MODELLING INTERACTIONS BETWEEN BUILDING, HVAC, REFRIGERATION AND DISPLAY PRODUCT IN SMALL FOOD SUPERMARKETS

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Brunel University London

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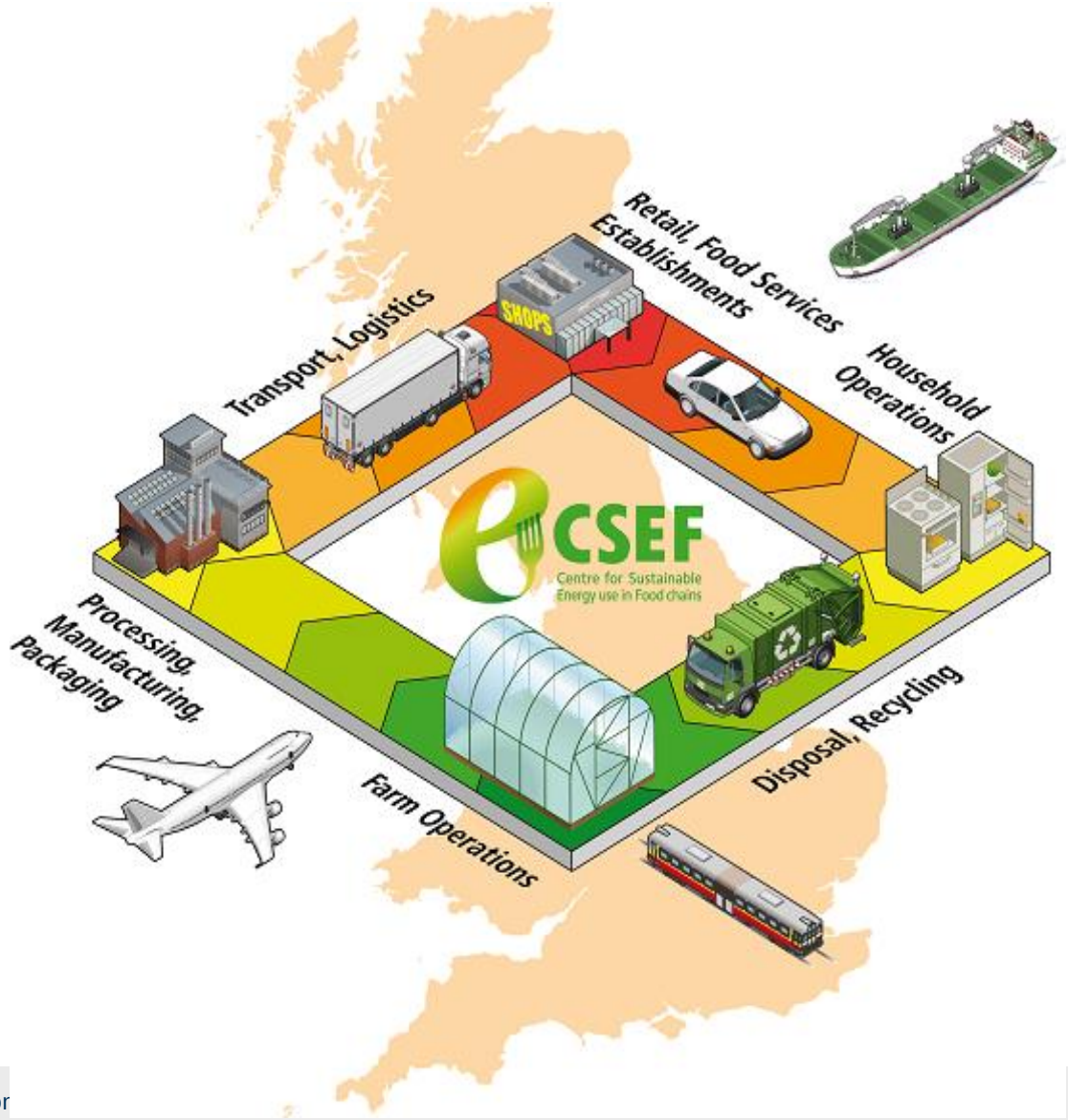
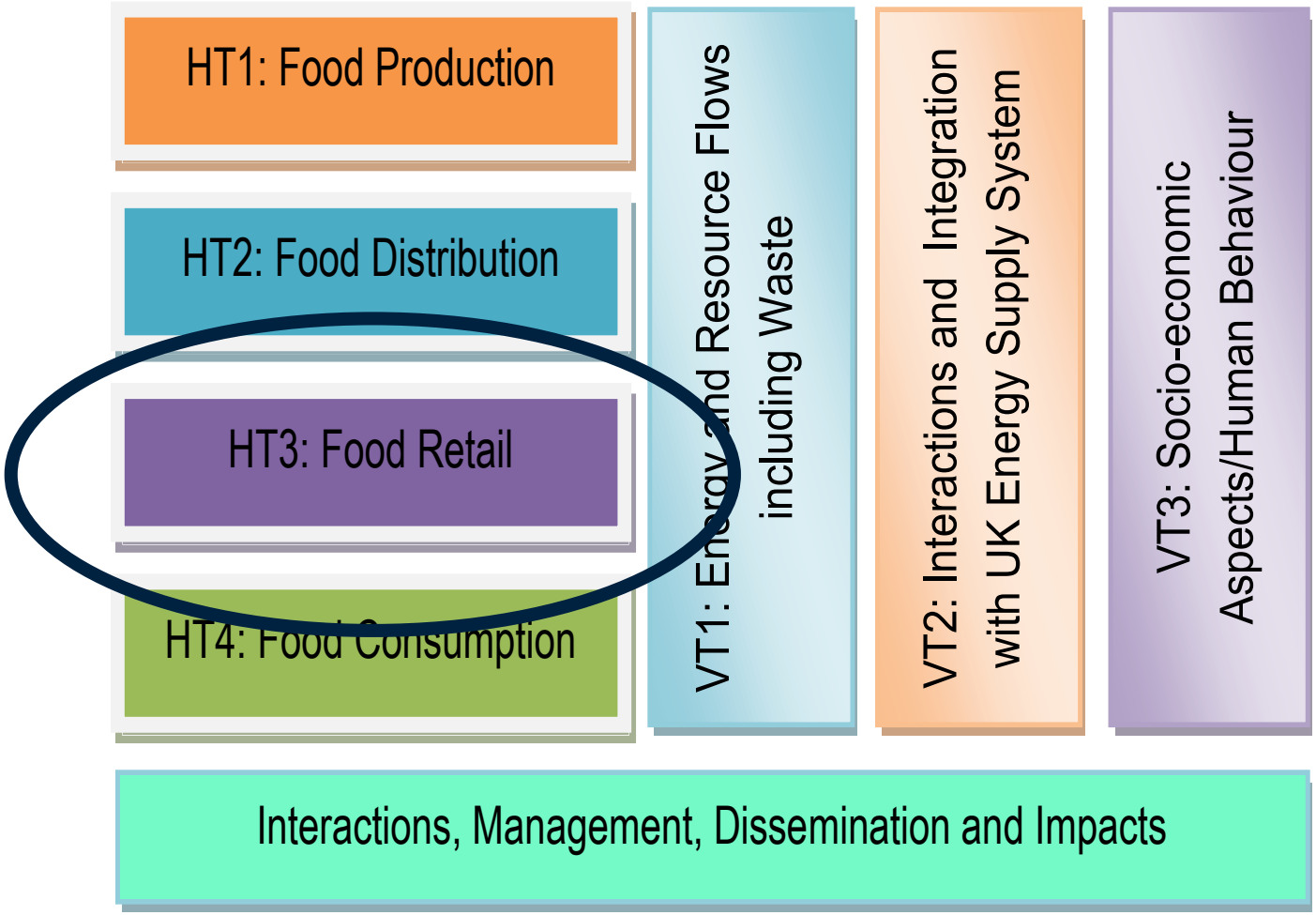
CSEF: Centre for Sustainable Energy in the Food Chain



