Moving towards life cycle thinking by integrating an advanced waste management system for expired food products and used disposable nappies valorization

Konstantina Tsigkou

Chemist, PhD

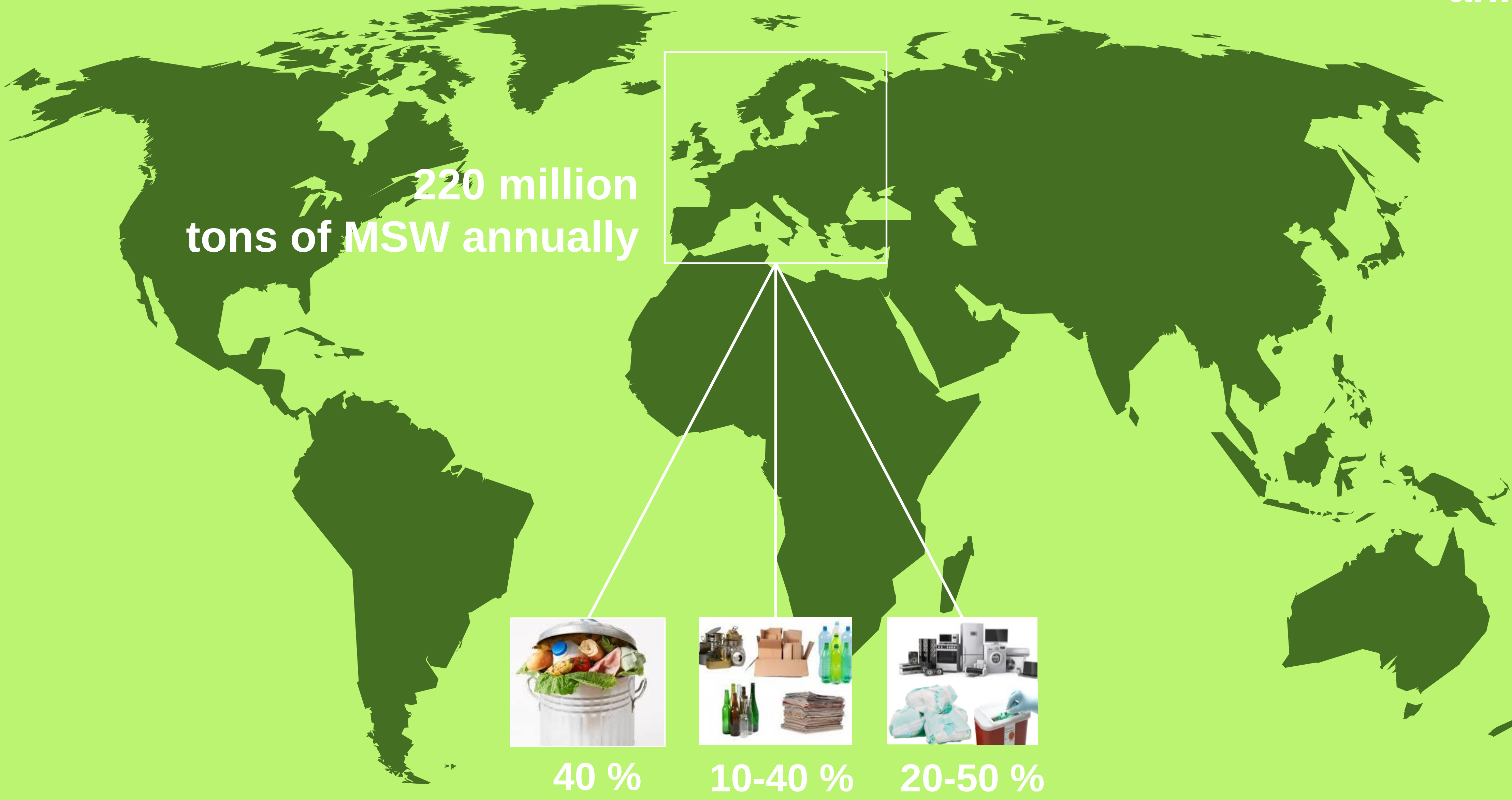
Laboratory of Biochemical Engineering and Environmental Technology

eit.europa.eu | eit-hei.eu | hei@eitrawmaterials.eu

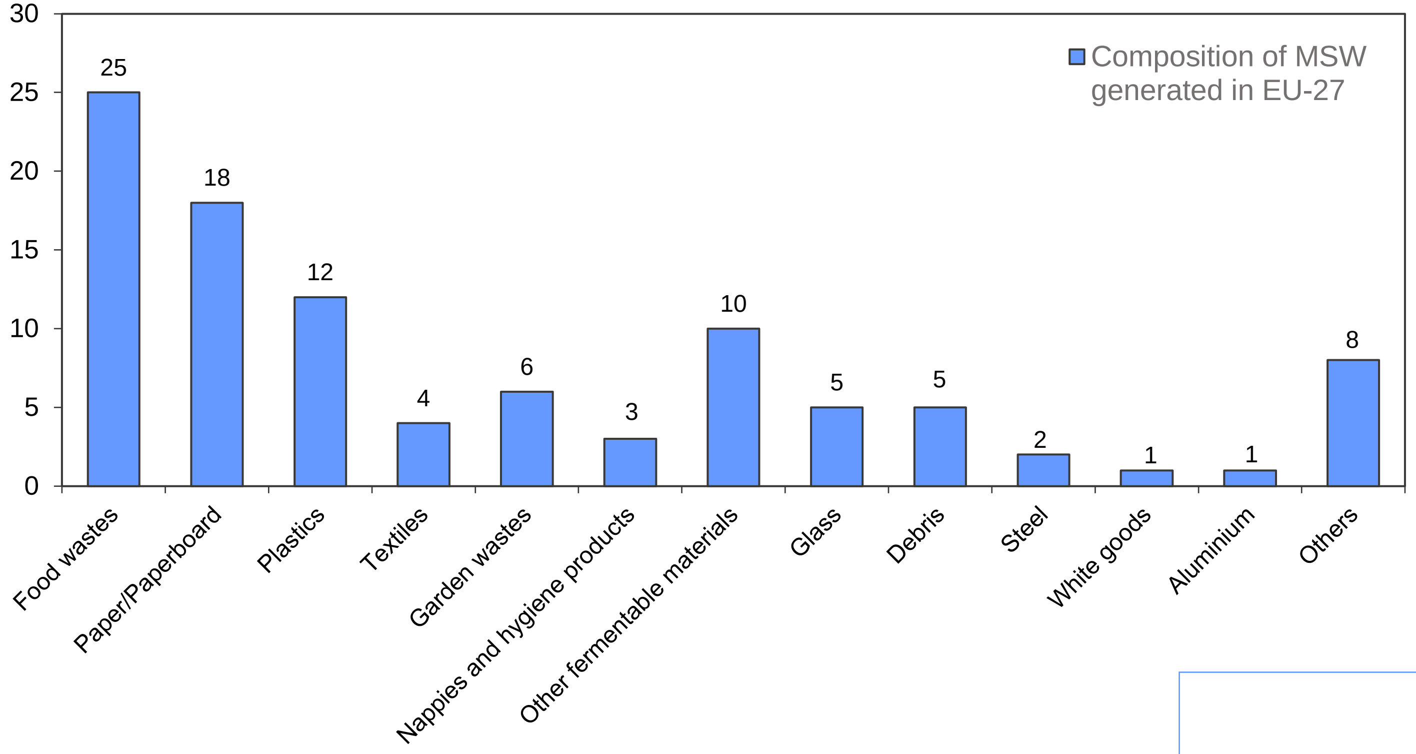
Content

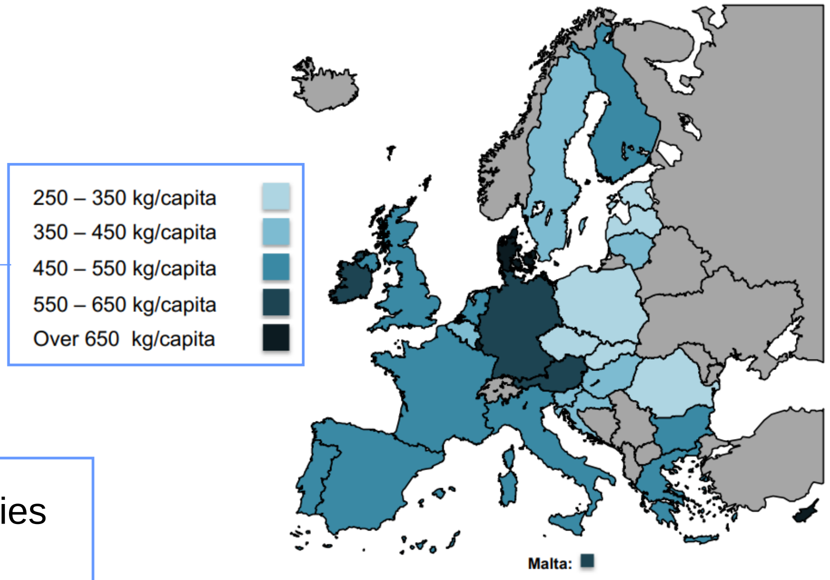
- *MSW: current situation, characteristics, EU & waste management*
- *Description of the proposed processes*
- *Physicochemical characterization of the substrates*
- *FVW-nappies valorization (lab-pilot scale results)*
- *EFP-nappies valorization (lab-pilot scale results)*
- *Valorization of the recovered materials & energy*
- *Conclusion*

2.01 billion tons MSW annually



Municipal Waste Production in EU

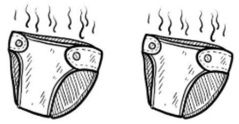




Municipal waste generation per capita

33% of Food Wastes consisted of Expired food Products

Used disposable nappies 2-15%



PROMETHEUS

Food waste

53% Households

Food processing 20%

12% Restaurants

Primary sector 10%

5% Retail & Wholesale stores

Used disposable nappies

2-15 % of SMW

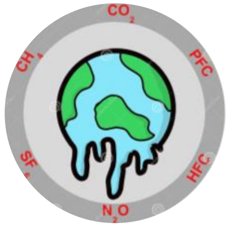
1 child uses

147 kg nappies during the first 2.5 years

Complex structure

Organic material is included

Soil and water contamination



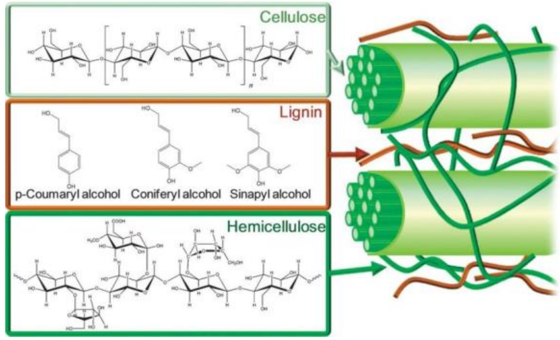
Greenhouse gas emissions

Lack of resources

PROMETHEUS

Fruit and Vegetables

- High carbohydrates concentration
- High moisture content
- Acidic pH



Bread

- High carbohydrates concentration

Meat

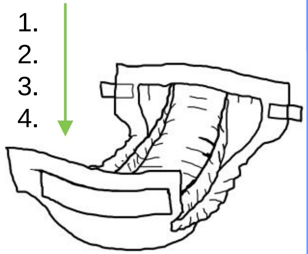
- High concentration of proteins and lipids

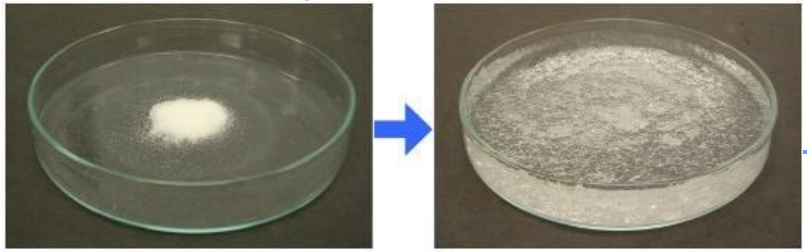
Disposable nappies

Material	%
Fluffy Pulp	36.6
SAP	30.7
Nonwoven	16
Elastics & adhesive tape	10.5
PE	6.2

1. Top-sheet layer next to the skin
2. Acquisition and distribution layer (ADL)
3. Absorbent core layer
4. Backsheet

Adhesives, hydrophobic fibers, elastics, Velcro.





LINEAR ECONOMY

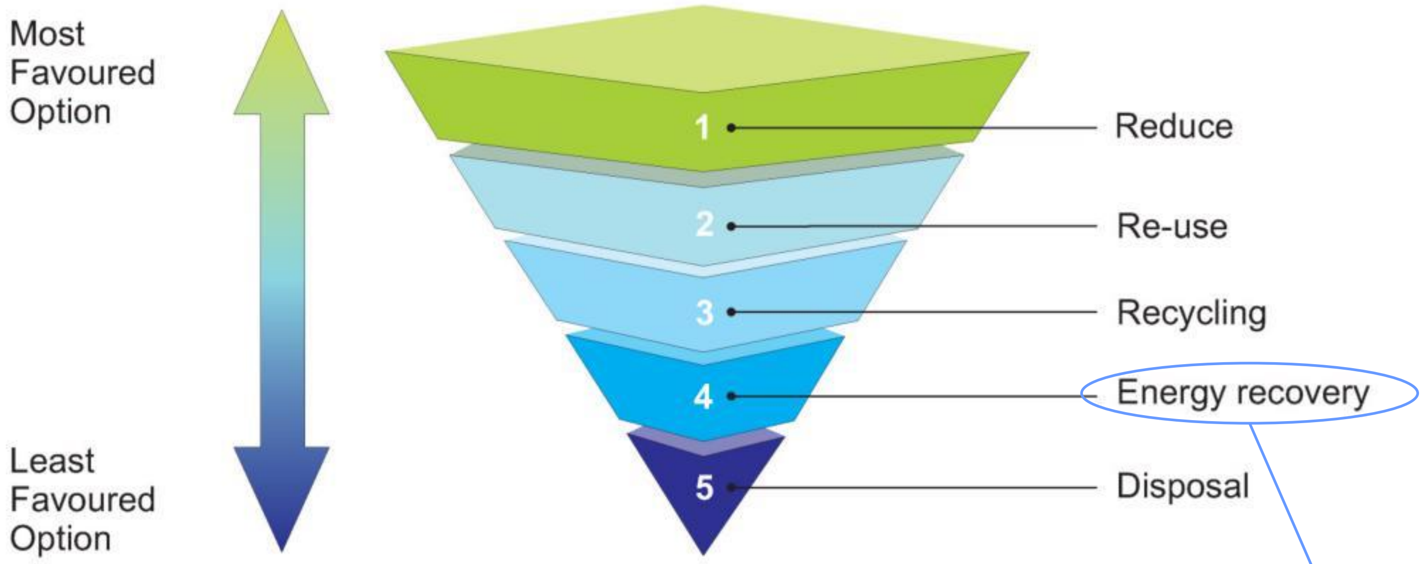
Materials in a **Linear Economy** create waste after use.

vs.

CIRCULAR ECONOMY

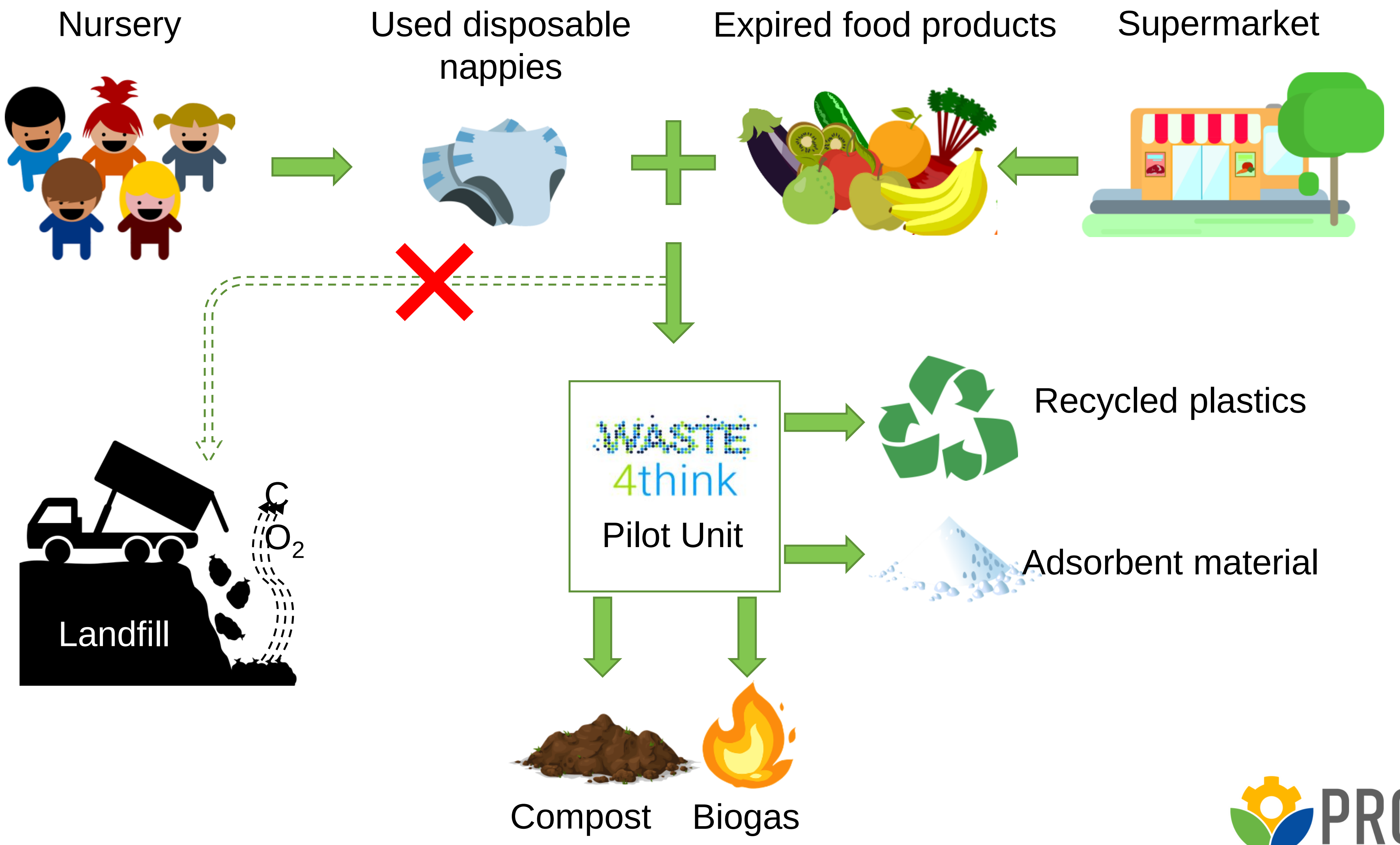
Materials in a **Circular Economy** are collected and reused after each use.

