Techno-economic assessment of a refrigeration system integrated with ice thermal energy storage.

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Master Dissertation

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Resumo

Nesta dissertação, é abordado o tema de armazenamento de energia térmica através da solidificação de água integrado num sistema de climatização de um edifico multiusos. Este sistema não estava em funcionamento e o objetivo desta dissertação passa por efetuar o comissionamento do sistema, obter uma estratégia de operação ótima e avaliar a viabilidade da mesma.

O plano de trabalhos consiste numa realização de testes para avaliar o funcionamento do sistema. Depois de assegurados os requisitos de bom funcionamento e solucionados os problemas encontrados, passa-se para uma segunda fase de testes com o objetivo de obter os parâmetros necessários à realização da simulação económica. No estudo económico, define-se uma estratégia económica hipotética como ponto de referência, estratégia esta que só tem em conta as capacidades do sistema de armazenamento de energia. Define-se também uma segunda estratégia que tem em conta o sistema de armazenamento de energia como também todo o sistema de climatização e produção de águas quentes sanitárias a qual o banco de gelo pertence e está diretamente ligado em termos de consumos e eficiência energética. A partir desta última estratégia de operação é possível tirar conclusões sobre a viabilidade do sistema em termos económicos.

A partir dos resultados do estudo económico foi possível perceber que o retorno de investimento seria muito superior ao calculado na fase de projeto. Também foi notório que, tendo em contas as tarifas de 2023, só é vantajoso usar o banco de gelo nas horas de pontas e não nas horas de cheia.

Através deste estudo, foi possível concluir que, atualmente, um sistema de armazenamento de energia pode ter tempos de retorno de investimentos extremamente voláteis devido à constante alteração dos preços de eletricidade. Por esse motivo, necessita de reavaliações periódicas da estratégia de operação. Relativamente a este sistema em específico, comprovou-se que é possível alcançar redução de custos, no entanto, de pequena dimensão, o que resulta num período de retorno de investimento superior a 15 anos.

Abstract

In this dissertation, the subject of thermal energy storage through water solidification integrated into the climate control system of a multipurpose building is addressed. This system was not in operation, and the objective of this dissertation is to perform the commissioning of the system, obtain an optimal operation strategy, and evaluate its viability.

The work plan consists of conducting tests to evaluate the operation of the system. After ensuring the requirements for proper operation and solving the problems encountered, the second phase of testing is carried out to obtain the necessary parameters to perform the economic simulation. In the economic study, a hypothetical economic strategy is defined as a reference point, a strategy that only takes into account the capacities of the energy storage system. A second strategy is also defined that considers the energy storage system as well as the entire HVAC system to which the ice bank belongs, and which is directly connected in terms of consumption and energy efficiency. From this last operation strategy, it is possible to draw conclusions about the viability of the system in economic terms.

From the results of the economic study, it was possible to see that the return on investment would be well over the results obtained in the design phase. It was also noticeable that considering the 2023 tariffs, it is only advantageous to use the ice bank during peak hours and not during standard hours.

Through this study, it was possible to conclude that, currently, an energy storage system can have extremely volatile payback times due to constantly changing electricity prices. For this reason, it requires periodic re-evaluations of the operating strategy. For this particular system, it was proven that cost savings can be achieved, however, on a small scale, resulting in a payback period of more than 15 years.

Acknowledgments

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Contents

Nomenclature

AHU	Air Handling Units
BMS	Building Management System
COP	Coefficient of Performance
CPL	Cooling Peak Loads
CSL	Cooling Standard Loads
CWS	Chilled Water System
CWTES	Chilled Water Thermal
DHW	Domestic Hot Water
EER	Energy Efficiency Ratio
HPL	Heating Peak Loads
HSL	Heating Standard Loads
HVAC	Heating Ventilation and Air Conditioning
IBC	Ice Bank Capacity
ITES	Ice Thermal Energy
PCM	Phase Changing Materials
TES	Thermal Energy Storage

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1 Introduction

With the increase of renewable energy production rises the need for energy storage. Since some of the sources of renewable energy are intermittent, which means the rate of energy production is not predictable and often irregular such as wind power, or their production curve is “offset” from the power consumption curve, such as solar power, which results in undesirable energy waste. Thus, technologies that enable humankind to store this energy and use it at will are fundamental to continuing to pursue the net-zero emissions goal, especially with our increasing dependence on renewable sources of energy.

There are numerous ways and forms of storing energy. However, it can be stored before entering the electric grid, by power companies or even consumers, or after entering the electric grid, mostly by consumers. For example, dams are highly efficient at storing potential energy, and the high level of water upstream of the dam is carefully managed so it can be used when needed. In periods of heavy accumulation of water, this energy is stored, and it can be used during daily peaks of demand or even stored for other seasons. Other common ways of storing energy are lithium batteries, for example, in cases of domestic use of photovoltaic panels.

Storing energy in electric form has many advantages; it can be used in every possible way, such as for cooling, heating, and powering electric devices. On the other hand, electric batteries have a very questionable carbon footprint and an undesirable rate of loss of energy capacity during their lifetime. So, a common strategy in finding technologies to store energy is to first understand what the final use of that same energy is.

Heating and cooling represent up to 50 % of buildings’ energy consumption (Pérez-Lombard et al., 2008), so every possible strategy to reduce costs and emissions can have a great economic and environmental impact. For this purpose, thermal energy storage is often used, to store the energy when electric demand is low and use it when electric demand is high. As we are going to explore further in this dissertation, thermal energy storage can have a great impact on the costs of construction and operation of a building.

1.1 Company Presentation

DTway is a company that specializes in the management and digitalization of buildings. DTWay provides building digitalization solutions, focusing on the potential of information technology to revolutionize the way a building is operated. They use IoT technology, Machine Learning tools, and Business Intelligence to increase the efficiency and sustainability of buildings and simplify the management of technical building systems through digital tools. They monitor all comfort-related aspects and any energy consumption in the building. They store and process data to prevent systems deficiencies and malfunctions and always keep in mind energy optimization and emissions reductions.

1.2 Objectives

The objective of this study is to provide meaningful data to DTWay and contribute to the whole process of commissioning and optimization of an Ice Thermal Energy Storage system. To study the optimal strategy of operation that decreases the costs of operation and increases the efficiency of the overall energy spent on HVAC systems and assess its feasibility. While providing new results and conclusions to the academic community on ITES systems.

1.3 Work Method

This study was conducted in the company´s facilities, all the design documents of the ITES system were studied, and was followed by the commissioning of the system, numerous tests were conducted to assess this point and the manufacturer of the ice bank was contacted to provide assistance in some matters. The tests results were analyzed and were used to conduct an economic evaluation that tested various parameters of the installation. Lastly, it is possible to draw a conclusion based in the results.

1.4 Dissertation´s structure

This dissertation was structured in the following order, starting with an introduction of the proposed study. Followed by the state-of-art describing the current state of this technology and its diversity. The description of the building and the equipment involved in the study. After that the methodology of the study is carefully described. The results obtained are carefully analyzed and discussed. And finally, it is possible to draw conclusions and suggest future works relevant to this matter.

2 State of Art

2.1 Thermal Energy Storage (TES)

TES systems exploit very different technologies, depending on the purpose of the energy. According to the literature, TES systems can be divided into categories and subcategories for cooling and heating. It can also be divided into the physical phenomena that the technology explores: latent heat or sensible heat. In sensible heat, energy is stored in a material without phase change occurring during the process. Latent heat uses the dense energy process of phase change to store energy. Inside of each are further categories and subcategories (Sarbu & Sebarchievici, 2018).

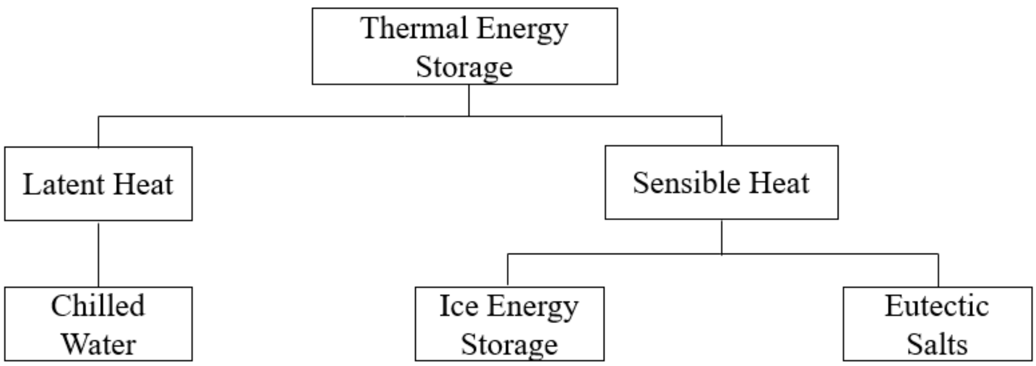


Figure 1 - Types of Thermal Energy Storage (Chan et al., 2006).

The most used for cooling applications according to Chan et al. (2006), are chilled water, ice storage, and eutectic salts.

