IOR
ior.org.uk

The knowledge hub for refrigeration, air conditioning and heat pumps

YT Ge
SA Tassou
A Foster
J Evans
GG Maidment

Modelling and Evaluation of Supermarket Energy Use and Emissions

Why this topic?

- It will help you to understand how supermarkets use energy for refrigeration
- It looks at how energy modelling can be used to evaluate technology options
- It provides specific information about how improved efficiency can achieve energy savings and reduced CO_2 emissions in a retail environment where there is both a cooling and heating demand

1 Introduction

A modern supermarket concurrently requires refrigeration for food storage, lighting and heating or cooling to maintain internal space conditions. In the UK, the energy consumption of a typical supermarket is around 700~1000 kWh/m^2, of which 30% to 50% is used for refrigeration, 15% to 25% for lighting and around 20% for mainly heat-based space conditioning [1]. This substantial consumption of energy in the form of grid electricity and gas makes a significant contribution to indirect greenhouse gas emissions. On the other hand, HFCs with higher GWPs such as R404A are charged in conventional supermarket refrigeration systems and have contributed remarkably to direct greenhouse gas emissions due to the unavoidable fluid leakages from the systems. It is therefore imperative to minimize overall supermarket energy consumption and resultant CO_2 emissions.

There are different technology options to reduce supermarket energy consumption and CO_2 emissions. These include heat recovery in the HVAC system, cooling load reductions in refrigerated cabinets, high efficiency refrigeration systems and components such as condensers and evaporators, utilization of natural refrigerants and corresponding system layouts, optimal lighting designs, applications of tri-generation and renewable energy, and building fabric designs and insulations etc. [1].

HVAC and refrigeration systems are known to operate independently in a supermarket. One way to conserve energy is to efficiently use the heat release from the condenser side of a supermarket refrigeration system. The amount of heat release from the high pressure side is directly related to the refrigeration load and head pressure controls. Considering the larger weighting of refrigeration energy consumption in a supermarket, such heat release could be far greater than the demand for space heating if outside ambient air temperatures are not too low and a fixed head pressure is applied instead of floating head pressure control [2,3]. However, in actual application, only 50% of the necessary space heating demand can be recovered [4,5]. This can be explained through reasons of mismatched designs and controls between refrigeration and HVAC systems.

The compressor power consumption in supermarket refrigeration systems is directly affected by the total refrigeration load of both display cabinets and cold rooms. The load of a cold room remains unchanged due to its fixed space temperature control. However, since display cabinets are mounted in the sales area, variations of space air parameters (temperature and humidity) can greatly affect the cabinet refrigeration load. Conventionally, there are seven breakdown load compositions for each cabinet including wall heat conduction, radiation, infiltration, light, evaporator fan, anti-sweat heater and defrost [6]. The percentage for each load composition varies with space ambient conditions and more importantly the cabinet type. For example, an open multi-deck display cabinet has a large infiltration load while radiation load is more significant for an open frozen food well cabinet. This knowledge and understanding can facilitate exploration into efficient methods and technologies to minimise overall refrigeration load. These include optimisation of the air curtain [7-8], night blinds and covers, defrost optimisation [9,10] and anti-sweat heater controls etc. The performance of a supermarket refrigeration system can also be improved by enhancing the efficiency of system components such as compressor, condenser and evaporator [11].

In contrast to HFC refrigerants, the CO_2 refrigerant is more environmentally friendly due to its negligible direct Global Warming Potential (GWP<1). It also has favorable thermophysical properties which include a higher density, latent heat, specific heat, thermal conductivity and volumetric cooling capacity, and lower viscosity than HFC refrigerants, which leads to better heat transfer. The application of CO_2 refrigerant to supermarket refrigeration systems can almost entirely eliminate direct CO_2 emissions and even has the potential to reduce indirect emissions. The CO_2 supermarket refrigeration system structures are mostly two-stage compression cycles with cascade and direct-stage or booster designs which both have the potential for further optimization in terms of controls and heat recovery [12, 13].

As a supermarket requires simultaneous cooling, refrigeration, heating and electricity, a tri-generation system may be a good option considering its advanced energy utilization rate [14,15]. In addition, an integration of renewable energy such as solar thermal and solar PV, biomass and geothermal with the supermarket energy control system could be a promising technology towards meeting the energy demand.

Although all the above technology options could potentially be applied to meet energy demand and ultimately achieve energy savings and CO_2 emission reductions in supermarkets, their contribution need to be quantified so as to facilitate their practical application. A better and economic approach for the quantification is to utilize a validated supermarket model to evaluate their feasibilities, which has not been done comprehensively so far.

In this paper, an operational supermarket in the UK has been selected to be modelled by the previously developed supermarket energy simulation software ‘SuperSIM’. Detailed information of the supermarket and model development procedures are explained. The model was previously validated through comparisons with site measurements of space air temperature and humidity and energy consumptions. It is therefore used to simulate, quantify and evaluate supermarket energy performance at various technology options in terms of heat recovery from refrigerant discharge, high efficiency condensers and evaporators and store locations etc.

2 System and model description

Data from an operational supermarket in North Somerset in the UK are used in this study. For simulation purposes, the supermarket is arranged into 5 zones: sales, office, restaurant, toilet and bakery. The temperature of the sales area is controlled by a constant volume air handling unit (AHU) comprised of supply and return air fans, DX unit from a R407C chiller for cooling, heating coil and supply and return air ducts and dampers. The AHU arrangement is shown in Fig. 1. There are interactions between the building, the HVAC and refrigeration systems. The space air conditions in the sales area can vary in response to a number of variables such as external weather conditions, internal gains including lighting, customers, store schedules and controls for the AHU and refrigeration systems. In the sales area there are heat and mass transfer exchanges between the refrigeration fixtures and the internal environment which influence both internal conditions and the energy consumption of the refrigeration plant. To account for all the interactions and their impact on energy consumption it is essential that the models of the three main subsystems are integrated into an overall supermarket system model.

