

Cold chain workshop

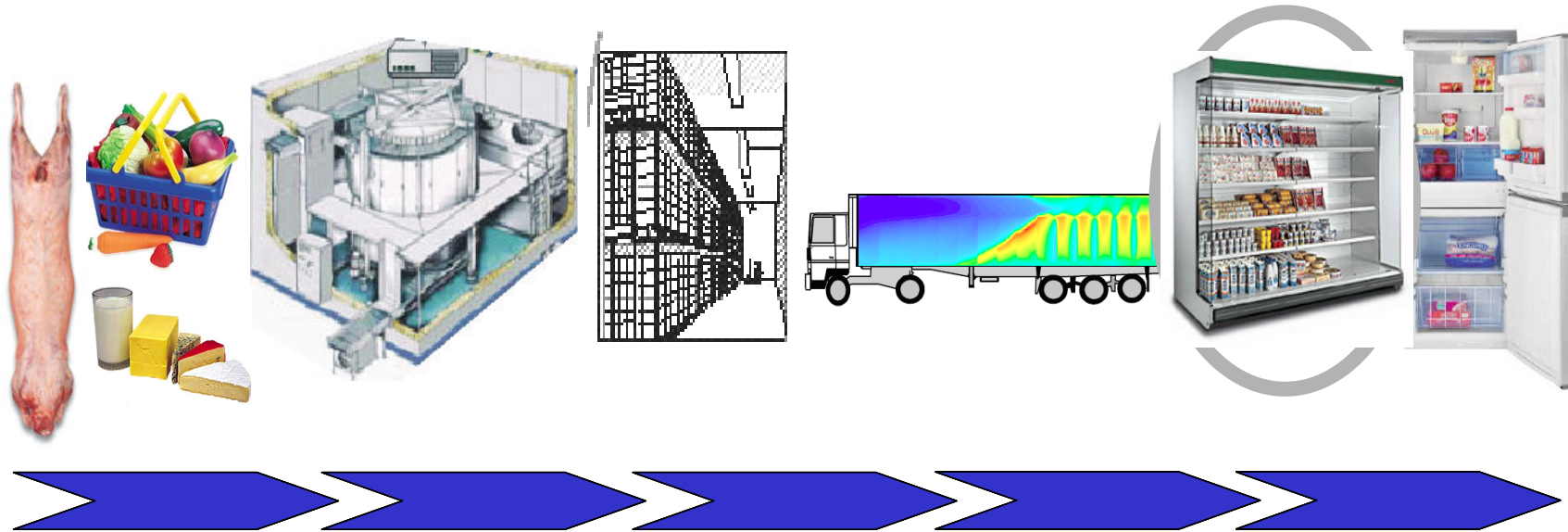
Retail

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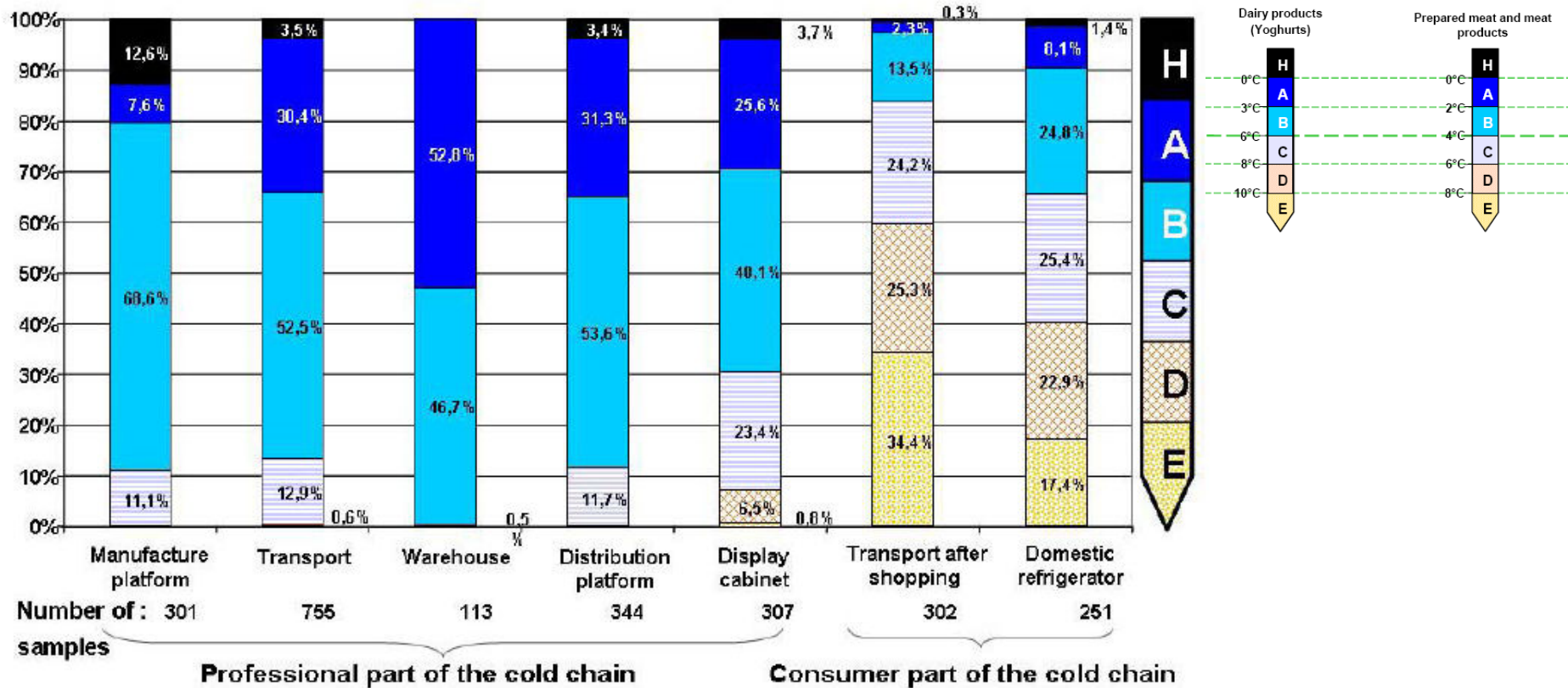
The cold chain



Retail

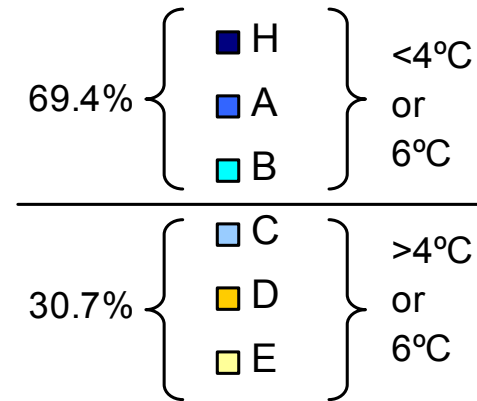
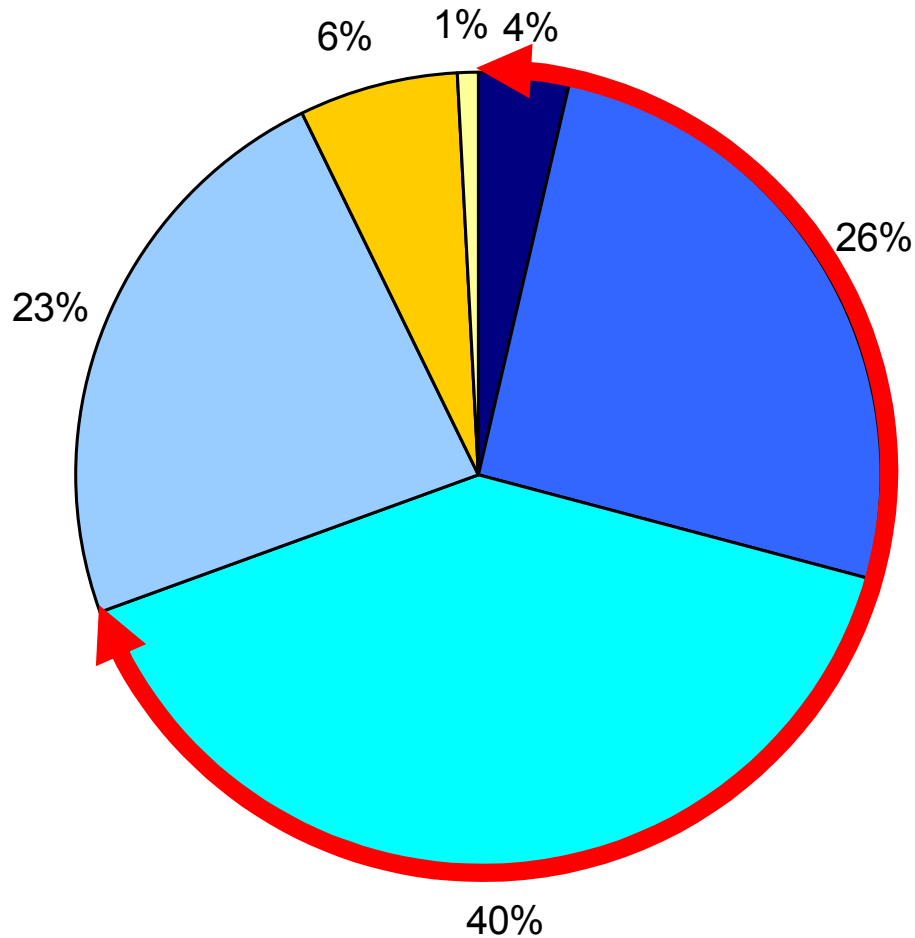
- Overview
 - Temperature control
 - Direct emissions
 - Indirect emissions
- Sustainability
- Improving temperature control
- Reducing direct and indirect emissions