2.1.1 Chilled Water

Chilled water systems (CWS) consist of cooling large amounts of water to temperatures of around 5ºC. During the night, energy is used to decrease the temperature in the tank for later use during the day for cooling purposes. On the discharge of the tank, chilled water leaves the bottom of the tank and returns to the top of the tank after absorbing heat; this differential in temperature along the stratified tank is what influences the cooling power of the CWS. The conventional configuration of the circuit and the chiller are used in this type of system. To have an impactful system, a large storage volume is needed due to the low energy density; however, the simplicity of the system can make CWS an attractive option. (Thakar et al., 2021)

2.1.2 Ice Storage

Ice thermal energy storage relies on the phase change between ice and water to store energy in the form of latent heat, making it possible to store large amounts of energy. In ITES, a subfreezing coolant removes heat from water turning it into ice; the normal charging temperatures are between -6ºC and-3ºC. The coolant, typically a solution of 25% glycol (in mass), must have a freezing point of around 10ºC below the freezing point of water due to safety measures. In this case, large amounts of energy can be stored, resulting in a lower volume needed. The chiller has a lower setup point that can negatively influence the overall COP of the installation due to an increase in the temperature difference between the evaporator and the condenser (MacPhee & Dincer, 2009) **.**

2.1.3 Eutectic Salts

Eutectic salts are another commonly used alternative when it comes to storing cooling energy. This method uses a mixture of inorganic salts to increase the melting point of the solution. Normally, the solution has a melting point of around 8ºC, and the charging temperatures are similar to the chilled water, between 4-6ºC, which allows the installation to have a conventional chiller setup while at the same time benefiting from the high-density process of the phase changing. Another advantage is that this solution doesn´t expand or contract during the transition between solid and liquid, which can increase the lifetime of the equipment (Dorgan & Elleson, 1993)**.**

2.1.4 Comparison between different TES

Chilled water is the least complex and the least expensive option. Eutectic salts and Ice have more energy density but have higher investment costs. All these methods are suitable for different conditions; the energy density and temperatures of operation can vary, as can the building and operations costs. For example, Chilled water is less expensive than ITES (Ice Thermal Energy Storage), however, the energy density is much lower, so to store the same energy we need more space as shown in Table 1.

Table 1- Types of Thermal Energy Storage (Chan et al., 2006).

	Chilled Water	Ice Storage	Eutectic Salt
Specific heat(kJ/Kg.K)	4.19	2.04	-
Latent heat of fusion (kJ/kg)	-	333	80-250
Packaged system availability	Medium	High	High
Heating capability	Low	High	Medium
Chiller type	Standard water	Low temperature	Standard water
Chiller cost	\$57-\$85/kW	\$57-\$142/kW	\$7-\$85/kW
Tank volume	0.089-0.169m^3/kWh	0.019-0.023m^3/kWh	0.048m^3/kWh
Storage installed cost	\$8.5-\$28/kWh	\$14-\$20/kWh	\$28-\$43/kWh
Charging temperature	4-6^o C	-6 - -3^o C	4-6^o C
Chiller charging efficiency	5.9-5.0 COP	4.1-2.9 COP	5.9-5.0 COP
Discharge temperature	1-4^o above charging temperature	1-3^o C	9-10^o C
Discharge fluid	Water	Secondary coolant	Water
Tank interface	Open tank	Closed system	Open tank
Strengths	Use existing chillers; fire protection duty	Modular tanks good for small or large installations	Use existing chillers
Maintenance	High	Medium	Medium
Warranty availability	Low	High	Medium

According to Hasnain (1997), to store 1 kWh of energy we need up to eight times the volume of chilled water when compared to the ice storage. On the other hand, the chiller for Ice storage can be roughly three times more expensive than for chilled water. Eutectic salts are similar to ice storage, a mixture of inorganic salts is used to increase the fusion point, so the chiller can use the conventional set point which highly affects the costs and efficacy of the Chiller. Eutectic salts can have half the energy density of the Ice storage while having more efficiency and a less expensive chiller, however, they can have the most expensive installation costs of the three. For large amounts of energy in the least possible occupied volume, the option with the best results is Ice storage. Nevertheless, all of them can be suitable for certain conditions.

2.2 Ice Thermal Energy Storage

Now focusing only on the storage of energy involving phase change of water. There are different methods of storing latent energy, each with different advantages and drawbacks. The authors MacPhee and Dincer (2009) categorize ITES into 4 different main technologies as we can see in Figure 2.

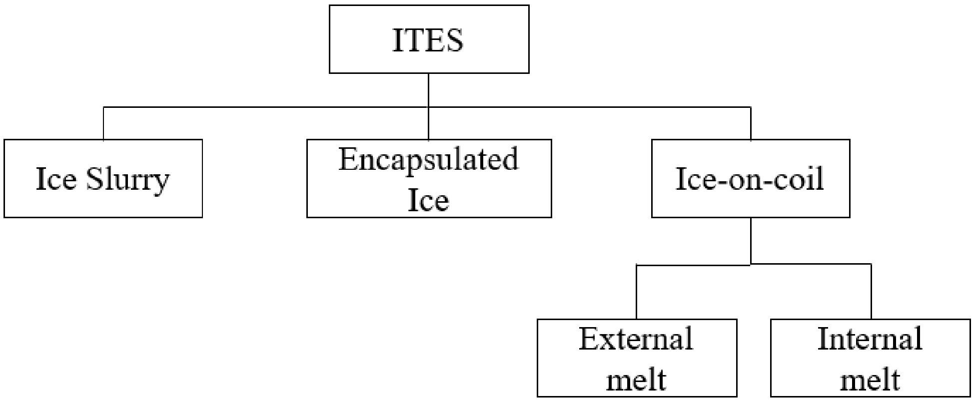


Figure 2- Different Types of ITES (MacPhee & Dincer, 2009)

2.2.1 Ice Slurry

As described by MacPhee and Dincer (2009), ice slurry can be defined as a mixture of ice crystals and liquid, often an antifreeze solution of water and a freezing point depressant like ethylene glycol. There are different types and sizes of ice slurry systems, with the scraped surface process being the most widely used method for making ice. In this process, a vapor-compression refrigeration cycle is employed, with the evaporator located on the outside of a tube-in-tube heat exchanger. A rotating scraper lifts off the ice, which is then transported through the length of the heat exchanger with the heat transfer fluid. Various experimental studies have been conducted on different methods for producing ice in slurries, such as cooling oil-water mixtures while stirring or using an oscillatory rotating cooled tube method. Some studies have also analyzed the effect of the ice-carrying solution.

An ice slurry-based cooling TES system has the advantage of high ice storage density, can be applied directly to any cooling load, and separates the ice formation from the ice storage, which can be very helpful to maintain high levels of heat transfer coefficients that can result in faster charging. But the production of ice using the scraped ice technique can be expensive due to the high amount of energy required and the complexity of the system, moving parts are always more susceptible to failure. However, new ice-making procedures are being studied to address this drawback.

2.2.2 Encapsulated Ice

Encapsulated ice, like ice slurry, is considered a dynamic system due to the harvesting process; in other terms, the formation of ice is separated from the storage. In this method, a plastic recipient containing deionized water is kept immersed in a sub-freezing fluid like ethylene glycol. There are mainly two types of ice containers: rectangular containers and dimpled spheres; the dimple in the spheres is to accommodate the increase in the volume of liquid water during the phase change from liquid to ice. Cylindrical tanks are typically used because of their low cost and low surface area-to-volume ratio. The Optimal positions of the bank were found to be vertical, where natural convective currents coincide with forced convection.

In the charging phase, thoroughly described by Dorgan and Elleson (1993), the coolant circulates through the tank, removing heat from the capsules and making them freeze. When the freezing starts, it changes the density of the capsules, making them rearrange their natural position, and giving priority to capsules that were less exposed to the coolant. Meanwhile, the excess material needed, and a large amount of sub-freezing fluid can have high investment costs.

2.2.3 Ice-on-Coil

The ice-on-coil method is one of the most used, due to its simplicity and low maintenance requirements. It consists of the cooling fluid passing through an immersed coil that will freeze the surrounding wall of the pipe, hence the name ice-on-coil. These coils can be the evaporator of the chiller or a separate circuit with a heat exchanger that transfers heat between the evaporator and the coil circuit. During the charging cycle, the thickness of the ice increases, making it more difficult for the coolant to absorb heat, so a properly dimensioned coil is very important. The most common option is to have several coils in parallel immersed in the tank, also this fluid must have a freezing point below the immersed fluid, at least ten degrees Celsius to ensure that freezing inside the coil doesn't happen at any cost. A common fluid is a glycol solution with concentrations around 25% (in mass). Innumerous mechanisms must be installed to prevent phase change of the working fluid as shown in many guides of manufacturers like by FAFCO (2019).

After the charging phase is complete, the desired level of ice is made, and the apparatus has a great amount of energy stored, ready to be used. To make use of this energy, the Ice must be melted. There are two ways of melting the ice attached to the coils: internal melting and external melting.

In internal melt, as shown in Figure 3, the discharge is accomplished by the fluid in the pipe that dissipates heat to the surrounding ice, melting the ice. This fluid is connected to some sort of heat exchanger or directly to a device for cooling applications, which will be later discussed.

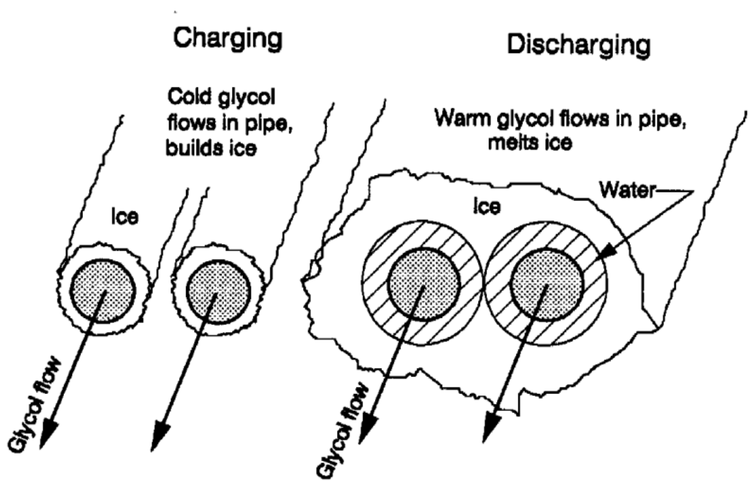


Figure 3 - Internal melt charging and discharging (Dorgan & Elleson, 1993).

