Identification of changes needed in supermarket design for energy demand reduction

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Identification of changes needed in supermarket design for energy demand reduction

• Supermarket energy usage/loads
• Difference between design and predicted load
• Modelling route
• Sensitivity differences
• Implications
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
Supermarkets: 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

- Heating fuel
- Electrical HVAC
- Lighting
- Services
- Catering
- Refrigeration
- Unsubmetered

SBEM: 46%
Not SBEM: 37%

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Design of supermarkets – heat gains and losses

Solar gain
Occupancy
Lighting
Radiant gain
Store temp 18-25C
Fabric
Ventilation
Radiant loss
Cooling
Appliances (mostly refrigeration)
Heating

To comply with SBEM

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re size elements to match figs from Excel R@Reg

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Heat transfers in a supermarket include **cold** refrigeration cabinets
FH2 needs an equipment arrow too, and resizing
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Model including non-SBEM (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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Building model

- Simple U value box
  - Plus (north) windows and aerogel rooflights
- 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
Heating and cooling

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

- COPs on Carnot cycle model
  \[ \frac{1}{2} \times \frac{\text{evaporation temperature}}{\text{evap-condenser temperature differential}} \]

- Condenser temperature dependent on ambient temperature, therefore

- COPs dependent on ambient temperature.
Refrigeration on SBEM

25 W/m²
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)
Optimisation - ventilation

SBEM

Refrigeration = cold

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Optimisation - insulation

SBEM

Refrigeration = cold
Optimisation – rooflight fraction

SBEM

125MWh/a

Refrigeration = cold

46MWh/a

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Optimising on insulation and ventilation

15% reduction = 280 MWh/a
Further research

• Modelling in EnergyPlus finds
  – Very similar comparison SBEM/COLD refrigeration
  – 25% potential savings from insulation, airtightness improvements suggested

• Stratification (present in case study store) may be responsible for further 10-25% heat losses
  – Which would not be an issue if cooling were needed as SBEM suggests
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 25-40%

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