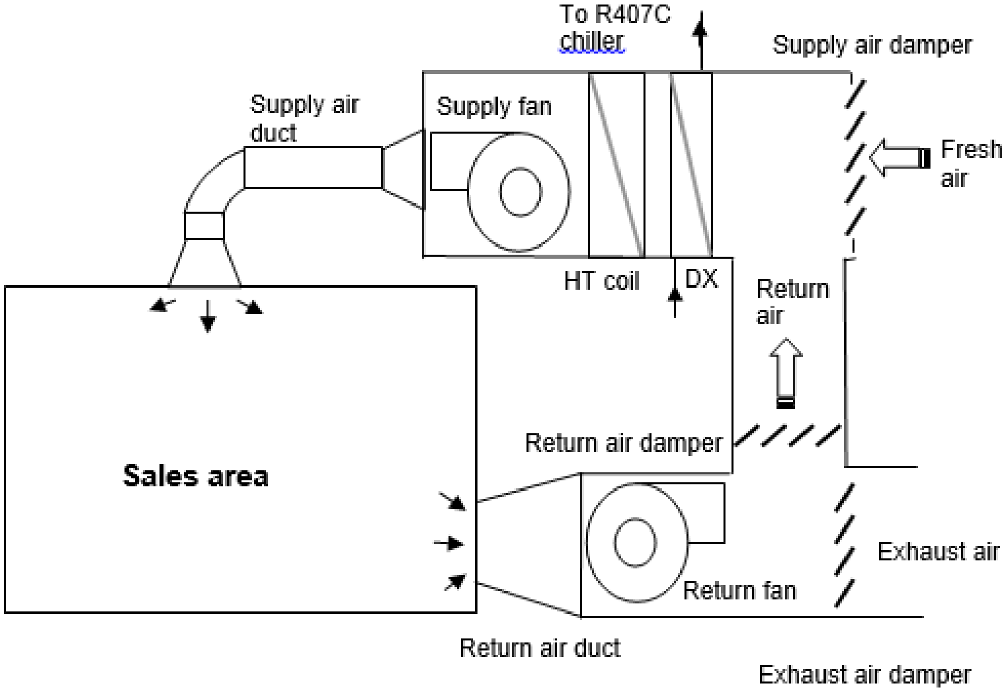

Fig. 1. Layout of HVAC system and heat reclaim coil connected with refrigeration system

2.1 Building model

The building model is based on the TRNSYS multizone building module (TRNSYS 2017). TRNSYS is a transient system simulation program with a modular structure to recognise a system description language whereby the user specifies the components that constitute the system and the manner in which they are connected. The sales area of the supermarket is 4205 m^2. For each zone, descriptions of the building fabric such as wall type, size and window details are required in addition to the specification of infiltration, ventilation, cooling and heating, gains, schedules, and temperature and humidity controls for each zone. In addition, inputs to the model are local hourly weather data including ambient temperature, humidity, wind velocity and direction and solar radiation. The schedules refer to the store's daily opening and closing time, the number of customers in each hourly period as well as the pattern of other internal gains. The space temperature is controlled to 21.5± 2.5°C; cooling is activated when temperatures rise above than 24°C, and heating when temperatures drop below 19°C. The space humidity is allowed to float. The store opens from Monday at 8am and operates for 24 hours each weekday and closes on Saturday at 10pm. On Sunday, it runs between 10am and 4pm. The space lighting is also controlled to drop 33% power between the hours of 22:00 and 06:00 each day.

2.2 HVAC model

The internal space air temperature in the sales area is controlled by an all-air system through an AHU, as shown in Fig. 1. The minimum fresh air flow is set at 10% of supply air. A cascade control method is used to control the supply air temperature. The supply air temperature set-point (SATSP) is controlled at 25°C when space heating is required, and 18°C if cooling is required and neutral when the space temperature is within the controlled point range.

2.3 Refrigeration system model

The refrigerated cabinets in the supermarket are served by seven multi-compressor packs (racks): four high temperature (HT) packs and two low temperature (LT) packs (LT1 and LT2) and the cold rooms by condensing units. Each temperature pack serves an independent refrigeration circuit consisting of an air-cooled condenser and several evaporator coils within various refrigeration fixtures such as display cabinets and cold rooms. Fig. 2 shows a schematic diagram of the HT refrigeration circuit and its interactions with the building and HVAC system. Fig. 3 depicts the process on the P-h diagram. The refrigerant from each operational compressor flows into the discharge manifold at "2" and then to the heat reclaim coil if there is any where it is desuperheated to “2a” before entering the condenser. The condensed or subcooled refrigerant then flows into the receiver at “3” from where it is distributed to refrigerant fixture groups with similar evaporating temperatures. The evaporator refrigerant inlet and outlet for cabinet group 1 are set at “4” and “5” respectively, cabinet group 2 at “4'” and “5'”, and cold room group 1 at “4"” and “5"”. Although only two cabinet groups and one cold room group are shown in the diagram, there are more groups in the actual supermarket. As the refrigerant flows through the suction line its temperature increases and pressure decreases to state point “6”, “6'” and “6"” respectively for the three fixture groups. The arrangement of the LT circuit for the frozen food fixtures is similar to that for the chilled temperature circuit.

The refrigeration system model should be capable of predicting the hourly and total power consumption of the refrigeration systems for the entire year. To achieve this, the state and properties of the refrigerant at all main cycle points “1”, “2”, “2a”, “3”, “4” , “5” and “6” need to be established at each ambient or part load condition.