In external melt, as shown in Figure 4, the fraction of fluid that is unfrozen inside the tank is recirculated and transfers heat to the ice by its outside layer. In this case, it is necessary to have an additional circuit to conduct the external melt. This circuit is normally connected to a heat exchanger or directly connected to a cooling device with the same purpose as the internal melt.

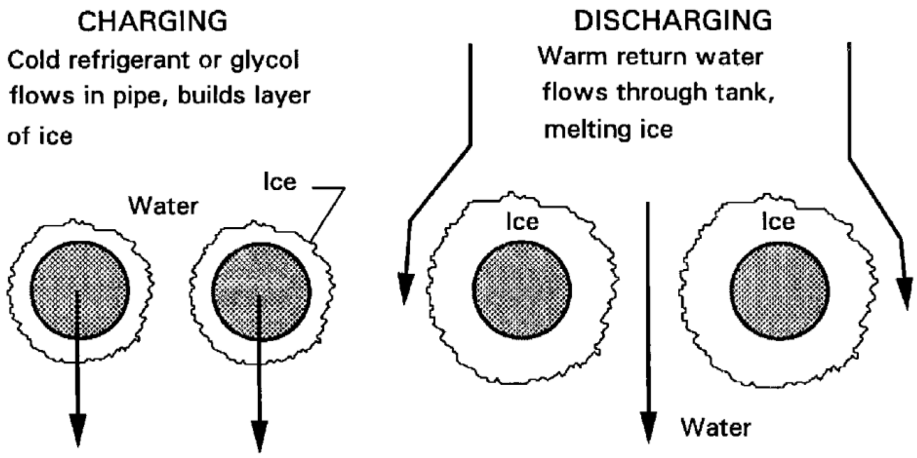


Figure 4- External melt charging and discharging (Dorgan & Elleson, 1993).

2.2.4 Comparison between the different ITES

Some studies have made the comparison between the different types of ITES in terms of performance, efficiency, costs of investment, operation, and maintenance, as mentioned by MacPhee and Dincer (2009)**.** In terms of storage density, both encapsulated ice and ice-on-coil (internal melt) have the highest energy per cubic meter of around 172.98 [MJ/m^3], ice-on-coil external being the least dense, having around 156.6[MJ/m^3]. Also, the optimal operating temperatures may vary; for ice slurry, the storage temperature is around -11ºC and the discharge temperature is around 2ºC. The ice-on-coil internal melt has a storage temperature of -4.5ºC and a discharge temperature of around 7ºC. All these temperatures can be used, adjusting the flow, to produce the typical 7/12ºC desired cooling temperatures.

The efficiency values are all above 98%, Figure 5, however energy efficiency can be a poor way of analyzing a system. Many studies resort to exergy efficiency to evaluate the entire system. Exergy, as mentioned by Afonso (2012) is the maximum useful work that can be obtained by a system or from a source of energy between the initial state and a reference state. Exergy can be more useful to measure the efficiency of a system since it includes the irreversibility of all the processes involved that come from entropy generation in the heat exchanges. So, an exergy analysis can measure the quantity of energy and its quality. Overall, in the processes that we are currently exploring, the exergy efficiency can be improved by having the storage temperature and the evaporator temperature closer to the solidification temperature, a higher thermal density, and a lower discharge temperature, which can be counter-productive since a lower discharge temperature decreases the heat transfer of discharging providing lower cooling power and taking more time to reach full-discharge.

Ice-on-coil (internal melt) has the most desirable exergy efficiency of all the methods, as shown by MacPhee and Dincer (2009) of around 13.9% as shown in the figure 5 provided by the same study.

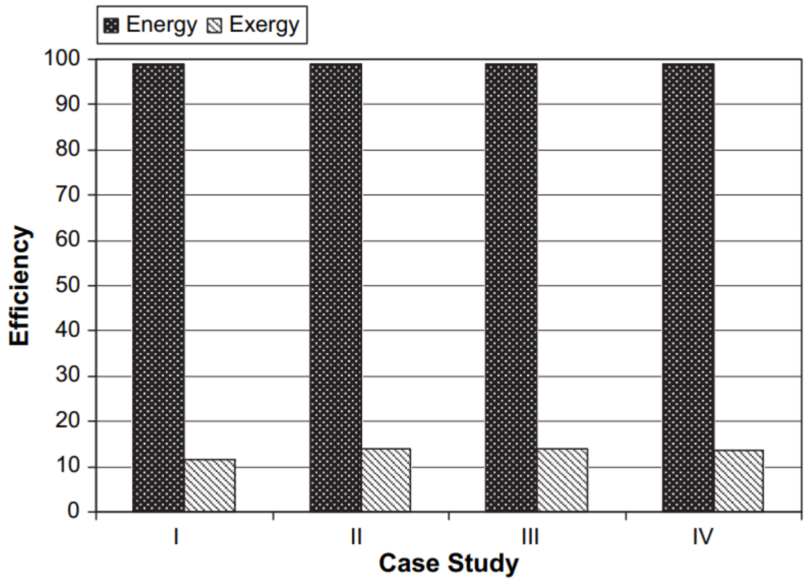


Figure 5- Energy and Exergy efficiency throughout the different studies MacPhee and Dincer (2009).

In another study, using an optimal value method with multiple objectives, Sanaye and Shirazi (2013) reached higher values of around 37%. A direct comparison between the two studies is not advised due to the fact they were carried out under different conditions and based on different assumptions. However, it proved that the methods could be optimized according to the needs.

2.3 Applications and Strategies of Operation

Now that all the methods and procedures have been covered, we can understand the capabilities of such a system. At this stage, the applications of ITES will be discussed, such as the strategies used to properly use this technology, followed by real case scenarios of ITES that were implemented for different reasons, such as financial, technical, or environmental.

In the 1970s, when electric demand had a significant growth during the summer months in the United States, electricity loads would reach 1.5 times the nighttime loads, as Hasnain (1997) points out, electric power plants had to be over-dimensioned to accommodate this unpredicted demand and had to spend nights in idle and waste enormous amounts of energy. In the 1980s and 1990s, the first water and ice storage systems for air conditioning started to appear.

As addressed by Dincer and Rosen (2001), as well as by Sharma et al. (2009), there are mainly three types of general applications. In a simplified way, these three factors drive this technology forward and are the principal reasons for its use. Starting with economic benefits for the consumer. It´s possible to read in the literature numerous studies done on successful cases where the user manages to save a significant amount on operation and investment costs. Environmental, due to a higher consumption of green energy, and lastly, grid management; in the last case it is in the interest of the electric companies due to many factors, like grid management.

From an Economic standpoint, the consumer uses the Ice bank to shift the on-peak energy consumptions, which has a higher cost, to off-peak hours which have a lower cost. This feat has been accomplished several times as many studies prove. In Figure 6, it is possible to see the typical cooling demand profile for different types of buildings (Alcântara, 2019).

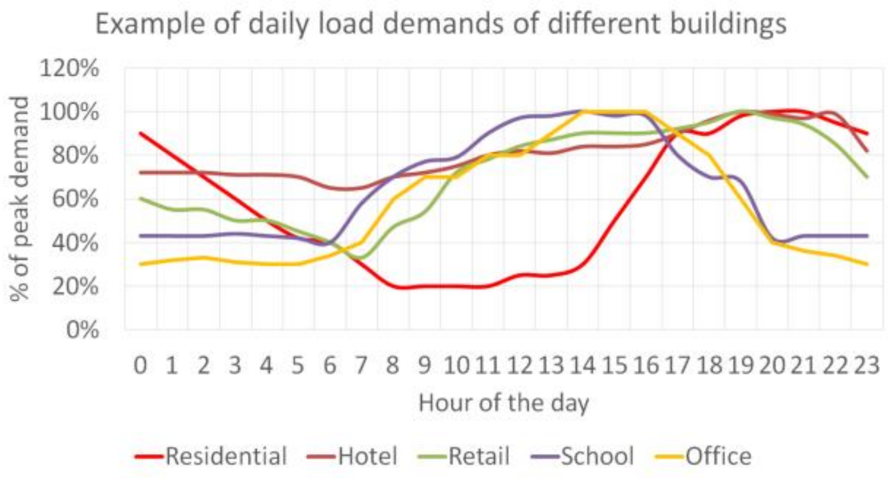


Figure 6- Example of daily load demands of different buildings (Alcântara, 2019) .

As explained previously, the cooling load of buildings represents a large share of the electric consumption. Doing a quick analysis of the different types of electric tariffs across developed countries, we can conclude that peak cooling demands often match the peak hours of electric consumption, which comes with high monetary costs, as displayed in the Figure 7.

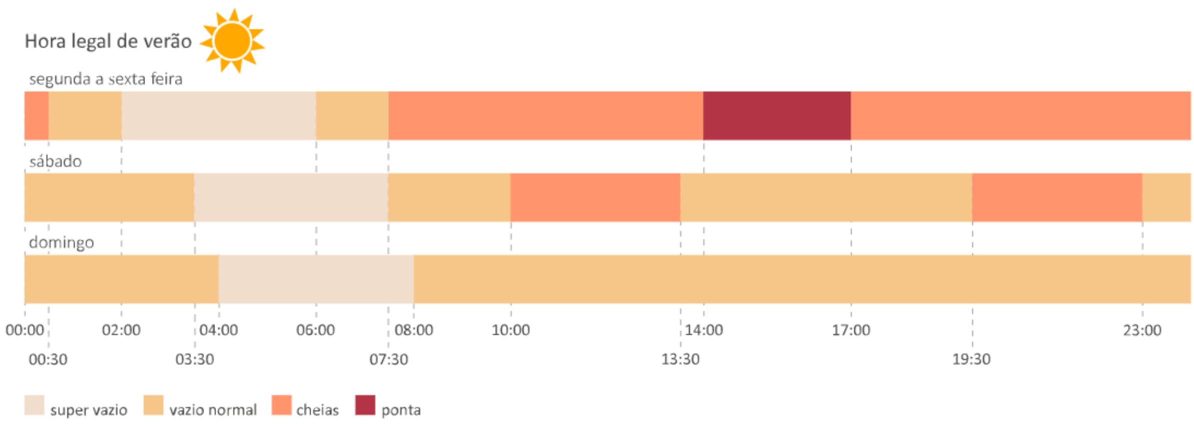


Figure 7- Example of different daily tariffs throughout the day (ERSE).