EU and waste management

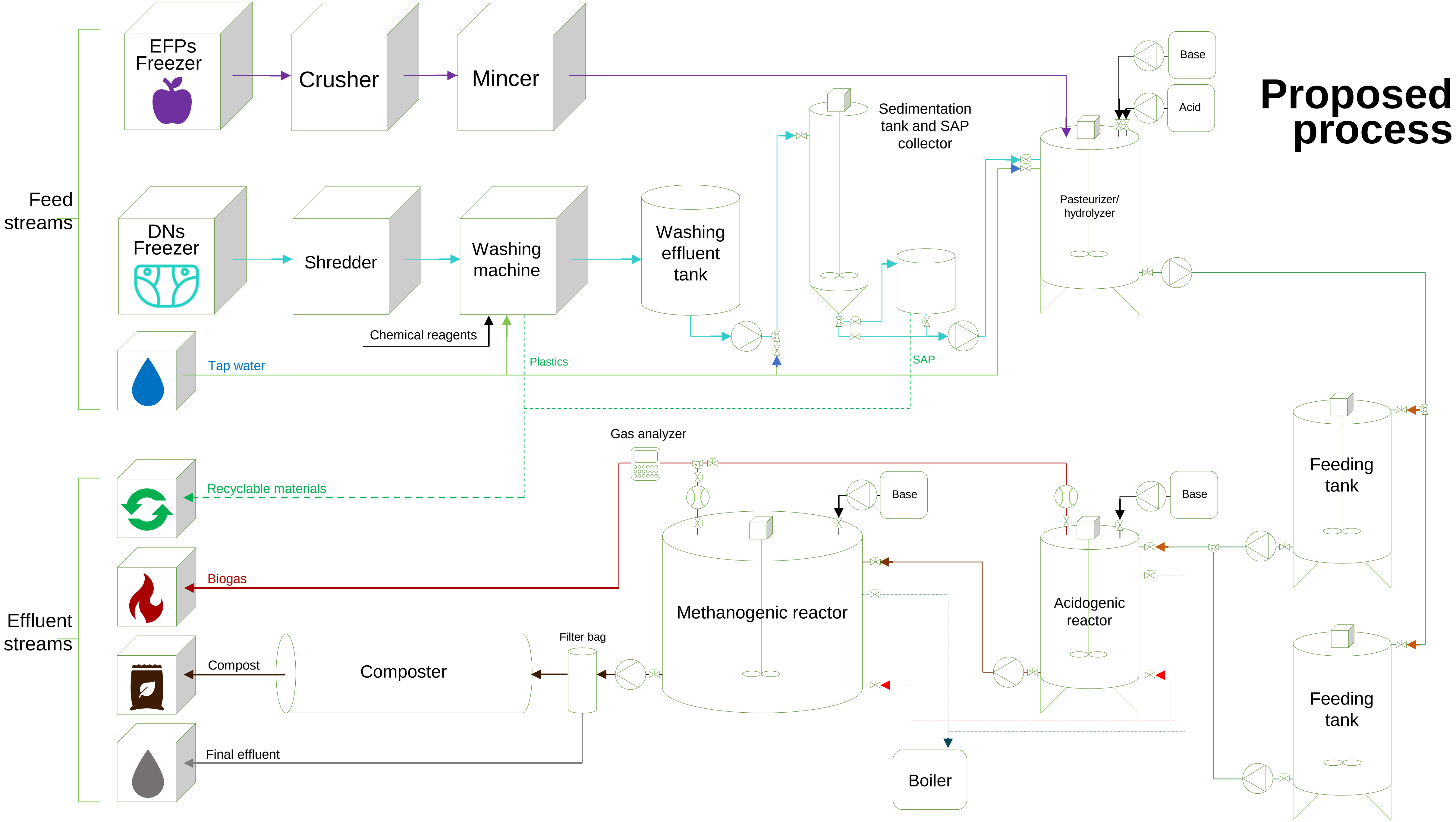


- *Anaerobic Digestion* is widely used for treatment of municipal wastes
- Benefits such as *energy generation* and *greenhouse gas mitigation* are presented

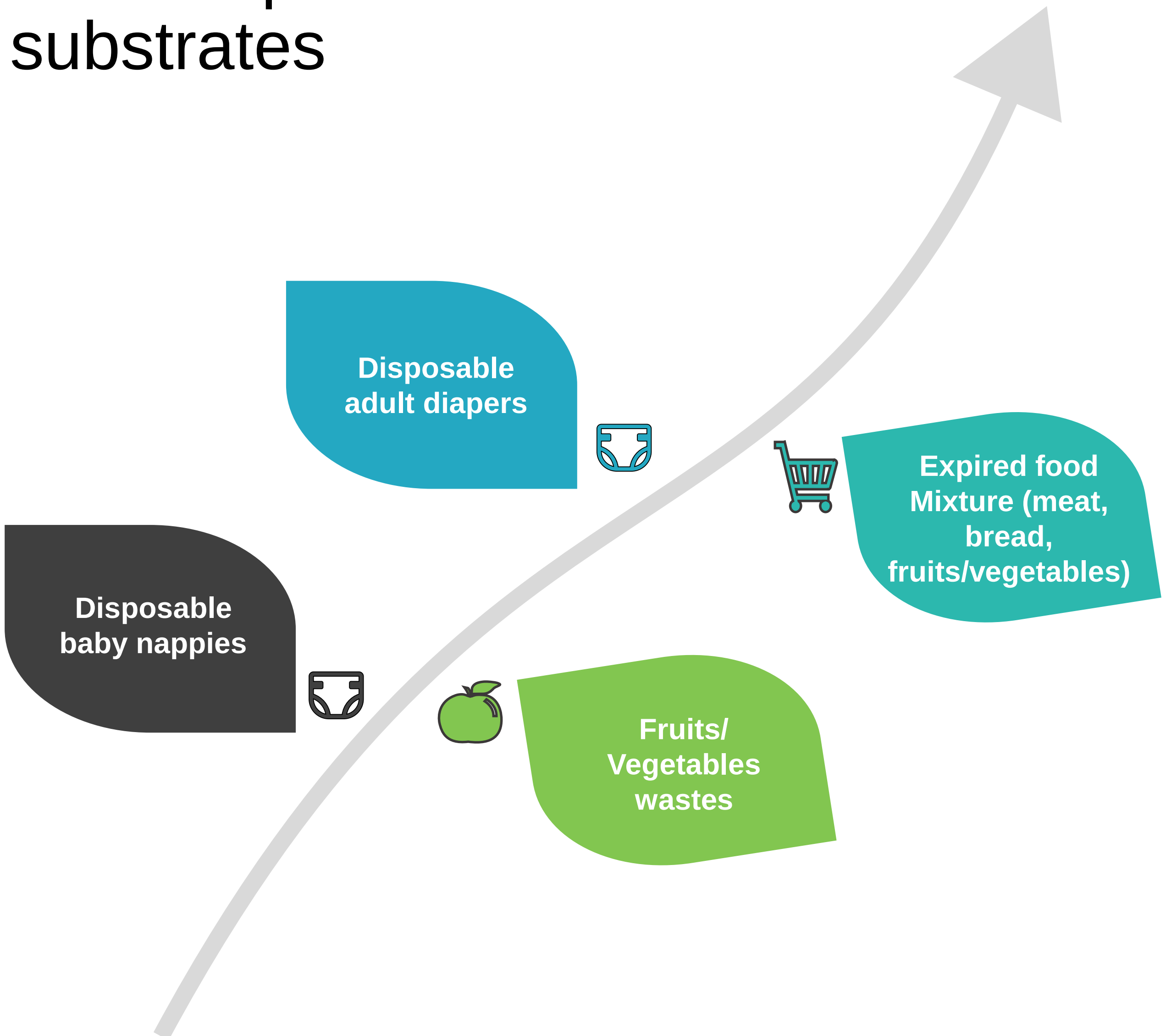
Proposed process



PROMETHEUS


Proposed process
Feed streams
EFPs Freezer
Crusher
Mincer
DNs Freezer
Shredder
Washing machine
Washing effluent tank
Sedimentation tank and SAP collector
Pasteurizer/ hydrolyzer
Base
Acid
Chemical reagents
Tap water
Plastics
SAP
Gas analyzer
Feeding tank
Feeding tank
Base
Base
Methanogenic reactor
Acidogenic reactor
Effluent streams
Recyclable materials
Biogas
Compost
Composter
Filter bag
Final effluent
Boiler

Studied processes and substrates



- *Deswelling optimization of SAP*
- *AD optimization*
- *Continuous AD lab scale reactors*
- *Pilot scale two stage AD*
- *Compost process and maturation*
- *Materials recovery and valorization*

Determination of qualitative, quantitative and physicochemical characteristics

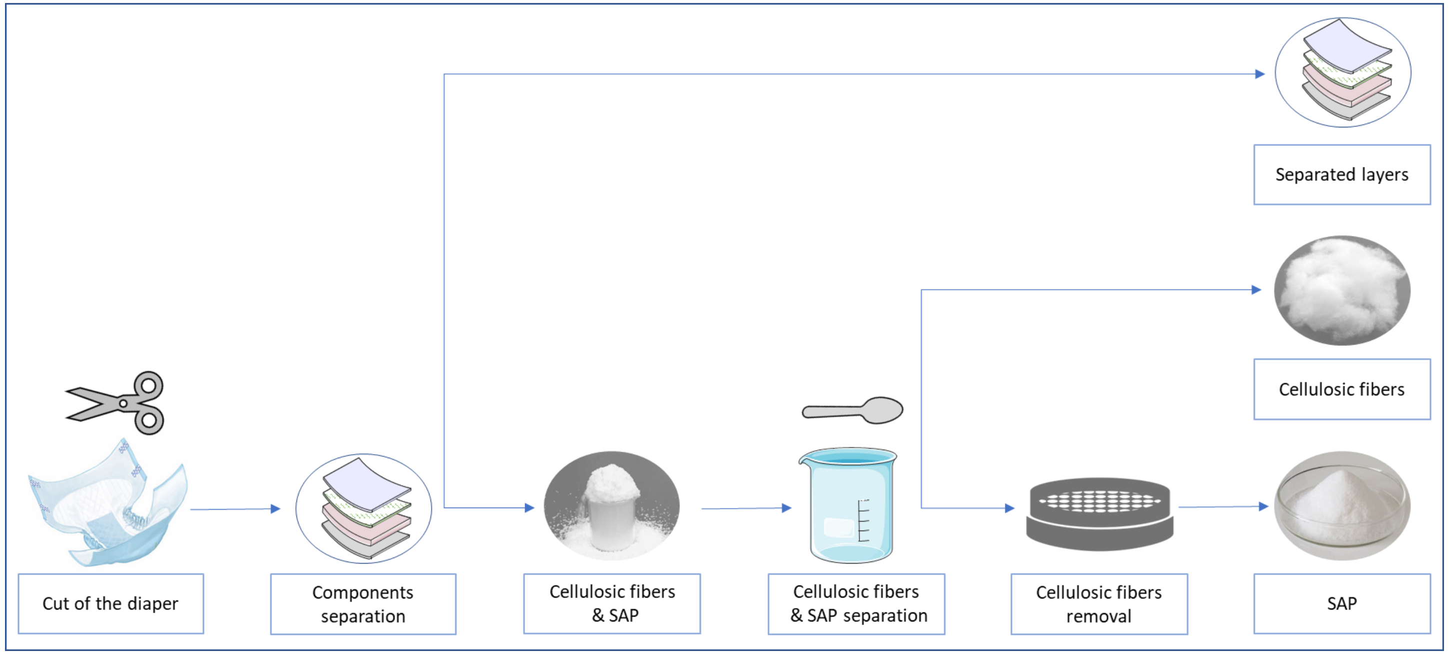
Substrate pretreatment

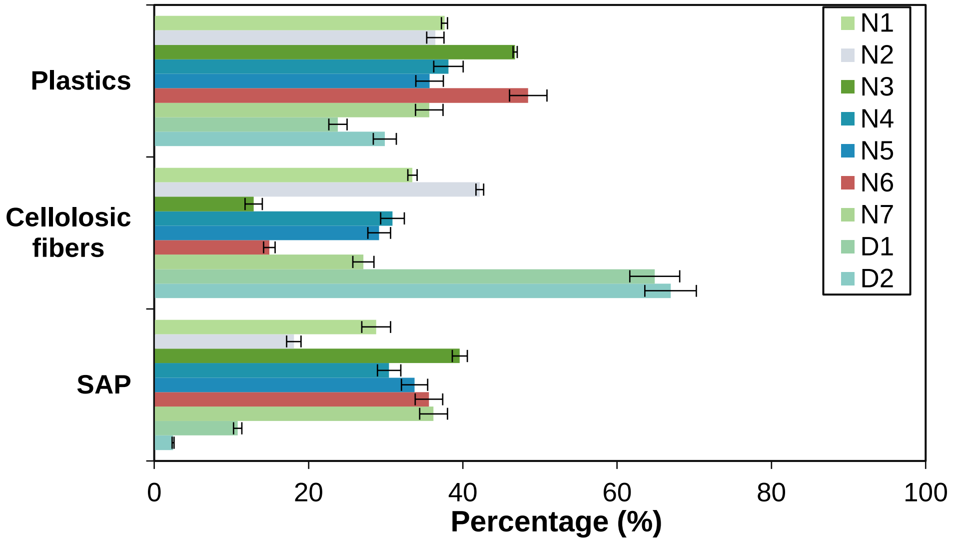
Determination of qualitative, quantitative and physicochemical characteristics

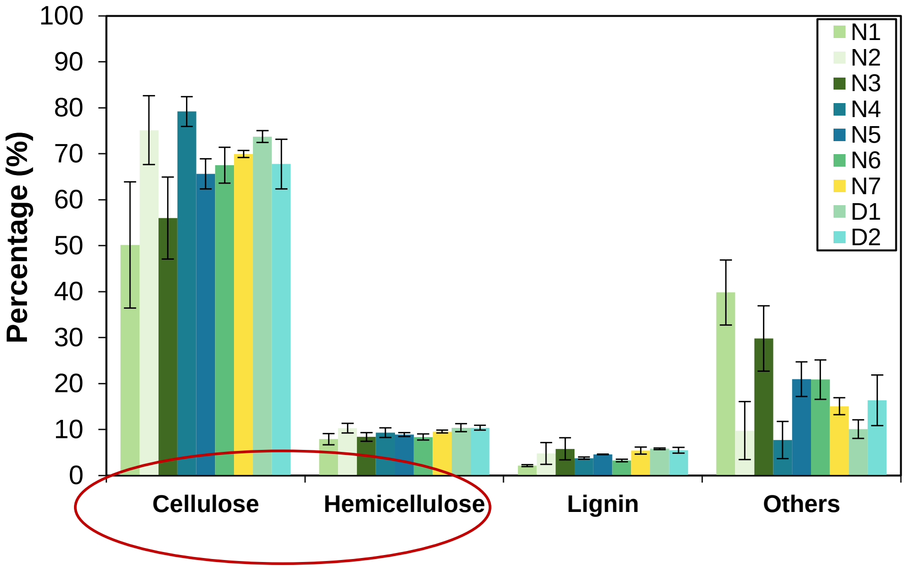
Disposable nappies structure

Substrate pretreatment

Sample	Country	Size	Type
N1	Greece	4+	Baby
N2	Greece	4+	Baby
N3	Greece	5+	Baby
N4	Spain	4	Baby
N5	Spain	4	Baby
N6	Spain	4+	Baby
N7	Spain	4	Baby
D1	Spain	S	Adult
D2	Spain	S	Adult