Temperature control in retail

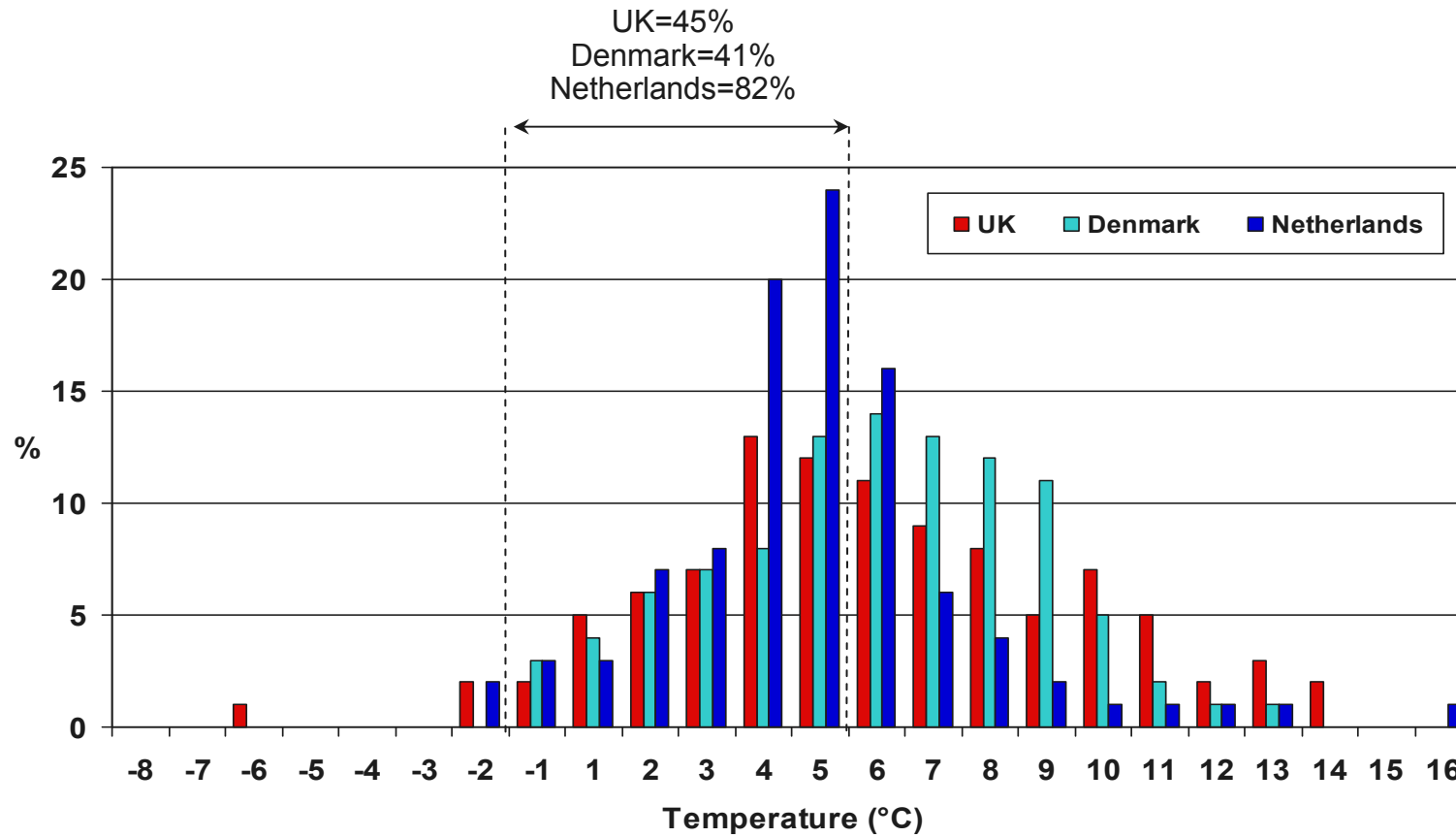


The food cold chain in France and its impact of food safety
 E. Derens, B. Palagol, M. Cornu, J. Guilpart. IRC, Beijing, 2007

Temperature control in retail



Temperature control in retail



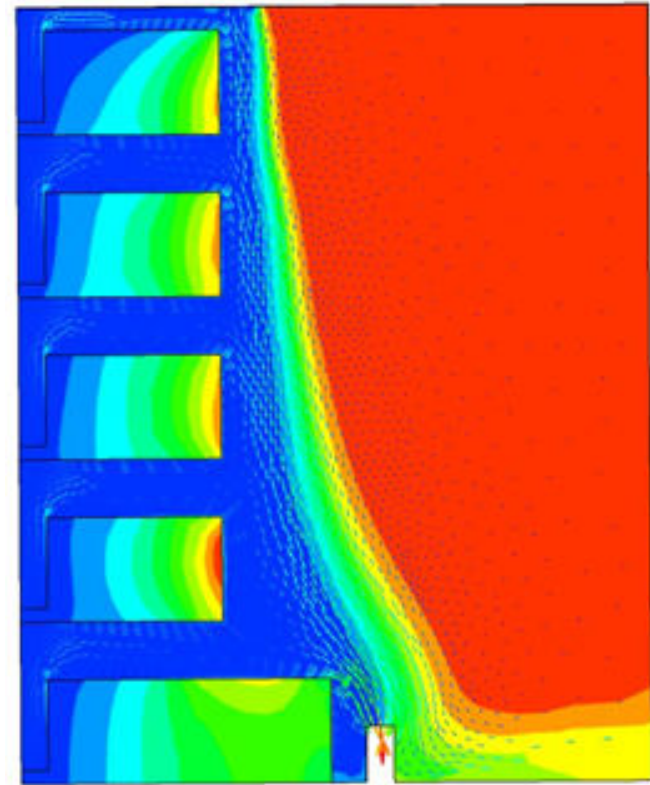
Bøgh-Sørensen, L. (1980) Product temperature in chilled cabinets. Proceedings of the 26th European Meeting of Meat Research Workers, Colorado (USA). Paper no. 22.

Malton, R. (1972) Observations on refrigerated display cabinets in the UK. In Meat Chilling: Why and How? Meat Research Institute Symposium No. 2 (Ed. C. L. Cutting). 29.1-29.11.

Moerman, P. C. (1972) Experience with refrigerated display cabinets and prefabricated butchers chillrooms. In Meat Chilling: Why and How? Meat Research Institute Symposium No. 2 (Ed. C. L. Cutting). 28.1-28.

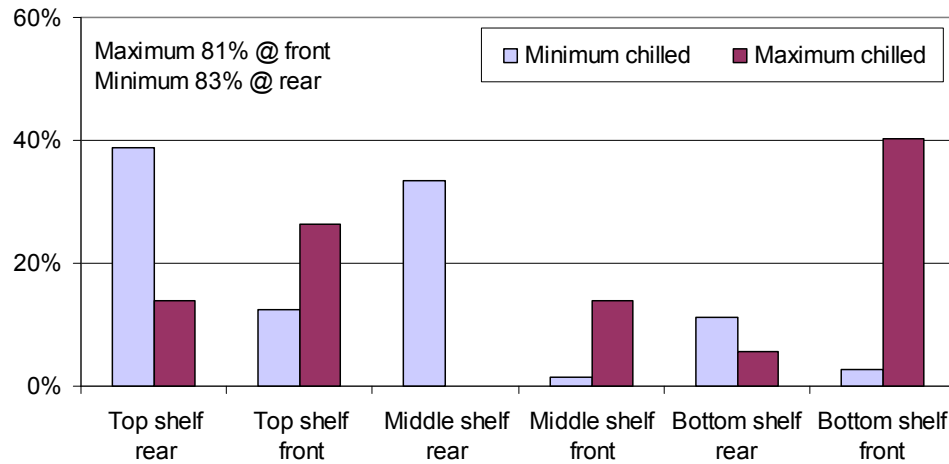
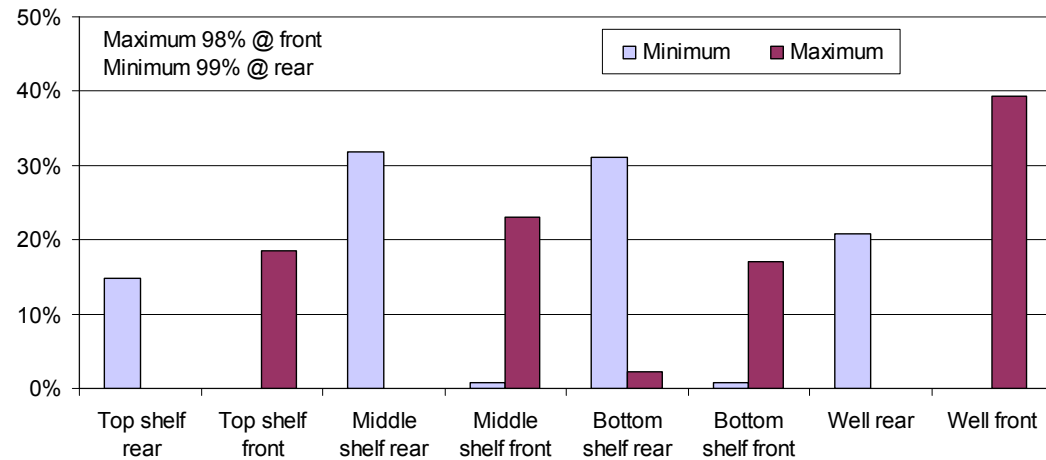
Range in temperature

- Range in temperature
 - Rear-front
 - Side-side
- Standards encourage temperature range
- Product that is frozen at rear of cabinet, to achieve 5/7°C at front
- If could reduce, potential to increase evaporating temperature



Temperature range

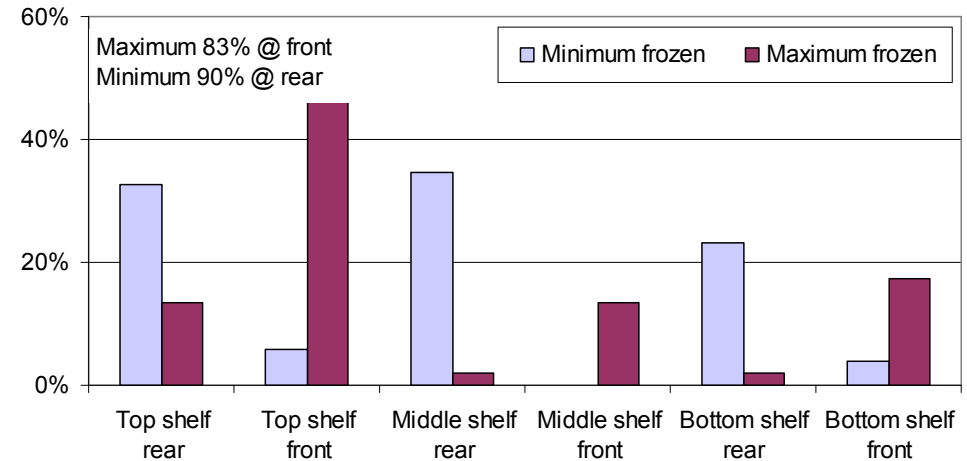
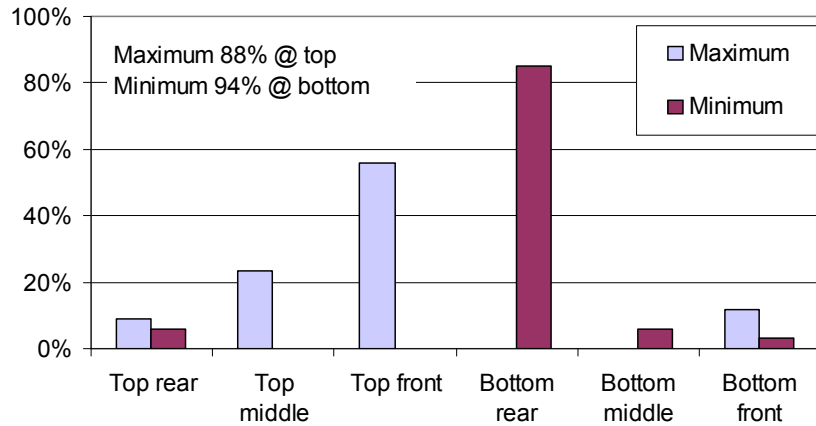
Multi-deck