So, shifting the cooling consumptions to a low-cost schedule could result in substantial economic benefits.

As described by Dincer and Rosen (2001), several studies were conducted in buildings with ITES after years of operation to assess the economic feasibility. This study reports five cases of success with energy savings ranging from one hundred thousand USD to one million USD annually. A different study suggests that it is very likely to achieve a payback time of fewer than ten years (Song et al., 2018). In this case, using a compound thermal storage for cooling, mixing ITES and CWTES, a reduction of 18.6% on the electric bill was achieved in a residential building complex (Yari, 2016). Another study reports ten different cases studies conducted on already existing buildings and shows a payback time of less than half a year on one office building in Dallas and a 24% reduction in cost in a library building in Malaysia, among other cases with positive results (Yau & Rismanchi, 2012). Apart from the savings due to the shift of consumption to a lower cost tariff, it is also possible to have high reductions on the investment cost of the installations by downsizing the chillers and having an ITES to help in the high cooling demand hours. This strategy can also bring economic benefits. From an environmental standpoint, it is shown in various scientific publications that ITES reduces the emission of pollutant gases. Many of these results were obtained due to the high percentage of fossil fuels used in the generation of energy in peak hours (Dincer & Rosen, 2001). By shifting a share of the loads to off-peak hours, the building is consuming a smaller percentage of fossil fuels which can reduce the ecological footprint of the building. It is possible to obtain an 11,4% reduction in carbon dioxide emissions for every kWh shifted from day-time to night-time in the UK (Beggs, 1994). It is important to have in mind that every country has different electric grid management strategies and different contributions from each type of energy.

Another way of reducing emissions is by having a private source of renewable energy attached to the building. In this case, we can store the energy in the form of ice for later use as mentioned by Ghaith and Onur Dag (2022), where a similar system was evaluated in two different buildings, both having positive outcomes with reasonable payback times.

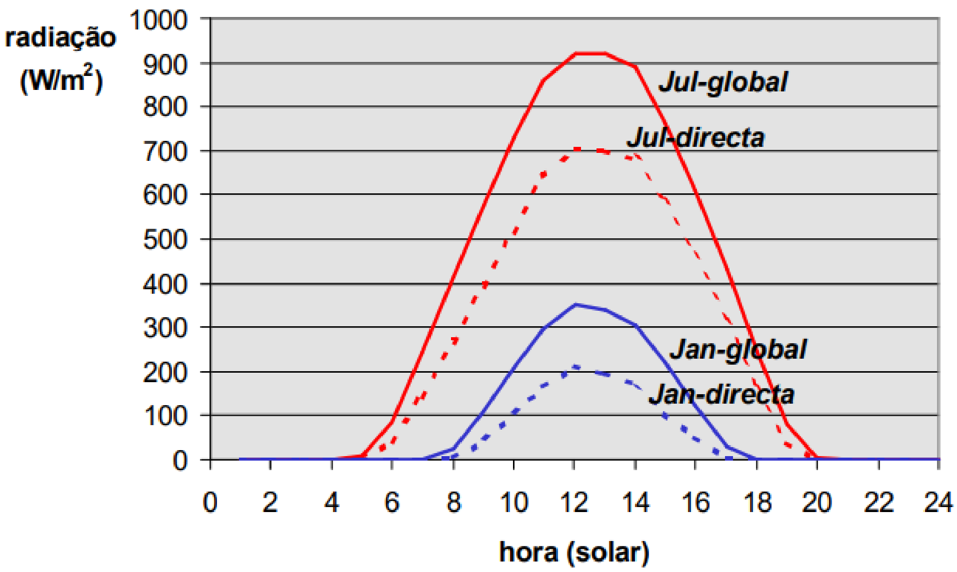


Figure 8- Solar Power variation throughout the day in July and January (Oliveira & Palmero, n.d.)

As presented in Figure 8, there are great variations in solar energy generated during the day, so the strategy is to store this energy in the form of ice during the hours when there is more energy production than energy consumption and use it in later hours where solar can´t meet the needs or there isn't any solar production at all.

Lastly, from a grid management standpoint, this point falls under economic and environmental benefit; however, these positive outcomes are in the interest of the companies or governments that oversee electricity production or distribution to the end user. A power plant is not only designed to meet the energy needs of the overall distributed energy but also designed to meet peak demand. A very simple example is displayed in the Figure 9.

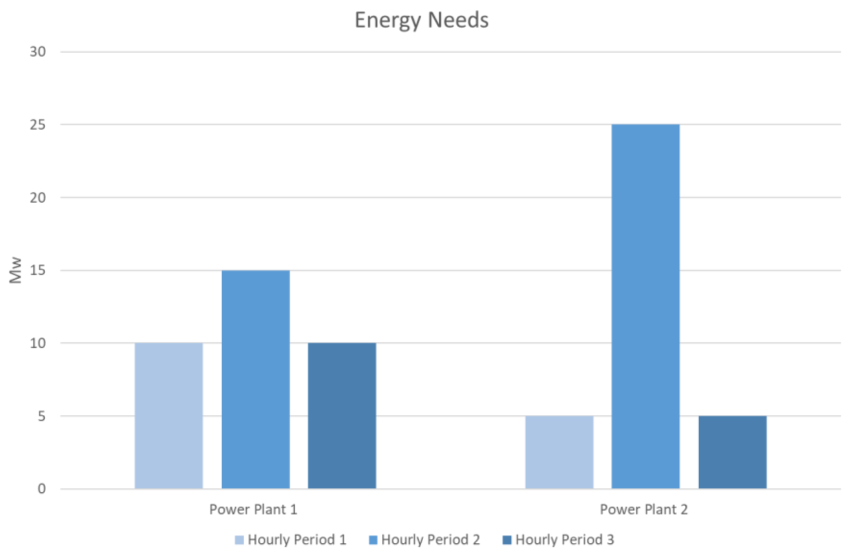


Figure 9- Example of Power demand and Energy Demand in two different power plants.

Both power plants have energy needs of 30kWh. However, Power Plant 2 must be designed to meet peak demand which means it has to be significantly larger than Power Plant 1. It can result in higher costs and higher emissions (HASNAIN, 1997). Flattening the demand curve can bring advantages and simpler management of the electric grid and can prevent major power cuts (Arcuri et al., 2017).

2.3.1 Operating Strategies

To fulfill all the objectives discussed previously, it can be found in the literature that different strategies are needed. While the objective is the same, the operation of the ITES can be run differently. Operating strategies can be primarily divided into **full storage** and **partial storage** and partial storage can be further divided into **demand limiting** and **load leveling.**

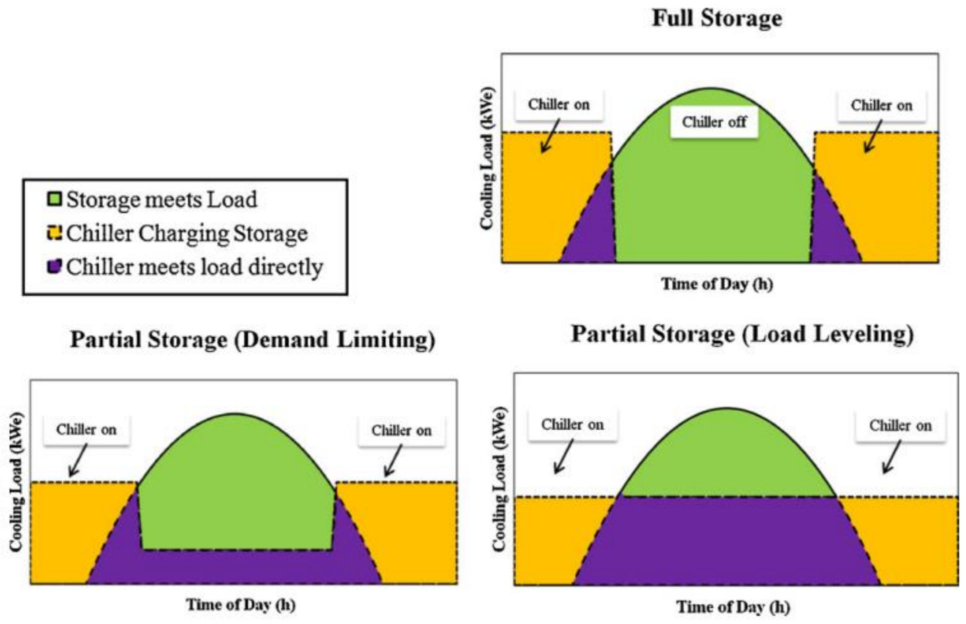


Figure 10- Display of Full Storage and the two types of Partial Storage (Yau & Rismanchi, 2012)

2.3.2 Full Storage

The strategy of fully storing or shifting the load aims to reduce the cost of cooling a building by moving energy usage from peak to off-peak hours. This approach can meet the building's entire cooling needs during the night by maximizing load shifting and reducing operating costs. During peak hours, the refrigeration equipment does not run, and all cooling needs are fulfilled from the stored energy. However, implementing this system requires significant refrigeration and storage capacities. The full storage approach is particularly advantageous in areas where on-peak demand charges are high or where the peak period is short. By using this strategy, the peak cooling electric demand can be almost zero compared to a traditional cooling system (Yau & Rismanchi, 2012).