Funding and Partners

+ 36 organisations

www.foodenergy.org.uk


HT1: Food Production
HT2: Food Distribution
HT3: Food Retail
HT4: Food Consumption
VT1: Energy and Resource Flows including Waste
VT2: Interactions and Integration with UK Energy Supply System
VT3: Socio-economic Aspects/Human Behaviour
Interactions, Management, Dissemination and Impacts

Food Retail: additional funding within EUED collaborative projects
Brunel, LSBU, UCL

The work to be presented focusses on small in size supermarkets which are food dominated with high ratio of chilled and frozen food.

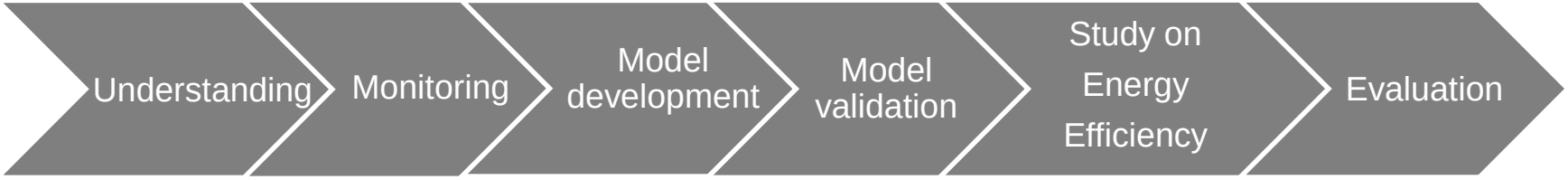
WHY?

- Evolution of retail landscape

  * Internet, home deliveries, consumers' lifestyles

- Shift towards small convenience food stores in UK, Europe and Asia
- Reduction in hypermarkets and supermarkets share
- Energy intensity depends on sales area, product food ratio, equipment, business practice and store format
- Increase of small supermarkets in urban areas and high street.

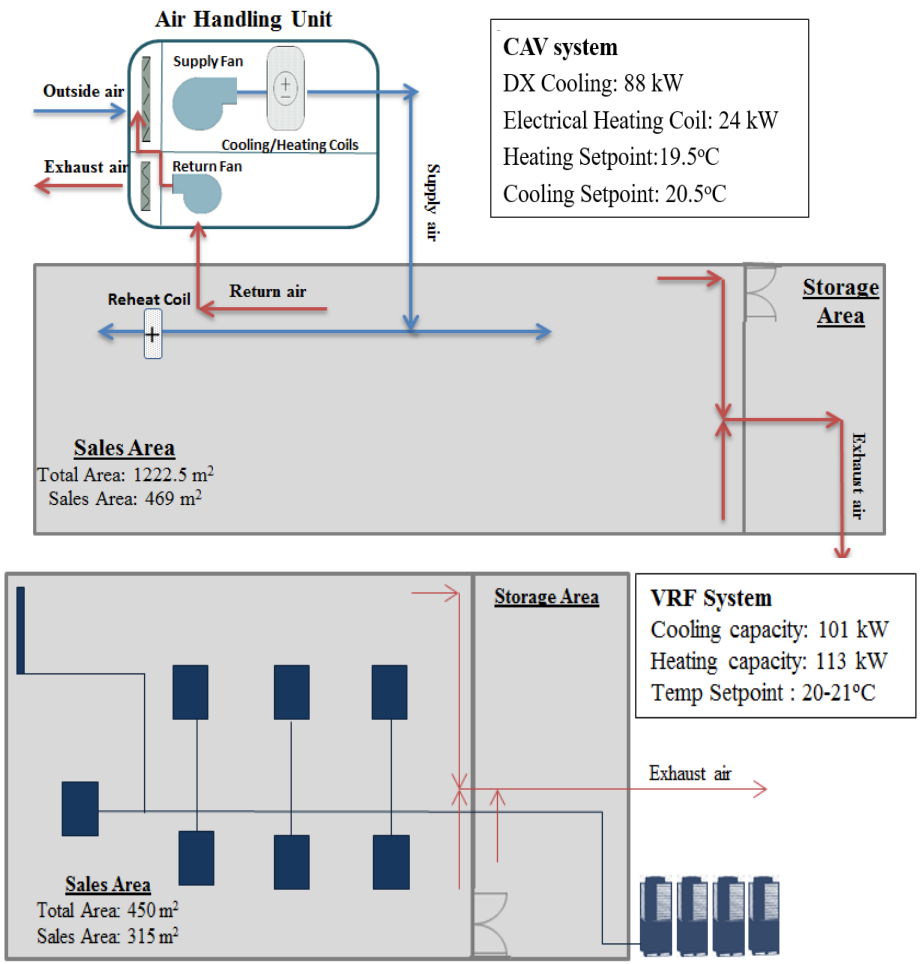
Methodology



Case studies of frozen food stores

Two supermarkets were selected for monitoring

1. Coupled HVAC
2. Decoupled Heating, Air conditioning from Ventilation

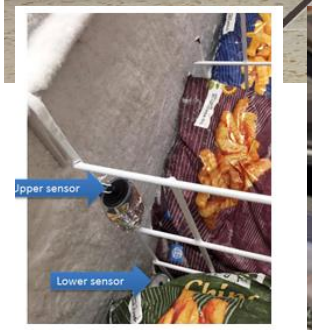


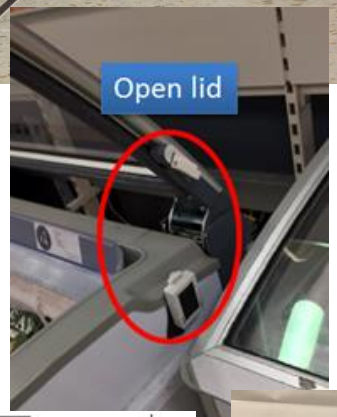
Refrigeration System

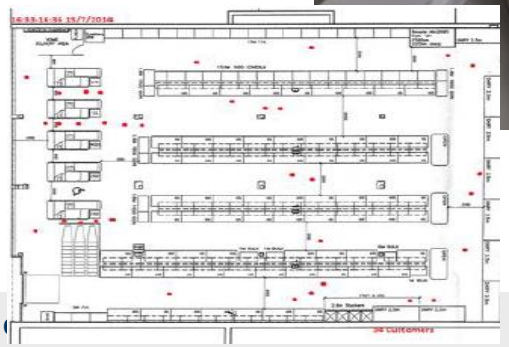
- ❑ Remote Type
- ❑ High LT equipment (double in size)

