Triple Bottom Line Accounting Applied for Industrial Symbiosis

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Presentation Overview

• Project background
• Industrial ecology
  – Industrial symbiosis
    • Industrial symbiosis in practices
    • Example of industrial symbiosis
• Evaluation method
  – TBL & LCA approach
• Three case studies
  – Water reclamation
  – Co-generation
  – Gypsum reuse
• Closing remarks & future research
Project Background

• Despite its compelling logic, industrial symbiosis faces a number of barriers; one of these is the limited evaluation of the complete costs and benefits of industrial symbiosis to both the individual participants and at the project level.
  – Reports relative, not absolute impacts; relative to conventional or current practices as ‘+’ or ‘-’
  – Need to measure and report the full implication of industrial symbiosis projects using a TBL and LCA approaches as an aid to decision makers.
  – Focus on heavy industrial areas with high concentration of minerals, metals, chemical and energy production.
Industrial Ecology

• Industrial ecology mimics natural processes in industrial production and consumption to achieve better environmental, economic and social outcomes.
  – Industrial symbiosis
  – Green chemistry
  – Bio-mimicry

(van Berkel 2004)
Definition of Industrial Symbiosis

• Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographical proximity (Chertow 2000)
Industrial Symbiosis: 5 Models

1. Waste exchanges
   • Recycling schemes etc

2. Firm, company or organisational level exchanges

3. Over the fence exchanges
   • Eco-Industrial Park

4. Regional exchanges (<20km??)

5. Virtual, exchanges across broad regions (>20 km??)
Eco-Industrial Parks and Industrial Symbiosis Networks

• Eco-industrial parks and industrial symbiosis networks are defined as a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resources issues including energy, water and materials. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realise if it optimised its individual performance only. (adapted from Lowe 1997)
Industrial Symbiosis in Practices

- **Sharing of facilities and equipment**
  - Laboratories etc

- **Water**
  - Reuse/Cascade
  - Recycle/Filter

- **Gas**
  - Capture and supply
    - \( \text{SO}_2 \) as gypsum
    - \( \text{N}_2, \text{H}_2 \) etc
  - \( \text{CO}_2 \)
    - Carbonisation
    - Sequestration

- **Energy**
  - Cascade of steam
  - Heat recovery
  - Cogeneration

- **Materials**
  - Cascade/reuse

- **Waste**
  - Convert to by-products
  - Bulk-up recyclables

- **Collaboration in transport, storage and logistics**
Examples of Industrial Symbiosis

• Kalundborg
  – Water saving of 3.2 million m$^3$ per year
  – 170,000 tonne gypsum per year from power station for wall board
  – Energy saving through waste heat recovery for heating

• Puerto Rico
  – Steam production cost reduced by 70% ($9.35 to $2.75)
  – SO$_2$ & NOx emissions reduced by over 84%
  – Fresh water saving of 6.57 million m$^3$ per year for power station

• Kwinana
  – 106 exchanges and increasing
  – Scheme water saving of 6 million m$^3$ per year
  – Education retention program for secondary schools
Evaluation Method

**TBL approach**
- Social
- Environmental
- Economic
- Integrated indicators
  - Socio-economic
  - Eco-efficiency
  - Social justice

**Life cycle approach**
- Stages
  - Planning & design
  - Construction
  - Operations
  - Refurbishment
  - Decommission
- Implement consistent system boundaries
Economic

**Method**

- Life cycle costing
- Total cost
  - Direct & indirect
    - Overheads
    - Material cost and disposal fees
  - Internal & external
  - Tangible & intangibles
    - Reputation
    - Productivity

**Indicators**

- Business generated
- Capital required
- Wages paid
- Taxes paid
- Profitability
- Share value
Life Cycle Costing

- Allows the comparison of projects with large up-front capital cost and lower operating cost with projects with limited capital requirements and higher operating costs
- Allow the comparison of projects with variable time frame
- Need to consider the issues of capital availability and opportunity costs
Social

**Method**
- Social impact assessment
- Employees and local community
- Engagement
- Quality of life
  - Job security
  - Community stability
  - Health and safety
  - Skilled workforce