Furthermore, the full-load and part-load refrigeration loads need to be calculated in order to determine the energy consumption of each refrigeration pack. Using fixed evaporator temperature controls, the evaporating temperature is specified at design conditions. The condensing temperature will be dependent on the control strategy employed for the condensing (head pressure) control and can be fixed or allowed to float with the ambient temperature.

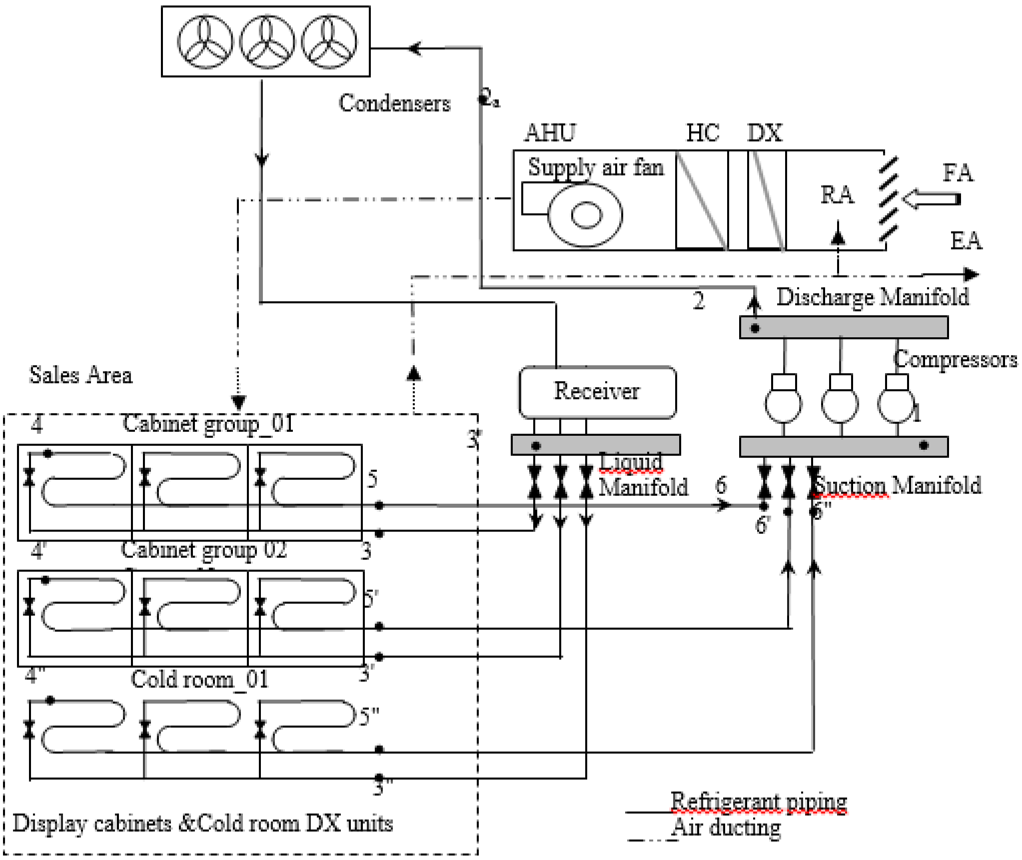

Fig. 2. Layout of HT pack refrigeration system and its interactions with HV system and building in supermarket

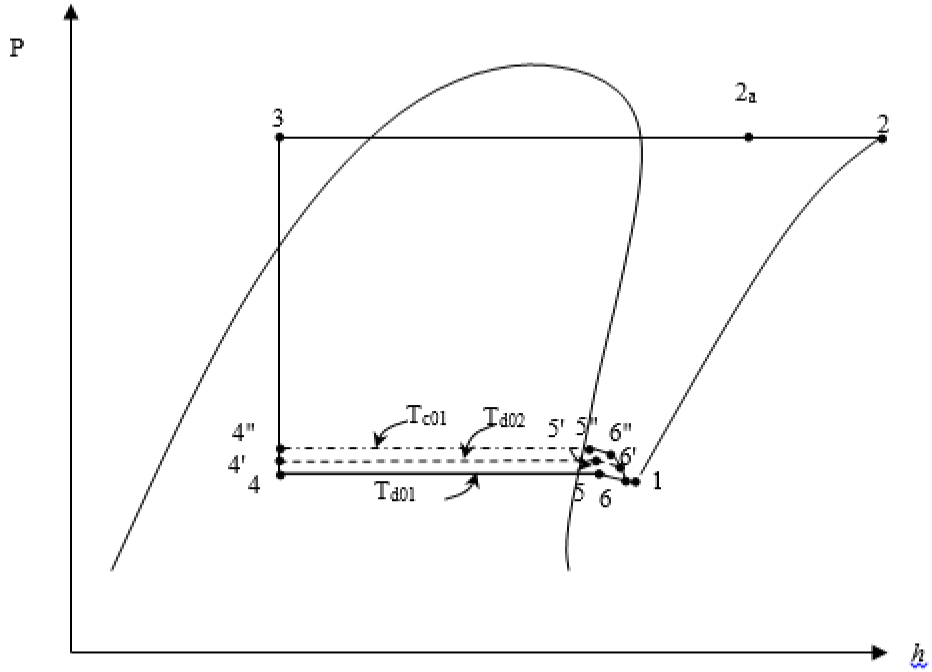

Fig. 3. Refrigeration cycle of the high-temperature pack circuit in the supermarket

2.3.1 Calculation of the refrigeration load

A critical component of the refrigeration system model is the accurate prediction of the refrigeration system load at part load conditions from the design cooling specification. At a steady state, the total cooling load of a display cabinet Q_{case} arises from wall heat conduction Q_{wall}, radiation Q_{rad}, cabinet lights Q_{light}, evaporator fan Q_{evfan}, infiltration Q_{inf} , anti-sweat heater Q_{asw} and defrost Q_{def}:

$$Q_{case} = Q_{wall} + Q_{rad} + Q_{light} + Q_{evfan} + Q_{inf} + Q_{asw} + Q_{def} \quad (1)$$

