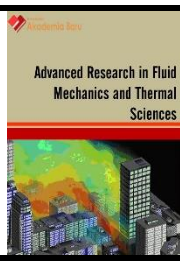
Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



The Replacement of the R404A Refrigeration System with The Environmentally Friendly R448A, to Improve Convenience Store Energy Efficiency in Thailand

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ARTICLE INFO

Article history:
Received 18 March 2020
Received in revised form 24 June 2020
Accepted 28 June 2020
Available online 3 September 2020

ABSTRACT

This study presents the energy saving characteristics of the R448A, instead of the R404A refrigeration system, in 5 convenience stores, with a total of 150 m^2, situated in Central Thailand. The R448A hydrofluorocarbons/hydrofluoroolefins (HFCs/HFOs) (GWP=1390) is a non-azeotropic mixture of R32 (26%), R125 (26%), R1234yf (20%), R134a (21%) and R1234ze (E) (7%), which can be retrofitted to replace the R404A refrigeration system. The R404A hydrofluorocarbons (HFCs) (GWP=3735) is a near azeotropic mixture of R125 (44%), R143A (52%), R134A (4%). Both refrigerants are composed of polyol ester oil (POE), are incombustible and non-toxic. The R448A has a higher cooling capacity (Qe) and lower global warming potentials (GWP) than the R404A due to its hydrofluorocarbons (HFCs) R32 component and hydrofluoroolefins (HFOs) R1234yf/R1234ze (E) component, as opposed to the R404A. This was determined by measuring power consumption (kWh) and the ambient temperature (°C) through the use of power meters and temperature data logger respectively. The result obtained was able to summarize the relationship of all the parameters concerned, and showed an energy-saving average of 7.9%, i.e. 28,273 kWh/year per 5 stores, and a decreased global warming potential (GWP) of 70%, through the use of a digital scroll compressor.

Keywords:
Refrigeration system; Energy technology; R448A Refrigerant; Environmentally Friendly

1. Introduction

1.1 Convenience Stores in Thailand

Energy usage in Thailand's business sector is ranked second for the overall energy users and are thus targeted for energy savings options [1]. The number of convenience stores in Thailand currently

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https://doi.org/10.37934/arfmts.75.1.137146

amounts to more than 20,000 locations in 2020, and tends to increase continuously on an annual basis. The majority of them are opened 24 hours day, and thus the retail sector is the 4th largest consumer of energy in the business sector, which is more than the energy consumed by residences [2].

1.2 Convenience Store Power Consumptions

The order of the energy ratio used by convenience stores in Thailand, ranked from high to low are refrigeration system, air conditioning system, electrical equipment, and lighting, respectively. However, for convenience stores in Taiwan, they are ranked as shown in Figure 1 below [3]. The best options for decreased energy consumption by convenience stores in Thailand, is recommended to be high energy efficiency and an efficient energy management system. A good example for energy savings in the refrigeration system is as shown in Figure 2 below [4]. Energy savings in the refrigeration system can be achieved through decreased power consumption of the compressor, as it is the primary component that utilizes the most energy. This research will show an average energy saving of 7.9%, 5,667 kWh/year per 5 stores, and a decreased global warming potential (GWP) of 70%, through the use of a digital scroll compressor.