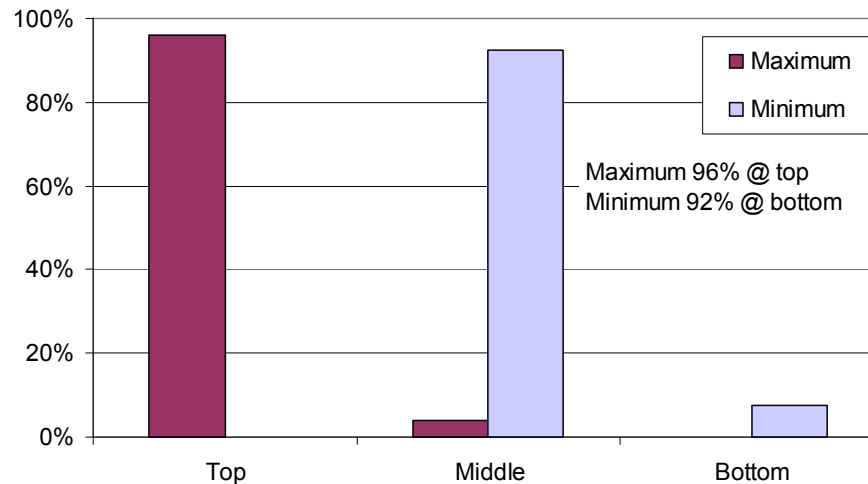
FGD/HGD chiller

Evans, J.A. and Swain, M.V.L. (2010). Performance of retail and commercial refrigeration systems. IIR International Cold Chain Conference, Cambridge, UK.

Temperature range



Well freezer



FGD/HGD freezer

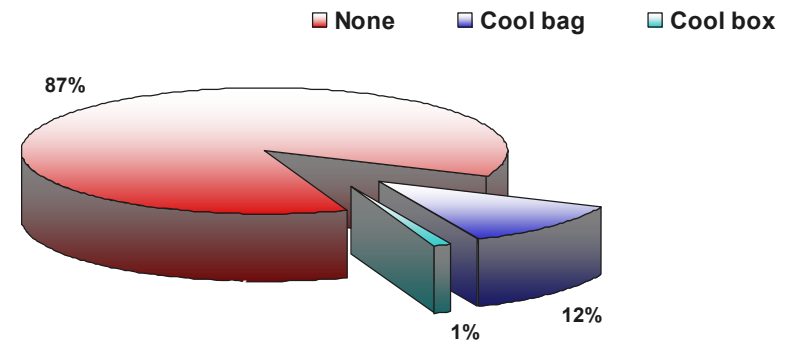
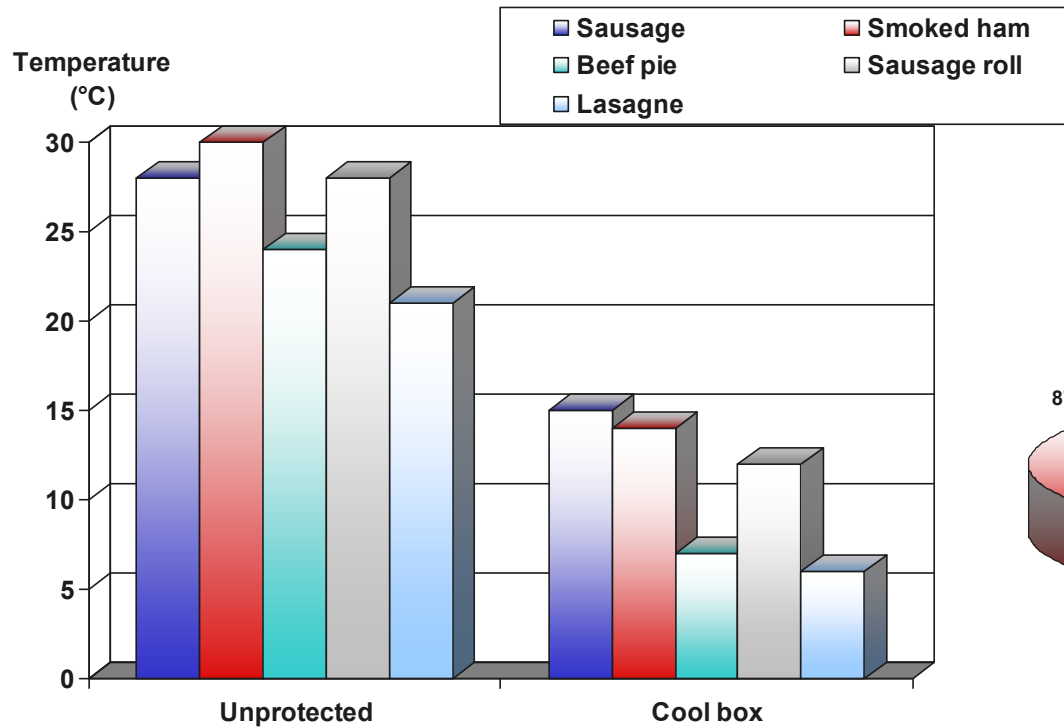
Chest freezer

Evans, J.A. and Swain, M.V.L. (2010). Performance of retail and commercial refrigeration systems. IIR International Cold Chain Conference, Cambridge, UK.

Temperature range

Cabinet type	Mean temperature (°C)	s.d.	Temperature range (°C)	s.d.
Multi-deck	2.7	2.1	8.6	4.5
Glass door (chilled)	3.7	1.2	5.1	1.6
Solid door (chilled)	4.3	2.1	8.3	4.3
Chest freezer	-27.0	2.2	19.5	1.2
Glass door (frozen)	-22.7	3.9	16.1	3.6
Well	-17.5	10.8	15.2	4.2

Transport to the home



Evans, J.A. (1998). Consumer perceptions and practice in the handling of chilled foods. In; Sous vide and cook-chill processing for the food industry, Edited by S. Ghazala, Aspen Publications, ISBN: 0:7514-0433-0.

Direct emissions

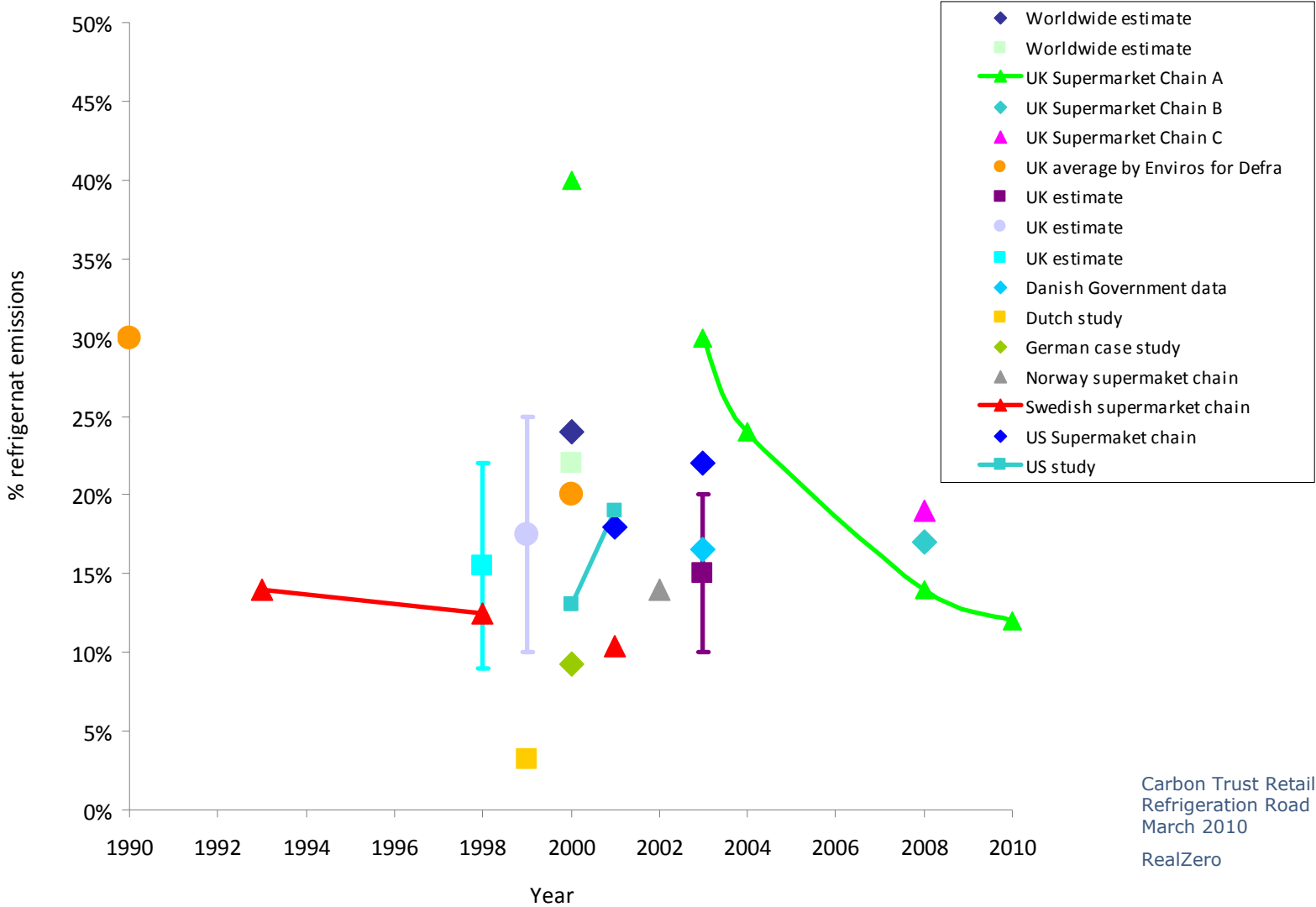
Store type	Sales area (m ²)	Charge/supermarket (kg)
Convenience store	80-280	20-50
Supermarkets (mid-range stores)	280-1400	50-150
Superstores	1400-5000	150-400
Hypermarkets	5000-10000	400-1000 (max 1500)

70% R404A (GWP=3900)

(R22, R407C, R417A, R507, R744)

Carbon Trust Retail Refrigeration Road Map,
March 2010

Direct emissions



Carbon Trust Retail Refrigeration Road Map, March 2010
RealZero

Direct emissions

- Historically 30-40% loss annually
- UK supermarkets 2010 target ~12%
 - Netherlands and Sweden losses of 2-3% Partially due to change to indirect/centralised systems
- Generally a few stores have high leakage and loose whole charge
 - Swedish study ~50% of stores had leakage of 4% or less, 67% had leakage <10%
- Integrals ~1% loss annually
- F-gas regulations reporting