On the right hand side of equation (1), Q_{light} and Q_{evfan} are constant when the cabinet is on but Q_{wall} and Q_{rad} are affected by space temperature variation while Q_{inf}, Q_{asw} and Q_{def} vary with different space temperatures and humidity. To account for these, based on the relevant heat transfer process, a correlation ratio is employed for each of these loads to the corresponding load at a specific rated condition of 25^{0}C and 50% humidity. The seven respective terms R_{wall}, R_{rad}, R_{light}, R_{evfan}, R_{inf}, R_{asw} and R_{def} are defined as follows:

$$R_{wall} = \frac{Q_{wall}}{Q_{wall,r}} = \frac{T_{sale} - T_{case}}{T_{sale,r} - T_{case}} \quad (2)$$

$$R_{rad} = \frac{Q_{rad}}{Q_{rad,r}} = \frac{T_{sale}^4 - T_{case}^4}{T_{sale,r}^4 - T_{case}^4} \quad (3)$$

$$R_{light} = 1 \quad (4)$$

$$R_{evfan} = 1 \quad (5)$$

$$R_{inf} = \frac{Q_{inf}}{Q_{inf,r}} = \frac{h_{sale} - h_{case}}{h_{sale,r} - h_{case}} \quad (6)$$

$$R_{asw} = \frac{Q_{asw}}{Q_{asw,r}} = \frac{Tdew_{sale} - T_{case}}{Tdew_{sale,r} - T_{case}} \quad (7)$$

$$R_{def} = \frac{Q_{def}}{Q_{def,r}} = \frac{Humr_{sale} - Humr_{case}}{Humr_{sale,r} - Humr_{case}} \quad (8)$$

At the rated condition, the percentage load distribution for different types of display cabinet used in the model are based on the results of Walker et al (2004), shown in Fig. 4. From these and the rated cooling loads of the cabinets taken from manufacturers' data, the individual loads of the cabinets at rated and part-load conditions can be determined.

Tables 1 and 2 show the rated loads of the refrigeration fixtures served by the HT pack 1 and LT pack 1 respectively. Similar information from other temperature packs in the refrigeration system can also be obtained from designers and manufacturers.

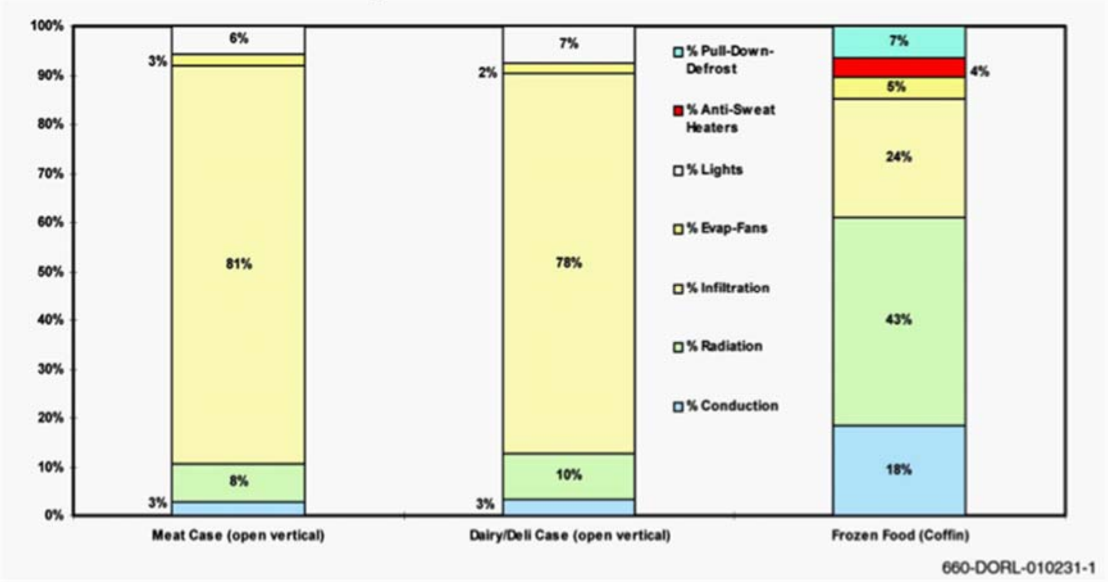

Fig. 4. Load distribution in some typical display cabinets

Table 1 Manufactures' data for display cabinets and cold rooms served by the high-temperature pack 1

HT-pack	STUB No.	Cabinet / Coldroom	Evap. Temp. °C	Display Temp. °C	Extraction Rate kW
Dcase	1	ROLL-IN-PRODUCE	-8	0 / +4	6.85
	2	ROLL-IN-PRODUCE	-8	0 / +4	4.5
	3	ROLL-IN-PRODUCE	-8	0 / +4	6.85
	4	ROLL-IN-PRODUCE	-8	0 / +4	6.85
	5	ROLL-IN-PRODUCE	-8	0 / +4	6.85
	6	ROLL-IN-PRODUCE	-8	0 / +4	6.85
	7	STORAGE	-10	-1/ +5	0.28
	8	STORAGE	-10	-1/ +5	0.28
Cold Room	1	FRESH MEAT CONVER	-1/+1	-7	4.05
	2	DAIRY	0/+2	-6	4.79
	3	PROVISIONS CHILLER	0/+2	-6	5.45
	4	PROVISIONS CHILLER	4/+6	-2	9.91
	5	MILK DAIRY CONVER	0/+2	-6	4.36
	6	50% FRESH FOOD	0/+2	-6	3.46
				Total=	71.33

