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Title: Potencial of energy saving in the fish and seafood cold storage in San Francisco de Campeche

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Introduction

Energy efficiency in refrigeration for conservation or freezing products is an issue that has gained relevance in recent years given the great energy demand of the equipment to get the appropriate temperatures on the different products. The main benefit is reflected in the savings that are getting without sacrificing the quality of the final product.

In this paper, two cases of the energy behavior of fish and seafood in a conservation room with a condensing unit model MDBX1000M6C installed in the city of San Francisco de Campeche are studied.

For case A, the energy behavior is evaluated with an ambient temperature in a range of 30 °C to 40 °C and heat exchange between the outside and the condensing unit.

For case B, the energy behavior is evaluated with an ambient temperature in a range of 30 °C to 40 °C but with inadequate heat exchange between the outside and the condensing unit (this case is currently presented in the company).

Introduction

The company under study is dedicated to the capture, processing, and commercialization of seafood and is in the city of San Francisco de Campeche, Camp., Mexico.

Of the total electricity consumption, 89% belongs to the consumption of refrigeration equipment as shown in **Table 1** (2 cold rooms for freezing and 2 more for conservation). This work focuses only on one of the conservation rooms that operates with a condensing unit model MDBX1000M6C with R404A refrigerant.

Tecnology	Installed Power kW	%	Monthly Consumption (kWh/month)	%	Anual Consumption (kWh/year)
Lighting	5.73	4.9	1,598.58	3.9	19,182.93
Air conditioner	8.11	6.9	2,028.12	4.9	24,337.4
Miscellaneous	7.55	6.4	39.25	0.1	471
Refrigeration	88.37	75.3	36,760.26	89.2	441,123.12
Motors and pumps	7.63	6.5	771.06	1.9	9,252.72
Total	117.4	100	41,197	100	494,364

Table 1 Total energy consumption. *Source (own elaboration)*

Introduction

The cold room is an insulated enclosure of 6x4.5x3.5 m with 50 mm thick expanded polyurethane (polyurethane foam). It has a maximum capacity of 5 tons to contain various kinds of fish and seafood.

In **Table 2**, an annual summary of the thermal loading conditions in the company is observed, for the desired product (shrimp, octopus, fresh fish) temperature of -13 °C, which consider the product entering at ambient temperature and the one that is kept at optimum temperature during the harvest and closed season.

Month	**Thermal load (BTU/h)**	**Tons of product/month**
January	72,754.77	4.5
February	67,456.07	4
March	64,243.73	6.5
April	72,754.77	4.5
May	76,542.45	5
June	75,455.54	5
July	75,455.54	50
August	77,085.91	5
September	71,787.21	4.5
October	71,515.49	4.5
November	71,068.28	5
December	71,068.28	5

Table 2 Thermal load for different months of operation of the company.
Source (own elaboration)

Metodology

To quantify the energy improvement obtained to reduce the evaporation and condensation temperature, it's necessary to evaluate the COP, cooling power (P_e), and the compressor power (P_c) under operating conditions with the R404A refrigerant and that it depends on the mechanical and electrical performance.

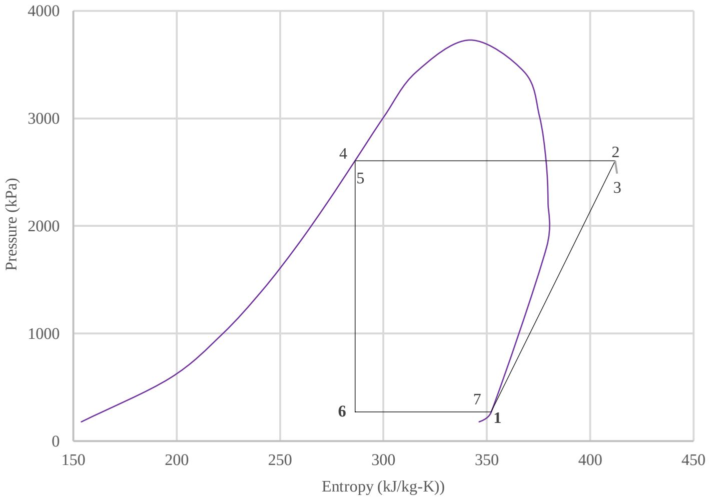


Figure 1 Refrigeration cycle of the case study. *Source (own elaboration with Genetron Properties Software)*

$$COP = \frac{h_7 - h_6}{h_2 - h_1} \quad (1)$$

$$Thermal\ load = \dot{m}(h_7 - h_6) \quad (2)$$

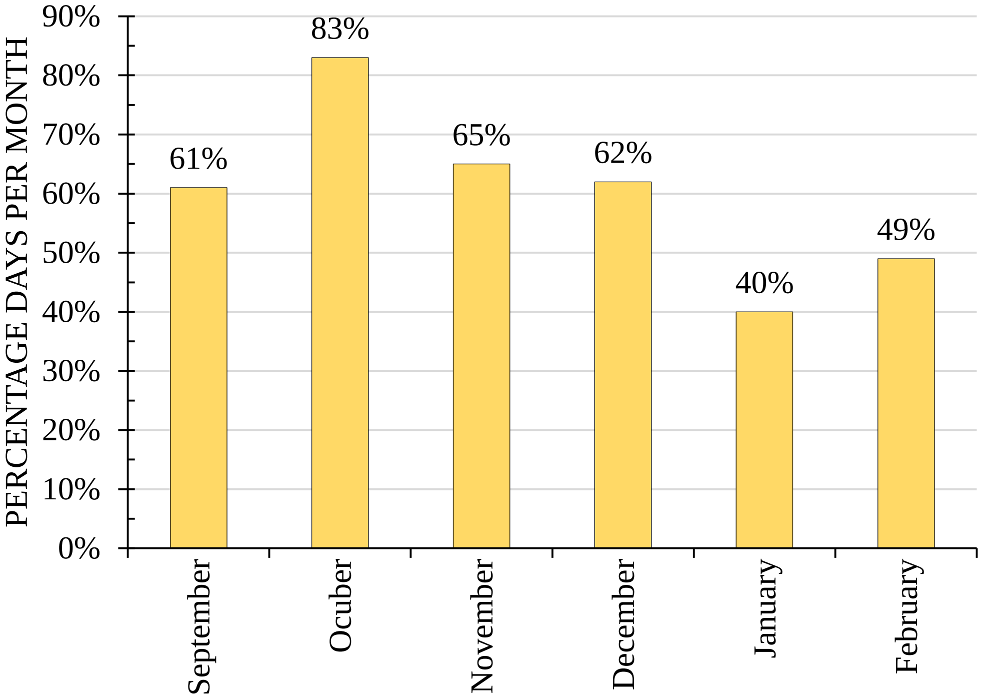
$$mass\ flow = \dot{m} = \frac{P_e}{h_7 - h_6} \quad (3)$$

