Improving Energy Efficiency within the food cold-chain

Stephen J James & Christian James
11th International Congress on Engineering and Food (ICEF 2011), Athens, Greece, 22-26 May 2011
Defra project

3 year Defra funded project to:
“identify, develop and stimulate the development and application of more energy efficient refrigeration technologies and business practices for use throughout the food chain whilst not compromising food safety and quality”
Main topics in work programme

1. Mapping of energy use
2. Identifying new technologies and business practices
3. Feasibility studies on promising technologies and business practices
4. Continuous interaction with food and refrigeration industries
Mapping of energy use

Objective

Identify and rank 10 ‘operations’ (process/food combinations) in order of the potential by the use of improved technology and enhanced business practice to reduce energy usage in food refrigeration
Mapping – Initial estimate

% Energy

- Retail: 53%
- Transport: 19%
- Primary & Secondary chilling & Freezing: 23%
- Chilled and frozen storage: 5%

FRPERC
Food Refrigeration and Process Engineering Research Centre
## Energy mapping – top ten ranking

<table>
<thead>
<tr>
<th>Rank</th>
<th>Category</th>
<th>GWh/y (Range)</th>
<th>% Range</th>
<th>GWh/y Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Retail display</td>
<td>5800 - 12700</td>
<td>30-50</td>
<td>6300</td>
</tr>
<tr>
<td>2</td>
<td>Catering – kitchen refrigeration</td>
<td>4000</td>
<td>30-50</td>
<td>2000</td>
</tr>
<tr>
<td>3</td>
<td>Transport</td>
<td>4820</td>
<td>20-25</td>
<td>1200</td>
</tr>
<tr>
<td>4</td>
<td>Cold storage - generic</td>
<td>900</td>
<td>20-40</td>
<td>360</td>
</tr>
<tr>
<td>5</td>
<td>Blast chilling – (hot) ready meals, pies</td>
<td>310 - 610</td>
<td>20-30</td>
<td>180</td>
</tr>
<tr>
<td>6</td>
<td>Blast freezing – (hot) ready meals, potato</td>
<td>220 - 420</td>
<td>20-30</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td>products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Milk cooling – raw milk on farm</td>
<td>100 - 320</td>
<td>20-30</td>
<td>100</td>
</tr>
<tr>
<td>8</td>
<td>Dairy processing – milk/cheese</td>
<td>250</td>
<td>20-30</td>
<td>80</td>
</tr>
<tr>
<td>9</td>
<td>Potato storage – bulk raw potatoes</td>
<td>140 - 190</td>
<td>~30</td>
<td>60</td>
</tr>
<tr>
<td>10</td>
<td>Primary chilling – meat carcasses</td>
<td>110 - 140</td>
<td>20-30</td>
<td>40</td>
</tr>
</tbody>
</table>
1- Retail display

- Improvements in insulation, fans and lighting but only 10 to 30% of heat load

- Concentrating on:
  - Infiltration in multi-decks (80% of load)
  - Radiation in frozen wells (40% of load)
2 - Catering

- Approximately 500,000 commercial service cabinets
- Chilled consume 2,900 kWh per year
- Frozen consume 5,500 kWh per year
- Large differences in efficiency
2 - Catering options to improve

- Cleaning the condenser coil reduced consumption by 8%
- Resetting the thermostat to a sensible value saved another 11%
Replacement of devices

- **2 door freezer**: 598 kWh (Before), 282 kWh (After)
- **Chiller 1**: 293 kWh (Before), 174 kWh (After)
- **Chiller 2**: 302 kWh (Before), 273 kWh (After)
- **Fridge freezer**: 507 kWh (Before), 450 kWh (After)

Energy used (kWh)
3- Refrigerated transport

• 52,000 refrigerated vehicles in use
• Average 26 litres/day for refrigeration
3 - Transport - Only measured data

![Graph showing refrigeration daily consumption (kWh) vs. vehicle number for different types of vehicles: Large Artic, Small Artic, Large Rigid, Small Rigid, Medium Rigid, and Urban Artic.](image-url)
Alternative and Emerging Refrigeration Technologies

- Magnetic
- Thermoacoustic
- Thermoelectric
- Stirling cycle
- Air cycle
- Tri-generation
- Sorption technologies (absorption and adsorption)
- CO$_2$ refrigeration systems
Alternative technologies

• Currently difficult to see any that will make a step reduction in food refrigeration energy consumption in next decade
• Many will find niche markets
Energy optimisation of a food refrigeration system

“No accurate model of a complete food refrigeration system is possible unless both the refrigeration users and mechanical plant are considered simultaneously in the model.”

(Cleland 1990)
This project’s model

- Integrates
  - A dynamic model of a refrigeration system (evaporator, compressor, condenser, etc.)

- With
  - A dynamic model of the food space and the temperature response of the food
Food depth - 80mm or 40mm
Overall - Potential

- On the best available data the energy saving potential in the top five operations retail, catering, transport, storage and primary chilling lies between 4300 and 8500 GWh/y

- Without real data on energy consumption and heat extracted it is impossible to benchmark existing operations, provide sensible targets or quantify the true effect of energy saving technologies
Overall - Top 10

• Applying current knowledge of most efficient systems would substantially reduce energy consumption in retailing, catering, storage and chilling/freezing processes

• Some generic transfer but real benefits from site to site study

• Much more information on http://www.grimsby.ac.uk/What-We-Offer/DEFRA-Energy/
What is the purpose of the factory/plant?

- **Input**
  - Raw materials (amount/temperature)
  - Packaging
- **Output**
  - Packaged finished product (amount/temperature)
- **Purpose**
  - Transform input into output in most cost effective manner
Input and Output

Input
- 350 tonnes at -20°C
- 125 tonnes at 0°C

Output
- 400 tonnes at 3°C
- 75 tonnes at 12°C
Heat energy in product

Input
32,500,000,000kJ

Output
121,525,000,000kJ
Question

Why are refrigeration systems required if the food has to gain heat?

“Cost 600,000 euro per year”