Table 2 Manufactures' data for display cabinets and cold rooms served by LT1

LT-pack	STUB No.	Cabinet / Coldroom	Evap. Temp. °C	Display Temp. °C	Extraction Rate kW
Dcase	1	3 DOOR FGD	-31	-18/-21	1.58
	2	WELL + HGD	-35	-18/-20	1.73
	3	WELL + HGD	-35	-18/-20	2.55
	4	WELL + HGD	-35	-18/-20	2.55
	5	WELL + HGD	-35	-18/-20	2.55
	6	3 DOOR FGD	-31	-18/-21	1.58
	7	WELL + HGD	-35	-18/-20	2.55
	8	WELL + HGD	-35	-18/-20	2.55
	9	WELL + HGD	-35	-18/-20	2.55
	10	3 DOOR FGD	-31	-18/-21	1.58
Cold Room	1	BAKERY FREEZER	-26	-18/-20	4.787
	2	WELL + HGD	-35	-18/-20	2.307
	3	3 DOOR FGD	-31	-18/-20	1.58
	4	WELL + HGD	-35	-18/-20	2.307
	5	FROZEN FOOD	-26	-18/-20	4.91
	6	FROZEN FOOD	-26	-18/-20	4.91
				Total=	20.8

3 Model validation and simulation results

The refrigeration systems for the supermarket considered employ R404A for compressor packs HT1, HT2, HT3, HT4, LT1 and LT2. The control strategies use a floating head pressure and fixed suction pressure controls for each pack, as listed in Table 3.

Table 3 Controls for the temperature packs in the supermarket refrigeration system

Pack	$T_{cd,min}$ (°C)	$T_{evc,set}$ (°C)	ΔT_{sh} (K)	ΔT_{cd} (K)	ΔT_{sc} (K)	Refrigerant
HT1	10	-12	22	11	8	R404A
HT2	10	-9	19	11	8	R404A
HT3	10	-10	20	11	8	R404A
HT4	10	-10	20	11	8	R404A
LT1	-10	-37	37	8	5	R404A
LT2	-10	-37	37	8	5	R404A

Since the developed supermarket model has been previously validated [16,17], this paper only presents the comparisons of simulation and test results for indoor space temperature and humidity in this particular supermarket and quantifies the effect of various technology options on system performance.

The hourly variations of sales indoor space air temperature and humidity from both simulation and measurement are compared and shown in Fig. 5. It is noted that there are some prediction errors for both temperature and humidity. This is because that the weather data for measurement year are difficult to find out and those from a previous year have to be utilized in the model. As depicted, the space air temperature can be controlled within specified limitations through the conditioned AHU. However, variation in space humidity is remarkable and reaches its peak in summer as it is not controlled. This large deviation in space humidity can greatly affect the infiltration load of cabinets in the sales area and thus total refrigeration load in the temperature pack. As shown in Fig.6, considering the higher percentage weight of infiltration load in cabinets of HT packs, the refrigeration load greatly increases during the summer period for HT packs but remains relatively constant for LT packs. When including refrigeration load in cold rooms, the total refrigeration load for any temperature pack is larger than load with cabinets only. Under such circumstances, inner space humidity control may be a technology option for reducing refrigeration load in sales area but will require more energy for the dehumidification.

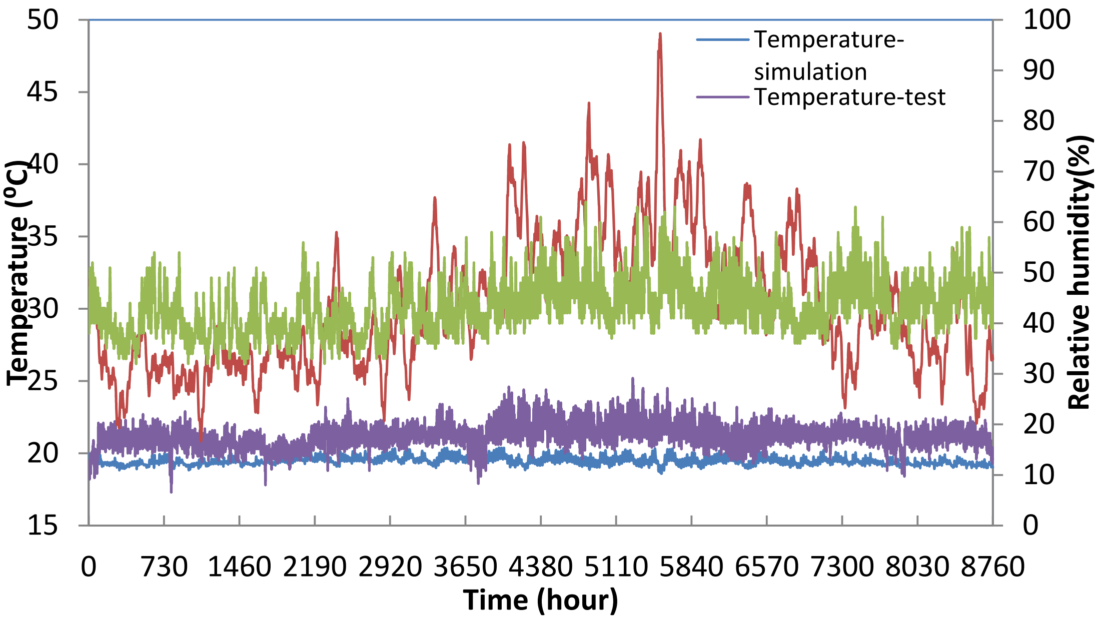

Fig. 5. Hourly variation sales space temperature and humidity during a year

The enhancement of refrigeration load for both HT and LT packs can directly affect compressor power consumption in the packs, as shown in Fig. 7. Subsequently, the total power consumption is higher in summer for both packs. On the other hand, since the floating head pressure control (not allowed to drop below 10.5 barg) is employed in the refrigeration system, a higher ambient during the summer months leads to higher refrigerant condensing temperatures and therefore contributes greater compressor power consumption compared to winter.