Carbon Trust Retail
Refrigeration Road Map,
March 2010
RealZero

Direct emissions - costs

- 15% loss in refrigerant can double the running costs of a refrigeration system
- Refrigerant loss costs additional 11% more to run systems¹
- Refrigerant loss - higher suction temperatures (reduction in compressor efficiency, higher discharge temperatures - oil breakdown and overheating)
- Refrigerant emission abatement measures capital cost range of \$20-280 per t CO₂-eq²

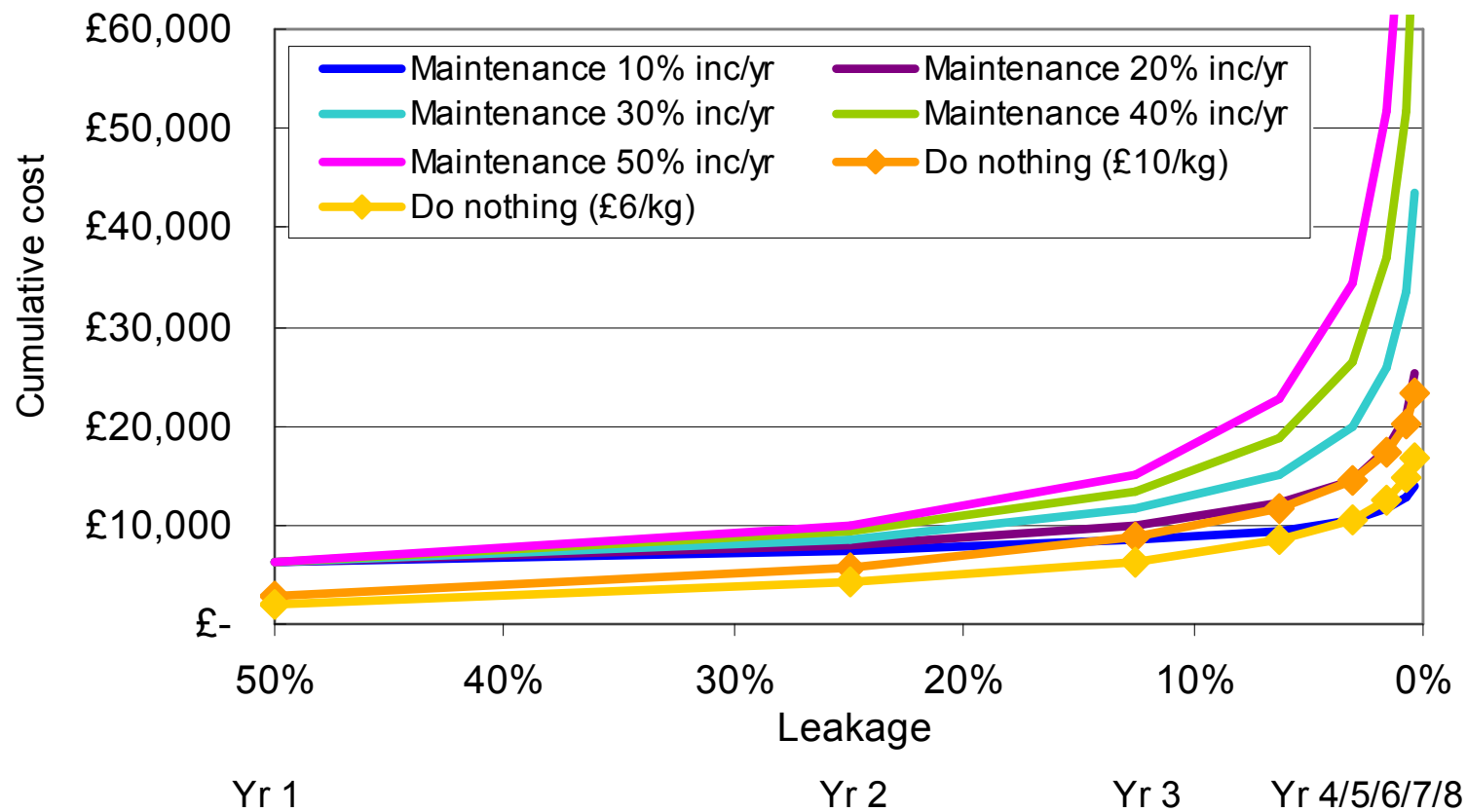
¹ UK EEP Best Practice Guidelines

² IPCC, 2010

Abatement

IPCC	20-280\$/tonne	£ 13.18	£ 184.48
GWP		Min abatement (1kg refrigerant)	Max abatement (1kg refrigerant)
3900	R404A	£ 51.40	£ 719.47
2100	R407A	£ 27.68	£ 387.41
1300	R134a	£ 17.13	£ 239.82
4	HFO-1234yf	£ 0.05	£ 0.74
3	R290	£ 0.04	£ 0.55
1	R744 (CO ₂)	£ 0.01	£ 0.18
	1kg refrigerant	£ 6	£ 10

Abatement costs



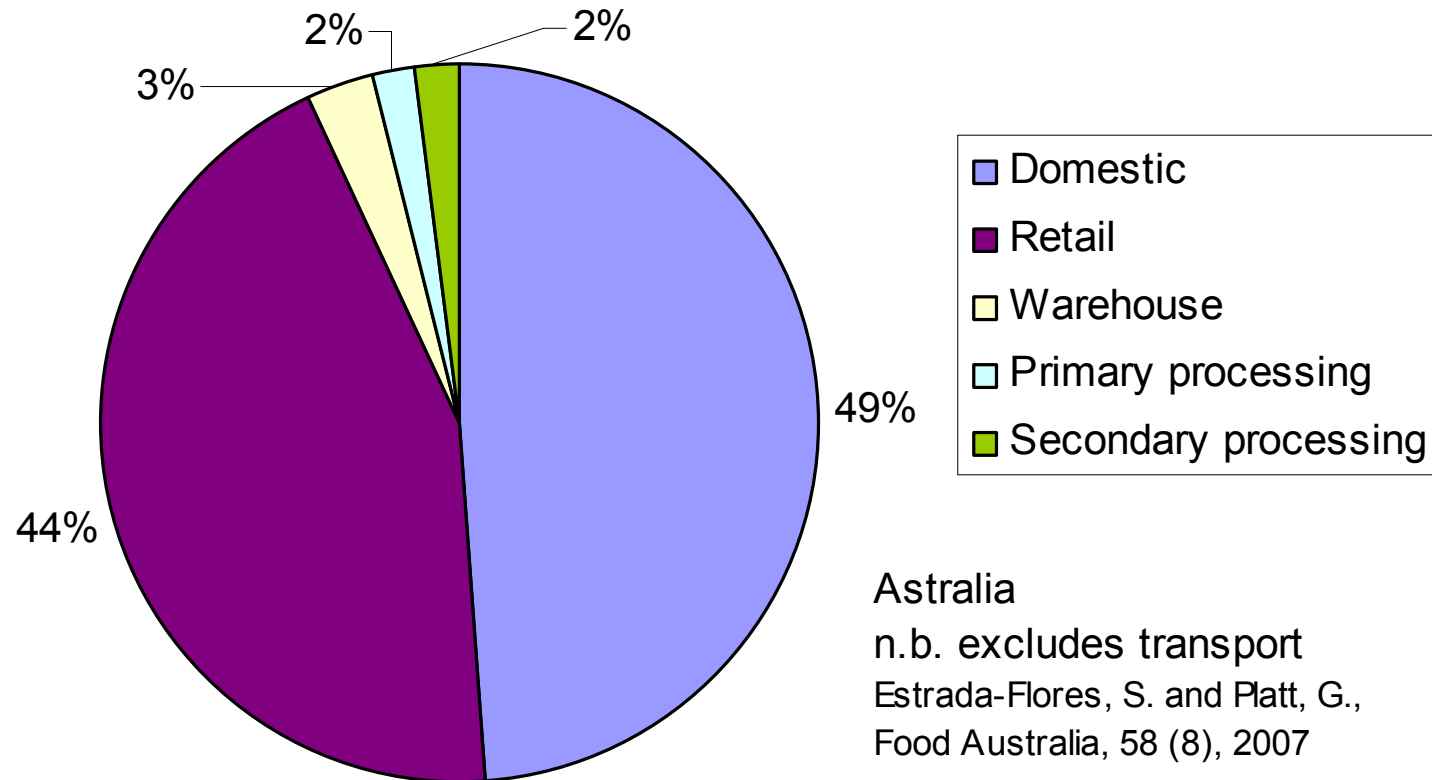
£5k maintenance cost in yr 1, assuming reduction in emissions of 50%/yr

Indirect emissions - UK

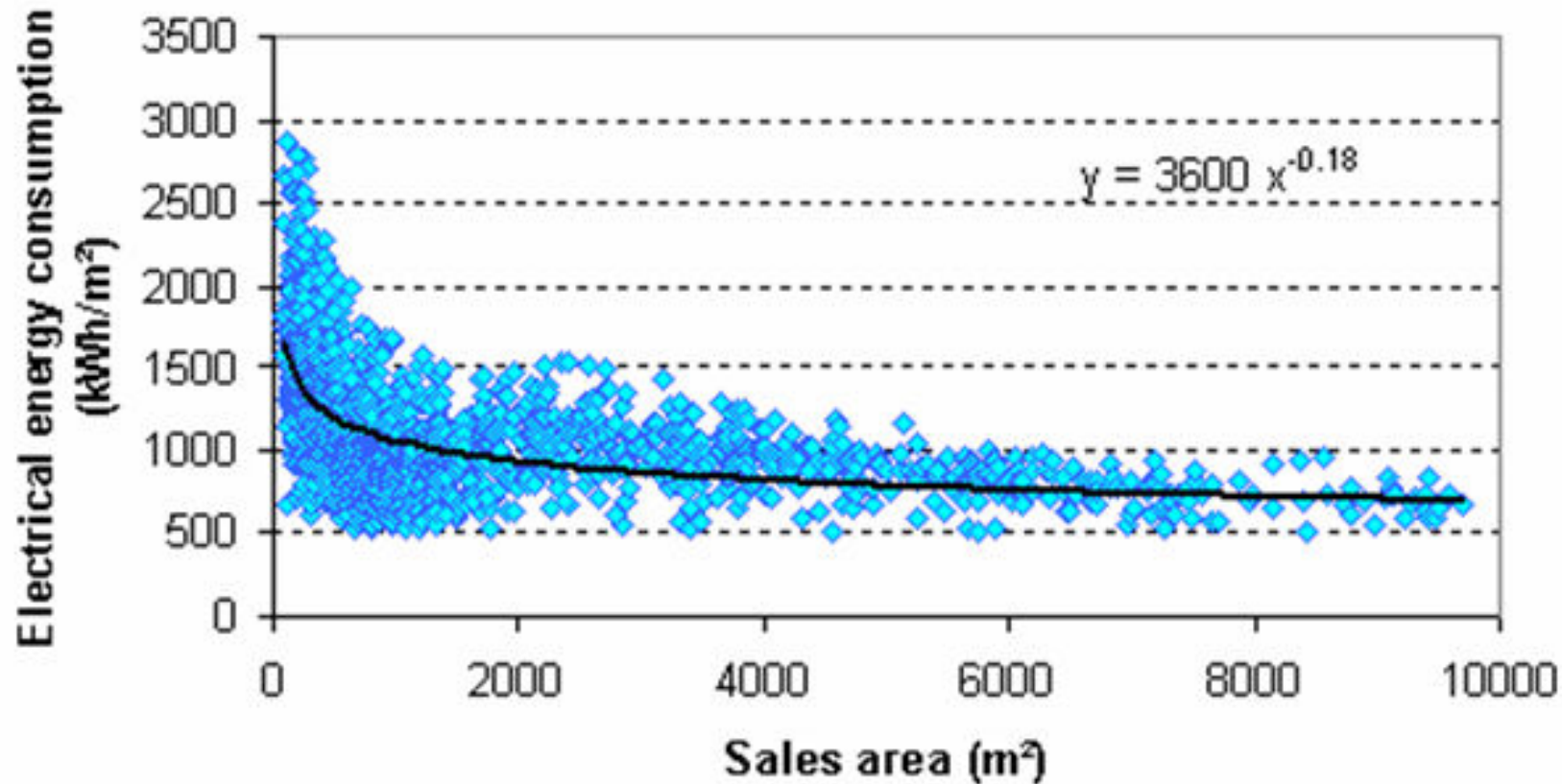
	GWh/yr
Domestic	15,354
Retail display	5,768-12,698 (7,459)
Catering – kitchen refrigeration	3,998
Commercial service cabinets	2,527

