K12: A REAL LIFE PROJECT where CO2 bubbles make the difference

S. Cavalca, Dow Italia

With the contribution of the LIFE financial instrument of the European Community
It aims to demonstrate the feasibility and effectiveness of an innovative Polyurethane technology offering significantly improved thermal insulation and, thus, energy efficiency of households cold appliances, contributing to the European Community’s goals of creating an energy efficient economy while mitigating the threat of global warming.
**Background: EU climate & energy package**

Set of binding legislation to ensure the EU meets its climate and energy targets

<table>
<thead>
<tr>
<th>2020:</th>
<th>2030:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 20% cut in <strong>greenhouse gas</strong> emissions (from 1990 levels)</td>
<td>• 40% cuts in <strong>greenhouse gas</strong> emissions (from 1990 levels) – at least</td>
</tr>
<tr>
<td>• 20% of EU energy from renewables</td>
<td>• 27% share for renewable energy – at least</td>
</tr>
<tr>
<td>• 20% improvement in <strong>energy efficiency</strong></td>
<td>• 27% improvement in <strong>energy efficiency</strong> – at least</td>
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</table>

The targets were set by EU leaders in 2007 and enacted in legislation in 2009.

The framework was adopted by EU leaders in October 2014.

**Energy Efficiency directive**

(Adopted 2012, under revision in 2016)
- Ecodesign & Energy Label-
Background: Energy Consumption

- Residential sector account for **30%** of total energy supply, distributed over **140M** household
- Cold appliances account for **14,5%** of total household energy consumption
Background: Energy Labelling

Year of application measure:

1995 Energy Label A-G
1999 Ban of classes D, E & F
2004 Label classes A+ & A++ added
2010 Ban of classes B & C
2011 Label class A+++ added
2012/2014 Ban of class A
Background: the market

- The cold appliances market is characterised by a **high level of substitution** of old appliances.

- Refrigerator stock reached the **saturation level**.

- Market trends of refrigerator-freezers are towards models with a **larger capacity**.

(Source: JRC Report Energy Trends 2000-2014)

An highly efficient refrigerator, with larger capacity and environmental friendly manufacturing can be a **real winner on the market**!
Project partners

**Dow Italia**
is owned by The Dow Chemical Company, global leading chemical company. Dow connects chemistry and innovation with sustainability to help address many of the world’s biggest challenges.

**Whirlpool Europe**
and **Whirlpool R&D**
are belonging to the Whirlpool Corporation the world’s No.1 producer of white good household appliances.

**Afros**
is part of the CANNON Group, an international, independent group, world leader in PU equipment providing a range of industries world-wide with dedicated to engineering solutions.
An innovative polyurethane chemistry to be injected with novel foaming equipment into a new designed refrigerator able to improve the refrigerators energy efficiency up to 20%
K12: A REAL LIFE PROJECT
<table>
<thead>
<tr>
<th>Project location</th>
<th>Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project start date:</td>
<td>01/06/2014</td>
</tr>
<tr>
<td>Project end date:</td>
<td>30/11/2017</td>
</tr>
<tr>
<td>Total Project duration (in months)</td>
<td>42 months</td>
</tr>
<tr>
<td>Total budget</td>
<td>€ 3,975,622</td>
</tr>
<tr>
<td>Total eligible budget</td>
<td>€3,975,622</td>
</tr>
<tr>
<td>EU contribution:</td>
<td>€ 1,941,310</td>
</tr>
<tr>
<td>(%) of total costs</td>
<td>48.83</td>
</tr>
<tr>
<td>(%) of eligible costs</td>
<td>48.83</td>
</tr>
<tr>
<td>Coordinating Beneficiary</td>
<td>Dow Italia s.r.l</td>
</tr>
<tr>
<td>Associated Beneficiaries</td>
<td>Afros S.p.a.</td>
</tr>
<tr>
<td></td>
<td>Whirlpool R&amp;D</td>
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<td></td>
<td>Whirlpool EMEA</td>
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</table>
K12 project Timeline and Actions