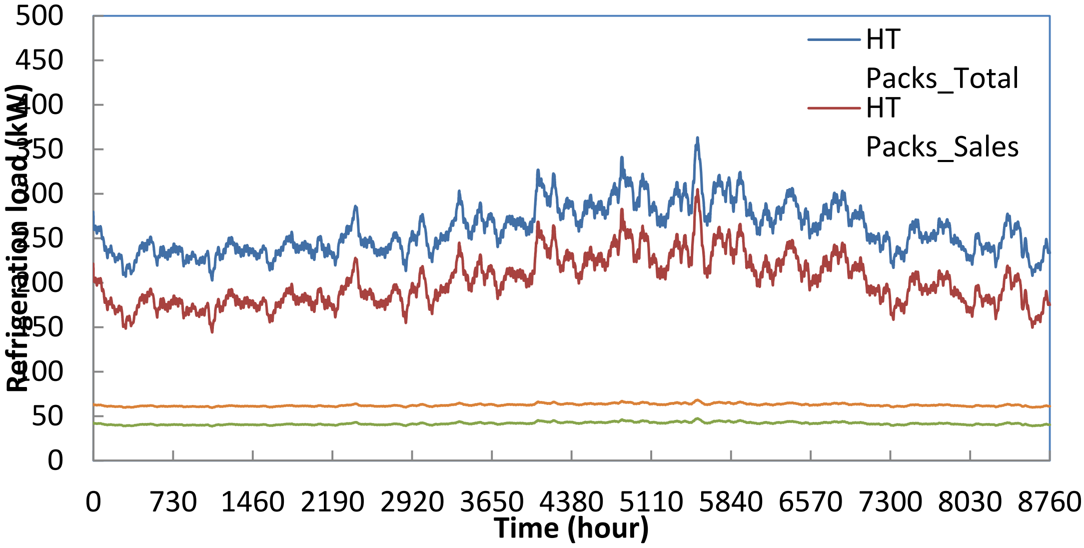

Fig. 6. Hourly variation of refrigeration load for HT and LT packs during a year

In the sales area, an increase in refrigeration load can withdraw a greater amount of heat from the inner space, thus requiring more heating from the AHU to maintain space temperature, as shown in Fig. 8. However, the contribution to AHU heating capacity is dominated more by ambient air temperatures considering heat losses/gains from building fabrics and the specified 10% fresh air flow for the AHU. Various technology options may be considered to reduce space heating demand. These include free heating from fresh air flow, heat recovery from refrigeration systems and application of tri-generation etc.

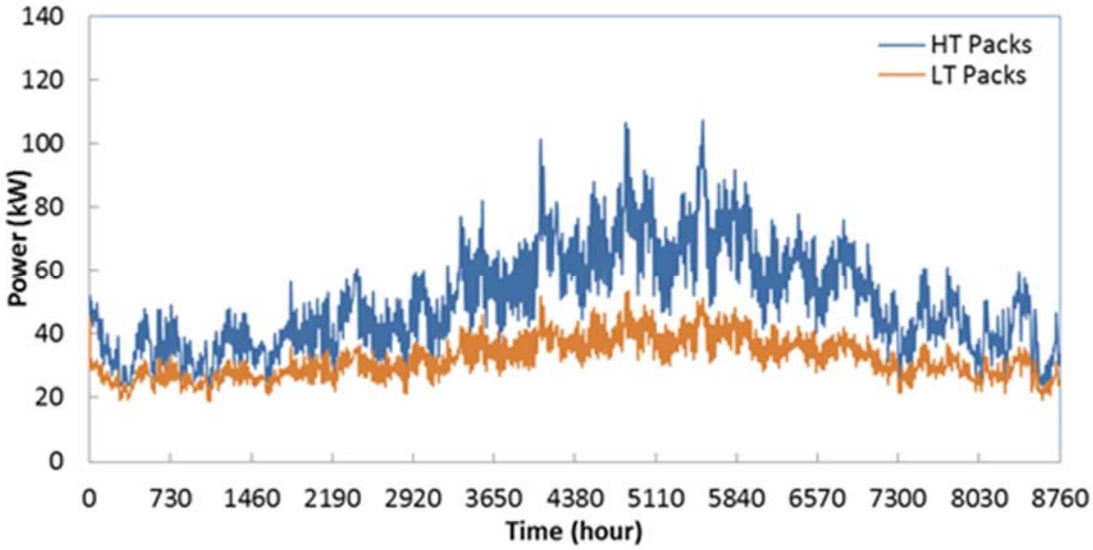

Fig. 7. Hourly variation of compressor power consumption for HT and LT packs during a year

