



aqualia

Frank Rogalla

The rainbow of circular water:  
the black, the white, the red  
the green... the purple  
and yellow” .

Lisboa, 10. 10. 2023



See, I am Funky Frank,  
and I'd like to say hello:  
to the black, to the white,  
**the red** and **the brown**,  
**the purple** and **yellow**



# Rainbow of Resource Recovery

The **Black:**

anaerobic pretreatment – direct biogas production

the **White:**

separation of toilet paper to halve sludge production

the **Brown:**

biosolids as materials and energy

the **Red:**

Anammox Bacteria for low energy nitrogen removal

the **Green:**

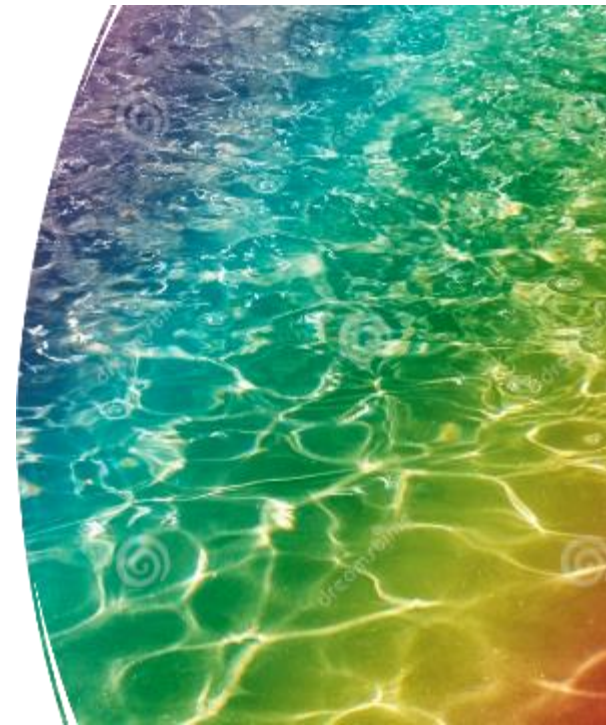
microalgae for energy positive water reuse

the **Purple :**

Bioplastics and biofertilizers from phototrophic purple bacteria PPB

and **Yellow:**

Urine separation reduces nitrogen in wastewater by 90 % - and recovery of fertilizer : ammonia is the new Gold

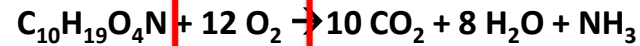


# Challenges

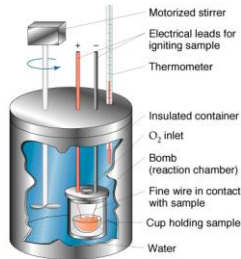
➤ 100 year old technology: Arden & Locket (Manchester, 1914)



Activated sludge



**> 0.5 kWh/m<sup>3</sup>**



Potential energy content of urban WW is typically

**~ 2 kWh<sub>th</sub> /m<sup>3</sup>  
(0.67 kW<sub>el</sub> /m<sup>3</sup>)**

**We are destroying >1.1 kWh el/m<sup>3</sup>**

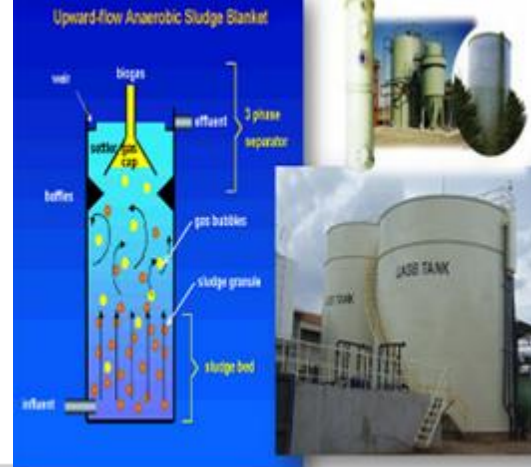




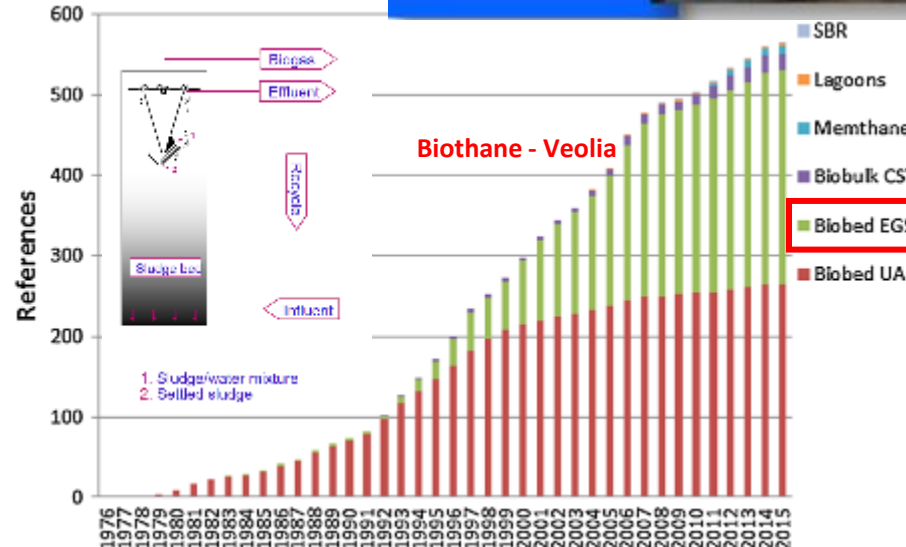
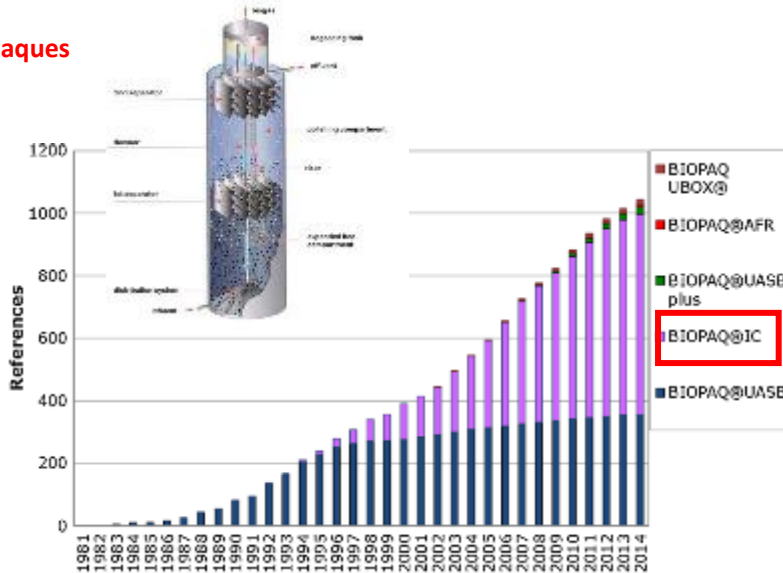
1. Biobed BIOTHANE (Veolia). OLR>5 kgCOD/m<sup>3</sup>/d.  
Memthane (AnMBR)

