SEAM engineering
l'acqua e l'ambiente

REVAMPING IMPIANTI DI DEPURAZIONE

Lomazzo (Como), 26/10/2018

Depurazione e bioeconomia circolare urbana in Europa: progettare oggi per realizzare domani (grazie ai risultati delle azioni di innovazione Horizon2020)

Francesco Fatone

UNIVERSITÀ POLITECNICA DELLE MARCHE

INNOVEN INNOVATION FOR THE ENVIRONMENT

ENERWATER

HYDROUSA

SMART-Plant

www.smart-plant.eu

Outline

- Tenders for revamping TODAY? Bits of innovation for TOMORROW
- Urban circular bioeconomy: from science to standard practice thanks to Horizon2020
- Decison Support Systems
- Revamping towards Energy recovery
- Revamping towards Energy- and carbon-efficient material recovery
- Revamping to Nature based solutions to close loops
- Are we ready to eco-innovate our infrastructures?

OGGI: esempio di sub-criterio di una gara pubblica di progettazione di revamping e spunti per l'innovazione

… rispetto del miglior rapporto fra i benefici ed i costi globali di costruzione, manutenzione e gestione, relativamente a:

- **soluzioni tecnico-costruttive innovative**;
- sezioni e manufatti di controllo della rete fognaria;
- scelta dei materiali;
- affidabilità delle apparecchiature e loro manutenibilità;
- **miglioramento gestionale dell'impianto di depurazione;** ***RQT ARERA?***
- **minimizzazione delle emissioni di CO_2 e contenimento dei consumi energetici.**

FP: Funding programmes

FP7 → HORIZON 2020 → HORIZON EUROPE

WP: Work programmes

WP 2014 - 2015 → WP 2016 - 2017 → WP 2018 - 2020

WP 2014 - 2015	WP 2016- 2017	WP 2018- 2020
Call on Waste with 7 topics Call on Water with 5 topics -> Water 1: bridging the Gap: from innovative water solutions to market replication => SMART-Plant	Call on Circular Economy with 4 topics Call on Water with 3 topics	**Circular Economy is a focus area**. 8 topics under SC5 Call on Water with 3 topics

>60 water and Circular Ec. projects

Executive Agency for SMEs


If you can not measure it, you can not improve it.*
-
Lord Kelvin
*kind of, sort of

ENERWATER

44 months (March 2015 – October 2018)

1.7 MM €

Universidade de Santiago de Compostela (ES)

Università degli Studi di Verona (IT)

Università Politecnica delle Marche, Ancona

University of Cranfield (UK)

Technical University of Cologne (DE)

Espina y Delfín (ES)

ETRA (IT)

Aggerverband (DE)

AENOR (ES)

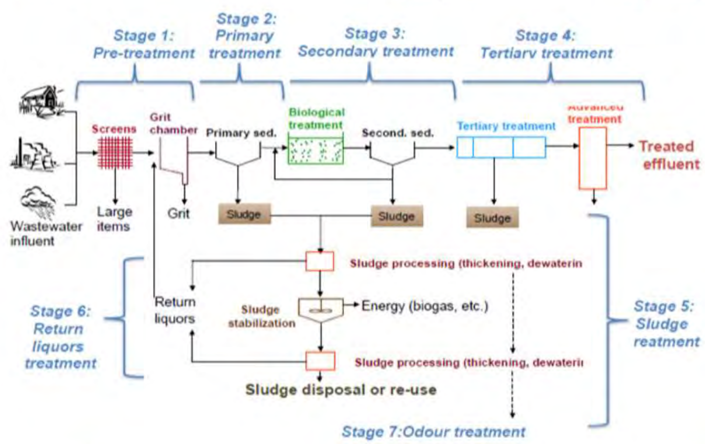
Wellness Smart Cities (ES)

ENERWATER methodology: Overview

50 WWTPs in Italy, Germany and Spain

Check the energy consumption and determine the KPIs

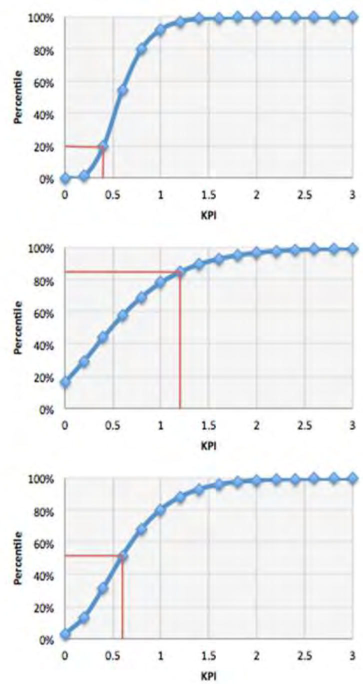
$KPI_1 = \frac{kWh}{m^3 \text{ of water treated}}$ $KPI_2 = \frac{kWh}{\text{kg solids removed}}$ $KPI_3 = \frac{kWh}{\text{kg pollutant removed}}$ $KPI_4 = \frac{kWh}{(m^{3} \cdot \text{log reduction of pathogens})}$



$KPI_6 = \frac{kWh}{\text{kg nitrogen removed}}$ $KPI_7 = \frac{kWh}{\text{kg volatile organic compound}}$ $KPI_5 = \frac{kWh}{\text{kg sludge treated}}$

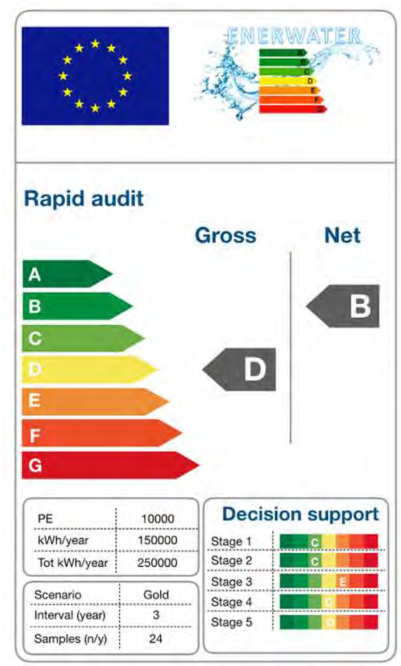
WWTP divided into functions -> a KPI is associated to each function performance

Compare vs other WWTPs



Assign a percentile to each KPI with a 600 WWTPs database

Get the energy label



Diagnosis of inefficient processes. Communication through the energy label

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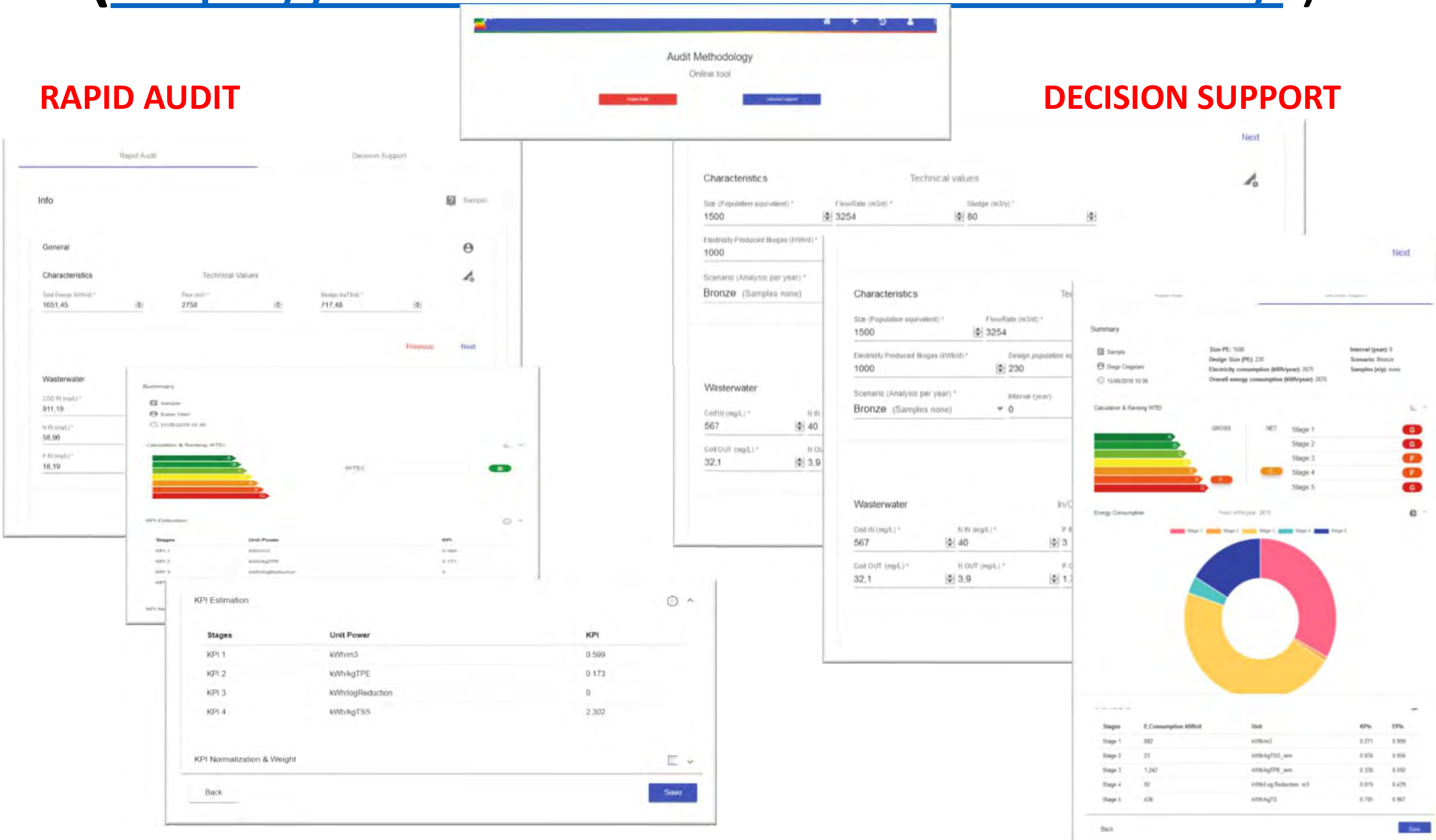
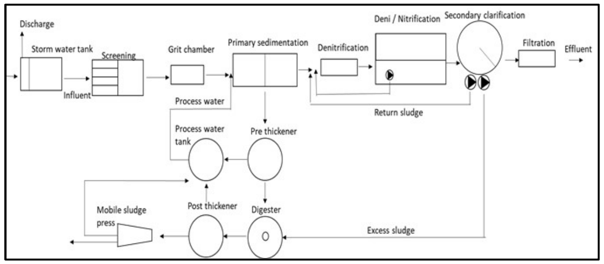
Validation of the on-line tool (https://enerwater-h2020.wtelecom.es/)

RAPID AUDIT

DECISION SUPPORT



ENERWATER decision support:
example process and equipment optimization



1

1- Current conditions are audited

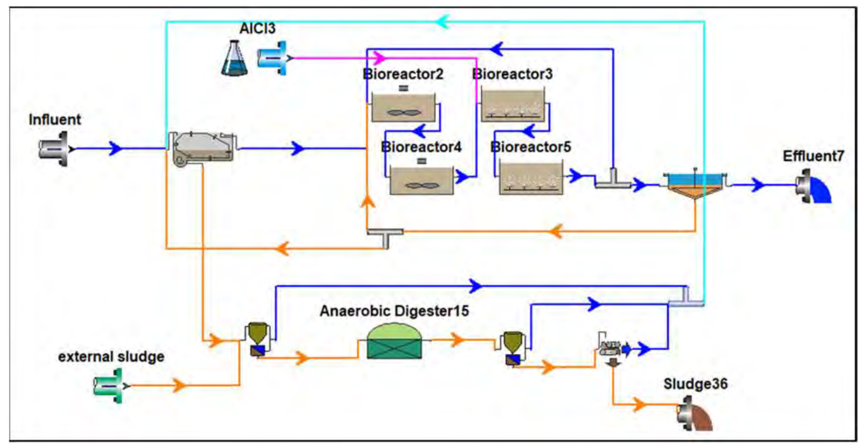
2

2- Equipment changes/revamping are identified and prioritized

Energy consumption Treatment stage 3 (kWh/d)	Total	Agitators	Recycling pump	Blower 1	Blower 2	Blower 3	Ground water pump	Secondary clarifica groundw pump
Before revamping	775	224	95	123	95	62	6	
After revamping	**460**	**46**	**47**		**191**		6	

2

2- Process changes are identified and prioritized



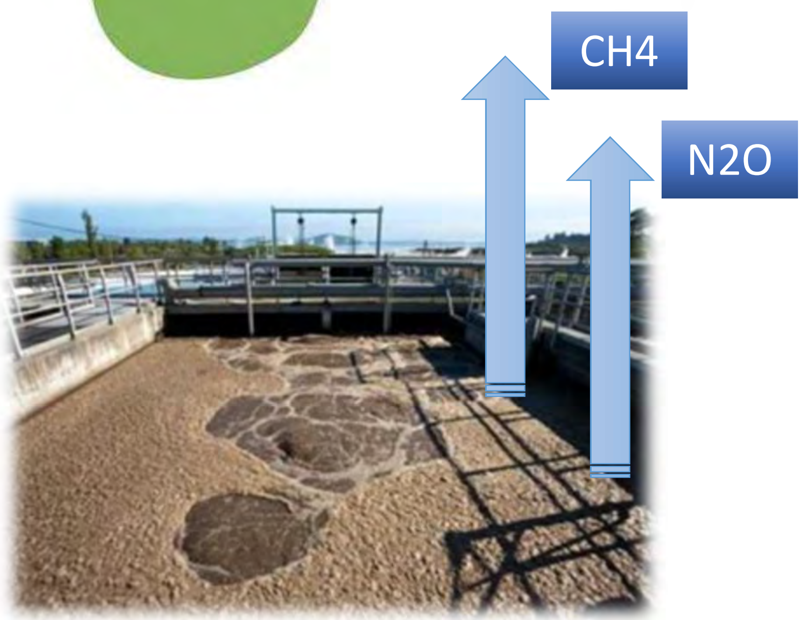
3

3- Energy efficiency improvement are verified

4

4- Impacts are verified and optimal parameters are applied

Rapid audit		**Pre-revamping**	**Post-revamping**
KPI1	kWh/m3	0.731	0.527
KPI2	kWh/TPE	0.523	0.392
KPI3	kWh/LogRed*m3		
KPI4	kWh/kgTSproc	3.371	1.944
	WTEI	0.721	0.481
	Label	***F***	***E***
Decision Support			
KPI1	kWh/m3	0.176	0.176
KPI2	kWh/TSrem		
KPI3	kWh/TPE	0.342	0.202
KPI4	kWh/LogRed*m3		
KPI5	kWh/TSE	0.066	0.058
Label Stage 1		G	G
Label Stage 2			
Label Stage 3		***F***	***D***
Label Stage 4			
Label Stage 5		A	A
	WTEI global	0.471	0.344
	Label global	***E***	***D***



Delibera ***ARERA 917/2017/R/idr*** *in relazione alla Regolazione della Qualità Tecnica del Servizio Idrico Integrato* (RQTI)

