ECONOMICS OF PHOSPHORUS RECOVERY

Dave Kinnear

Gary Grey, Mario Benisch, JB Neethling, David Vaccari
INTRODUCTION

• Environmental Science – Stockton State College
• Environmental Engineering – Penn State, Lehigh, Utah
• Technology-Driven Engineer
• Environmental Engineering – Gent University, Belgium
• Economics ruined engineering career
PHOSPHORUS AND DRIVERS
PHOSPHORUS

• Essential to life...yada yada
• Production – 158 Mt/yr (USGS)
• Reserves - 16,000 Mt (USGS 2010)
• Reserves – 60,000 Mt (IFDC)
• Resources – 290,000 Mt (IFDC)

• Technology and Price convert Resources into Reserves in time.

• Why prospect for 300 years in future?
PEAK PHOSPHORUS

• Same concept as peak oil – we are soon going to reach a supply-side plateau.
• Peak oil will occur – but likely due to reduced demand as renewable sources become available at lower price (without subsidies).
• Will something similar happen for P? P has no substitute – or does it?
02 THE BET
SIMON-EHRLICH WAGER

• Ehrlich – Malthusian Stanford ecologist. *Author of Population Bomb.*

• Simon – Business Professor at Maryland

• Bet whether a basket of commodity metals would increase or decrease in real dollars over the 1980s decade.
Do substitutes exist for Phosphorus?
03 COMMODITY PRODUCTION
Nitrogen – ammonia (HB)
Phosphorus – MAP (Mining)
Energy – Methane or Electricity (Fracking, Power, Solar)

More unit capital required due to limited economy of scale
03 TECHNOLOGY CHANGE
ENERGY REQUIRED FOR N FIXATION

- nitric acid by electric arc
- calcium cyanide
- ammonia from coke (Haber & Bosch)
- ammonia from electrolysis of water
- ammonia from natural gas
- partial oxidation
- steam reforming

Energy (GJ tN⁻¹)

Year

1900 1920 1940 1960 1980 2000
Average US installed solar power costs, $/watt, by year, 2000-2014, compared with 2020 SunShot target

Source: NREL
Unsubsidized Levelized Cost of Energy Comparison

Certain Alternative Energy generation technologies are cost-competitive with conventional generation technologies under some scenarios; such observation does not take into account potential social and environmental externalities (e.g., social costs of distributed generation, environmental consequences of certain conventional generation technologies, etc.) or reliability-related considerations (e.g., transmission and back-up generation costs associated with certain Alternative Energy generation technologies).

<table>
<thead>
<tr>
<th>ALTERNATIVE ENERGY</th>
<th>CONVENTIONAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar PV—Rooftop Residential</td>
<td>$180</td>
</tr>
<tr>
<td>Solar PV—Rooftop C&amp;I</td>
<td>$126</td>
</tr>
<tr>
<td>Solar PV—Crystalline Utility Scale</td>
<td>$86</td>
</tr>
<tr>
<td>Solar PV—Thin Film Utility Scale</td>
<td>$118</td>
</tr>
<tr>
<td>Solar Thermal with Storage</td>
<td>$115</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>$102</td>
</tr>
<tr>
<td>Microturbine</td>
<td>$89</td>
</tr>
<tr>
<td>Geothermal</td>
<td>$87</td>
</tr>
<tr>
<td>Biomass Direct</td>
<td>$37</td>
</tr>
<tr>
<td>Wind</td>
<td>$37</td>
</tr>
<tr>
<td>Energy Efficiency</td>
<td>$50</td>
</tr>
<tr>
<td>Battery Storage</td>
<td>$168</td>
</tr>
<tr>
<td>Diesel Generator</td>
<td>$297</td>
</tr>
<tr>
<td>Gas Peaking</td>
<td>$179</td>
</tr>
<tr>
<td>IGCC</td>
<td>$168</td>
</tr>
<tr>
<td>Nuclear</td>
<td>$124</td>
</tr>
<tr>
<td>Coal</td>
<td>$51</td>
</tr>
<tr>
<td>Gas Combined Cycle</td>
<td>$87</td>
</tr>
</tbody>
</table>

Levelized Cost ($/MWh)

Source: Lazard estimates.
Engineering phosphorus metabolism in plants to produce a dual fertilization and weed control system

Damar Lizbeth López-Arredondo & Luis Herrera-Estrella

Affiliations | Contributions | Corresponding author

Received 07 May 2012 | Accepted 01 August 2012 | Published online 26 August 2012

**HOW THE BURGERS ARE GROWN**

1. Tissue is taken from cow
2. Stem cells are extracted from the tissue
3. Stem cells are then grown into muscle fibres in the lab in six weeks
4. 20,000 muscle fibres are then coloured, minced, mixed with fats and shaped into burgers
04 HRSD NANSEMOND PLANT
Struvite Facility Cost

Project Cost $ 5.6 M

- Building and Sitework: 40%
- Process Equipment and Technology license: 56%
- Design: 4%

C. Bott - HRSD
# COST REVIEW

<table>
<thead>
<tr>
<th>Product Sales</th>
<th>Option 1 Side Stream Treatment Cost Estimate</th>
<th>Option 2 Original Ostara Cost Estimate</th>
<th>Ostara CY 2013 Actual Costs</th>
<th>Ostara CY 2014 Projected Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>165,000</td>
<td>65,900</td>
<td>111,900</td>
</tr>
<tr>
<td>Annual Operating Costs</td>
<td></td>
<td>(88,800)</td>
<td>(141,900)</td>
<td>(86,600)</td>
</tr>
<tr>
<td>Annual Debt Service*</td>
<td></td>
<td>(425,300)</td>
<td>(425,300)</td>
<td>(425,300)</td>
</tr>
<tr>
<td>Net Annual Operating Costs**</td>
<td></td>
<td>(349,100)</td>
<td>(521,500)</td>
<td>(400,000)</td>
</tr>
</tbody>
</table>

* Sunk costs for Side Stream option  
** Side Stream Net Annual Operating Costs adjusted to 2013 $
PRODUCT PRODUCTION/SALES

HRSD Annual Bagged Production
YTD Production - 2015
YTD Production - 2014 ------> (365D)
YTD Production - 2013 ------> (730D)

C. Bott - HRSD
HRSD AND OSTARA’S AGREEMENT

- 10-year contract with Ostara to purchase all product produced at the facility with increases to purchase price based on the CPI. **KEY**
- HRSD compensated for labor, materials and operating costs.
- Ostara provided the equipment and process oversight.
- HRSD retains ownership of the building and equipment after contract expires.
- Ostara markets and distributes the fertilizer product under the name as CrystalGreen™. HRSD’s name is not used on any packaging.

C. Bott - HRSD
05 CONCLUSIONS
1. Peak P may be demand side driven as efficiencies are found.
2. Does S-E wager apply to P?
3. HRSD driver = least expensive P removal technology.
4. Ostara at HRSD cost $5.6 M and costing $0.5 M/yr to operate (including debt).
5. Will sunken capital pan out compared to higher operating cost of sidestream?
ECONOMICS OF PHOSPHORUS RECOVERY

Dave Kinnear, Gary Grey, Mario Benisch, JB Neethling, David Vaccari, Charles Bott