2.3.3 Partial Storage

Partial storage meets a portion of the peak cooling load, as shown in Figure 10, while the remaining load is met by the cooling equipment. As mentioned previously, this strategy can be divided into load leveling and demand-limiting systems. In load leveling, the chiller runs continuously during the 24 hours of the day. In the hours of low cooling load, when the chiller output surpasses the needs of the building, the excess cooling power is stored in ITES. In the hours when the chiller can´t meet the cooling loads, the storage discharges the additional cooling. The chiller is downsized compared to the conventional option; the storage size is smaller than the full storage option, and the chiller runs continuously. This method saves 40-60% of peak electric demand, and it´s particularly attractive when the on-peak cooling load is much bigger than the average cooling load (HASNAIN, 1997).

Demand limiting can be seen as a combination of full storage and partial storage, where only a portion of the on-peak demand is met by the storage but the chiller doesn´t run all day at the same capacity. In the hours of peak demand, the storage output increases, and the chiller output decreases to save electricity costs; in other words, the chiller capacity is controlled during the daytime to maximize savings. It still has the same benefits as load leveling. like the downsize of the chiller but has more savings on electric costs; however, the complexity of the chiller control can be a challenge. Partial storage discharge strategies can be categorized in two ways, storage priority, and chiller priority. In both methods, the storage system or the chillers provide the building's cooling. However, the principal device that oversees the load is the main distinction between these strategies. The storage tank supplies the majority of the load in the storage priority approach, and in the chiller priority, as the name says, the chiller is in charge of the load and the storage only discharges if necessary. The storage priority method typically needs a larger storage capacity and more intricate chiller control, which results in less energy consumption (Yau & Rismanchi, 2012).

2.4 Limitations of ITES

It´s proven that ITES is not only a matured technology but also a promising future, has already presented positive results and is in continuous evolution; however, some limitations can be pointed out. One of them is energetic efficiency. When compared to a conventional system, ITES can consume more energy due to imperfections in the charging, storing, and discharging processes, which can be an environmental problem. Another relevant problem is the variation in electricity costs during the day; this variation in prices can have a low amplitude, making the savings irrelevant compared to the investment cost.

All the design procedures highly rely on the cooling load calculation, so a mistake at this stage can lead to oversized designs that can cause economic loss. This type of system can be very difficult to design and manage, which results in economic losses or even malfunctioning of the system (Alcântara, 2019); (Gang et al., 2015).

3 Case Study

The purpose of this dissertation is to assess the use of ITES in the making of chilled water for climatization purposes. The building in question is the Word of Wine, a multi-purpose retail and services building located in Vila Nova de Gaia, Porto. This building is divided into numerous restaurants, retail shops, and museums; they all share a centralized cooling and heating system, some form of district climatization. To decrease operation costs, an ITES system was included in the project of the building. The ITES system and many other systems in the building are managed by DTWay. As expected from an infrastructure of this size, cooling, and heating loads have a considerable magnitude; thus, any reduction in electric prices can have a meaningful impact in the medium-long term. The Word of Wine is a very recent project that opened its doors in 2020. This structure relies on state-of-the-art technology to manage and monitor all the aspects associated with HVAC systems, domestic hot water (DHW) systems, and overall energy consumption.

3.1 The building

To give a better understanding of the dimensions of this commercial structure the decomposition of the building into smaller sections may be helpful. The World of wine is divided into three groups, stages 1, 2, and 3. Each group can have multiple museums, food courts, bathrooms, and office spaces, among others. Stages 1 and 2 share a centralized cooling and heating system and contribute to most of the building´s loads. The focus of this dissertation is on stages 1 and 2, where the ITES system is installed.

Figure 11- Areal view of the building.

3.2 ITES

The building relies on three heat pumps to meet the cooling and heating loads plus the DHW needs. Two of them referred to as Chiller 1 and 2, are 4-pipe heat pumps, that can provide cooling and heating simultaneously or individually. These chillers, when heating and cooling simultaneously can achieve high COPs, up to 7 according to the datasheet. The other heat pump, referred to as Chiller 3, is more capable in terms of power but its only purpose is to produce chilled water; however, it also has a small heat capability that relies on heat recovery during colling processes. Chillers 1 and 2 are connected to the hot water and chilled water reservoirs. From these reservoirs, water is distributed through the different AHUs (air handling units) or FCU (Fan Coil Units). In these units, the water heats or cools the air that is inflated into the different rooms. Chiller 3 can also produce chilled water and send it to the same reservoirs, but it can also produce below-freezing point water that can be used to charge the ITES system. To better understand we can see in Figure 12, the layout plan of the three chillers, chilled water reservoirs, and the ITES.

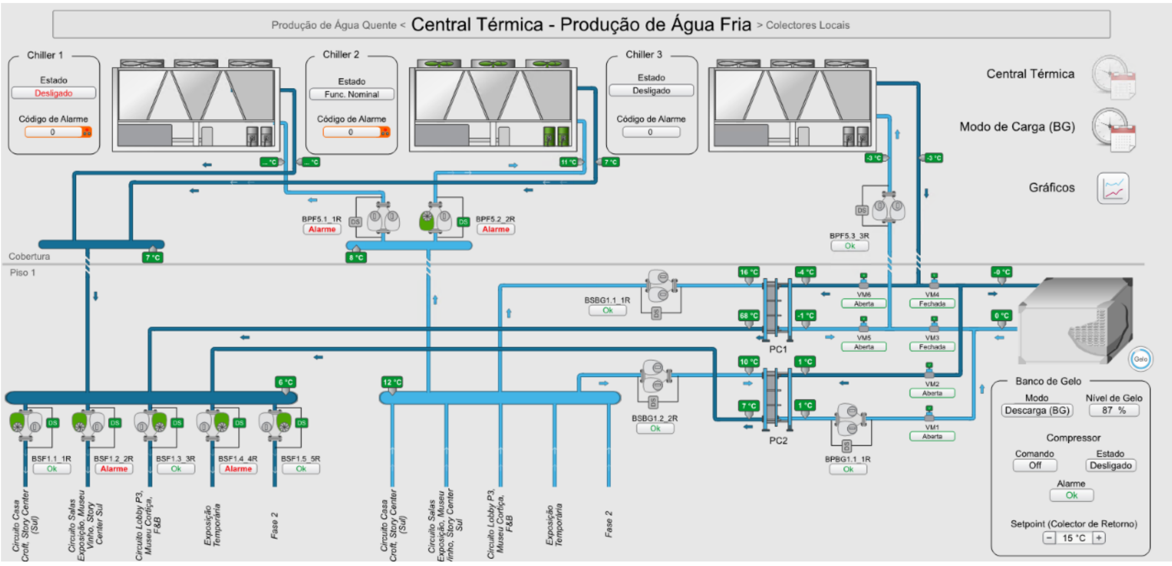


Figure 12- BMS layout plan.

The object of this layout is for the Chiller 3 to be able to contribute directly to the cooling needs of the building or to charge the ITES. We can identify three processes that can happen. Chiller 3 produces chilled water; in this process, it uses its conventional setpoint to produce chilled water in the same way that chillers 1 and 2 do it, as we can see in Figure 13. The conventional set point is 7/12º C.

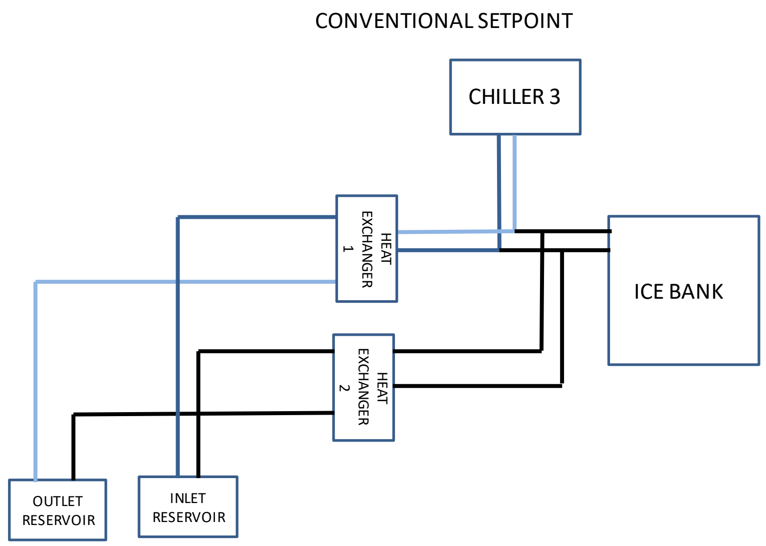


Figure 13- Chiller in the conventional setpoint producing chilled water directly to the installation.

Charging, in this case, Chiller 3 changes to a sub-freezing setpoint and starts to charge the ice bank; this process is facilitated by opening and closing automated valves. As we can see in the following image, the same pump from the previous process oversees the deployment of the working fluid to the ice bank, Figure 14.

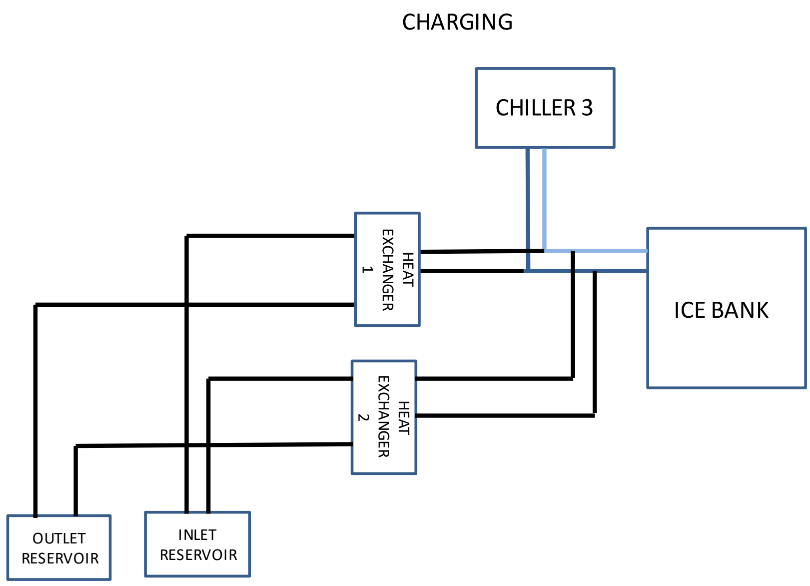


Figure 14- Chiller in the subfreezing setpoint charging the ice bank.