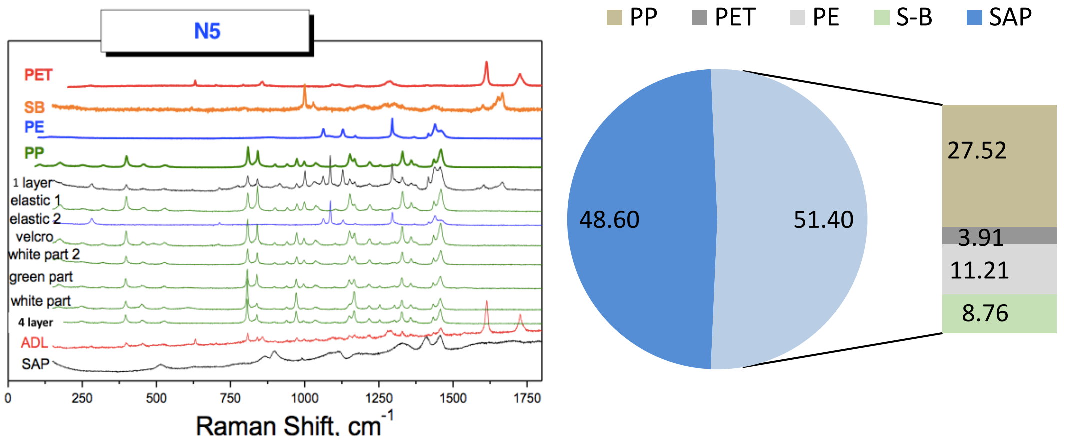


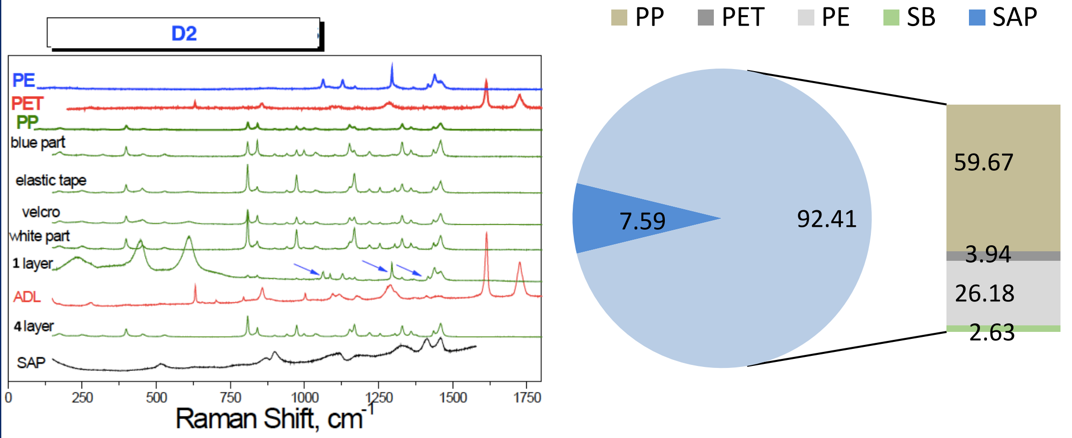




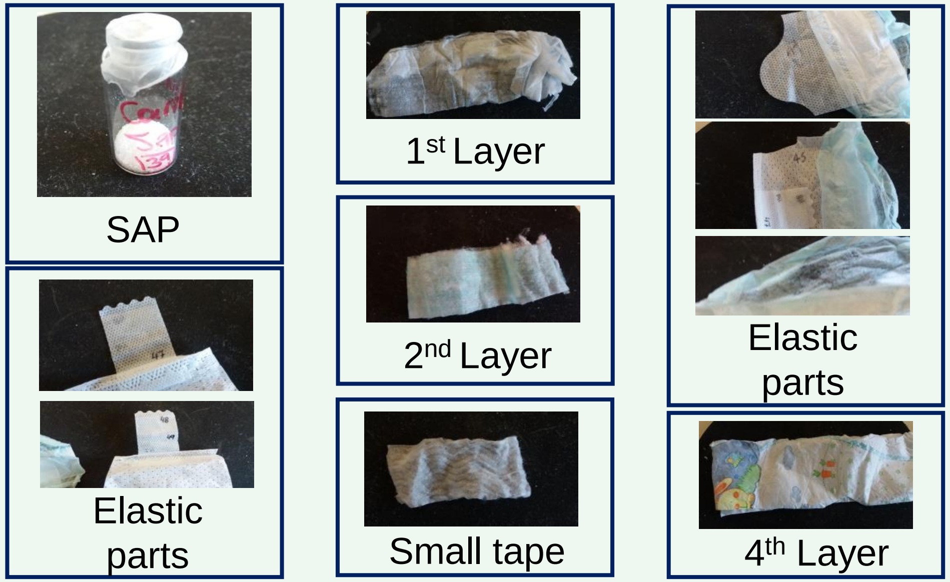
Determination of qualitative, quantitative and physicochemical characteristics

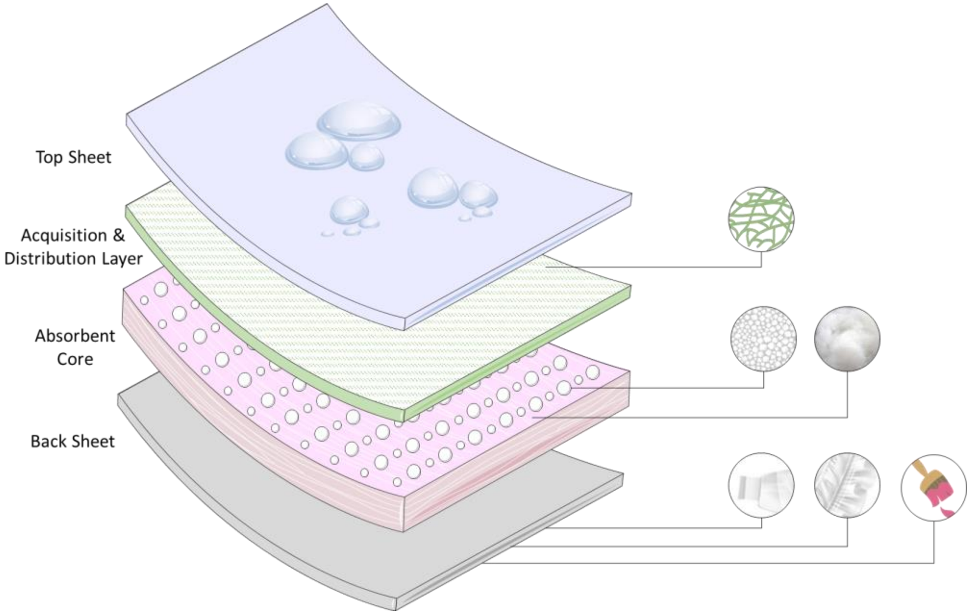
Substrate pretreatment





Samples for qualitative analysis

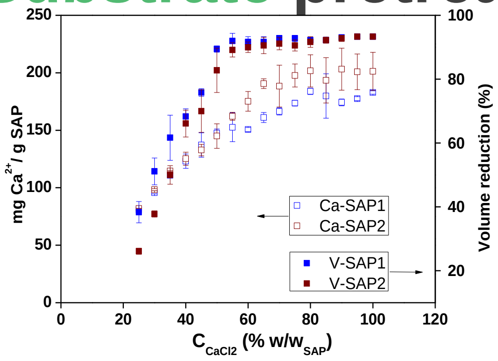


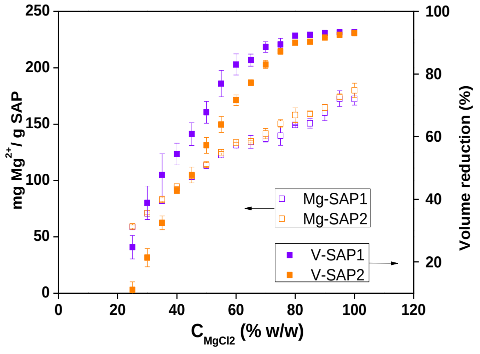


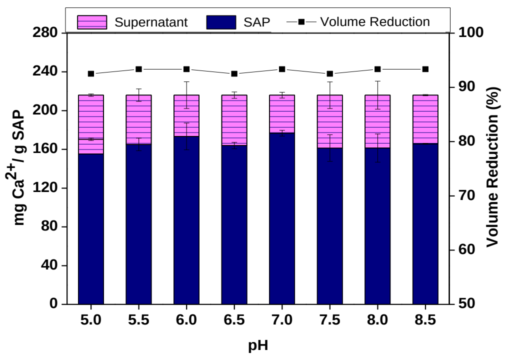
SAP: Adsorption effect

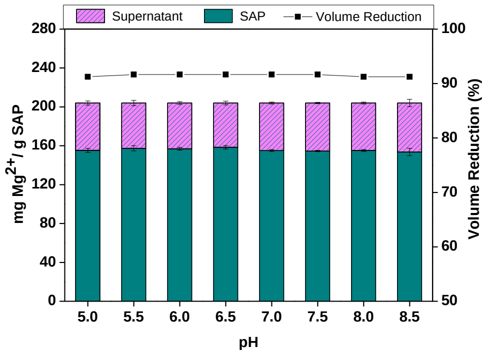
Determination of qualitative, quantitative and physicochemical characteristics

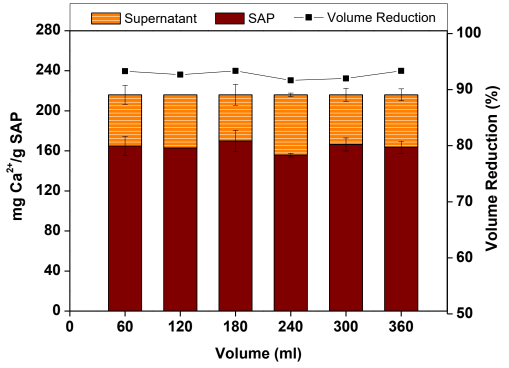
Substrate pretreatment

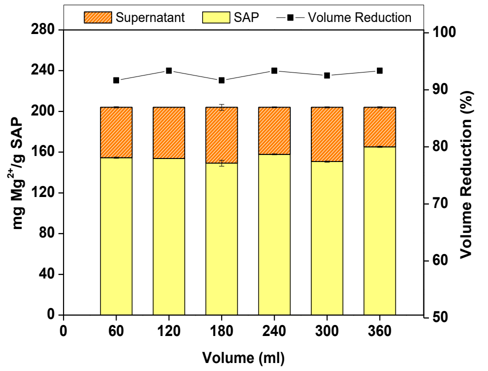


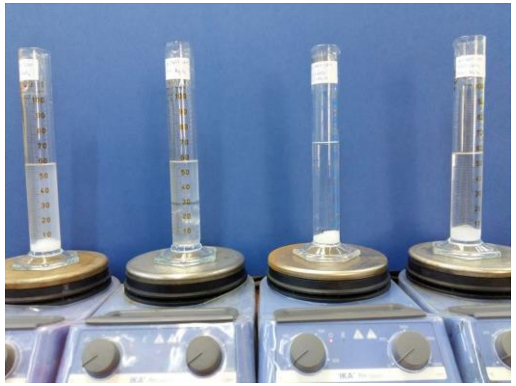




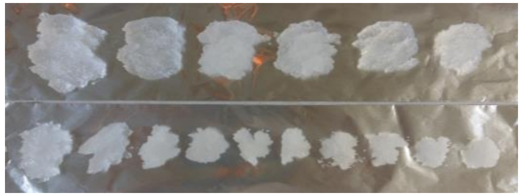








Volume reduction of SAP due to salt concentration increase



Salts mixture tests

Test No	$CaCl_2$ (% w/w SAP)	$MgCl_2$ (% w/w SAP)	V reduction (%) ± SD	Residual concentration: Ca^{+2} (mg/g SAP) ± SD	Residual concentration: Mg^{+2} (mg/g SAP) ± SD	[1]Average cost (€) /nappy
1	20	20	58.3 ± 1.7	3.56 ± 0.66	2.66 ± 0.10	0.045
2	20	40	88.3 ± 0.0	5.10 ± 0.53	5.98 ± 0.30	0.065
3	20	60	92.8 ± 1.0	10.18 ± 0.98	22.46 ± 0.55	0.086
4	20	80	93.3 ± 0.0	15.72 ± 1.66	33.81 ± 1.87	0.106
5	40	20	91.1 ± 1.0	21.21 ± 5.68	4.85 ± 0.18	0.069
6	40	40	93.3 ± 0.0	28.07 ± 3.55	11.09 ± 0.45	0.090
7	40	60	93.3 ± 0.0	42.17 ± 6.49	30.68 ± 1.26	0.110
8	40	80	92.8 ± 1.0	29.22 ± 7.10	34.95 ± 1.35	0.130
9	60	20	91.1 ± 1.0	40.31 ± 3.88	8.36 ± 0.57	0.094
10	60	40	91.9 ± 0.5	58.14 ± 3.41	22.39 ± 1.24	0.114
11	60	60	91.7 ± 0.0	39.98 ± 5.75	33.35 ± 3.24	0.135
12	60	80	92.5 ± 0.8	73.49 ± 4.58	42.26 ± 2.30	0.155
13	60	50	93.1 ± 0.5	40.00 ± 1.30	27.32 ± 3.03	0.125
14	40	50	93.2 ± 0.5	35.74 ± 6.48	24.09 ± 2.18	0.100
15	20	50	92.8 ± 1.0	9.61 ± 0.46	16.59 ± 0.87	0.075

[1] An average nappy is consisted of 10 g SAP, cost calculation for industrial chemicals.

Determination of qualitative, quantitative and physicochemical characteristics

Substrate pretreatment

Used baby nappies→ 1:3 tap water
Used adult diapers → 1:10 tap water

Parameter	FVW	EFP	Nappies hydrolysate 1	Nappies hydrolysate 2	Diapers hydrolyzate
	Value (g/kg) ± SD*	Value (g/kg) ± SD*	Value (g/L) ± SD*	Value (g/L) ± SD*	Value (g/L) ± SD*
pH	4.34 ± 0.22	4.9 ± 0.26	7.77 ± 0.04	7.33 ± 0.07	7.37 ± 0.03
t-CHOs	109.20 ± 5.66	183.80 ± 37.20	1.37 ± 0.13	1.47 ± 0.29	3.37 ± 0.21
d-CHOs	84.90 ± 4.76	-	0.24 ± 0.01	0.07 ± 0.01	0.09 ± 0.01
t-COD	124.55 ± 2.89	663.27 ± 86.59	5.87 ± 1.26	4.48 ± 0.95	7.27 ± 0.04
d-COD	72.75 ± 1.33	-	1.51 ± 0.22	0.55 ± 0.05	0.42 ± 0.07
Fats/oils	0.00 ± 0.00	47.00 ± 1.38	0.06 ± 0.01	0.02 ± 0.00	0.02 ± 0.00
TKN	1.29 ± 0.09	3.92 ± 0.42	0.26 ± 0.02	0.15 ± 0.03	0.07 ± 0.01
NH_3-N	0.04 ± 0.00	2.65 ± 0.06	0.26 ± 0.02	0.15 ± 0.02	0.05 ± 0.02
t-P	0.28 ± 0.02	1.24 ± 0.25	0.10 ± 0.02	0.02 ± 0.00	0.09 ± 0.01
d-P	0.23 ± 0.00	-	0.04 ± 0.01	0.01 ± 0.00	0.05 ± 0.00
TSS	32.50 ± 4.44	-	4.45 ± 0.18	4.76 ± 0.81	6.22 ± 0.65
VSS	30.33 ± 3.01	-	4.30 ± 0.32	4.45 ± 0.35	6.00 ± 0.61
TS	92.51 ± 1.96	554.51 ± 58.60	8.07 ± 0.97	5.53 ± 0.15	8.15 ± 0.11
VS	85.92 ± 1.17	509.20 ± 7.13	4.99 ± 0.98	4.82 ± 0.40	7.29 ± 0.11

* Not applicable for pH

Where, CHO: Carbohydrates, TKN: Total Kjeldahl Nitrogen, NH_3-N: Ammonia Nitrogen, P: Phosphorus, TSS/VSS: Total/Volatile Suspended Solids, TS/VS: Total/Volatile Solids

Physicochemical characterization of the final mixtures

Mixture	FVW: Nappies Hydrolyzate	EFP: Nappies Hydrolyzate	EFP: Diapers Hydrolyzate
Ratio	2:3 (v/v)	1:9.5 (w/w)	1:9.7 (w/w)
Parameter	Value (g/L) ± SD*		
pH	5.01 ± 0.30	5.32 ± 0.01	5.40 ± 0.01
t-CHOs	32.30 ± 0.32	24.36 ± 1.55	28.85 ± 2.20
d-CHOs	23.59 ± 2.75	12.85 ± 0.35	7.37 ± 0.18
t-COD	50.27 ± 2.45	46.85 ± 3.34	43.42 ± 3.32
d-COD	33.53 ± 2.43	19.55 ± 1.46	14.49 ± 1.96
Fats/oils	0.00 ± 0.00	4.06 ± 0.28	3.81 ± 0.24
TKN	0.43 ± 0.02	0.57 ± 0.06	0.62 ± 0.12
NH_3-N	0.16 ± 0.03	0.22 ± 0.03	0.25 ± 0.02
t- P	0.19 ± 0.02	0.18 ± 0.01	0.20 ± 0.02
d- P	0.12 ± 0.01	0.10 ± 0.01	0.13 ± 0.01
TSS	13.61 ± 2.15	21.66 ± 1.81	20.54 ± 0.35
VSS	13.17 ± 2.00	20.21 ± 1.12	16.73 ± 0.30
TS	26.70 ± 1.90	52.56 ± 0.67	42.01 ± 0.85
VS	23.20 ± 2.01	48.05 ± 0.74	32.53 ± 0.95