2. BIOPAQ IC (Paques) CADAGUA (Ferrovial).  
Para OLR>10 kgCOD/m<sup>3</sup>/d.

3. UASB WATERLEAU (Biotim).  
Para OLR>5 kgCOD/m<sup>3</sup>/d. UASB



Paques

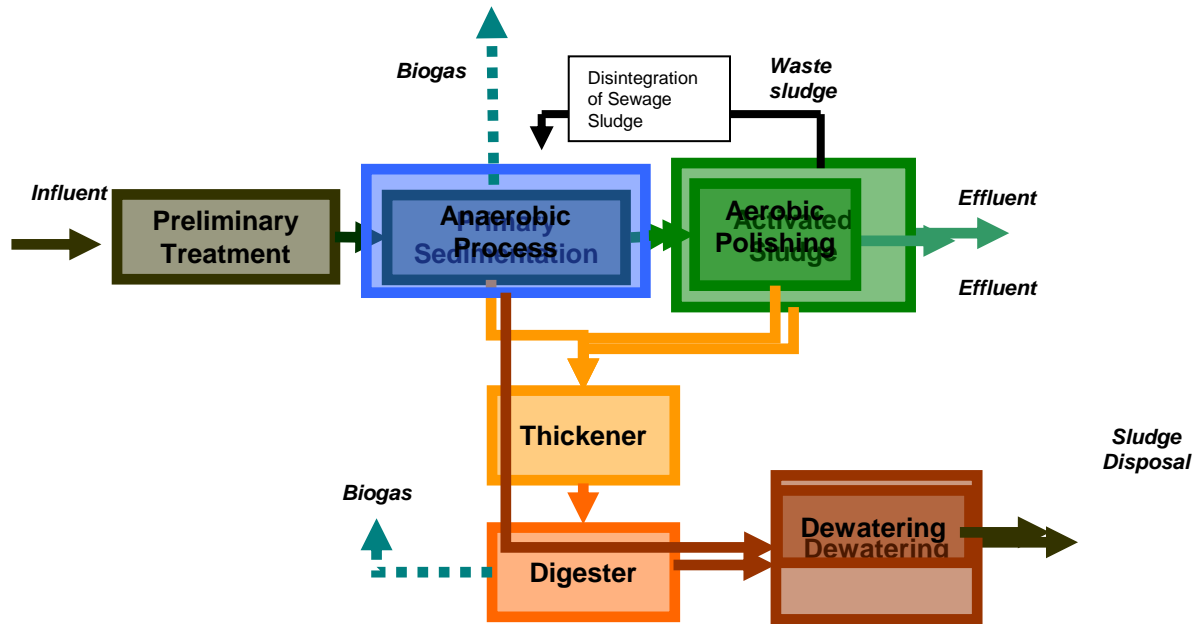


The project leading to this application has received funding from the European Union Horizon 2020 research and innovation programme under grant agreement No 869318

J.B. Van Lier et al 2015. *Celebrating 40 years anaerobic sludge bed reactors for industrial wastewater treatment.*



# The **Black** - Anaerobic Pre-treatment to maximize bioenergy and minimize biosolids:



48

Views

15

CrossRef  
citations to date

0

Altmetric

Original Articles

# Anaerobic treatment of municipal sewage in UASB and AFBR reactors

I. Sanz & F. Fdz-Polanco

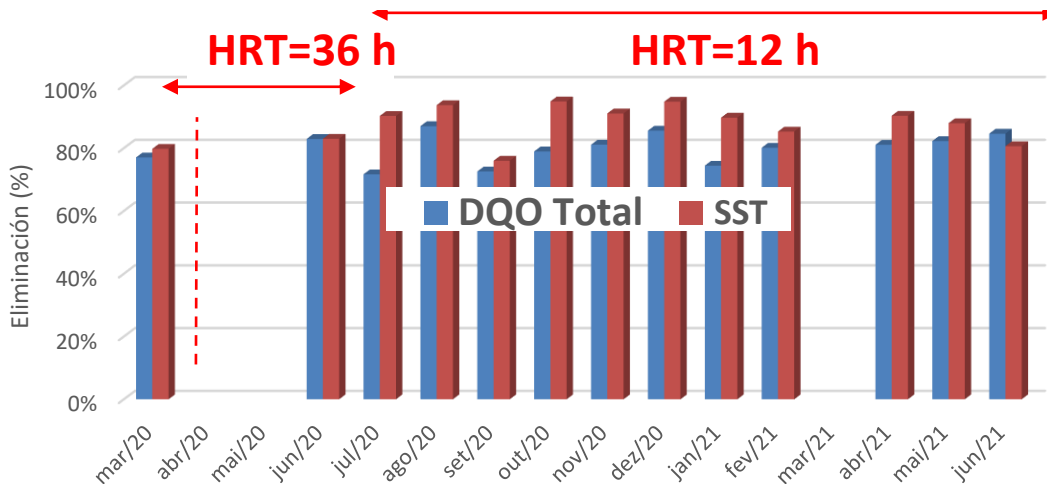
Pages 453-462 | Received 09 Mar 1989, Accepted 24 Apr 1989, Published online: 17 Dec 2008

🗨️ Cite this article 🌐 <https://doi.org/10.1080/09593338909384761>

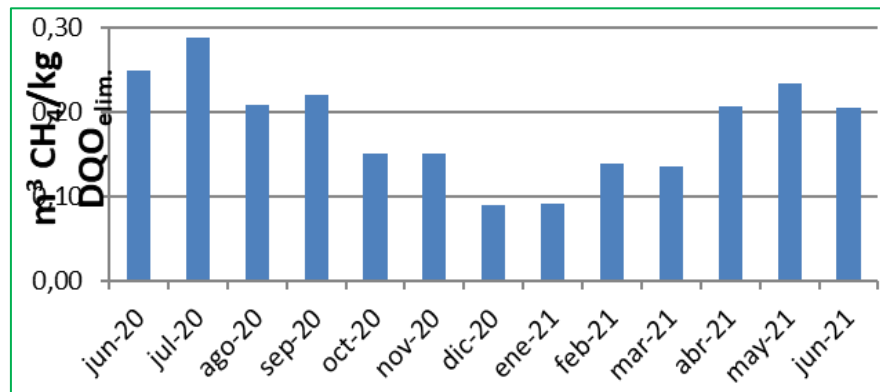




# Loulé (Algarve, S. Portugal) UASB - mínimum temp (dic. 2020- feb 2021) : 14-16 °C



Parámetro	Influent X ± SD	Effluent X ± SD	% removal
DQO Total (mg/L)	1123 ± 293	223 ± 58	80%
DQO Soluble (mg/L)	316 ± 78	93 ± 49	70%
Sulfato (mg/L)	45 ± 10	10 ± 5	78%
SST (mg/L)	415 ± 163	44 ± 20	89%
SSV (mg/L)	395 ± 161	40 ± 20	90%

