Sustainable supply chains in a circular economy

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Overview

- Introduction
- Systems approach and life cycle thinking
- “Circularity” vs “sustainability”
- Illustrative examples
  - Food waste
  - Energy-using appliances
  - Packaging
- Conclusions
Circular economy

- Regenerative and restorative by design
- Keep products and resources in use as long as possible
- Extract the maximum value while in use
- Recover and regenerate products and resources at the end of life
Sustainable supply chain

- Economically viable
- Environmentally benign
- Socially beneficial
Sustainable supply chain in a circular economy

- Regenerative and restorative by design
- Keep products and resources in use as long as possible
- Extract the maximum value while in use
- Recover and regenerate products and resources at the end of life
Food waste
To digest, compost, burn or bury?

7.3 Mt/yr of household food waste generated in the UK of which 4.9 Mt is managed
Resource recovery from food waste

Resources

Household food waste (4.9 Mt/yr)

Anaerobic digestion

In-vessel composting

Incineration

Landfill

Electricity

Fertiliser

Compost

Electricity

Electricity

Env’l impacts

Environmental impacts (per tonne)

<table>
<thead>
<tr>
<th></th>
<th>Anaerobic digestion</th>
<th>Incineration</th>
<th>In-vessel composting</th>
<th>Landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon footprint</td>
<td>19-30 x</td>
<td></td>
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<td></td>
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<tr>
<td>Acidification</td>
<td>26-43 x</td>
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<tr>
<td>Eutrophication</td>
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<td>Human toxicity</td>
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<td>Marine ecotox.</td>
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<tr>
<td>Particulates</td>
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</tbody>
</table>

Not to scale

In-vessel composting is the worst option for most impacts

- In this case “circular” does not translate into “sustainable”

Anaerobic digestion is the best option for the carbon footprint and most other impacts

- However, it has much higher acidification and particulates (PM10)

Much greater benefits would be achieved through waste prevention (several orders of magnitude)
Circular economy concept

- Regenerative and restorative by design
- Keep products in use as long as possible
- Extract the maximum value while in use
- Recover and regenerate products and resources at the end of life
Restorative by design

Vacuum cleaners

200 M vacuum cleaners are in use in the EU, with 45 M sold annually
Annual impacts in the EU

- Carbon footprint (Mt/yr) = 11
- Resource depl. (U/yr) = 31
- Acidification (kt/yr) = 58
- Eutrophication (kt/yr) = 37
- Human toxicity (Mt/yr) = 8
- Marine ecotox. (Gt/yr) = 20

www.sustainable-systems.org.uk
Eco-design: Improving energy efficiency

Graph showing the comparison of environmental impact with and without eco-design. The categories include Carbon footprint, Resource depl., Acidification, Eutrophication, Human toxicity, and Marine ecotox. The graph indicates a significant reduction in environmental impact with eco-design.
Eco-design: Improving material efficiency

Accessories  Exterior casing  Cord rewind mec.  Motor

Dust cup  Interior casing
## Disassembly analysis

<table>
<thead>
<tr>
<th>Product disassembly characterisation</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of pieces</td>
<td>150</td>
</tr>
<tr>
<td>Pieces theoretically not required</td>
<td>41</td>
</tr>
<tr>
<td>Number of task repetitions</td>
<td>313</td>
</tr>
<tr>
<td>Number of tool manipulations</td>
<td>116</td>
</tr>
<tr>
<td>Number of non-value-added tasks</td>
<td>104</td>
</tr>
</tbody>
</table>


www.sustainable-systems.org.uk
8 types of plastics (2.3 kg)

6 types of metals (1.2 kg)

Cardboard (packaging; 0.9 kg)

15 types of materials (total 4.4 kg)

Eco-design: Improving circularity

- Painted surfaces
- Recyclable materials
- Parts with label
- Same material joints
- Reversible joints

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CE in practice for vacuum cleaners

- Long lasting product (20 years)
- Recyclability
- Size reduction
- Second-hand products
- Take-back systems
- Sustainable materials
- Easily replaceable components
- Recycled content
- Low-impact materials
- Easy disassembly
- Plastics from the sea
- High recyclability
- Availability of spares
- Reverse supply chain

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Circular economy concept

- Regenerative and restorative by design
- Keep products in use as long as possible
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Reuse or recycle?