Swain M J (2006), Energy use in food refrigeration
Calculations, assumptions and data sources

Indirect emissions - Australia



Indirect emissions



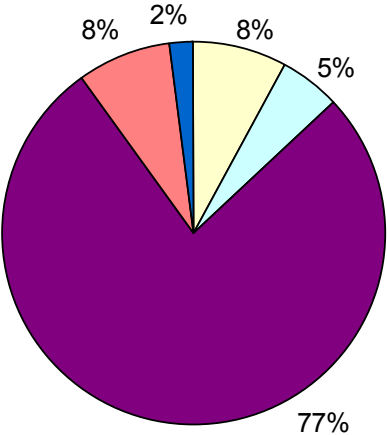
Linear relationship > 2000 m²

40-80% energy in supermarket for refrigeration

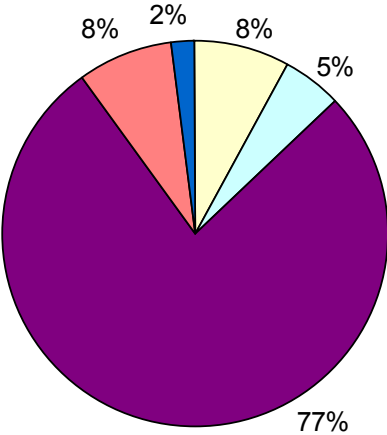
Tassou S. A., Ge Y., Hadaway A. and Evans J.A. (2009). Energy consumption and conservation in food retailing. <http://www.grimsby.ac.uk/documents/defra/retl-retailrefrigeration.pdf>.

Heat loads

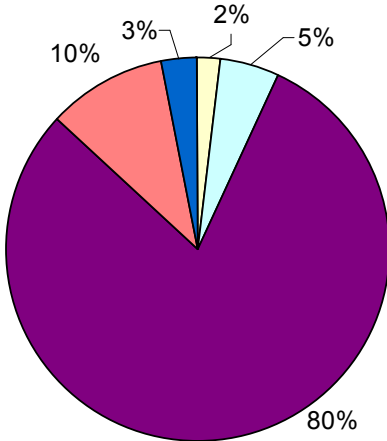
Chilled multi-deck-produce (data from ASHRAE)



Chilled multi-deck-dairy (data from ASHRAE)

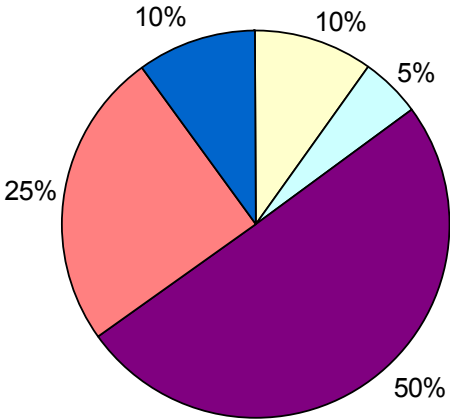


Chilled multi-deck-meat (data from ASHRAE)

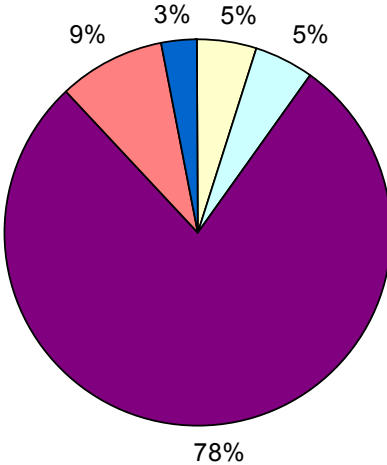


- Defrost
- Anti sweat heaters
- Lights
- Evaporator fans
- Infiltration
- Radiation
- Conduction

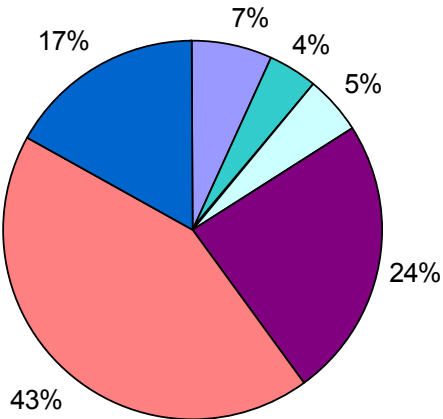
Chilled delicatessen



Frozen FGD/HGD



Frozen well (data from ASHRAE)

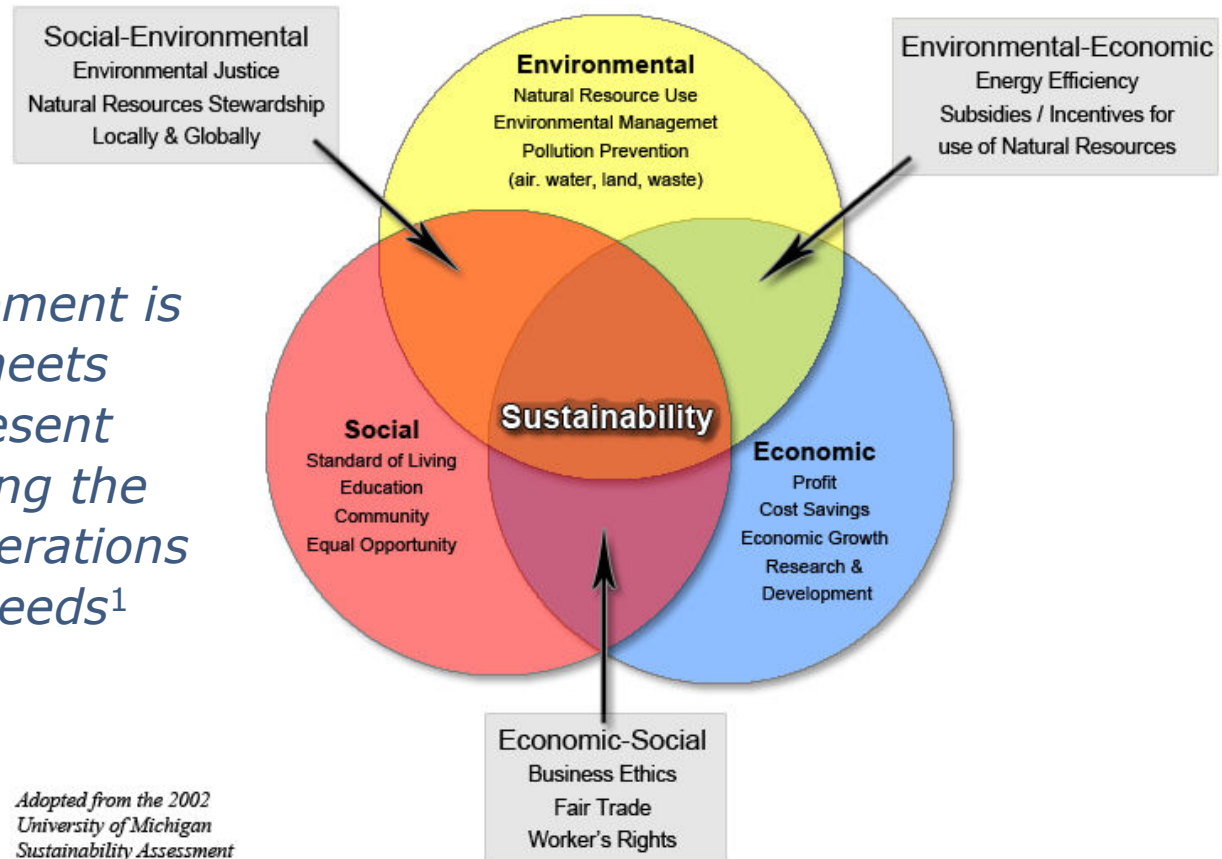


Carbon Trust Retail Refrigeration Road Map, March 2010

Sustainability

The Three Spheres of Sustainability

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs¹



*Adopted from the 2002
University of Michigan
Sustainability Assessment*

¹ Brundtland Commission of the United Nations

How can retail be sustainable?