Lastly, in the discharge of the ice bank, water runs through the ice reservoir and dissipates heat, cooling the water, which then proceeds to go to the chilled water reservoirs. Once again, we can have a better understanding by looking at the pathways of the fluids in this process, Figure 15.

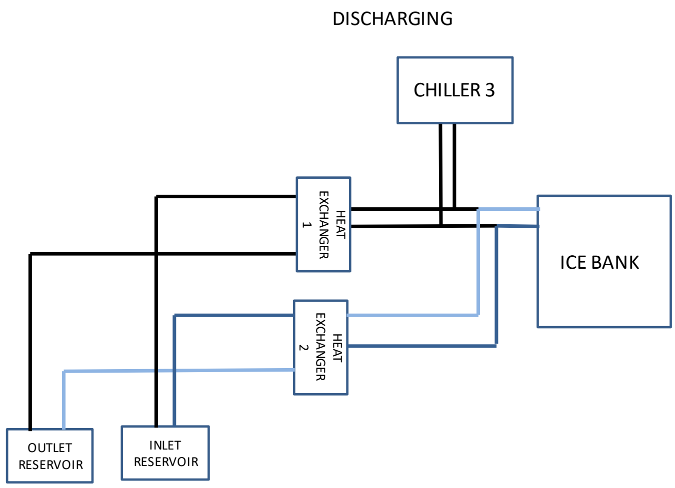


Figure 15- Discharging of the Ice Bank.

With this layout, it is also possible to combine discharging with the normal function of Chiller 3, in what is called partial storage. As discussed previously, partial storage happens when both the chiller and the ice bank work to meet the cooling load simultaneously. This procedure can happen when Chiller 3 can´t meet the cooling loads and the discharge of the ice bank is activated as chiller priority. Or when the discharge can´t meet the loads, the chiller is activated, storage priority.

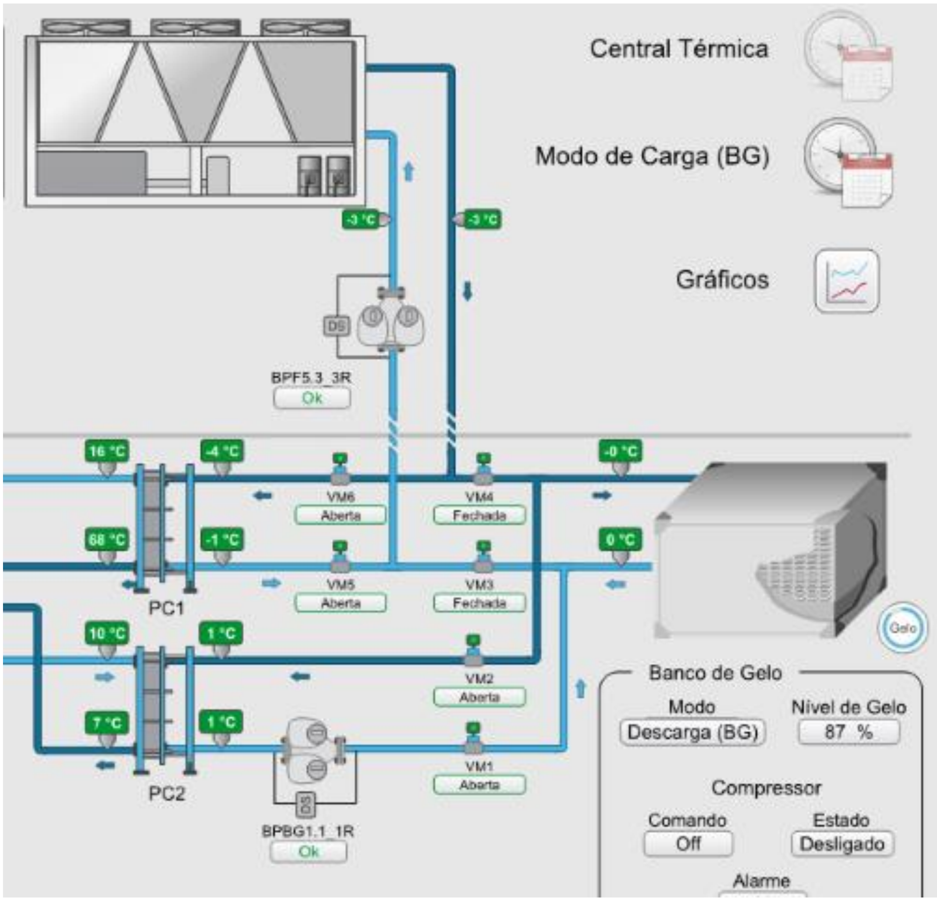


Figure 16- BMS regarding the ITES

Looking at the layout of chiller 3/ITES, we can see the transition between processes is made possible by valve and water pump actuation. This process is all automated. The programmed logic behind conventional chillers, charging, and discharging can be summarized in Table 2. The names and locations of the valves and pumps that intervene in the processes can be seen in Figure 16.

Table 2- Programmed logic for the different processes.

	VM1	VM2	VM3	VM4	VM5	VM6	BPF5.3/3R	BPG1.1/1R	BSBG1/1R	BSBG1.2/2R
Conventional Chiller Use	0	0	0	0	1	1	1	0	1	0
Charging	0	0	1	1	0	0	1	0	0	0
Storage	0	0	0	0	0	0	0	0	0	0
Discharging	1	1	0	0	0	0	0	1	0	1

It is possible to combine the process of "conventional chiller use" with any other process. In that case, to obtain the logic parameters, simply sum the rows of the two processes, noting that any sum with a result equal to 2 must be changed to the number 1. Because 1 represents the actuated state and 0 represents the off state the number 2 doesn´t have any meaning and should be interpreted as the number 1.

The ice bank has a latent energy storage capacity of 8000 kWh and 300 kWh of sensible energy storage capacity. Contains 122 000 liters of water.

Table 3- Specifications of the Ice Bank.

ICEBAT UWH 306/8/19 HP

Full Capacity	8 355	kWh
Latent Capacity	8 053	kWh
Sensible Capacity (0-4º C)	302	kWh
Max Temperature	40	º C
Max Pressure	3	Bar
Total Water Volume	121 930	L
Water/Ice Volume	86 570	L
Glycol Water Mixture	4680	L
Drained Weight	10 150	kg
Max Weight	137 050	kg
Solar Exposed Surface	48	m^2

The output power of the ice bank is improved by an air compressor that promotes agitation in the ice bank. It´s possible to achieve 2500 kW. Although this parameter also depends on the building´s needs and the heat exchanger´s rate flow, Figure 17.

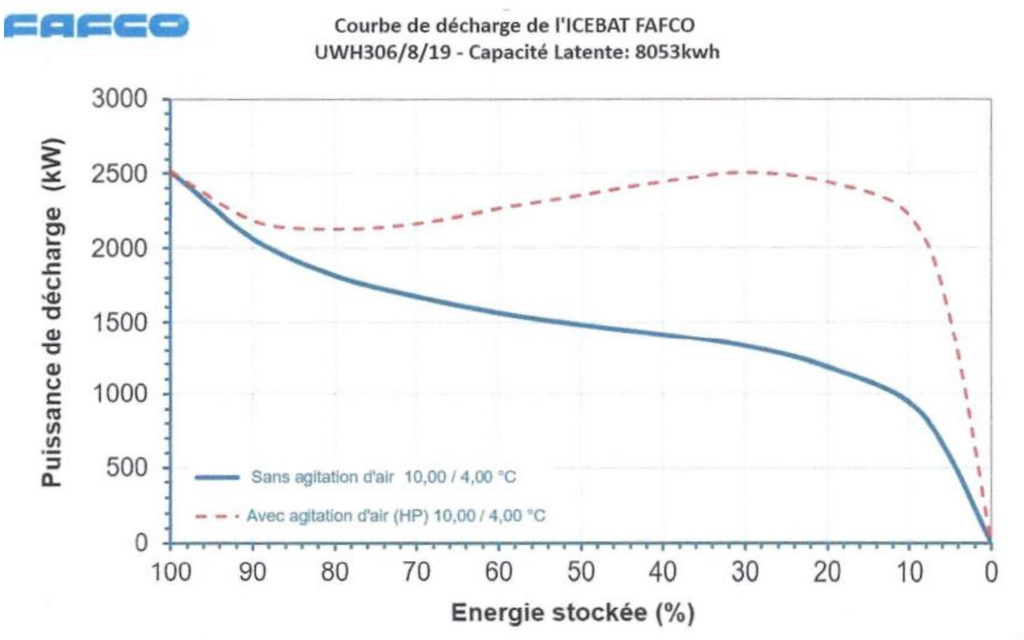


Figure 17- Ice bank´s output power.

3.3 Building Management System

The building is equipped with a Building Management System (BMS), where all the different systems of the building can be controlled, and data can be collected. This data is processed by another program. This system helps to prevent and correct malfunctions since it makes the task of detecting them much easier. The BMS can control the system manually or through a pre-written code to automatically control the different processes and implement safety measures to ensure the good function of all the components of the building. Figure 16, is a screenshot of one of the many interfaces available to monitor and control the various systems. For example, Figure 18, it is possible to collect information or input commands to change the setpoint, among other controls.