$$Compressor\ power = P_c = \frac{\dot{m}(h_2 - h_1)}{n_m * n_e} \quad (4)$$

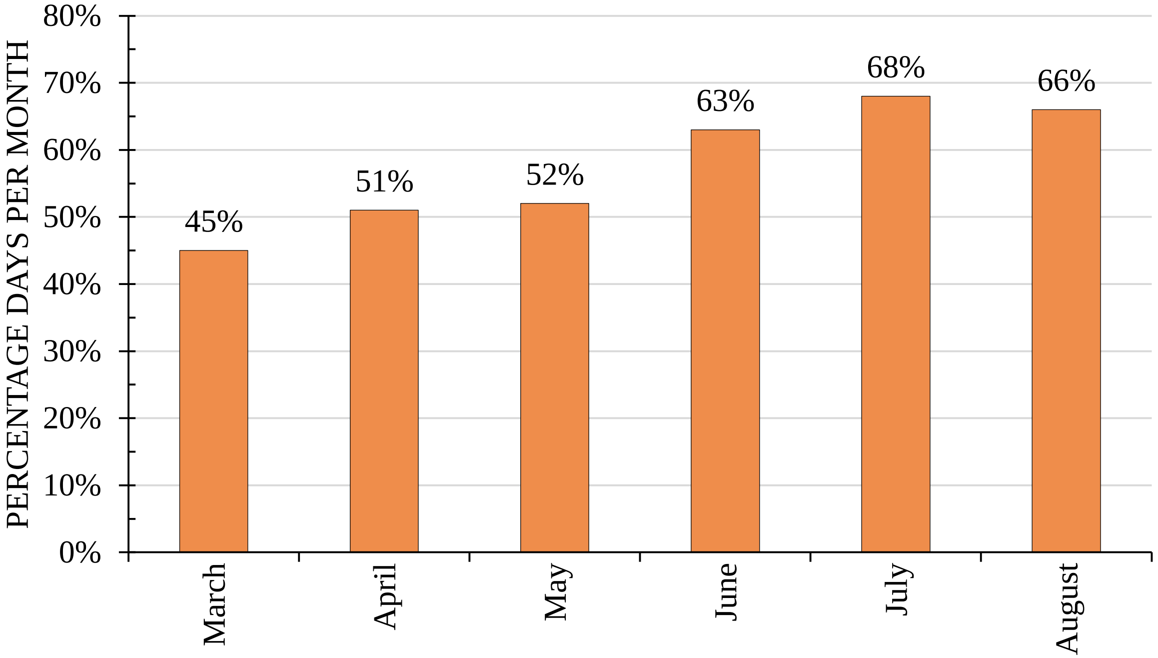
In the following calculations, an initial evaporation temperature of -23 °C to -20 °C was considered. Also, it was considered condensation temperature related to ambient temperatures in a range of 30 °C to 40 °C for months of the summer and off summer.

Metodology

This interval corresponds to the average maximum average temperature of the 2015-2018 period prevailing in the entity and reported by the Campeche observatory Campeche of the Comisión Nacional del Agua (CONAGUA).



Graph 1 Percentage of days per month with temperatures ≥30 °C and <35 °C, 2015-2018.
Source (own elaboration)



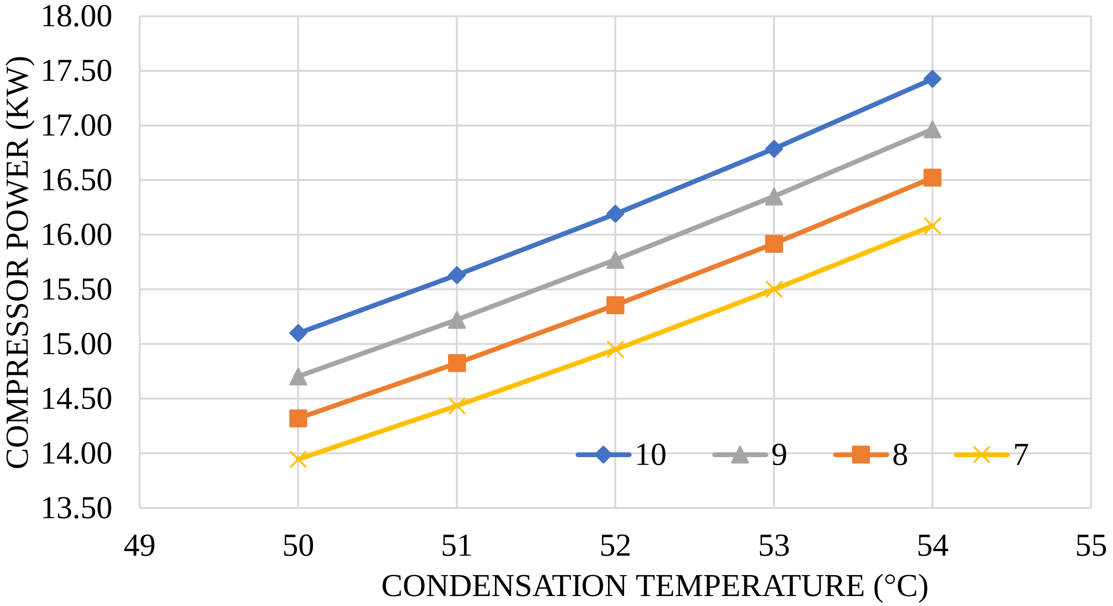
Graph 2 Percentage of days per month with temperatures ≥35 °C and <40 °C, 2015-2018.
Source (own elaboration)