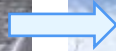




# Pulsed Upflow Sludge Hydrolyser PUSH REACTOR: Anaerobic pretreatment of wastewater at ambient temperature

Pretreated municipal  
wastewater

Q = 15 m<sup>3</sup>/d



Biogas



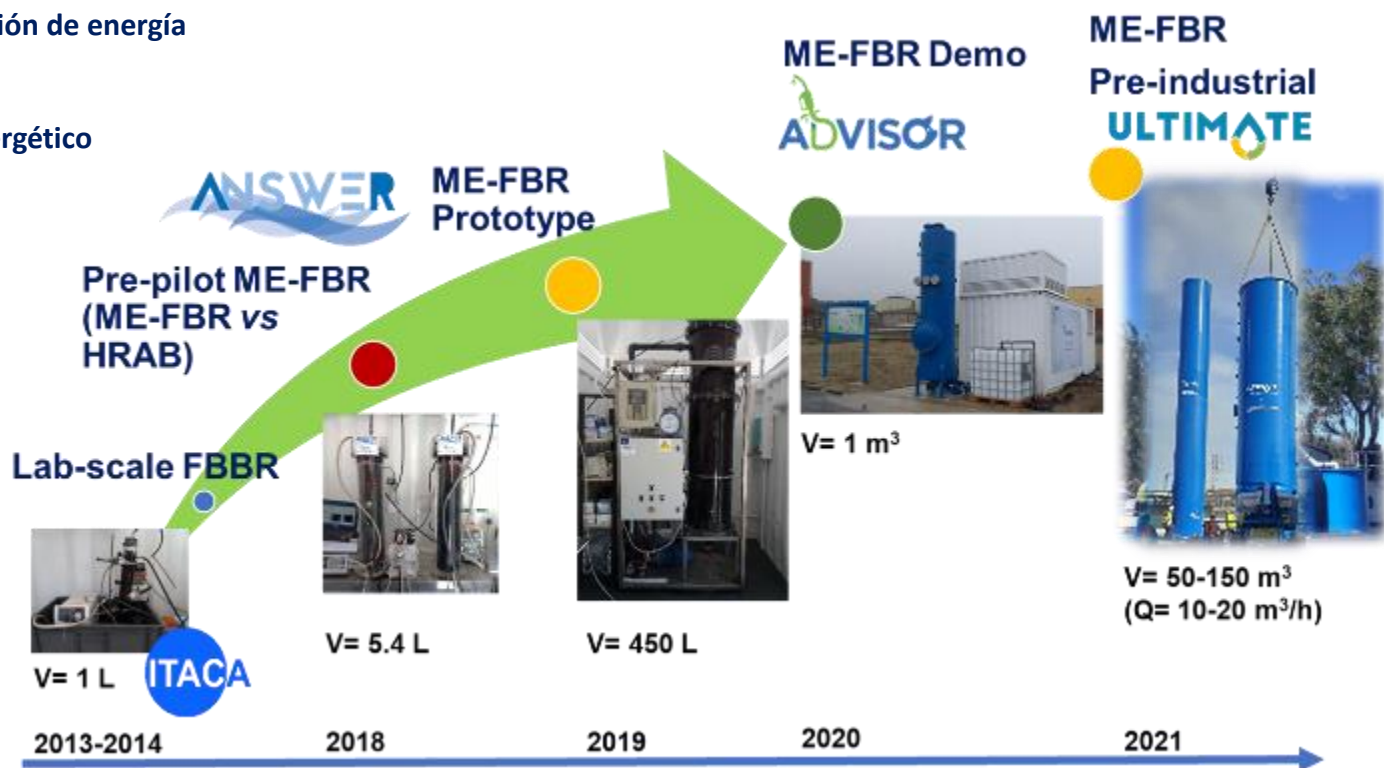
Stripping of  
dissolved methane



LIFE ULISES is a project co-funded by the European Union under the LIFE Programme Grant Agreement no. LIFE18 ENV/ES/000165

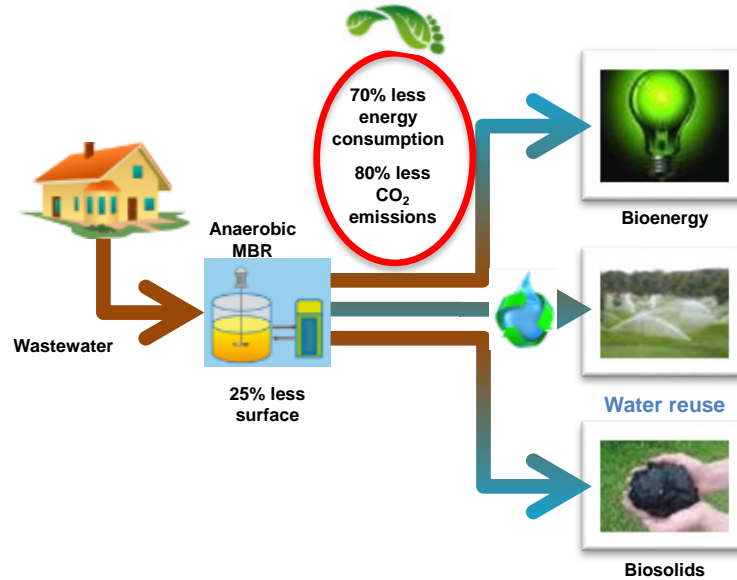
# Diseño y construcción de un sistema anaerobio bioelectroquímico de lecho fluidizado (EL SAR® Electro-Stimulated Anaerobic Reactor)

- 1 Depuración con generación de energía (biogás)
- 2 Minimizar consumo energético
- 3 Sin generación de lodos



# The **Black**: Bioenergy from Organic Matter

Life Memory: MEMbrane for Energy and Water RecOveRY  
Anaerobic Membrane Bioreactor AnMBR





