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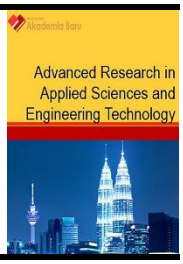

Improving Energy Efficiency in the Supermarket by Retrofitting Low E Glass Doors for Open Refrigerated

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ABSTRACT

This research presents the improving energy efficiency by retrofitting doors for open refrigerated in central Thailand supermarkets that open in the daytime (06.00 am - 6:00 pm) and close in night-time (00.00 am – 6:00 am). The Materials and Methods were open refrigerated 15 cabinet and retrofitting doors for open refrigerated that 41 frames, 82 doors in medium temperature refrigeration system and measure power consumption kW, kWh by power meter data logger for analysis and summarize. The power consumption saving average per 7 days for retrofitting doors was 576 kWh/day, 39.67% that daytime 418 kWh/day, 41.93%, and night-time 116 kWh/day, 33.24%. Besides, the energy of day time more than night time because 1) The time of opening store is longer than closing store 2) In the night time, the refrigerated will close by plastic curtain 3) The request cooling load of day time is longer than day time 4) The sale area/ambient temperature of night time more than day time but the humidity was contrasted. Before retrofitting doors, the maximum and minimum of power consumption was 83.25 kw/hour and 44.73 kw/hour, respectively. Also, the power consumption swing at 38.52 kw/hour, 46.72%, and the maximum and minimum of power consumption after retrofitting doors was 33.15 kw/hour and 30.19 kw/hour, respectively. The power consumption swing at 2.96 kw/hour, 8.93%. In addition, the power consumption swing will after be retrofitting doors will less than before retrofitting doors by 1) The average cooling load will be the same as bolt conditions 2) The request cooling load of doors refrigerated will less than by product load, the swing of sale area temperature and humidity, customer behavior that effect power condition will have the low running operation. This research's investment was 21,694 €, while the payback period of this research was 14 months. Besides, within 1.1 years, that energy saving was 16,020 kWh/Month or 1,542 €/Month, 16,020 kWh/month or 192,220 kWh/Year or 18,503 €/Year.

Keywords:
Refrigeration system; Energy efficiency;
Low E glass doors; open refrigerated;
retrofitting

1. Introduction

Energy use in Thailand's business sector is ranked second among overall energy users in the country and is thus being targeted for energy-saving options [1]. The number of supermarkets in Thailand is numbered to more than 1,500 locations in 2020, which continuously increases annually [2]. The majority are open 18-24 hours per day, so the retail sector is the fourth largest consumer of energy in the business sector, consuming more energy than residences do [3]. The components that

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contribute to supermarkets' energy consumption in Thailand, ranked from highest to lowest, are refrigeration systems, air-conditioning systems, electrical equipment, and lighting [4-5]. However, proportions of energy use in the supermarkets in Thailand were previously ranked, as shown in Figure 1 below [6]. The best options for reducing energy consumption in supermarkets in Thailand are high energy efficiency and an efficient energy-management system. An excellent example of energy savings in refrigeration systems is shown in Figure 2 below [7]. Energy savings in refrigeration systems can be achieved through decreased power consumption of the compressor, as this is the component that utilizes the most energy.