Results

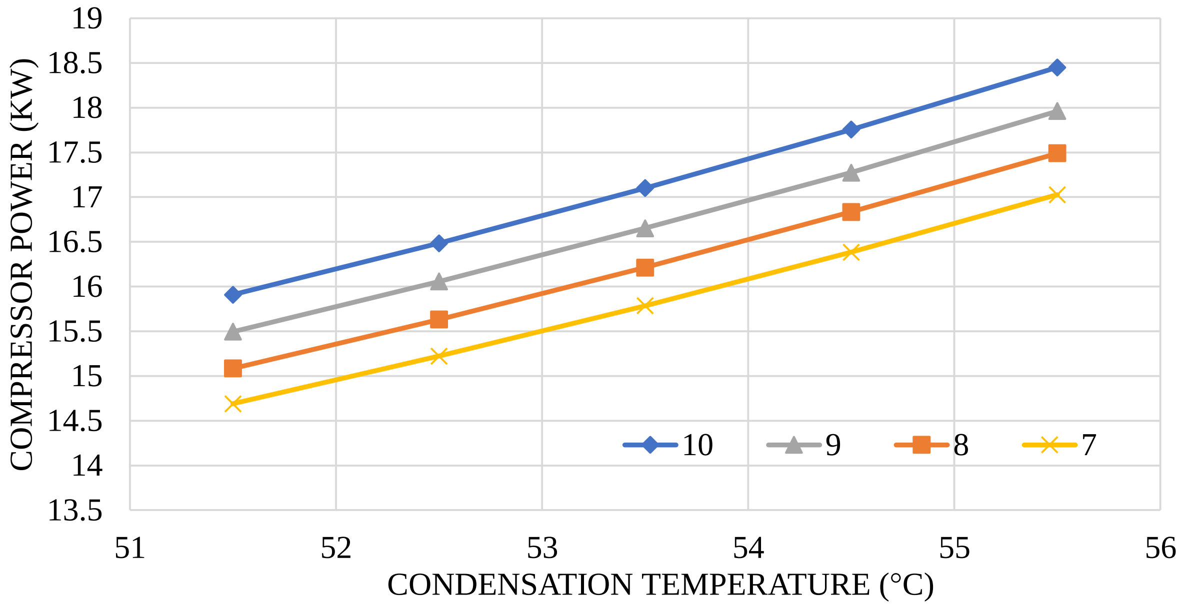
The results obtained were carried out with the support of the Genetron Properties Software considering a volumetric and isentropic efficiency of 0.75. Two cases were evaluated:

A.- Energy behavior of the system under the operating conditions of table 3 and ambient temperatures from 30 °C to 40 °C for a correct distribution of the condensing units.

B.- Energy behavior of the system under the operating conditions of table 3 and ambient temperatures from 30 °C to 40 °C for an inadequate distribution of the condensing units (current situation).

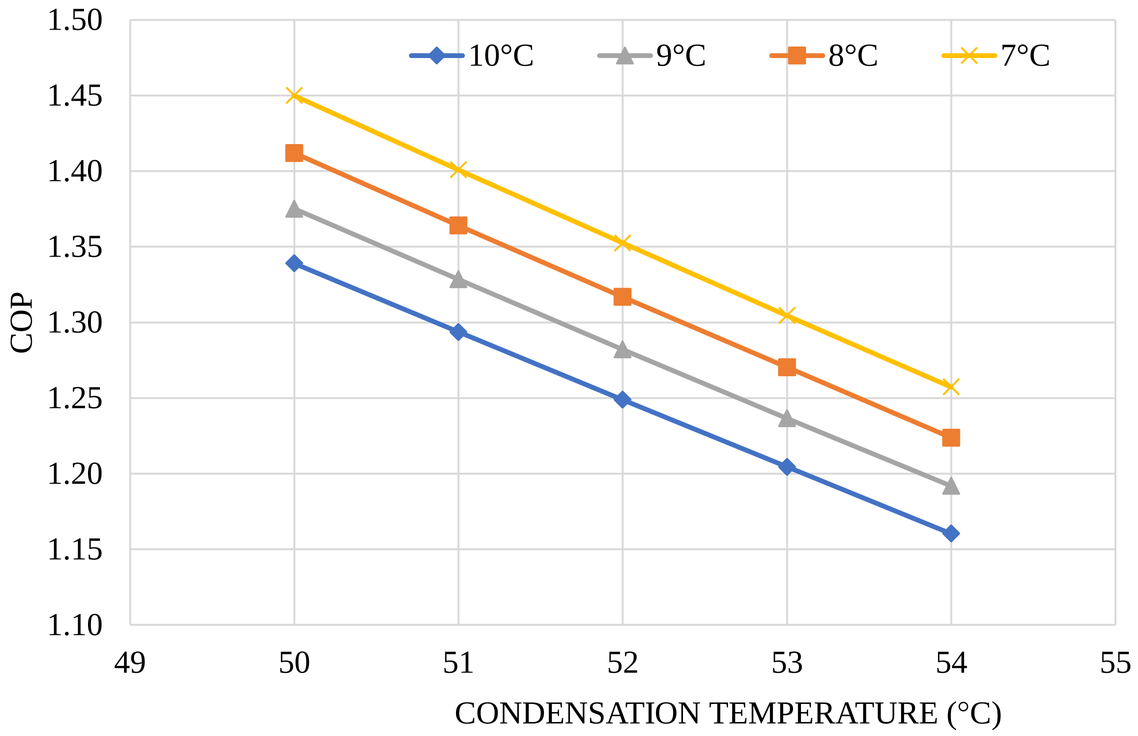


Graph 3 Compressor power at different condensing temperatures in January case A. *Source (own elaboration)*