(Entrata in vigore il 1 gennaio 2018)

«Ad integrazione del macro-indicatore ***M5*** *(smaltimento fanghi in discarica) […] si considera l'indicatore* ***G5.3*** *denominato "Impronta di carbonio del servizio di depurazione", valutato in accordo alla norma UNI EN ISO 14064-1 e misurato in termini di tonnellate di CO2 equivalente".*

Scope 1:

Emissioni dirette correlate ai processi

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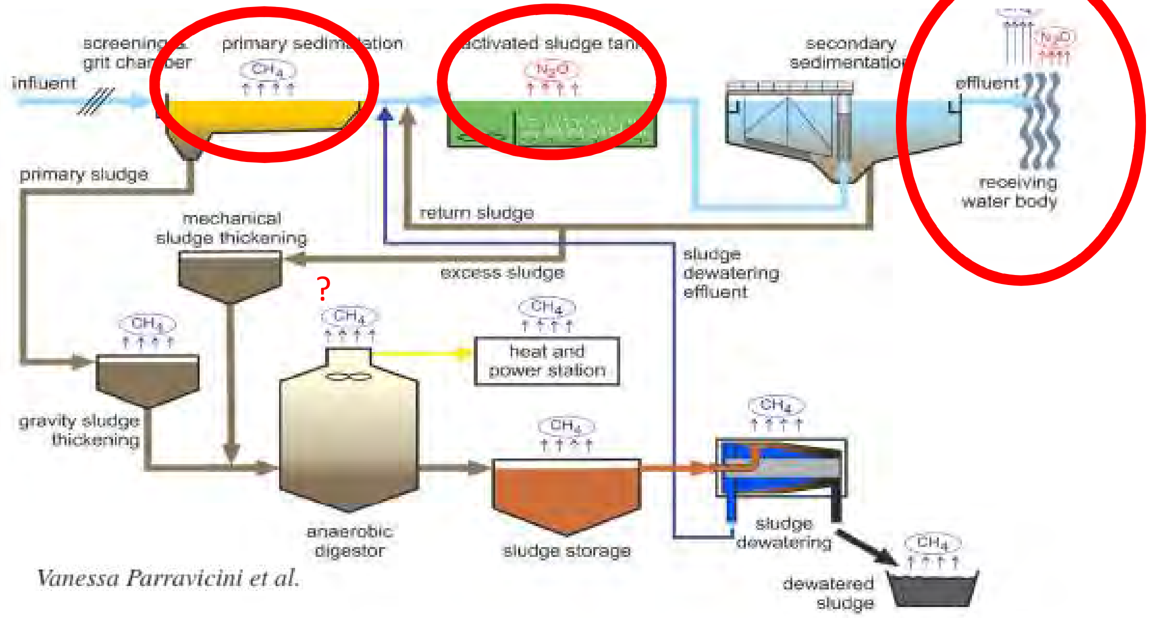
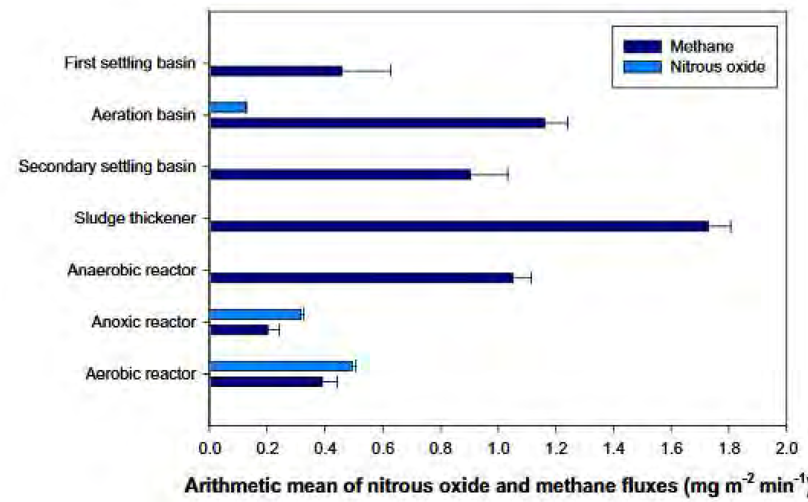
Punti di Produzione/Emissione



Vanessa Parravicini et al.



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How to minimize N2O in the secondary treatment ?

Table 2

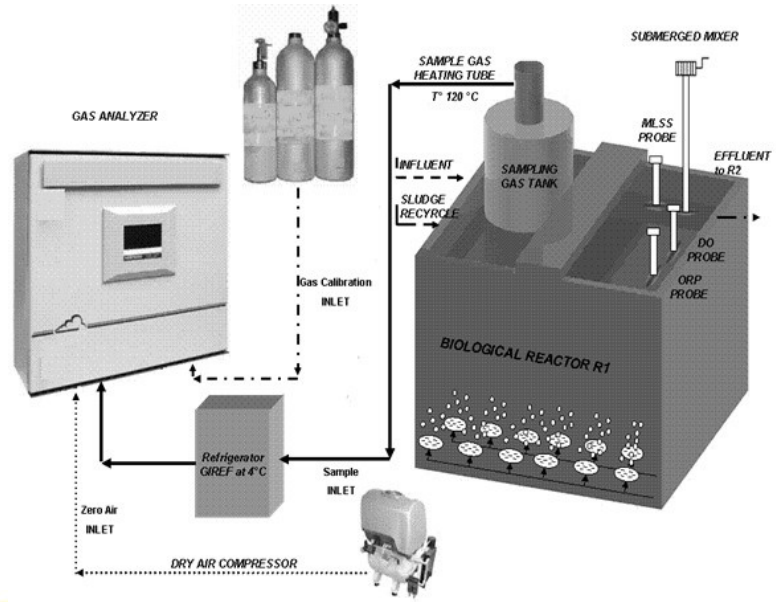
Overview of N_2O mitigation strategies

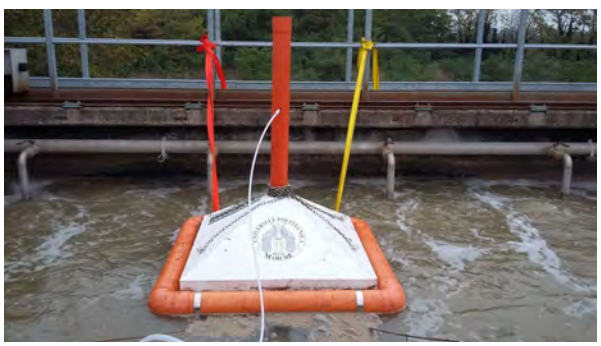
Objective	Approach	Outcome
Minimize aerobic N_2O production	Ensure stable substrate levels by gradual feeding regime, sufficient mixing and buffer volume capacity	Few NH_4^+ fluctuations
	Ensure sufficiently high DO (N/DN) or adapted aeration regime (1-stage PN/A)	Prevent NH_2OH and NO_2^- accumulation
	Ensure low free ammonia and low free nitrous acid	Prevent NO_2^- accumulation by NOB stimulation (N/DN)
	In case of high NO_2^-, ensure sufficiently high DO	Prevent NO_2^- accumulation
	Ensure constant DO (no repeated changes from anoxic to oxic), low NH_4^+, sufficiently high SRT, neutral pH, bio-augment with AOB (+NOB)	Prevent high sludge-specific activity and changes from low to high specific activity
	Bio-augment with AOB	Lower nitritation functionality dynamics
Minimize aerobic N_2O emissions	In case of active aeration: Lower aeration rate	Lower mass transfer coefficient (k_La)
	In case of passive aeration: Limit turbulence	Lower mass transfer coefficient (k_La)
	In case of bubble-less aeration: preferable in terms of N_2O emissions, for example, membrane aerated bioreactor (MABR)	Lower mass transfer coefficient (k_La)
Maximize anoxic N_2O consumption	Lower aerobic COD breakdown and COD-removing pre-settling (sewage), or provide external COD	Sufficiently high COD/N
	In case of external COD dosage: choose carbon source carefully (e.g. N_2O emissions ethanol > methanol)	Prevent incomplete denitrification
	Ensure efficient aeration in preceding stage (no overaeration) and provide sufficient anoxic HRT	No DO, stimulate complete denitrification
	Bio-augment with N_2O-consuming HDN *Pseudomonas stutzeri*	Increase N_2O reduction potential
	Ensure sufficient copper availability	Ensure N_2O reductase synthesis
End-of-pipe treatment	In case of capped BNR plants: biofilter, … (to be developed)	Lower N_2O release to environment

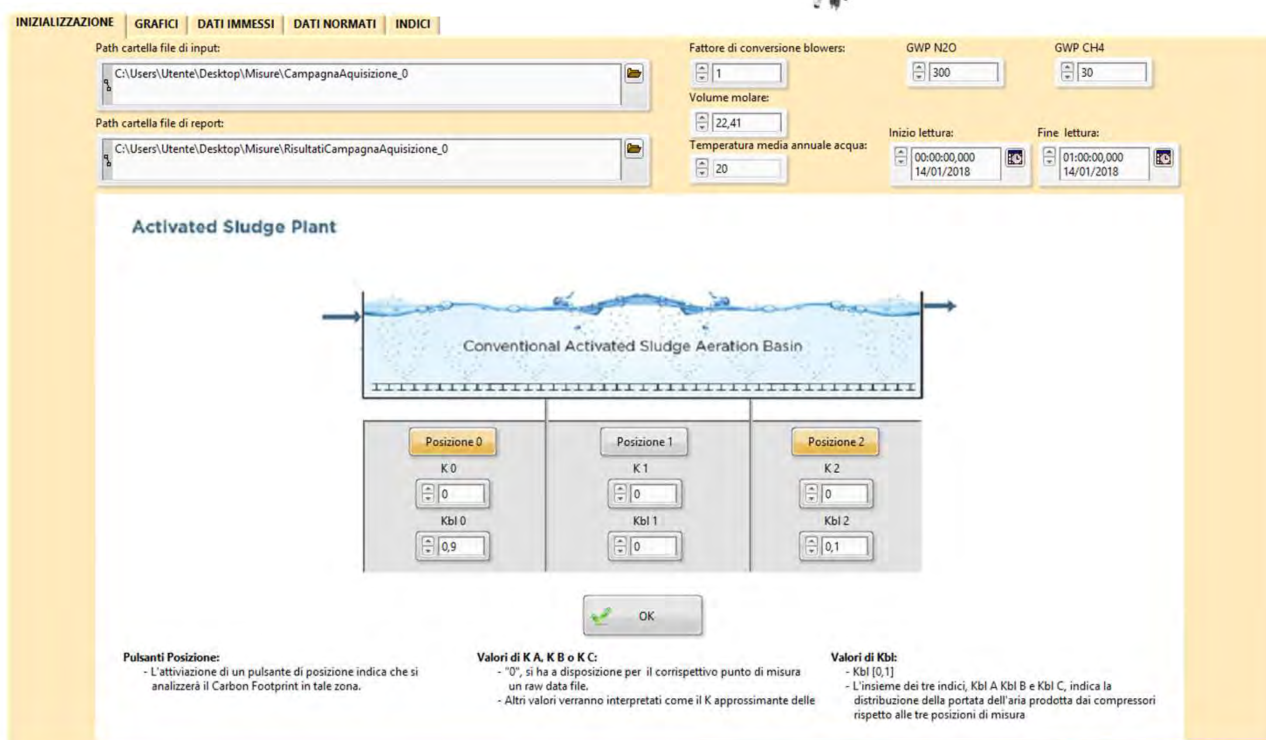
COD: chemical oxygen demand; DO: dissolved oxygen; HRT: hydraulic retention time; N/DN: nitrification/denitrification; PN/A: partial nitritation/anammox; SRT: sludge retention time; AOB: ammonia-oxidizing bacteria; NOB: nitrite-oxidizing bacteria; HDN: *heterotrophic denitrifying bacteria.*

Online/offline TOOL for GHGs emissions:

1. Global Warming Potential (GWP) conversion
2. Standardization with temperature
3. Comparison with Emission Factor (EF) calculation
4. Carbon footprint da emissioni dirette







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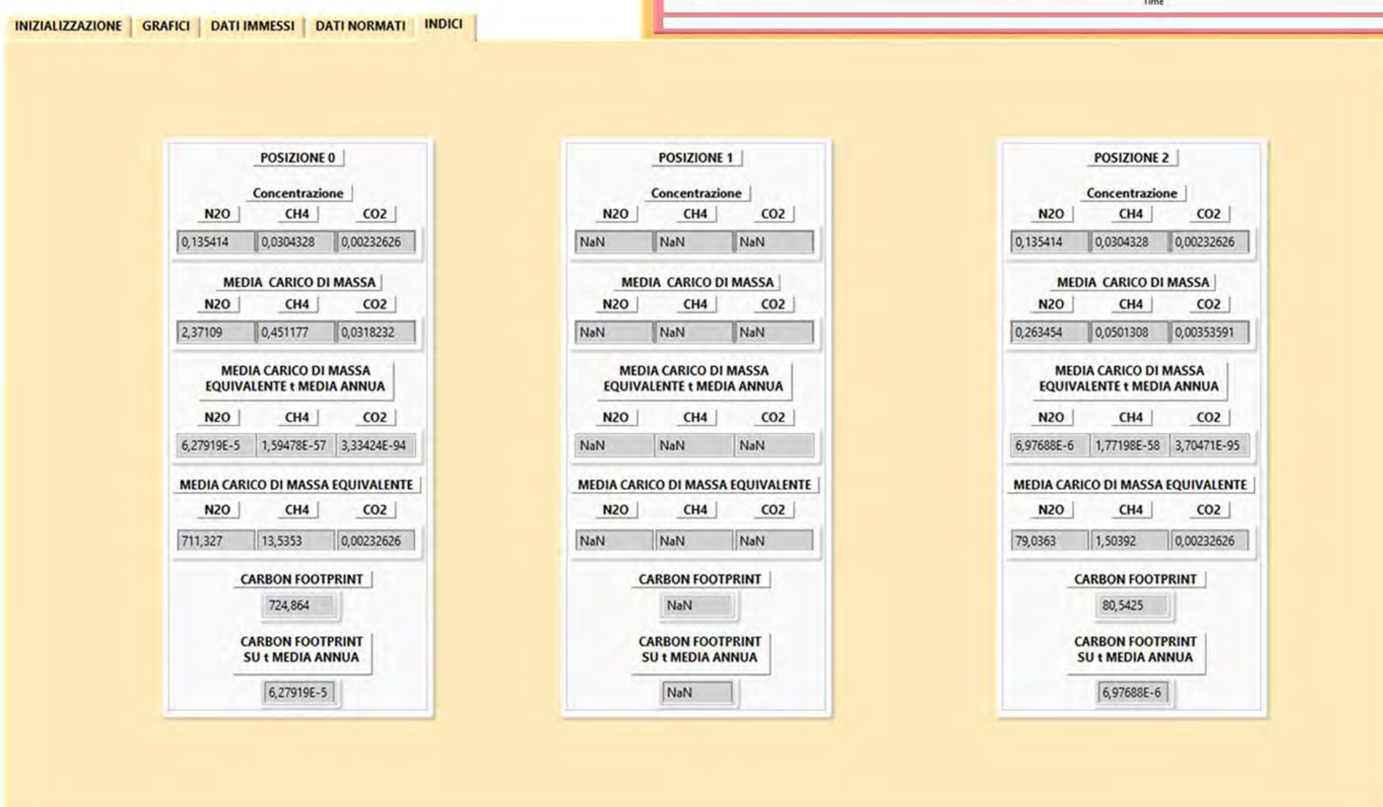
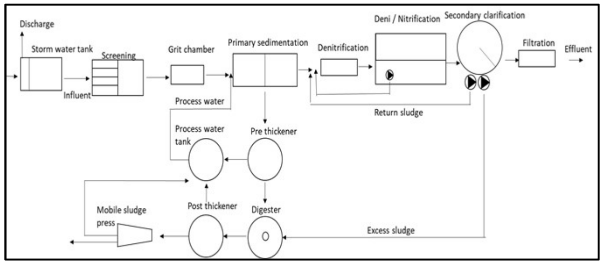
Results:

