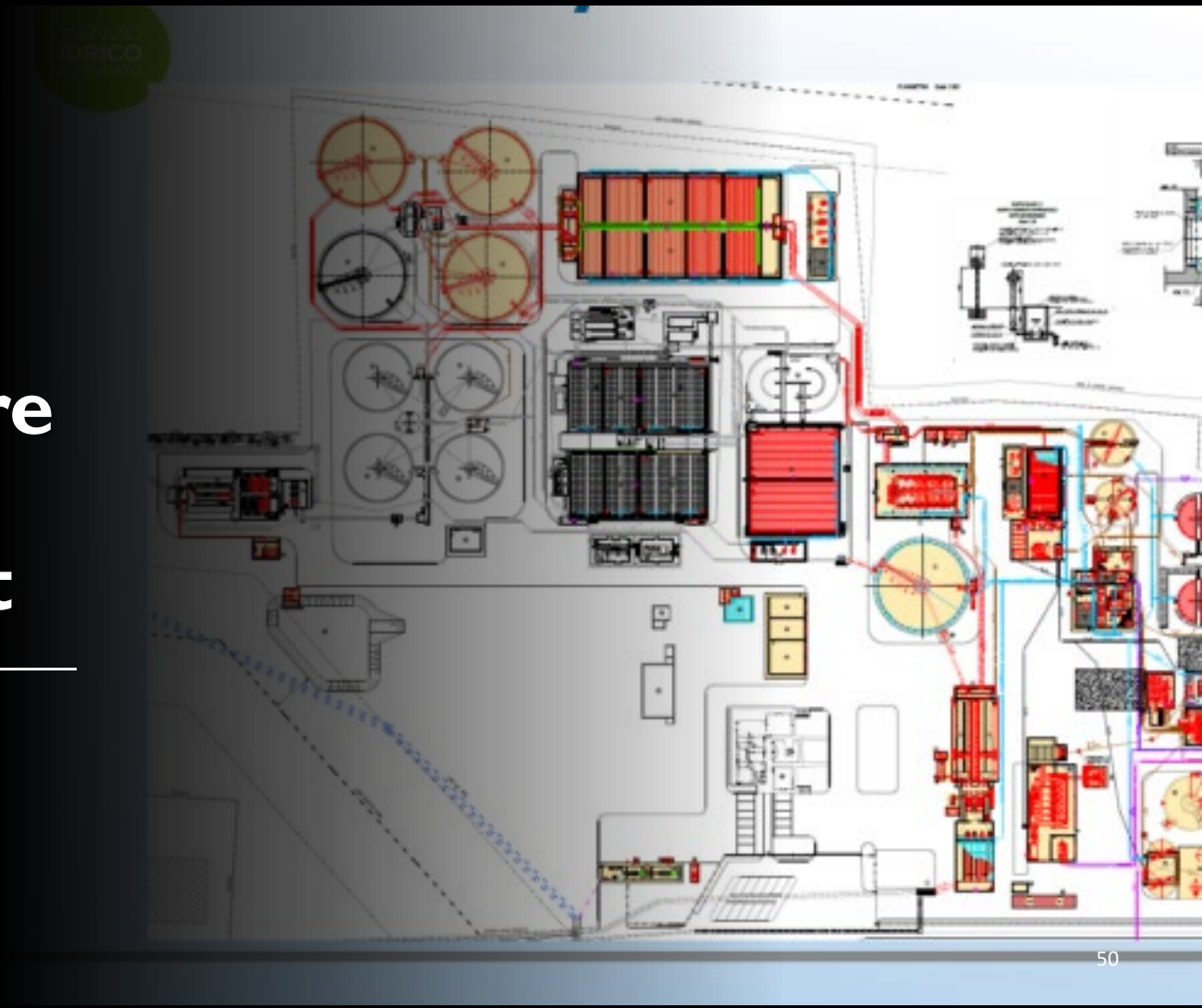
Documento per la consultazione

1 ottobre 2019

Regulation: proposed incentive for water tariff when resource are recovered, wherever sustainable

SMART-Plant HYDROUSA FIT4REUSE Digital Water .City ULTIMATE UNIVERSITÀ POLITECNICA DELLE MARCHE WWE LAB Water and Waste Enviromental Engineering