* Not applicable for pH

Determination of qualitative, quantitative and physicochemical characteristics

Substrate pretreatment

Valorization of FVW & Hydrolyzate mixture

Before the process implementation in full scale…

BMP

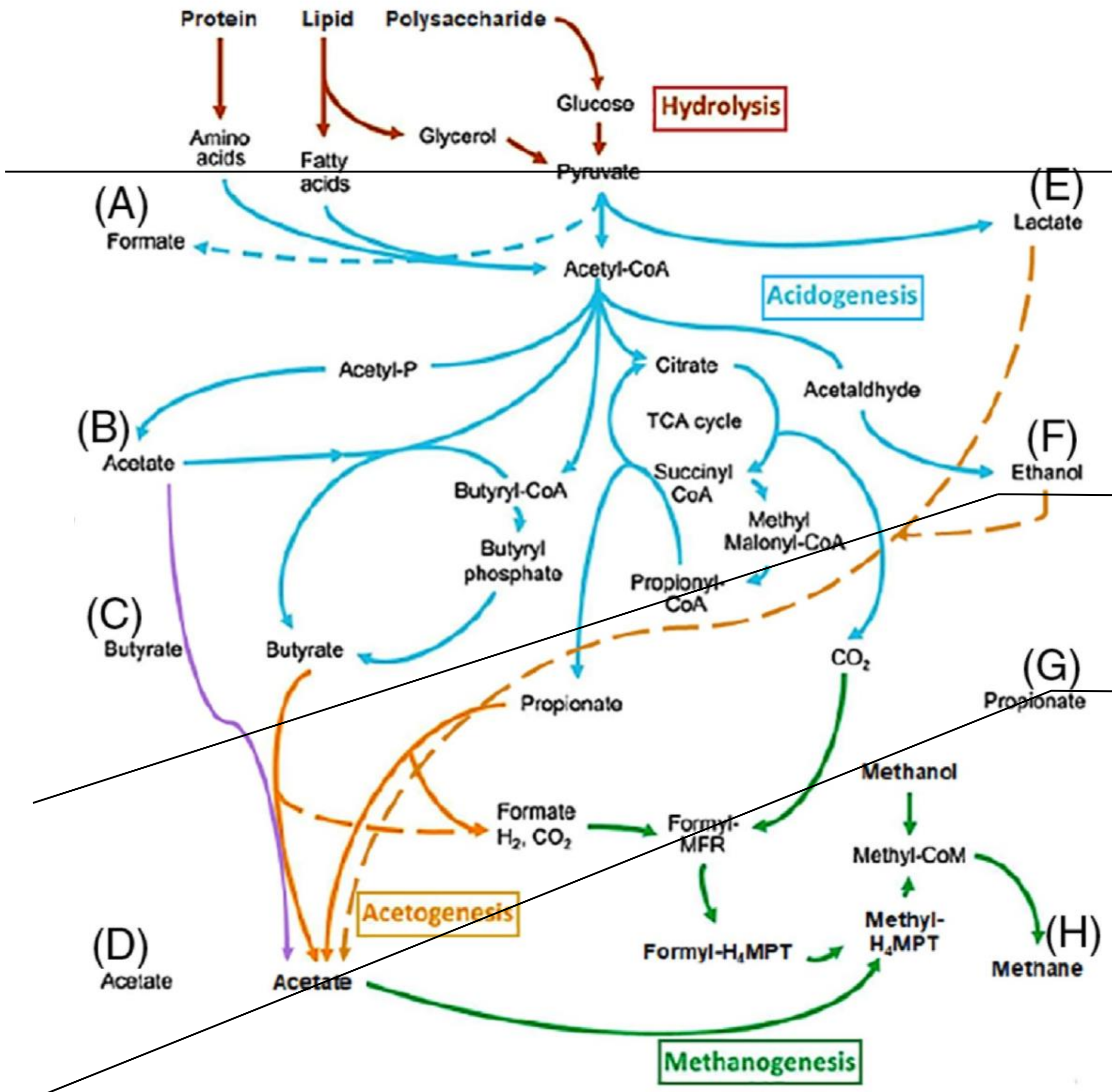
Lab scale tests

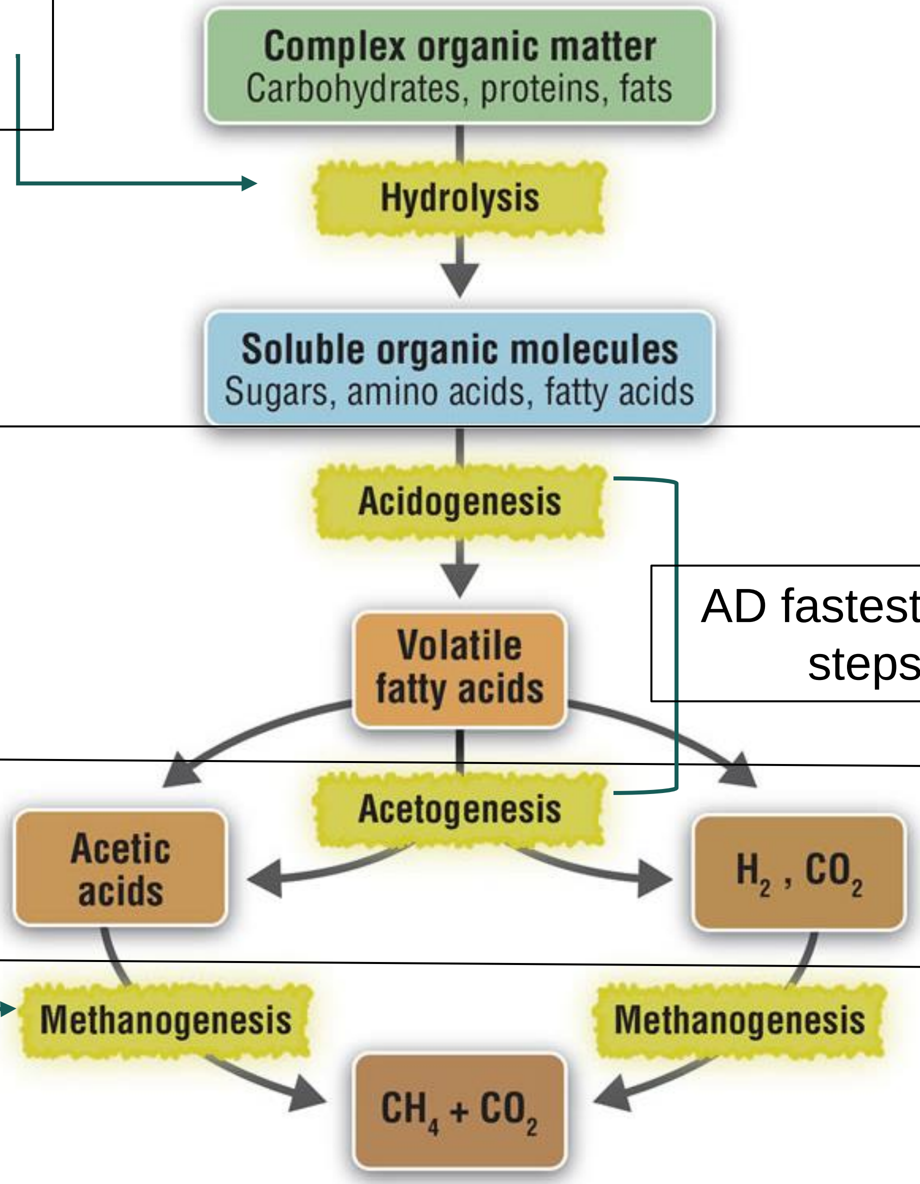
Pilot scale

Anaerobic Digestion (AD) process

Rate limiting step according to literature

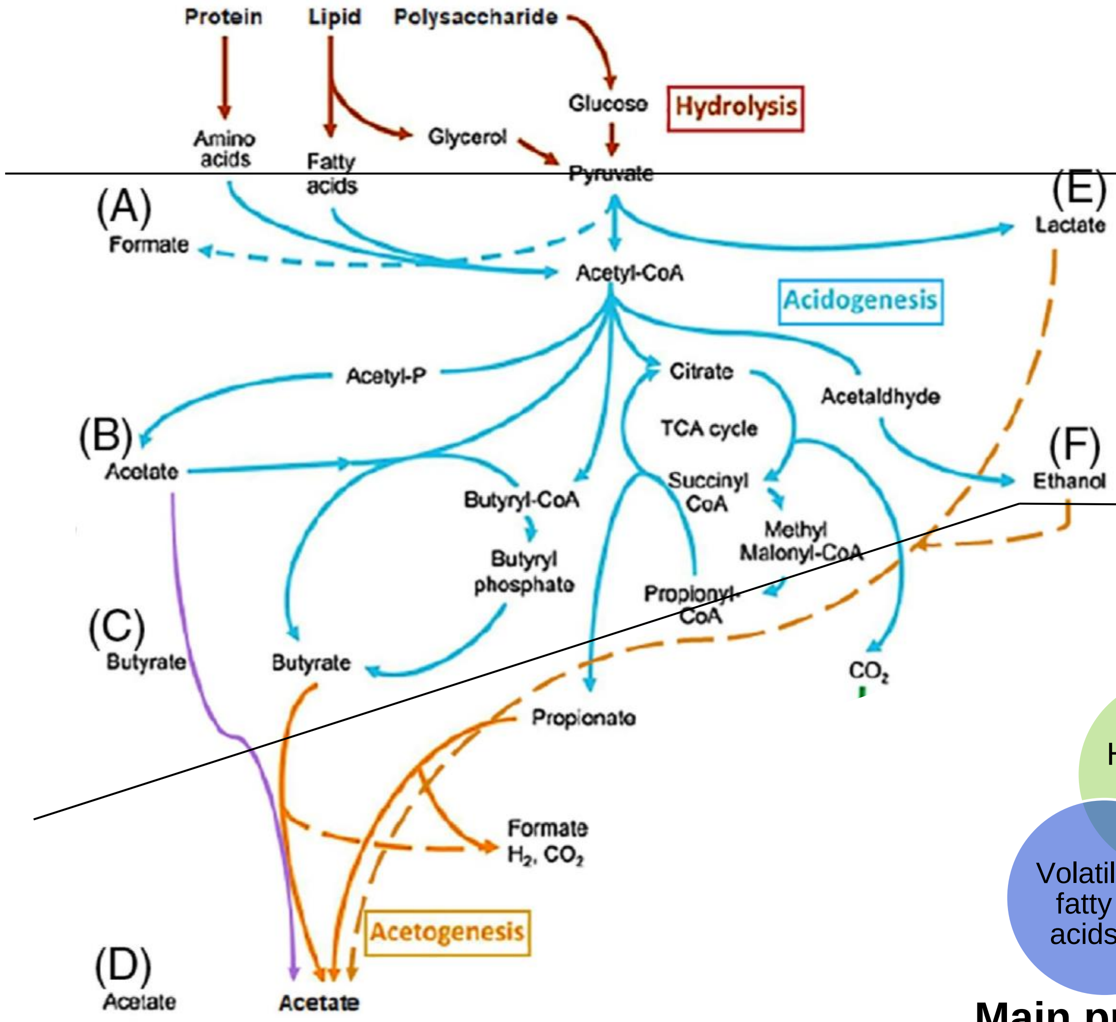
AD fastest steps

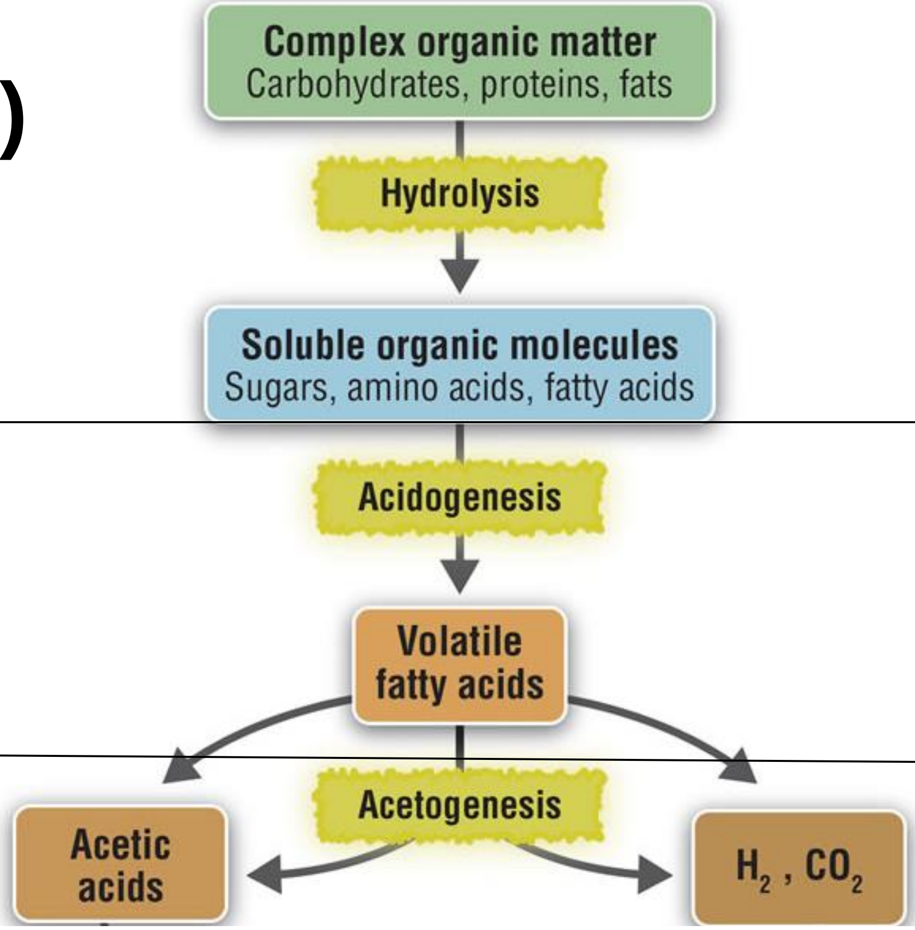


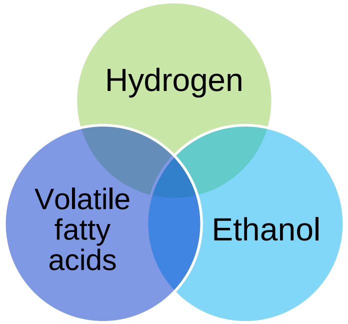


green.BMP

Anaerobic or Dark Fermentation (DF)







Main products of DF

green.BMP

Anaerobic inocula for the processes

A robust anaerobic inoculum is the key to a successful process by providing the abundant bacteria needed for converting substrate to biogas.

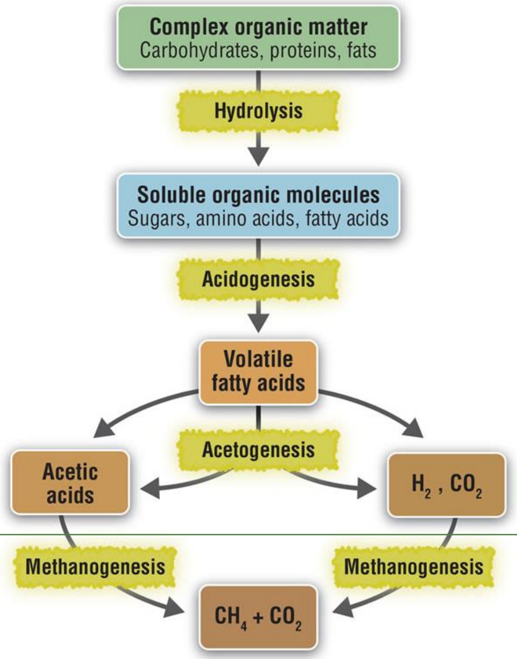
Production of extracellular enzymes from the group of hydrolases (amylases, proteases and lipases) by the hydrolytic bacteria

Acidogenic or acid-producing bacteria

Heat-shock
Acid-pretreatment

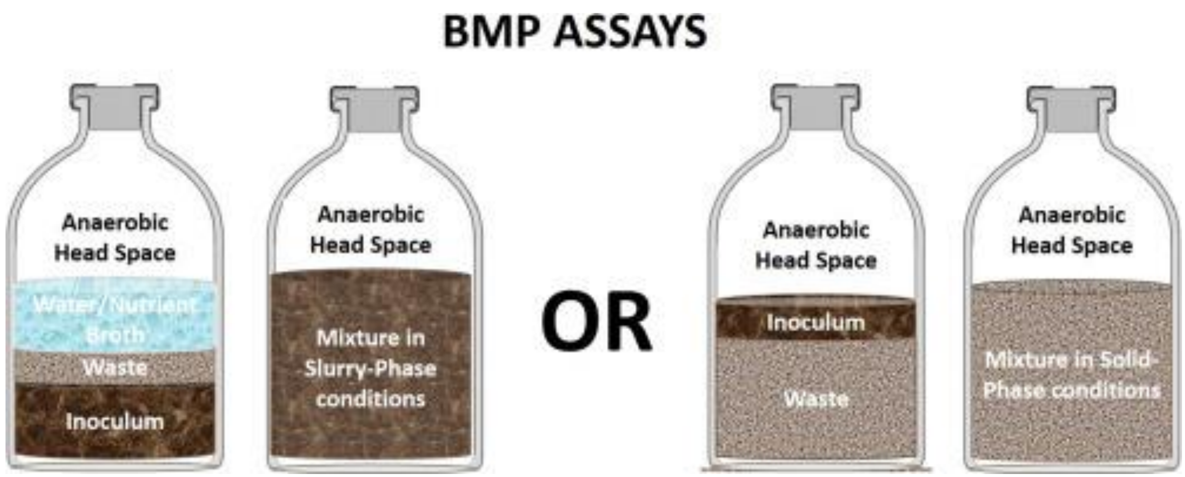
Acetogenic bacteria

Methanogenic archaea



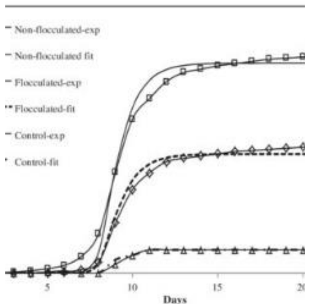
Biochemical methane potential (BMP) assays

BMP is defined as the experimental procedure, developed to estimate the CH_4 production of an organic substrate during its anaerobic degradation



Simple and reliable method

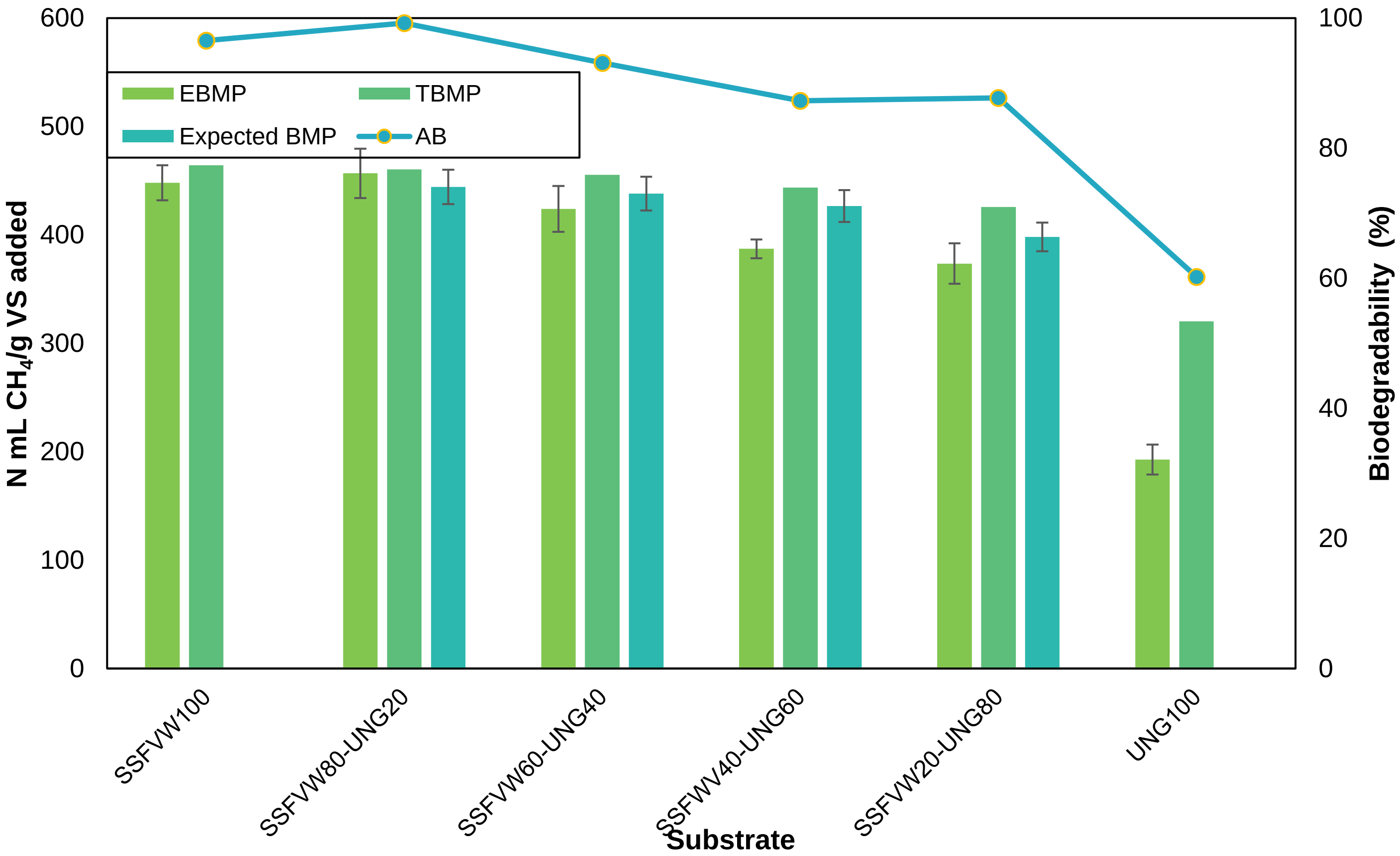
Methane yield estimation and conversion rates of the organic matter