1. Graphical results
2. Greenhouse gases emissions
3. Equivalent CO2 emissions (x GWP)
4. Carbon footprint



ENERWATER decision support: example process and equipment optimization



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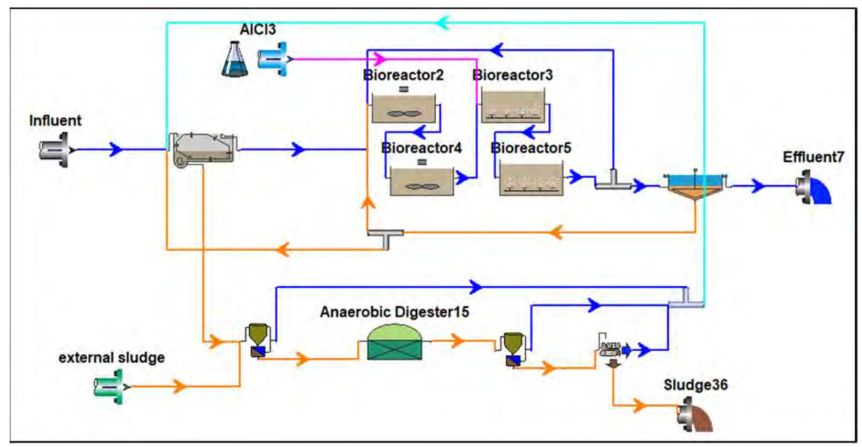

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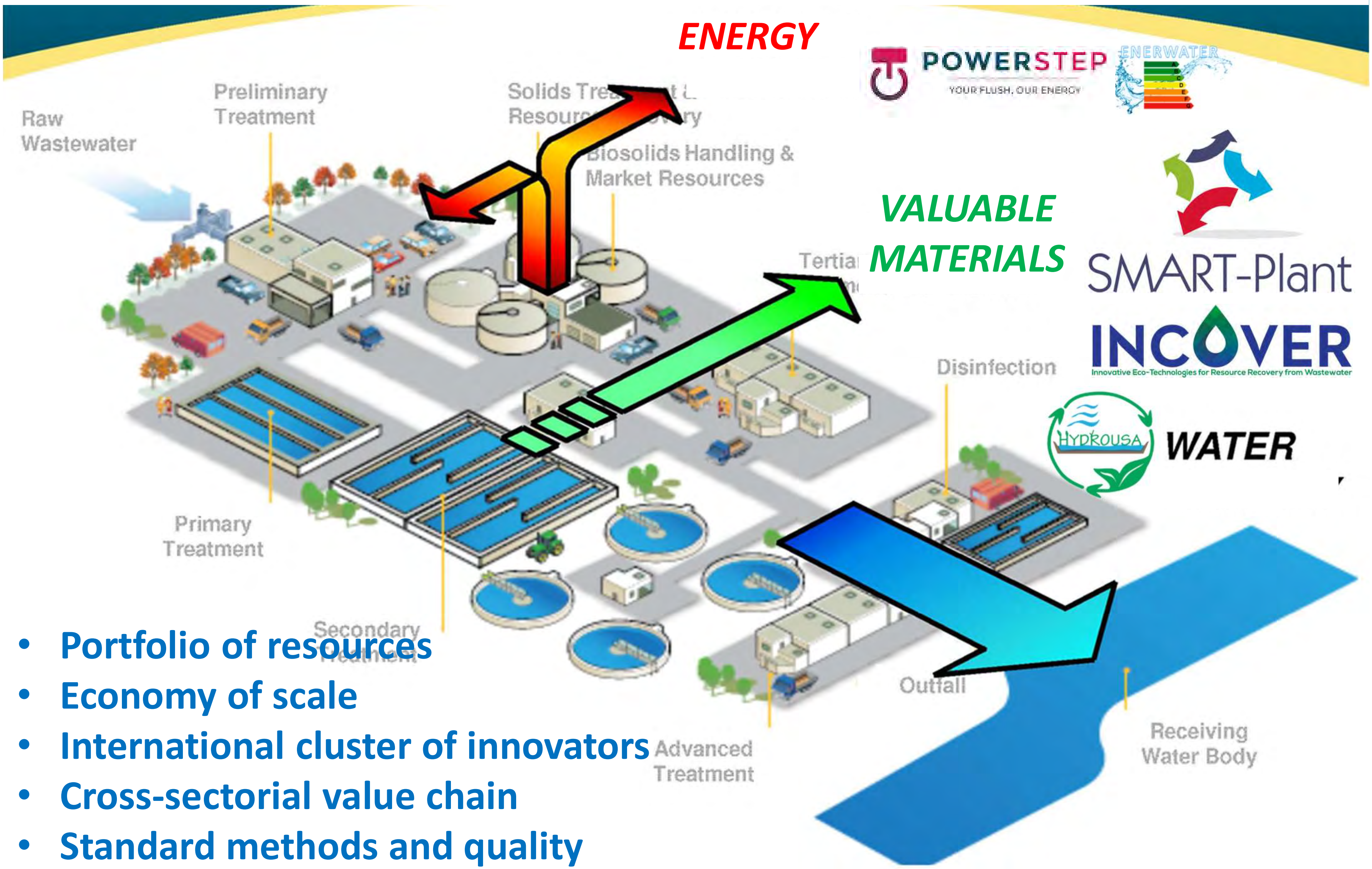
Once measures are known and data are validated: Water utility pathways in the circular economy

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

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

H2020 IN THE THREE MAIN PATHWAYS TO DELIVER CIRCULAR ECONOMY



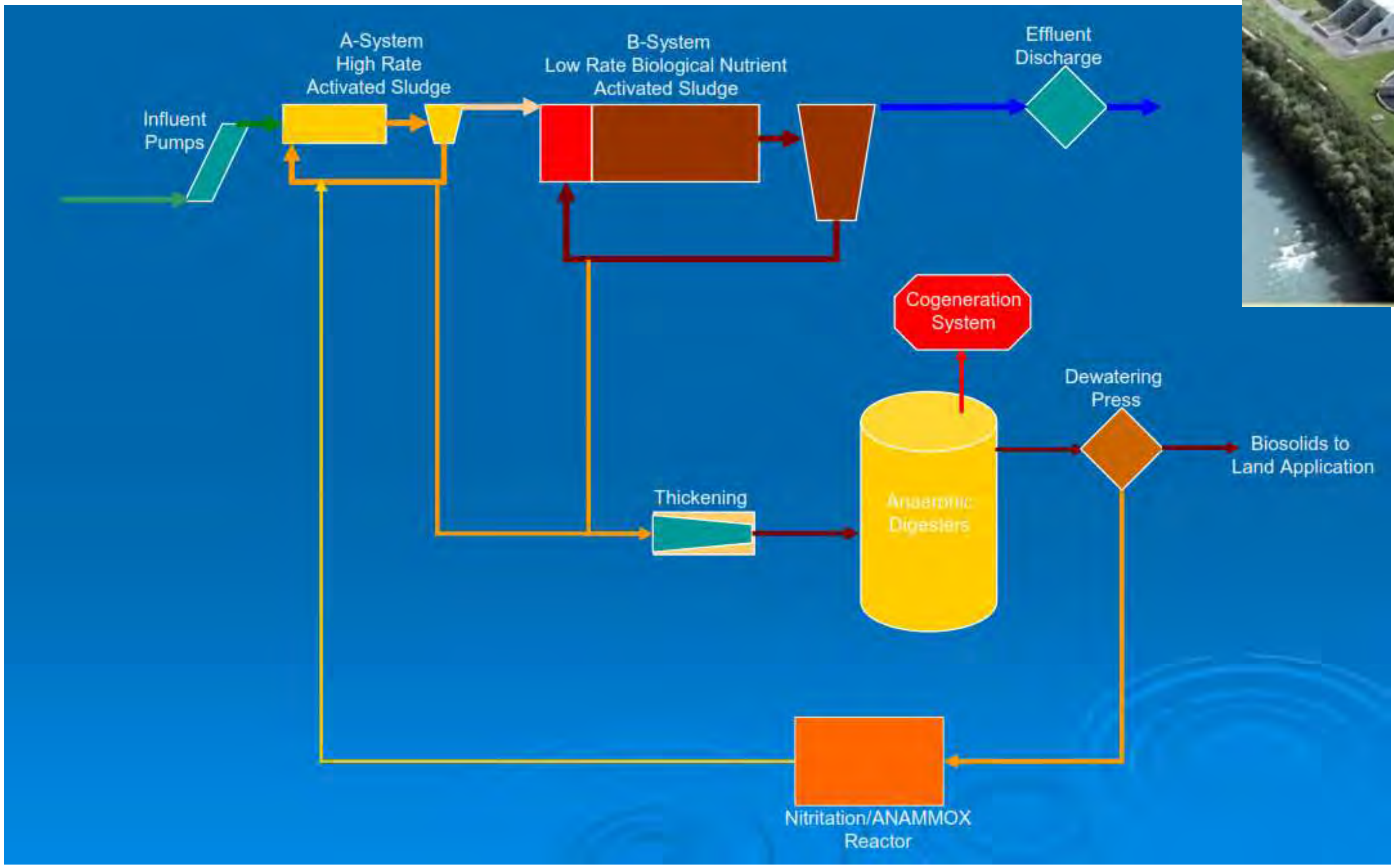
- Portfolio of resources
- Economy of scale
- International cluster of innovators
- Cross-sectorial value chain
- Standard methods and quality

The ENERGY PATHWAY
(to deliver circular economy)

Current TRL = 8-9

but
WATER-ENERGY-CARBON NEXUS!

Strass WRRF: energy positive since 2005



Source: Wett et al.

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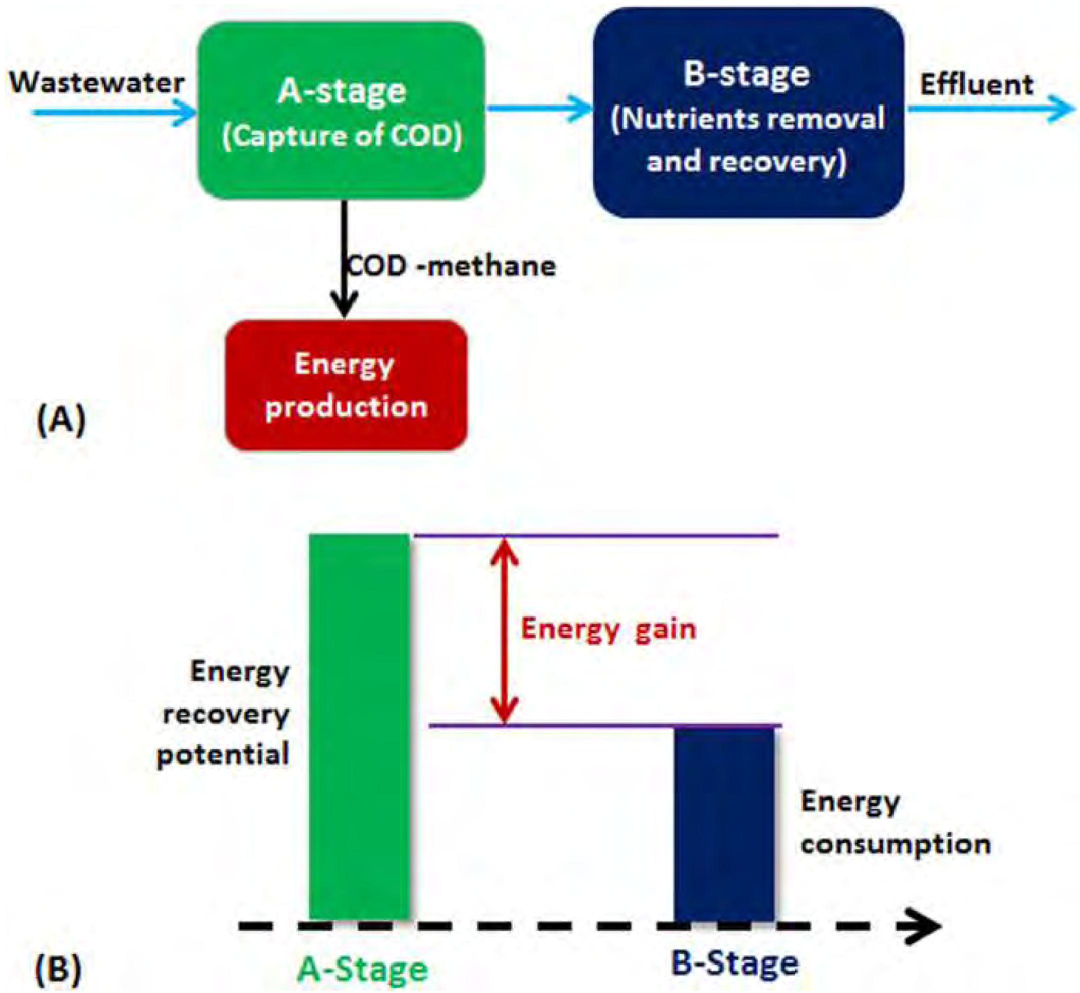
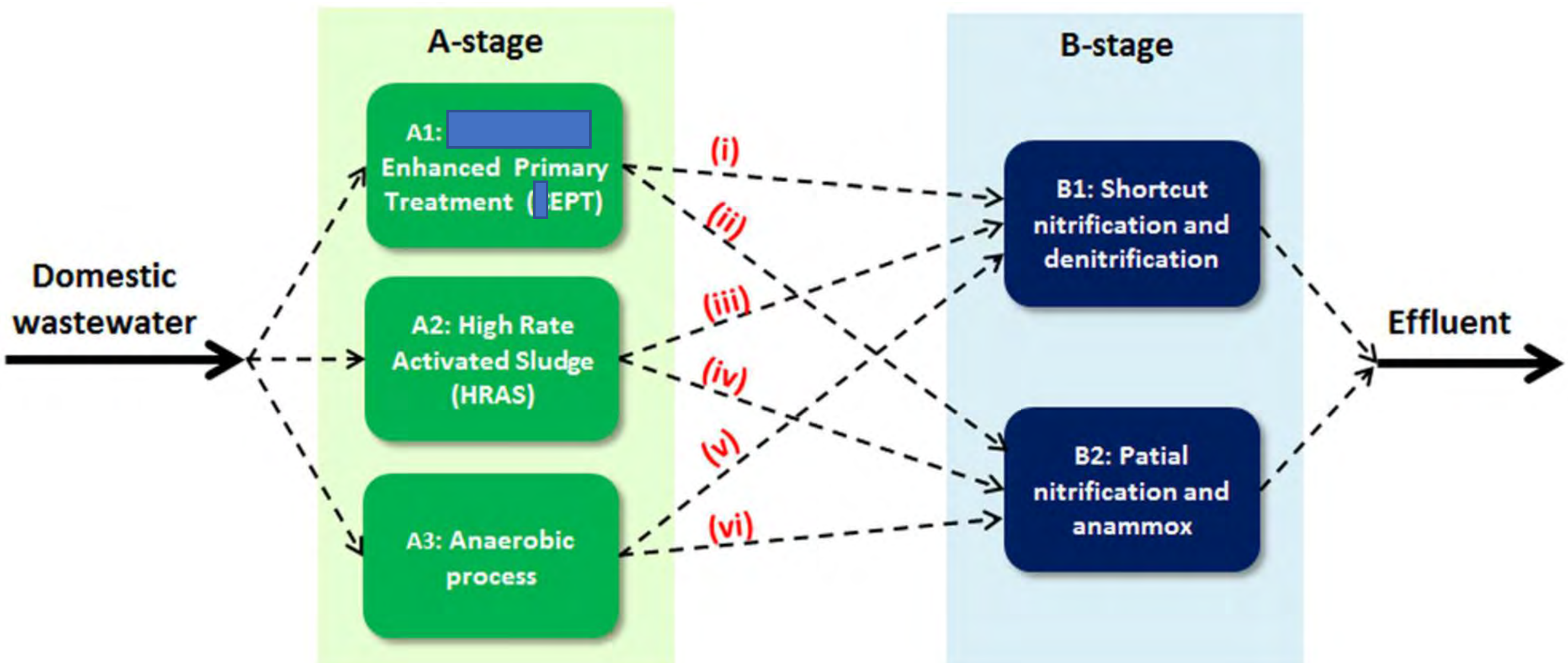
Energy positive in full scale: how?