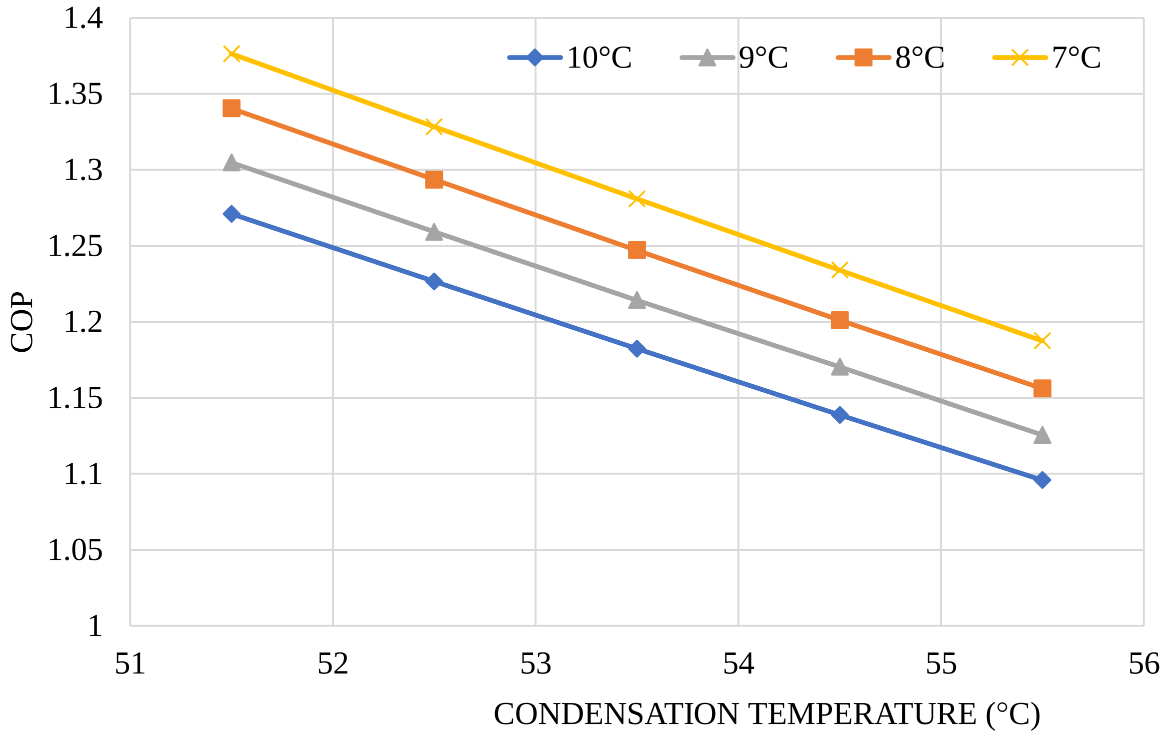


Graph 4 Compressor power at different condensing temperatures in January case B. *Source (own elaboration)*

Results

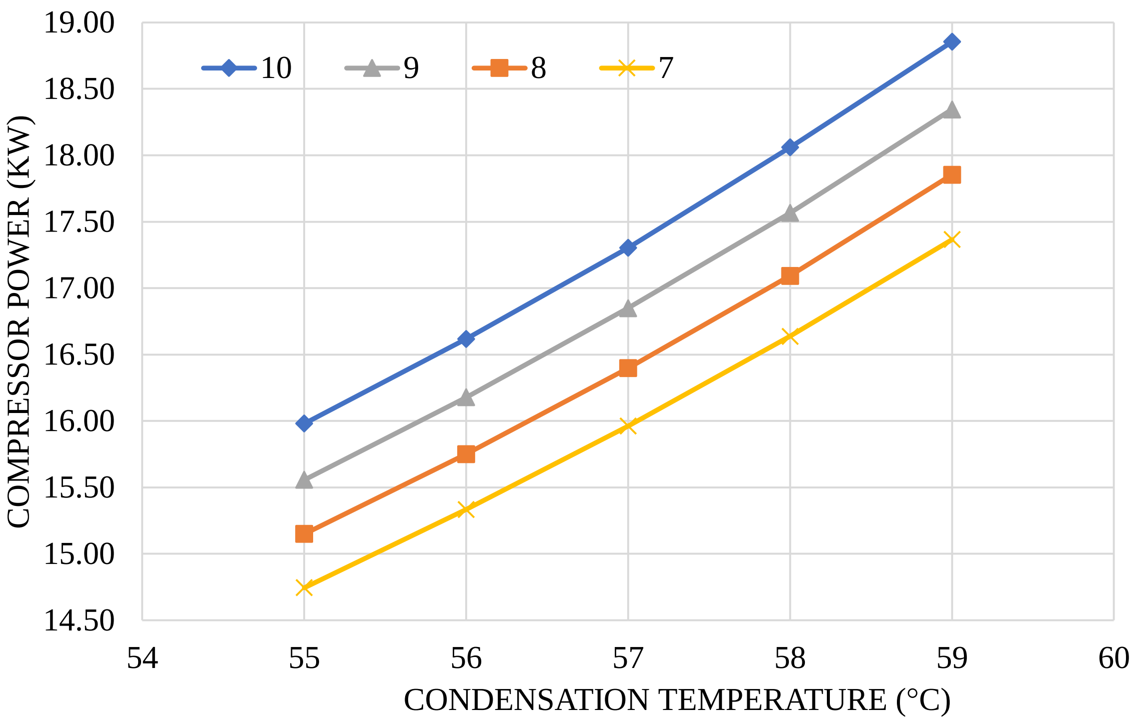


Graph 5 COP at different condensation and evaporation temperatures in January case A. *Source* (*own elaboration*)

