Industrial Demand Reduction through Innovative Storage Technologies (EPSRC EP/M008088/1)

Centre for Renewable Energy Systems Technology

Opportunities for industrial heat storage in the UK using Phase Change Materials

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1) Introduction

The reduction of the industrial energy demand is of significant importance for meeting the government's 2050 emission targets. In heat intensive industries significant cost and emission savings can be achieved by the effective management of site-specific thermal loads. Thermal energy storage is envisioned to play an important part in this context, because it provides the possibility to extend process integration approaches to batch operation plants allowing for the design of energy efficient yet flexible production systems.

2) Site and process characteristics for determining the suitability of thermal storage applications

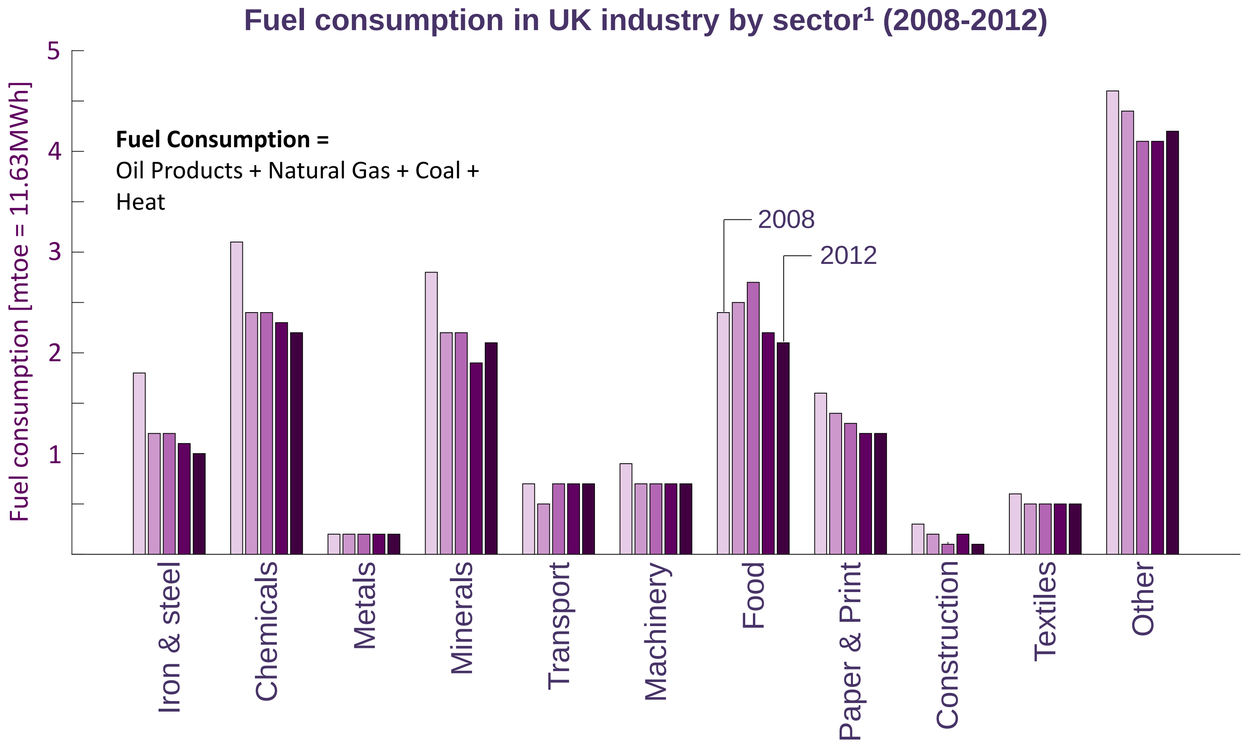
A list of process and site specific attributes is compiled to help assess the suitability of thermal storage applications to individual production systems.