- Upstream diversion of more carbon to anaerobic digestion
- Separate short-cut treatment of the reject water
- Energy-efficiency in the mainline (e.g. short-cut (via-nitrite) processes)

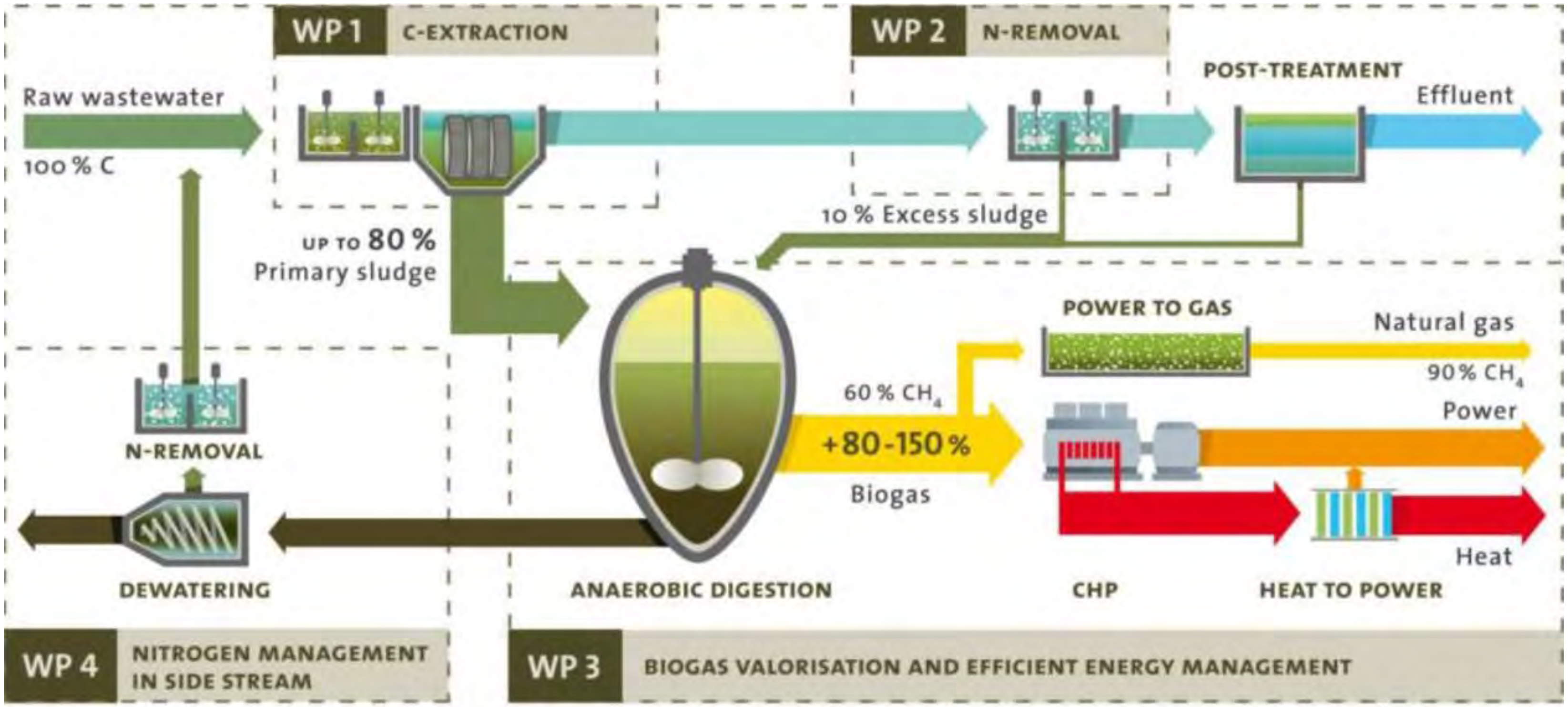
The A-B schemes



The A-B schemes



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 valorization and efficient energy management

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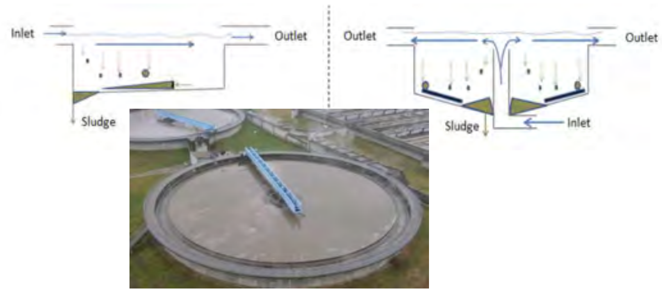
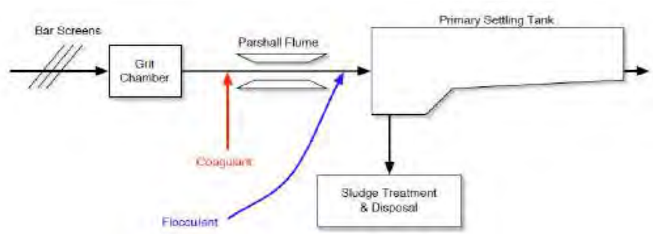
Benchmark and market analyses for enhanced primary separation

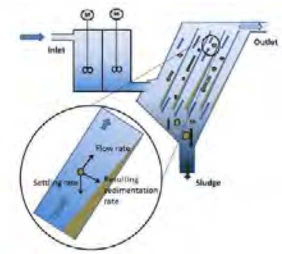
Primary Settling Tank - PST



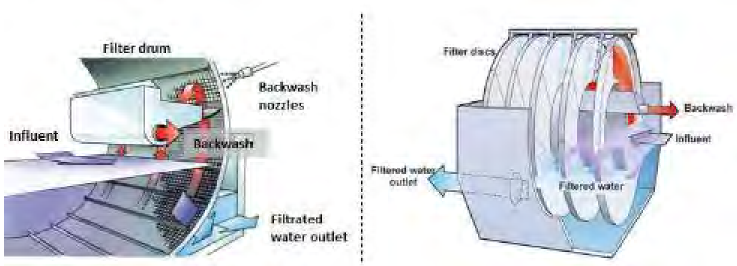
Chemically Enhanced Primary Treatment - CEPT



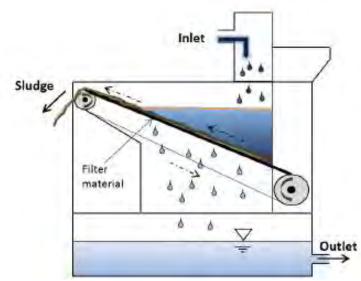
Lamella settler - LS



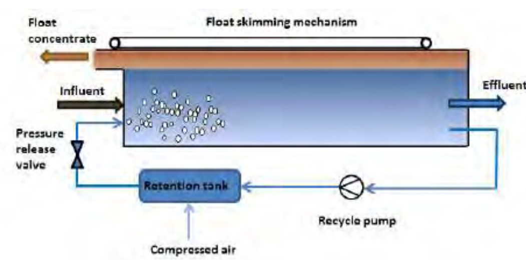
Drum & Disc Filters –D&DF



Rotary Belt Filter - RBT



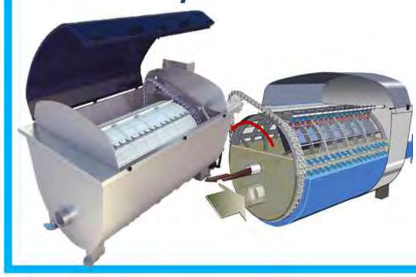
Dissolved Air Flotation - DAF



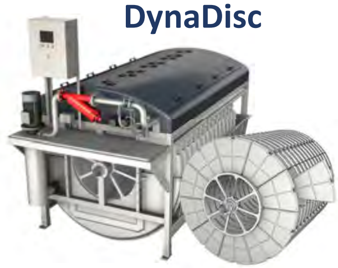
Many options for Enhanced Primary Separation