Figure 18- BMS chiller 3 Interface.

The data collected also has a big role; this data can help optimize the system by understanding imperfections and more complex problems. This data is processed and displayed through software; a quick example can be seen in Figure 19, where the temperature of the entrance and exit of the working fluid is shown during the discharge of the ice bank for 8 hours. Every single valve, pump, AHU, FCU, and chiller, among numerous probes and sensors, gives constant feedback to the database. The interval of information given can be adjusted according to the needs, for example, in intervals of 15 minutes or 1 minute.

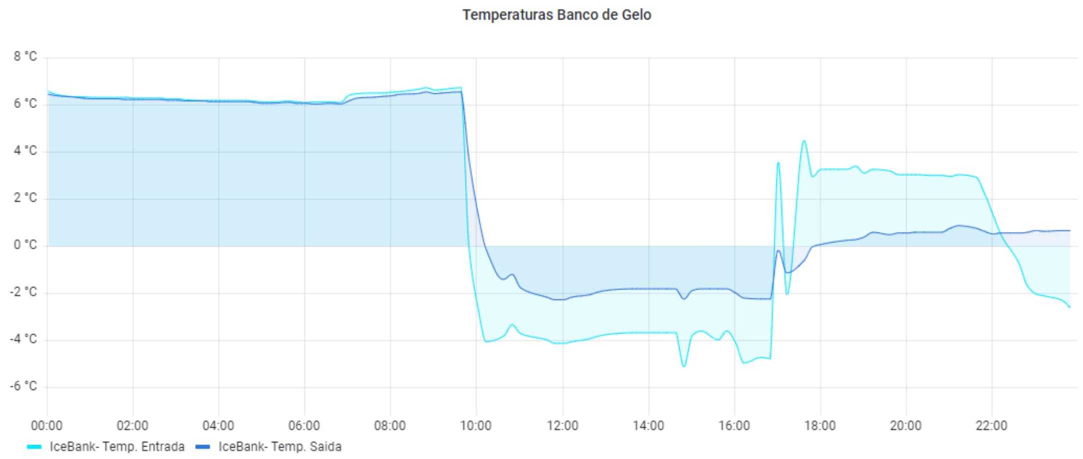


Figure 19- Ice bank´s inlet and outlet temperature in a designated period.

3.4 Design strategy of operation

In this building, the ITES was specifically built to operate according to the strategy of full storage, where the ice bank meets all the cooling loads of the building at some interval of time when the electric costs are higher. When the load can´t be met by the Ice bank, chillers 1 or 2 can be activated to fulfill the surplus. An economic study was conducted during the project´s conception, evaluating two different electric tariffs, and shifting the consumption of peak-hour cooling loads to off-peak. The study concluded that was possible to have a return on investment of around 6 years and annual savings of 18 000€, as we can see in Table 4.

Table 4-Economic study for different solutions made by design engineers.

Solutions Tariff 1	Loads (MWh)		Investment (k€)	Electric annual cost (€)	Year 0 (k€)	Year 1 (k€)	Year 2 (k€)	Year 3 (k€)	Year 4 (k€)	Year 5 (k€)	Year 6 (k€)	Year 7 (k€)	Year 8 (k€)	Year 9 (k€)	Year 10 (k€)
	Cooling	Heating	DWH+HVAC												
4 Pipe Heat Pump	580	670	417	40	417	456	496	535	575	614	654	693	733	772	812
4 Pipe Heat Pump + ITES	580	669	516	24	516	540	564	588	612	636	660	685	709	733	757

Solutions Tariff 2	Loads (MWh)		Investment (k€)	Electric annual cost (k€)	Year 0 (k€)	Year 1 (k€)	Year 2 (k€)	Year 3 (k€)	Year 4 (k€)	Year 5 (k€)	Year 6 (k€)	Year 7 (k€)	Year 8 (k€)	Year 9 (k€)	Year 10 (k€)
	Cooling	Heating	DWH+HVAC												
4 Pipe Heat Pump	580	670	417	40	417	457	496	536	576	616	655	695	735	774	814
4 Pipe Heat Pump + ITES	580	670	516	21	516	537	558	579	601	622	643	664	686	707	729

In this table, we can see the solution with or without the ITES and the costs of investment and operation over a period of 10 years for tariffs 1 and 2. After year 6, both solutions start to save money when considering investment costs. However, after a careful analysis of the economic study, it was possible to conclude there was a mistake in the calculation of the cost reduction, making it inaccurate and unfit to draw conclusions. The energy used in the calculation of cost reductions was thermal energy, the output from the Chillers, and not the electric consumption. Also, the power on peak parcel of the electric bill was not considered and it represents a reasonable share of the cost´s reductions. These two flaws have different impacts on the results, on increases and another decrease reductions in costs, so it´s not possible to say that a new study will have better or worst results.

However, since the opening of the building complex, the ITES has never been used. The main reasons were a lack of knowledge and confidence to supervise an unknown system by building technicians and due to some distrust in the system in terms of added value when compared to the already known system of a 4-pipe chiller to meet the cooling requirements.

4 Methodology

This chapter is mainly divided into two sections. In the first stage, commissioning, various tests were conducted in all the circuits of the Chiller 3/ITES. The commissioning stage has two objectives: assessing the conditions of the pieces of the circuit in terms of good function and programmed logic and evaluating temperatures throughout the different processes and consequently evaluating times of full charging and discharging. The second stage, economic assessment, consists in making an economic analysis of possible cost reductions considering previous years’ data on the cooling loads in the building and the data extracted from the first stage, for example, real-time charging.

4.1 Stage 1-Commissioning

As previously referred, this chapter consists of data analysis of the equipment during the different processes.

4.1.1 Basic Requirements and programmed logic

In chronological order, the procedures that were conducted in the ITES system are going to be listed. First, the water in the Ice Bank was checked for possible life forms or pollution. After that, all valves and pumps were opened or activated and left running for a period of 8 hours to verify that there were no leakages or abnormal pressures.

This was followed by a charging and discharging of the Ice bank to ensure that the previous automation commands were working as expected. To verify this programmed logic, data from the system was collected and analyzed thoroughly, especially during the change of processes, for example, charging and discharging. Once again, all this data can be checked live or later. This data has been collected and stored since 2022. To do this assessment, we use the data software to check the chiller 3 power output and setpoint, pumps, and valve states. An example of how this data is going to be analyzed is displayed in Figure 20.

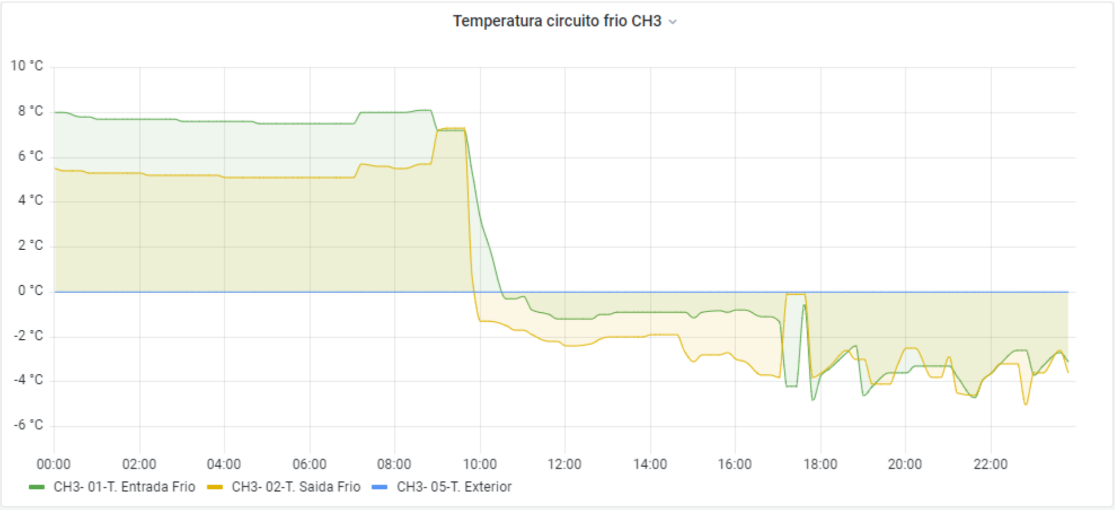


Figure 20- Inlet and outlet temperatures of chiller 3 from DTWay data.

With this data, it is possible to evaluate if this chiller 3 is in the conventional setpoint or is in the subfreezing setpoint used for charging.