**A. Preparatory Actions**
- 1. Lab Development and Testing
- 2. Pilot plant runs
- 3. Project impacts
- 4. Communication
- 5. Whole management

**B. Implementation Actions**

**C. Monitoring of the Impact**

**D. Comm. & Dissemination**

**E. Project Management**

**Technical and financial report**

- Inception Report
- Midterm Report
- Final Report

**Project start date:** 2014 June

**Project end date:** 2017 November

→ Extension 2018 November

1. Lab Development and Testing
2. Pilot plant runs
3. Project impacts

**http://www.dow.com/en-us/k-12**
where CO2 bubbles make the difference
K12 would allow one step change in Energy Efficiency

**EU: average energy consumption of refrigerator sales in 2014**

- **A+++**: 146 kWh/year, -40%
- **A++**: 196 kWh/year, -25%
- **A+**: 247 kWh/year, -21%
- **A**: 243 kWh/year

Data: GfK, Graph: Topten.eu

* Energy Saving, ** Data: Gfk, Energy Efficiency of white goods in Europe, dec 2016, for ADEME, Sowatt & Bush energy – www.topten.eu
Domestic Refrigerators: insulation material

Why Polyurethane?

Comparison of thermal efficiency:

- 2.5 cm rigid PU foam
- 4.0 cm poli-styrene
- 4.5 cm fiber-glass
- 5 cm cork
- 12 cm wood
- 40 cm bricks
How a refrigerator is injected with PU foam?

Most conventional injection technology:
Injection from the compressor side—door up
Energy Efficiency Impact of PU insulation

- Fast reactivity
- Modified fixture
- Foaming under vacuum
- Blowing Agent

- Microcellular foam
- CO2 blowing agent
- Lowest GWP
- Long term sustainable solution

- Current process
- PU injected into the refrigerator
- Blowing Agent

LIFE08 ENV/IT/000411
LIFE13 ENV/IT/001238
Non-PU available alternate solutions in the market

k-factor @10°C (mW/m.K)

Xenergy™ is a Tradename of The Dow Chemical Company
Thermal insulation by VIPs + PU foam

<table>
<thead>
<tr>
<th>Fumed silica typical VIP physical properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (kg/m³)</td>
<td>170-210</td>
</tr>
<tr>
<td>Thermal Conductivity at mean temperature of 22.5°C (72.5°F) (W/m.K)</td>
<td></td>
</tr>
<tr>
<td>@ 1 mbar</td>
<td>≤0.005</td>
</tr>
<tr>
<td>@ ambient pressure</td>
<td>≤0.019</td>
</tr>
<tr>
<td>Rated Value (W/m.K)</td>
<td>0.008</td>
</tr>
</tbody>
</table>

Source: Porextherm web site

\[
\lambda_{\text{Wall}} = f(\lambda_{\text{VIP}}, \lambda_{\text{PUfoam}})
\]
PU Foam Thermal Conductivity

\[ \lambda_{\text{Foam}} = \lambda_{\text{gas}} + \lambda_{\text{solid}} + \lambda_{\text{radiative}} \]

- Smaller cell size → reduce the radiation contribution
- Lower foam density → reduce the solid contribution
- Low gas thermal conductivity (k) → reduce the gas/blowing agent contribution

However, combination of all these options must be considered and gauged, for example...

Reduced density will decrease the solid conduction contribution, but will also increase the radiation contribution due to thinner cell walls

*K-12 Project is active in all these aspects and works on reducing all heat transfer contributions and to maximize thermal insulation, thus energy efficiency*
Towards K12: microcellular foam upscale
...where CO2 bubbles make the difference

PU R&D Lab, Dow Italia

< 30-60 μm →

Pilot Plant, Afros

Elongated cells

Bimodal cells

Cell size 100-120 μm

Refrigerator prototype, Whirlpool

...Next step
Thank You