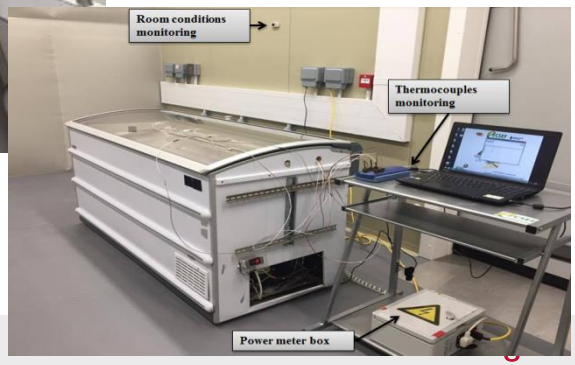
Monitoring

- Total energy use data
- Subsystems energy data from similar stores
- Indoor air environmental conditions (temperature, RH, light intensity, CO_2 levels)
- Lift up lid frozen food cabinet energy use data (in operation and in laboratory)
- Lift up lid frozen food cabinet open/close statement, operating temperature and glass surface temperature
- Daily and hourly transactions data and customers counts and observations



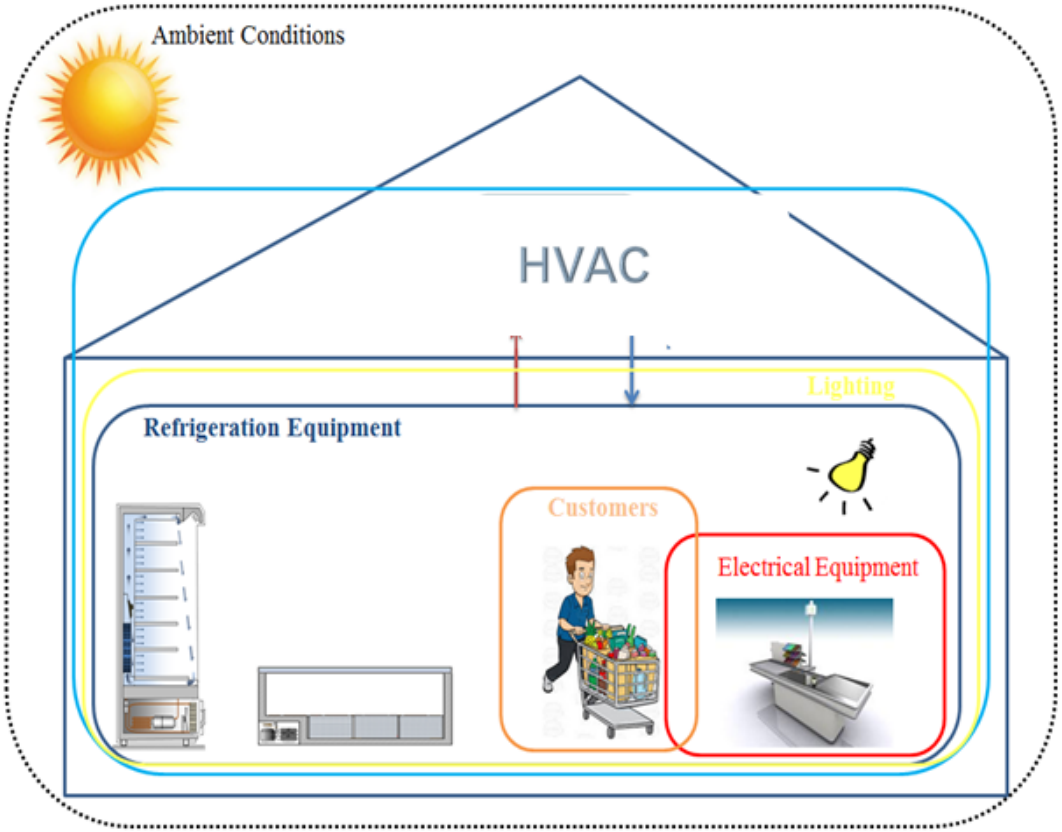




