Formacel® 1100: Life cycle assessment for use in a household refrigerator


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Introduction: Foam Expansion Agents (FEA)

Goal and Scope of this study

Methodology

Results

Sensitivity Analysis

Summary and Conclusions
Introduction: Foam Expansion Agent

Prefabricated Polyurethane (PU) insulation panels

Isocyanate
Polyol
Catalyst

Foam expansion agent

- Formacel® 1100
- HFC-245fa
- CP/IP
- Other historical FEAs
Introduction: Environmental concerns - the tradeoffs

Concerns about climate change of current commercial FEAs - creating demand for products with low greenhouse gas footprints

<table>
<thead>
<tr>
<th>Foam expansion agent</th>
<th>Global Warming Potential, kg CO₂ eq per kg FEA</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCFC-141b</td>
<td>725</td>
<td>[IPCC 4th ed. 2007]</td>
</tr>
<tr>
<td>HFC-245fa</td>
<td>1030</td>
<td>[IPCC 4th ed. 2007]</td>
</tr>
<tr>
<td>HFO-1336mzz-Z</td>
<td>8.9</td>
<td>[Baasondorj, M., et.al]</td>
</tr>
<tr>
<td>Hydrocarbon</td>
<td>11</td>
<td>[IPCC 4th ed. 2007]</td>
</tr>
</tbody>
</table>

In addition, the GHG due to

1. Foam formulation Manufacturing
2. Loss during installation
3. Emission during use
4. End of life
5. Energy savings during use

A holistic life cycle approach is necessary
Goal

- Identify key steps in the life cycle of PU foam insulation in a refrigerator contributing to Climate Change Potential (CCP)

- Perform an environmental comparative assertion about the performance of Formacel-1100® and other commercially available foam expansion agents for a top mounted standard refrigerator with freezer

  - Life cycle assessment work followed the procedure outlined in ISO 14040/14044
  
  - Part of a more extensive LCA work on the use of Formacel® 1100 in residential wall and household refrigerator application
Scope of Study

- Application: Refrigerator
  - US: 26 cubic feet AV, 12.95 cubic feet foam

- Functional unit: 1 refrigerator unit, for 14 years

- FEAs: HC, pure Formacel® 1100, blends of Formacel® 1100 and HC

- Geography: USA including sub-regional grids

Impact studied: Climate change potential (kg CO₂ equivalents)

<table>
<thead>
<tr>
<th>Region</th>
<th>Climate Change Potential (CCP)</th>
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<tbody>
<tr>
<td>NYUP</td>
<td>kg CO₂ eq./kWh 0.296</td>
</tr>
<tr>
<td>RFCW</td>
<td>kg CO₂ eq./kWh 0.923</td>
</tr>
<tr>
<td>US average</td>
<td>kg CO₂ eq./kWh 0.751</td>
</tr>
</tbody>
</table>
# FEA emissions contributing to GWP

<table>
<thead>
<tr>
<th>Stages</th>
<th>Amount</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEA emission loss</td>
<td>• 5% during installation</td>
<td>ICF international, internal communication</td>
</tr>
<tr>
<td></td>
<td>• 10% during overpacking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 8% during use</td>
<td></td>
</tr>
<tr>
<td>EOL incineration</td>
<td>22% of remaining FEA</td>
<td>US municipal waste treatment</td>
</tr>
<tr>
<td>EOL land fill</td>
<td>78 % of remaining FEA</td>
<td>US municipal waste treatment</td>
</tr>
</tbody>
</table>
Goal and Scope of Study

System Boundaries

Cradle to grave analysis
Energy usage

- Yearly energy usage (kWh/year)\(^1\) = 7.84*AV + 220.8
  - AV: adjusted volume (cubic feet)
  - For US region: 35.6 kWh/month
- Assumed corresponds to a refrigerator with HC expansion agent

1. From NAECA energy start correlation
2. Thomaz et al. (2003)
Methodology

- Life Cycle Assessment (LCA) - GHG emissions throughout foam insulation lifecycle

- SimaPro™ LCA software from the American Chemical Council (ACC)

- Life Cycle Inventory (LCI) – USLCI, EcoInvent, Plastics Europe, Joint development and test partners, DuPont internal communications

- Manufacturing data – SRI Report, PERP report, open literature, DuPont internal communication

- Electricity Grid – USLCI average and sub-regional grids

- Formulation recipe and characteristics – various industry formulators, open literature
Life Cycle Impact Assessments

SimaPro software used for impact assessment

Detailed report will be made available shortly after external peer review process
CCP with net energy use - USA

Appliance life: 14 years

- Net energy use calculated with respect to PU using HC FEA
- Burden includes manufacturing, installation use phase emission and EOL
- No significant difference in CCP burdens from manufacturing, installation, use phase emission and EOL combined
- The high blend provides the lowest net CCP burden
Effect of electricity grid on net CCP

- Similar trend in all regions
- However better CCP savings despite same energy usage for RFCW region
For refrigerators being used for longer time, the CCP savings using Formacell® 1100 is amplified.
Summary & Conclusions

- Formacel® 1100 showed promise in lowering net CCP in comparison to HC expansion agent.
- The best result was obtained for a high blend of Formacel® 1100 in HC
- The energy usage during use phase of the appliance contributes most to the GWP and all other impact categories.
- The regional variations in electricity grid has significant effect on climate change potential.
- Refrigerators used for a longer time, the benefit of using Formacel® 1100 is enhanced.
- Significantly more experimental work is underway to validate the conclusions drawn in this work.
Questions?