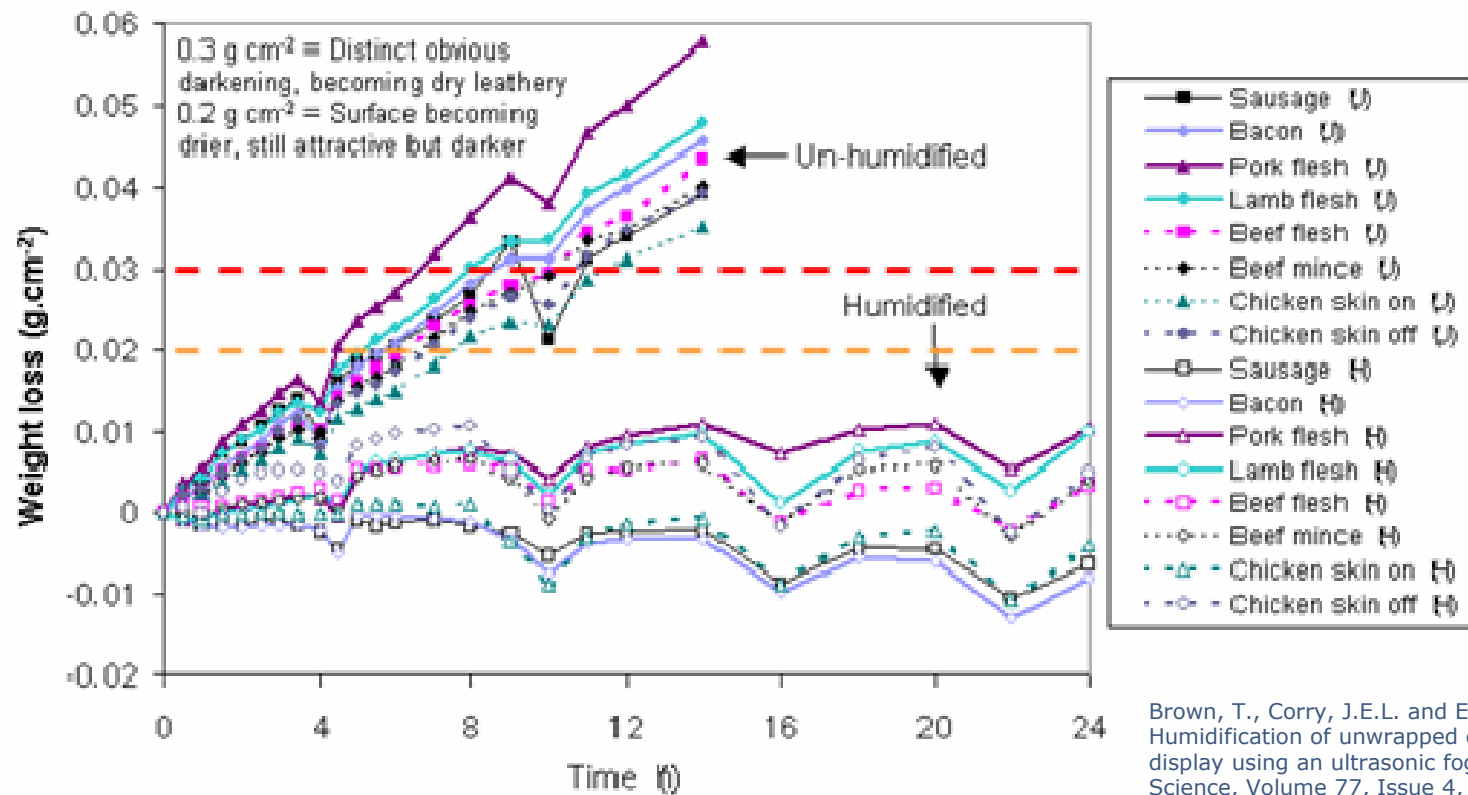
- Environment
 - Reduce direct emissions
 - Use of natural refrigerants/low GWP refrigerants
 - Reducing indirect emissions
 - Use of natural resources
 - Reduce waste
 - Recycle
- Economic
 - Reduce energy used
 - Minimise replacement of systems/cabinets
 - Reduce waste
- Social
 - Maintaining food temperature
 - Ease of access to food
 - Making shopping pleasurable
 - Fair pricing

Reducing waste

- 95% of the environmental impact in energy used
- Energy embedded in materials primarily from release of:
 - Respiratory inorganics
 - Use of fossil fuels
 - Minerals
- Stainless steel and copper main material with impact (can replace SS 304 with 430)

Reducing waste

- Main waste from delicatessen
- Can be reduced by minimising weight loss from unwrapped product



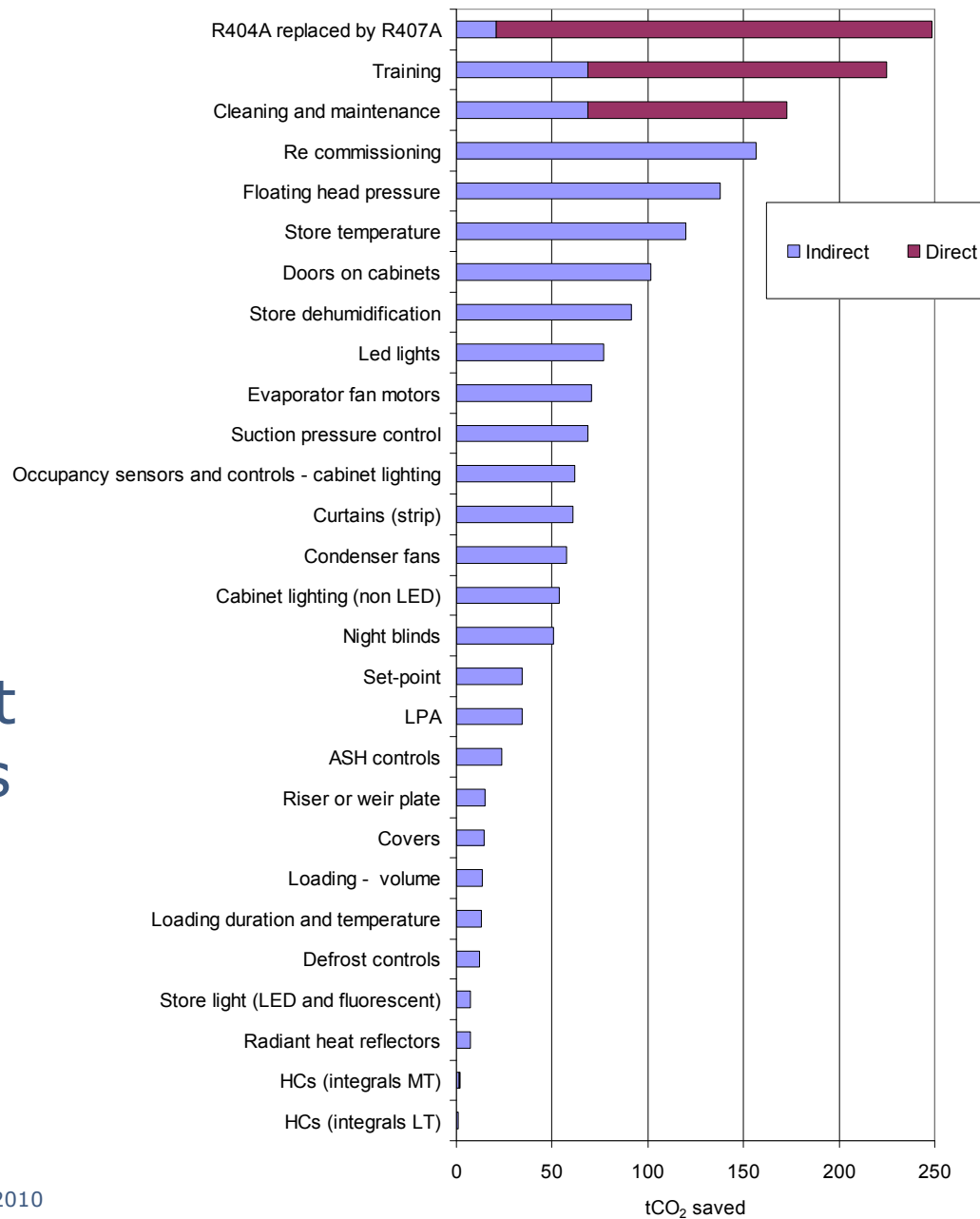
Brown, T., Corry, J.E.L. and Evans, J.A. (2007). Humidification of unwrapped chilled meat on retail display using an ultrasonic fogging system. Meat Science, Volume 77, Issue 4, Pages 670-677.

Direct and indirect emissions

- Large number of options available
- Based on 'standard' supermarket
 - 5,000 m² supermarket (applicable from 2,000 m² upwards)
 - £0.12 per kWh
 - Conversion factor of 0.43 kg CO₂/kWh
 - R404A as refrigerant
 - 400 kg refrigerant charge
 - 20% emissions p.a
- Technologies examined tend to either save CO₂ by either reducing direct OR indirect emissions
- Greater emissions reduction potential over time