NORDIC WATER

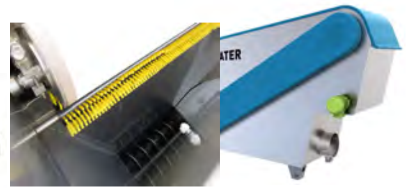
DynaDrum



DynaDisc



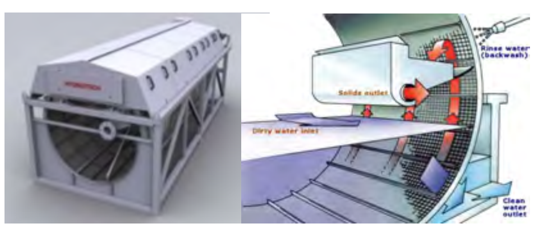
Soybe belt filter TD



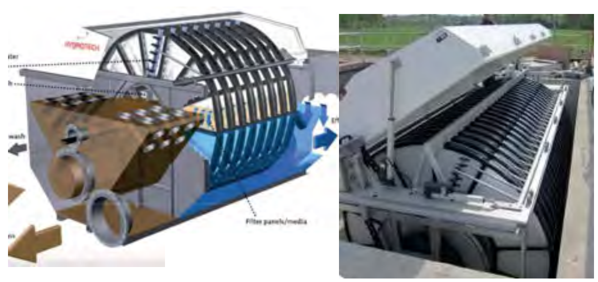
salsnes Filter

VEOLIA

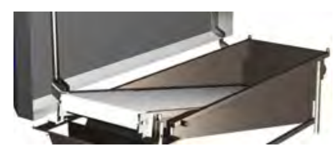
Hydrotech Drumfilter



Hydrotech Discfilter



Hydrotech Beltfilter



Dynamic separation implemented at Univpm and UniVr

Combined Sewer Overflows

		SF1000
Flow rate	m3/h	15 ÷ 50
Filtration	µm	90 ÷ 350
SS Removal	%	28 ÷ 58

Urban Wastewater

		SF1000
Flow rate	m3/h	30 ÷ 50
Filtration	µm	350
SS Removal	%	≈50

Urban Wastewater

		SF1000
Flow rate	m3/h	15 ÷ 50
Filtration	µm	90 ÷ 350
SS Removal	%	8 ÷ 70

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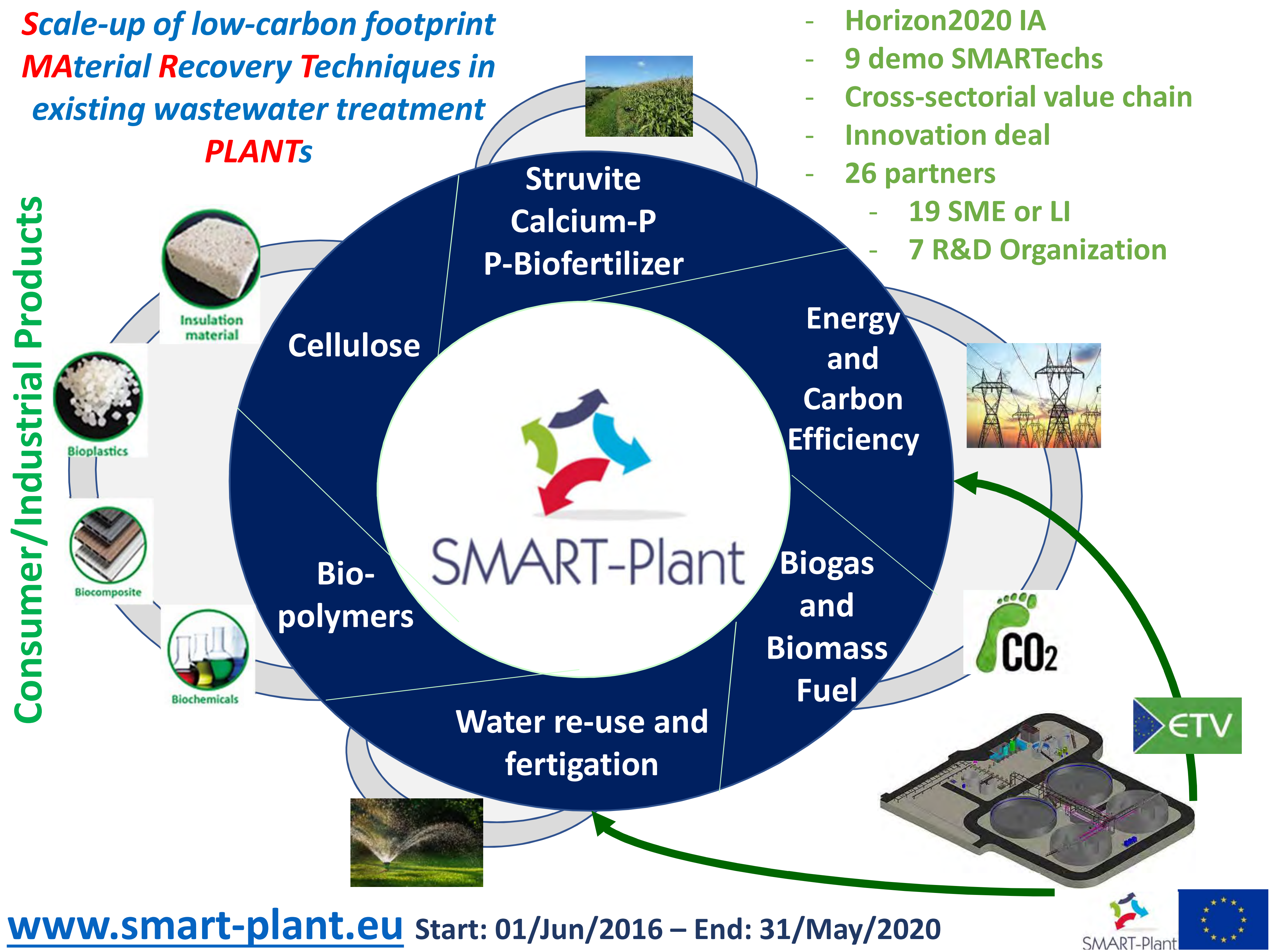
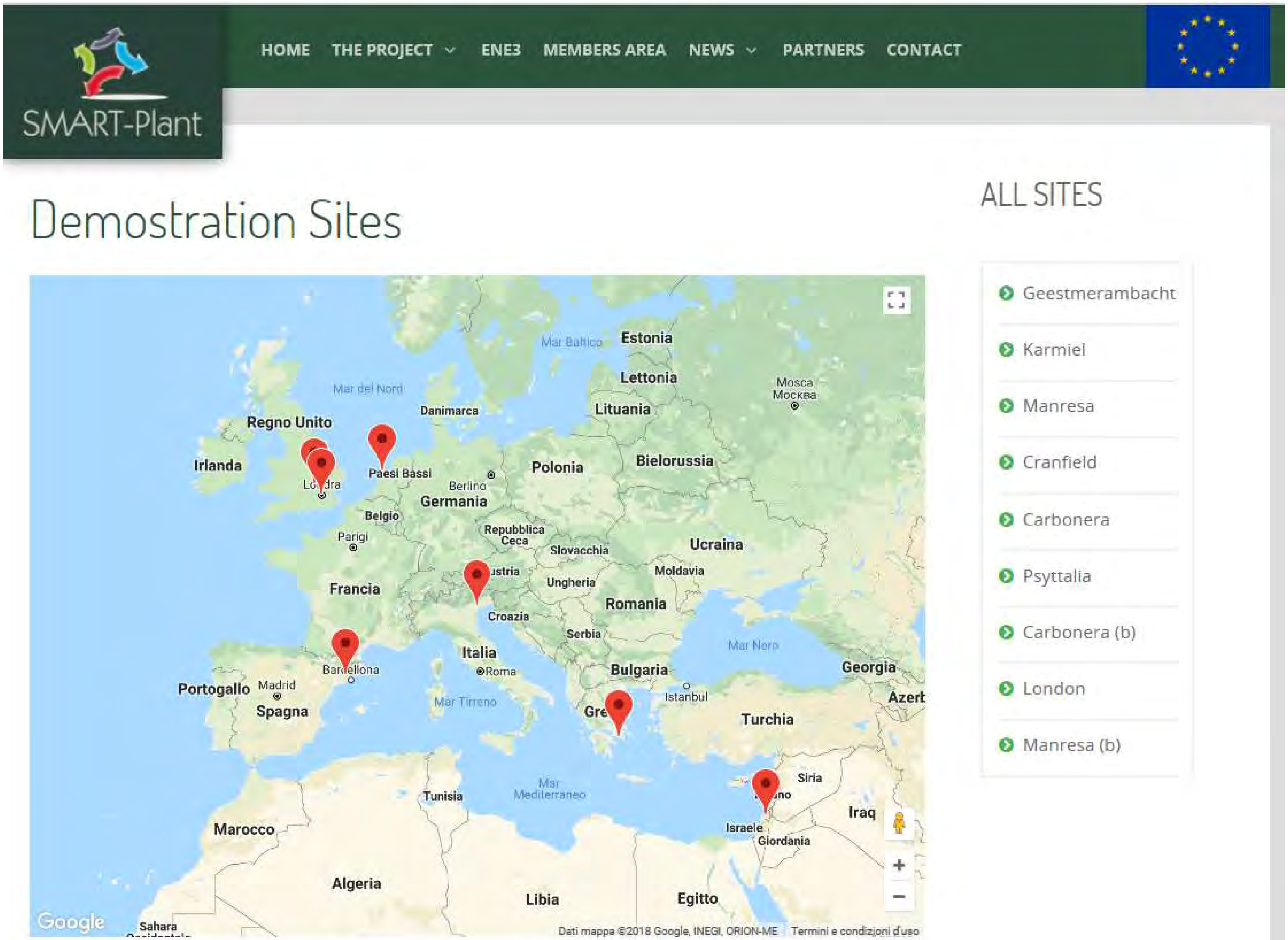
The (ENERGY- and CARBON-EFFICIENT) MATERIALS PATHWAY

Phosphorus = TRL 8-9
Other (Focus on cellulose, VFA and biopolymers) = TRL 4-7

but: social, market and regulatory barriers!


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
Insulation material
Bioplastics
Biocomposite
Biochemicals
Struvite
Calcium-P
P-Biofertilizer
Cellulose
Energy and Carbon Efficiency
Bio-polymers
SMART-Plant
Biogas and Biomass Fuel
Water re-use and fertigation
CO2
ETV
www.smart-plant.eu
Start: 01/Jun/2016 – End: 31/May/2020
SMART-Plant



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

SMARTechs integrated in existing WWTPs (transformed in WRRFs)

SMARTech1 - Geestmerambacht WWTP (NL)


SMARTech2a – Karmiel WWTP (IL)


SMARTech2b and Downstream SMARTech B - Manresa WWTP (Spain)


SMARTech3 – WWTP at Cranfield University (UK)

SMARTech 4a and SMARTech 5 Carbonera WWTP (Italy)


SMARTech 4b - Psyttalia WWTP (Greece)

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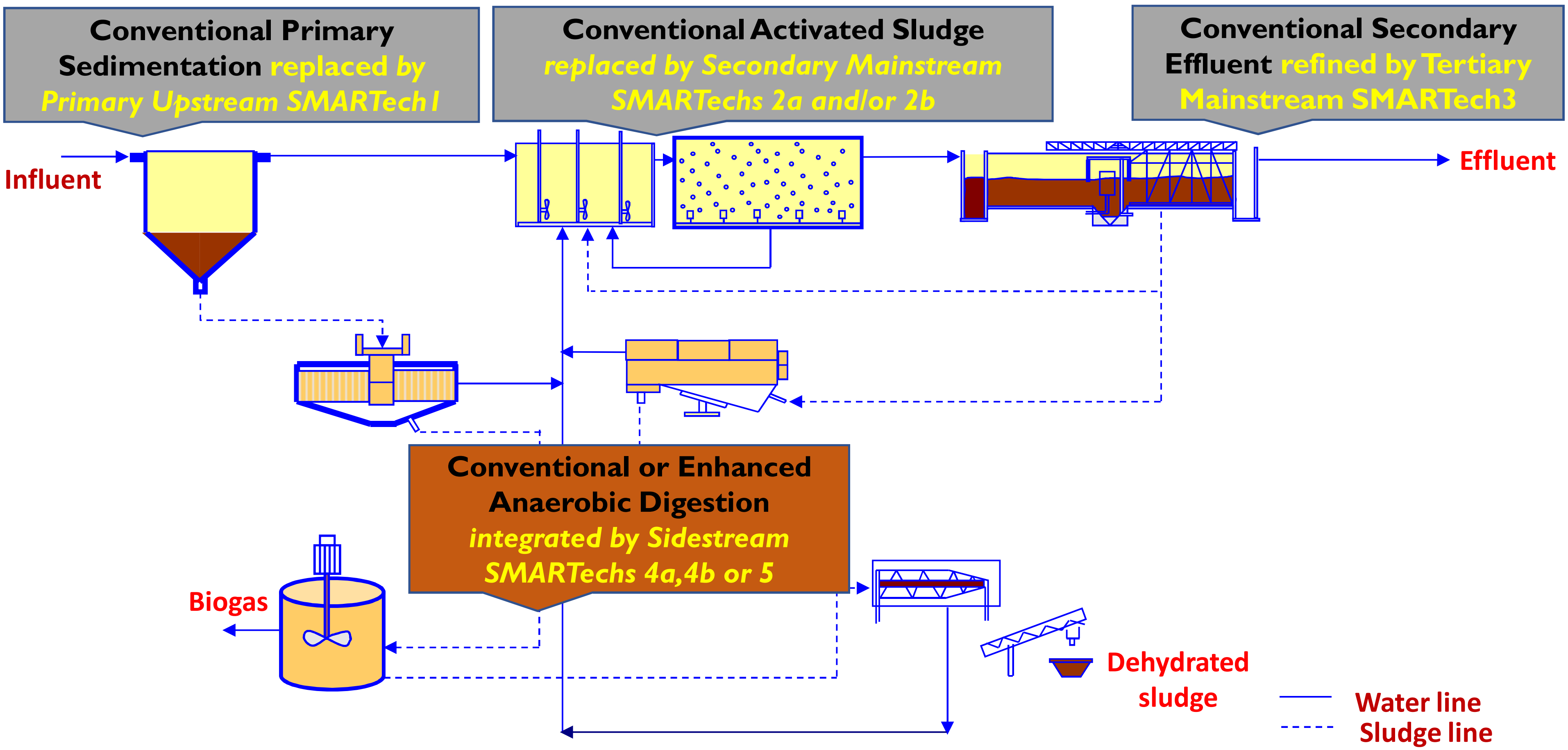
SMART-Plant approach and SMARTechs



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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**
	2a	Karmiel (Israel)	Mainstream polyurethane-based **anaerobic biofilter**	**Biogas, Energy-efficient water reuse**
	2b	Manresa (Spain)	Mainstream **SCEPPHAR**	**Struvite, PHA**
	3	Cranfield (UK)	Mainstream **tertiary hybrid ion exchange**	**Nutrients**
Sidestream	4a	Carbonera (Italy)	**Sidestream SCENA**	**P-rich sludge, VFA**
	4b	Psyttalia (Greece)	**Sidestream Thermal hydrolysis – SCENA**	**P-rich sludge**
	5	Carbonera (Italy)	**Sidestream SCEPPHAR**	**PHA, struvite, VFA**

Demos commissioned: June 2017 – Long-term validation: May 2019

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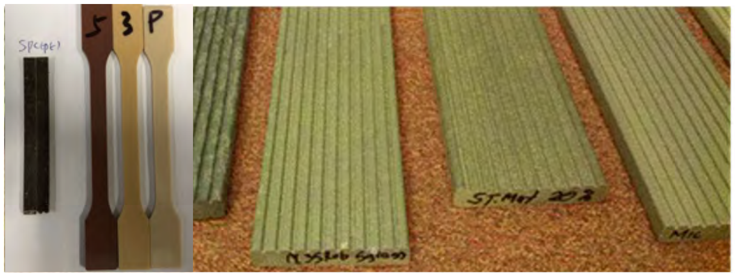
CURRENT ACHIEVEMENTS OF THE PROJECT:
Energy and Carbon-Efficient Valuable Materials Recovery in SMART-Plant demos

- 350-400 kgCellulose per week;
- 1,0-1,2 kgPHA per day;
- > 250-300 gStruvite per day;
- 2000-3000 Liters of biogas per day;
- 60% of P recovered as $CaPO_4$ from the tertiary treatment;
- 15-20 kg of P-rich sludge, 60-65 gP/kgTS
- > 10 kg BioFertilizers per day;
- **10-30% Energy Efficiency;**
- **10-50% Carbon Efficiency;**

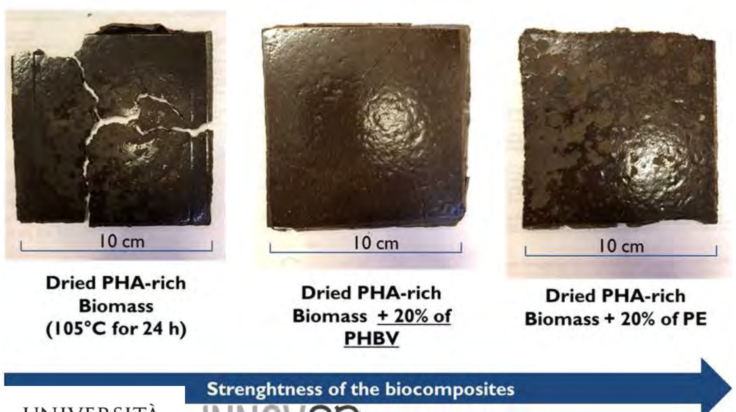
ONGOING STEPS OF THE PROJECT: closed value chain with validated technologies and marketable industrial/consumer products

Industrial production of lignocellulosic PHA biocomposites



Post-processing of recovered cellulose in mortars and concrete

Pilot-scale production of biocomposites from raw PHA-rich biomass



Production and testing of phosphorus bio-fertilizers and biomass fuels

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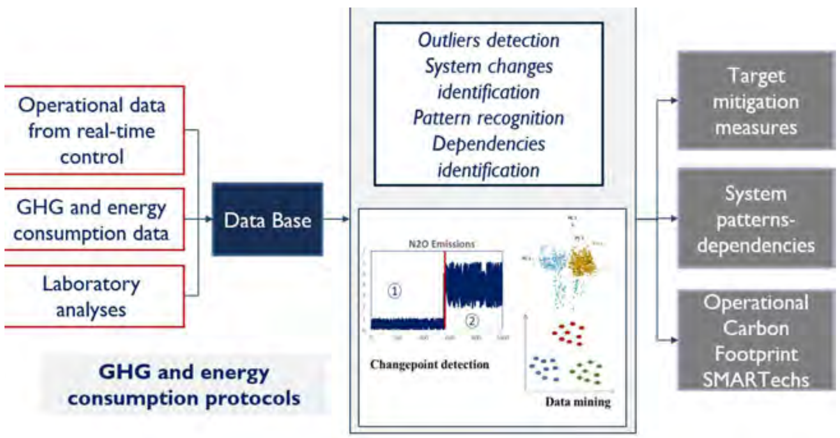
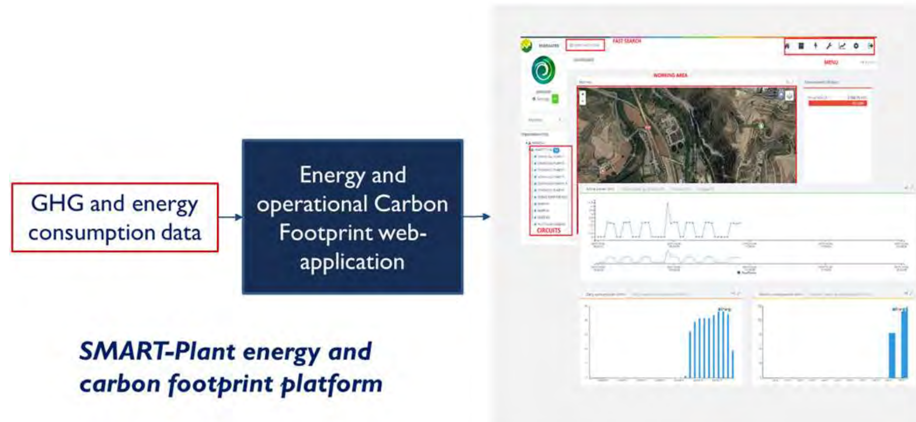
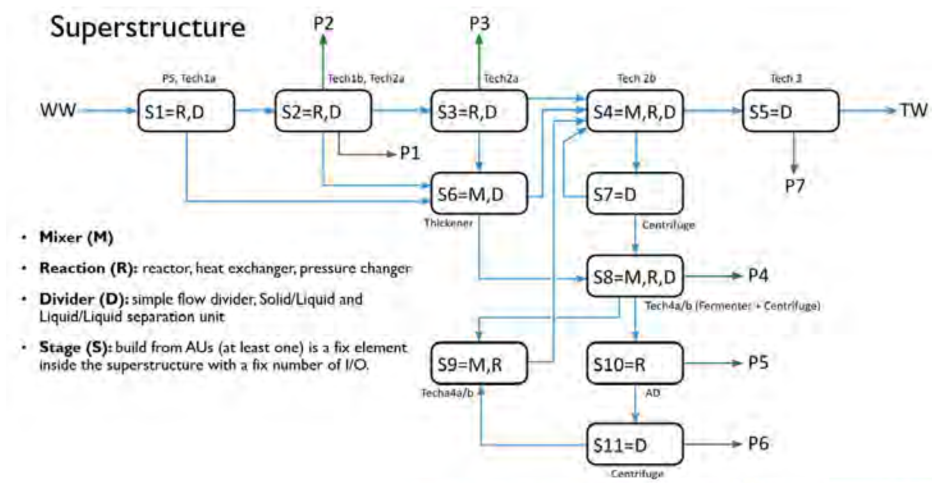
ONGOING STEPS OF THE PROJECT: REAL-TIME FOOTPRINTING and DSS







