PRETREATMENT OF DISPOSABLE NAPPIES TOWARDS VALORIZATION OF THE FERMENTABLE FRACTION THROUGH ANAEROBIC DIGESTION

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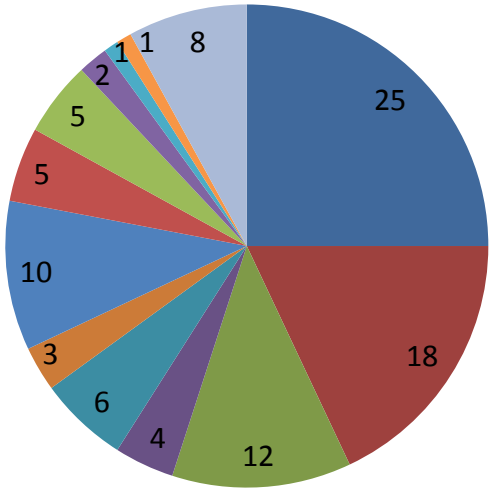
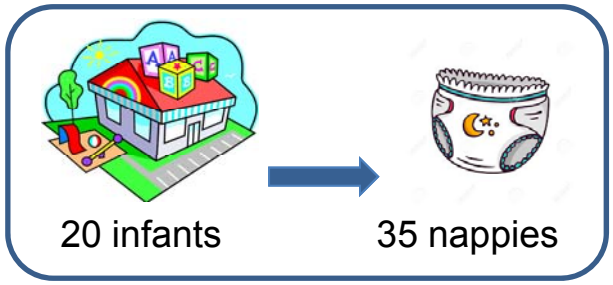
Composition of MSW generated in EU-27



- Food wastes
- Paper/Paperboard
- Plastics
- Textiles
- Garden wastes
- Diapers and hygiene products
- Other fermentable materials
- Glass
- Debris
- Steel
- White goods
- Aluminium
- Others



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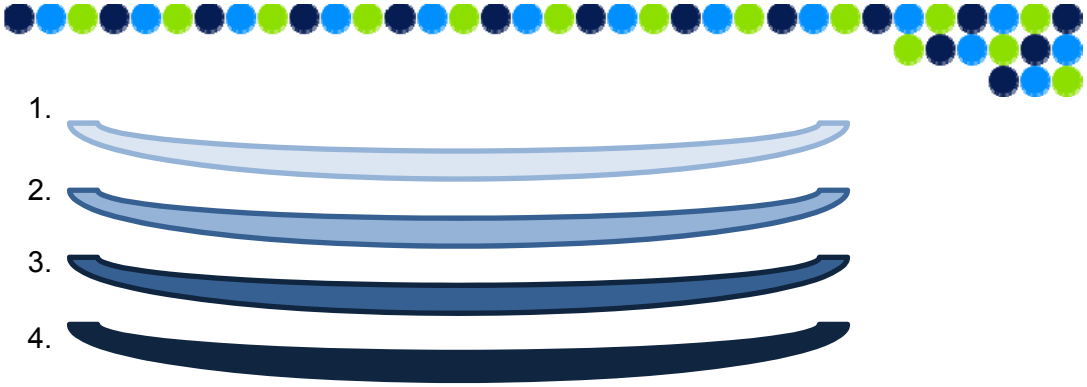
Overview of a nappy



1. Top-sheet layer next to the skin
   - Allows fluid pass through the next layer
   - Materials: Usually PP, sometimes replaced by PLA
2. Acquisition and distribution layer (ADL)
   - Transfers the liquid to the storage part of ADL before it is diffused within the absorbent core structure
   - Materials: PLA, PP, Nonwoven
3. Absorbent core layer
   - Superabsorbent polymer (SAP) and a blend of fiberized fluffy pulp is used, in order to avoid gel blocking
   - SAP: sodium polyacrylate, potasium polyacrylate etc
4. Backsheet
   - Provides a fluid impervious barrier so that moisture is contained within the structure
   - Materials: Usually PE, polyester and nonwoven

Adhesives, hydrophobic fibers, elastics, Velcro.