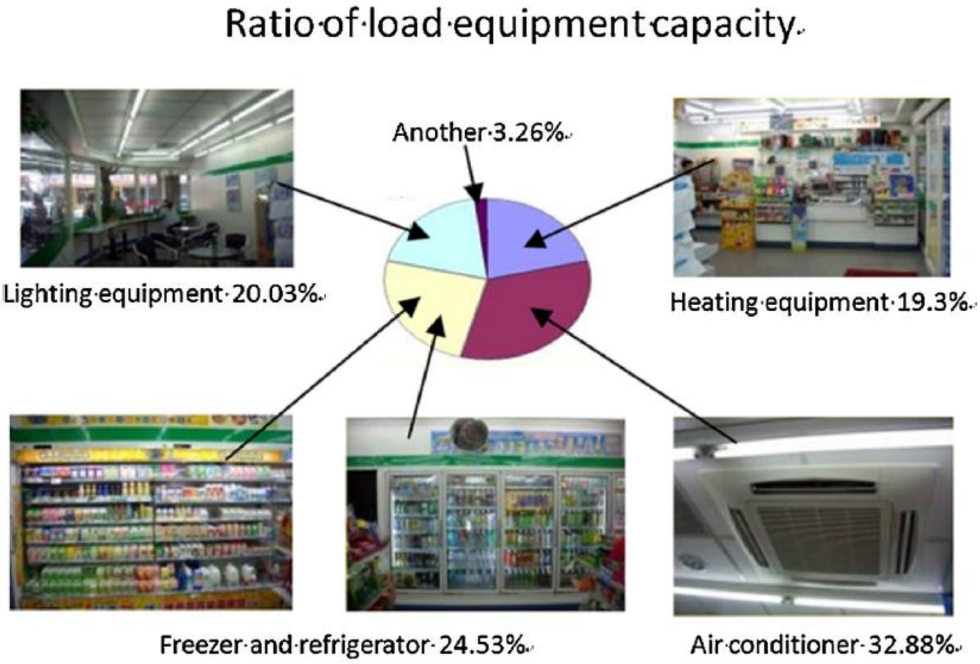

Fig. 1. The energy used ratio of convenience store in Taiwan [2]

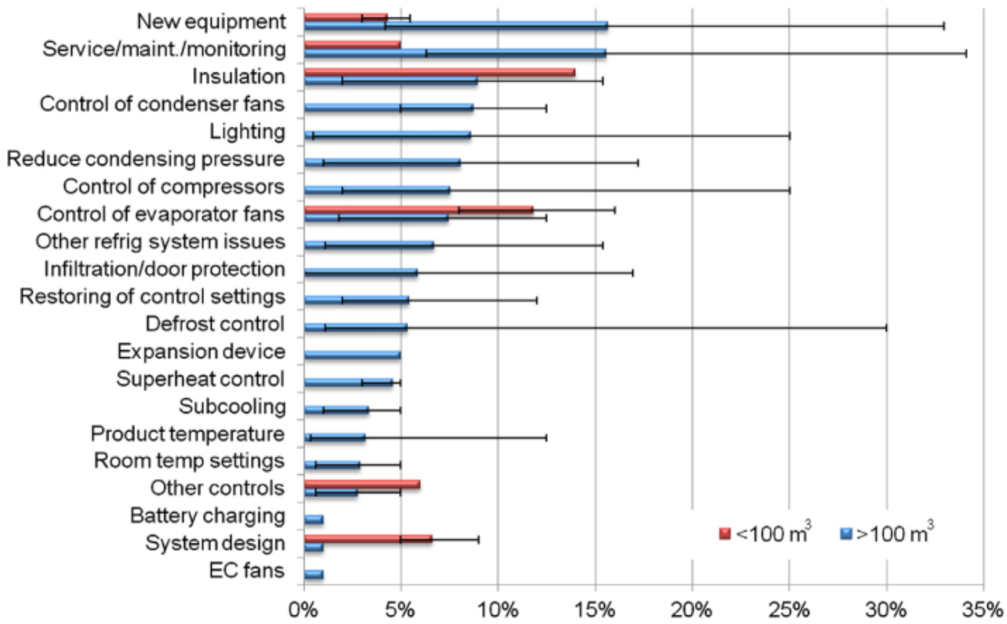

Fig. 2. Example of energy savings in the refrigeration system [3]