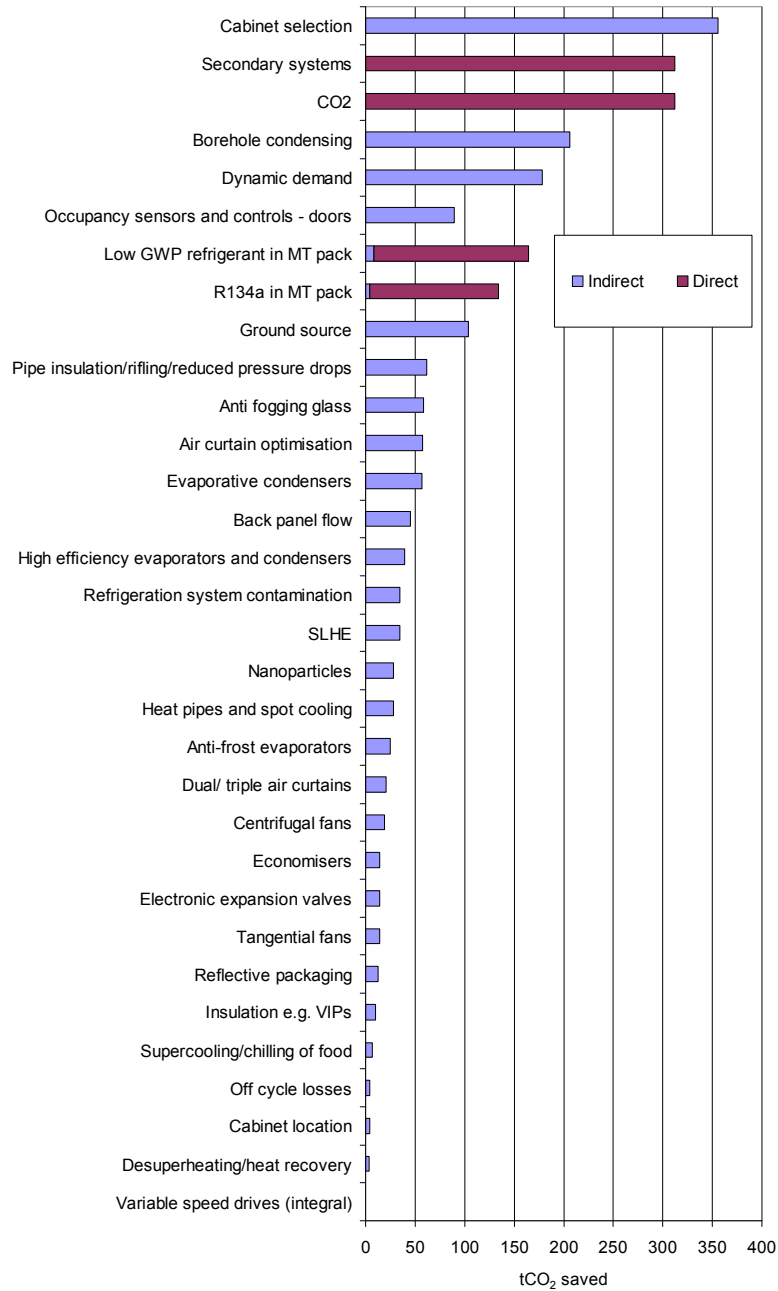
Direct and indirect emissions

Retrofit options



Direct and indirect emissions

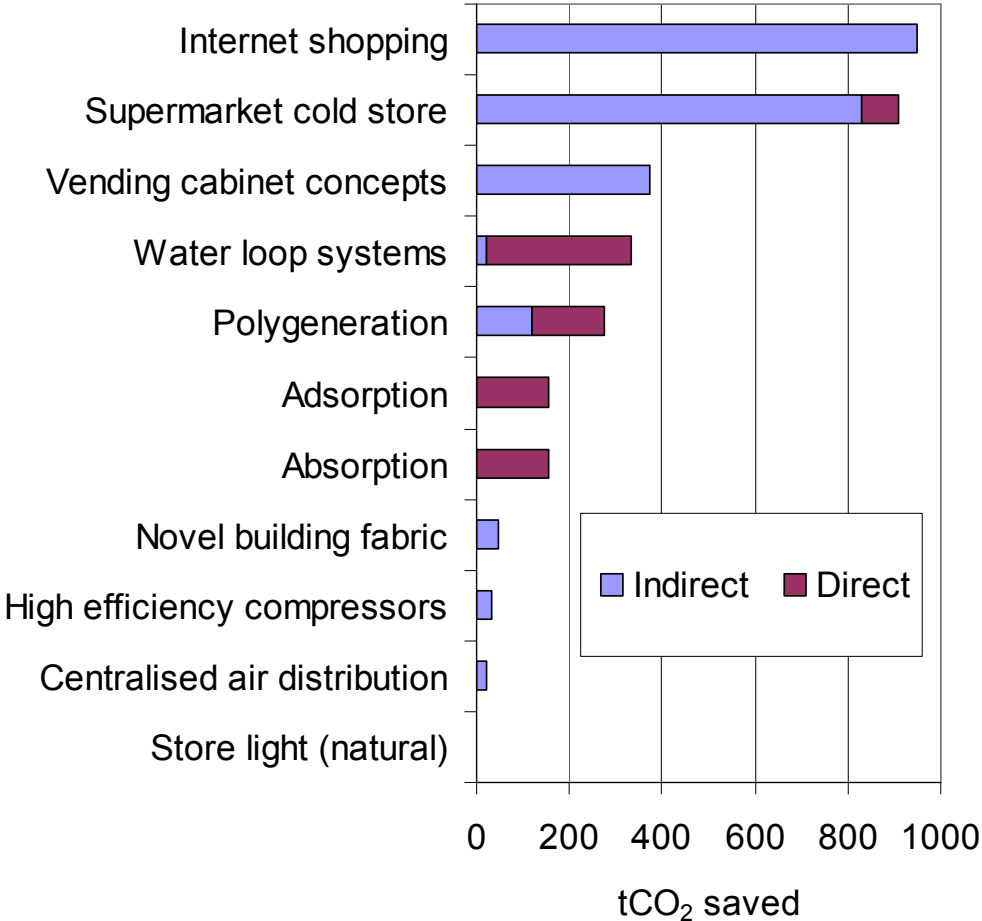
Refit options



Carbon Trust Retail Refrigeration Road Map, March 2010

Direct and indirect emissions

New store



Direct emissions

- Use of natural refrigerants
 - CO₂
 - Ambient air
 - Hydrocarbons (+water loop)
 - Ab/adsorption systems (\pm polygeneration)
- Use of low/er GWP refrigerants
 - HFO (R1234yf GWP=4)
 - R134a (MT only) (GWP=1300)
 - R407A (GWP=2100)
- Reduce/centralise refrigerant charge
 - Secondary systems

Direct

Sorted by direct tCO ₂	tCO ₂	Payback (yrs)	Application		Indirect (tCO ₂)	Direct (tCO ₂)
Water loop systems	332.7	4.3	1.5	New store	20.7	312.0
Secondary systems	312.0	9.0	1.0	Store refit	0.0	312.0
CO ₂	312.0	8.0	1.0	Store refit	0.0	312.0
R404A replaced by R407A	248.7	2.2	0.5	Retrofit	20.7	228.0
Polygeneration	274.7	7.0	3.0	New store	118.7	156.0
Training	224.8	2.6	0.2	Retrofit	68.8	156.0
Adsorption	156.0	10.0	1.0	New store	0.0	156.0
Absorption	156.0	15.0	1.0	New store	0.0	156.0
Low GWP refrigerant in MT pack	164.2	11.6	3.0	Store refit	8.3	155.9
R134a in MT pack	134.2	5.3	0.5	Store refit	4.2	130.0
Cleaning and maintenance	172.8	1.3	0.2	Retrofit	68.8	104.0

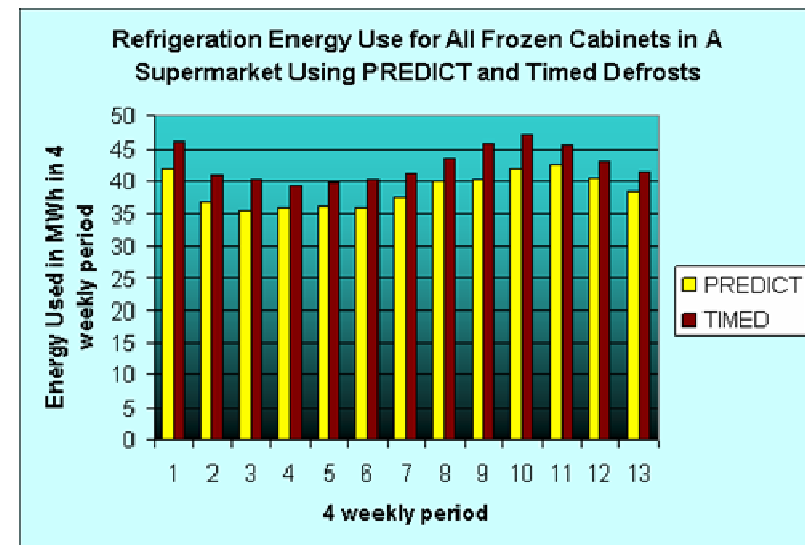
Carbon Trust Retail Refrigeration Road Map, March 2010

Training and maintenance

- Installation – leak testing
- Training
 - Reducing refrigerant leaks
 - Cabinet set up and operation
 - Plant set up and operation
 - Store temperature
 - Supermarket staff training in cabinet use
 - n.b. re commissioning shown to save 15% energy
 - Optimisation of cabinet set points
 - Limited training except F-gas training
- Cleaning and maintenance

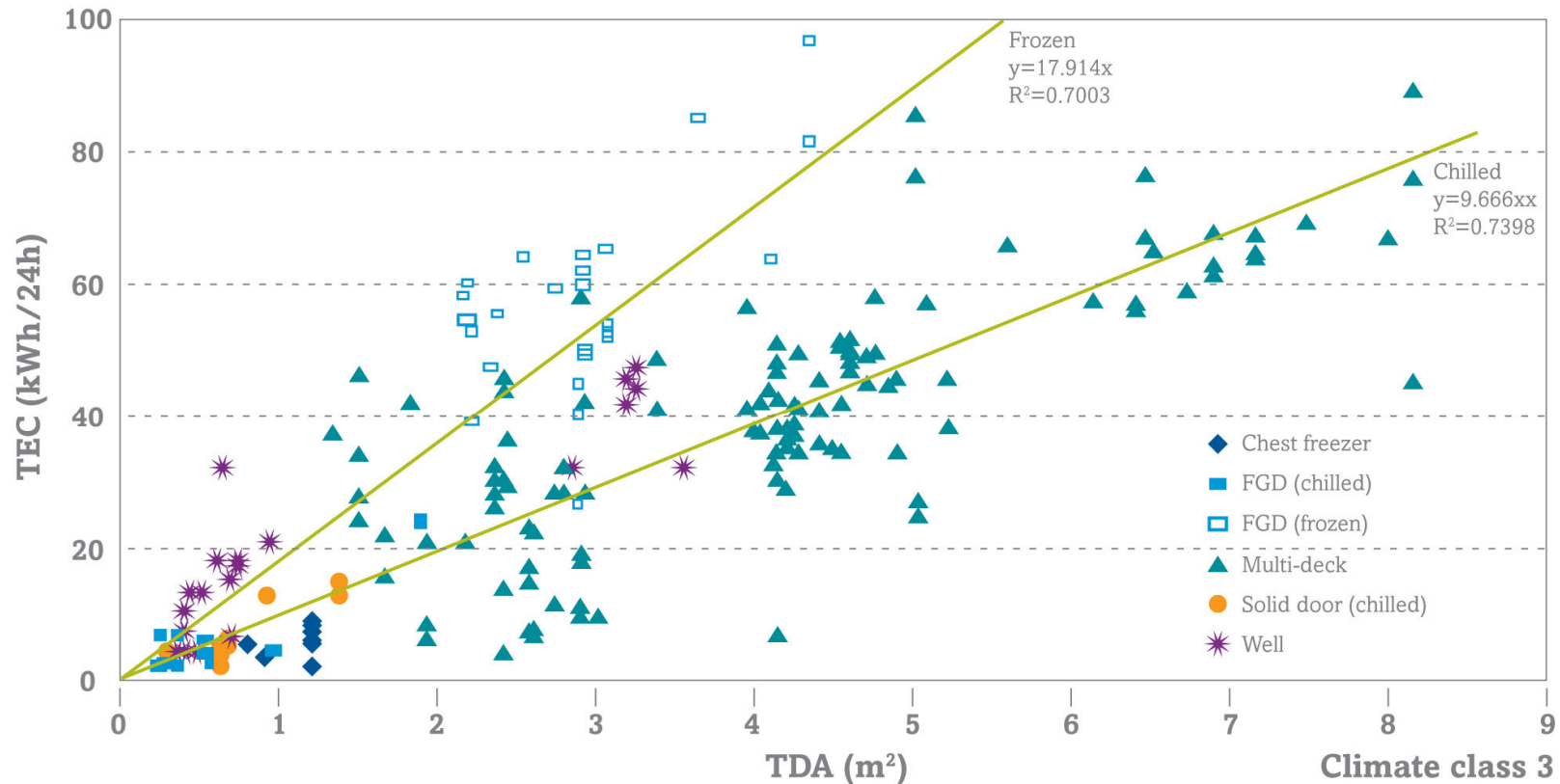
Indirect emissions

- Number of retrofit options:
 - LED lights
 - High efficiency fans
 - Controls
 - Defrost
 - Occupancy lighting sensors
 - ASH
 - Suction pressure control
 - Dehumidification
 - Covers
 - Curtains, blinds, covers
 - Doors
 - Riser/weir plates
 - Radiant heat reflectors
 - Refrigeration system
 - Floating head pressure
 - LPA



