Innovative utility partnership to reach economy of scale for phosphorus recycling: technoeconomic assessment

Emilio Caporossi Hera Group – Partnership HERA-IREN-SMAT

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Summary

➢ HERA, IREN and SMAT: who we are

➢ About our innovation partnership

➢ Why struvite recovery?

➢ Techno-economic assessment

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➢ HERA, IREN and SMAT: who we are

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HERA SpA was founded in 2002 through the merge of 11 municipalities and based its following growth on efficiencies and M&As.

**Geographical footprint and shareholders**
- 2002: HERA SpA founded
- ~1.5 bln shares (31.12.2017)
- 50.4% Floating
- 28.9% Public foundation partners
- 20.7% Following public partners

**Current market position**
- 1° Waste
  - Water cycle
  - Public lighting
- 2° Gas distribution
- 3° Gas e EE sales
- 4° EE distribution

**Assets and industrial platform**
- 128 front offices on the territory
- ~85,000 km network
- ~8.800 employees
- ~6 bln€ Invested Capital
- >90 treatment and recovery plants
- >4.700 providers

**Key figures 2017A**
- EBITDA: 985 mln€
- CAPEX*: 497 mln€
- PFN: 2.523 mln€
- PFN/EBITDA: 2.56 x

**MARKET CAP**
- 4.4 bln€

In 15 years Hera achieved a leadership position in all its core businesses
The water service: a core business

In 2014 Hera joined the UN Global Compact

In 2017 Hera joined the CEO Water Mandate

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IREN Group is structured as an industrial parent company with its main corporate offices in Reggio Emilia and its operating units in Genoa, Parma, Piacenza and Turin, with more 6,200 employees on 11 provinces.

**EBITDA 2016:** 814 € mln

Breakdown SBU:
- Market: 16.6%
- Energy Infr.: 19.4%
- Water: 20.2%
- Generation and DH: 29.0%
- Waste: 14.8%
- Services and Others: 197

- **Over 2,8 € bln** invested in 2009-2015
- **Almost 2/3** invested in the **energy sector** (generation and infrastructure)
- From 2011 to 2013 entered into operation:
  - **2 WTE** (421,000 ton/y and 130,000 tonn/y)
  - **1 cogeneration CCGT** (400 MW)
  - **1 LNG FSRU** (3.75 bln m3/y)

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IREN key drivers

3rd operator in Italy

16.500 km of main water networks
9.300 km of sewerage networks
1.085 high efficiency treatment plants

Integrated Water Services
3rd operator in Italy
16.500 km of main water networks
9.300 km of sewerage networks
1.085 high efficiency treatment plants

EBITDA 2016
163 € mln
Integrated Water Services
SMAT is a wholly public company that manages the Integrated Water Service for almost the entire territory of the Metropolitan City of Turin, 99.02% of the population of the ATO3 Torinese.

District → 293
Area → 6.292 km²
Citizen served → 2,26 mln
Users → 404.544

District → 293
Area → 6.292 km²
Citizen served → 2,26 mln
Users → 404.544

employees → 1000
Production value → 330 mln €
EBITDA → 146 mln €
Profit → 60 mln €

sewerage networks → 9.439 km
Population equivalent → 2,97 mln PE
Water treated → 335 mln PE
Sludge → 23.361 ton (dry)

of pipelines → 12.428 km
Water supplied → 181 mln m³
Sources → Wells → 1.800
water purifying → 90

PE Category | number | PE served
---|---|---
< 2.000 | 362 | 117.891
2.000 ÷ 10.000 | 33 | 167.943
10.000 ÷ 200.000 | 16 | 740.078
Castiglione T.se | 1 | 1.943.851
Total | 412 | 2.969.763

Year 2017

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In 2014 HERA, IREN e SMAT signed a collaboration agreement for the joint development of research and technological innovation projects with the aim to:

- share the best practices
- rationalize commitments and resources on issues of common interest
- facilitate access to external financing

In 2018 A2A joined the partnership
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WHY STRUVITE RECOVERY?