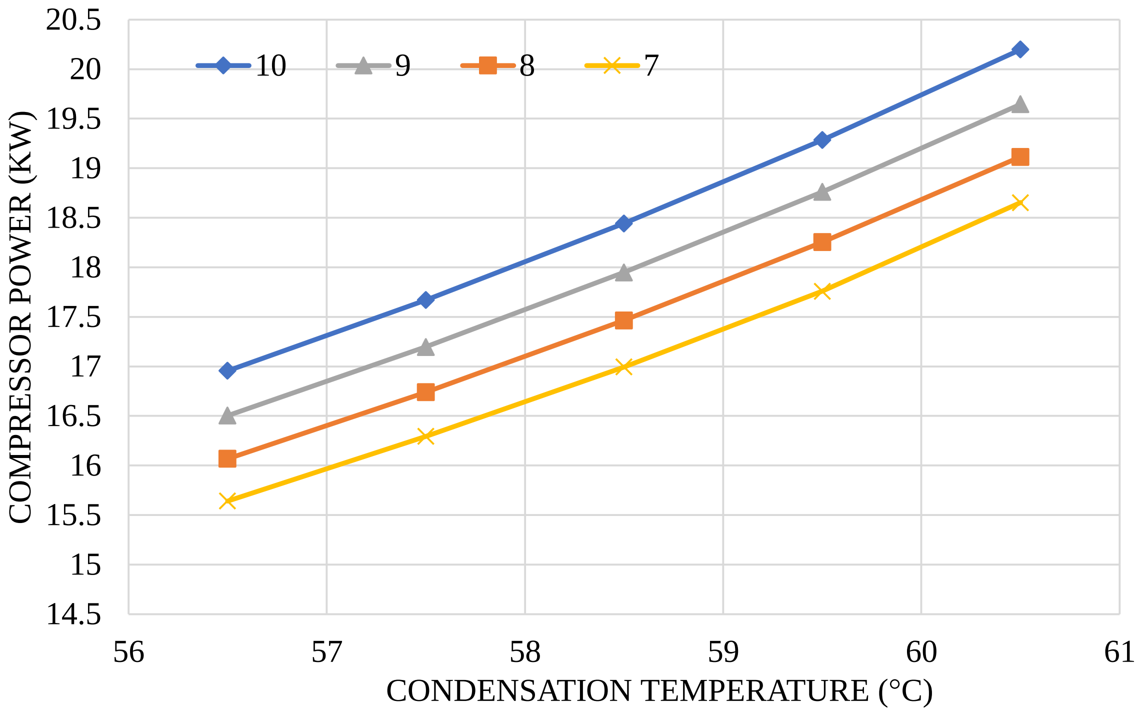


Graph 6 COP at different condensation and evaporation temperatures in January case B. *Source* (*own elaboration*)

Results

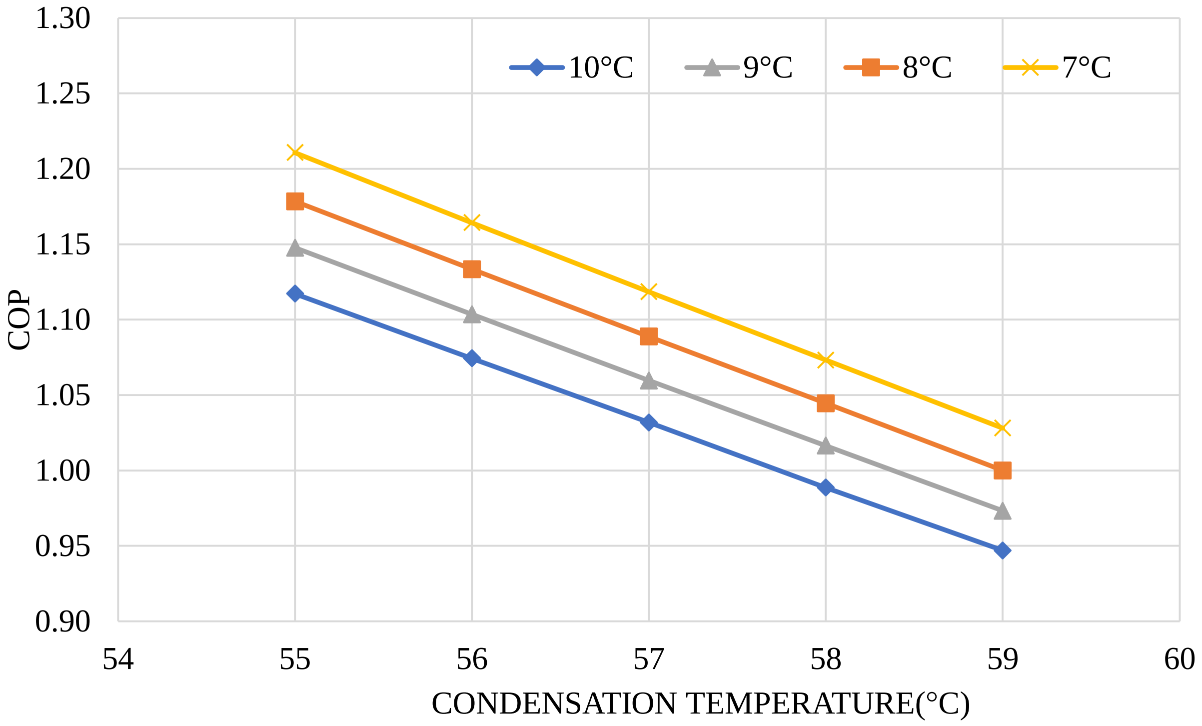


Graph 7 Compressor power at different condensation temperatures in March case A. *Source (own elaboration)*