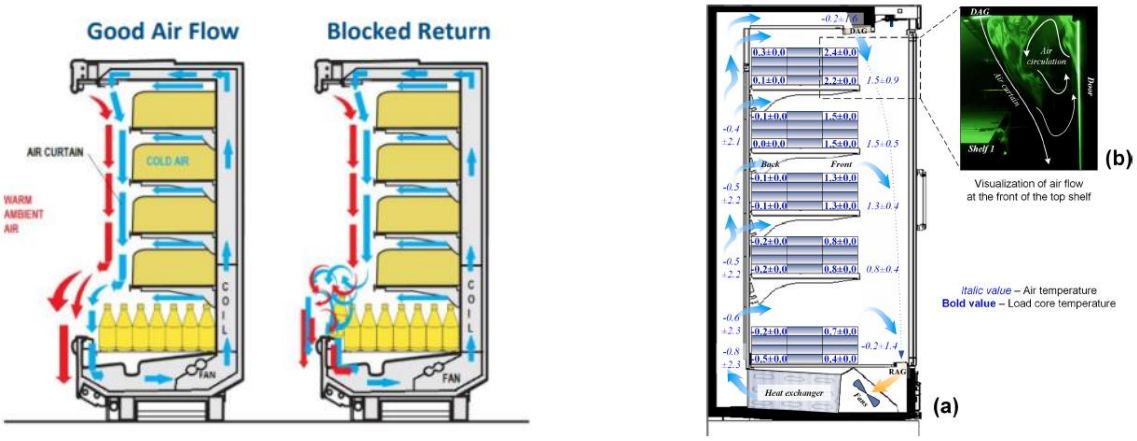


Fig. 1. How to open and close refrigerated operated [8-9]

The open showcase can keep the cabinet's temperature by air curtain systems, as shown in Figure 1 [8-9]. The airflow supply was sperate by 70% for air curtains that keep the temperature and 30% for airflow supply at back wall panel that product cooling. Besides, Bolt airflow supply will comeback 100% at return gill and operating continuously. If there is some condition effect to air curtain, for example, 1) Something block return supply 2) Customer pick product 3) Sales area temperate and humidity 4) Wind form air condition return and supply, and 5) Staff Storage that effect to the performance of refrigerated and power consumption of compressor [10-11]. For the refrigerated with doors that can operate and perform better than open refrigerated [12-13] because there are no 5 effect conditions as before, as shown in Figure 2 below [14]. The comparison of cabinet temperature simulation with open refrigerated and doors refrigerated, that doors refrigerated can keep the temperature. Also, the minimum temperate and maximum temperature does not swing. This research will present improving energy efficiency by retrofitting doors for open refrigerated in central Thailand supermarkets. Thus, customers can get good quality products, while retail companies and suppliers can get reliability.

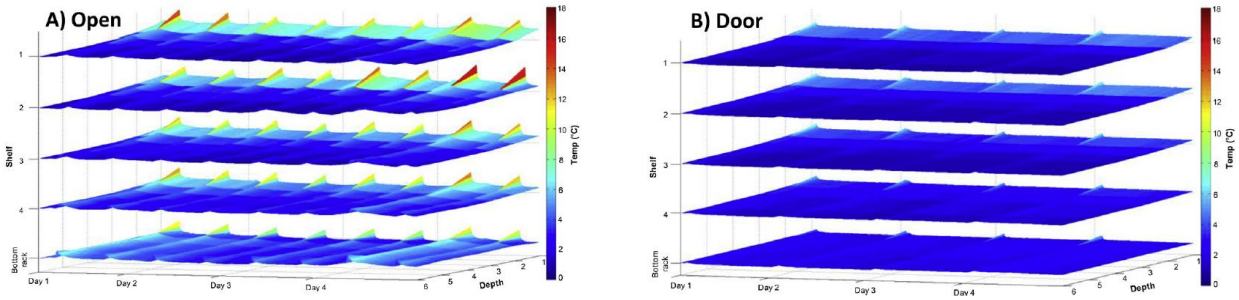


Fig. 2. Cabinet temperature compare with close and open refrigerated [15]

2. Materials and Methods

The Low E glass door for cabinet will reduce the power consumption of compressor to protect heating or cooling, as shown in Figure 3 below. The Low E will be a coating that filler for reducing transmission and absorption of infrared [16-17]. The most common type of a Low-E window uses two or three panes of glass, with a gas gap between them in the fridge [18-19]. The performance is to reduce transmission and absorption of infrared will hill and cost [20]. This research used Low-E glass two-layer with a gas gap for retrofits to open refrigerated, as showed in the fridge, the percentage of transmission for Low-E glass at all layer types lower than regular glass shown in Figure 4 below [21].

