Integrating product and energy life cycles towards a Circular Economy

Deborah Andrews, Zaneta Muranko, Zoe De Grussa, Issa Chaer, Gordon Lowry and Elizabeth Newton
Ref: Ellen MacArthur Foundation Circular Economy Introductory Kit
integrating energy & product chains

- Manufacture
- Use
- End-of-life remanufacture/reuse/recycling

- Energy
  - Fuels
  - Feedstocks
  - Infrastructure

- Emissions pollutants
Product bench marking:
Assessing the Life Cycle impacts of thermostatic and programmable thermostatic radiator valves in a UK household

RV – radiator valve
TRV – thermostatic radiator valve
PTRV - programmable thermostatic radiator valve
Design Decision Making
integrating product and energy chains
building construction / operational energy heating and cooling
bespoke LCA tool – designers and engineers
Circular Economy - alternative business models

- **Open loop recycling**
  - Raw Material Acquisition
  - Bulk Processing
  - Use and Service
  - Manufacture & Assembly
  - Engineered & Speciality Materials
  - Retirement
  - Treatment & Disposal
  - Material, energy and labour inputs for process and management
  - Transfer of materials between stages for product, includes transportation & packaging

- **Closed loop recycling**
  - Recycling
  - Remanufacture
  - Reuse
  - Includes e.g. leasing, selling a service

- **Life Cycle Stage**
  - Fugitive and untested residuals
  - Airborne, waterborne and solid residuals
  - Environmental Protection Agency (EPA)
Carbon Footprint vs Life Cycle Assessment

Life Cycle Assessment

1\textsuperscript{st} order – energy flows

2\textsuperscript{nd} order – energy and materials flows

3\textsuperscript{rd} order - energy and materials flows and capital goods
Refrigerated Display Cabinet - RDC
'typical' RDC - life cycle impact

Product Carbon Footprint

‘typical’ RDC - life cycle impact

Product Carbon Footprint

- Embodied: 2.50%
- Use phase: 97.50%

Life Cycle Assessment

- Embodied: 20%
- Use phase: 80%

Eco-indicator 99 damage assessment model

- Extraction of minerals & fossil fuels
  - Concentration of minerals
  - Surplus energy for future extraction
- Land-use: occupation & transformation
  - Change in habitat size
  - Regional effect on vascular plant species
- NOx, SOx, NH₃, Pesticides, Heavy Metals, CO₂, HCFC, Nuclides (Bq), SPM, VOCs, PAHs
  - Concentration in air, water & food
  - Concentration of greenhouse gases
  - Concentration of ozone depl. gases
  - Concentration of radionuclides
  - Concentration of SPM & VOCs
  - Concentration of minerals
  - Concentration of SPM & VOCs
- Resource analysis
  - Land use analysis
  - Fate analysis
- Exposure and effect analysis
- Damage analysis
- Normalisation and weighting

Ecopoints

Damage to mineral and fossil resources [MJ surplus energy]
Damage to human health [disability adjusted life years (DALY)]
Damage to ecosystem quality [% vasc. plant species * km² * yr]
Climate change - disease & displacement
Ozone layer depletion - cancer & cataract
Respiratory effects (cases & type)
Carcinogenesis (cases & type)
Acid / eutrop. (occurrence target species)
Ecotoxicity: toxic stress (PAF)
Climate change - disease & displacement
Ozone layer depletion - cancer & cataract
Respiratory effects (cases & type)
Carcinogenesis (cases & type)
Going North for Sustainability

Using Life Cycle Assessment to illustrate the benefits of blinds as a passive and sustainable energy saving product for use in the domestic environment in the UK

Deborah Andrews ¹, Zoe De Grussa¹, Andrew Chalk and Dave Bush ²
London South Bank University¹ with The British Blind and Shutter Association ²
heat loss – U value

insulated cavity wall
0.2 W/m$^2$K

single glazed window
5.8 W/m$^2$K

double glazed window
2.9 W/m$^2$K

triple glazed / low emissivity glass
1.0 W/m$^2$K
correct use - potential to reduce energy for cooling – 30-70%

heat loss
single glazed window – 25%
double glazed window – 15%
life cycle processes for blinds

- materials extraction
  - end-of-life treatment with transport
    - landfill
    - reuse / recycling
    - use
    - installation with transport
  - bulk materials processing with transport
    - component manufacture
    - product assembly

blind components:
wood venetian
lindenwood
vertical
polyester vanes
roller
polyester blackout
metal venetian
aluminium

mechanisms:
polymers
nylon 6, acetal, PVC, polyester, polyester yarn
metals
aluminium, brass, nickel plated, mild & stainless steel

manufacturing processes:
moulding, cutting, forming & machining, braiding, painting, powder coating
overall impact – different blinds