**Indicators**
- Jobs creation
- Sensory stimuli
  - dust
  - odour
  - noise
- Hours of training
- Lost time injuries
- Sick-day taken
Environmental

**Method**

- **Life cycle assessment**
  - Direct and indirect impacts

**Indicators**

- Material use
- Energy consumption
- Water consumption
- Waste generation
- Wastewater generation
- Air emissions
- Greenhouse Gases
- Land use impacts
- Product toxicity
Kwinana Water Reclamation Plant

- Reverse osmosis plant for secondary treated effluent
- Treated water supplied to 5 major water consumers
- Reduced scheme water consumption
- Industrial wastewater diverted from sensitive marine environment
# TBL Impacts of KWRP

<table>
<thead>
<tr>
<th>Life Cycle Stage</th>
<th>Environmental</th>
<th>Score</th>
<th>Social</th>
<th>Score</th>
<th>Economic</th>
<th>Score</th>
</tr>
</thead>
</table>

--- major negative, -- negative, - minor negative, 0 neutral, + minor positive, ++ positive, +++ major positive

* Job creation and security will principally be because of industries using the KWRP water have greater security for their process water, together with increased tourism and aquaculture in waters of coastal zone and not the plant itself which will be fully automated.
Co-generation

- 116-megawatt gas-fired cogeneration plant
- Produces both electricity and steam from a single operation.
- Generates 2,800 tonnes per day of steam
- Plant avoids 170,000 tons of CO$_2$ per year
# TBL Impacts of Co-generation

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Gypsum

- Gypsum is a by-product of many industrial processes
- This by-product has a variety of uses including:
  - cement manufacturing process.
  - wallboard manufacturing.
  - soil stability.
- 10,000 tonne per year of stockpiled gypsum used for soil conditioning in Kwinana
# TBL Impacts of Gypsum Reuse

<table>
<thead>
<tr>
<th>Life Cycle Stage</th>
<th>Environmental Impact</th>
<th>Score</th>
<th>Social Impact</th>
<th>Score</th>
<th>Economic Impact</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovering from stockpile</td>
<td>Reduction of stockpiled waste.</td>
<td>+</td>
<td>Reduced hazards associated with stockpile.</td>
<td>+</td>
<td>Reduction of liabilities encountered with gypsum stockpile.</td>
<td>+</td>
</tr>
<tr>
<td>Use of gypsum</td>
<td>Improved site rehabilitation. Reduced water erosion. Reduced dust.</td>
<td>++</td>
<td>Improved amenity value of rehabilitated site.</td>
<td>+</td>
<td>Reduced liability. Improved value of rehabilitated site.</td>
<td>+</td>
</tr>
<tr>
<td>Gypsum Mining</td>
<td>Avoided impact from gypsum mining. Reduced transport.</td>
<td>++</td>
<td>Reduced jobs in mining.</td>
<td>0</td>
<td>Mine operations.</td>
<td>0</td>
</tr>
</tbody>
</table>

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Benefits of Industrial Symbiosis to Regional Sustainability

• Economic
  – Increased business opportunities
  – Increased wages and taxes

• Social
  – Increased job creation
  – Improved job security
  – Increased revenue for local authority
    • Improved local services

• Environmental
  – Improved environmental quality
  – Reduced resource consumption and ecological footprint
  – Reduced waste generation and landfill demands
Closing Remarks

• One of the problems encountered is difficulty in quantifying and allocating economic, social and environmental benefits for participating companies and effected communities, as well as industry and community at large.

• Further method developments and quantification is necessary, and the evaluation method is likely to be most useful in cases were straight financial project evaluation does not provide compelling evidence for project implementation.

• Need to resolve what to do when mixed results

• Identify method to factoring-in capital cost
Future Research

• Develop and trial a model in 3-5 heavy industrial areas, the model comprises
  – Facilitation structure
  – Evaluation method
  – Operational and contractual arrangements
• Need to minimise transition costs
• Promoting business inter-dependency
  – Both parties have different aims to meet