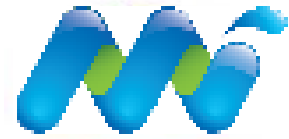
## LIFE MEMORY PROJECT- ANMBR: MEMBRANE FOR ENERGY AND WATER RECOVERY



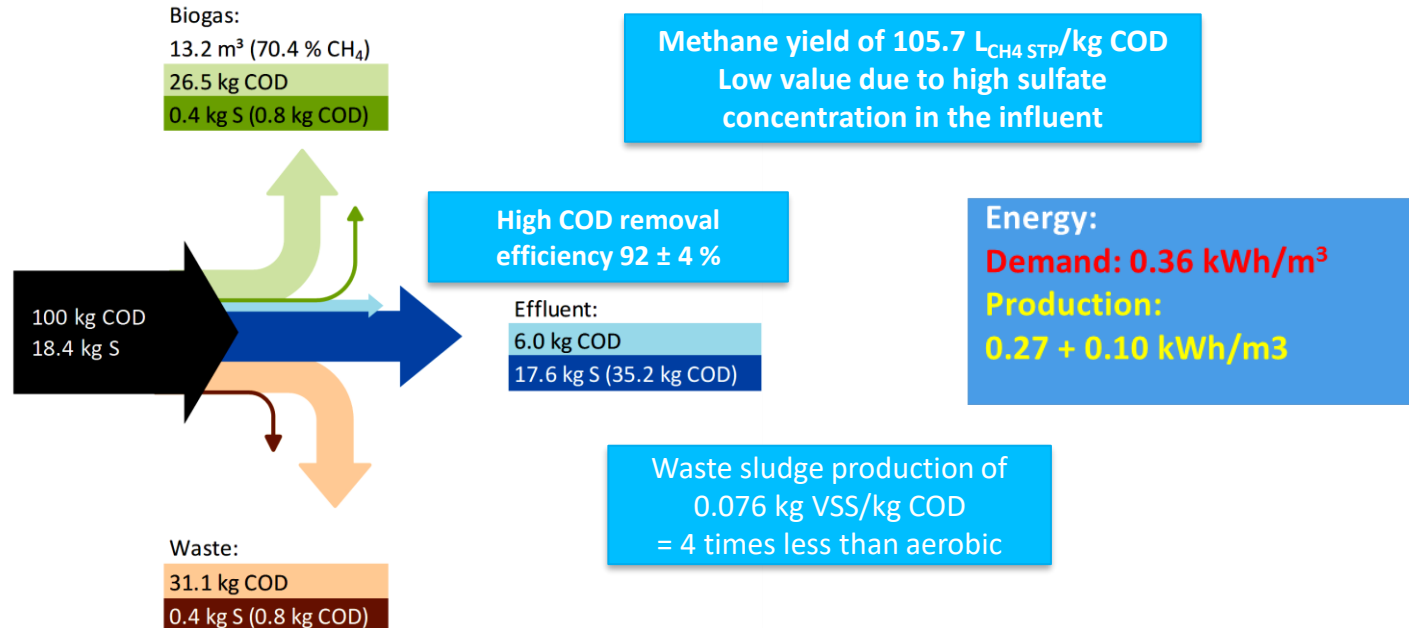
Location: Alcázar de San Juan WWTP (Ciudad Real, Spain)



# LIFE MEMORY PROJECT – ANMBR : MEMBRANE FOR ENERGY AND WATER RECOVERY



- Overall performance of the prototype:



# AnMBR

- Filene: Pilot Grefusa Corn Snacks
- Innpronta IISIS – Municipal Pilot at UVA
- Alegria: Pilot Frinova Fish Canning
- Life Memory : Prototype Alcazar Municipal WWTP
- Life Methamorphosis: MSW Digestor Leachate
- BioWaMet : Tortosa WWTP
- H2020 Run4Life: Blackwater Demo ZF Vigo



# RUN4LIFE

Recovery and Utilisation of  
Nutrients 4 Low Impact Fertiliser  
H2020 (2017-2021)

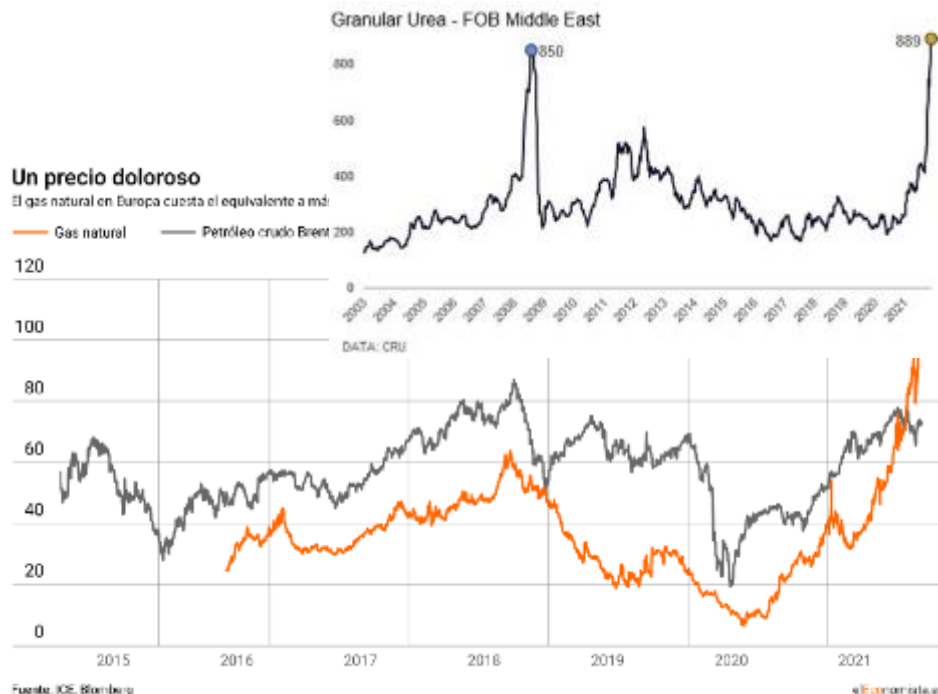


- Sneek, the Netherlands: 32 homes
- Vigo, Spain: 3 office buildings
- Ghent, Belgium: 120 homes
- Helsingborg, Sweden: 320 homes
- Czech Republic: large industrial area (replication site)



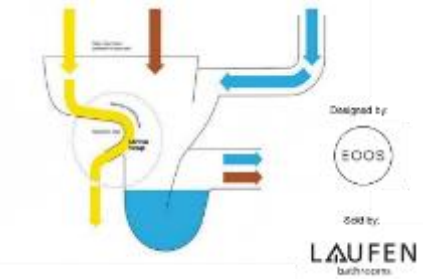


Artificial Fertilizer Production with Haber Bosch: 1 kg N = 10...15 Kwh of Natural Gas





# Urine Separation Toilets: No mix and Novaquatis (Eawag/CH)





## The **Yellow**: Urine Separation ?



**Urine contains the majority of the NPK excreted - 1,5 l/PE/d :**

- **80-90% of the total 4 kg of N excreted ( 12 g/pe/d x 365 = 4,4 kg /yr)**
- **50-80% of the 0.4 kg of P and**
- **80-90% of the 1 kg of K (Vinnerås et al., 2006).**
- **The main limitation with using urine as a fertiliser is that it is mostly water (97%),**
  - **nitrogen concentration in urine (without flush water) is about 0.6% (Vinnerås et al., 2006) whereas manufactured fertiliser ammonium nitrate (NH<sub>4</sub>NO<sub>3</sub>) is 36% N.**
  - **for a 90 kg N ha<sup>-1</sup> application rate:**
    - 15 000 L urine ha<sup>-1</sup> is required, compared with 265 kg NH<sub>4</sub>NO<sub>3</sub> ha<sup>-1</sup>,**
  - **approximately 500 L of urine / per person / per year**
    - but not competitive as fertiliser compared with synthetic fertilisers (high NKP concentrations)**

# Demonstration of separative urine concentration in Malmoe



*Balance of 38 days with daily measured water consumption .  
Values based on the assumption of 90% of toilet visits  
used the 2 L flush and 70% of the urine was retained.*

Water consumption	m <sup>3</sup> /d	# flushes/d	Volume urine (L/d)
Min:	0.005	2.4	0.5
Max:	0.212	100.7	21.1
Average:	0.081	38.3	8.0
Median:	0.076	36.1	7.6
Total:	1 466 (m <sup>3</sup> )	696.4 (#)	146.2 (L)

**Urine diverting toilet installed in VASYD headquarters captures roughly 70% of the urine.**

**Alkaline stabilisation and drying bed of wood-ash with air evaporation at 35 deg C gives end-product with nitrogen concentration of 7.8% and 0.6% for phosphorous.**

**With the nitrogen ten times more than phosphorus in fresh urine, 0.6% and 0.07% respectively, the majority (>90%) of the nitrogen was retained.**

# The White : *Struvite Precipitation - Aquavite®*

*WWTP Jerez and Collaboration with Fertiberia*

The image illustrates the struvite precipitation process using the Aquavite® system. It features a schematic diagram, a photograph of the industrial equipment, and a close-up of the product.