1.3 Evolution of the Refrigerant

The refrigerant trends in Thailand has shown progressive improvement in increasing energy efficiency, and at the same time decrease global warming potential (GWP), as shown in Figure 3 below [5-6], which is related to the HFCs phase-down schedule, as shown in Figure 4 below [7]. First and second-generation refrigerants were composed of natural refrigerants and hydrocarbons (HCs), both of which does not impact the environment, has a low global warming potential (GWP), and a zero-ozone depletion potential (ODP). R744 operates under high pressure, is highly toxic [8], and flammable. Following the second generation, third generation refrigerants was composed of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbon (HCFCs), that was easy to use, they could operate under low pressure, is non-toxic, and possess a high GWP and ODP. The R22 had an ODP = 0.055 and GWP = 1810 [9], that effected ozone and global warming [10]. Therefore, the development of refrigerates has significantly decreased ODP and GWP. The R407C, R453A, R417A, R424A and R422D was developed as an alternative to the R22, which had zero ODP, but a COP not greater than R22 [10-13]. Moreover, the third-generation refrigerants, CFCs and HCHCs will be developed to hydrofluorocarbons (HFC) refrigerants that will still possess GWP and zero ODP. The R134A, is a generation of HFC that possess zero ODP and a GWP = 1800 [14], that was developed for the R22, but it has a low refrigerant effect. The R513A, R515A, R450A, R456A were developed to be alternatives to R134, but the performances of all refrigerants were nearly [15-18], subsequently, the refrigerant developed to the R404A. The fourth generation R404A was the baseline for this research, and is currently the most used refrigerant, as shown Figure 5 below [7]. The R404A is a near azeotropic blend of 143a/125/134a, with zero ODP but a GWP = 3922 [16]. Fourth generations are hydrofluoroolefins (HFO) with low GWP and low capacity. The R1234ze and R1234yf are categorized as Class A2L with a low GWP, which is an alternative for R134A. and not for because the performance of R134A, R1234yf and R1234ze were similar [18-20]. Therefore, fourth generation refrigerants; R407A, R407F, R407H, R410A, R448A, R449A, R442A, R453A, and R463A, are refrigerants mixed with HFC, HFO, HC. Natural refrigerants require low GWP, zero ODP, high capacity, low pressure, and is non-toxic [6].

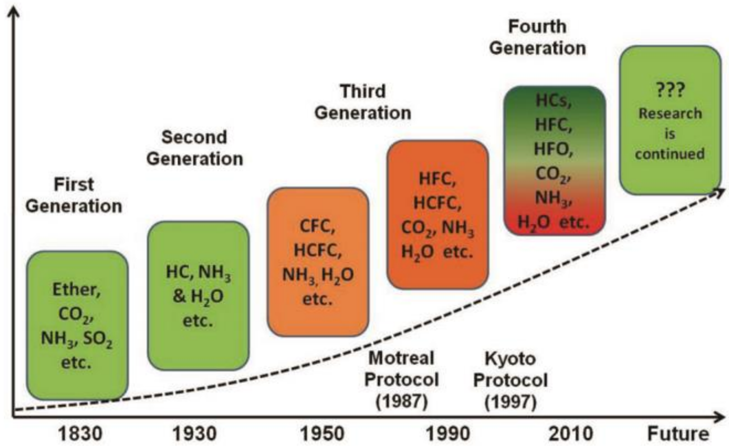

Fig. 3. Evolution of Refrigerants [5-6]

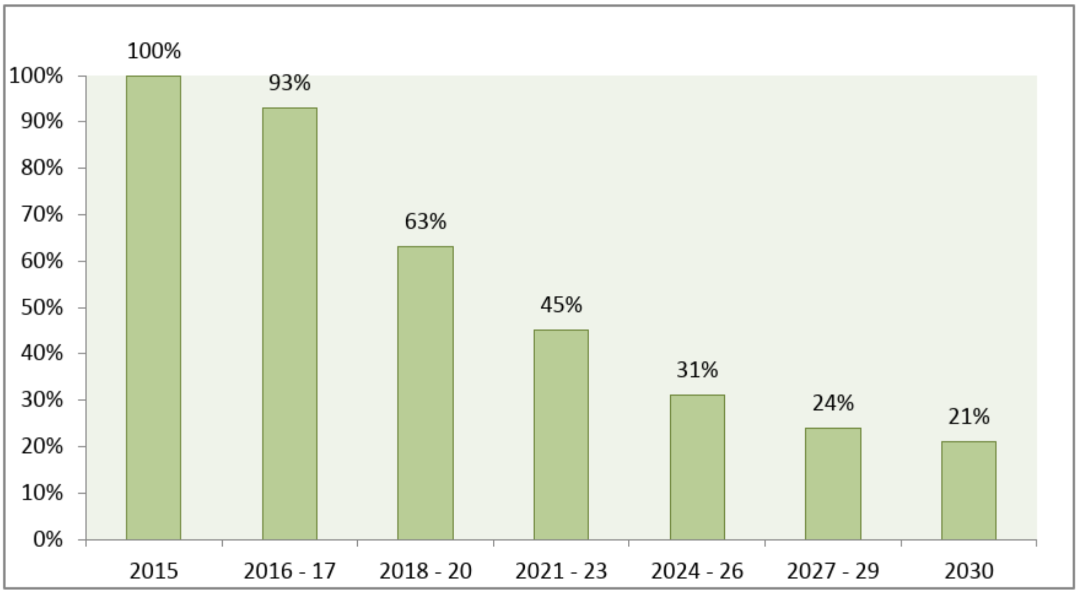

Fig. 4. HFC phase-down schedule (%Co2e) [7]