- P is a EU critical raw material
- Cost variability on the P market
- Possible recovery in existing infrastructure
- EU measures for "Circular Economy"
- Successful EU projects and initiatives: es. P-Rex, STRUBIAS WG
- P platform: European, German, Italian

Struvite is a mineral (an hydrated ammonium and magnesium phosphate), characterized by good fertilized properties. This name derives from the Russian diplomat Heinrich Christoph Gottfried Struve

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Struvite recovery from municipal WWTP: a preliminary study
✓ A significant sample of WWTPs: Bologna 800,000 PE, Rimini 560,000 PE, Torino 2,000,000 PE, Reggio Emilia 280,000 PE
✓ Techno-economic evaluations about the insertion in the process schemes of ad hoc treatment sections for phosphorus recovery
✓ Scientific support by three Italian universities: Università Politecnica delle Marche, Università di Trento, Politecnico di Torino

The project team

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Struvite recovery from municipal WWTPs: a preliminary study

Goal (for each of a selected group of WWTPs)
Evaluation of the minimum feasibility conditions for struvite recovery in relation to:
- plant size
- effective presence of phosphorus in the streams of interest (centrifugals / filter presses / belt presses / thickeners / digesters supernatants)
- compliance with the current process scheme
- availability of space and other constraints
- cost/benefit analysis

Main steps
1. definition of contracts for techno-scientific support (Universities)
2. review of recovery processes and their real applications, check of the available commercial technologies (possible contacts with technology suppliers), selection of a small number of WWTPs with good preliminary characteristics
3. analysis and verification of the technical and economic feasibility of struvite recovery on the identified plant park
4. analysis and comparison of the results
5. production of a final report

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Techno-economic assessment - HERA

1. Two WWTPs (Bologna 800,000 PE and Rimini 560,000 PE) of HERA were selected on the basis of the actual capacity, of the influent mass loads and of the sludge treatment line configurations.

2. Characterization and analysis of the anaerobic supernatants (mainly from the post thickeners and dewatering units).

<table>
<thead>
<tr>
<th>WWTP</th>
<th>Q (m³/d)</th>
<th>pH</th>
<th>F (mg/l)</th>
<th>Cl (mg/l)</th>
<th>NO₂ (mg/l)</th>
<th>NO₃ (mg/l)</th>
<th>PO₄ (mg/l)</th>
<th>SO₄ (mg/l)</th>
<th>Na (mg/l)</th>
<th>NH₄ (mg/l)</th>
<th>K (mg/l)</th>
<th>Mg (mg/l)</th>
<th>Ca (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bologna</td>
<td>833</td>
<td>7.9</td>
<td>0</td>
<td>203</td>
<td>0</td>
<td>0</td>
<td>519</td>
<td>16</td>
<td>94</td>
<td>1110</td>
<td>214</td>
<td>4</td>
<td>44</td>
</tr>
<tr>
<td>Rimini</td>
<td>396</td>
<td>8.1</td>
<td>0</td>
<td>314</td>
<td>0</td>
<td>2.9</td>
<td>157</td>
<td>34.2</td>
<td>205</td>
<td>602</td>
<td>162</td>
<td>5.3</td>
<td>49</td>
</tr>
</tbody>
</table>
Techno-economic assessment - HERA

3. Evaluation of the optimal sustainable operating conditions for Struvite recovery (Mg:P; pH; T) >> MASS BALANCES and DETAILED THERMODYNAMIC MODELING

4. Potential STRUVITE recoverable at different operative conditions

<table>
<thead>
<tr>
<th>Recovery BOLOGNA WWTP</th>
<th>0.86</th>
<th>0.70</th>
<th>0.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>P rec/P treated</td>
<td>0.53</td>
<td>0.59</td>
<td>0.65</td>
</tr>
<tr>
<td>T °C</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>pH</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Mg/P</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mg/Ca</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Hydroxyapatite Kg/d</td>
<td>76</td>
<td>76</td>
<td>76</td>
</tr>
<tr>
<td>CaSO4 Kg/d</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Struvite Kg/d</td>
<td>961</td>
<td>782</td>
<td>558</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recovery RIMINI WWTP</th>
<th>0.53</th>
<th>0.59</th>
<th>0.65</th>
</tr>
</thead>
<tbody>
<tr>
<td>P rec/P treated</td>
<td>0.53</td>
<td>0.59</td>
<td>0.65</td>
</tr>
<tr>
<td>T °C</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>pH</td>
<td>8.1</td>
<td>8.1</td>
<td>8.5</td>
</tr>
<tr>
<td>Mg/P</td>
<td>1</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Mg/Ca</td>
<td>1.3</td>
<td>2.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Hydroxyapatite Kg/d</td>
<td>34</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>CaSO4 Kg/d</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Struvite kg/d</td>
<td>84</td>
<td>95</td>
<td>104</td>
</tr>
</tbody>
</table>
Techno-economic assessment - HERA