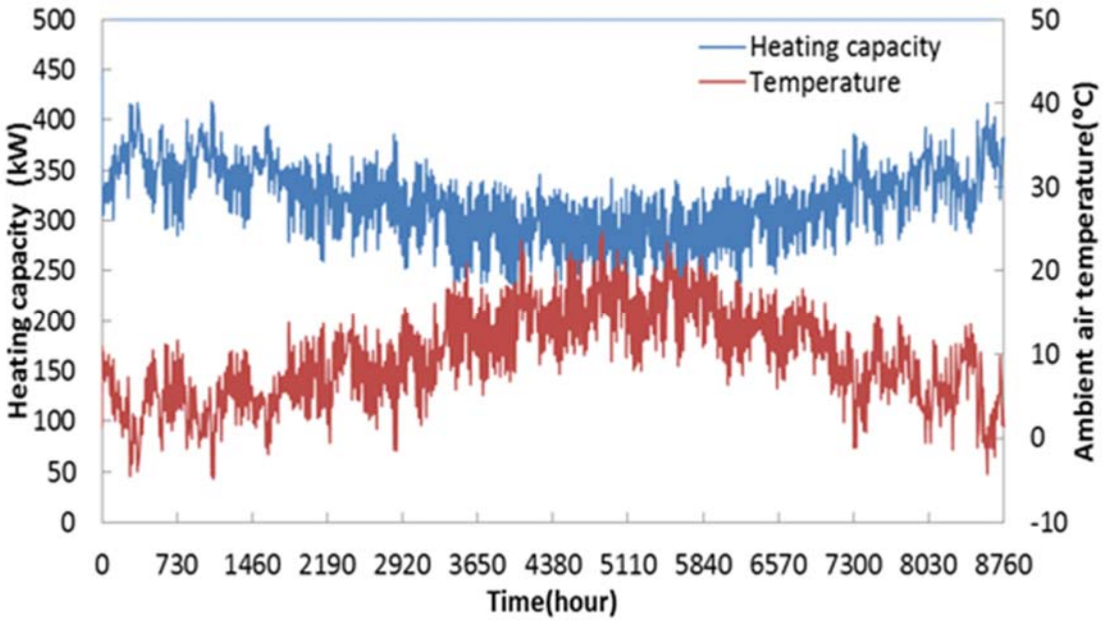

Fig. 8. Hourly variation of AHU heating capacity and ambient air temperature during a year

As mentioned before, there are a number of technology options to consider for improving supermarket energy performance, although modelling quantification is expected. In the paper, to save page space, the following are considered and evaluated by the supermarket model:

- Option-1: heat recovery from compressor discharge of refrigerant at condition floating head pressure control;
- Option-2: high efficiency evaporators;
- Option-3: high efficiency condensers;
- Option-4: different store locations.

For the option-1, a heat recovery coil is assumed to be connected to refrigerant discharge pipe of each temperature pack and installed in the AHU. The potential recovery heat can be calculated as:

$$Q_{hrc} = \dot{m}_r\left(h_{rexcp} - h_{rexhrc}\right) = \dot{m}_a Cp_a(T_{aexhrc} - T_{asuhrc}) \qquad (9)$$

To calculate recovery heat, the temperature difference between the refrigerant side outlet and air flow inlet of the heat recovery coil is fixed to 10 K. If the calculated refrigerant side outlet temperature is less than the refrigerant condensing temperature, the condensing temperature will be applied instead. This will ensure that there is no phase change in the heat recovery coil.

For option-2, the evaporating temperature is assumed to be one degree higher when high efficiency evaporators are applied. Similarly, the condensing temperature of each temperature pack is assumed to be one degree lower in the presence of higher efficiency condensers.

For the last option, the store is assumed to be located in Aberdeen in Scotland where the ambient air temperature is relatively lower.

The supermarket model therefore simulates these specific technology options to quantify, evaluate and compare their effects on the system performances, as summarized in Table 4. It should be noted that option 0 marks the results from the original design and the CO_2 emissions calculation is based on the annual consumption of electricity and gas consumption from the table.

Table 4. Energy consumptions and CO2 emissions for different technology options

Option	Q_{evtot} (kWh/year)	W_{cptot} (kWh/year)	Q_{ht_AHU} (kWh/year)	Q_{hrc_AHU} (kWh/year)	CO_2 emissions (tonne/year)
0	2827884	723578	2787327	-	901
1	2827884	723578	2194320	593007	791
2	2827884	698139	2787327	-	887
3	2827884	704720	2787327	-	891
4	2739100	655772	2887122	-	883

The table shows the various reductions in CO_2 emissions when employing different technology options, compared to the original wherein. Option 1 produces the largest energy savings and the least CO2 emissions. It becomes apparent that a better combination of these options can create notable energy saving opportunities.

4 Conclusions

The vast energy demand in modern supermarkets worldwide can produce significant CO_2 emissions. The different technology options to reduce energy demand in supermarkets and consequently CO_2 emissions can be quantified, evaluated and compared by a validated model supermarket energy control system.

In this paper, an operational supermarket in the UK has been selected to evaluate possible technology options using the developed supermarket model or software 'SuperSIM'. For each refrigeration fixture, the accurate breakdown of refrigeration load and the effect of ambient conditions are very important for model development. In addition, the sales area temperature and relative humidity, which is not normally controlled, can greatly affect the system refrigeration load.

Furthermore, the significant space heating demands in the supermarket can be met by means of heat recovery from refrigeration system integration and tri-generation etc. Through the developed supermarket model, four technology options have been selected for performance evaluation including heat recovery, high efficiency condensers, high efficiency evaporators and different store locations. These technology options can improve system performance in terms of both energy savings and CO_2 emission reduction. It is expected that greater energy savings can be achieved if a combination of these options is employed.

About the author

Dr Yunting Gee is currently a Reader in the Building Services Subject Group and a member of the Centre for Energy and Built Environment Research (CEBER), School of Engineering and Design of Brunel University London. He has over fifteen years' research experience in the areas of refrigeration, air conditioning, building energy and controls, and renewable energy. He is now a Principle or co investigator in several funded research projects. His specialist research areas include investigation of advanced supermarket energy control systems including refrigeration, air conditioning and buildings; application of tri-generation systems in supermarket; simulation and optimal design of various refrigeration systems and components; and heat and mass transfer analysis for different types of heat exchangers. He began his career as an Application Engineer for Siemens Building Technologies.