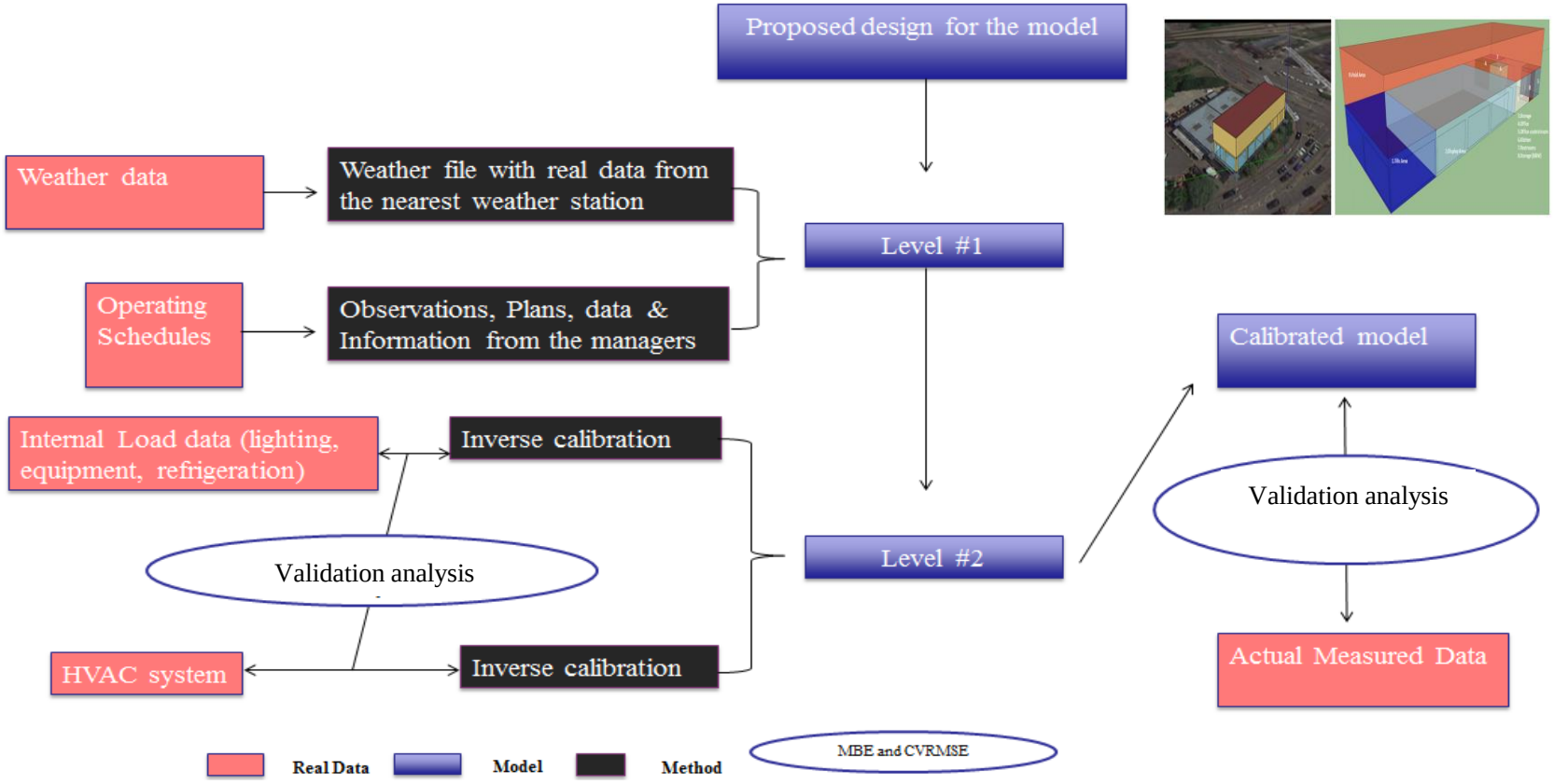


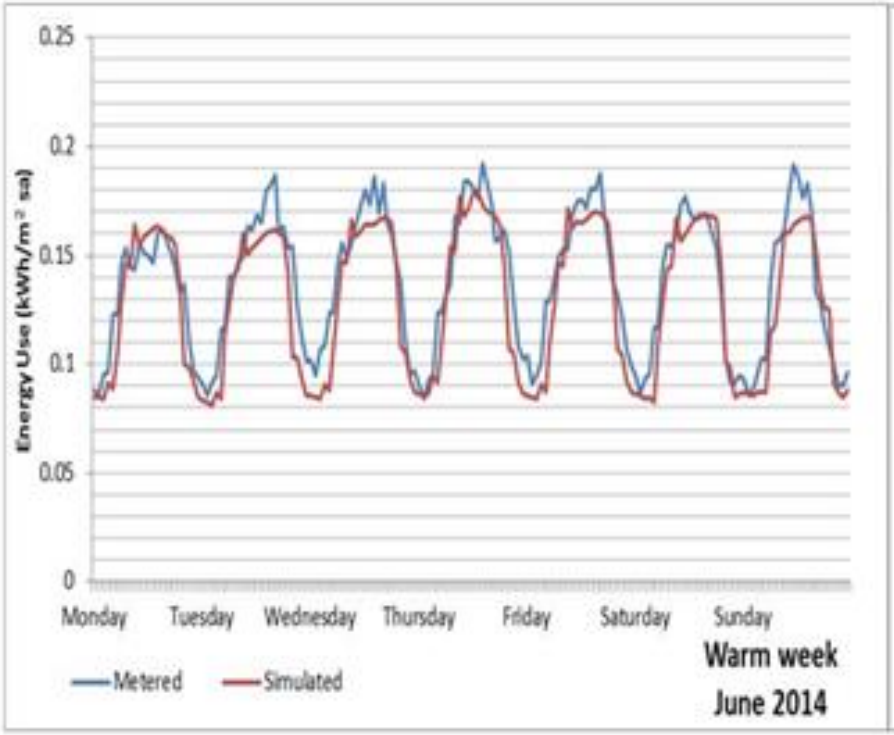
Model Development and Validation

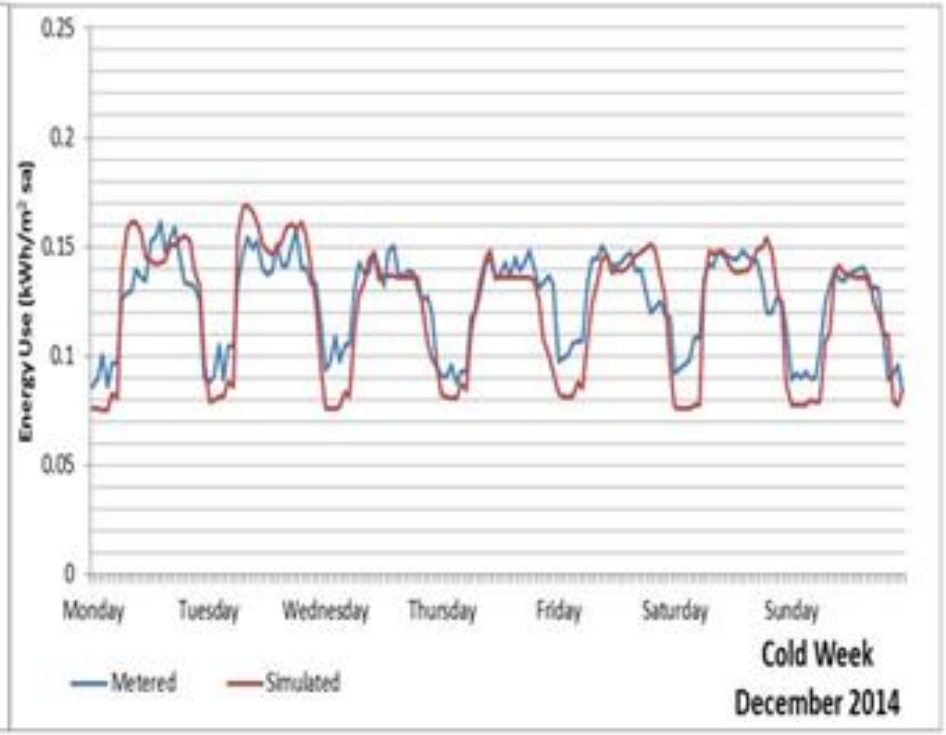
- EnergyPlus Software for Dynamic simulation to solve simultaneously building, system and plants
- Energy and environmental monitoring data used for validation
- Weather file customised with data from the nearest meteorological station
- Both stores within EnergyPlus model presented MBE and CVRMSE values within acceptable limits for both energy use (total-Subsystems) and indoor air temperature