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Composition of an unused baby diaper

Material	%
Fluff Pulp	24
SAP	33
Nonwoven	21
Elastics & adhesive tape	13
PE	5
Adhesives	3
Others	1

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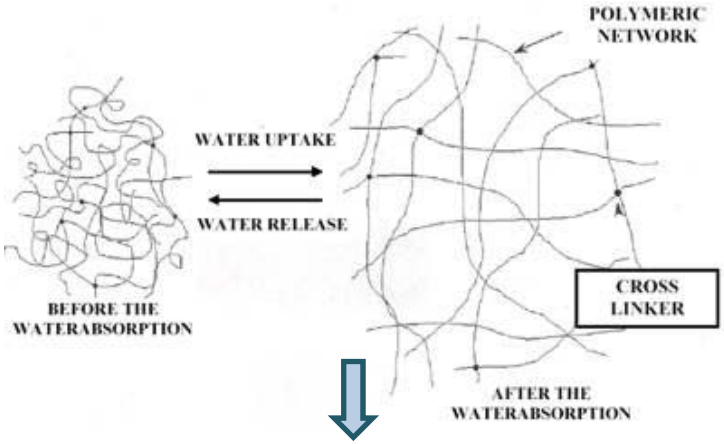
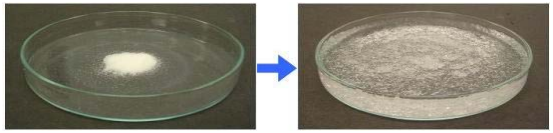
The main problem



SAP swelling depends on:

- **time** ↑ time → ↓ swelling ratio (g/g)
- **pH** ↓ pH → ↓ swelling ratio (g/g)
- **temperature** ↓ temperature → ↓ swelling ratio (g/g)
- **Salinity** ↑ salinity → ↓ swelling ratio (g/g)



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Purpose

The development of an alternative approach to landfilling of used nappies, including energy recovery through biofuels production and plastics recycling.

SAP volume minimization is the key for disposable nappies treatment, since it facilitates fluffy pulp recovery and other biodegradable baby by-products in a form of nappies hydrolyzate for further deployment through anaerobic digestion.

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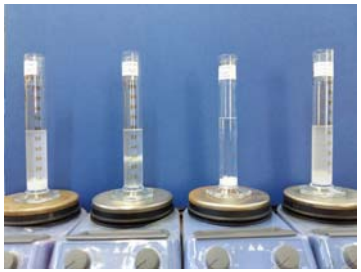
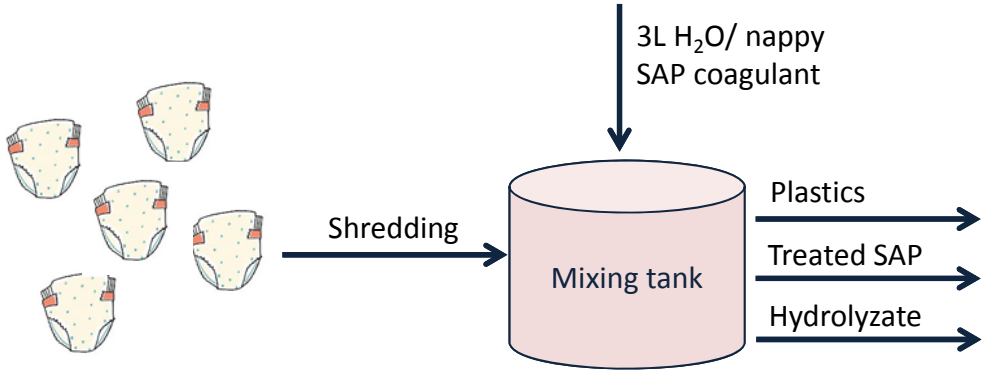
Materials and Methods