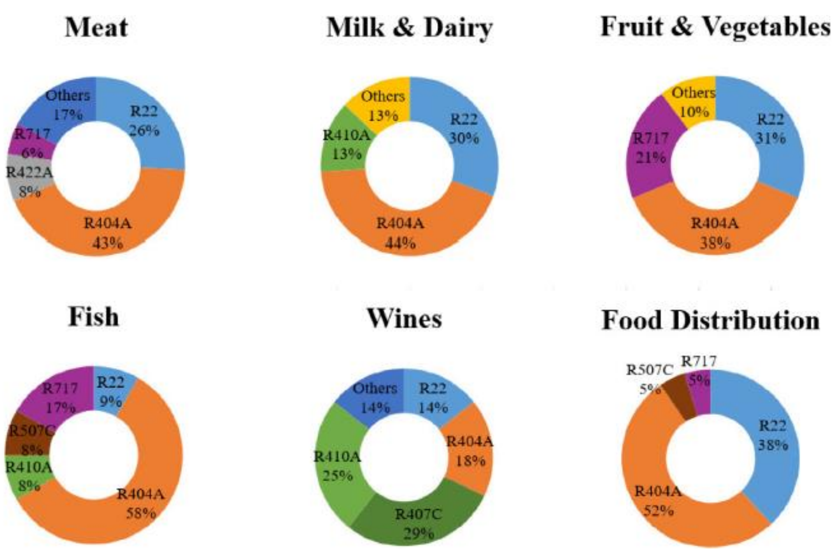

Fig. 5. Top Refrigerants used in the Food Industry [7]

The R410A and R407F refrigerants were developed to be retrofitted to the R404A. The hydrofluorocarbons (HFCs) R410A (GWP=2088) is a near azeotropic mixture of R32 (50%), R125 (50%), and the hydrofluorocarbons (HFCs) R407F (GWP=1825) is a non-azeotropic mixture of R32 (30%), R125 (30%) and R134A (40%), and can be used to retrofit in the refrigeration system which is using R404A. Both refrigerants use polyol ester oil (POE), are Class A1 incombustible (Figure 6), and has a lower toxicity. The R410A and 407F have a higher cooling capacity (Qe) and lower global warming potentials (GWP) than the R404A as it is composed of hydrofluorocarbons (HFCs) R32 [6]. The results show a decreased global warming potential of 46.8% and 53.5% for the R410A and R407F respectively. The R407F also shows a COP higher than the R404A. Both refrigerants contain R32 (A2L) and R125 (A1) mixed in the same mass percentage as the A1 class of refrigerants mix [21].