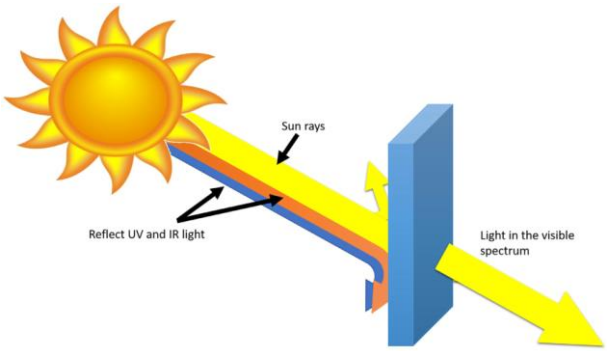


Fig. 3. Low-E filters on windows [21]

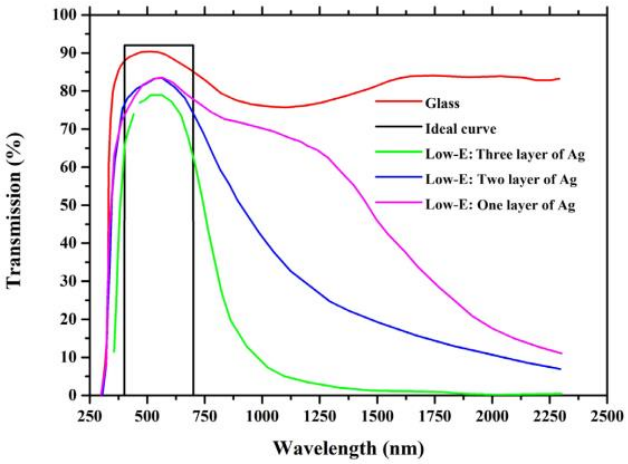


Fig. 4. Transmittance of different Low-E filters [21]

The 15 cabinets of open refrigerated and retrofitting doors are using for open refrigerated with 41 frames, 82 doors in medium temperature refrigeration system summarize in Table 1. The cabinet type was for sausage, dairy, and meat products that evaporated the temperature at -8, -8, -10 degrees Celsius, and cabinet temperate (+2 / +4), (+2 / +4), (+0 / +2) degrees Celsius, respectively. The cabinet dimensions were 3750Lx800Dx2000H and 2500Lx800Dx2000H, which having 3 frames, 6 doors, and 2 frames 4 doors, respectively. The result reveals the measurement of power consumption in kW, kWh by power meter analysis for data logger, and the summary of medium temperature refrigeration system. The picture for retrofitting doors for open refrigerated as showed in Figures 5 and 6.

Table 1
Cabinet Detail in supermarket

No.	DESCRIPTION	DIMENSION MM	Cabinet Temp °C	Evap Temp °C	MT Cooling load kW	Retrofits Frames	Doors
1	Sausage No.1	3750Lx800Dx2000H	(+2/+4)	-8	5.08	3	6
2	Sausage No.2	3750Lx800Dx2000H	(+2/+4)	-8	5.08	3	6
3	Sausage No.3	3750Lx800Dx2000H	(+2/+4)	-8	5.08	3	6
4	Sausage No.4	2500Lx800Dx2000H	(+2/+4)	-8	3.4	2	4
5	Dairy No.1	3750Lx800Dx2000H	(+2/+4)	-8	5.08	3	6
6	Dairy No.2	3750Lx800Dx2000H	(+2/+4)	-8	5.08	3	6
7	Dairy No.3	3750Lx800Dx2000H	(+2/+4)	-8	5.08	3	6
8	Dairy No.4	3750Lx800Dx2000H	(+2/+4)	-8	5.08	3	6
9	Dairy No.5	2500Lx800Dx2000H	(+2/+4)	-8	3.4	2	4
10	Dairy No.6	2500Lx800Dx2000H	(+2/+4)	-8	3.4	2	4
11	Meat No.1	3750Lx800Dx2000H	(+0/+2)	-10	5.7	3	6
12	Meat No.2	3750Lx800Dx2000H	(+0/+2)	-10	5.7	3	6
13	Meat No.3	3750Lx800Dx2000H	(+0/+2)	-10	5.7	3	6
14	Meat No.4	3750Lx800Dx2000H	(+0/+2)	-10	5.7	3	6
15	Meat No.5	2500Lx800Dx2000H	(+0/+2)	-10	3.82	2	4