Unused nappies of 2 Greek best-selling brands

$CaCl_2$ $MgCl_2$ $AlCl_3$



Experimental set up for the SAP deswelling optimization



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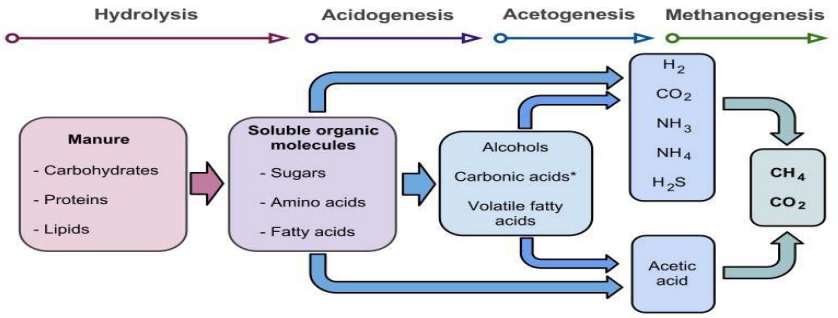
Salinity effect for Anaerobic Digestion

Toxic and inhibition effects by

- Sulfide/ Sulfate ions
- Ammonia
- Heavy metals



Ion	Concentration (mg/L)	Comments/Observations
Ca^{2+}	200 100-200 2500-4000	Ideal concentration for CH_4 production from CH_3COOH Beneficial for sludge granulation Moderately inhibitory
Mg^{2+}	≤7200 ≥400	Cultures could be adapted without changes in growth rate Culture growth ceased, lysis of cells
K^{+}	<400	Enhancement in performance
Na^{+}	3500-5500	Moderately inhibitory
Al^{3+}	≥1000	Methanogenic and acetogenic activity decreased by 50% and 72% respectively

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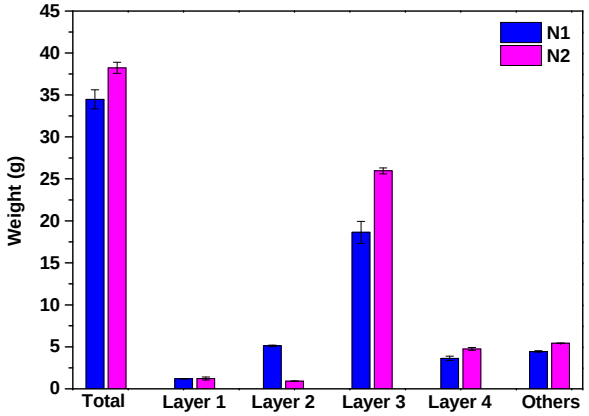
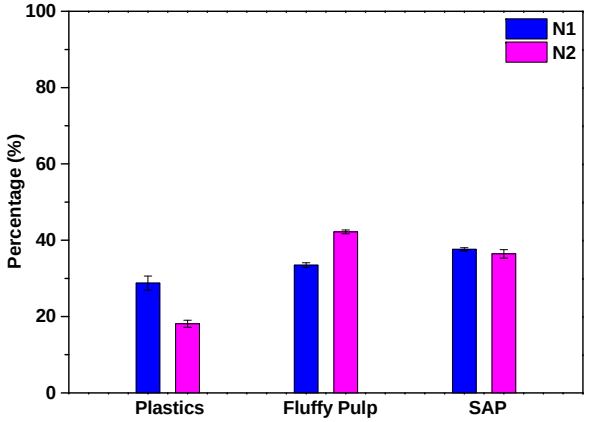
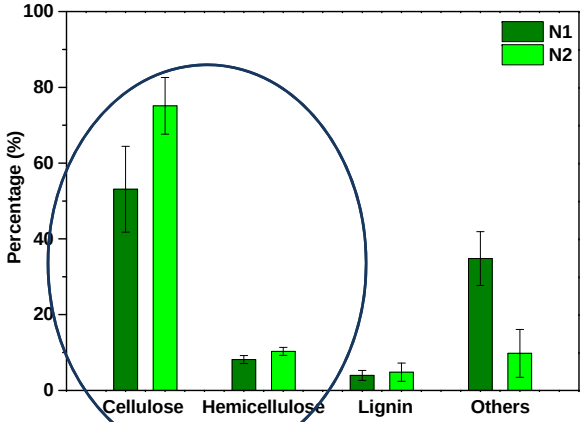
Results



Weight (g) of unused nappies' layers



Percentages of plastics, fluffy pulp and SAP in unused nappies.