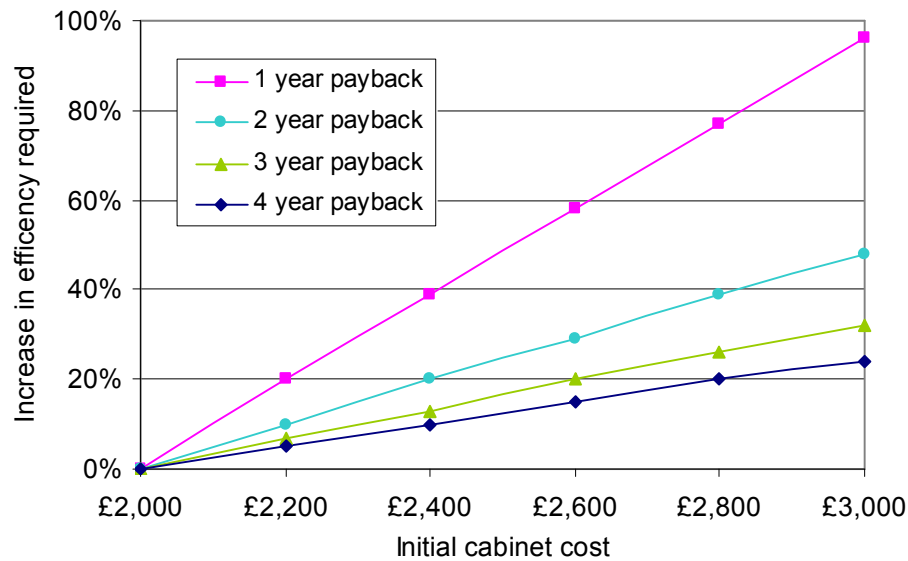
Indirect emissions

- Refit of store – cabinet selection vitally important



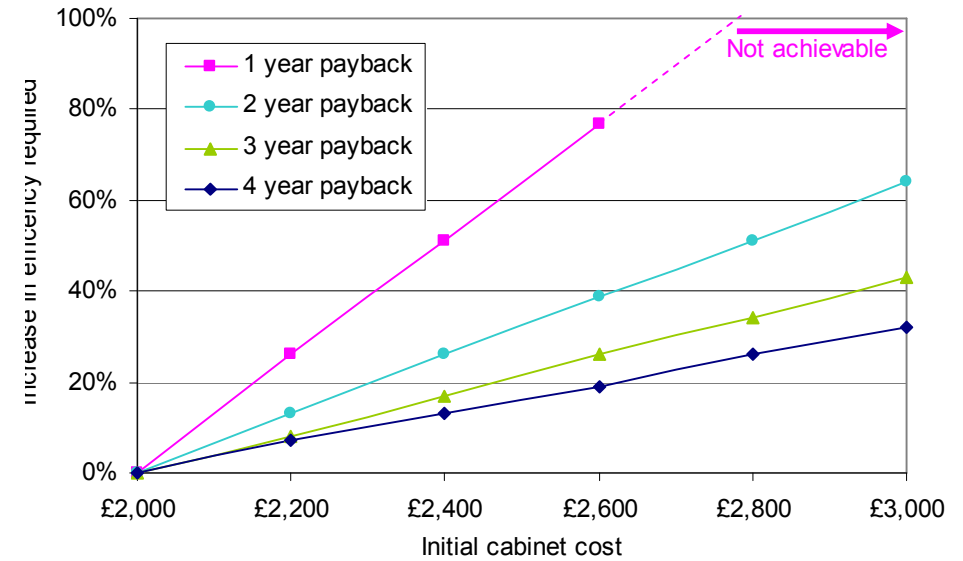
Evans, J.A. and Swain, M.V.L. (2010). Performance of retail and commercial refrigeration systems. IIR International Cold Chain Conference, Cambridge, UK.

Cost-benefit



12 p/kWh

£2k baseline cabinet (24 kWh/day energy)

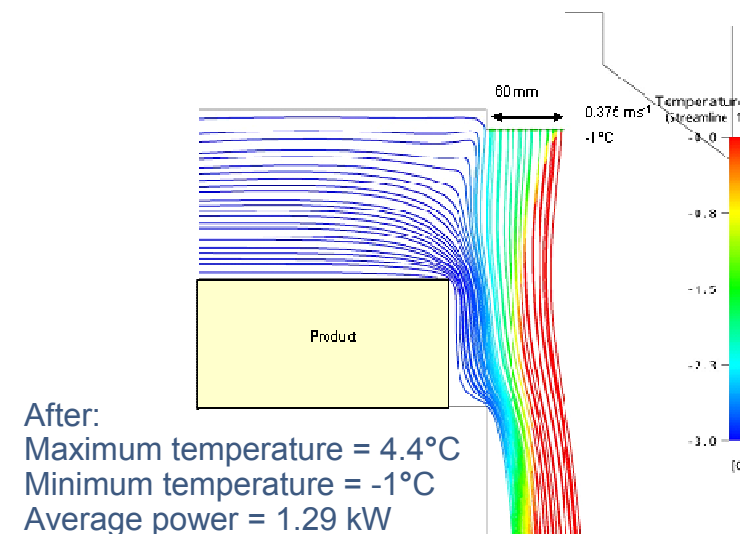
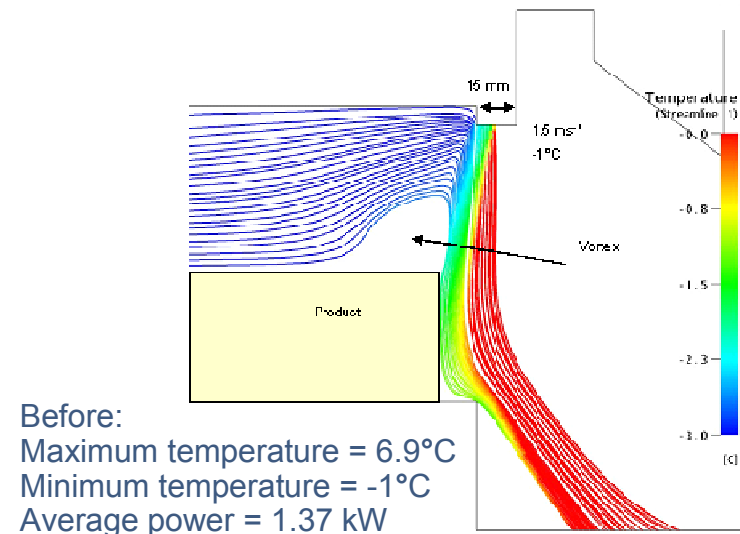


9 p/kWh

Potential to save 30% energy relatively easily by selecting best cabinet, if require short payback cannot pay >£300 extra at current energy costs

Optimisation

- Potential to improve cabinets by
 - Optimising air curtain and air flow
 - Reducing range in min-max temperature (heat pipes, spot cooling)
 - Novel air curtains – dual/triple, short curtains, chute shelves



Foster, A.M., Madge, M. and Evans, J.A. (2005). The use of CFD to improve the performance of a chilled multi-deck retail display cabinet. International Journal of Refrigeration. Volume 28, Issue 5, Pages 698-705.

Indirect

Sorted by indirect tCO ₂	tCO ₂	Payback (yrs)	Application		Indirect (tCO ₂)	Direct (tCO ₂)
Internet shopping	949.4	10.0	10.0	New store	949.4	0.0
Supermarket cold store	908.8	0.2	2.0	New store	830.8	78.0
Vending cabinet concepts	373.4	0.3	6.0	New store	373.4	0.0
Cabinet selection	356.0	0.2	1.0	Store refit	356.0	0.0
Borehole condensing	206.5	0.9	1.0	Store refit	206.5	0.0
Dynamic demand	178.0	0.2	2.0	Store refit	178.0	0.0
Re commissioning	156.7	0.7	0.2	Retrofit	156.7	0.0
Floating head pressure	137.7	0.3	0.5	Retrofit	137.7	0.0
Store temperature	120.1	0.3	0.1	Retrofit	120.1	0.0
Polygeneration	274.7	7.0	3.0	New store	118.7	156.0
Ground source	103.3	10.0	1.5	Store refit	103.3	0.0
Doors on cabinets	101.8	3.7	0.5	Retrofit	101.8	0.0

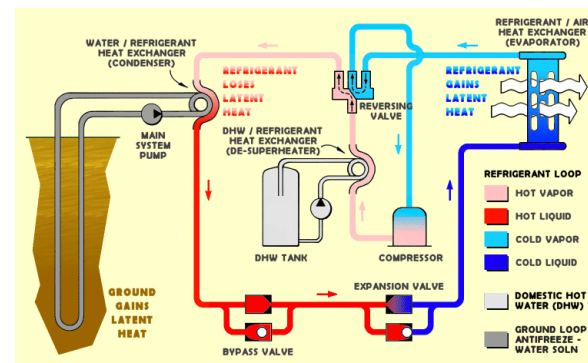
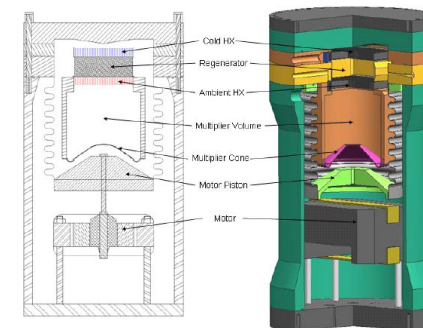
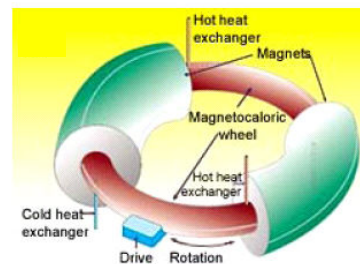
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Future

- Legislation:
 - CRC Energy Efficiency Scheme (formerly Carbon Reduction Commitment) mandatory UK climate change and energy saving scheme, start April 2010
 - Annually published league table
 - Qualification:
 - at any point during qualification period the business had at least one half hourly meter (HHM) settled on the half hourly market, and
 - the 2008 annual electricity supply through all HHMs was at least 6,000 MWh
 - MEPS (EuP) – 2012??
 - F-gas
- Non legislation:
 - Campaigning groups (e.g. EIA)
 - ECA scheme

Future

- Natural refrigerants/technologies
 - Absorption
 - Acoustic
 - Adsorption
 - Air cycle
 - Electrocaloric
 - Magnetic
 - Stirling
- Solar
- Wind
- Ground cooling/bore hole
- Heat reclaim
- Free cooling
- CHP, polygeneration



To conclude....

- Direct emissions
 - Difficult to justify financially
 - Legislation and public pressure more likely to drive
- Indirect emissions
 - Major emissions through energy usage
 - Many options to improve efficiency
 - Many options still difficult to justify financially
 - Others that can be justified often not implemented as first cost overrides life time cost
 - Greatest savings longer term options that need further development