Valuable information about the AD reactors construction and operation

Results
Theoretical BMP calculation and anaerobic biodegradability

$$C_aH_bO_cN_d + \left(\frac{4a - b - 2c + 3d}{4}\right) H_2O \rightarrow \left(\frac{4a + b - 2c - 3d}{8}\right) CH_4 + \left(\frac{4a - b + 2c + 3d}{8}\right) CO_2 + \; d\,NH_3$$



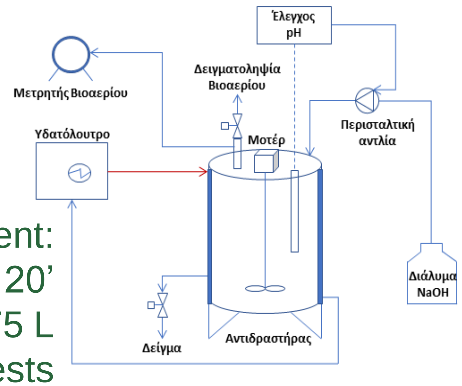
$$Y_{CH4}\left(\frac{mL}{g\ VS}\right) = \left(\frac{\frac{4a + b - 2c - 3d}{8}}{12a + b + 16c + 14d}\right) \cdot V_m \cdot 1000$$

$$\textit{Anaerobic biodegradability (\%)} = \frac{experimental}{theoretical}\ BMP$$

Valorization of FVW & Hydrolyzate mixture

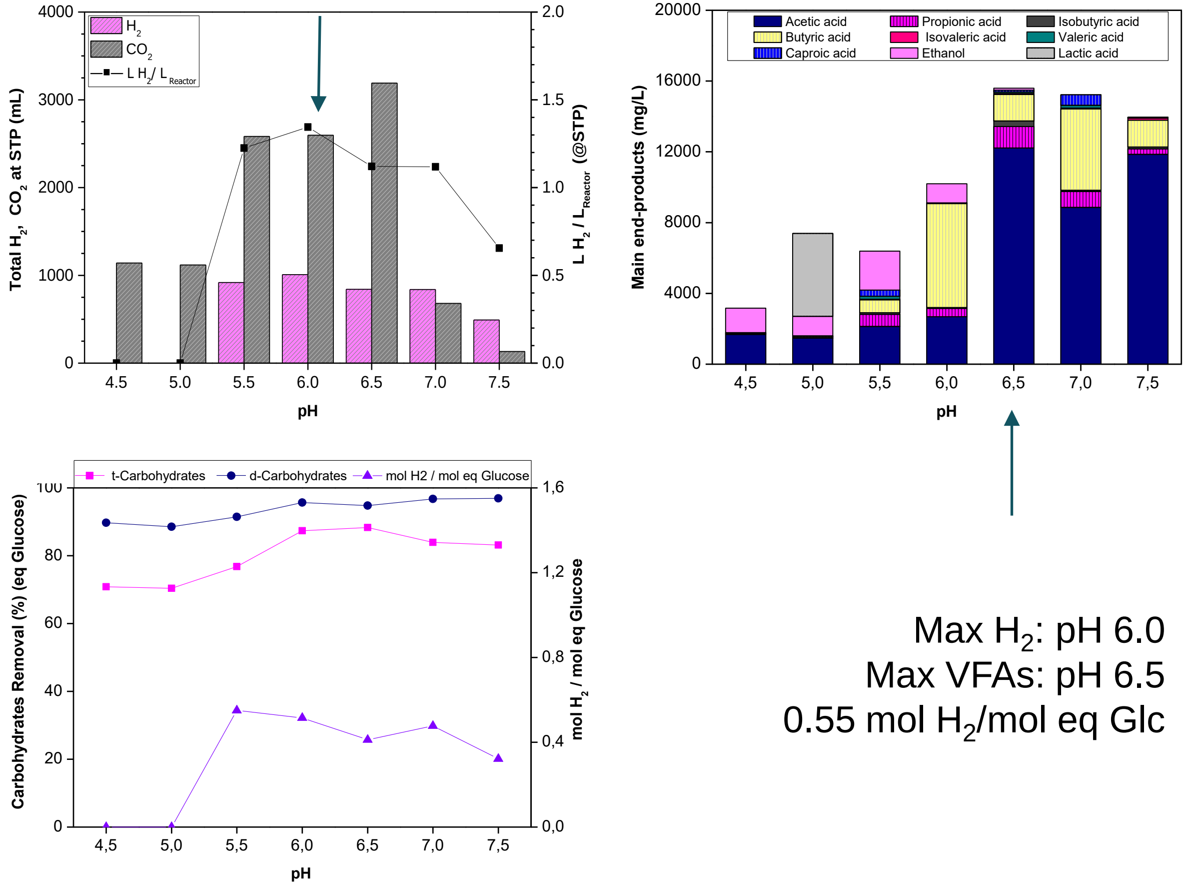
Dark fermentation optimization

(Batch)



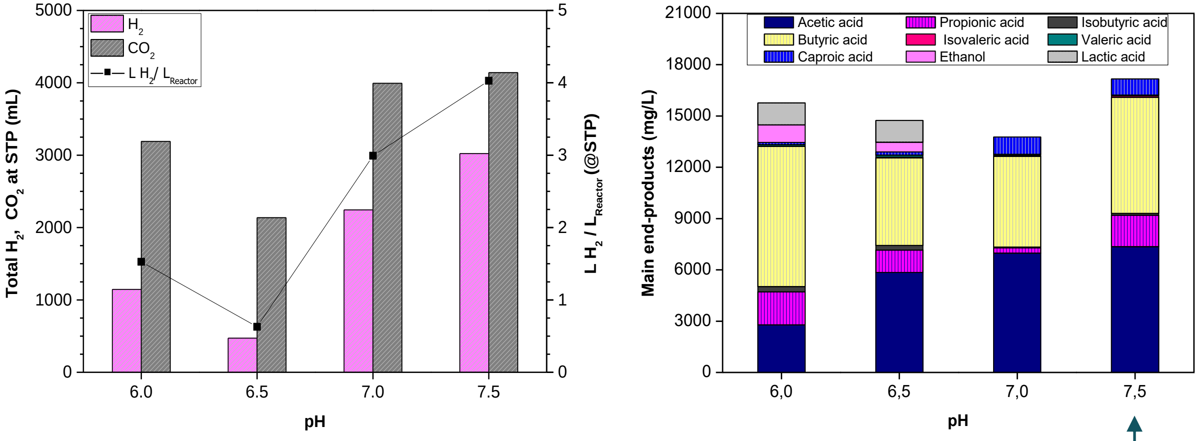
Inoculum pretreatment:
100 ºC , 20’
V: 0.75 L
Batch tests

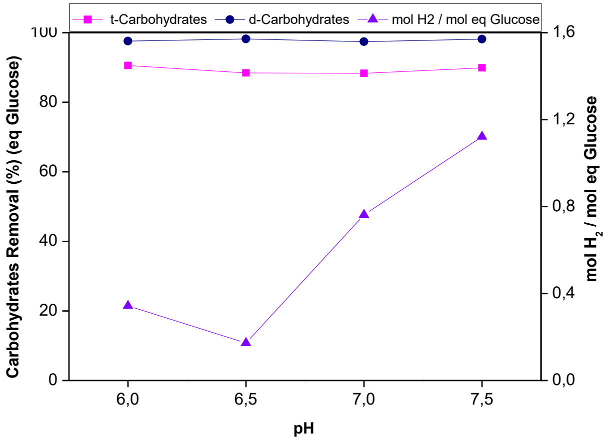
FVW



Max H_2: pH 6.0
Max VFAs: pH 6.5
0.55 mol H_2/mol eq Glc

FVW & Hydrolyzate mixture



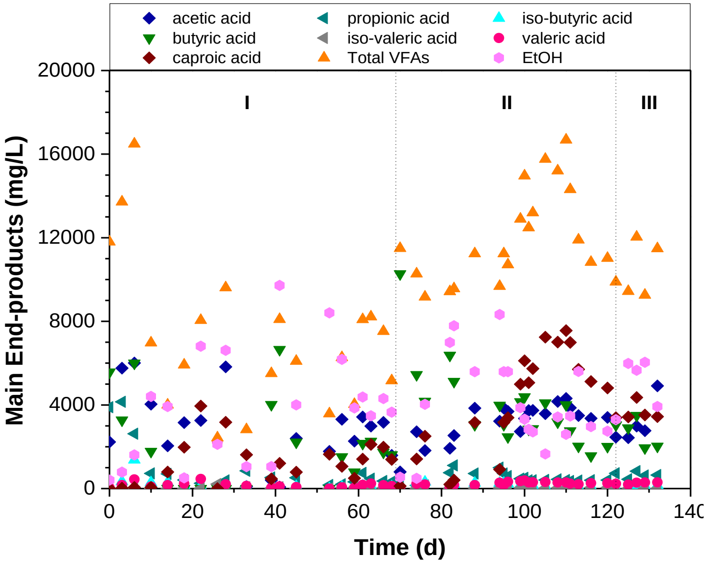


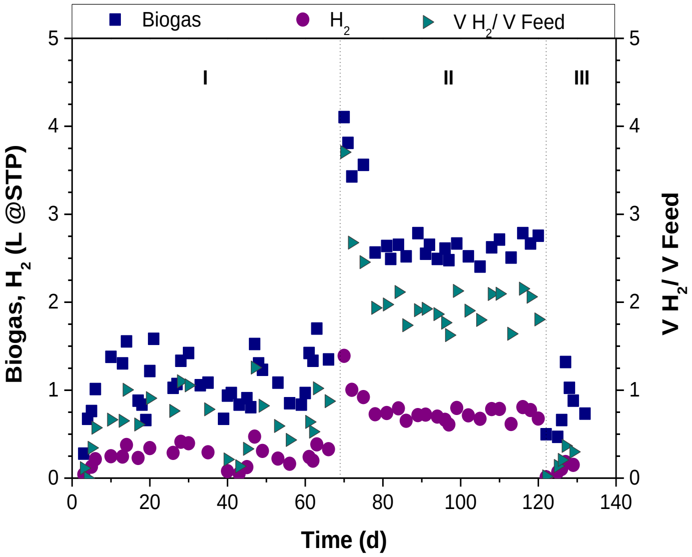
Max H_2: pH 7.5
Max VFAs: pH 7.5
1.12 mol H_2/mol eq Glc

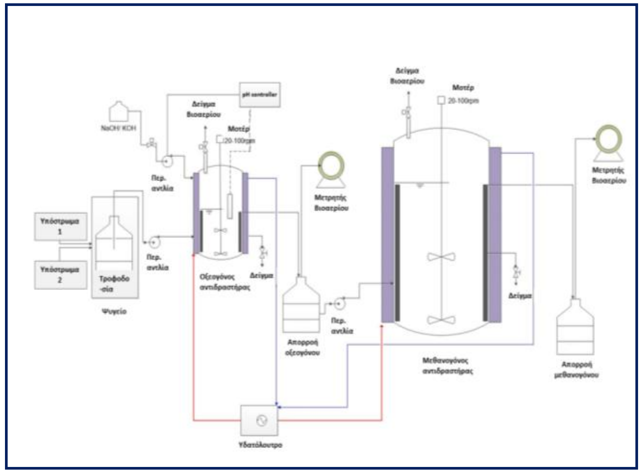
Valorization of FVW & Hydrolyzate mixture

One- and two-stage CSTR lab scale systems:
Acidogenic reactor

Run	I	IIa	IIb	IIc	III	IV
One stage	-	-	-	-	+	+
Two stage	+	+	+	+	-	-
pH of Acidogenic reactor	5.5	6.0	6.0	6.0	5.5	-
HRT (d) of acidogenic reactor	2	2	2	2	1.5	-
HRT (d) of methanogenic reactor	25	25	15	10	-	15
OLR ($kg_{VS}/m^3 \cdot d$) of methanogenic reactor	0.92	0.92	1.54	2.3	-	1.54
OLR ($kg_{COD}/m^3 \cdot d$) of methanogenic reactor	1.75	1.75	3.36	4.60	-	3.36







$V_{acidogenic}$: 0.75 L
$V_{methanogenic}$: 4 L
CSTR

***HRT:** a measure of the average length of time that a compound remains in a constructed bioreactor*

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Valorization of FVW & Hydrolyzate mixture

One- and two-stage CSTR lab scale systems: Methanogenic reactor

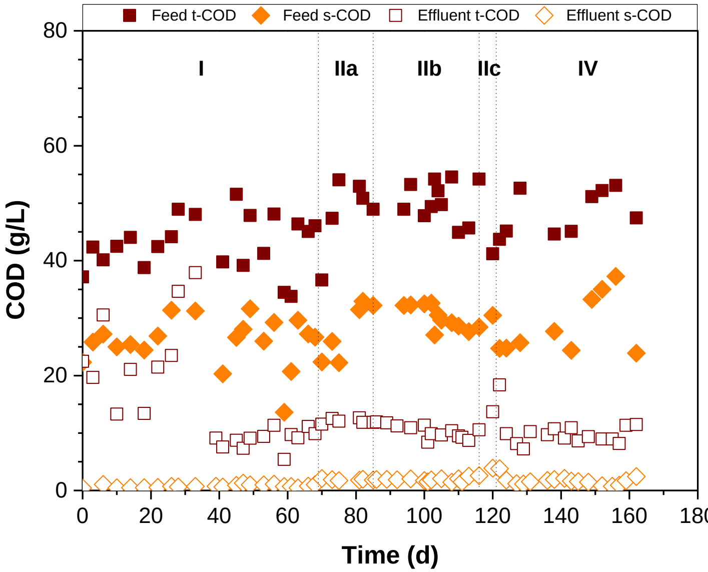
Parameter	Run					F-Value	p-Value
	I	IIa	IIb	IIc	IV		
pH	7.94 ± 0.10 A	7.91 ± 0.13 A	7.84 ± 0.08 A	7.84 ± 0.27 A	7.32 ± 0.19 B	19.13	0.000
t-COD removal %	78.03 ± 3.97 A	76.05 ± 1.19 A	79.95 ± 0.96 A	62.36 ± 4.72 C	69.71 ± 5.14 B	30.98	0.000
d-COD removal %	96.62 ± 1.01 A	93.47 ± 1.01 B	93.45 ± 1.40 B	86.67 ± 2.28 C	95.64 ± 1.95 A, B	40.16	0.000
t-CHO removal %	81.84 ± 9.63 B	77.00 ± 2.76 B	75.84 ± 2.10 B	78.16 ± 0.56 B	93.85 ± 1.15 A	17.77	0.000
CH_4 (%)	63.22 ± 3.44 C	65.63 ± 2.32 B, C	68.11 ± 3.36 B	77.97 ± 1.91 A	55.27 ± 1.95 D	103.46	0.000
$L\ CH_4/L_{feed}$	14.74 ± 0.67 A	14.05 ± 0.69 A	10.89 ± 0.79 B	6.92 ± 0.74 D	9.89 ± 0.29 C	187.46	0.000

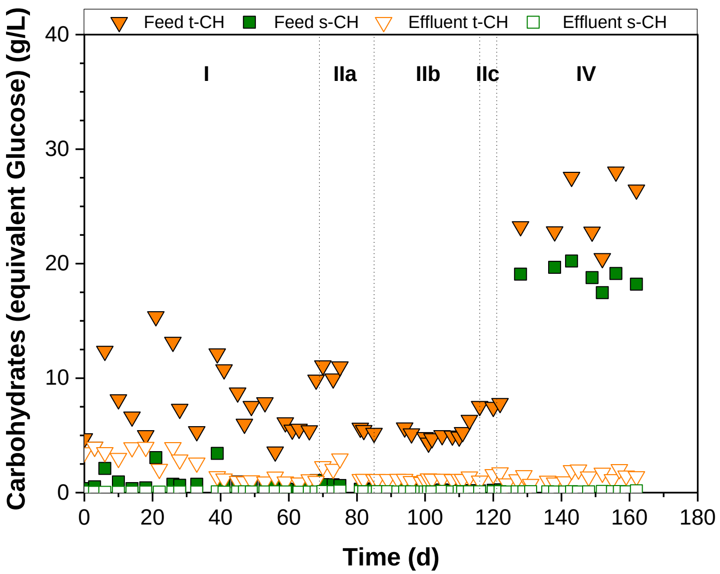
According to Tukey's post hoc test, statistically insignificant differences are characterized by the same symbol