Castelfranco Sludge Centre – Inspired by SMART-Plant

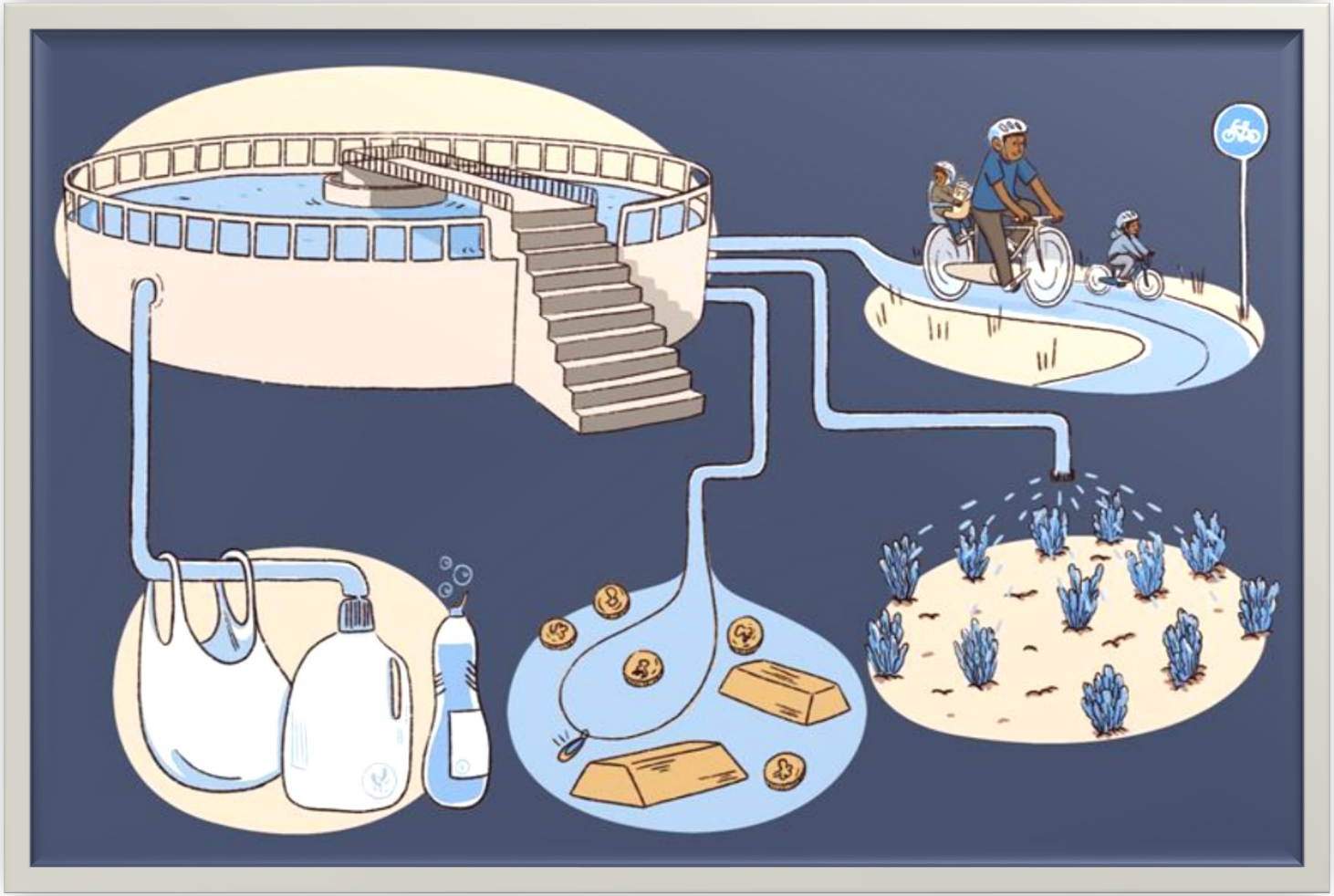


CHEMISTRY WORLD

The water industry has an interest in the circular management of wastewater, but the market isn't ready

FRANCESCO FATONE, MARCHE POLYTECHNIC UNIVERSITY, ITALY

Thank you!



Francesco Fatone (f.fatone@univpm.it)

Water and Waste Environmental Engineering Lab

Università Politecnica delle Marche

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