Impact of blinds with differing end-of-life scenarios and transport

- roller
- wood venetian
- vertical
- metal venetian

- product only
- transport + recycle at end of life
- transport + landfill at end of life
overall average impact – recycle at end of life

Benefits of blind use when *recycled* at end-of-life - different levels of energy saving over time

- 5% energy saving
- 10% energy saving
- 15% energy saving
- 20% energy saving

Impact of energy savings in Points

Product life span:
- 3 year life
- 5 year life
- 10 year life
- 15 year life
- 20 year life
overall average impact – landfill at end of life

Benefits of blind use when *landfilled* at end-of-life - different levels of energy saving over time

- 5% energy saving
- 10% energy saving
- 15% energy saving
- 20% energy saving

impact of energy savings in Points

product life span
visual and thermal comfort and well being
natural light and well being
joint funded PhD – Zoe De Grussa

CIBSE ‘use of blinds and shutters increasingly important’

behaviour change

educate specifiers, retailers and end users

developing policy and practice

real time studies

new shading products

Deborah Andrews, Zaneta Muranko, Issa Chaer and Alan Foster
London South Bank University with The Bond Group
<table>
<thead>
<tr>
<th>materials in a typical RDC</th>
<th>widely reused / recycled</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>metals</strong></td>
<td>steel (stainless, carbon, galvanised), aluminium alloy, brass, copper</td>
</tr>
<tr>
<td><strong>polymers – thermoplastics and thermoset plastics</strong></td>
<td>rigid polyurethane foam (PUR), polystyrene (PS) &amp; phenolic foams, polycarbonate (PC), polypropylene (PP), polyethylene (PE)</td>
</tr>
<tr>
<td><strong>glass</strong></td>
<td>plate, fibre</td>
</tr>
<tr>
<td><strong>MDF (medium density fibreboard)</strong></td>
<td>wood and other natural fibres, urea formaldehyde resin</td>
</tr>
<tr>
<td><strong>electronics</strong></td>
<td>including precious metals</td>
</tr>
</tbody>
</table>
rigid polyurethane foam (PUR) in construction easier to recycle than insulation in fridges substitute materials?
candidates for substitution – differing thermal performance

established synthetic materials
  mineral wool
  glass fibre

high-tech synthetic materials
  VIP (vacuum insulated panels)
  aerogel

natural materials
  cork
  sheep’s wool
  cotton
whole life cycle: integrating energy & product chains

PRODUCT (RDC)

materials / component manufacture

USE – food storage and display

emissions pollutants
dot dotted arrows

COOLING (refrigeration)
operational energy (electricity)

dot dotted arrows

extending life - remanufacture / end-of-life - recycling, disposal
Combined impact of 40mm insulation + operational energy over 5 years

<table>
<thead>
<tr>
<th>Material</th>
<th>Impact in Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUR</td>
<td>80</td>
</tr>
<tr>
<td>Mineral wool</td>
<td>100</td>
</tr>
<tr>
<td>Glass fibre</td>
<td>120</td>
</tr>
<tr>
<td>VIP</td>
<td>60</td>
</tr>
<tr>
<td>Aerogel</td>
<td>40</td>
</tr>
<tr>
<td>Cork</td>
<td>140</td>
</tr>
<tr>
<td>Sheep's wool</td>
<td>160</td>
</tr>
<tr>
<td>Cotton</td>
<td>120</td>
</tr>
</tbody>
</table>

**Legend:**
- **energy**
- **product**
Life Cycle Impact over 5 years - 40mm insulation + operational energy

- **PUR**
- **Mineral Wool**
- **Glass Fibre**
- **VIP**
- **Aerogel**
- **Cork**
- **Sheeps wool**
- **Cotton**

**Legend:**
- Green: recycle
- Yellow: reuse or compost
- Red: landfill or incinerate with energy recovery
Circular Economy - alternative business models

Closed loop recycling

Open loop recycling

Includes e.g. leasing selling a service

Life Cycle Stage
Fugitive and untested residuals
Airborne, waterborne and solid residuals
Material, energy and labour inputs for process and management
Transfer of materials between stages for product, includes transportation & packaging

Environmental Protection Agency (EPA)
http://www.epa.gov/ORD/NRMRL/lcaccess/lca101.htm
Difference in overall cost (operational energy & materials) between PUR and other insulation materials over time.

- Mineral wool
- Glass fibre
- VIP
- Aerogel
- CORK
- Sheeps wool
- Cotton

Cost comparison across different insulation materials over 5, 10, and 20 years.
joint funded PhD - Zaneta Muranko

developing circular economy
remanufacture
change perception
behaviour change
retailers / procurement
design thinking
communication strategies
new product development
thank you

any questions?