5. Evaluation of the impacts on the Final Effluents and Sludge (Effluent quality and final P%TS in the sludges) >> Validated Simulation in the WWTPs configurations implemented with P Recovery Unit

<table>
<thead>
<tr>
<th>Prec/KgP treated</th>
<th>Actual P%TS</th>
<th>P% in Future Configurations</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.86</td>
<td>0.88</td>
<td>0.322</td>
</tr>
<tr>
<td>0.70</td>
<td>0.88</td>
<td>0.430</td>
</tr>
<tr>
<td>0.60</td>
<td>0.88</td>
<td>0.496</td>
</tr>
<tr>
<td>0.50</td>
<td>0.88</td>
<td>0.562</td>
</tr>
</tbody>
</table>

Bologna WWTP
6. Economic Assessment

Costs/Savings Items

<table>
<thead>
<tr>
<th>COST</th>
<th>Specific Costs/Savings in the Case Study of BOLOGNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>reagents</td>
<td>NaOH (30%) MgCl$_2$·6H$_2$O</td>
</tr>
<tr>
<td>energy</td>
<td>kWh/kg Prec</td>
</tr>
<tr>
<td>extra</td>
<td>EXTRA Maintenance EXTRA Lab. Analysis EXTRA Worker</td>
</tr>
<tr>
<td>SAVINGS</td>
<td>sell of struvite</td>
</tr>
<tr>
<td></td>
<td>save of coagulants</td>
</tr>
<tr>
<td></td>
<td>save of chemical sludges not disposed</td>
</tr>
<tr>
<td></td>
<td>save of nitrogen not treated in the water line</td>
</tr>
<tr>
<td></td>
<td>increment of dewterability</td>
</tr>
</tbody>
</table>

Ref. Costs Struvite Recovery from Acqueous Solution from 8-10 €/kg P rec (Engle et al., 2016)

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We expect to improve the nutrient concentration because the recovery technology will replace the lime dosage.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquor flow rate</td>
<td>339 m³/day</td>
</tr>
<tr>
<td>Ortho-Phosphate concentration</td>
<td>31 mg/l</td>
</tr>
<tr>
<td>Ammonia concentration</td>
<td>536 mg/l</td>
</tr>
<tr>
<td>Theoretical mass of P recovered</td>
<td>3 kg/day</td>
</tr>
<tr>
<td>Theoretical mass of struvite produced*</td>
<td>26071 kg/year</td>
</tr>
</tbody>
</table>

*Pilot-scale struvite recovery from anaerobic digester supernatant at an enhanced biological phosphorus removal wastewater treatment plant’

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Techno-economic assessment - SMAT

Torino WWTP

EVALUATION IN PROGRESS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digested sludge Volume</td>
<td>2555 m³/d</td>
</tr>
<tr>
<td>Dry substance</td>
<td>2 %</td>
</tr>
<tr>
<td>Ortho-Phosphate content</td>
<td>50 mg/l</td>
</tr>
<tr>
<td>Ammonium content</td>
<td>700 mg/l</td>
</tr>
</tbody>
</table>
The study highlighted the feasibility of P-recovery with theoretical variable percentages between 0.5-0.7 (P-rec/P-in), in HERA WWTPs.

The costs (capex and opex) for the P-recovery and the market/potential destiny following the recovery have to be defined in more detail.

Valorization through incentives of the recovered P-rec compared to the P-extracted could be a road?

The potential P-recovery of the three companies on the basis of the citizens served represents about 30% of the Italian citizens served and mapped (source Blue Book 2017).

The normative question remains open: at the moment the law does not provide for a recovery and considers the struvite a waste.

Possible way out, law permitting, could be the withdrawal from the technology provider.
Thank you for your attention

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