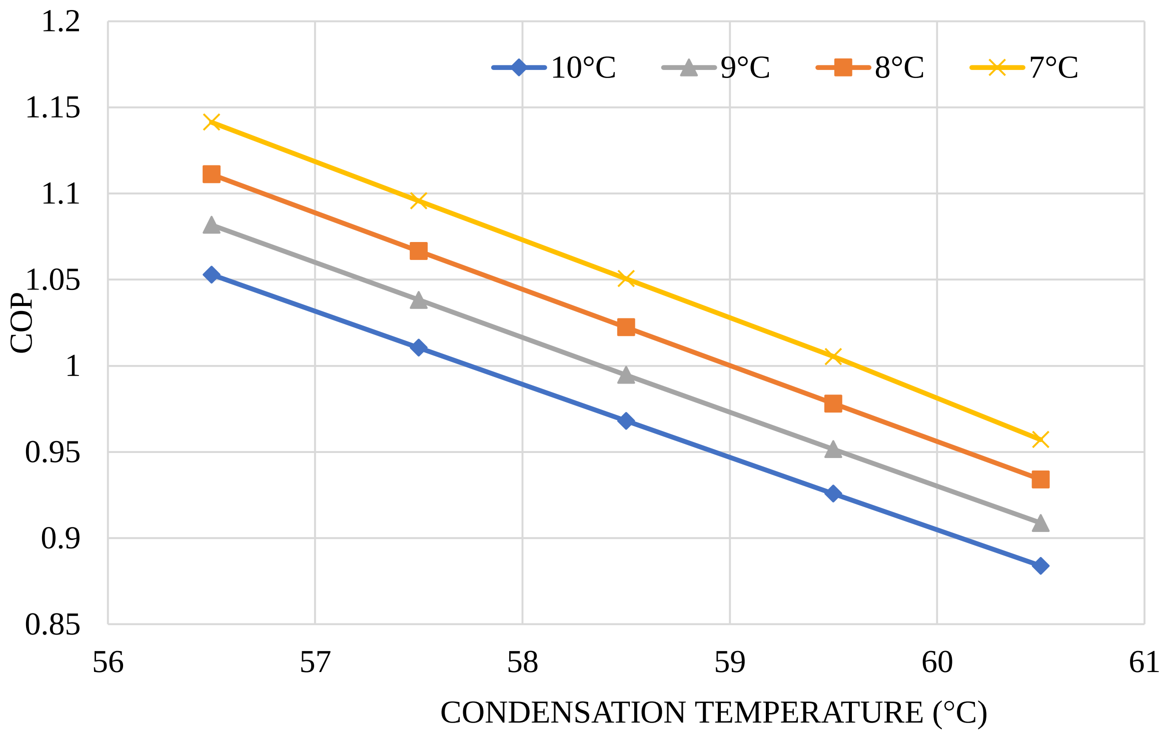


Graph 8 Compressor power at different condensation temperatures in March case B. *Source (own elaboration)*

Results

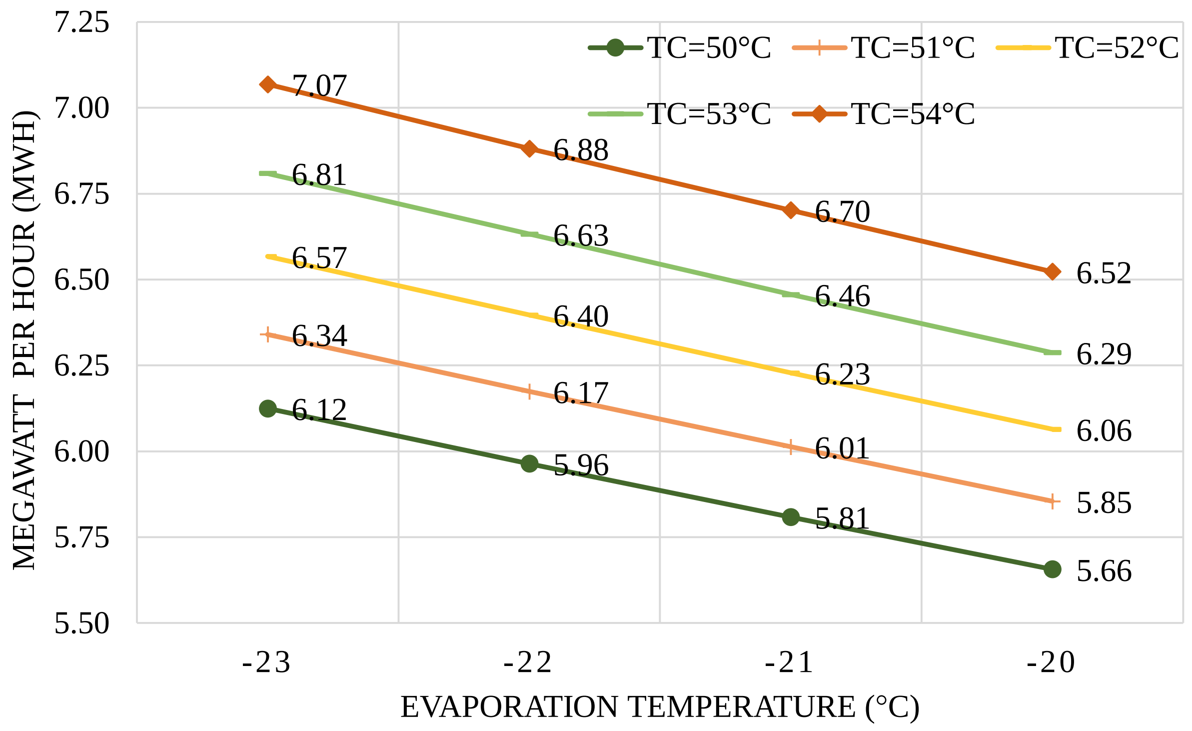


Graph 9 COP at different condensation and evaporation temperatures in March case A. *Source (own elaboration)*

