Sector Focus

Carcass Chilling

	Sector	GWh/y
1	Retail display	9,233
2	Catering – kitchen refrigeration	4,380
3	Transport	4,822
4	Frozen storage – generic	900
5	Blast chilling – (hot) ready meals, pies	425
6	Blast freezing – (hot) prepared products	316
7	Dairy processing – milk/cheese	250
8	Milk cooling – raw milk on farm	207
9	Potato storage – bulk raw potatoes	165
10	Primary chilling – meat carcasses	129

Mean estimated annual UK energy usage

Technology

The aim of a carcass chiller is to reduce the temperature of freshly slaughtered red and poultry carcasses to one where the rate of microbial growth is very slow. Over 3.5 million tonnes of meat is produced in the UK each year. This is chilled from approaching 40°C to a final average temperature of 0 to 4°C. Lamb, poultry and some pig chilling systems cool whole carcasses. However, most pig and all beef carcasses are split into sides prior to chilling.

EU temperature legislation governs the chilling of beef, lamb, pork and poultry in the majority of abattoirs within the community. The only derogations are for very small abattoirs and for retail shops cutting meat for direct sale to the final consumer. The EC legislation does not define a chilling time, only a maximum final meat temperature of 7°C (beef, lamb & pork) and 4°C (poultry) before transport or cutting.

Refrigeration accounts for between 60 and 70% of the total electrical energy consumed in an abattoir

Energy used in sector

Meat carcass chilling systems in the UK are estimated to consume 129 GWh of energy per year.

Systems in use

The majority of carcass chilling systems pass refrigerated air over the warm (38 to 41°C) freshly slaughtered carcasses. Air based chillers range in complexity, size and cost depending on throughput and species to be cooled. Other types of carcass chilling systems are available including spray, immersion and multi stage.

Beef chilling

Data were from 14 commercial beef chilling that ranged in capacity from 18000 to 93000 kg (mean 30625 kg) of beef in carcass form and in size from 216 to 1124 m^3. The energy data was broken down into a base demand and a product demand (see table 1). Base demand is the energy required to maintain the chiller at the desired temperature with the doors closed. Product demand is the additional energy needed to reduce the temperature of the meat. The infiltration of warm air through the open doors during loading further adds to the product load on the refrigeration plant.

The base demand will depend on the average ambient air temperature, the level of insulation, the fan power and the control system used. Plant 1 achieved a zero-base demand in the winter because the control system cut out the fans and compressor when the desired room temperature was reached. The other plants were controlled such that all the evaporator fans ran continuously, except during defrosts, resulting in considerable base demands. To aid comparison where chillers were not fully loaded specific energy consumption for full loading was calculated by multiplying product demand per kg for a partially loaded chiller by its total capacity and adding this to the base demand.

Specific energy consumption for the first 24 hours of chilling varied from 57.8 to 78 $kJkg^{-1}$ in the winter to 78 to 102.8 kJ kg^{-1} in the summer. Substantially less energy was required in the subsequent 24 hours ranging from 3.0 to 45.8 kJ kg^{-1} (average 14.1 kJ kg^{-1}).

Pork chilling

In normal operation of a pork chiller the base energy demand, i.e. the amount of energy required to run the empty, closed chill room at its design temperature, was 57% of the total energy consumption during the chilling operation (table 2). The energy cost of the chilling operation per kg of pork chilled was therefore dependent on the utilisation of the chill room. The average cost of the evaporative weight loss during the chilling period was a factor of 15 higher than the energy costs.

Simple low cost energy savings

The energy cost of operating a carcass chiller can only be reduced by:

- Reducing the refrigeration load;
- Reducing the related refrigeration electricity use (fans, lights, etc); or
- Improving the plant coefficient of performance.

Examples in the following recommendations are based on a 60 carcass beef chiller.

Reducing Main heat inputs

- Minimise heat that has to be extracted from cooling food.
  - Use ambient cooling to remove heat from carcass prior to cooling.
  - Cover unwrapped foods to reduce evaporation and subsequent condensation and freezing of moisture on evaporator coils.
- Minimise heat generated.
  - Fit energy efficient fans with drive motors outside freezer.
  - Switch off fans when systems are empty.
  - Reduce fan speed when surface temperature of food is within 2°C of air temperature.
- Minimise heat infiltration.
  - A chiller door left open can add 33 kW to the chiller heat load

- Batch carcasses outside the chiller and load in the shortest period.
- Fit effective door protection systems on all personnel and food entry and exit points.
- Minimise surface area of chiller that is exposed to ambient temperatures.
- Use maximum thickness of insulation and design structure without thermal bridges.