Cellulose, hemicellulose and lignin content in the absorbent layer of unused nappies

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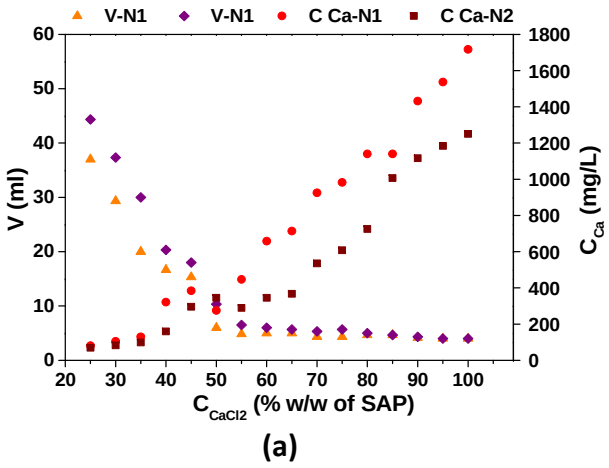
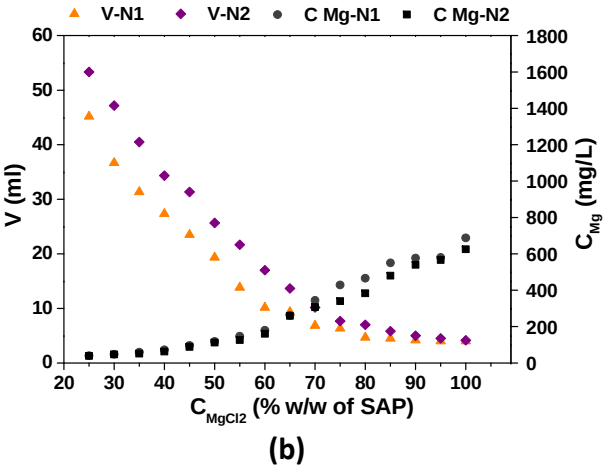
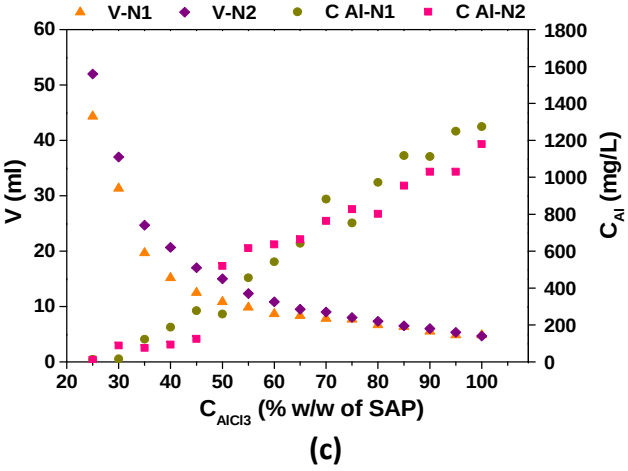
Results

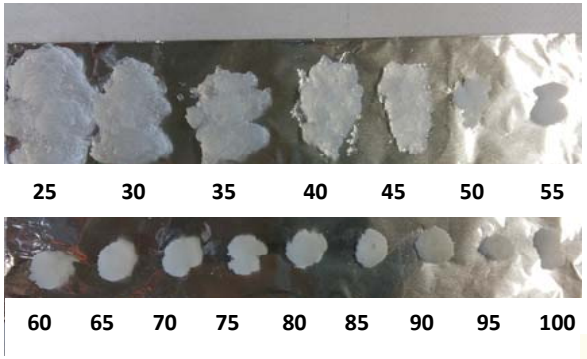






Volume of SAP (left) in correlation with different added concentrations of: (a) $CaCl_2$, (b) $MgCl_2$ (c) $AlCl_3$ and residual cation concentration in the bulk solution (right)

1% w/v wet SAP
50 ml solution
25-100% w/w reagent
t=30 min



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Results

Mixture combinations of $CaCl_2$ and $MgCl_2$ concentrations for SAP deswelling optimization treatments, final SAP volume after a 30 min treatment, residual concentration of salts in the supernatant and final cost of reagents. Data are mean values ±SD (n=3).

