Resource recovery from waste streams: from LIFE LIVEWASTE to H2020 SMART-Plant

Francesco Fatone and SMART-Plant Consortium
The SMART-Plant Consortium
Outline

• Livestock effluents as source of fertilizers, biofuels, reusable water: the LIFE LIVEWASTE project

• Municipal wastewater treatment as source of reusable water, cellulose, fertilizers, biofuels, biopolymers: the Horizon2020 SMART-Plant Innovation Action

• The integration of existing plants: the SMARTTechnologies

• The exploitation, business plan and market deployment strategy
Current scenario in Cyprus (...and in the EU)
How to integrate the livestock effluent treatment plants towards the circular economy concept?

Integrated eco-innovations:
TPAD, scSBR, struvite, biofiltration, dynamic composting
The LIFE LIVEWASTE prototype
### Resources recovered by the LIFE LIVEWASTE prototype

<table>
<thead>
<tr>
<th><strong>Unit</strong></th>
<th><strong>Treatment capacity</strong></th>
<th><strong>Bio-hythane production</strong></th>
<th><strong>Struvite recovery</strong></th>
<th><strong>Treated effluent</strong></th>
<th><strong>Reusable treated effluent</strong></th>
<th><strong>High quality compost</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment capacity</strong></td>
<td>tonLIVEWASTE/year</td>
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<tr>
<td><strong>Bio-hythane production</strong></td>
<td>m³/tonLIVEWASTE</td>
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<td><strong>Struvite recovery</strong></td>
<td>Kg/tonLIVEWASTE</td>
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<td><strong>Treated effluent</strong></td>
<td>m³/tonLIVEWASTE</td>
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<tr>
<td><strong>Reusable treated effluent</strong></td>
<td>m³/tonLIVEWASTE</td>
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<tr>
<td><strong>High quality compost</strong></td>
<td>Kg/tonLIVEWASTE</td>
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<tr>
<td><strong>Values</strong></td>
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<tr>
<td></td>
<td>90-100</td>
<td>25-30</td>
<td>0.4-1.2</td>
<td>0.5-0.7</td>
<td>0.5-0.7</td>
<td>140-160</td>
</tr>
</tbody>
</table>
Technology Maturity is proven and

- Environmental
- Socio-economic
- Cost-benefit

 sustainability is assessed

Did we pass the «death valley» of innovation?
From farms to cities

From manure/slurry to municipal wastewater

From LIFE LIVEWASTE to SMART-Plant
Current wastewater treatment: is this right for the next 100 years?

750,000 tonnes per year (0.1% recycled)

Wastewater IN

Chemicals IN

Sewage works

Energy IN

Treated Water Out

Sludge out

406 kgCO₂e (5% of CH₄)

Per ML: 634 kWh (2-3% of UK)

Courtesy: Bruce Jefferson (2015)
## Resources embedded to municipal wastewater

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Reusable water (m$^3$/capita year)</td>
<td>91,3</td>
</tr>
<tr>
<td>Cellulose (kg/capita year)</td>
<td>6,6</td>
</tr>
<tr>
<td>Biopolymers; PHA (kg/capita year)</td>
<td>3,3</td>
</tr>
<tr>
<td>Phosphorus in P precursors (kg/capita year)</td>
<td>0,9</td>
</tr>
<tr>
<td>Nitrogen in N precursors (kg/capita year)</td>
<td>4,6</td>
</tr>
<tr>
<td>Methane (m$^3$/ capita year)</td>
<td>12,8</td>
</tr>
<tr>
<td>Organic Fertilizer (P-rich compost) (kg/capita year)</td>
<td>9,1</td>
</tr>
</tbody>
</table>

Verstraete et al. (2009) *Bioresource Technology* 100, 5537–5545
The overall target of SMART-Plant is to validate and to address to the market a portfolio of SMARTechnologies that, singularly or combined, can renovate and upgrade existing wastewater treatment plants and give the added value of instigating the paradigm change towards efficient wastewater-based bio-refineries.
The SMART-Plant partners

Countries of the SMART-Plant project

Partners from EU and associated countries:

1. UNIVR
2. UR
3. UBRUN
4. CU
5. UAB
6. UVIC-UCC
7. NTUA
8. KWB
9. BIOTR
10. SOC
11. BYK
12. SCAE
13. AGRB
14. SALSNES
15. IBET
16. EYDAP
17. ATS
18. MEKOROT
19. AdM
20. BWA
21. EXC
22. STW
23. AKTOR
24. ECODEK
25. WSC

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SMART-Plant open the pathway to deliver circular economy
SMART-Plant workplan structure

Scale-up of low-carbon footprint material recovery techniques in existing wastewater treatment plants “SMART-Plant”

KICK-OFF MEETING Verona (Italy) 08-09/June 2016
The SMARTechnologies

Conventional Primary Sedimentation replaced by Primary Upstream SMARTech1

Conventional Activated Sludge replaced by Secondary Mainstream SMARTechs 2a and/or 2b

Conventional Secondary Effluent refined by Tertiary Mainstream SMARTech3

Influent

Conventional or Enhanced Anaerobic Digestion integrated by Sidestream SMARTechs 4a, 4b or 5

Biogas

Dehydrated sludge

Water line

Sludge line

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SMARTech1: Primary (upstream) dynamic sieving and clean cellulose recovery

Inactivation of biological activity

Screenings

Mixed buffer

Separation course parts (> 1.5 mm)