System loading

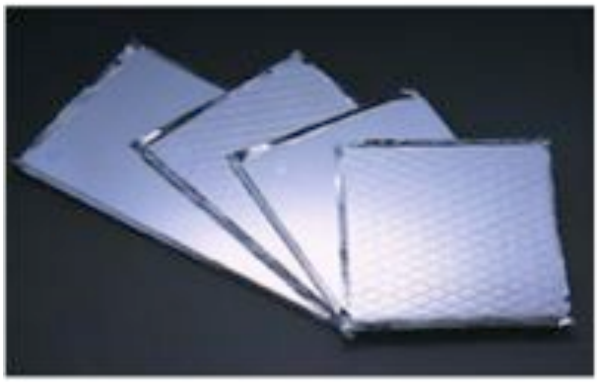
- The energy efficiency of a carcass chiller operating without any food in it is zero.
- When the system is only partially loaded:
  - Make sure the loading pattern does not allow air to short circuit and return to the evaporator without extracting heat from the food.
- Make sure that air cannot by-pass the evaporator by sealing ducts to force all air through the evaporator.

Maintenance

- Ensure that refrigeration systems are checked to ensure heat exchangers are free of dirt and that refrigerant is not leaking. Check operation of refrigeration components to ensure operating at installed capacity and efficiency.
- Replace and adjust worn or badly fitted door and food entry protection systems.
- Replace worn door seals.
- Check for any breakdown in insulation and replace.

Retrofit options

- Advanced insulation such as VIPs (Vacuum Insulated Panels) has the ability to reduce heat load across insulation. VIPs could replace current insulation and reduce energy consumption by 5-10%.



- Fit variable speed drives to fans controlled by feedback from IR surface temperature measurement of food being chilled.

Other options to consider

- High efficiency components such as compressors, heat exchangers, fans and lighting can reduce energy by up to 20%.
- Improving performance of the refrigeration system through liquid pressure amplification, suction pressure optimisation, evaporative condensers and checking to ensure no leakage of refrigerant can produce energy savings of up to 30%.
- Consider reclaiming heat from refrigeration plant for heating water or space heating.
- Consider reclaiming heat from refrigeration plant for low temperature thawing, tempering, drying or smoking processes.

Table 1. Average weight of beef sides, average air velocity over deep leg, average chiller temperature over and at end of 24 hours, deep leg temperature after 24 hours and when removed from chiller, time of removal from chiller and percentage weight loss

Chiller number	Average side weight (kg)	Air velocity ($m\ s^{-1}$)	Chiller temperature		Side temperature		Time of removal (hours)	Weight loss	
			Mean 24 hours (°C)	End 24 hours (°C)	After 24 hours (°C)	On removal (°C)		After 24 hours (%)	After 48 hours (%)
1	128	0.49	3.0	0.0	10.8	5.8	44.0	1.18	1.45
2	138	0.27	4.0	2.0	10.8	10.8	24.0	1.75	-
3	148	0.90	1.5	0.0	11.9	9.0	26.5	1.36	-
4	178	0.60	3.0	6.0	14.5	8.0	48.0	1.46	1.66
5	152	0.66	8.0	4.0	15.0	12.0	26.0	1.79	-
6.1	145	0.08	3.0	1.0	15.6	3.9	50.0	1.82	-
6.2	137	0.08	3.0	1.0	-	-	-	-	2.31
7	129	0.75	12.5	3.0	17.0	17.0	24.0	1.61	-
8	130	0.40	5.5	1.0	17.5	7.0	48.0	1.66	-
9	163	0.34	9.0	5.0	18.5	8.6	48.0	1.67	-
10	-	0.20	6.0	2.0	19.0	9.0	44.0	1.12	-
11	152	0.41	16.5	7.0	19.8	4.4	48.0	1.89	-
12	154	0.90	7.0	2.0	20.0	14.5	32.0	1.43	-
13	142	0.33	6.0	4.0	-	-	-	2.06	2.3
14	-	0.75	10.0	3.0	-	-	-	-	-
Means	140	0.45	6.5	2.7	15.9	9.2	38.5	1.6	1.93

Table 2. Energy consumption and product weight loss during commercial chilling of pork

Plant no	Base demand	Product demand in full room	Total energy consumption in full room	Weight loss
	(MJ)	(MJ)	($kJ\ kg^{-1}$)	(%)
1	778	378	208	3.50
2	1728	1624	112	2.60
3	781	648	89	2.17
4	1332	1206	96	1.85
5	3658	2371	258	2.06
Mean	1655	1245	153	2.44

Fostering the Development of Technologies and Practices to Reduce the Energy Inputs into the Refrigeration of Food

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For further information on saving energy see: www.grimsby.ac.uk/What-We-Offer/DEFRA-Energy