Test No	$CaCl_2$ (% w/w of SAP)	$MgCl_2$ (% w/w of SAP)	SAP (ml) ± SD	Residual Ca^{+2} (mg/L) ± SD	Residual Mg^{+2}(mg/L) ± SD	Final Cost (€)/g treated SAP
1	20	20	25.00 ± 1.00	59.30 ± 10.98	44.32 ± 1.65	0.1874
2	20	40	7.00 ± 0.00	84.92 ± 8.84	99.73 ± 4.95	0.2638
3	20	60	4.33 ± 0.58	169.67 ± 16.40	374.33 ± 9.09	0.3402
4	20	80	4.00 ± 0.00	262.00 ± 27.75	563.50 ± 31.22	0.4166
5	40	20	5.33 ± 0.58	353.42 ± 94.71	80.88 ± 3.06	0.2984
6	40	40	4.00 ±0.00	467.83 ± 59.10	184.83 ± 7.42	0.3748
7	40	60	4.00 ±0.00	702.83 ± 108.16	511.33 ± 21.00	0.4512
8	40	80	4.33 ±0.58	487.00 ± 118.30	582.50 ± 22.49	0.5276
9	60	20	5.33 ±0.58	671.83 ± 64.73	139.27 ± 9.58	0.4094
10	60	40	4.83 ±0.29	969.00 ± 56.76	373.17 ± 20.68	0.4858
11	60	60	5.00 ±0.00	898.00 ± 407.08	555.83 ± 54.00	0.5622
12	60	80	4.50 ±0.50	1224.83 ± 76.29	704.33 ± 38.39	0.6386
13	60	50	4.17 ±0.29	666.67 ± 21.69	455.33 ± 50.58	0.5240
14	40	50	4.10 ±0.22	595.70 ± 108.08	401.50 ± 36.31	0.4130
15	20	50	4.33 ±0.58	160.13 ± 7.67	276.50 ± 14.55	0.3020

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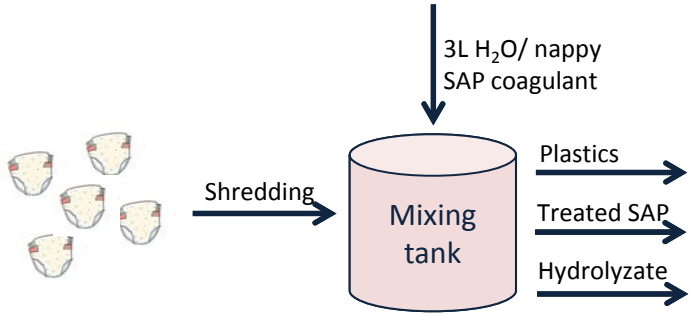
Results

Physicochemical characterization of used nappies' hydrolysates following SAP recovery. Data are mean values ±SD (n=3).

COD : N : P
350 : 7 : 1



	Hydrolysate (GR)	Hydrolysate (SP)
Parameter	Value ± SD	Value ± SD
pH	7.77 ± 0.04	7.51 ± 0.05
Humidity (%)	99.19 ± 0.10	99.29 ± 0.13
Alkalinity (g $CaCO_3$/L)	0.53 ± 0.08	0.44 ± 0.02
t-Carbohydrates (g/L)	1.37 ± 0.13	1.52 ± 0.17
d-Carbohydrates (g/L)	0.24 ± 0.01	0.16 ± 0.02
Phenols (g/L)	0.04 ± 0.00	0.01 ± 0.00
t-COD (g/L)	5.87 ± 1.26	2.56 ± 0.11
d-COD (g/L)	1.51 ± 0.22	1.32 ± 0.23
Fats and Oils (g/L)	0.06 ± 0.01	0.02 ± 0.00
t-Phosphorus (g/L)	0.024 ± 0.00	0.04 ± 0.00
d-Phosphorus (g/L)	0.017 ± 0.00	0.02 ± 0.00
TKN (g/L)	0.26 ± 0.02	0.07 ± 0.04
NH_3-N (g/L)	0.26 ± 0.02	0.07 ± 0.03
TSS (g/L)	4.45 ± 0.18	3.52 ± 0.05
VSS (g/L)	4.30 ± 0.32	3.44 ± 0.03
TS (g/L)	8.07 ± 0.97	7.06 ± 0.67
VS (g/L)	4.99 ± 0.98	4.56 ± 0.48
Ca^{2+} (g/L)	0.12 ±0.01	0.17 ± 0.01
Mg^{2+} (g/L)	0.14 ±0.00	0.11 ± 0.02