E+ Model development and validation




0.25
0.2
0.15
0.1
0.05
0
Energy Use (kWh/m² sa)
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Metered
Simulated
Warm week
June 2014


0.25
0.2
0.15
0.1
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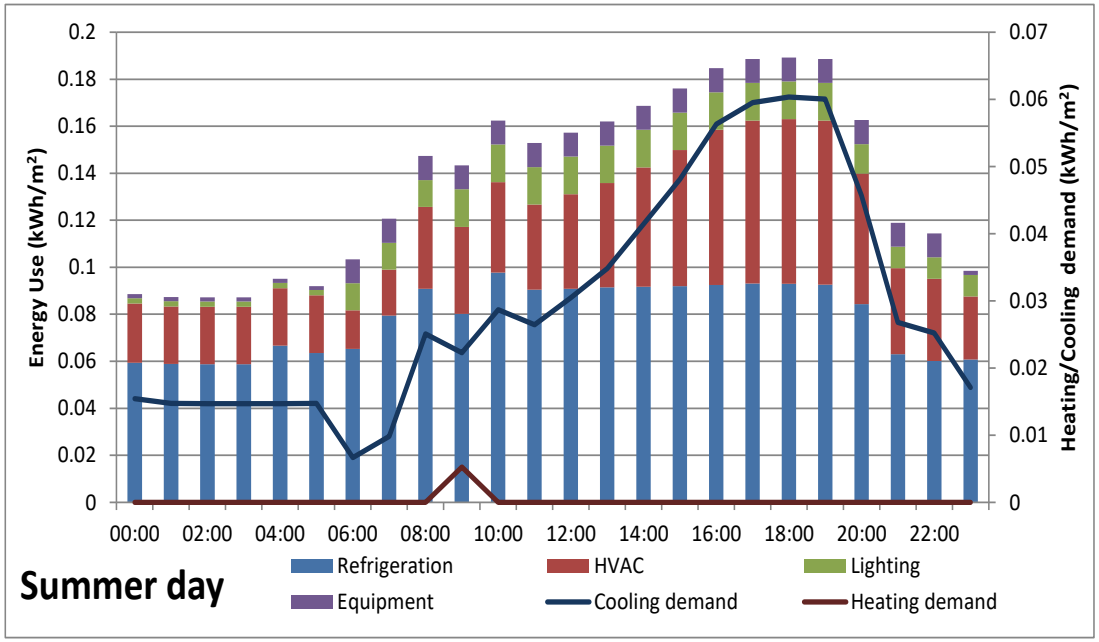
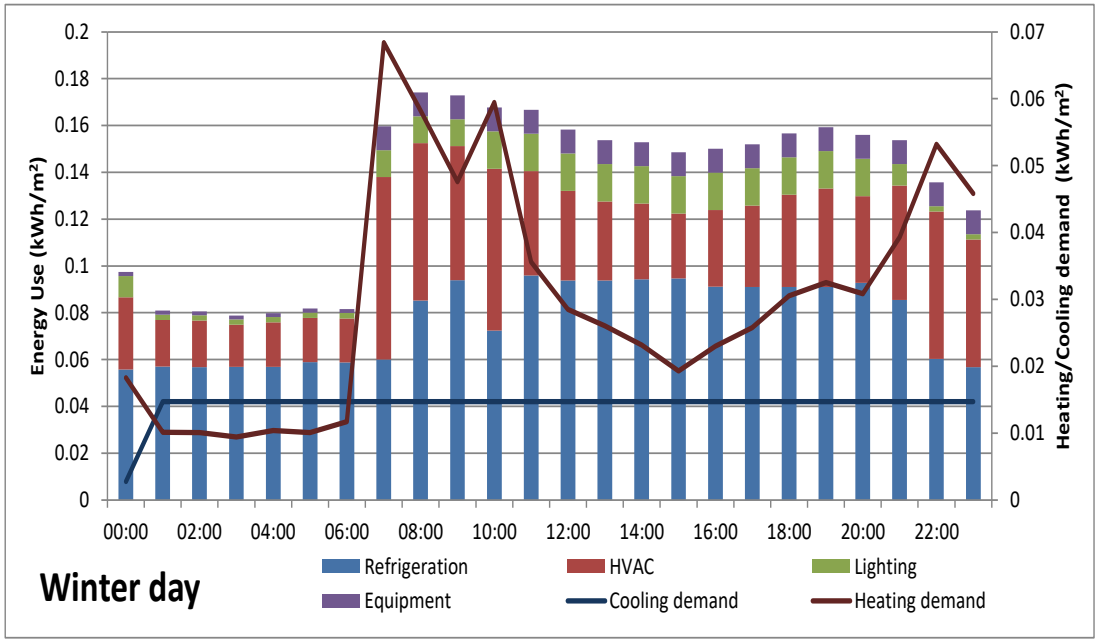
Energy Use (kWh/m² sa)
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Metered
Simulated
Cold Week
December 2014