Characteristic	Description
Heat intensity	The heat intensity of a process is a measure of the relative importance of thermal energy in running costs and emissions of production. It is therefore directly related to the impact heat integration can have on the reduction of those figures.
Batch production	Many possibilities for thermal storage integration due to the discontinuous nature of the production process. Thermal storage useful in continuous production processes for reducing shut-down and start-up times for maintenance and transport of heat e.g. for district heating.
Low added value good	High relative cost of production make thermal integration an effective tool for production efficiency enhancement in heat intensive industries.
Space limitation	Apart from operation in a tight temperature range, latent heat storage systems provide energy storage densities far superior to sensible heat storage systems, enabling the design of smaller stores. For sites with limited availability of space, this can be an important advantage.
Process temperature cascade	The multitude of process streams with heating and cooling demands at different temperature levels can be organised into a series of time-dependent heat cascades. While traditional heat integration routines (based on continuous production processes) only focus on heat integration within individual cascades (direct heat transfer), the integration of a thermal storage system furthermore allows the integration of heat from different cascades, i.e. different points in time (heat integration between time intervals or between batches). Still, the more extensive the heat cascades are, the larger the possibilities for heat recovery during production.

3) Assessment of heat intensity of UK industry

An assessment based on the fuel consumption of industry sectors[1] revealed the Chemical Industry and the Food Sector to be the major industrial thermal energy consumers in the UK.

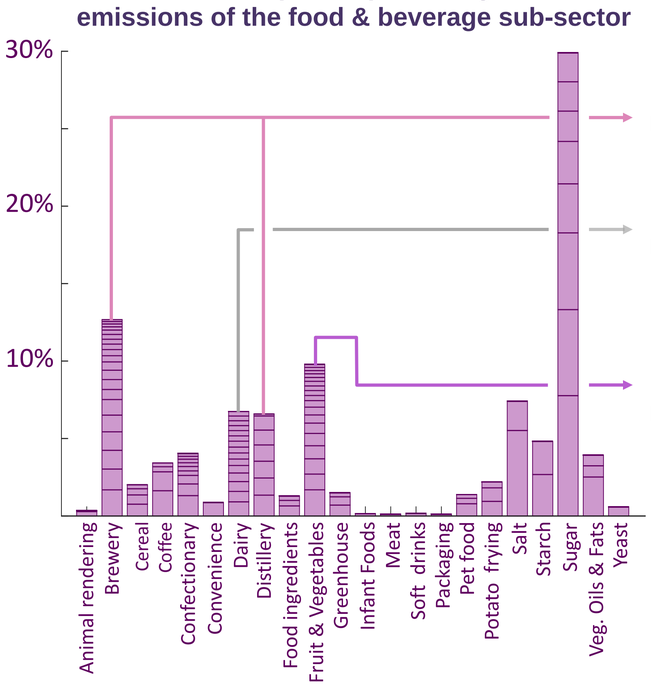
Fuel consumption in UK industry by sector[1] (2008-2012)



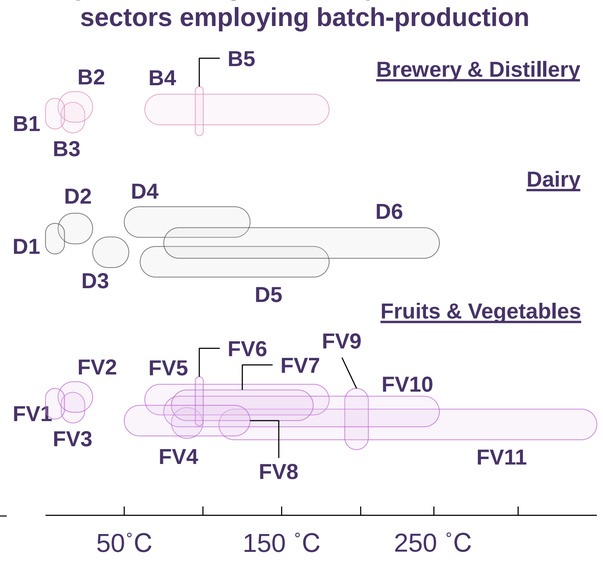
4) Detailed look at the food & beverage sector

The UK National Allocation Plan[2] calculates a site specific "relevant CO_2-emission" value, that is used as a basis for the for participation in the European Union Emissions Trading Scheme for the period 2008 to 2012 (Phase II). A comparison of the site-specific emissions relative to the sector's overall emissions indicates, that the brewery, distillery, dairy, and fruit & vegetable sub-sectors, where batch-production is common, claim a significant portion of the sector's overall heat demand. Temperature ranges of unit-processes common for those sub-sectors are determined from industry-specific best-practice documents[3].