**Schematic Diagram:** A grey cylindrical tank (1) feeds into a rectangular filter unit (2). The filter unit has a brown layer at the bottom. An arrow labeled "Biosólidos" points from the filter to a brown box. Another arrow labeled "Agua rica en nutrientes" points from the filter to the right.

**Photograph:** A large blue industrial tank with "aqualia" and "B-Ferst" branding. The tank is situated outdoors with a white building in the background. A blue pipe system is visible on top of the tank.

**Product:** Two white buckets filled with a white, granular precipitate, labeled "AQUALIA".

**Logo:** The B-Ferst logo, featuring a green leaf inside a circle, is located in the top right corner.

# The White:

## Toilet Paper Use

12 kg/pe/yr=

33 g TSS/PE/d

## Specific sludge production in wastewater

35 to 85 gTS PE-1 d-1

## Primary sludge settleable solids in raw wastewater is typically 50-60 gTSS PE-1 d-1

(Tchobanoglous et al., 2003; Metcalf & Eddy 4th Edition).











One big tree can produce 1,500 rolls = meet the demands of 10 people, annually

- In the United States: 31.1 million trees
- UK : 5.7 million trees
- China 47 million trees annually

## The U.S. Leads the World in Toilet Paper Consumption

Estimated annual per capita toilet paper consumption in selected countries (2018)







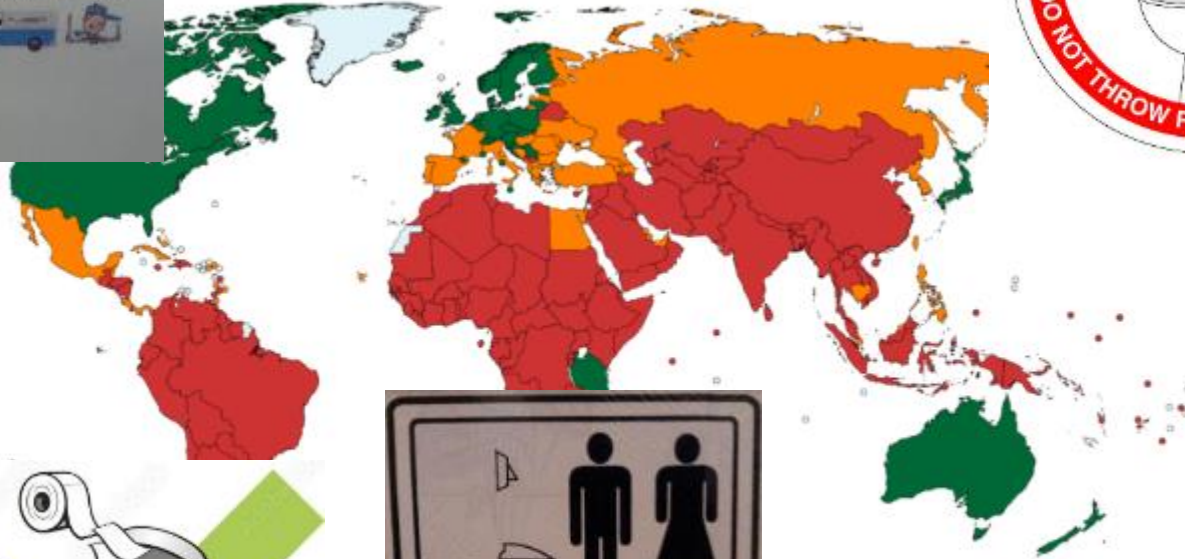
Please be aware that   are smaller than   and block easily. So please use the  provided and do not put  down the  or we will have to  a  a 

Thank you

# Separative Collection of Toilet Paper



-  Don't flush the toilet paper
-  Flush it!
-  It depends.
-  No information, assume situation in nearest country.

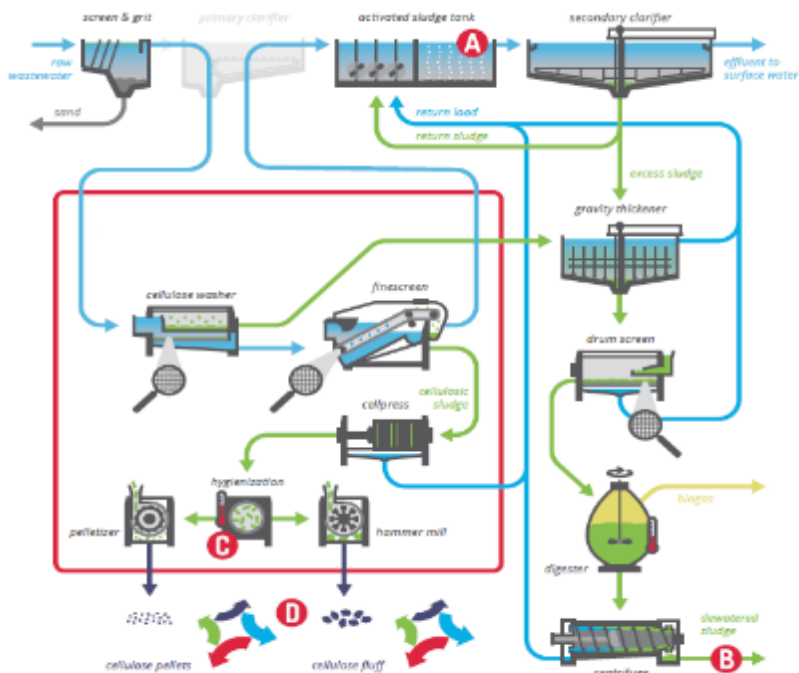


# The White: cellulose recovery from wastewater



Recovery of 100 g cellulosic material/m<sup>3</sup> municipal wastewater and removal of > 85% suspended solids from wastewater

Demo site 1 WWTP Linares (Spain)