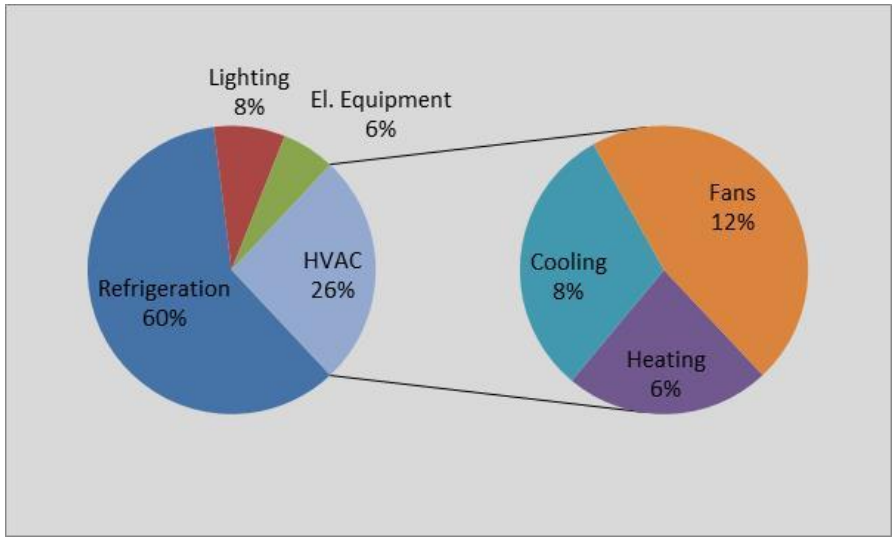
Predictions

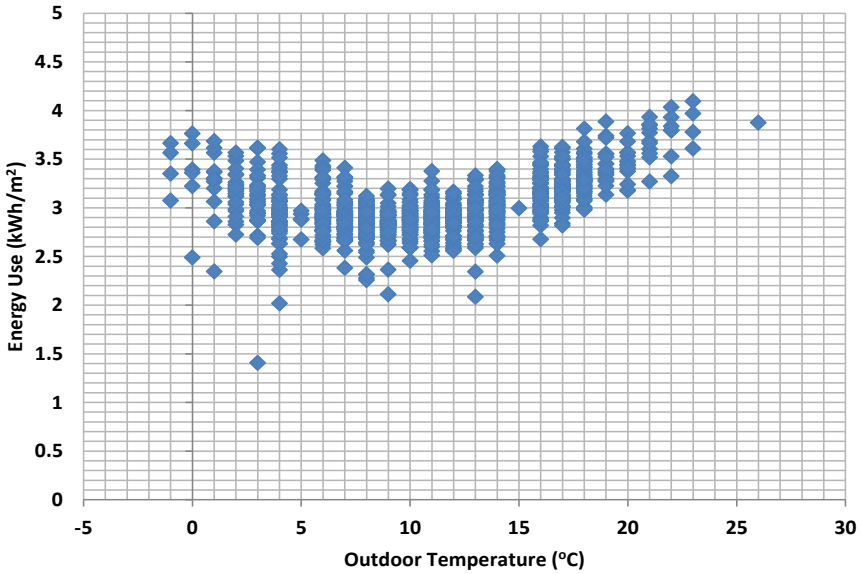


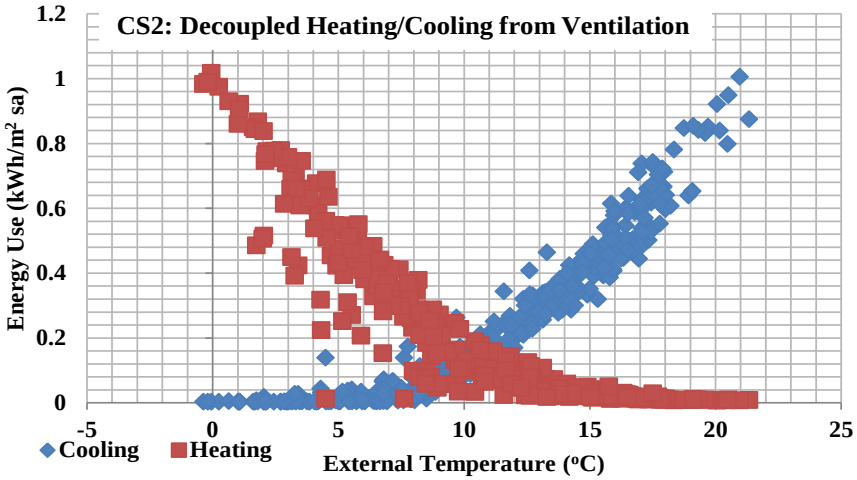


Energy performance evaluation

Baseline store







Impact of the refrigeration system and food product ratio on energy use

- The scope is to evaluate the impact of the refrigeration equipment and load (MT, LT or mixed) in the sales area to the HVAC performance and consequently to total energy use.

0%	72%	100%
Fully Chilled food	Baseline model	Fully Frozen food

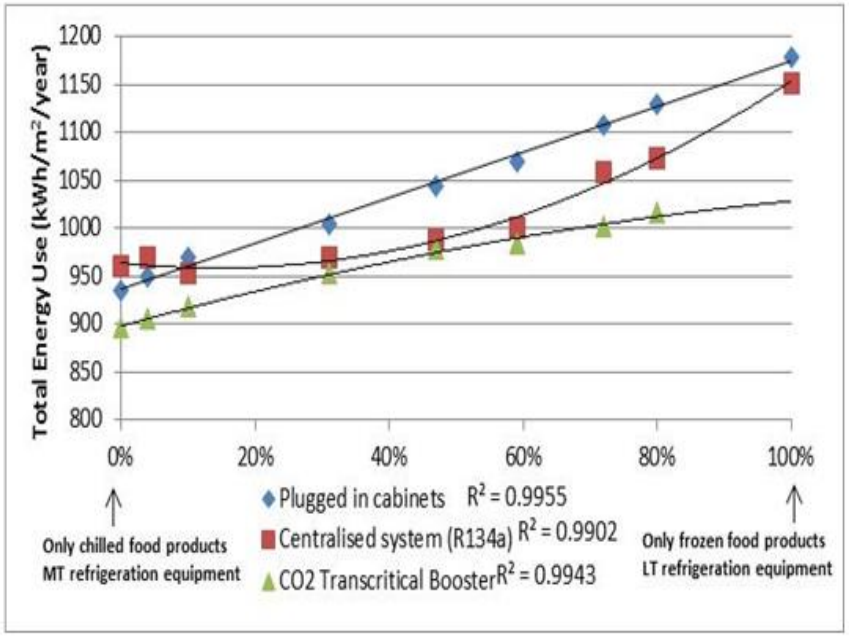
LT/MT

- Comparison for different refrigeration systems applied in the store
  - Plug-in cabinets
  - Centralized (R134a)
  - Transcritical CO_2 booster

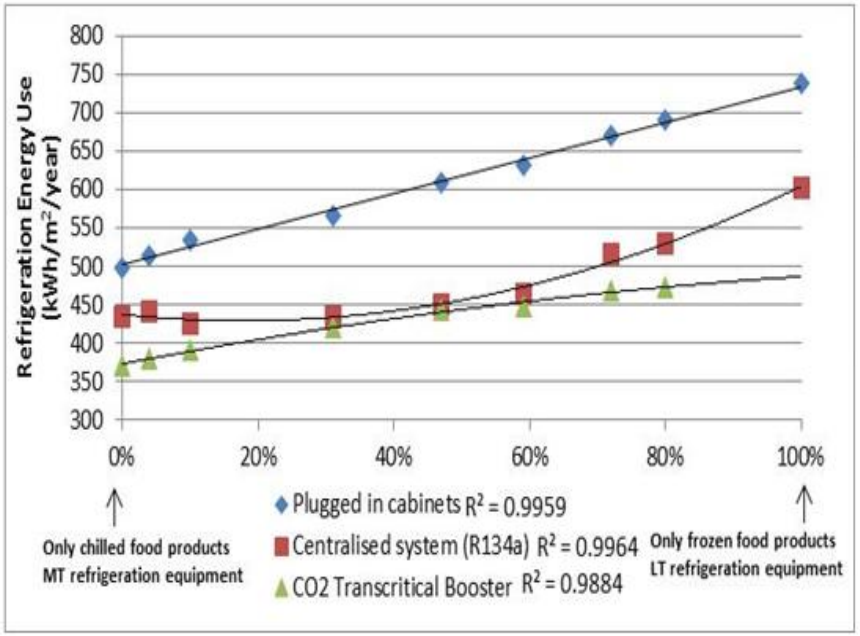
Impact of the refrigeration system and food product ratio on energy use

