IDRIST

Estimations of the market potential for high temperature PCMs for industrial heat recovery

Thorsten Spillmann
Contents

• IDRIST project introduction
• Classification of industrial processes
  • Production process
  • Energy consumption
  • Temperature levels
• Examples from the food processing industry
• Preliminary conclusions
IDRIST Project Phases

1. Market Potential
   1. Identify industry needs and market potential (100-300°C)

2. Integrated PCM thermal storage systems
   1. Identify and characterise candidate PCMs
   2. Design laboratory tests and simulation
   3. Experimental evaluation & model validation
   4. System modelling for industrial applications

3. Thermo-chemical heat storage and transformation
   1. Short list salt-refrigerant working pairs using ideal thermodynamics

4. Whole systems modelling
   1. Business models, techno-economic assessments
   2. Whole system performance modelling
Model of industrial production process

Unit Processes

11 Production Processes
- Decomposing
- Mixing
- Cutting
- Joining
- Coating
- Forming
- Heating
- Melting
- Drying/Concentrating
- Cooling/Freezing
- Packing

7 Support Processes
- Lighting
- Compressed Air
- Ventilation
- Pumping
- Space heating/cooling
- Hot water heating
- Internal transport

Heat Integration

continuous

batch

Source:
Thollander and Palm (2013) Improving Energy Efficiency in Industrial Systems
## Batch vs. Continuous Production

### Example: Chemical Industry

<table>
<thead>
<tr>
<th>Batch Process</th>
<th>Continuous Process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>Good for <strong>small amounts</strong> of speciality chemicals</td>
<td>Frequent start up and shutdown of equipment</td>
</tr>
<tr>
<td>Make a <strong>range of products</strong> using same equipment</td>
<td>Cleaning time between batches</td>
</tr>
<tr>
<td>Good for developing new products</td>
<td>May be batch to batch variability</td>
</tr>
<tr>
<td>Easier to scale up from lab scale</td>
<td>Not good for bulk chemical production</td>
</tr>
<tr>
<td>Generally <strong>cheaper set up costs</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Continuous Process</th>
<th><strong>Advantages</strong></th>
<th><strong>Disadvantages</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Good for <strong>large volumes</strong> (bulk chemicals)</td>
<td>Requires periodic shutdown of whole plant for inspection and maintenance</td>
<td></td>
</tr>
<tr>
<td>Fewer start up and shutdowns</td>
<td>May rely on critical pieces of equipment which have the potential to stop production on whole plant</td>
<td></td>
</tr>
<tr>
<td>Potentially <strong>greater yields</strong></td>
<td>Higher initial costs</td>
<td></td>
</tr>
<tr>
<td>Potentially easier to maintain quality</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Source:** C. McEvoy (2010) *The Industrial Manufacture of Chemical Compounds.* [www.ulster.ac.uk](http://www.ulster.ac.uk)
Applications for thermal storage

- Continuous Process
  - Transportation of heat
  - Long-term storage

- Batch Process
  - Heat recovery between operation to reduce heat loss of cooling down equipment
  - Chemical Processing: Heat input to reach reaction temperatures, heat removal during exothermic reaction
  - Food production: Cooking of product, subsequently cooling to down for storage.
Approach for identification of relevant industries

1. Fuel demand of industrial sectors
2. Temperature Ranges of relevant processes and common production practices

→ preselection: Food & Tobacco, Pharmaceuticals, small scale Chemicals, Textiles

3. Identification of relevant subsectors
4. Temperature ranges and heat demand of target industries

Sources of Information

- Energy Audit documents (Einstein II)
- Best Available Techniques Reference Documents
- Estimations for industrial waste heat recovery
- Solar thermal industrial heat applications
Fuel Consumption in the UK

Fuel consumption in UK industry by sector


Fuel Consumption =
Oil Products + Natural Gas + Coal + Heat

*Calculations based on data from 1987
Temperature levels of individual processes

- **Chemicals (30%): 33.63EJ**
  - Ammonia: Hydrogen production 1,000°C
  - Soda ash: Calcination 950-1,100°C
- **Iron & steel (19%): 21.44EJ**
  - Coke making 850-1100°C
  - Furnaces 1,200-1,600°C
- **non-metallic minerals (9%): 10.61 EJ**
  - Cement (70-80%): Rotating kiln 1,500°C
  - Lime: Calcination 1,000°C
- **Pulp & paper (6%): 6.45 EJ**
  - Pulp Pre-steaming & Impregnation 110°C
  - Pulp Digester Cooking 170-176°C
- **Food & Beverages (5%): 5.98 EJ**
  - Cooking, Bleaching 60-90°C
  - Sterilising 100-140°C
  - Baking 100-300°C
- **Textile & leather (2%): 2.17 EJ**
  - Bleaching, Dyeing 60-90°C
  - Fixing 160-180°C

* worldwide primary energy demand

- **Petrochemicals: Steam cracking 760-850°C**
- **Casting 700-900°C**
- **Glass: Furnace 1,575°C, Annealing 580°C**

**most relevant sectors**

- **Pulp Bleaching 130-150°C**
- **Paper Drying 60-80°C**
- **Pasteurising 60-95°C**
- **Drying 120-180°C**
- **Pressing 80-100°C**
- **Drying 100-130°C**
# Nature of industrial sectors

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Heterogeneous</th>
<th>Homogeneous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-3</td>
<td>-2</td>
</tr>
<tr>
<td>Iron &amp; Steel</td>
<td></td>
<td></td>
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<tr>
<td>Aluminium</td>
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<tr>
<td>Cement</td>
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<td>Lime</td>
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<tr>
<td>Glass</td>
<td></td>
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<tr>
<td>Ceramics</td>
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<td></td>
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<tr>
<td>Paper &amp; Pulp</td>
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<tr>
<td>Unclassified</td>
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<tr>
<td>Food &amp; Drink</td>
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<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td></td>
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</tbody>
</table>

*Source: McKenna and Norman (2010) Spatial modelling of industrial heat loads and recovery potentials in the UK*
Example Food & Tobacco Sector (1/3): Dairy

Source:
Example Food & Tobacco Sector (2/3): Baking

**Source:**
## Example Food & Tobacco Sector (3/3): Brewery

<table>
<thead>
<tr>
<th>Process</th>
<th>10°C</th>
<th>20°C</th>
<th>30°C</th>
<th>40°C</th>
<th>50°C</th>
<th>60°C</th>
<th>70°C</th>
<th>80°C</th>
<th>90°C</th>
<th>100°C</th>
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<tbody>
<tr>
<td>1st drying of green malt</td>
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<td>2nd drying of green malt</td>
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<tr>
<td>Cleaning of bottles and cases</td>
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<tr>
<td>Cleaning of production halls and equipment</td>
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<td>Production of brewing water</td>
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<td></td>
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<tr>
<td>Pasteurisation of beer</td>
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<tr>
<td>Mashing</td>
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<tr>
<td>Wort heating</td>
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<td></td>
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<tr>
<td>Wort boiling</td>
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</tbody>
</table>

*Source: 2014Mauthner - Manufacture of malt and beer with low temperature solar process heat*
Preliminary conclusions

• Applicability of thermal storage is broadest in batch production
• Food & Beverage and Chemical Industry appear to be most promising target industries
• 90% of processes in the food industry are at temperature levels below 200°C the majority of those below 120°C
• Due to the diversity of the respective sectors, a detailed analysis of site specific processes are necessary to obtain relevant information for the system design (e.g. storage capacity, discharge rates, etc.)
Thank you for your attention!