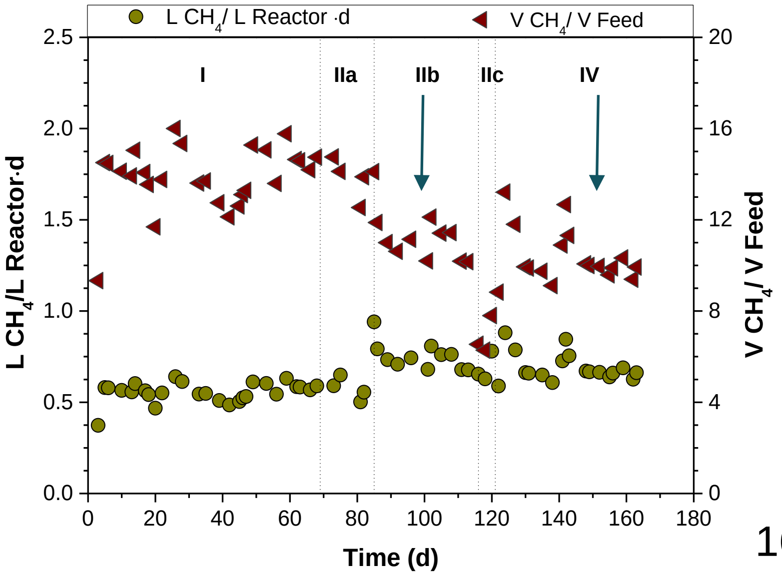
Run	I	IIa	IIb	IIc	III	IV
One stage	-	-	-	-	+	+
Two stage	+	+	+	+	-	-
pH of Acidogenic reactor	5.5	6.0	6.0	6.0	5.5	-
HRT (d) of acidogenic reactor	2	2	2	2	1.5	-
HRT (d) of methanogenic reactor	25	25	15	10	-	15
OLR ($kg_{VS}/m^3 \cdot d$) of methanogenic reactor	0.92	0.92	1.54	2.3	-	1.54
OLR ($kg_{COD}/m^3 \cdot d$) of methanogenic reactor	1.75	1.75	3.36	4.60	-	3.36

Comparison between one- and two-stage systems

↑ % CH_4
↑ % COD removal
18.4 % higher energy yield







Pilot scale-
Pretreatment stage

Nappies crushing/cutting

Model	Weight [kg]	Capacity [kg/h]
BB-230, BLIK	280	250

Food waste crushing

Model	Weight [kg]	Capacity [kg/h]
PG400, MEGALAB SA	520	300

Food waste milling

Model	Weight [kg]	Capacity [kg/h]
JMS 130, MEGALAB SA	330	400

Pilot scale-
Separation of nappies constituents' stage

- Conventional washing machine
- Separation of SAP and cellulosic fibers
- Pasteurization
- Pump

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Pilot scale-
AD stage (Acidogenic reactor)

- Feeding tanks (2 X 200 L)
- Acidogenic reactor (200 L)
- Monitoring of produced biogas
- Composition analysis of produced biogas

Pilot scale-
AD stage (Methanogenic reactor)

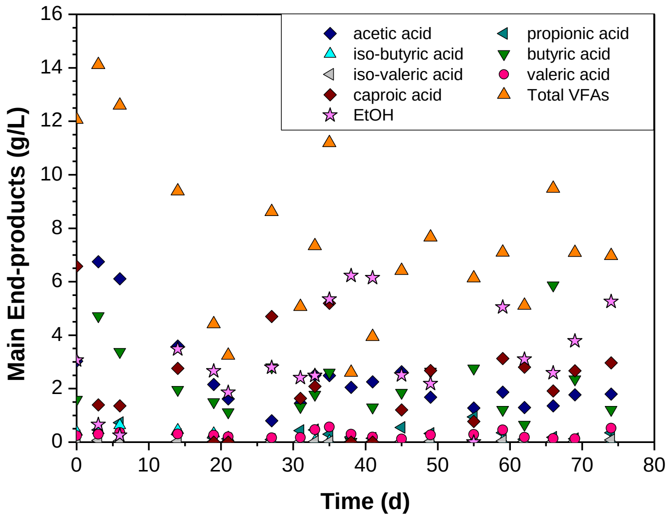
- Methanogenic reactor (2000 L)
- Filterbags

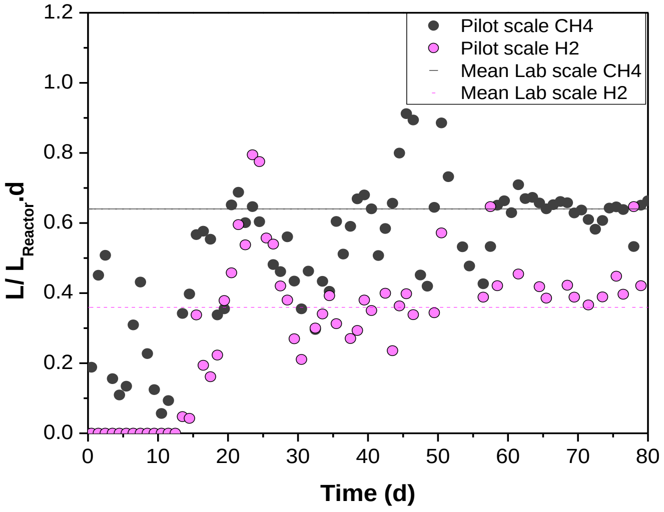
Pilot scale- Storage and combustion unit of biogas

- Biogas storage tanks (temporary storage)
- Biogas compression tank
- Boiler 10 KW
- Fire safety system

Valorization of FVW & Hydrolyzate mixture

Two-stage pilot scale CSTR system

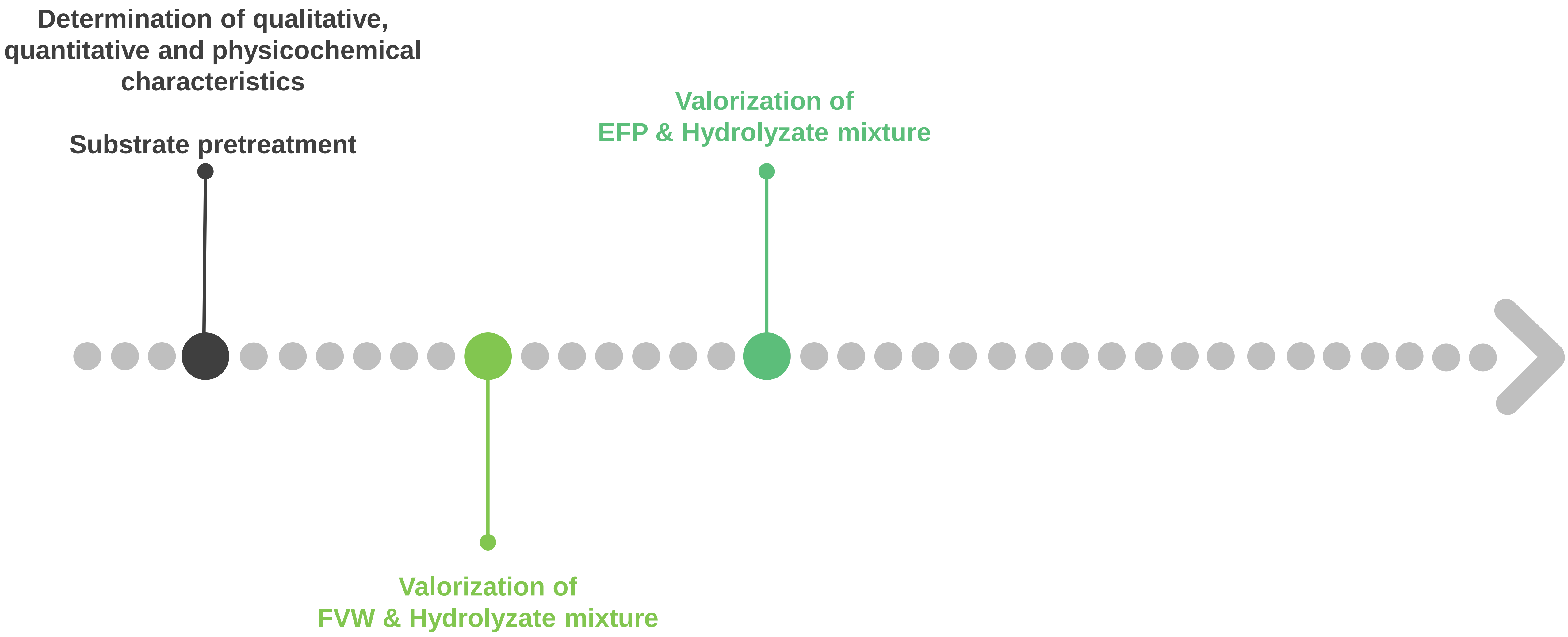




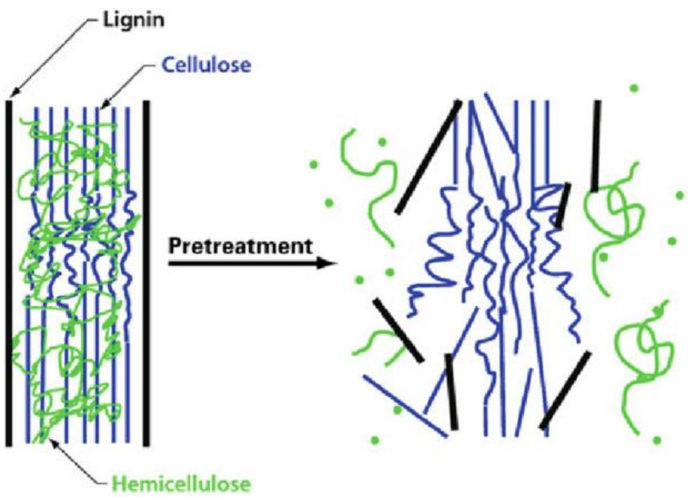
Parameter	Acidogenic reactor	
	Lab scale	Pilot scale
t-COD removal (%)	4.0 ± 1.9	3.1 ± 2.0
d-COD removal (%)	-14.3 ± 5.1**	-10.6 ± 8.4**
t-Carbohydrates removal (%)	77.3 ± 8.7	76.4 ± 9.6
Biogas composition in H_2 (%)	21.5 ± 5.5	30.3 ± 2.3
TSS (g/L)	14.2 ± 2.2	14.3 ± 1.9
VSS/TSS (%)	95.5.0 ± 4.2	93.8 ± 3.6
t-VFAs (g/L)	6.1 ± 1.8	7.0 ± 1.3
EtOH (g/L)	5.9 ± 2.1	3.5 ± 1.2
$L_{H2}/L_{Reactor}.d$	0.36 ± 0.14	0.37 ± 0.09
L_{H2}/L_{feed}	0.72 ± 0.30	0.74 ± 0.17
Na^+ (g/L)	2.4 ± 0.9	1.17 ± 0.30
K^+ (g/L)	3.1 ± 0.8	1.62 ± 0.26

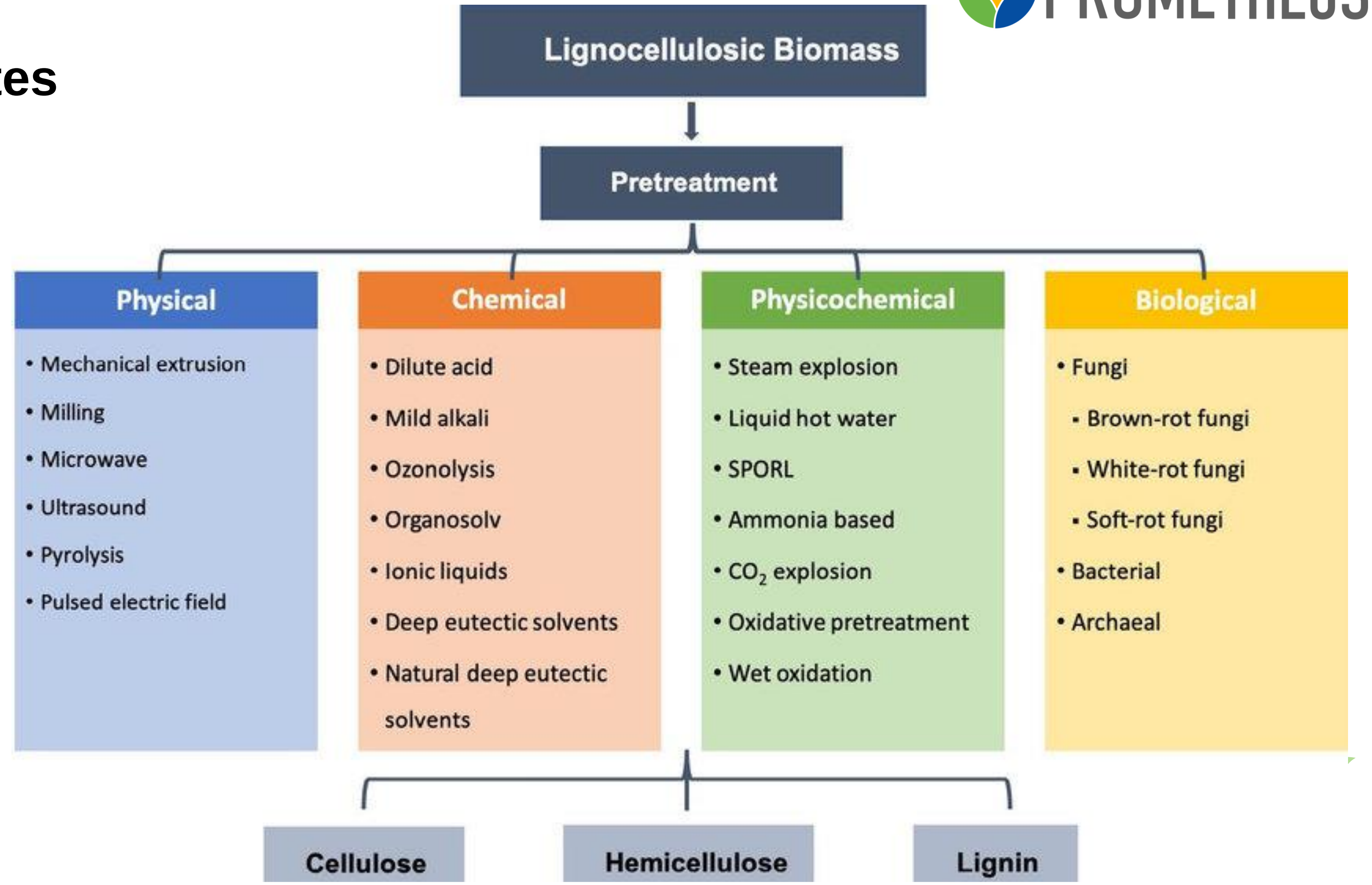
Negative d-COD values indicate solubilization of organic compounds

Parameter	Methanogenic reactor	
	Lab scale	Pilot scale
t-COD removal (%)	77.8 ± 1.6	74.5 ± 4.5
d-COD removal (%)	93.3 ± 1.2	96.4 ± 1.8
t-COD system removal (%)	78.7	75.3
t-COD (g/L)	11.0 ± 1.3	12.7 ± 1.9
t-Carbohydrates removal (%)	78.7 ± 2.3	78.6 ± 6.3
TSS (g/L)	7.11 ± 1.02	8.35 ± 1.2
Na^+ (g/L)	2.7 ± 0.6	1.5 ± 0.2
K^+ (g/L)	3.2 ± 0.4	2.3 ± 0.2
Biogas composition in CH_4 (%)	65.6 ± 2.3	62.8 ± 2.1
$L_{CH4}/(L_{Reactor} \cdot d)$	0.65 ± 0.05	0.63 ± 0.06
L_{CH4}/L_{Feed}	12.63 ± 0.95	12.58 ± 1.17
$L_{CH4}/g_{COD\ Removed}$	0.35	0.35


Determination of qualitative, quantitative and physicochemical characteristics
Substrate pretreatment
Valorization of FVW & Hydrolyzate mixture
Valorization of EFP & Hydrolyzate mixture

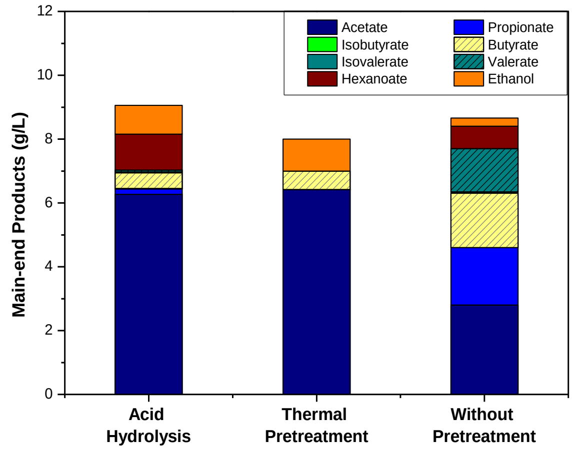
Pretreatment of substrates

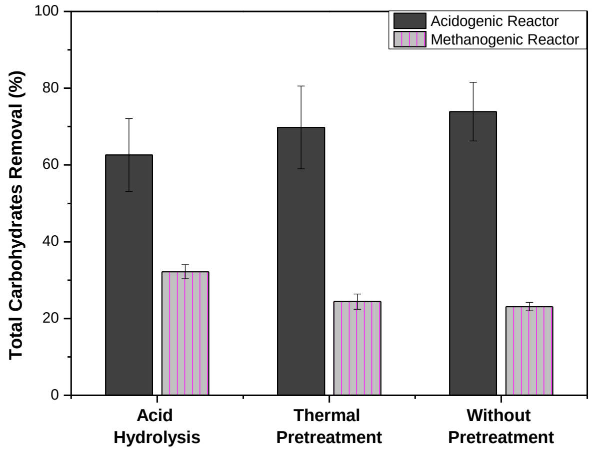


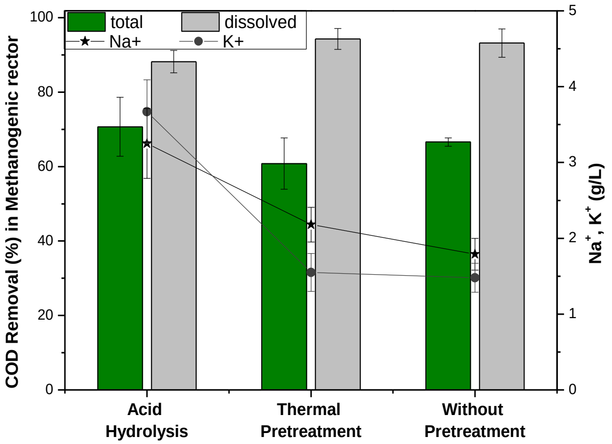


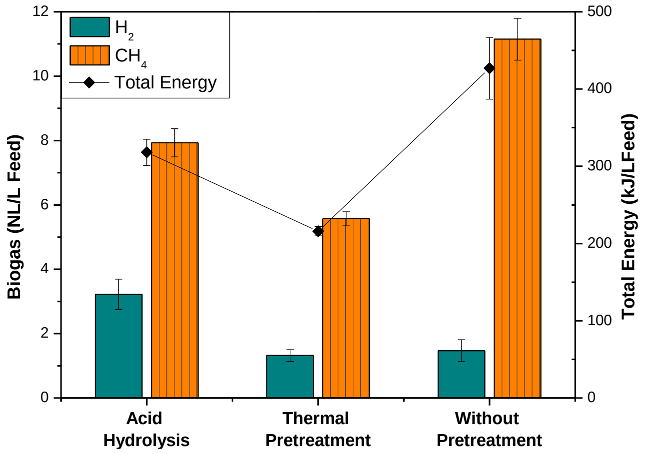
Valorization of EFP & Hydrolyzate mixture