Cumulative site-specific percentage of relevant emissions of the food & beverage sub-sector



Temperature ranges of unit processes of sub-sectors employing batch-production

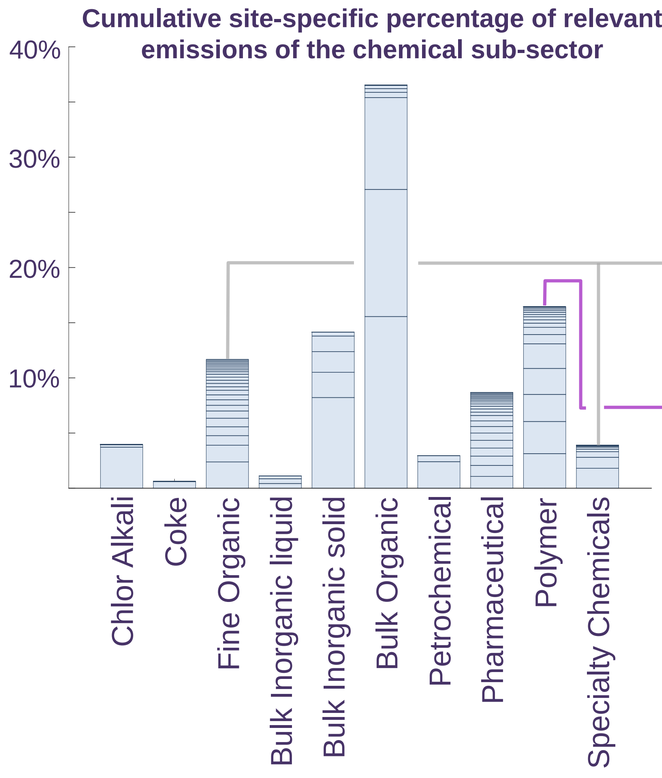


FV1 Cooling, **FV2** Fermentation, **FV3** Soaking, **FV4** Blanching, **FV5** Sterilization, **FV6** Cooking, **FV7** Dehydration, **FV8** Evaporation, **FV9** Frying, **FV10** Drying, **FV11** Baking
D1 Cooling, **D2** Fermentation, **D3** Coagulation, **D4** Evaporation, **D5** Pasteurisation, **D6** Drying
B1 Cooling, **B2** Fermentation, **B3** Soaking, **B4** Sterilization, **B5** Cooking

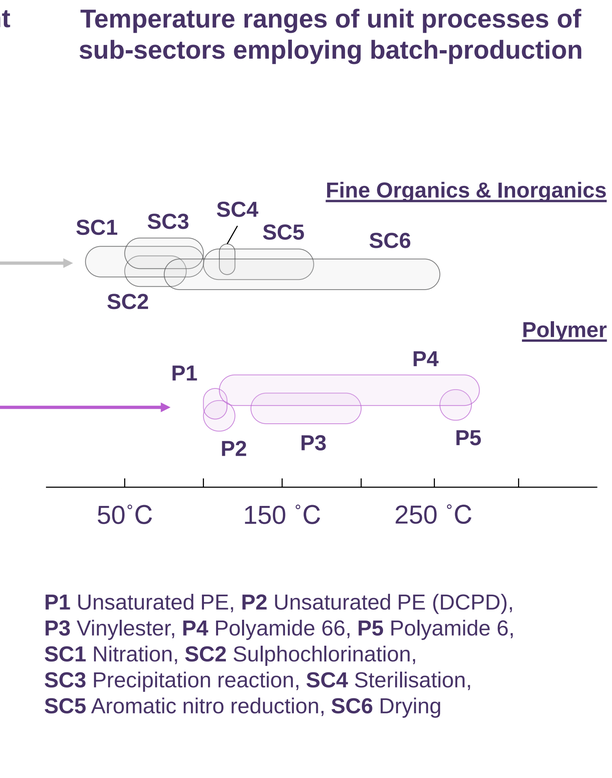
5) Detailed look at the chemical sector

The majority of CO_2-emissions in the Chemical sector is attributed to bulk chemicals, that are usually produced in continuous processes. The diverse nature of the subsectors of Pharmaceutical, Fine Organic and Specialty Inorganic Chemicals, where batch production is common, make the identification of representative processes difficult. Based on sub-sector specific best practice reference guides[4,5,6], temperature levels of some relevant batch unit-processes could be determined.