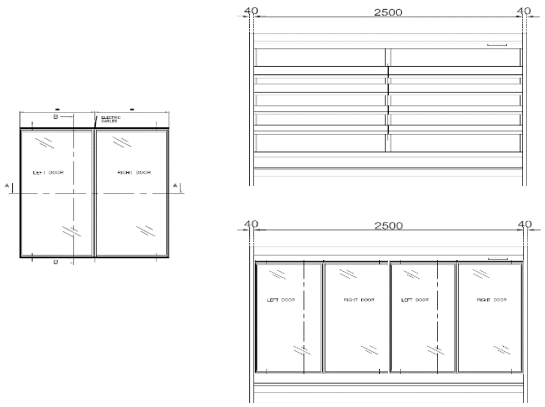
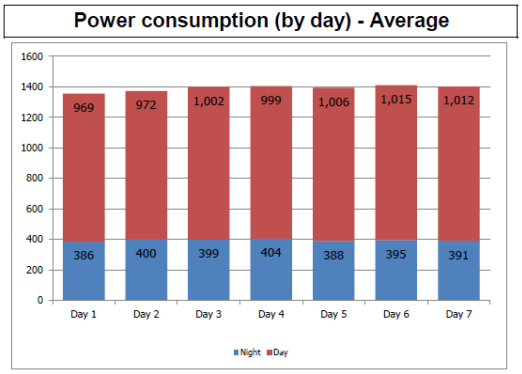


Fig. 5. Doors and refrigerated drawing

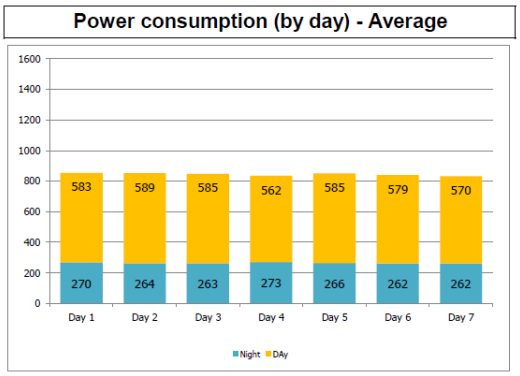
Fig. 6. Before and after retrofits doors

3. Results and Discussion

The power consumption before and after retrofitting doors in Figure 7 shows power consumption in daytime operation (06.00 am - 6:00 pm) and when supermarket close and night-time (00.00 am – 6:00 am). Before retrofitting doors, the average power consumption per 7 day was 1,388 kwh/day that daytime 997 kWh/day and night-time 391 kWh/day. After retrofitting doors, the average power consumption per 7 day was 812 kwh/day that daytime 579 kWh/day and night-time 233 kWh/day. The power consumption saving average per 7 day for retrofitting doors was 576 kWh/day, which is different by 39.67% from daytime and 418 kWh/day, which is different by 41.93% and night-time was 33.24 kWh/day. Besides, the energy of day time is more than night time because of 1) The time for opening store is longer than closing time 2) In night time the refrigerated will close by plastic curtain 3) The request cooling load of day time more than night time, and 4) The sale area/ambient temperature of night time more than day time, however, the humidity was contrasted.