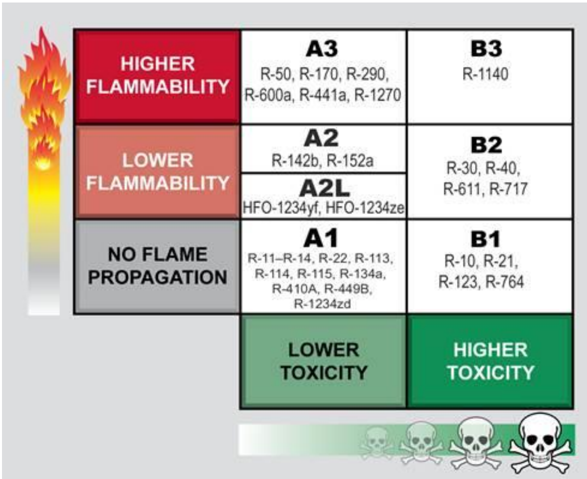

Fig. 6. Classification of refrigerants

1.4 R448A Refrigerant

The R448A refrigerant was developed to be retrofitted to the R404A. The hydrofluorocarbons/hydrofluoro-olefins (HFCs/HFOs) R448A (GWP=1390) is a non-azeotropic mixture of R32 (26%), R125 (26%), R1234yf (20%), R134a (21%), and R1234ze (E) (7%), which can easily be retrofitted to the R404A refrigeration system. The R404A hydrofluorocarbons (HFCs) (GWP=3735) is a near azeotropic mixture of R125 (26%), R143A (52%), and R134A (4%) [22]. Both refrigerants use polyol ester oil (POE), are Class A1 incombustible (Figure 6), and has a lower toxicity. The R448A has a higher cooling capacity (Qe) than the R404A as it is composed of the hydrofluorocarbons (HFCs) R32 [6, 21, 23] and has a lower global warming potential (GWP) than the R404A, which is composed of hydrofluoroolefins (HFOs) by R1234yf and R1234ze (E) [24-25]. The result show a decrease in the global warming potential by 70%, and a COP higher than R404A [26], as shown in Figure 7 [27].

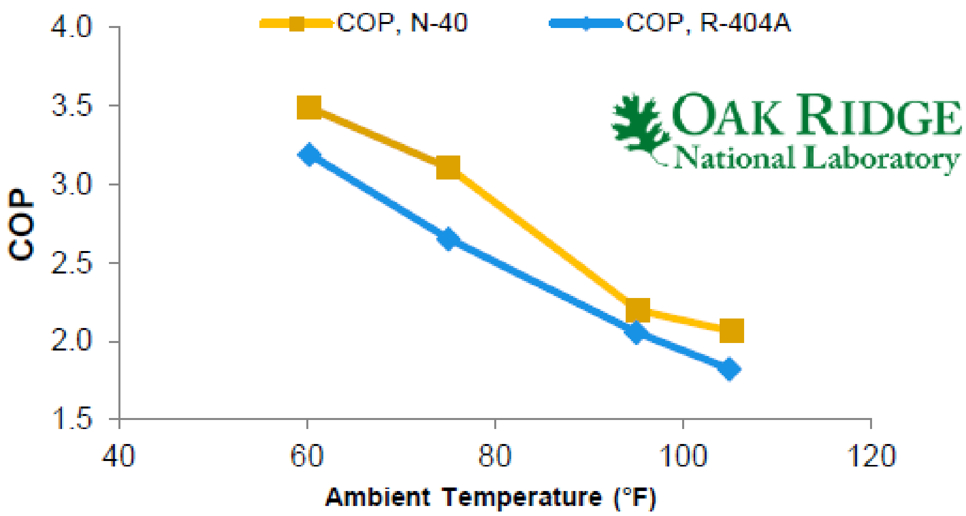

Fig. 7. COP Result Comparison between R448A and R404A [28]

2. Methodology

The methodology used, was to measure the power consumption (kWh) and the ambient temperature (°C), through the use of power meters and temperature data logger respectively.

3. Results

The average energy used of by the R404A refrigeration system for 5 convenience stores, was 72,010 kWh/year per 5 stores, while the average of the R448A refrigeration system was 66,343 kWh/year per store, an energy saving of 7.9%, or 5,667 kWh/year per 5 stores. See Figure 8 below.