Cumulative site-specific percentage of relevant emissions of the chemical sub-sector



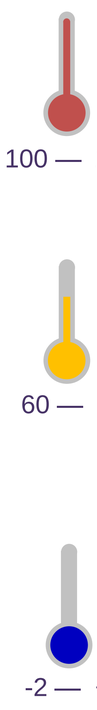
Temperature ranges of unit processes of sub-sectors employing batch-production



P1 Unsaturated PE, **P2** Unsaturated PE (DCPD), **P3** Vinylester, **P4** Polyamide 66, **P5** Polyamide 6, **SC1** Nitration, **SC2** Sulphochlorination, **SC3** Precipitation reaction, **SC4** Sterilisation, **SC5** Aromatic nitro reduction, **SC6** Drying

6) Temperature levels of target applications and candidate materials

Based on the information obtained about the sector-specific production processes, three temperature bands are identified, in which the application of latent heat storage systems have the highest potential. This allows for a preselection of a number of suitable candidate materials[7,8,9] for industrial heat storage.



100 — 170˚C

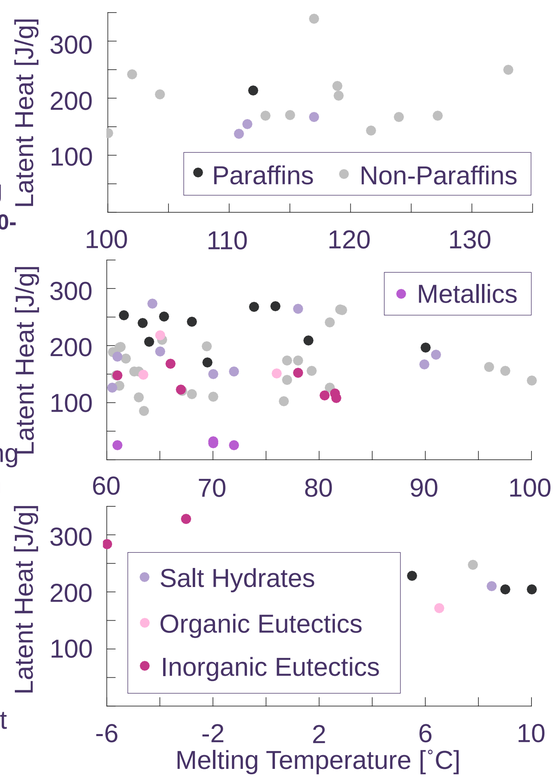
Waste heat sources: PE polymerisation Reaction heat from **100-120˚C**, PA polymerisation Reaction heat from **110-275˚C**, process waste heat
Heat sinks: Sterilisation **110-120˚C**, drying **75-250˚C**, PE polymerisation initialisation **20-200(+)˚C**

60 — 100˚C

Waste heat sources: Air compressors **80˚C**, cooking water, process heat
Heat sinks: Dairy pasteurisation **60-80˚C** , concentration processes **60-80˚C**, boiler water preheating **60-90˚C**, tinned food cooking **60-90˚C**, bleaching **60-90˚C**, cleaning of equipment **60-80˚C**, PVC polymerisation **35-75˚C**, drying **75-250˚C**, Nitration **25-100˚C**, sulphochlorination **50-89 ˚C**, precipitation reactions **50-100 ˚C**

-2 — +5˚C

Energy sources: Process heat fired adsorption chillers, night-time powered compression cooling system
Energy sinks: Cold-stores used in almost every sub-sector of food industry



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