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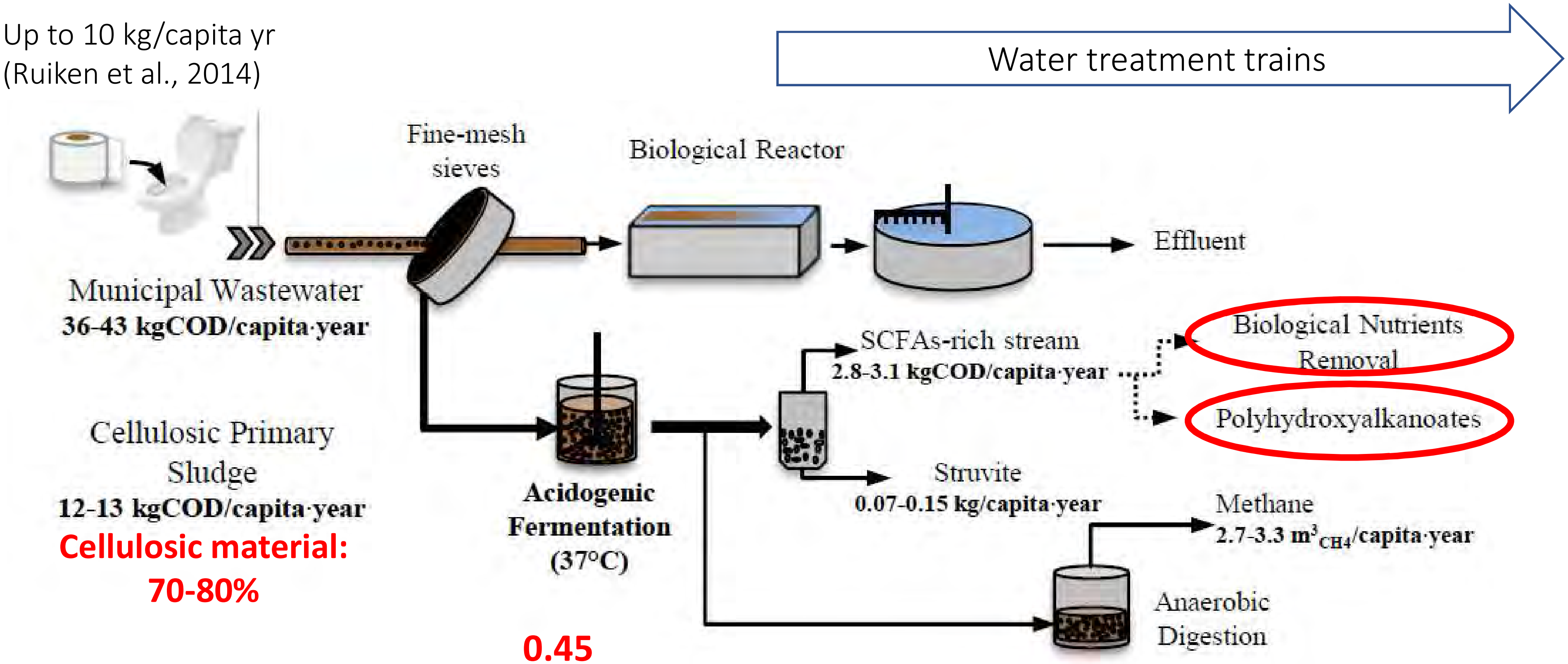
More value?
Biorefinery of Cellulosic Primary Sludge (CPS)

Up to 10 kg/capita yr
(Ruiken et al., 2014)

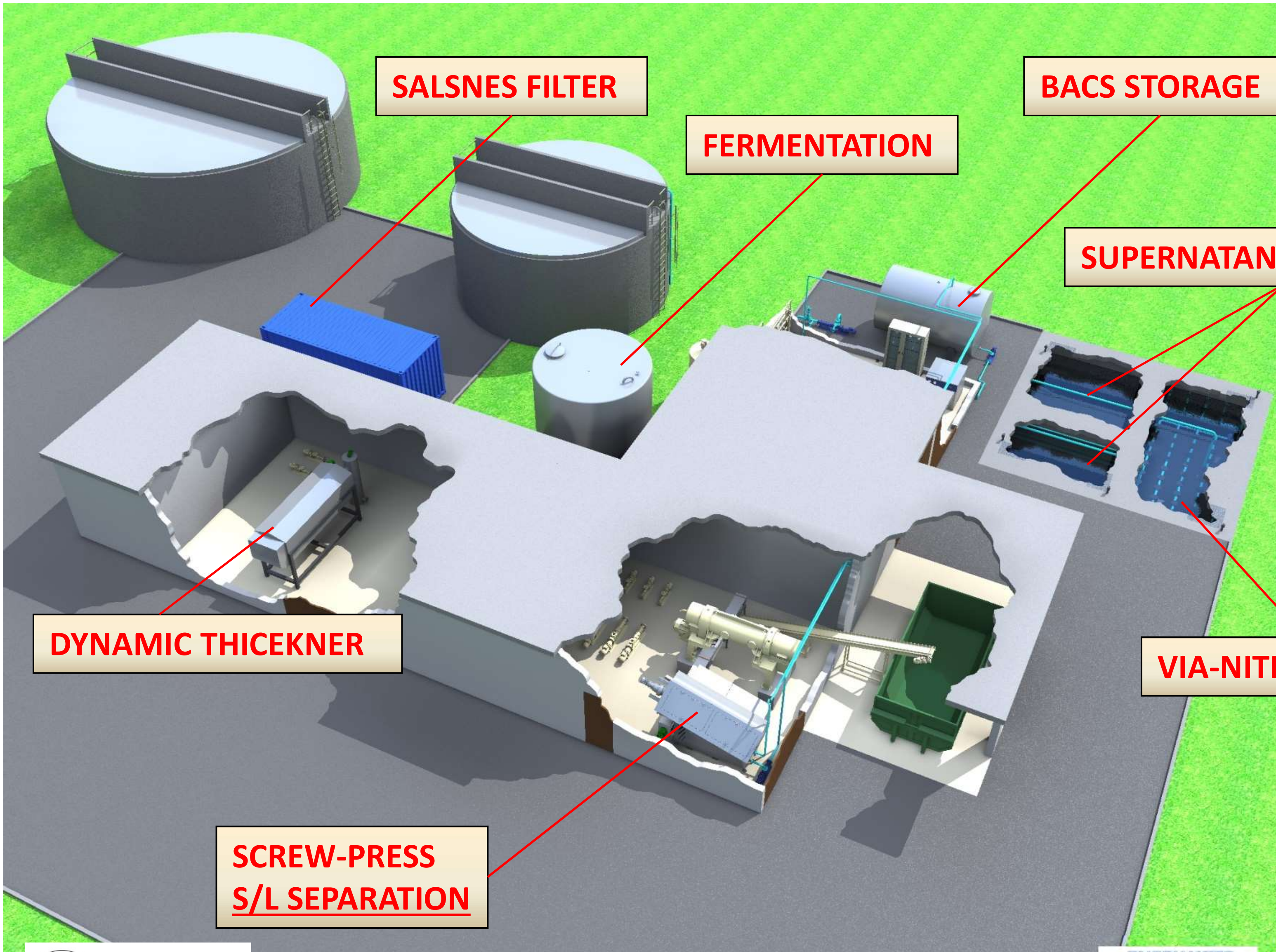


Cellulosic material: 70-80%

0.45 gCOD(SCFA)/gTVS fed (45-50% HAc; 30-35% HPr)

Water Research, Crutchik et al., 2018

The sludge treatment in the Carbonera WRRF (H2020 SMART-Plant demo: SCENA and SCEPPHAR)



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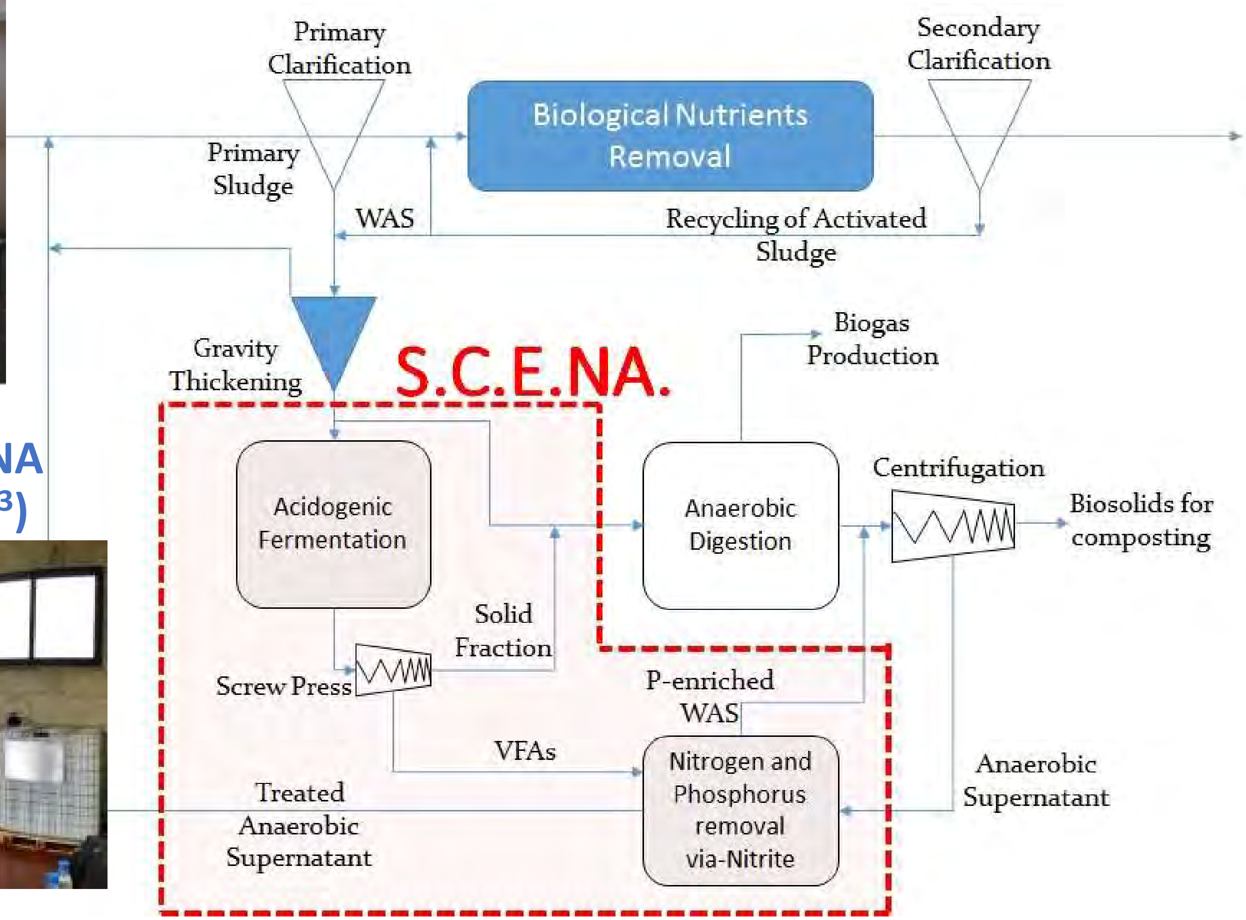
Short-cut enhanced nutrients abatement to treat sludge liquors

2011-2013: Lab scale SCENA process in Verona (30 L)

2014-2016: Pilot scale SCENA process in Carbonera (3 m^3)



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SCENA application at demo scale

Carbonera WWTP
100 m^3/d reject water

SCENA bridging the gap between small pilot application and large demo or even full scale application in real environment

Validate and demonstrate that SCENA is an effective and low carbon footprint process for nutrient removal/recovery

Psyttalia WWTP
2-3 m^3/d reject water

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S.C.E.N.A. OPEX after 4 months

NITROGEN REMOVED = 36 kgN/d			€/kgN rem
STORAGE SUPERNATANT	kWh/d	3,2	0,02
SBR	kWh/d	123,2	0,59
FERMENTER	kWh/d	9,0	0,04
S/L SEPARATOR	kWh/d	23,0	0,11
TOTAL ENERGY CONSUMPTION	kwh/d	158,4	**0,75**
POLYELECTROLYTE DOSAGE	kg/d	9,2	**0,36**
SLUDGE PRODUCTION	kg/d	54,0	**0,15**
PERSONNELL	€/d	4,9	**0,14**
MAINTENANCE			**0,10**
			1,50