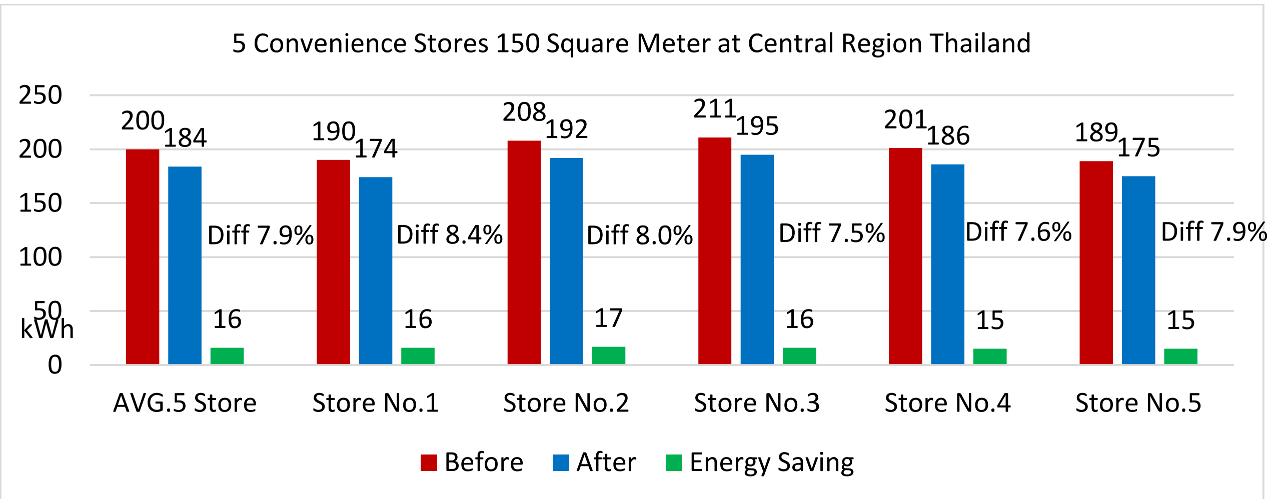

Fig. 8. Power Consumption for 5 convenience stores, with an area of 150 m^2 in Central Thailand

Store No. 1 registered the highest energy savings at 8.4%, as shown in Figure 9 below, which shows a similar ambient temperature when using the R448A and R404A refrigerants. The energy savings of Store No.2 and No.5, was 8.0% and 7.9% respectively, as shown in Figure 10 below. The ambient temperature of the R448A was slightly higher than the R404A. The lowest energy savings for Store No.3 and No.4, was 7.5% and 7.6% respectively, as shown in Figure 11 below. The ambient temperature of the R448A was higher than the R404A.

