Comparison between alternative waste-to-recycling systems to produce energy efficient recycled foam glass

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RECYCLED FOAM GLASS - RFG

Raw material: Recycled glass
Shape: Variable
Granulometry: 8÷16 mm
Volumic mass: 0.45÷0.63 t/m³
Bulk density: 0.16 t/m³
Gas expansion temperature: 900 °C
Additive: Silicon carbide

Applications:

• Lightweight concrete
• Road construction
• Pile foundation
• Building insulation
• Trench filling material
• Stabilizing of slipping soil
• Insulation of sports grounds
• Insulation of swimming pools
• Roof insulation
Glass recycling rejects composition

<table>
<thead>
<tr>
<th>Waste</th>
<th>Glass</th>
<th>Ceramics</th>
<th>Plastic</th>
<th>Paper</th>
<th>Metals</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>94</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**ENVIRONMENTAL GAINS**

- **Landfill avoidance**
  - Saving of waste dump capacity
  - No emissions
  - No land use derived damage

**ENVIRONMENTAL IMPACTS**

- **Emissions due to enhanced transportation distances**
- **Processing impacts**
  - Machinery
  - Water depuration
  - Transport
- **Primary building material substitution**
- **Avoided production**
  - Glassy sand
  - Metals
  - Plastic

**Recovery of secondary raw materials**

**RFG manufacturing**
•Prove the environmental quality of innovative process
•LIFE projects:

**MEIGLASS**: Minimising the Environmental Impact of GLASS recycling and glass container production:
•From plastic to energy: study, plan and realize a plant able to separate plastics from cullet;
•Glassy sand, ceramic sand, brick sand: optimization of the technical of raw material obtained from the treatment of cullet rejected from primary recycling plants.

**NOVEDI**: NO VEtro in DIscarica (No glass in landfill):
•Demonstrate new technologies allowing the production of glass based insulation materials with a high performance in thermal insulation, mechanical strength, fireproof and eco-compatibility.

•Life Cycle Assessment - LCA according to ISO 14040–44:
  1. Quantifying environmental performances;
  2. Minimizing environmental impacts throughout the life cycle;
  3. Increasing the credibility of sustainability claims.
GOAL AND SCOPE

Functional Unit: **1 m³ and 1 ton**

• Comparing with competitors (similar properties and applications)

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>FGG</th>
<th>EP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material</td>
<td>Recycled glass</td>
<td>Perlite</td>
</tr>
<tr>
<td>Shape</td>
<td>Spherical</td>
<td>Spherical</td>
</tr>
<tr>
<td>Granulometry</td>
<td>0.5±1 mm</td>
<td>0.15±1 mm</td>
</tr>
<tr>
<td>Volumic mass</td>
<td>0.47 t/m³</td>
<td>0.15±0.2 t/m³</td>
</tr>
<tr>
<td>Bulk density</td>
<td>0.27 t/m³</td>
<td>0.1 t/m³</td>
</tr>
<tr>
<td>Gas expansion temperature</td>
<td>790 °C</td>
<td>850±1000 °C</td>
</tr>
<tr>
<td>Additive</td>
<td>Unspecified</td>
<td>-</td>
</tr>
</tbody>
</table>

• FGG producer conducted an LCA for internal use
• Provided FGG LCI data upon request (no system boundaries or process details)
• EP was taken from Ecoinvent database
Avoided Landfill
- Special glass waste
- Sodium-calcium glass waste

Transport
Glass washing, drying, sorting and milling
Glass Powder
Silicon carbide
Gypsum

Thermal process
Recycled Foam Glass

Avoided Products
- Glass sand
- Brick sand
- Metal scrap

Plastic Scrap

Energy recovery

SYSTEM BOUNDARIES
EXTENDED SYSTEM BOUNDARIES

•ENVIRONMENTAL INDICATORS
- Gross Energy Requirement (GER)
- Global Warming Potential (GWP)
- Acidification potential (AP)
- Eutrophication potential (EP)

