Supermarket POE modelling including refrigeration heat transfers

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Understanding the gaps between operational energy use and modelling, for supermarkets

• Supermarkets, energy, and CO$_2$
• Operational energy use vs Design, SBEM/NCM
• Modelling
• Improving design cf NCM
• Conclusions
UK supermarkets

• Over 91,500 supermarkets in UK
• ~ 300 new stores each year
  – Many others refitted
• Use 3% of UK electricity – on site
• Account for 1% UK CO₂ emissions
Supermarket energy demands: Reality is very different from design

Lighting demand is similar to design, cooling and heating demands are very different - Why?

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Components of energy use

Reality is very different from design

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Model including non-NCM (unregulated) energy use

- Spreadsheet in Excel
- Hourly weather data
- Store temperature range 18-25°C
- Profiled occupancy, 24 hours
- Include refrigeration
  - With doors,
  - Opened according to occupancy

- But not catering or in-store bakery
  - Yet

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• Store temperature range 18-25C
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• Include refrigeration
  – With doors,
  – Opened according to occupancy
  .....For thermal impacts
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Building model

• Simple U value box
  – Plus windows and aerogel rooflights
  – Thermal bridging not modelled
• Rooflight solar gains
• Radiant gains and losses to/from roof and rooflights
• Ventilation rate set values
  • Windcatchers explored
• No stratification
Lighting

- 900/400lux
- Daylight sensitive
- Light from rooflights evenly spread
- Lighting infinitely dimmable
  - No staging
  - No lower limit
- Heat from lights incorporated into thermal balance
  - But not stratified!
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Heating and cooling

• 2 boilers, one cooler
• Modelled as ON / OFF per iteration (15 mins)
• Hysteresis range $2^0C$ at each end
  – 18-20$^0C$ for heating
  – 23-25$^0C$ for cooling

• Fans and pumps according to demand
Refrigeration

• Freezer cabinets with doors
• Chiller cabinets with doors
• Open chillers

• Fabric
• Ventilation
• Auxiliary power uses
Refrigeration on NCM

25 W/m$^2$
Dehumidification

• Only if needed
• Humidity ratio maintained at or below 7.5 g/kg
  – Based on ambient humidity and anthropogenic water vapour
  – To maintain efficiency of evaporator coils in refrigeration cabinets
  – (may not be appropriate with mostly closed cabinets)
Thermal mass

• Floor
• Goods
• Air

• Used with first order equation on 4x hourly iteration
Sensitivity to ventilation

**NCM**

**Refrigeration = cold**

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Sensitivity to insulation

NCM

Refrigeration = cold
Sensitivity to rooflight fraction

NCM

Refrigeration = cold

125MWh/a

46MWh/a

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Halving ventilation, doubling insulation

Retail floor energy demand (MWh/a)

15% reduction = 280 MWh/a

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Conclusion

• In a supermarket, omission of refrigeration heat transfers on the retail floor is causing a major gap between operation energy use and design expectations

• Inclusion of refrigeration cabinet heat transfers at design stage could reduce energy demand by 15%

• Inclusion could also incentivise improvement in cabinet design, as improvements have effect on both refrigeration and heating demands
Thank you!