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Conclusions

- Three salts namely $AlCl_3$, $MgCl_2$ and $CaCl_2$ were tested for SAP deswelling
- Concerning the environmental impacts $AlCl_3$ was rejected as SAP coagulant
- The combination of 20% w/w $CaCl_2$ and 50% w/w $MgCl_2$ resulted to SAP volume of 4.33 ± 0.58 ml (for 0.5g SAP) with low enough residual ion concentrations and final cost
- The hydrolyzate can be used as substrate in high rate anaerobic digestion systems or as co-substrate in conventional systems without limitations and inhibition risks

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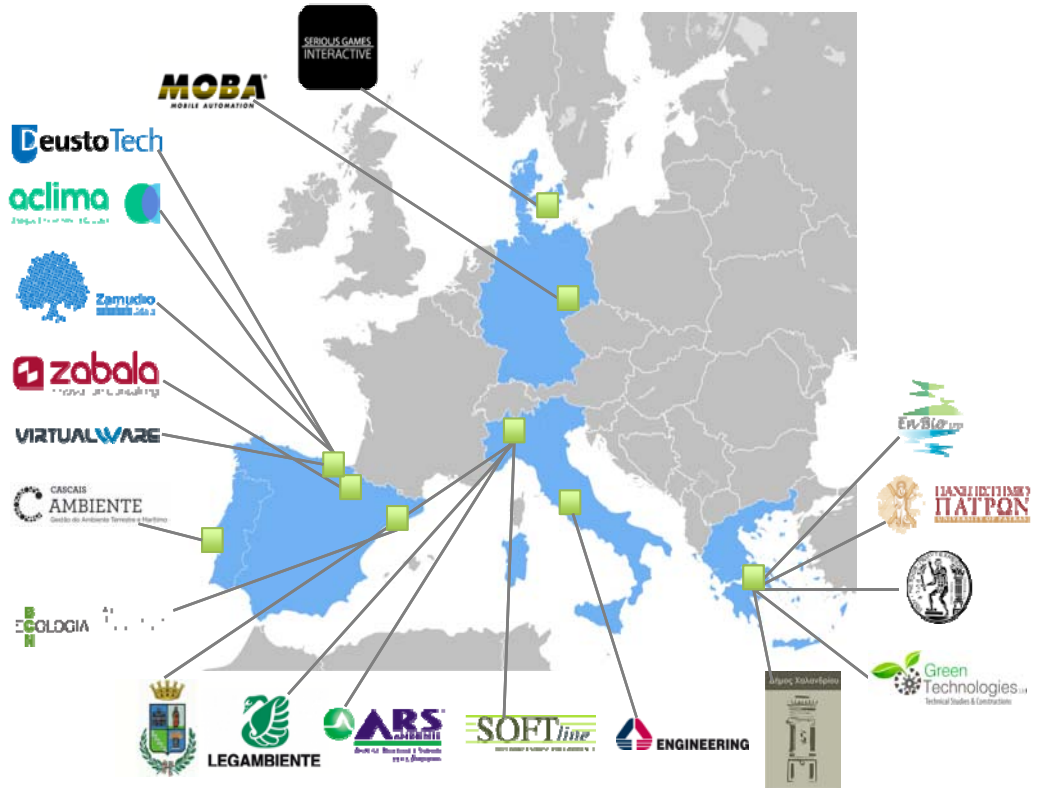

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