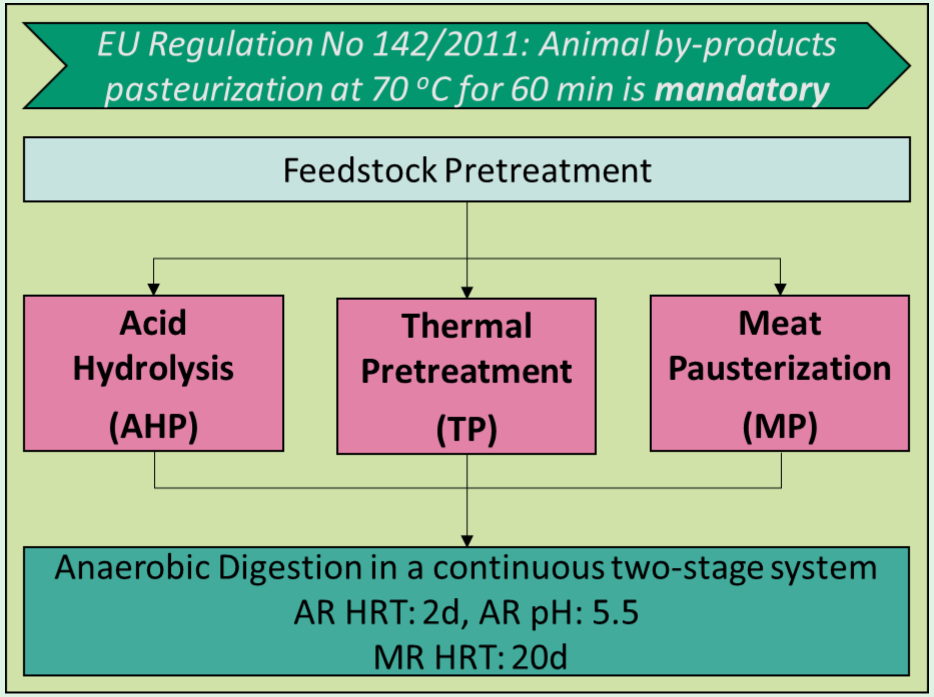
Two-stage CSTR lab scale systems: Pretreatment effect











Double H_2 production during the AHP. Significant different VFAs profile between the tests

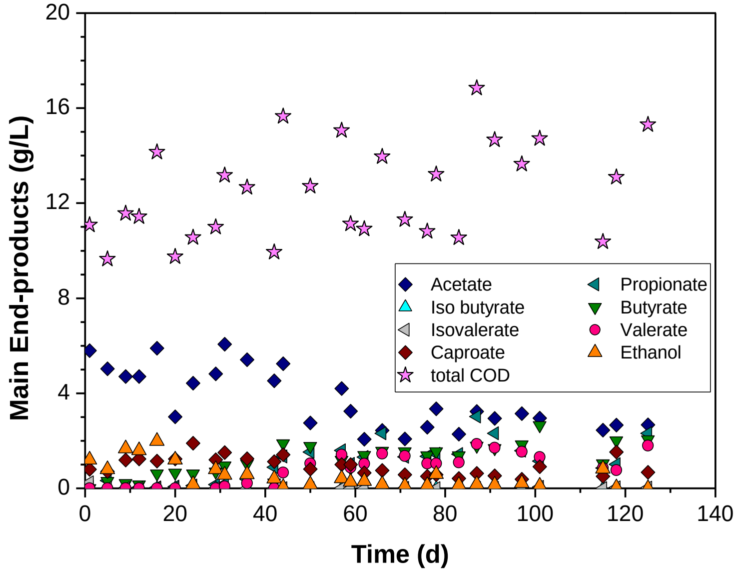
The highest yield was achieved for the case of MP, taking into consideration the overall efficiency of the system

Maximum yield (MP) at 427 kJ/L_{feed}. During the testes of TP and AHP, the recover energy was reduced by 49.4 and 25.5 %.

Valorization of EFP & Hydrolyzate mixture

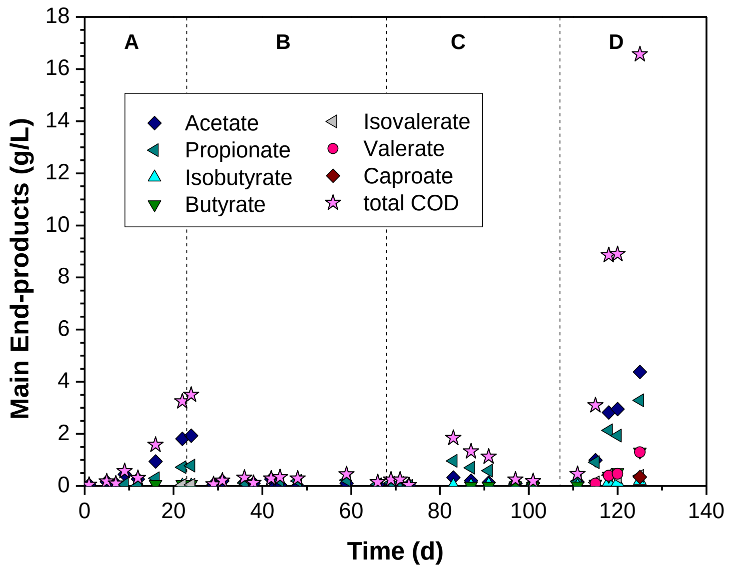
Ac: pH 5.5, HRT 2d
Met: HRT 20, 15, 10.6, 8 d

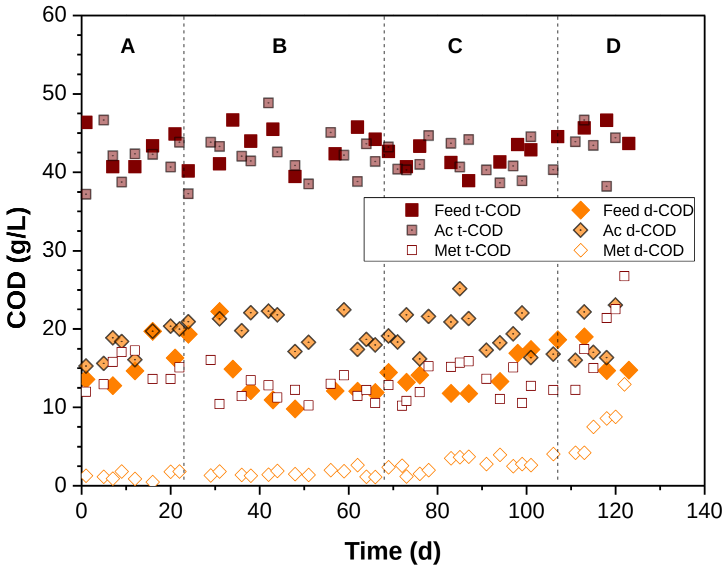
Two-stage (CSTR) lab scale system - HRT reduction

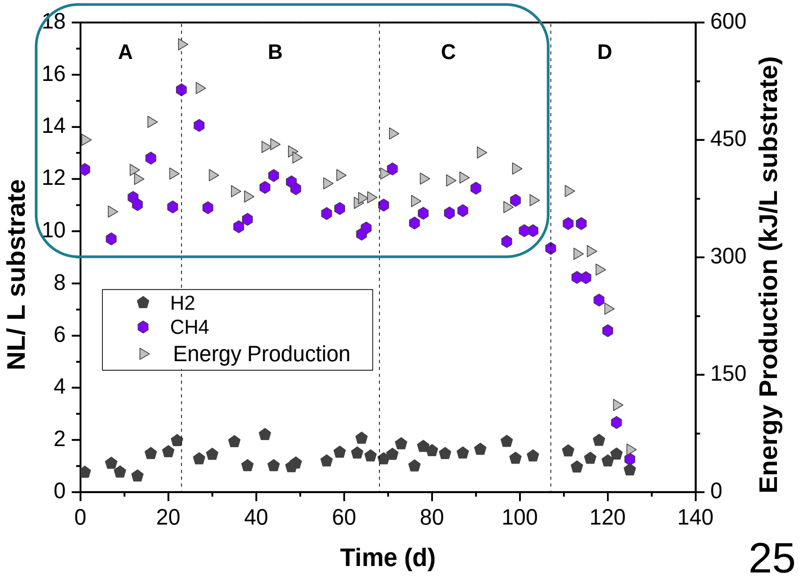


Parameter	Methanogenic reactor runs			F-Value	P-Value
	A(20d)	B(15d)	C(10.6d)		
pH	7.76 ± 0.16[II]	7.94 ± 0.11[I]	7.95 ± 0.05[I]	6.54	0.006
Alkalinity (g $CaCO_3$/L)	8.23 ± 1.03[II]	10.34 ± 0.32[I]	8.93 ± 0.28[II]	22.52	0.000
t-COD removal (%)	64.79 ± 5.84[II]	72.27 ± 1.60[I]	68.68 ± 3.56[I, II]	6.79	0.005
d-COD removal (%)	92.94 ± 2.60[I]	91.36 ± 2.82[I]	83.63 ± 4.94[II]	15.21	0.000
t-Carbohydrates removal (%)	87.07 ± 7.79[I]	73.09 ± 11.68[II]	40.03 ± 9.16[III]	49.81	0.000
L CH_4/L_{Feed}	11.35 ± 1.11[I]	11.09 ± 0.94[I]	10.03 ± 0.63[I]	3.51	0.056
CH_4 (%)	65.38 ± 2.37[I]	68.15 ± 2.13[I]	65.72 ± 1.81[I]	2.54	0.120

According to Tukey's post hoc test, statistically insignificant differences are characterized by the same symbol







Meat pasteurization (70 ºC)

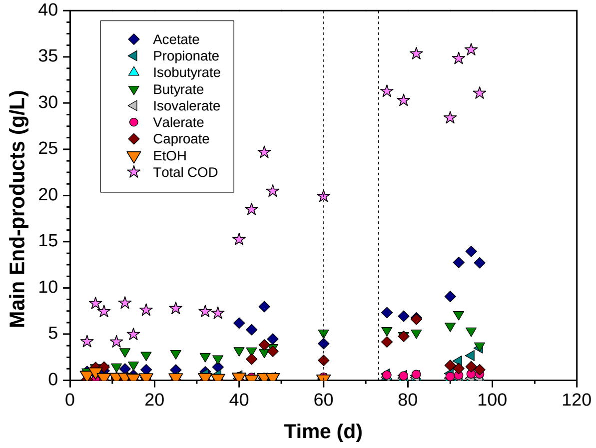
Valorization of EFP & Hydrolyzate mixture

Two-stage (CSTR) pilot scale system

Feedstock composition

Parameter	Lab scale	Pilot scale
TS (g/kg)	554.51 ± 58.6	512.96 ± 24.11
VS (g/kg)	509.20 ± 7.13	497.59 ± 24.6
t-CHO (g/kg)	183.8 ± 37.20	182.19 ± 10.18
Proteins (g/kg)	24.50 ± 2.63	6.31 ± 0.63
Fats/oils (g/kg)	47.00 ± 1.38	124.65 ± 13.31

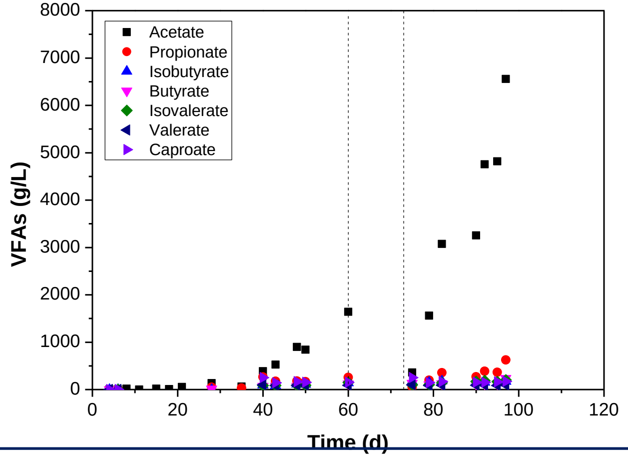
Acidogenic reactor

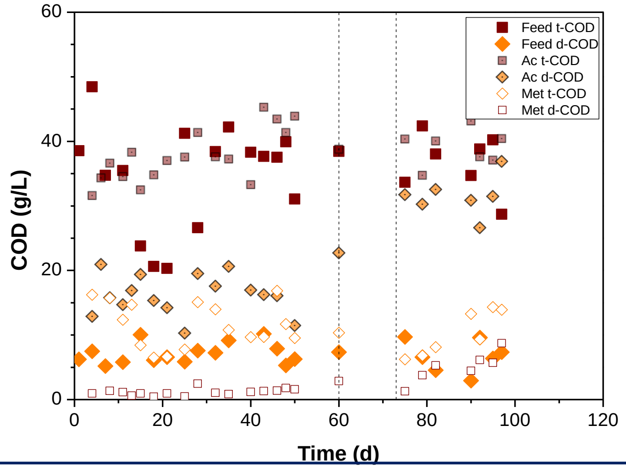


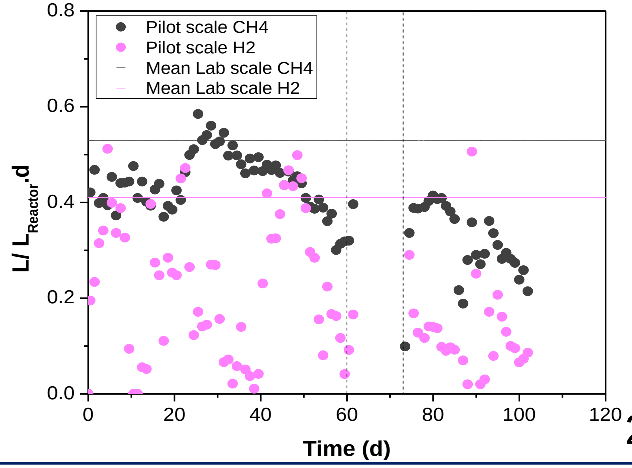
Parameter	Acidogenic reactor		Parameter	Methanogenic reactor	
	Lab scale	Pilot scale		Lab scale	Pilot scale
t-CHO removal (%)	79.3 ± 8.3	82.7 ± 5.7	t-COD removal (%)	83.3 ± 2.8	67.9 ± 5.7
VFAs-EtOH (g COD/L)	9.9 ± 1.9	32.4 ± 2.9	t-CHO removal (%)	85.1 ± 7.9	69.2 ± 4.1
L H_2/L_{feed}	0.84 ± 0.19	0.28 ± 0.11	Total VFAs (g/L)	0.2 ± 0.1	Up to 6.7
Na^+ (g/L)	1.9 ± 0.2	3.1 ± 0.3	CH_4 % in Biogas	67.2 ± 2.6	60.7 ± 6.0
K^+ (g/L)	1.7 ± 0.2	3.4 ± 0.4	L_{CH4}/L_{Feed}	11.06 ± 0.99	5.72 ± 0.80

Ac: pH 5.5, HRT 2d
Met: HRT 20d

Methanogenic reactor







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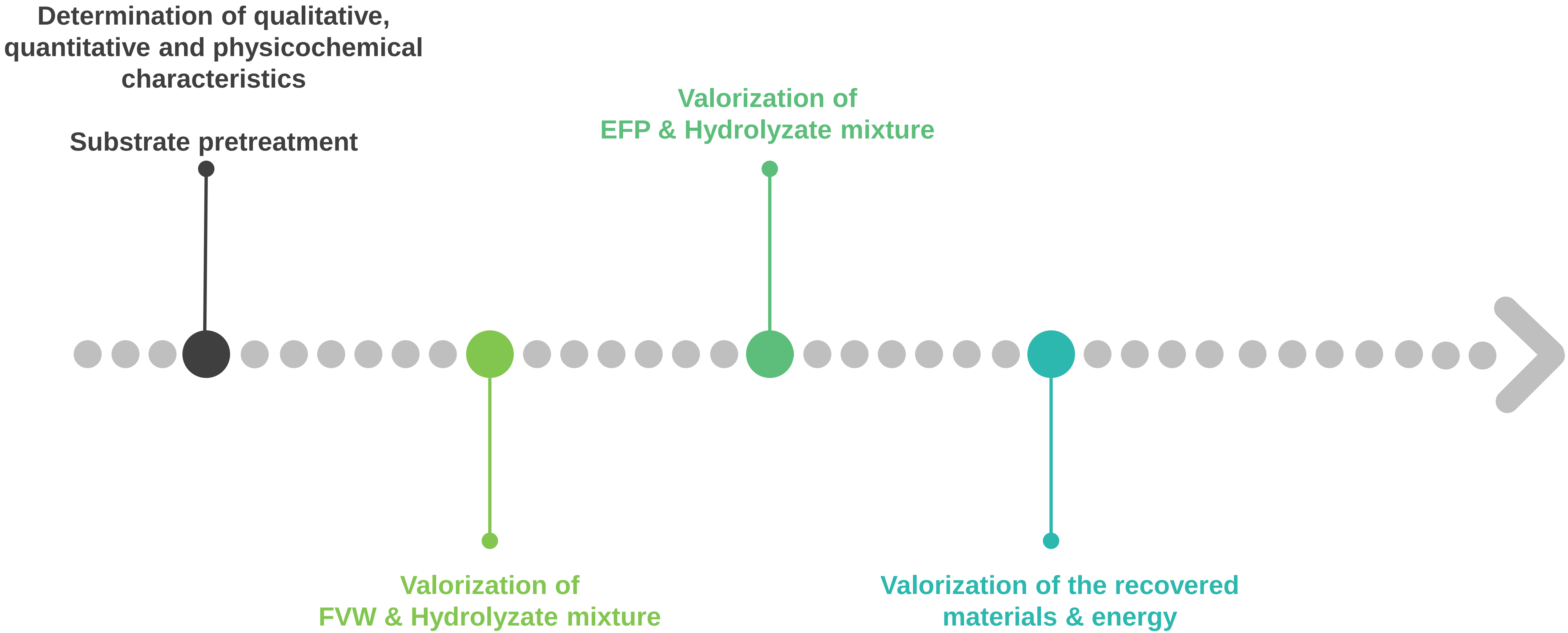

Determination of qualitative, quantitative and physicochemical characteristics
Substrate pretreatment
Valorization of FVW & Hydrolyzate mixture
Valorization of EFP & Hydrolyzate mixture
Valorization of the recovered materials & energy

Valorization of the recovered energy

Biogas

Decrease of
NH_3, H_2S (use of adsorbents)
H_2O (cooling)

Hot water supply for the **thermal needs** of the unit or other installations close to the unit.