Grid removal

FOG removal

Fibre separation

Inactivation biological activity

Dewatering

further upgrading

Desinfection

Product sales

Sand/grid removal

Fibre separation

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SMARTech1: Primary (upstream) dynamic sieving and clean cellulose recovery

Realization of a full-scale plant
✓ all process steps combined in one process

Optimization:
✓ Efficiencies of different process steps
✓ Energy-/chemical consumption individual process steps
✓ Quality cellulose fiber after different process steps
✓ Optimization interdependence

Market development
✓ Marketing and valorization of recovered cellulose
  ✓ Reuse in asphalt
  ✓ Raw material for composite (Brunel)
  ✓ Insulation materials (In development, not sure yet)

First pilot testing
SMARTech2a: Secondary mainstream biogas recovery by polyfoam biofilter

- **B1 Technical Part**
  1. An innovative anaerobic immobilized polymeric biofilter.
  2. Reaction volume -25 m³ will be designed and installed in the WWTP of Karmiel (North of Israel)
  3. Characteristics:
     - 100-120 m³/d.
     - Removal of 30-40% of CODf
     - Additional of 25% biogas
     - Reduction of 25-30% energy consumption.
  4. Operation optimization, monitoring and validation:
     - biogas yield
     - biomass activity
     - treated effluent quality
SMARTech2b: Secondary mainstream SCEPPHAR

SMARTech2b

Mainstream SCEPPHAR

- Two SBR
- Buffer tank
- P-recovery system
SMARTech3: Tertiary nutrient recovery by mesolite and nano ion exchange

Secondary influent 10-60 m³/day

NH₃-N removal

PO₄-P removal

Regeneration: 30 m³/d

Regeneration: 15 m³/d

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SMARTech4a/b Sidestream S.C.E.N.A.
1-Production of VFAs and struvite from cellulosic sewage sludge

2-Nitrogen removal via nitrite driven by selection of PHA storing biomass

3-PHA accumulation

Wastewater → Cellulosic Sludge → Fermentation → S/L → Struvite → Mg(OH)₂

Reject Water → Nitritation and Selection SBR → Selected PHA storing biomass → Fed-bacth reactor

VFAs → Treated Reject Water

VFAs → PHA extraction
Downstream SMARTechA Post-processing of recovered cellulose and PHA for bio-composites production

- Downstream SMARTechA: Incorporation of the recovered cellulosic and PHA-rich materials as raw materials for the production of new type of sludge plastic composite (SPC);
- Processing of SPC is to be based on the modified extrusion process used for processing classical WPC;

<table>
<thead>
<tr>
<th>Die Zone</th>
<th>TEMP °C</th>
<th>Barrel Zones</th>
<th>TEMP °C</th>
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<tbody>
<tr>
<td>1</td>
<td>160</td>
<td>1</td>
<td>100</td>
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<tr>
<td>2</td>
<td>130</td>
<td>2</td>
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<td>3</td>
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<td>4</td>
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<td>5</td>
<td>170</td>
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<td></td>
<td></td>
<td>6</td>
<td>130</td>
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</tbody>
</table>
Dynamic Composting → Obtain a compost rich in nutrients from P-rich sludge

Biodrying → Obtain a biofuel from cellulosic sludge

Bio-drying is a compost-like process, however, the eventual goal of this concept is to use the metabolic heat to remove water from the cellulosic sludge at the lowest possible residence time and minimal carbon biodegradation hence preserving most of the gross calorific value of the waste matrix.

1) Mixture of bulking agent + P-rich sludge (SCENA)
2) Mixture of bulking agent + Mesolite recovered compounds + Prich sludge
3) Mixture of mesolite recovered compounds + P-rich sludge + conventional WWTP sludge
SMARTechB Post-processing of cellulosic and P-rich sludge

Evaluation of P fertilizing effects of P-rich sludge and struvite

P: “the disappearing nutrient” find new sources

Mg: “the forgotten element” widespread deficiency, increasingly used in fertilizer programs

Plant species: monocots (maize) and dicots (grapevine)
SMART-Plant Business plan and market deployment strategy

SMART-Plant Model

Urban Water Utilities

Efficient water treatment

Primary licensing stream

Lever and Cross licensing stream

SMART-Portfolio

Benefits from recovery of resources

Chemical/Processing Companies

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The business model is developed profiling key target groups:

- **Water utilities**: grouped into basic, intermediate and advanced clusters

- **Chemical and downstream processing industries**: related to the four main strategic pillars: Construction, additive, Agrics and Intermediates
Public/private water utility management perspectives to deliver circular economy with the chemical industries

Water pricing

Interviews
Information partners

Public
Private

Water pricing models
Residual value
Production function approach
Optimization models and programming
Hedonic pricing
Opportunity Cost

SMART-PLANT
VALUE

Basic
Intermediate
Advanced

Value scenarios

Water utilities needs
Pricing Scenarios

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SMART-product portfolio dvt. for the recovered resources

SMART-Plant strategic pillars

Construction
- Compounds PHB / cellulose to be developed by ECODEK defined in key product grades based on market end use

Additives
- Selected additive applications for consumer, incl. plastics, oil & gas and construction to be refined for SMART products

Intermediates
- VFA and N and P derivatives recovered from SMARTtechnologies to be assessed as chemical intermediates

Agriculture
- Struvite and P rich compost to be assessed with respect to use for agriculture, in selected European countries

SMART- Product portfolio with key product offer by strategic pillar to guide exploitation

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SMART-Plant exploitation matrix and heat map
Shall we pass the «death valley» of innovation, and go to market exploitation?
Yes, we will! Thank you