References

[1] S.A. Tassou, Y.T. Ge, A. Hadawey, D. Marriott. Energy consumption and conservation in food retailing. Applied Thermal Engineering 31 (2011) 147-156.
[2] L. Cecchinato, M. Corradi and S. Minetto . Energy performance of supermarket refrigeration and air conditioning integrated systems. Applied Thermal Engineering 30(2010) 1946-1958.
[3] Y.T. Ge, S.A. Tassou ,Control Optimisations for Heat Recovery from CO2 Refrigeration Systems in Supermarket. Energy Conversion and Management 78 (2014) 245-252.
[4] J. Arias. Energy Usage in Supermarkets Modelling and Field Measurements.Department of Energy Technology. Stockholm, Royal Institute of Technology 2005; Doctoral thesis.
[5] J. Arias , P. Lundqvist . Heat recovery and floating condensing in supermarkets. Energy and Buildings 38(2006) 73-81.
[6] D. Datta, R. Watkins, S.A. Tassou, A. Hadawey, A. Maki, Formal Based Methodologies for the Design of Stand Alone Display Cabinets. Final report to DEFRA for project AFM144, November 2005, 177 pp.
[7] A.M. Foster, M. Madge , J.A. Evans .The use of CFD to improve the performance of a chilled multi-deck retail display cabinet. International Journal of Refrigeration 28 (2005) 698–705.
[8] G. Cortella , M. Manzan, G. Comini. CFD simulation of refrigerated display cabinets. International Journal of Refrigeration 24(2001) 250–260.
[9] S.A. Tassou, D. Datta, D. Marriott, Frost formation and defrost control parameters for open multideck refrigerated food display cabinets, Proceedings of the Institution of Mechanical Engineers, Professional Engineering Publishing Vol. 215 (No. 2) (2001) 213-222.
[10] J.M.W. Lawrence , J.A. Evans. Refrigerant flow instability as a means to predict the need for defrosting the evaporator in a retail display freezer cabinet. International Journal of Refrigeration 31(2008) 107–112.
[11] Y.T. Ge, S.A. Tassou, A. Hadawey, Performance Simulation of Multi-deck Medium Temperature Display Cabinets with the Integration of CFD and Cooling Coil Models. Applied Energy 87 (2010) 3178–3188.
[12] Y.T. Ge, S.A. Tassou ,Control Optimisations for Heat Recovery from CO2 Refrigeration Systems in Supermarket. Energy Conversion and Management 78 (2014) 245-252.
[13] Y.T. Ge, S.A. Tassou, Control optimisation of CO2 cycles for medium temperature retail food refrigeration systems. International Journal of Refrigeration 3 2 (2009) 1 3 7 6 – 1 3 8 8.
[14] Y.T. Ge, S.A. Tassou I. Chaer N. Suguartha, Performance Evaluation of a Tri-generation System with Simulation and Experiment. Applied Energy 2317-2326.
[15] G.G. Maidment, X. Zhao, S.B. Riffat . Combined cooling and heating using a gas engine in a supermarket. Applied Energy 68(2000) 321–335.
[16] Y.T. Ge, S.A. Tassou. Performance Evaluation and Optimal Design of Supermarket Refrigeration Systems with Supermarket Model "SuperSim", Part I: Model Description and Validation. International journal of refrigeration 34 (2011) 527 -539.
[17] Y.T. Ge, S.A. Tassou. Performance Evaluation and Optimal Design of Supermarket Refrigeration Systems with Supermarket Model "SuperSim", Part II: Model Applications. International journal of refrigeration 34 (2011) 540 -549.

Abstract

The developed supermarket simulation software "SuperSIM" with its integrated refrigeration, building and HVAC system models, can be used to evaluate, compare and optimize different technology options based on predicted supermarket energy use and CO_2 emissions. To do this, an operational supermarket in the UK has been selected and modelled by the software according to detailed supermarket descriptions. These include building fabric, lighting, HVAC systems, refrigeration compressor packs, store opening time schedules, system integration and controls which are all considered and included in the model. For a whole year, the hourly indoor space temperature and humidity in the sales area and energy performance of each subsystem were predicted and validated with site measurements. The model was then used to evaluate supermarket energy use and emissions with different technology options including heat recovery and high efficiency condensers and evaporators, and performance comparisons at different store locations in the UK. Further model improvements and application are also discussed.

Key Words: supermarket system model 'SuperSIM', model validation and application, technology options, energy use and emissions, evaluation.

Nomenclature

Cp	specific heat capacity (kJ/kg.K)
DX	direct expansion unit
h	enthalpy (J/kg)
HT	high temperature
Humr	air humidity ratio (kg/kg)
LT	low temperature
$\dot{m}$	mass flow rate (kg/s)
Q	capacity , refrigeration load (kW)
R	ratio
Tdew	dew point temperature (K)
T	temperature (K)
ΔT	temperature difference (K)
W	power (kW)

Subscripts

a	air
asw	anti sweat heater
aexhrc	air flow at heat recovery coil exit
asuhrc	air flow at heat recovery coil inlet
cd	condensing
cd,min	minimum condensing
cptot	compressor, total
def	defrost
evfan	evaporator fan
evtot	evaporator, total
hrc_AHU	heat reclaim coil, AHU
ht_AHU	heating, AHU
inf	infiltration
r	refrigerant, rated
rad	radiation
rexhrc	refrigerant flow at heat recovery coil exit
rsuhrc	refrigerant flow at heat recovery coil inlet
sc	subcooling
sh	superheating
suc,sat	equivalent suction saturated

Join us at this free open meeting

either by webinar below (to listen in live on 3rd March or be sent a recording after the presentation)
https://attendee.gotowebinar.com/register/5270134422894660353

or register below to join the presentation at 5.15pm on 3rd March 2016 at CEREB Building, London South Bank University, Keyworth Street, SE1 6NG

Register at: https://www.eventbrite.co.uk/e/supermarket-energy-use-and-emissions-technology-options-review-tickets-20558832020

CEREB Building
London South Bank University
Keyworth St
LONDON
SE1 6NG