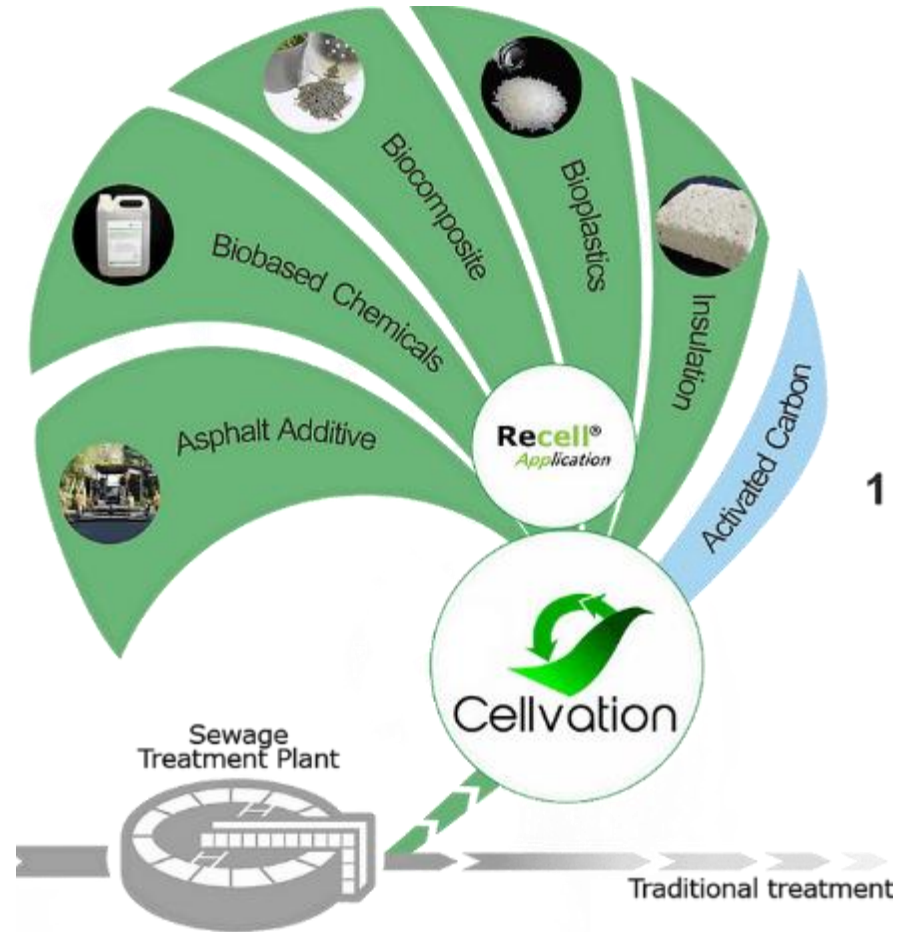


Appearance	fibre fluff
Cellulose content	60 - 80 %
Hemicellulose/Lignin	10 - 15 %
Ash	5 - 15 %
Organic residue	5 - 10 %
pH	5 - 8
Dry matter	> 90%
Odour	Neutral
Colour	Light grey
Brightness	> 50%
Loose density	50 - 80 kg/m <sup>3</sup>

Cellvation demonstration at WWTP Geestmerambacht In N. Holland recovers 200 kg/d cellulose, marketed under the brand [Recell©](#) to produce biocomposites and biopolymers.

Large scale WWTPs ( $Q > 100\,000\text{ m}^3/\text{d}$ )

- 40% SST reduction
- 15% reduction aeration energy
- 20% sludge reduction
- 10% increase treatment capacity
- 20% reduction  $\text{CO}_2$  emissions
- Cellulose screenings as raw material
- for construction, biopackaging and chemicals





# The RED: AnMBR + Anammox in Mainstream

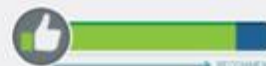


# Economía Circular: OFMSW - FORSU + agua?

De media cada ciudadano g  
europea de residuos sólido  
segregada y sostenible de lo



**432 HOUSEHOLDS**  
without disposers were given them, with free installation, by InSinkErator®  
Household waste volume was measured before and after disposers were installed.



**80% OF PARTICIPANTS\*\*** said they'd recommend a disposer to a friend or family member  
"Once you have a disposer, you can't live without one."  
- Project Participant



**30% REDUCTION** in food waste volume when food waste disposers are used, as reported by participants  
After 3 years, that's almost like keeping a year's worth of food waste out of landfills.



**2,200 CARS** EMIT AS MUCH greenhouse gas as could potentially be removed from Milwaukee landfills each year, if 30% of the food scraps were annually diverted to an advanced anaerobic digestion wastewater treatment plant  
Plus, in cities like Milwaukee that employ anaerobic digestion plants citywide, the biogas generated through the processing of an additional 30% of food waste going into disposers could potentially produce enough energy to power over 1,000 homes per year.



**50 LOADED JUMBO JETS** weigh as much as much as the food waste that could be diverted annually if all of Philadelphia homes used disposers  
Keeping 19,000 tons of food waste out of landfills may save the city \$11 million annually in waste disposal fees.  
Municipalities should take potential and achievable disposer adoption rates for their city into consideration.



**1 RESULT**

Disposers counteract growing food waste problems, while offering potential savings and environmental benefits to participating communities that encourage use.



LIFE ZERO WASTE WATER - LIFE19 ENV/ES/000631

With the contribution of the LIFE Programme of the European Commission



# Life ZWW: Objetivos y Resultados esperados

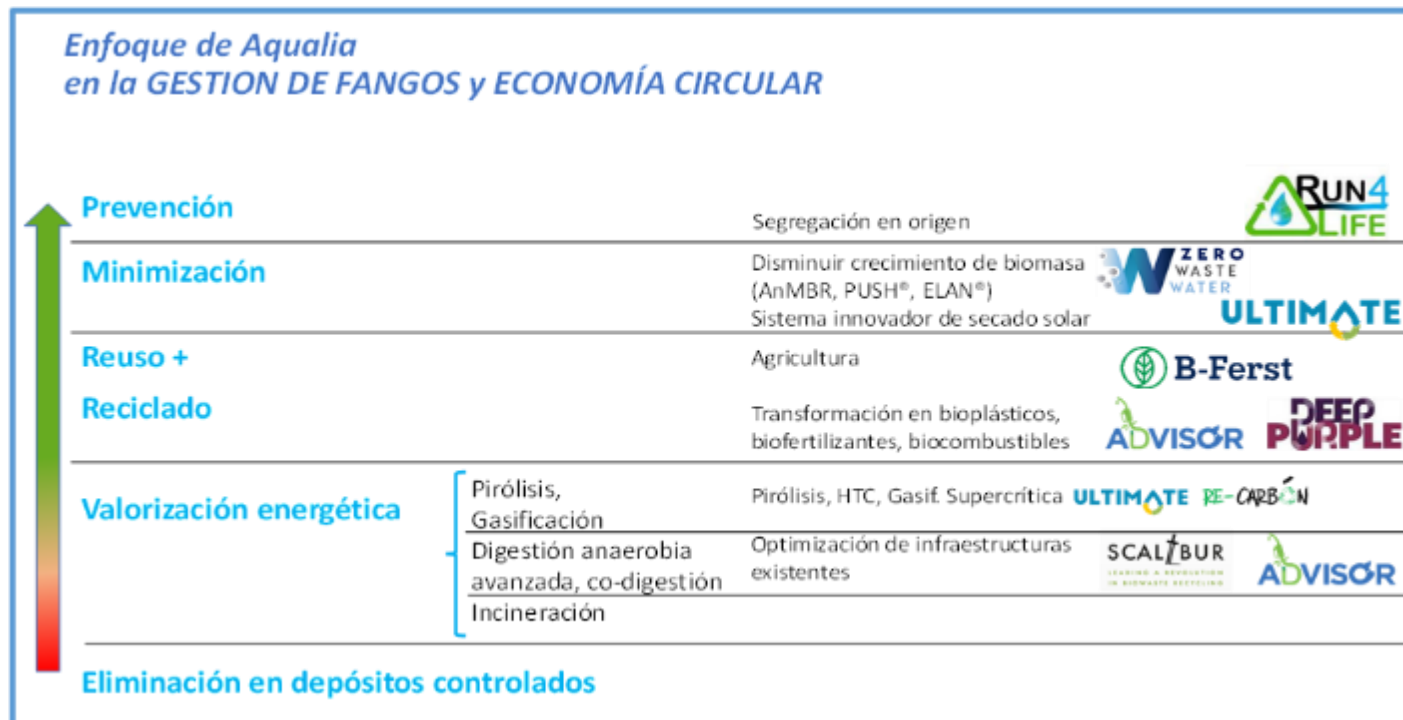
## HITOS:



**LIFE ZERO WASTE WATER - LIFE19 ENV/ES/000631**  
With the contribution of the LIFE Programme of the European Commission



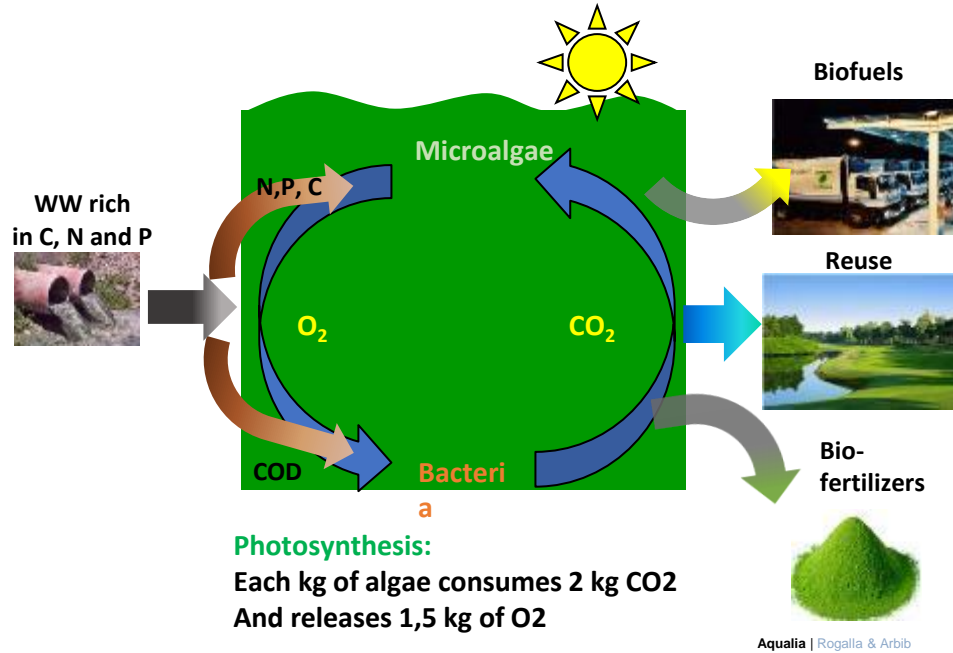
## The **BROWN**: biosolids as materials and energy





# The Green... Algae Biomass

THE CONCEPT: Symbiotic interaction microalgae & bacteria





# The **Green... Dream:** to design, to demo



**Pilot plant**  
**32m<sup>2</sup>**



**Pre-Demo**  
**3.000m<sup>2</sup>**



**Prototype**  
**500m<sup>2</sup>**



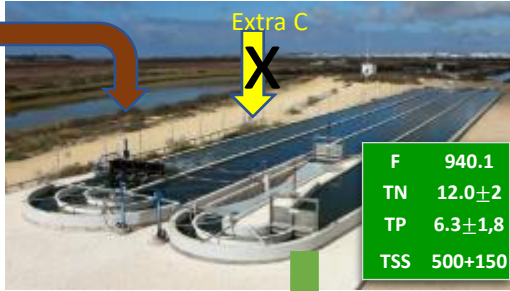
**DEMO**  
**> 5.000m<sup>2</sup>**

# Algae Raceway operation - from dream to design, to demo

Cultivation: wastewater treatment = biomass production & digestion = biofuel

HRT: <3d  
Aerobic and anoxic daily periods  
pH < 8.5  
No CO2 needed

F (m <sup>3</sup> /d)	1000
TN (ppm)	50.4±8
TP (ppm)	10.3±3
COD (mgO <sub>2</sub> /L)	525±120