Results

Total Energy Use



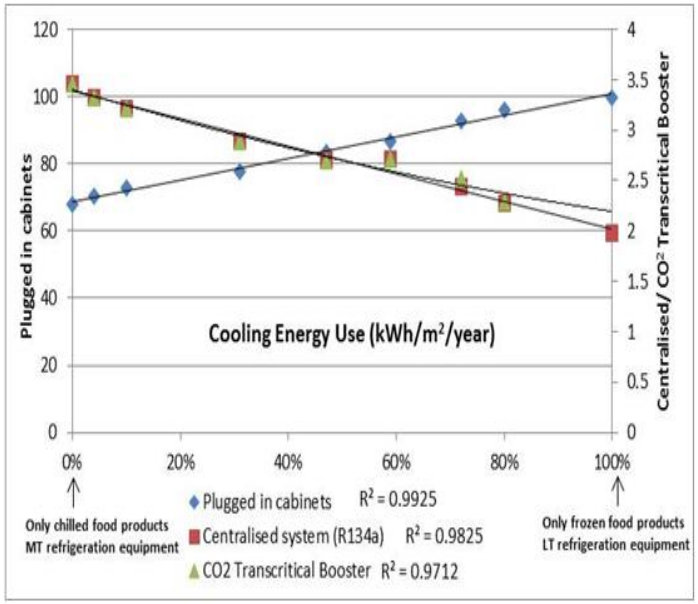
Refrigeration Energy Use

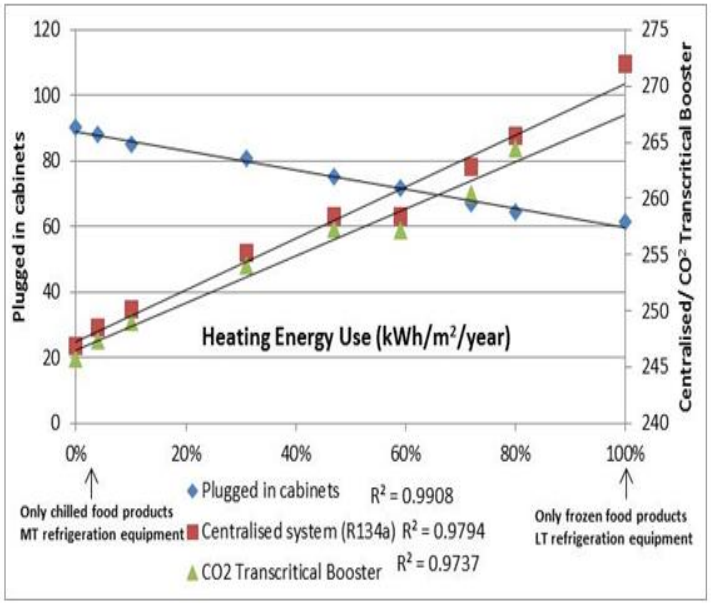


- The higher the percentage of frozen food the higher the total energy use, due to the increase of the refrigeration energy use serving lower evaporating temperatures
- Plugged in cabinets system presents higher increase due to the lower efficiency of the system

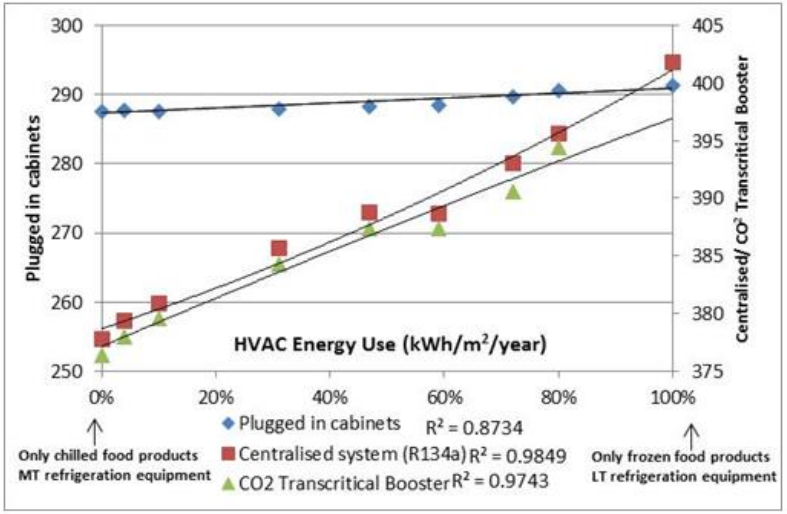
Impact of the refrigeration system and food product ratio on energy use

Results





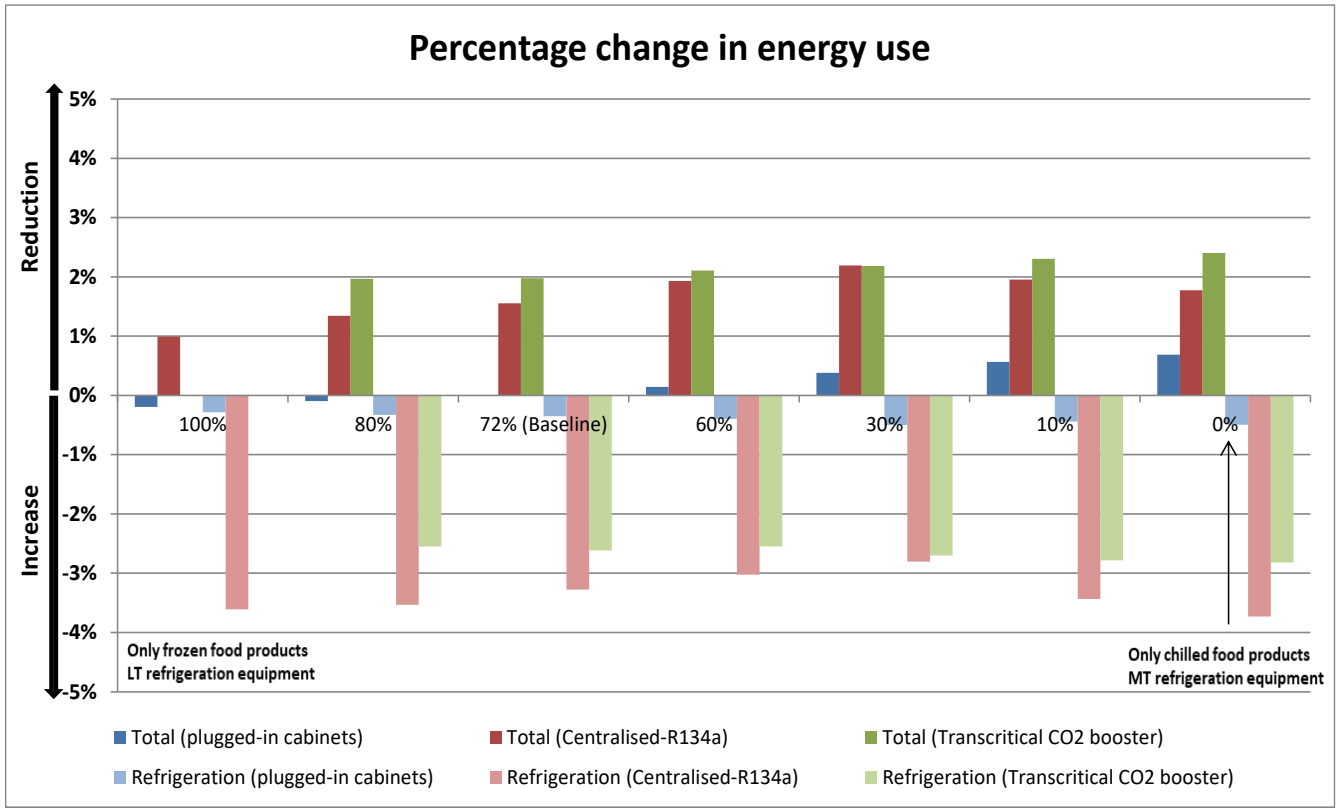
- Cooling energy demand increases with the increase of frozen food only in the case of plugged in cabinets system due to the increase of the heat release in the sales area