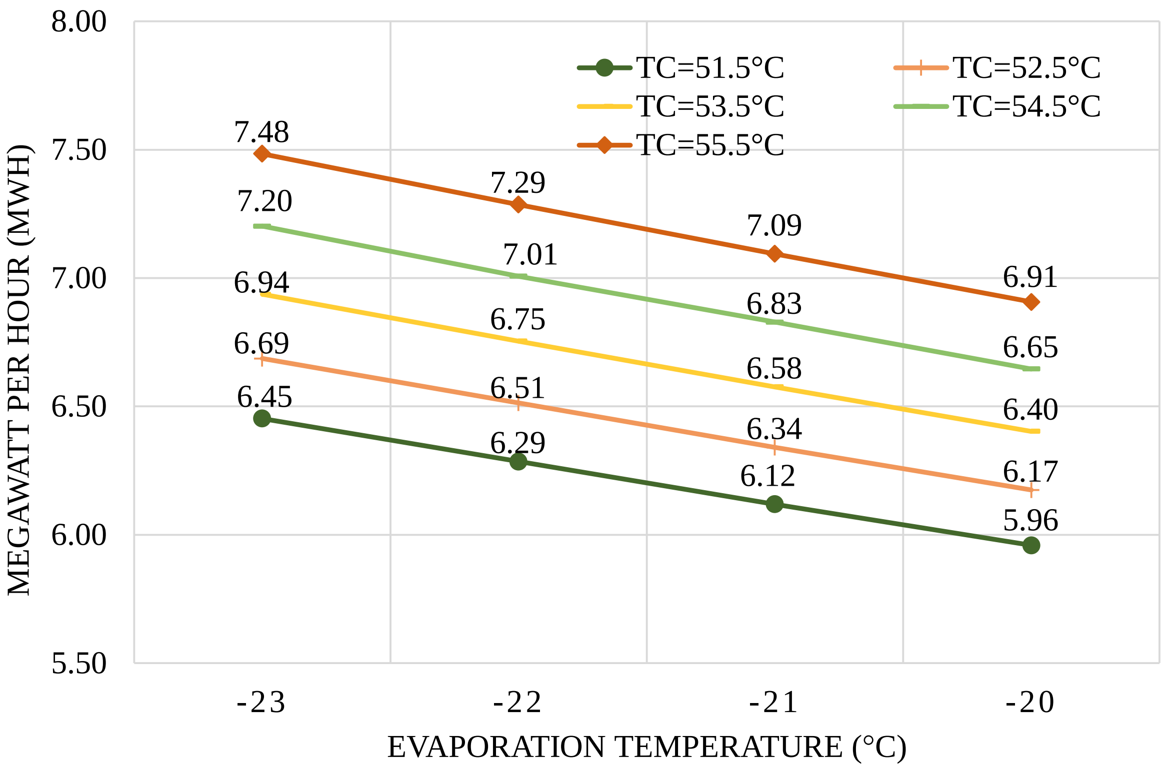


Graph 10 COP at different condensation and evaporating temperatures in March case B. *Source (own elaboration)*

Results

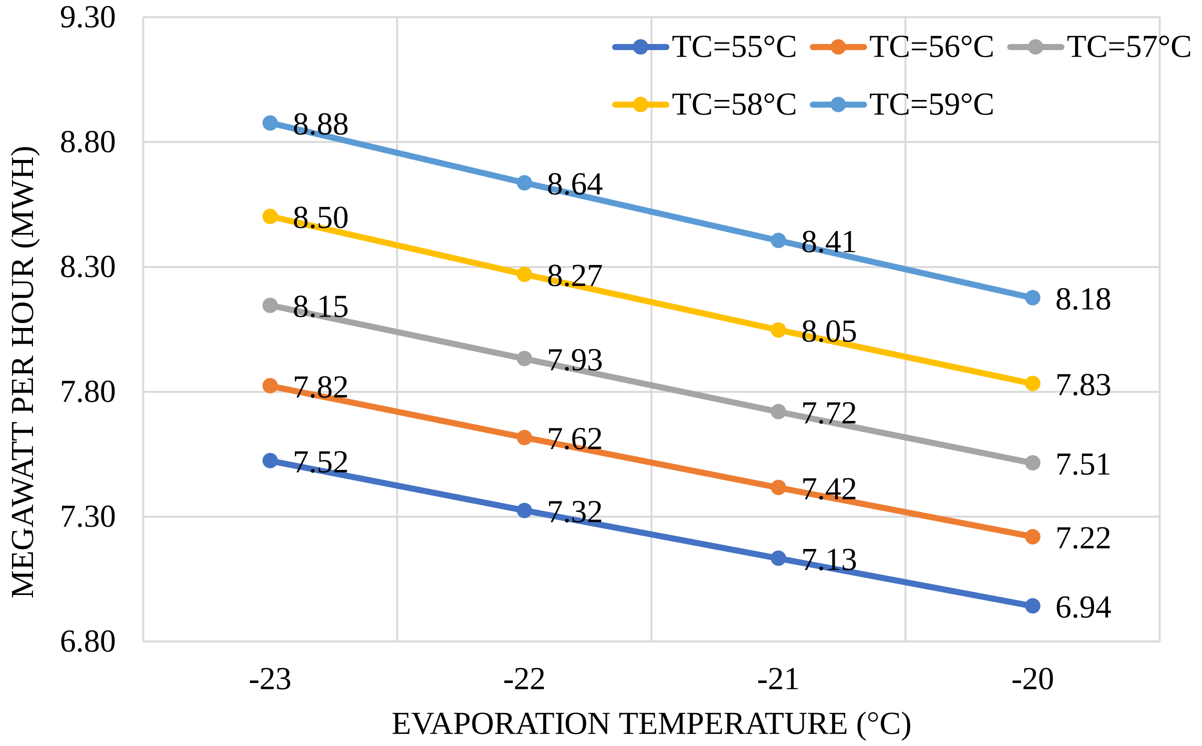


Graph 11 Behavior of energy consumption without increases in ambient temperature from September to January case A. *Source (own elaboration)*