Fizzzy drinks packaging

1.5 Mt CO$_2$ eq./yr emitted from the UK fizzy drinks sector
13% of the GHG emissions from the whole F&D sector

Amienyo and Azapagic, Int. J. LCA (2013) 18 77–92
Carbon footprint of fizzy drinks

- Glass bottles (0.75 l)
  - Total: 555 g CO₂ eq./l
  - Packaging: 414 g CO₂ eq./l (35% recycled)
- Aluminium cans (0.33 l)
  - Total: 312 g CO₂ eq./l
  - Packaging: 248 g CO₂ eq./l (48%)
- PET bottles (0.5 l)
  - Total: 293 g CO₂ eq./l
  - Packaging: 174 g CO₂ eq./l (24%)
- PET bottles (2 l)
  - Total: 151 g CO₂ eq./l
  - Packaging: 74 g CO₂ eq./l

Amienyo and Azapagic, Int. J. LCA (2013) 18 77–92
Reusing glass bottles

![Graph showing carbon footprint (g CO₂ eq./l) over various numbers of reuses.](Image)

Amienyo and Azapagic, Int. J. LCA (2013) 18 77–92
Reuse or recycle?

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- PET bottles (0.5 l): 293 g CO₂ eq./l
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Amienyo and Azapagic, Int. J. LCA (2013) 18 77–92
Recycling PET bottles (0.5 l)

![Bar graph showing carbon footprint (g CO₂ eq./l) for recycling PET bottles. The graph compares three recycling scenarios: 24%R; 76%L* (293 g CO₂ eq./l), 40%R; 60%L (197 g CO₂ eq./l), and 60%R; 40%L (152 g CO₂ eq./l).](image)

Amienyo and Azapagic, Int. J. LCA (2013) 18 77–92
Reusable or recyle?

- Glass bottles (0.75 l): 555 g CO₂ eq./l
- Aluminium cans (0.33 l): 312 g CO₂ eq./l
- PET bottles (0.5 l): 293 g CO₂ eq./l
- PET bottles (2 l): 197 g CO₂ eq./l

Amienyo and Azapagic, Int. J. LCA (2013) 18 77–92
Summary

- It pays to reuse glass bottles
- Benefits ‘fizzle out’ beyond 3-4 times
- Reusing glass 7 times comparable to recycling 40% of plastic bottles
- Larger plastic packaging still better than glass used 25 times

Amienyo and Azapagic, Int. J. LCA (2013) 18 77–92
Single-use plastics:

To ban or not to ban?
Food containers: Single-use vs reusable

500-850 million units/yr used and disposed in the EU
End-of-life management (EU28)

- Polypropylene
  - 11% recycled, 44% incinerated and 45% landfilled

- Aluminium
  - 54% recycled and 46% landfilled

- Extruded polystyrene
  - 50% landfilled and 50% incinerated
Life cycle impacts of single-use containers

Life cycle impacts of single-use containers

- **EPS**
  - 7% to 28 times lower impacts than aluminium
  - 25% to six times lower than polypropylene

- Less EPS needed than PP and less energy used than for aluminium
## Single-use vs reusable container

Number of uses of reusable PP containers needed to equal the impacts of single-use containers

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<thead>
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</thead>
<tbody>
<tr>
<td>Carbon footprint</td>
<td>18</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Resource depl.</td>
<td>208</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Acidification</td>
<td>29</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Eutrophication</td>
<td>18</td>
<td>14</td>
<td></td>
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<td>Human toxicity</td>
<td>37</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Marine ecotox.</td>
<td>24</td>
<td>4</td>
<td></td>
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<tr>
<td>Ozone depletion</td>
<td>27</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Summer smog</td>
<td>16</td>
<td>9</td>
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</tbody>
</table>
Summary

- Single-use, non-recyclable EPS has the lowest life cycle environmental impacts
- Single-use polypropylene container is the worst option for most impacts
- Reusable PP container needs to be reused 16-208 times to match the single-use EPS container
- Recycling of EPS is technically possible but costly
- In this case, “circular” does not translate into “sustainable”
Conclusions

- Most supply chains are not designed for a circular economy
- We still need to understand better when “circular” is “sustainable”
- The systems and life cycle approaches are essential
- Implementation of CE will be challenging but is achievable
  - Drivers are increasing
  - Methods and evaluation tools are available
  - Technologies are developing (slowly)
- More success stories are needed to stimulate the uptake
- Legislation will need to get tougher
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References