F	940.1
TN	12.0±2
TP	6.3±1,8
TSS	500+150

Simultaneous Removal:  
COD 80%,  
TN 74% and TP 88%

Energy requirement  
0,15 kWh/m<sup>3</sup>  
2 to 3 m<sup>2</sup>/PE

Simple process:  
No external carbon  
Single stage

Biomass rich in:  
N and P

47±20  
g TSS/m<sup>2</sup>/d

Aqualia | Rogalla & Arbib

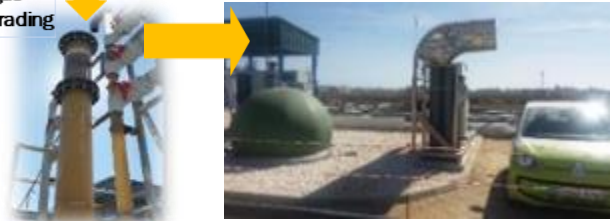
110±32  
Ton/Ha yr



Digestion



Biogas Upgrading



TN	12.0± 2,2
TP	1.01±0,75
COD	80.2±20
TSS	25.4±7,5

>90%CH<sub>4</sub>  
fleet vehicle  
quality



from dream to design, to demo

Chiclana site: Full train of downstream processing



Aqualia Rogalla & Arbib



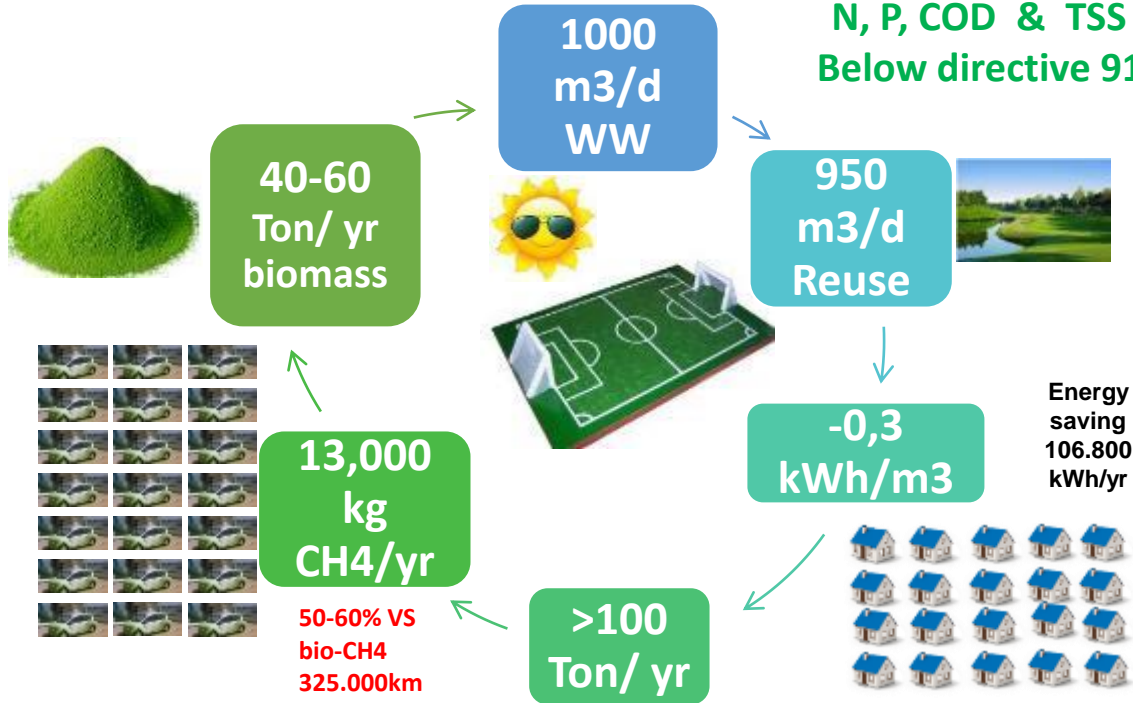
From dream to design, to demo

Potential 1 HECTARE cultivation surface

5000 PE

Simultaneous

N, P, COD & TSS removal  
Below directive 91/271/EC



# From dream to design, to demo

## Microalgae fleet vehicles



May 2016  
First car moved by biomethane from algae  
130.000km



2019: More than 350.000km

2000km/d  
730.000km/yr



04/2019  
MICROBUS 100% biogas in Chiclana WWTP



# PROGRAMA CLIMA ABAD BIOENERGY (2023)

6 AÑOS (2018-2023)

MADRID → JEREZ → CHICLANA → LLEIDA → GUIJUELO → ALMERÍA → KARVINA



9.300 T



430.000 árboles



Wastewater is Bioenergy



## The Purple ....

Bioplastics From Purple Phototrophic Bacteria (PPB)



# UPSCALING ANPHORA<sup>®</sup> : ANAEROBIC PHOTO-TROPHIC RACEWAYS



**2015. Lab-scale**  
10 L/ 2.6 gal  
URJC (Madrid, Spain)  
Synthetic wastewater + acetate

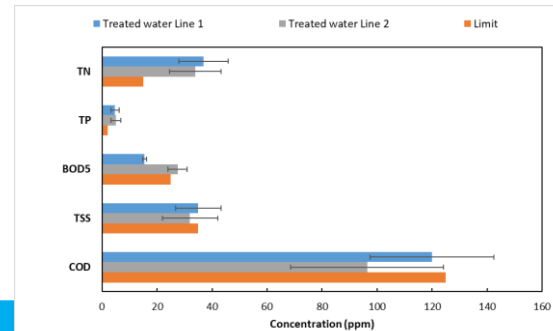


**2016. Pre-pilot**  
1.4 m<sup>3</sup>/370 gal  
URJC (Madrid, Spain)  
1 m<sup>3</sup>/d (264 gal/d)  
Synthetic wastewater+acetate

**2018. Pilot**  
1.4 m<sup>3</sup>/370 gal  
WWTP Estiviel (Toledo, Spain)  
1 m<sup>3</sup>/d (264 gal/d)  
Domestic wastewater

**2018. Prototype**  
70 m<sup>3</sup>/18,500 gal  
WWTP Estiviel (Toledo, Spain)  
10 m<sup>3</sup>/d (2,642 gal/d)  
Domestic wastewater

**2022. Demo scale**  
300 m<sup>3</sup> /79,300 gal  
WWTP Linares (Jaén, Spain)  
350 m<sup>3</sup>/d (92,460 gal/d)  
Domestic wastewater



# The PURPLE: moving towards real application



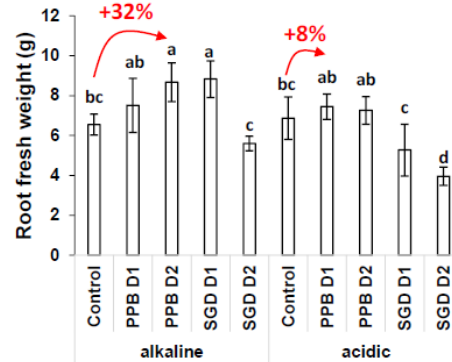
## Validating analysis (Roullier):

Confirming the positive effect of PPB on the growth and development of both maize and soybean plants. The effect of soil pH enhancement is evident in soybean growth

### Large scale production of pellets

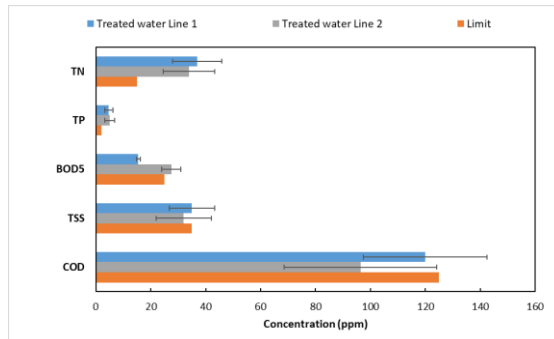


### Performing field trials in Italy, Spain and France



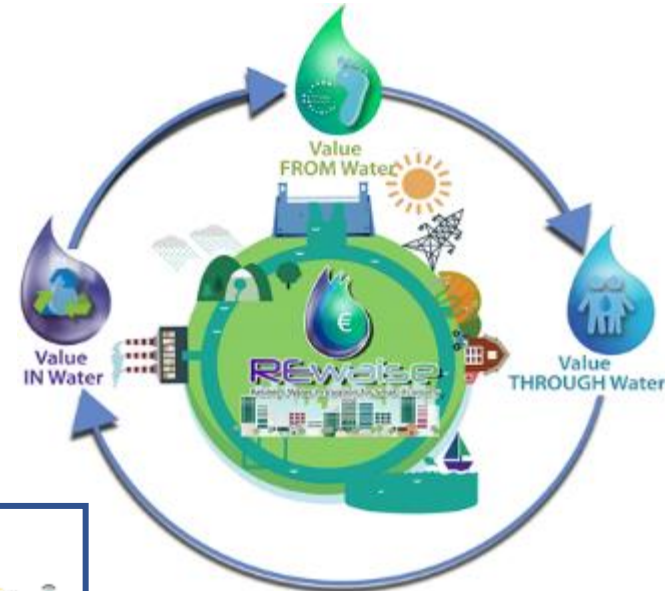
Field trial (spring wheat) in Italy

Field trial (maize) in Italy



## The Value of Water

- Extract the Value **in** Water:
  - promoting efficient use + reuse, recovery energy and materials
- Generate Value **from** Water
  - Boosting economic activities + services, creating Jobs and business
- Enhance Value **through** Water
  - Improve Societal Well-Being



25 research and water industry entities working together to create a new "smart water ecosystem" (2020 - 2025)



This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 869406

**Gracias**

**Gràcies**

**Grazas**

**Eskerrik asko**

**Grazie**

**Merci**

**Obrigado**

**Shukran** شكرا

**Děkuji**

**დიდი მადლობა**

**Thank You**

**Danke**

**Aqualia - casi 45 millones de usuarios de 18 países:**

**Europa: España, Francia, Georgia, Italia, Portugal, República Checa y Rumanía**

**MENA: Argelia, Arabia Saudí, Egipto, Emiratos Árabes, Omán, Qatar**

**America Latina: Colombia, Chile, Estados Unidos, Mexico, Peru**