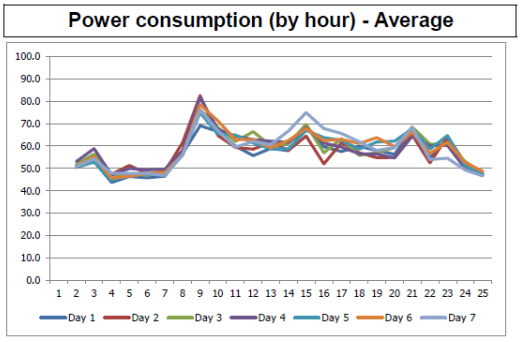
(kW)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Day	969	972	1,002	999	1,006	1,015	1,012
Night	386	400	399	404	388	395	391
Total	1,355	1,372	1,401	1,404	1,394	1,410	1,403



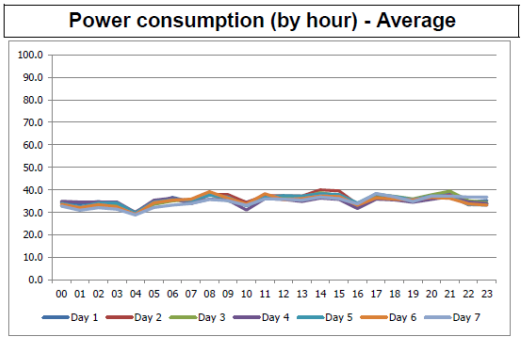
(kW)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Day	583	589	585	562	585	579	570
Night	270	264	263	273	266	262	262
Total	853	853	848	835	851	841	832

Fig. 7. Before and after retrofits doors power consumption average/day

Before retrofitting doors, the average power consumption per 7 days was 111.62 kw/day, daytime was at 62.29 kW/day, and night-time was at 49.33 kW/day. After retrofitting doors, the average power consumption per 7 days was 69.48 kW/day, daytime was at 36.33 kW/day, and night-time was at 33.15 kW/day, as showed in Figure 8. The maximum and minimum of power consumption before retrofitting doors was 83.25 kw/hour and 44.73 kw/hour, respectively. That power consumption swing at 38.52 kw/hour, 46.72%, and the maximum and minimum of power consumption after retrofitting doors was at 33.15 kw/hour and 30.19 kw/hour, respectively, that power consumption swing at 2.96 kw/hour, or 8.93%. The power consumption swing after retrofitting doors will less than before retrofitting doors because of 1) The normal cooling load will same of bolt conditions 2) The request cooling load of doors refrigerated will less than by product load, the swing of sale area temperature and humidity. Also, the effect of customer behaviour towards the power condition will low running operate.



(kW-hr)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Day	60.57	60.78	62.62	62.45	62.89	63.46	63.25
Night	48.23	49.96	49.84	50.56	48.47	49.38	48.87
Avg.	56.46	57.17	58.36	58.49	58.09	58.77	58.46



(kW-hr)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Day	36.45	36.80	36.55	35.14	36.57	36.17	35.62
Night	33.76	33.00	32.90	34.08	33.24	32.73	32.73
Avg.	35.55	35.53	35.34	34.78	35.46	35.02	34.66

Fig. 8. Before and after retrofits doors power consumption average/hour

The investment for this research was 21,694 € with 41 frames or 82 doors. The payback period of this research was 14 Months. Besides, within 1.1 year, the energy saving 16,020 kWh/Month or 1,542 €/Month, as well as16,020 kWh/month or 192,220 kWh/Year, which counted as 18,503 €/Year. Besides, the energy saving per frames and energy saving per doors was 4,689 kWh/Year or 451 €/Year and 2,344 kWh/Year or 225 €/Year, respectively.

4. Conclusions

For further recommendations, the researchers should apply the retrofitting doors for another open refrigerated, such as horizontal refrigerated and other door types. For example, use slide door that is resulting in energy saving and retrofitting doors to open another refrigerated in the convenience store, which can get energy-saving from 20,000 stores all over Thailand.

Acknowledgement

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