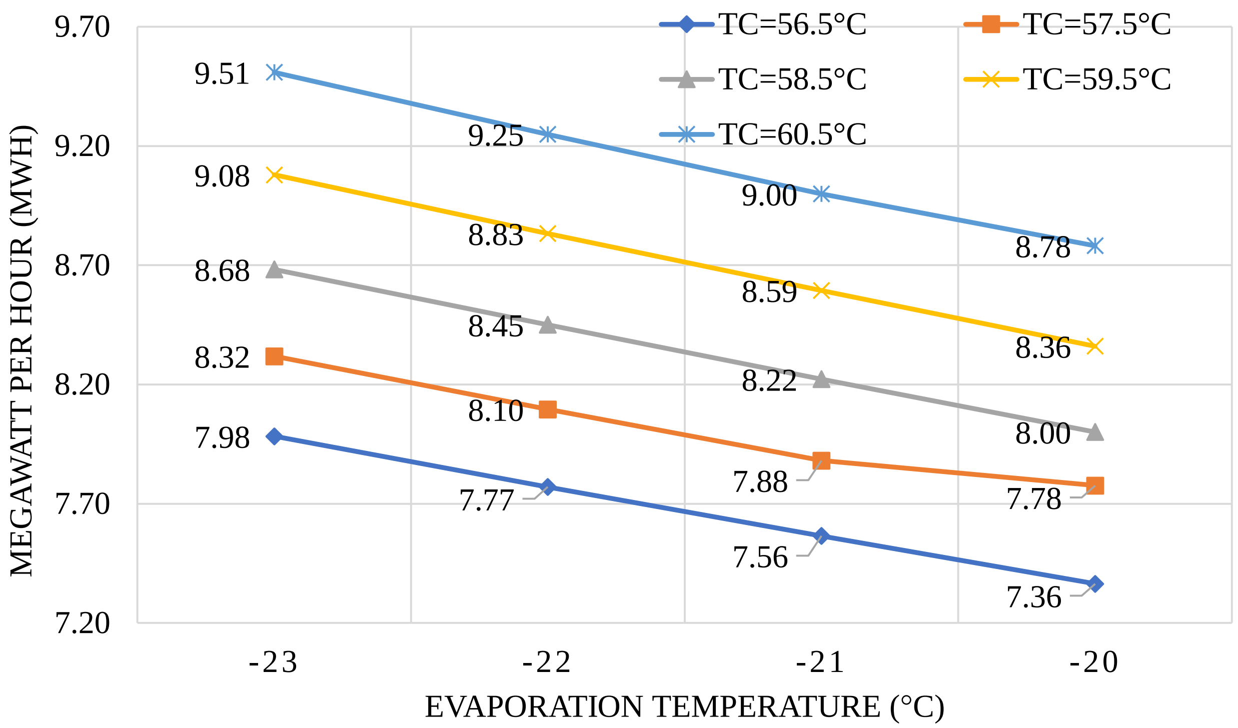


Graph 12 Behavior of energy consumption with an increase of up to 1.5 °C in ambient temperature from September to January case B. *Source (own elaboration)*

Results



Graph 13 Behavior of energy consumption without increases in ambient temperature from March to August case A. *Source (own elaboration)*



Graph 14 Behavior of energy consumption with an increase of up to 1.5 °C in ambient temperature from March to August case B. *Source (own elaboration)*

Anexxes

Tc (°C)	≥30 °C at <35 °C	Te (°C)			
		-23	-22	-21	-23
		Save money mnx/month			
50 - 51.5	SEP-FEB	$1,107	$1,085	$1,182	$1,020
51 - 52.5	SEP-FEB	$1,169	$1,145	$1,103	$1,080
52 - 53.5	SEP-FEB	$1,248	$1,208	$1,175	$1,144
53 - 54.5	SEP-FEB	$1,328	$1,266	$1,256	$1,211
54 - 55.5	SEP-FEB	$1,404	$1,368	$1,326	$1,297

Anexxe 1 Saving estimates for months with ambient temperatures ≥30 °C and <35 °C. *Source* (*own elaboration*)

Tc (°C)	≥35 °C at <40 °C	Te (°C)			
		-23	-22	-21	-23
		Save money mnx/month			
55 - 56.5	MAR-AUG	$1,558	$1,513	$1,466	$1,432
56 - 57.5	MAR-AUG	$1,680	$1,626	$1,578	$1,533
57 - 58.5	MAR-AUG	$1,820	$1,757	$1,704	$1,649
58 - 59.5	MAR-AUG	$1,957	$1,910	$1,856	$1,790
59 - 60.5	MAR-AUG	$2,147	$2,078	$2,014	$2,055

Anexxe 2 Saving estimates for months with ambient temperatures ≥35 °C and <40 °C. *Source* (*own elaboration*)

Conclusions

From de results obtained in the case study, it is concluded that:

1. Decreasing the condensation temperature of the system by one degree Celsius will reduce electrical energy consumption by up to 3% and there will be an increase of to 4% del COP.

2. There is an increase of more than 5% in energy consumption for the first group of months (≥30 °C and <35 °C) due to inadequate distribution of condensing units. While in the second group (≥35 °C and <40 °C) the increase is greater than 6% on average.

3. The results when varying the condensation and evaporation temperatures indicated an increase in the energy consumption of the compressor for each degree centigrade that both temperatures increased with average values of 4% and 2.7% respectively.

4. If the condensation temperature increases to 1.5°C, the theoretical results show an increase of up to 6% in electrical energy consumption during the months with higher temperatures.

5. Despite only obtaining an economic saving of 1%, it´s advisable to maintain a correct distribution of the condensing units to make the most of it. The economic saving of 1% of the billing only considers a cold room of the four that operate in the company.

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