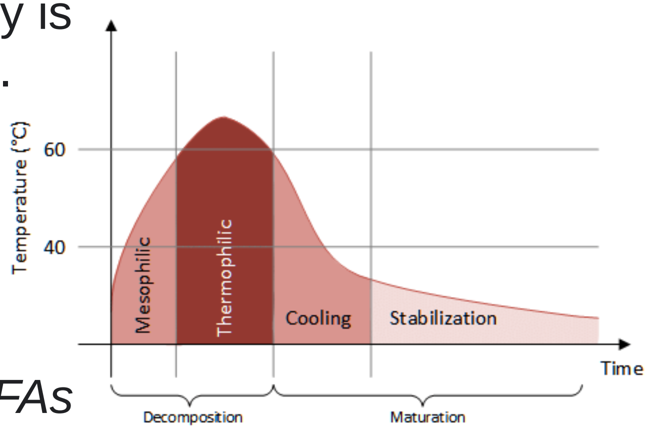
Valorization of the recovered materials

Digestate

- Liquid part
- Solid part

Composting process & maturation of the product

- Aerobic conditions
- Compost bacteria combine C with O_2 to produce CO_2 and energy. Some of the energy is used by the microorganisms for reproduction and growth, the rest is given off as heat.
- The four phases include:



1) Mesophilic phase

Reproduction of microorganisms by breaking down C & N. The metabolic activity ↑ temperature to 40-45 °C between 2-8 days and ↓ the pH due to the production of VFAs

2) **Thermophilic phase (45-70 ºC)**

Thermophiles break down more complex carbon sources, the nitrogen is transformed into NH_3 and the pH of the mixture becomes alkaline.

3) **Cooling phase**

After the consumption of C&N the temperature decreases and fungi as well as bacteria grown, which further decrease the still untreated compounds.

4) **Curing phase**

Production of humic and fulvic acids, both of them are important parameter for the quality of compost.

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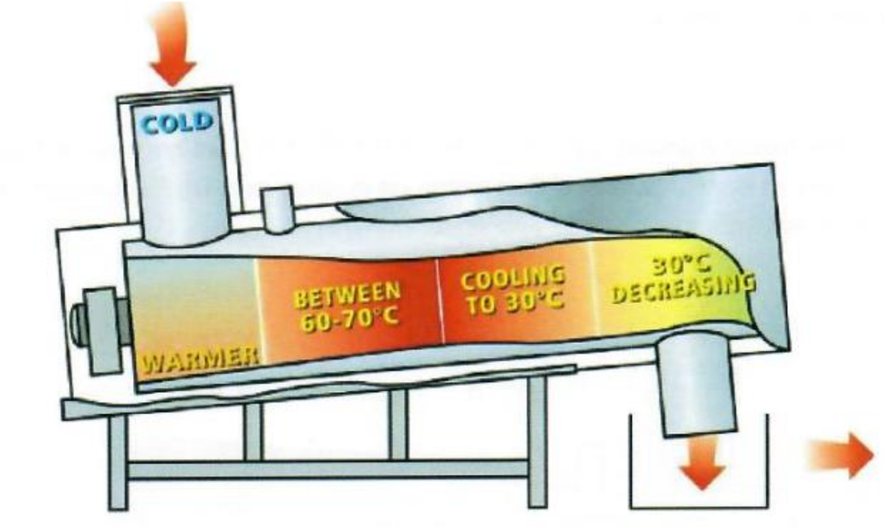
Composting process & maturation of the product

Important Parameters

- *Feedstock and nutrient balance*
- *Particle size*
- *Moisture content*
- *Oxygen flow*
- *Temperature*



Onsite composting

Vermicomposting

Aerated windrow composting

Aerated static pile composting

In vessel composting

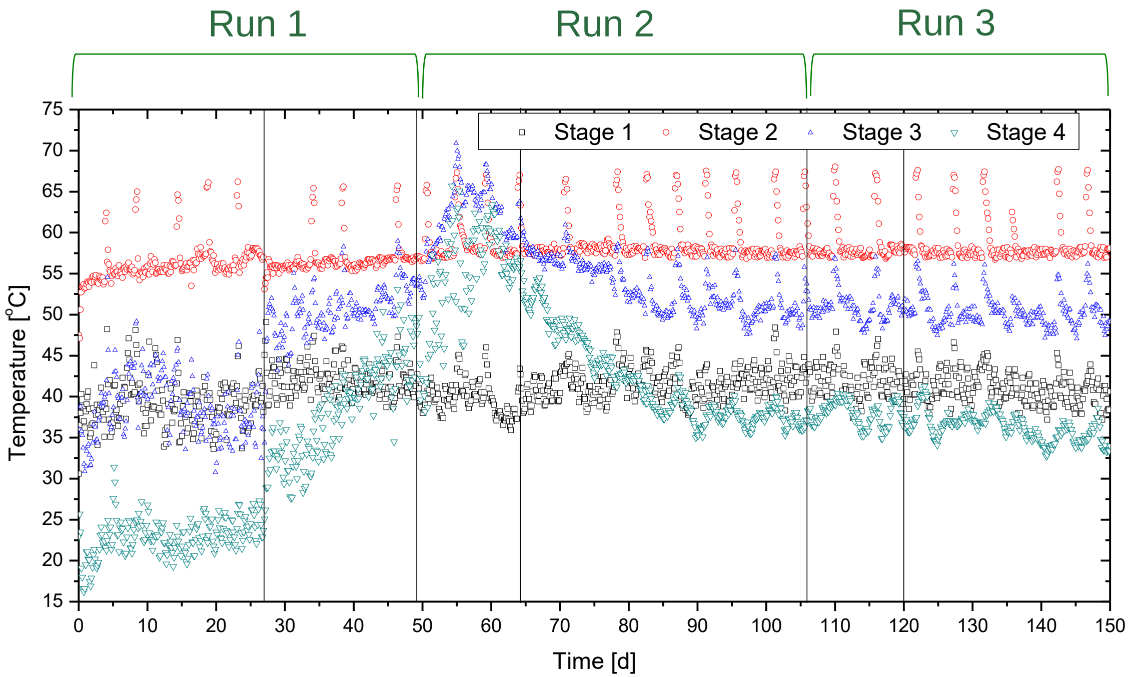
Valorization of the recovered materials

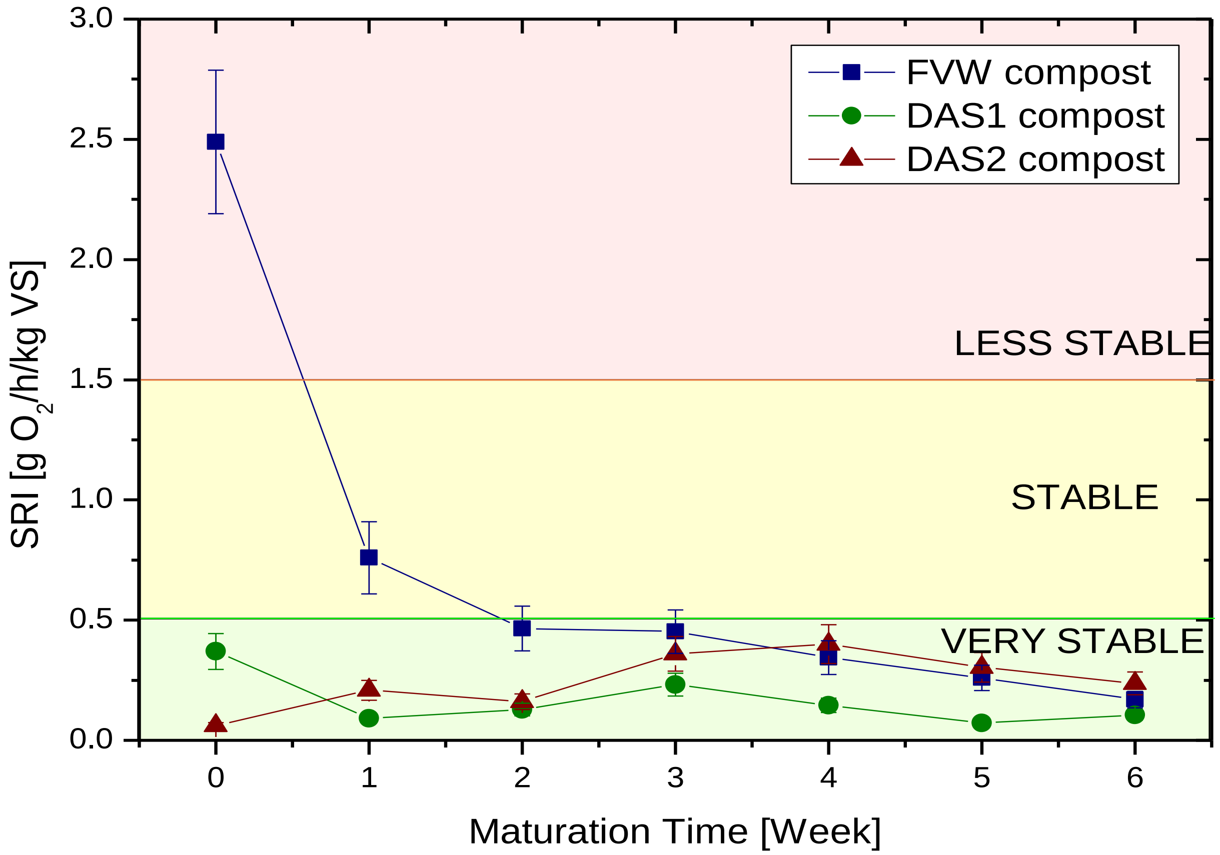
Digestate

- Liquid part 
- Solid part 

Humidity & C/N correction

Run	FVW (% w/w)	DAS1 (% w/w)	DAS2 (% w/w)	Pellet (% w/w)	Urea (% w/w)
1	100	-	-	-	
2	-	68.50	-	30.49	0.91
3	-	-	68.57	30.48	0.95





Valorization of the recovered materials

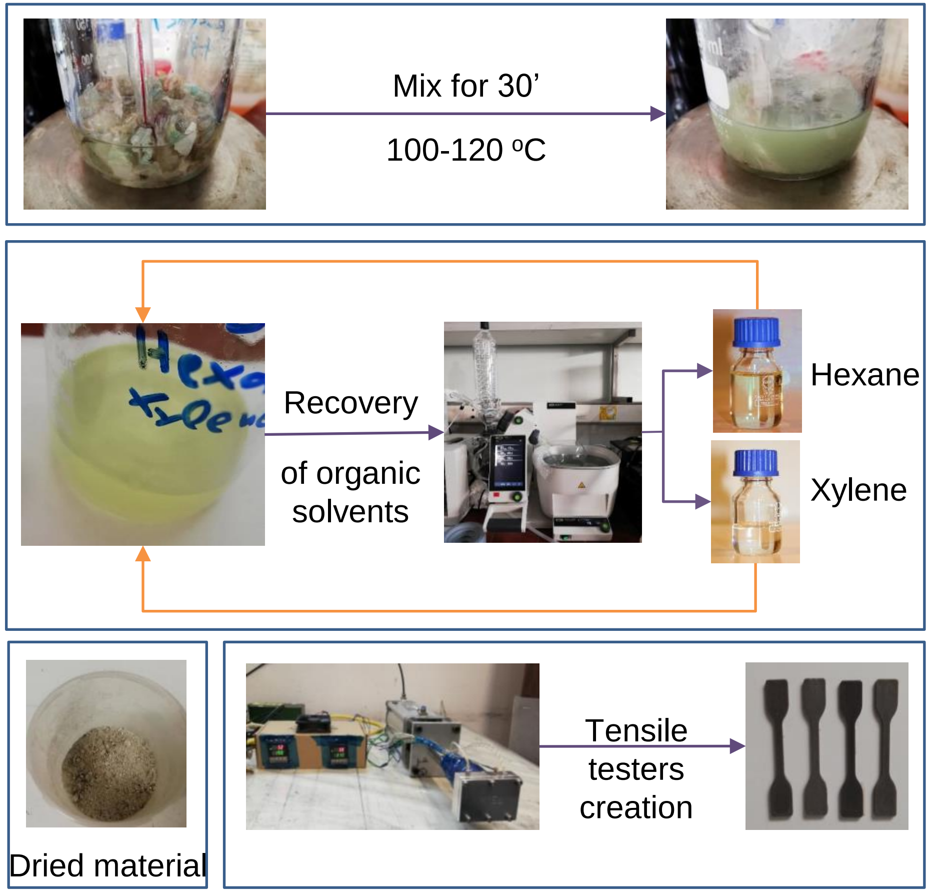
Plastics mixture & SAP

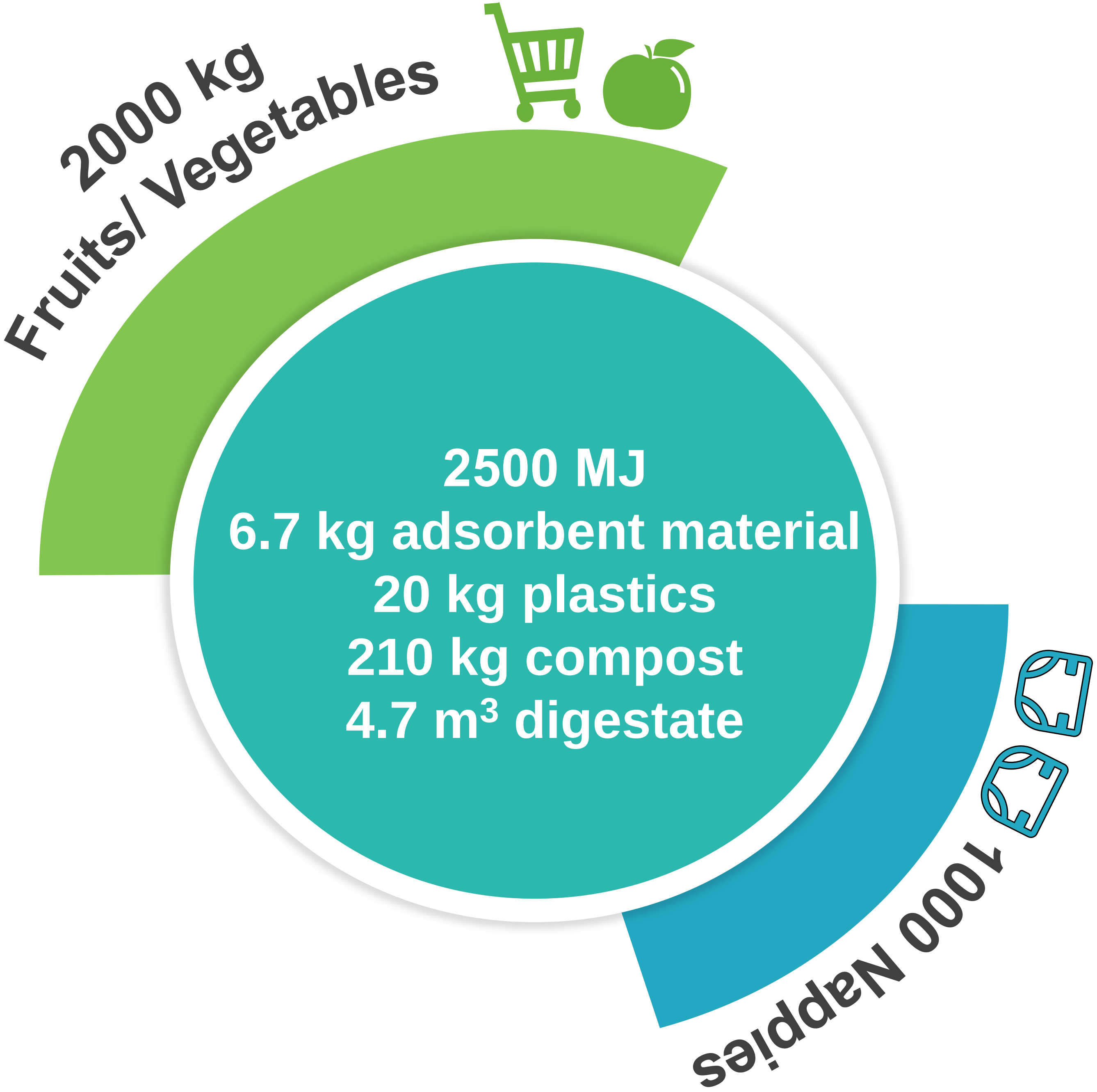
Mixture plastics

Parameter	Mix (average value ± SD)	PP (min-max)	PE (min-max)	PET (min-max)	SB (min-max)
Tensile strength at break (MPa)	16.41 ± 0.68	18-22	30.5-33	2.1-90	12-21
Elongation at break (%)	2.43 ± 0.41	50-145	600-1800	4-600	475
Modulus of elasticity (GPa)	1.65 ± 0.15	1.95	0.57-1.5	0.11-5.2	High range

SAP

Adsorbent materials	Test	Max adsorbent capacity (mg/g)
Caoline	Methylene Blue	72.57
Carbon nanofibers		72.46
MgAl-LDH/Biochar material		406.47
Treated SAP		153.75
Polyvinyl alcohol fbers with functional phosphonic acid group	Uranium (VI)	75.22
Activated sludge-graphene oxide composites		202.4
Polyacrylic acid hydrogels		445.11
Treated SAP		217.4




2000 kg
Fruits/ Vegetables
2500 MJ
6.7 kg adsorbent material
20 kg plastics
210 kg compost
4.7 m³ digestate
1000 Nappies

Concluding remarks

- *An efficient process for the valorization of food waste and used disposable nappies was presented*
- *The “non-complex” mixture of FVW & nappies was successfully treated in lab and pilot scale*
- *The results about the mixture of EFP & nappies were not reproduced at pilot scale due to the complexity of the mixture ingredients*
- *Valuable materials and energy are produced due to the valorization of the MSW in the context of the circular economy model*

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