Impact of city location on energy use

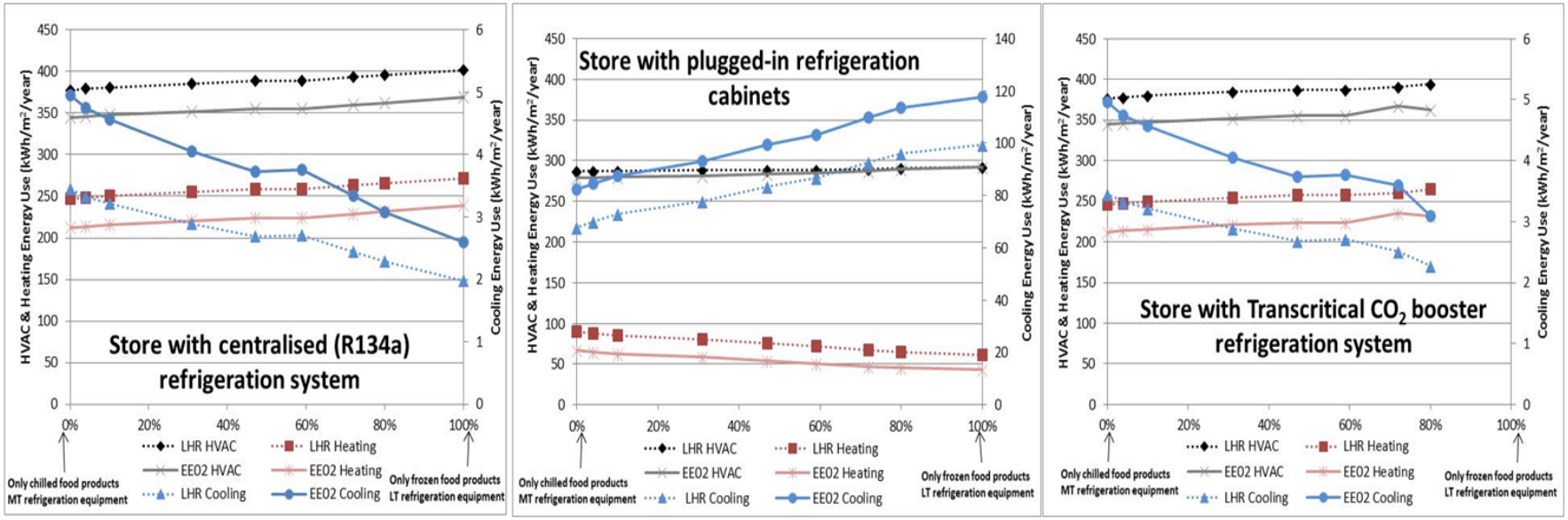
- Urban Heat island effect was investigated for the increase of cooling requirements of the supermarkets as well as the energy performance of refrigeration systems
- Weather files have been developed to include the UHI effect when simulating energy demand (London – Heathrow are compared)
- Simulation was done for a small supermarket located in urban high street areas with a main entrance in the high street and back entrance for systems or stocking/restocking of products
- Comparison for different refrigeration systems applied in the store
  - Plug-in cabinets
  - Centralized (R134a)
  - Transcritical CO_2 booster

Impact of city location on energy use
Results



- There is a reduction in the total energy use for every refrigeration system and load (MT, LT or mixed refrigerated food)
- An increase is observed in the refrigeration energy use

Impact of city location on energy use
Results



- An increase is observed in cooling energy use for central London for the whole load range with higher increase for plugged in cabinets system
- Heating energy use which is dominant in stores with centralized systems, is reduced, more pronounced for centralized systems
- HVAC energy use presents a net reduction mainly when centralized systems are applied

Conclusions

- A thermal model for small food dominated supermarkets was developed using Energy Plus and validated using data from two operational supermarkets.
- The developed model is capable to model interactions between building, HVAC system, refrigeration system, supermarket operation.
- Sub-systems energy consumption as well as resulting environmental conditions inside the supermarket can be predicted.

More details can be found in:

1. Z. Mylona, M. Kolokotroni, S. Tassou (2017). *Frozen food retail: Measuring and modelling energy use and space environmental systems in an operational supermarket*. **Energy and Buildings**, (129) 129-143 https://doi.org/10.1016/j.enbuild.2017.03.049
2. K.M. Tsamos, Y.T. Ge, I. D. Santosa, S. Tassou, G. Bianchi, Z. Mylona (2017). *Energy analysis of alternative CO_2 refrigeration system configurations for retail food applications in moderate and warm climates*, **Journal of Energy Conversion and Management**, http://dx.doi.org/10.1016/j.enconman.2017.03.020
3. Zoi Mylona, M. Kolokotroni, K. Tsamos, S. Tassou (2017). *Comparative analysis on the energy use and the environmental impact of different refrigeration systems for frozen food supermarket application***, Energy Proceedia**, International Conference of Sustainable Energy Use in Food Chain, https://doi.org/10.1016/j.egypro.2017.07.234
4. Z. Mylona, M. Kolokotroni, S. Tassou (2018). *Coupling night ventilative and active cooling to reduce energy use in supermarkets with high refrigeration loads,* **Energy and Buildings,** (submitted-under review)

Thank you!