• Eco-Indicator 99
# LIFE CYCLE INVENTORY

<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass landfilling (Avoided)</td>
<td>Sodium-calcium glass; flat glass, windshield glass, light bulbs, tableware and Containers. Special glass; mosaic glass, artistic glass, tv screens glass, solar and pv panels.</td>
<td>---</td>
<td>Landfill life cycle emissions</td>
</tr>
<tr>
<td>Waste glass collection</td>
<td>Waste materials are transported from waste management facilities to the RFG production site.</td>
<td>30-tonne payload trucks</td>
<td>166 km 179 km</td>
</tr>
<tr>
<td>Glass washing (1 ton)</td>
<td>Quasi-closed loop. Water is stored in two natural water basins where is injected with oxygen to prevent anaerobic fermentation. A small amount of water is pumped from an artesian well.</td>
<td>Electricity 1.4 kWh Al₂(SO₄)₃ 2.2 kg Liquid oxygen 0.49 kg</td>
<td>glass brick sands 65 kg</td>
</tr>
<tr>
<td>Glass sorting, drying and milling (1 ton)</td>
<td>Sodium-calcium glass</td>
<td>Electricity 25 kWh Diesel 0.5 l Natural gas 103.59 MJ</td>
<td>Ceramic sand 150 kg Glass sand 800 kg Plastic scrap 10 kg Metal scrap 5 kg</td>
</tr>
<tr>
<td>Special glass (Diesel and natural gas consumptions as in Sodium-calcium)</td>
<td>Electricity 25 kWh</td>
<td>Glass 990 kg</td>
<td></td>
</tr>
<tr>
<td>Thermal process (1 ton)</td>
<td>Inputs are sent to a furnace in which the raw mix undergoes preheating, foaming and cooling.</td>
<td>Glass powder 970 kg Gypsum 10 kg Silicon Carbide 2 kg Heat 1800 MJ</td>
<td>RFG 1 ton CO₂ emissions 11 kg</td>
</tr>
</tbody>
</table>

Foreground data gathered at RFG production site, background data from Ecoinvent database
Foam Glass Granulate - FGG

- Aggregate made from pure glass (no secondary recycling)
- Many application in building industry:
  - Lightweight concrete, Panels

FGG producer provided:
- LCI results ONLY
- No information about system boundaries
- No process and process flow information

Ecoprofile A: using provided data as they are
Ecoprofile B: crosschecking LCI data with product patent and with Ecoinvent foam glass

- LCA model according to patent data;
- Ecoinvent Foam Glass was used for comparison and gap filling;

<table>
<thead>
<tr>
<th>Raw materials</th>
<th>Recycled glass (61%)</th>
<th>Process</th>
<th>Energy consumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Glass binder (37%)</td>
<td>Grinding</td>
<td>0.025 kWh/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mixing (stirring)</td>
<td>0.27 kWh/kg</td>
</tr>
<tr>
<td></td>
<td>Expanding agent (2%)</td>
<td>Granulating</td>
<td>Neglected</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expansion</td>
<td>11.6 MJ/kg (natural gas)</td>
</tr>
</tbody>
</table>
### RESULTS

<table>
<thead>
<tr>
<th>IMPACT CATEGORY</th>
<th>UNIT</th>
<th>RFG (0.45 t/m³)</th>
<th>FGG A (0.47 t/m³)</th>
<th>FGG B (0.47 t/m³)</th>
<th>EP (0.175 t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 m³</td>
<td>1 t</td>
<td>1 m³</td>
<td>1 t</td>
<td>1 m³</td>
</tr>
<tr>
<td>GER</td>
<td>MJ</td>
<td>2432</td>
<td>5405</td>
<td>4338</td>
<td>9075</td>
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<tr>
<td>NRER</td>
<td>MJ</td>
<td>2363</td>
<td>5252</td>
<td>4256</td>
<td>8904</td>
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<tr>
<td>GWP100</td>
<td>kg CO₂eq</td>
<td>173.6</td>
<td>385.8</td>
<td>309.1</td>
<td>647</td>
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<tr>
<td>ODP</td>
<td>g CFC11eq</td>
<td>0.023</td>
<td>0.05</td>
<td>0.01</td>
<td>0.02</td>
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<tr>
<td>AP</td>
<td>mol H⁺</td>
<td>16.8</td>
<td>37.3</td>
<td>28.9</td>
<td>60</td>
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<tr>
<td>EP</td>
<td>g O₂eq</td>
<td>2512</td>
<td>5582</td>
<td>6210</td>
<td>12991</td>
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<td>POCP</td>
<td>g C₂H₄eq</td>
<td>2.6</td>
<td>5.8</td>
<td>10.6</td>
<td>22</td>
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<tr>
<td>EI 99</td>
<td>pt</td>
<td>10.9</td>
<td>17.2</td>
<td>15.7</td>
<td>32.8</td>
</tr>
</tbody>
</table>

**EI-99**

**Analyzing 1 m³**

**Analyzing 1 ton**
* For FGG this represents just the contribution of recycled glass
CONCLUDING

• RFG has lower impacts in all indicators except in ODP (1 ton and 1 m3);
• Both FGG eco-profiles (A and B) have higher impacts in all indicators (mass) or in the majority of them (volume);
• Ecoprofile B (volume and mass) has approximately double impacts than A;
• Most of RFG advantage comes from avoided products, not from landfill;
• Landfill avoidance can be easily counteracted by transport impacts.

HOWEVER

• RFG based products still in development (lightweight concrete);
• More interesting comparison on the whole building (increased efficiency of the building process and better recyclability at end-of-life);
• FGG ecoprofile B was calculated for