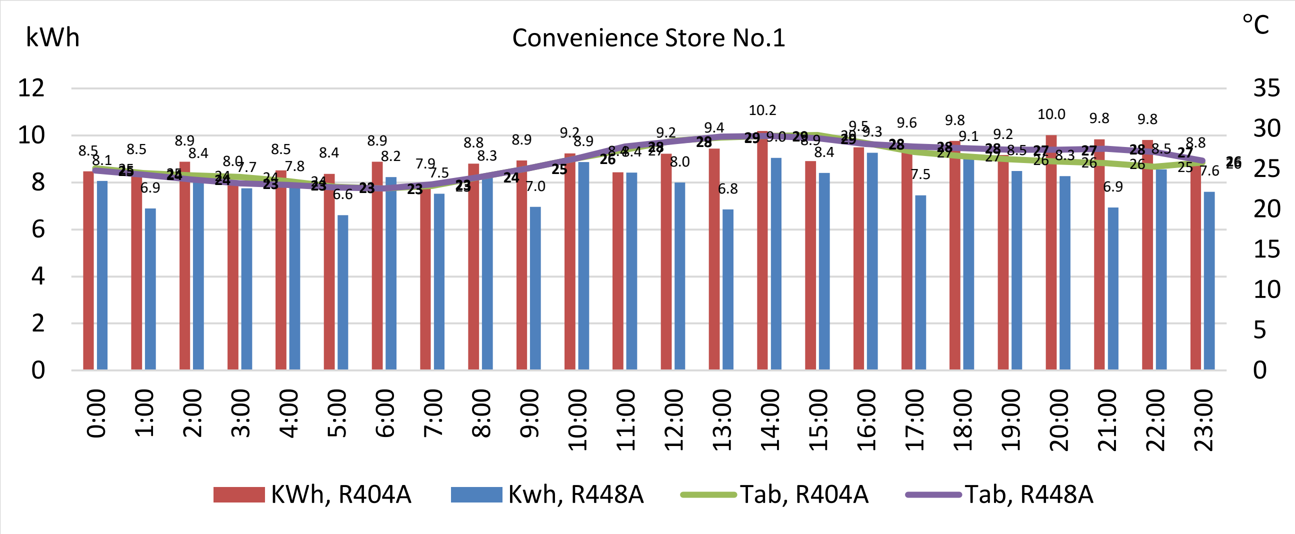

Fig. 9. Power Consumption for Convenience Store No. 1

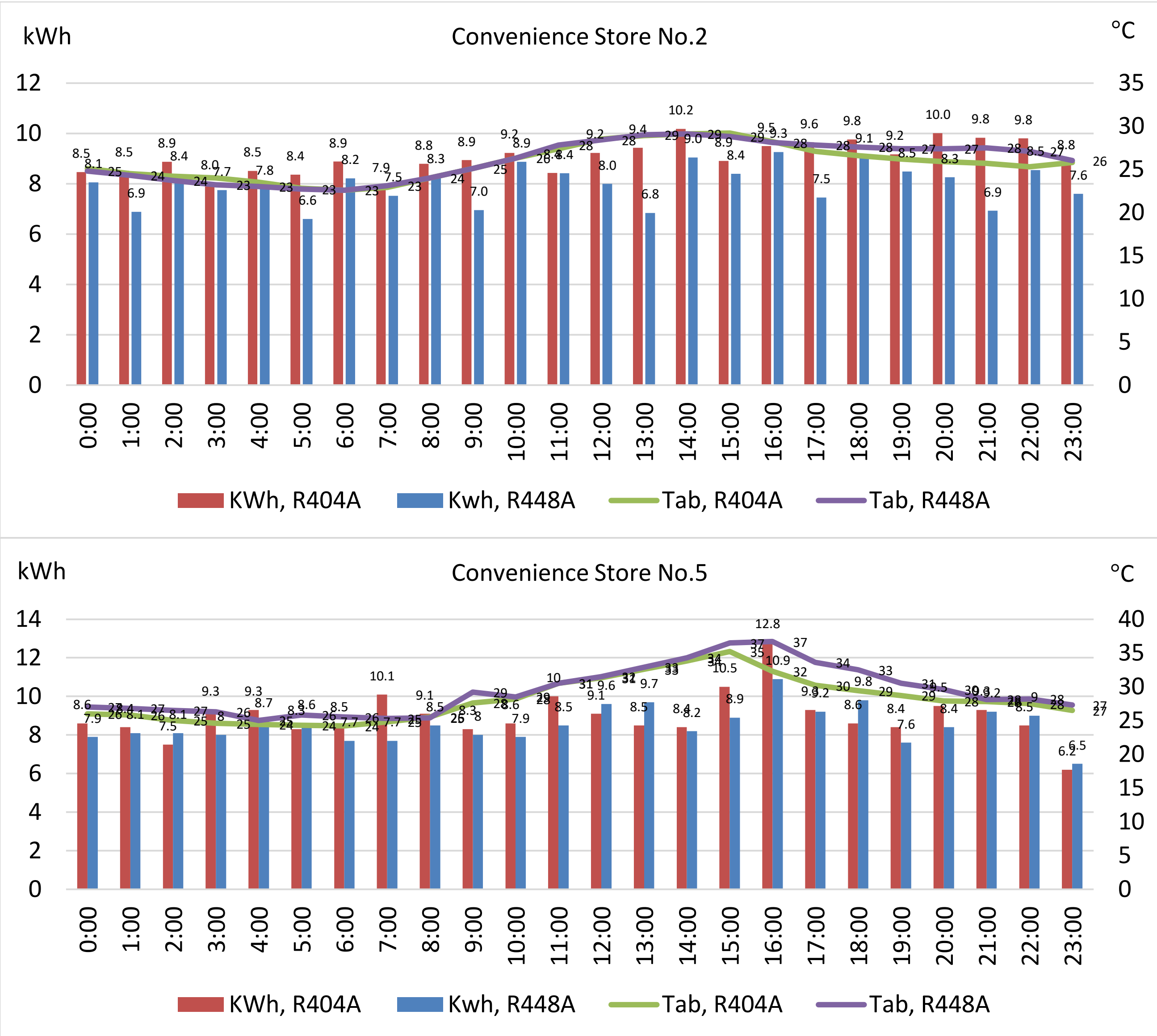

Fig. 10. Power Consumptions for Convenience Stores No. 2 and No. 5

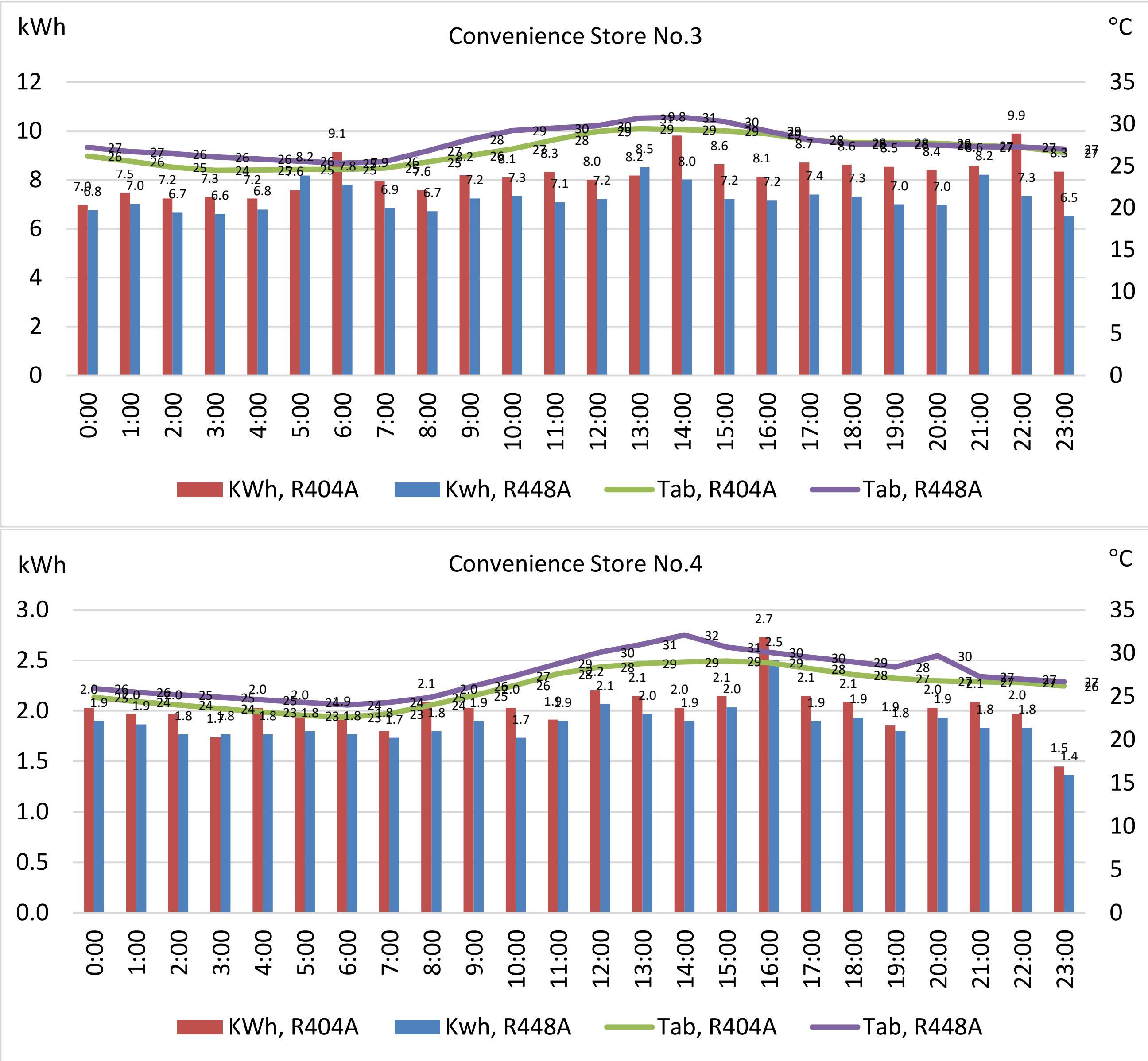

Fig. 11. Power Consumptions for Convenience Stores No. 3 and No. 4

4. Conclusion

The R448A can be retrofitted to the R404A, of which the R448A has a higher COP than R404A. Both refrigerants use polyol ester oil (POE), are Class A1 incombustible, and has a lower toxicity. The energy saving results will differ depending on the ambient temperature, and shows an average energy saving of 7.9%, or 5,667 kWh/year per 5 stores, and an increased global warming potential (GWP) of 70%.

Acknowledgement
This study supported by SANYO S.M.I. (Thailand) Co., Ltd., Ek-Chai Distribution System Co., Ltd., Sangchai Refrigeration co. ltd.

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