Carbonera WWTP

4-4,5 €/kgN rem

OPEX reduction the treatment of An. Supernatant: around 65%

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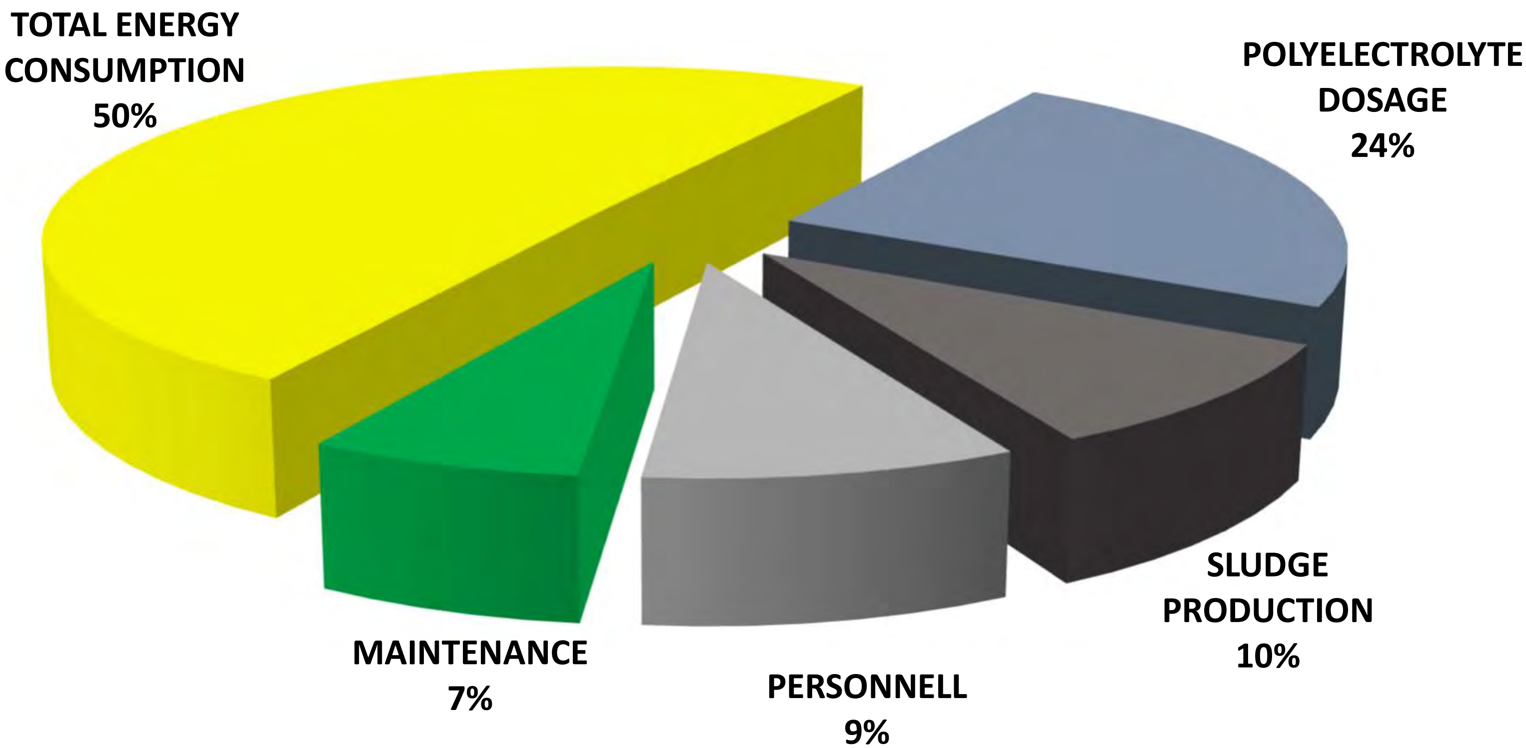
Specific OPEX for treating supernatant after 4 months operations



electrical energy Carbonera WWTP
3,4 €/kgN rem

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External carbon source (acetic acid) VS carbon souce from sewage sludge fermentation

External Carbon Source (eg. Acetic Acid)	Carbon source from sewage sludge fermentation
✓ Stable N removal in denitrification	✓ Stable N removal in denitrification
✓ Instable BIO P removal	✓ Stable and linear BIO P removal
✓ Higher Carbon Footprint	✓ Lower Carbon Footprint
✓ Commercial product	✓ Homemade Product
✓ Cost 1,69 €/kg N rem + extra cost for sludge disposal	✓ Cost 0,51 €/kg N rem…+ P rem

Carbon source from sewage sludge fermentation cost vs. ACETIC ACID cost – 67%

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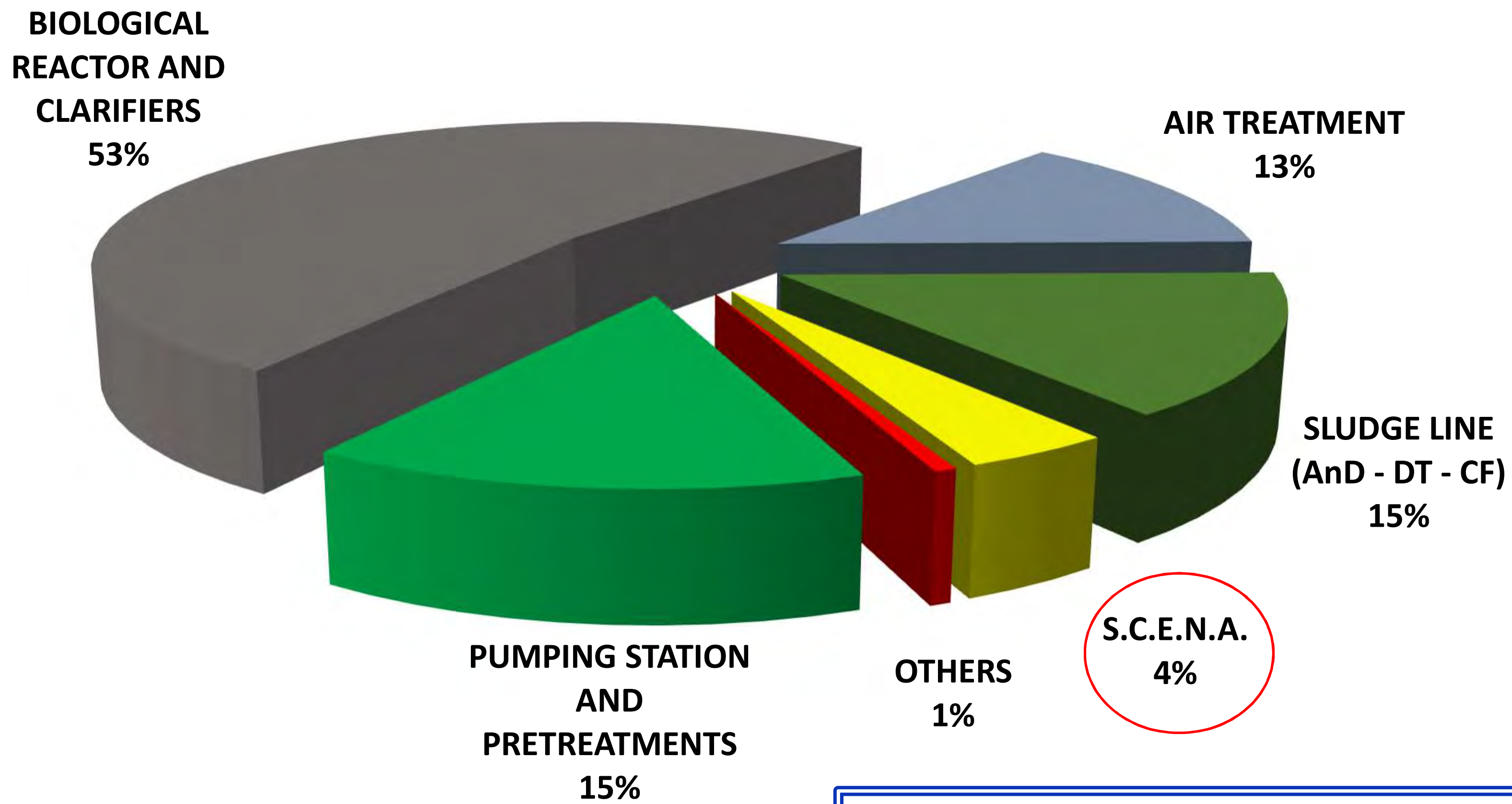
Carbonera WWTP energy scenario



energy consumption in Carbonera WWTP 5000 kWh/d

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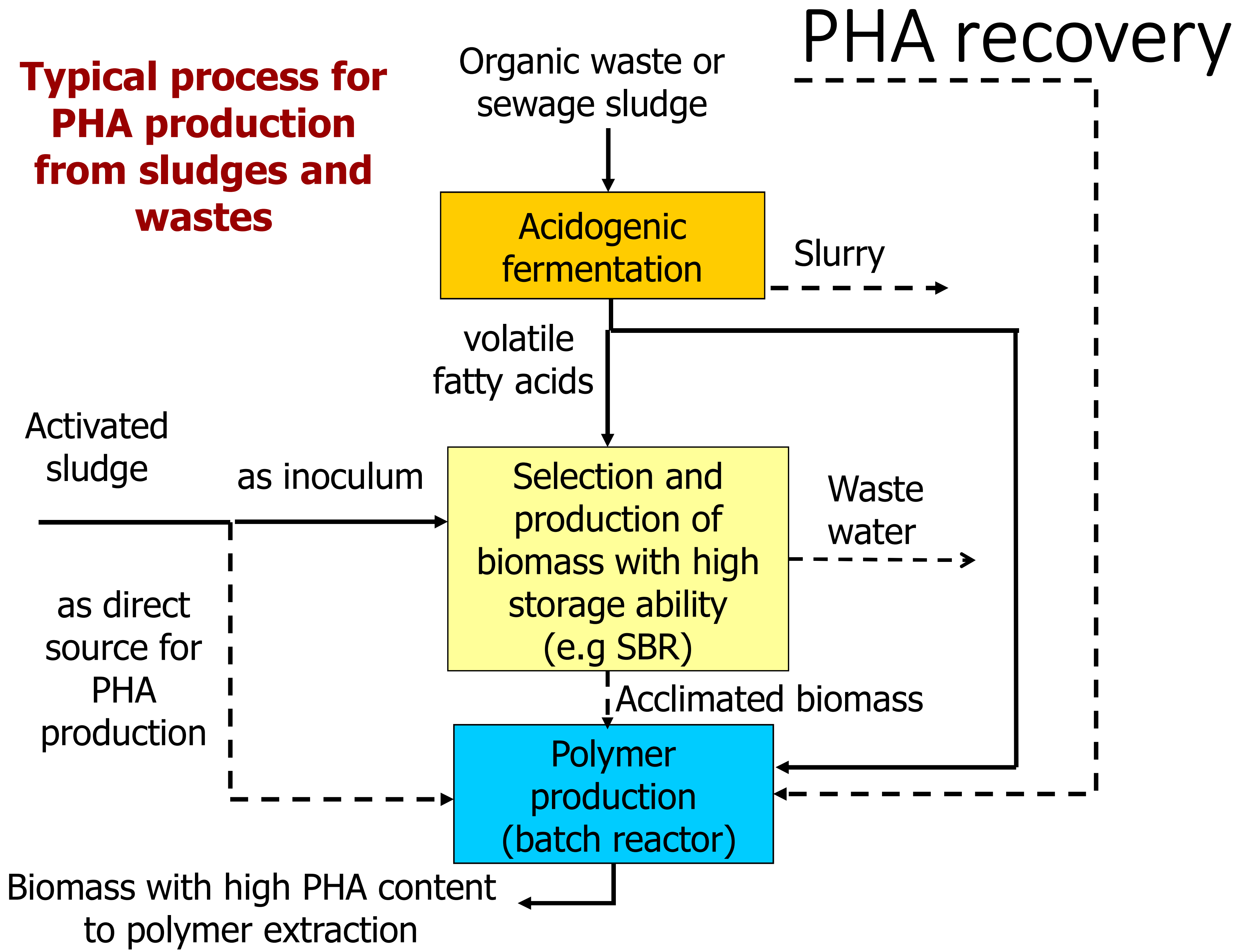
Verification procedure for S.C.E.N.A.

Timeline

- ✓ Contact phase with Verification Body
- ✓ Quick-Scan (QS) eligibility assessment
- ✓ Verification proposal
- ✓ Offer and contractual agreement
- ✓ Specific verification protocol phase (*starting*)
- → Testing
- → Verification
- → Reporting and publication

ETV

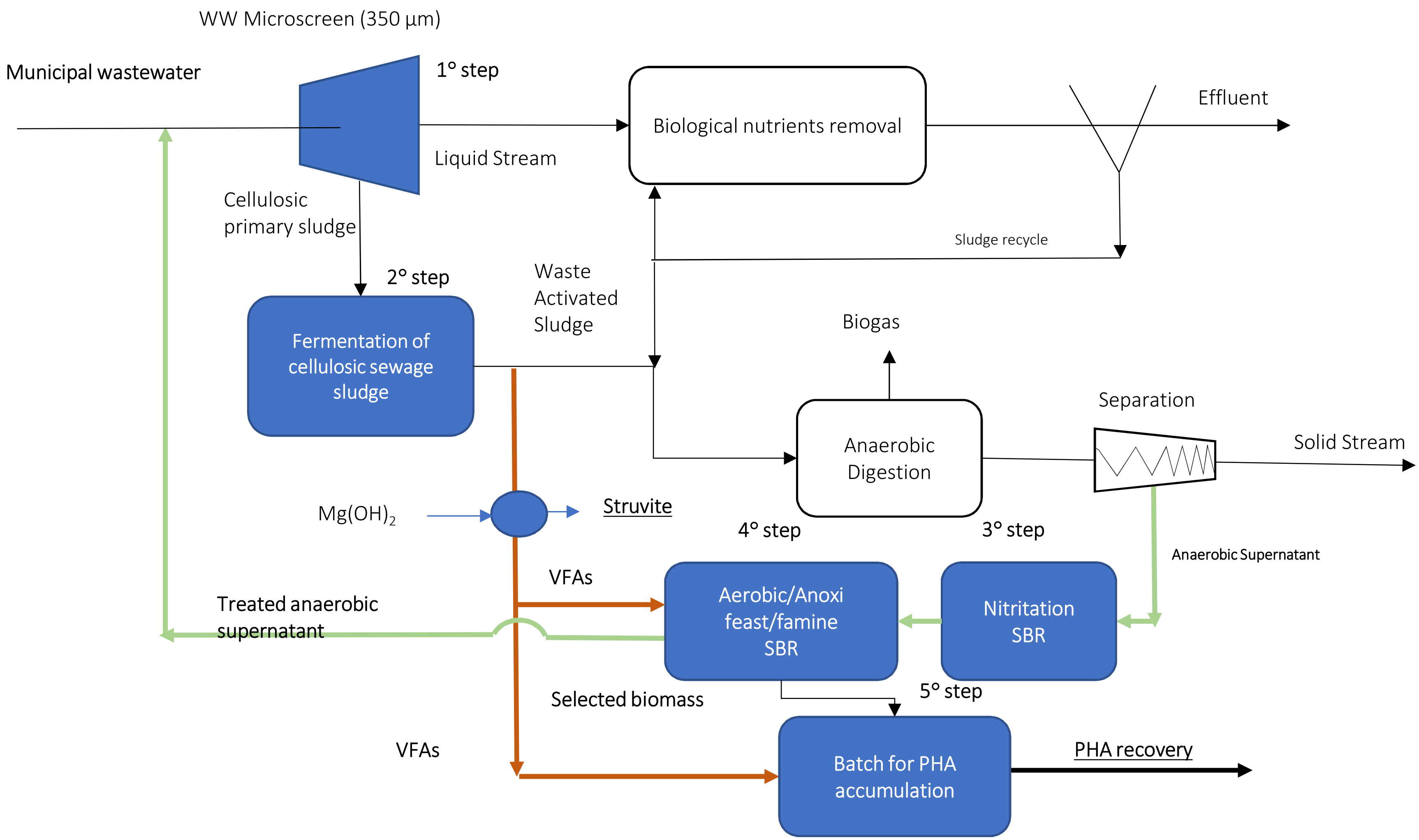
Typical process for PHA production from sludges and wastes



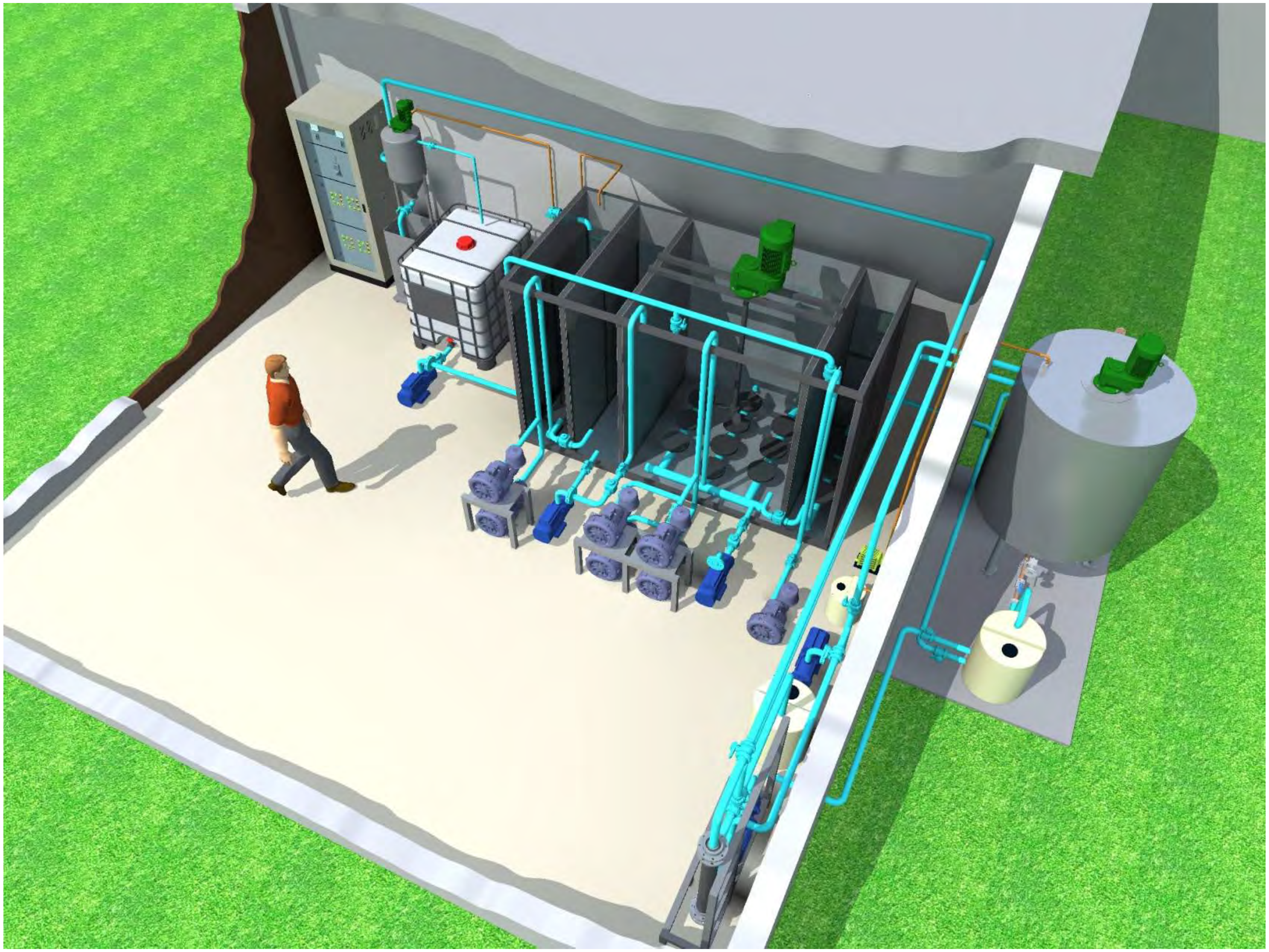
The «short-cut» innovation in SCEPPHAR:

- Integrate the via-nitrite nitrogen removal with the PHA recovery → major interest of the water utility
- Adopt anoxic (via-nitrite) conditions to optimize energy consumptions
- Phosphorus (struvite) recovery even to support the balance of nitrogen and phosphorus to the PHA recovery

Sidestream S.C.E.P.P.H.A.R.: Short-Cut Enhanced Phosphorus and PHA recovery (Smartech 5)



SMARTech5: sidestream S.C.E.P.P.H.A.R.



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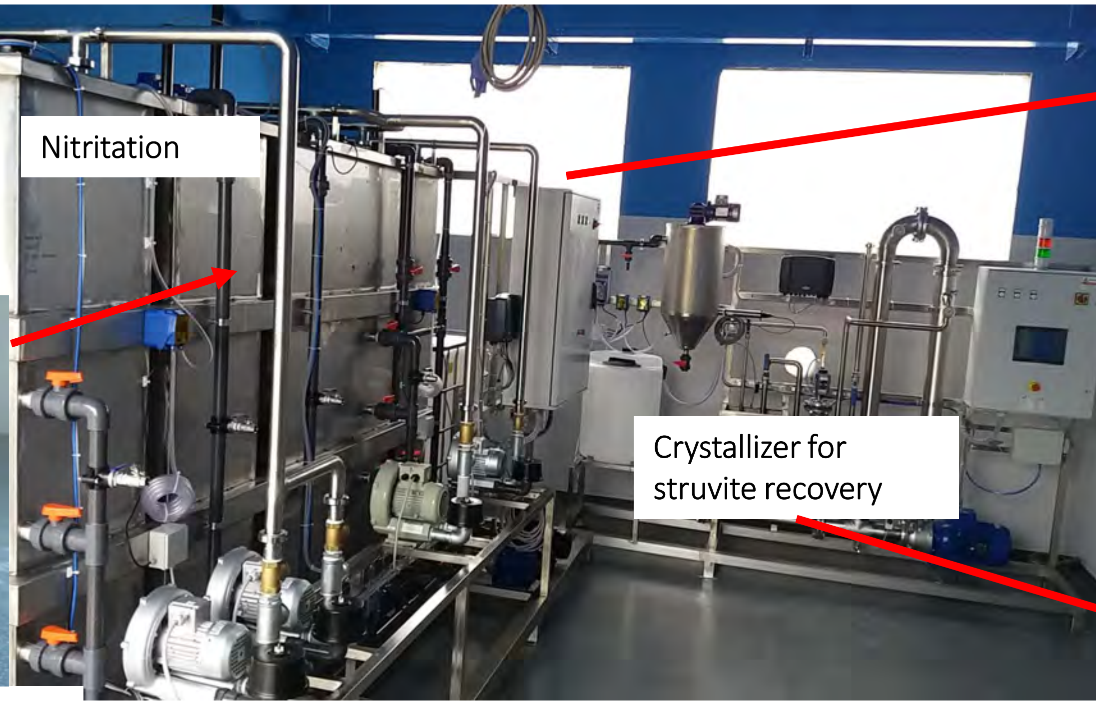
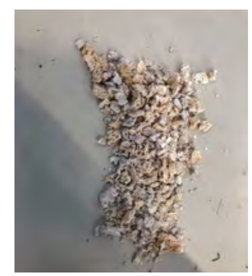
Short-cut Enhanced Nutrients Abatement (SCEPPHAR)



Selected PHA biomass

Biomass during PHA accumulation



Struvite recovered
(purity and agronomic properties under assessment

<u>Start-up: 28/08/2017</u>
<u>To date: 1,0-1,2 kgPHA/day, 53%(dw) of PHA content ; up to 300 gStruvite/day)</u>

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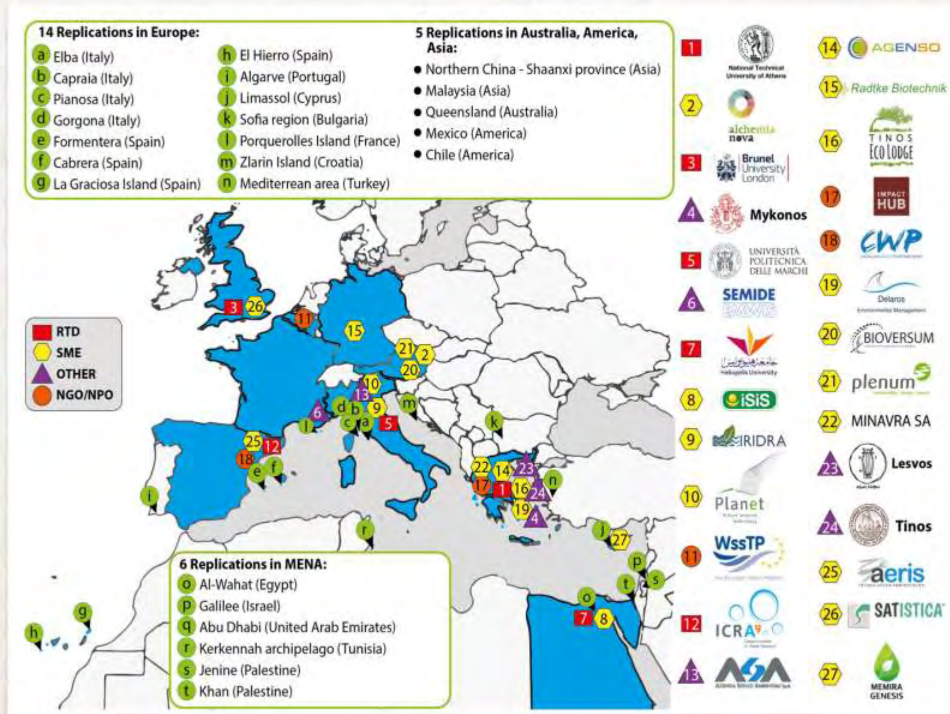
BASIC PROJECT INFO

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776643



Title:
Demonstration of water loops with innovative regenerative business models for the Mediterranean region

Acronym:
HYDROUSA

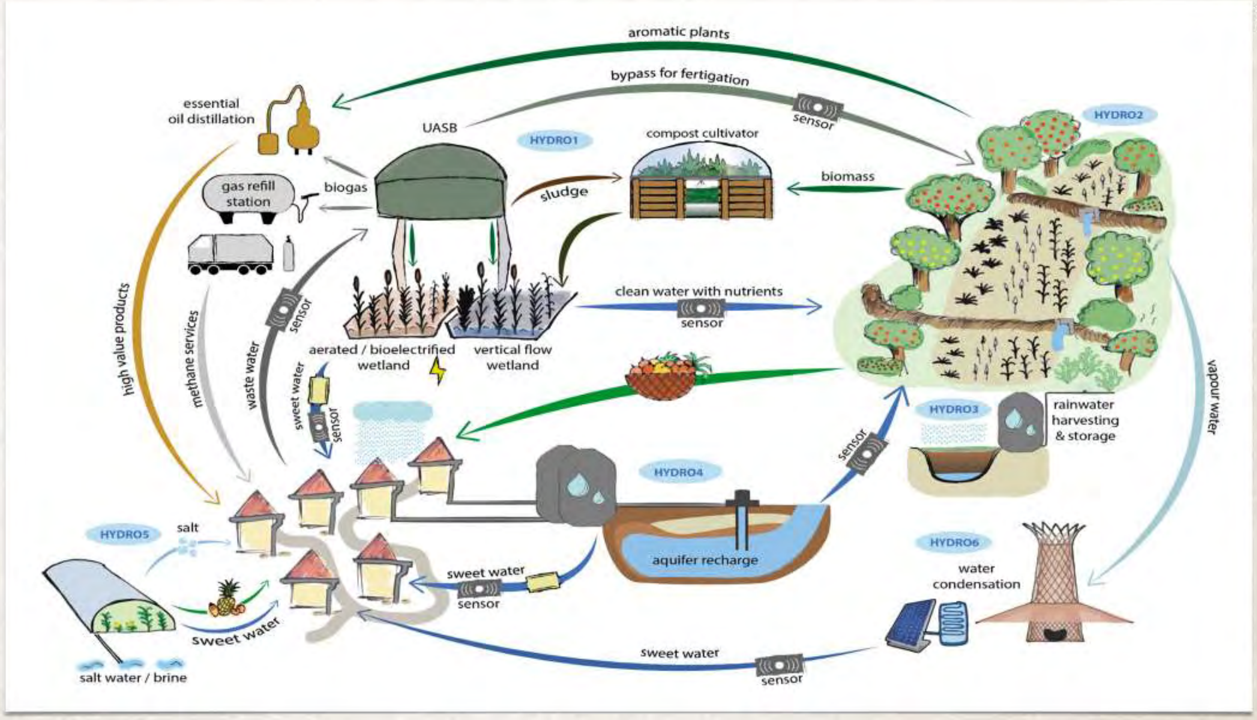
CIRC-02-2016-2017:
Water in the context of the circular economy, Innovation Action

Total budget:
€12,015,448.75;
EC contribution: €9,958,706.88

Duration:
54 months
Start date:
01/07/2018
Number of partners: 27

CLOSING WATER LOOPS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776643



European Sustainable Phosphorus Platform

This project has received funding from the EU Horizon 2020 research and innovation programme under grant agreement No. 690323

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The 3rd European Nutrient Event is co-organised with the **Horizon2020 SMART-Plant EU Innovation Action (ESPP member), the European Sustainable Phosphorus Platform (ESPP), HERA, and ECOMONDO** for the Mediterranean area.

European Sustainable Phosphorus Platform | Italian Phosphorus Platform | HERA | SMART-Plant | UNIVERSITÀ POLITECNICA DELLE MARCHE

III EUROPEAN NUTRIENT EVENT

@ ECOMONDO 2018

8 - 9 November 2018, Rimini, Italy

Neri 2 Room South Hall

Phosphorus recycling:

technology update, R&D perspectives

This 3rd edition in Rimini, Italy, is a follow up of the previous R&D events in Berlin (2015) and Basel (2017) (www.phosphorusplatform.eu/R&D) and focuses on phosphorus and nutrient recycling and management in Italy and the Mediterranean region and in EU research, development and innovation.

DAY 1 – 10.30-18.00
State of the art and regulatory framework + nutrients recovery technologies and water reuse

DAY 2 – 10.00-17.00
Nutrients recycling research, development and innovation

www.smart-plant.eu/ENE3

ECOMONDO Green & Circular Economy 6-9 Novembre 2018 Rimini Italy KEY ENERGY

Contact and Information: f.fatone@univpm.it ; smart-plant@univpm.it; info@phosphorusplatform.eu

3RD IWA RESOURCE RECOVERY CONFERENCE 2019

www.IWARR2019.org

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THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

REVAMPING IMPIANTI DI DEPURAZIONE

Lomazzo (Como), 26/10/2018

Thank you

Francesco Fatone

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