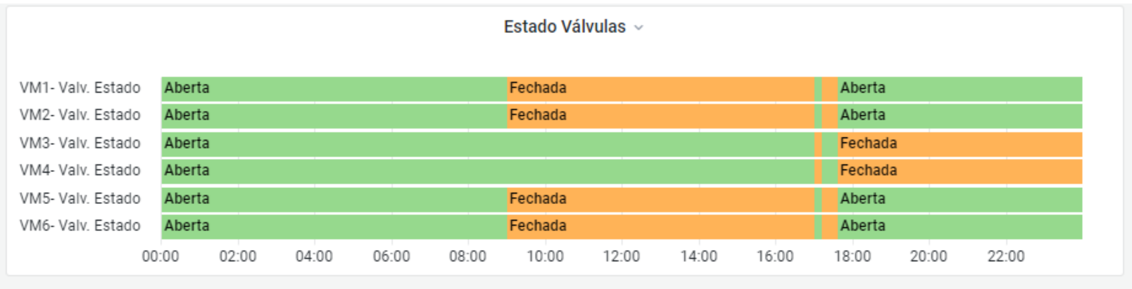
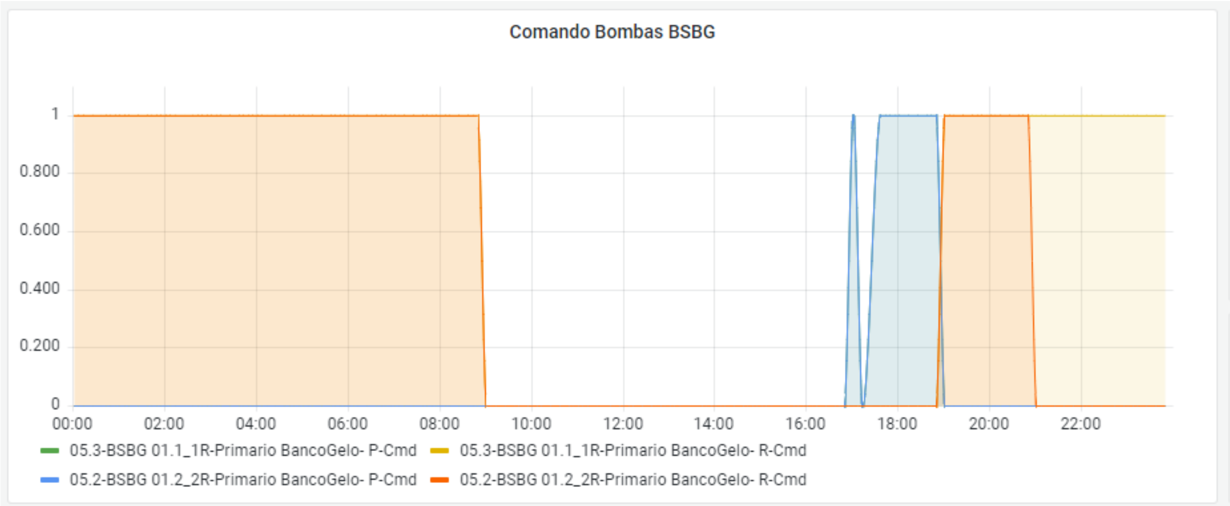


Figure 21- State of the valves in charge of changing processes orange meaning closed and green open.

Knowing the system layout and looking and the state of the valves we can assess their supposed positions in any given process.



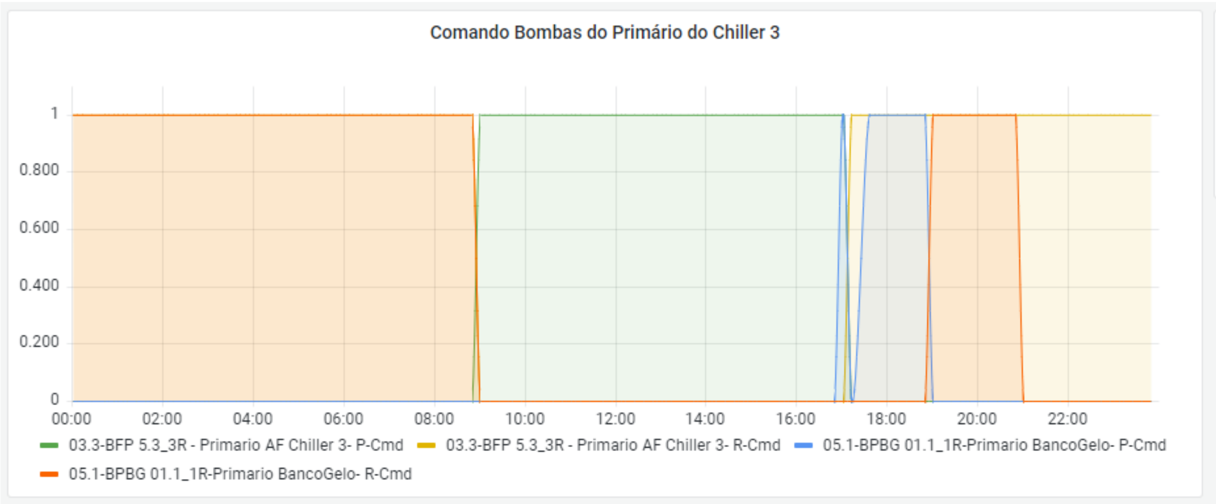


Figure 22- State of the 4 pumps in the primary and secondary circuits.

It is possible to observe the 4 pumps in the system. The first graph Figure 22, shows the state of the two pumps on the secondary circuit. These two pumps enable fluid to run from the chilled water reservoirs to two different heat exchangers: one pump for when the Ice bank is being discharged and another pump for when the chiller is working in the conventional setpoint.

It is the combination of all these pumps, valves, and chiller setpoints that allow us to change processes. So, to assess the proper function, one has only to analyze these graphs.

4.1.2 Temperatures and cycle time evaluation

At this stage, another set of tests was conducted to evaluate the inlet and outlet temperatures of the different heat exchange processes, such as the differential temperature in the two heat exchangers of the circuit, in the charging/discharging of the bank, in the chiller 3, as well as the time of charging, to compare this data to the values of the manufacturer and the design engineers. These results are also valuable to conclude the second stage, economic analysis, where it is important to know the quantity of energy stored in the ITES per unit of time.

This test consists in charging the Ice Bank to almost maximum capacity and then discharging it. The data analyzed in this test are the inlet and outlet temperatures of the heat exchangers, ice bank, and chiller 3, as well as the cooling power output of the chiller and water pumps. From the chiller 3, verify the temperature difference, Figure 20, and output power, Figure 23. The output power comes from the inlet and outlet temperature, which are used in the following equation (1).

$$\dot{Q}=\Delta T \cdot \rho \cdot \dot{v} \cdot c_P \tag{1}$$

$\dot{Q}$ being the power output, ΔT the difference between inlet and outlet temperature, c_p, the specific heat of the glycol and water mixture, ρ, the density of the mixture, and $\dot{v}$, the flow. This value is expressed graphically as a function of time. Due to this formula, depending on the ΔT, at the start of the chiller, we have an inflated value, caused by a great ΔT. This first value should be ignored because it´s not the cooling power used to charge the bank.

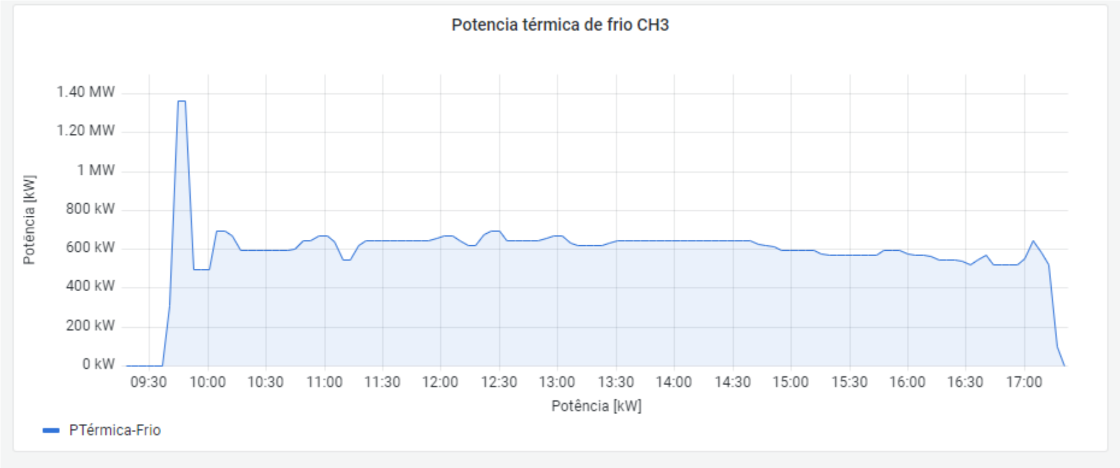


Figure 23- Cooling power of Chiller 3.

From the ice bank, the difference between the inlet and outlet in both charging and discharging, Figure 19, and the temperature in the heat exchangers 1 and 2.

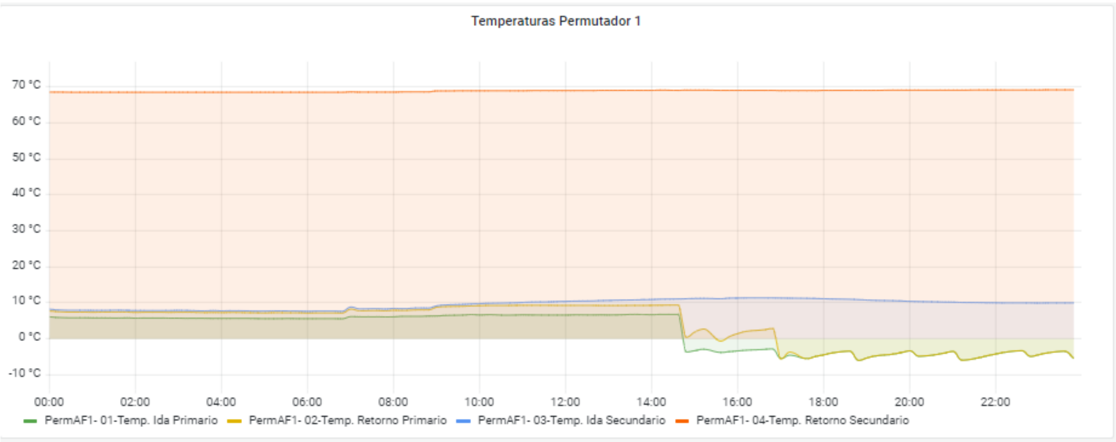


Figure 24- Heat exchanger 1 between Chiller 3 and Chilled water reservoirs.

The heat exchanger 1 transfers cooling power between the chiller 3 circuit, when it is in conventional setpoint, and the chilled water reservoirs, in the figure we can observe four temperatures, inlet and outlet temperatures on the primary side (Chiller 3), and in the secondary side (Chilled Water Reservoir). The same information is displayed below for heat exchanger 2, in this case, cooling power is transferred from the ice bank to the chilled water reservoirs, this process only happens when the ice bank is being discharged, Figure 25.

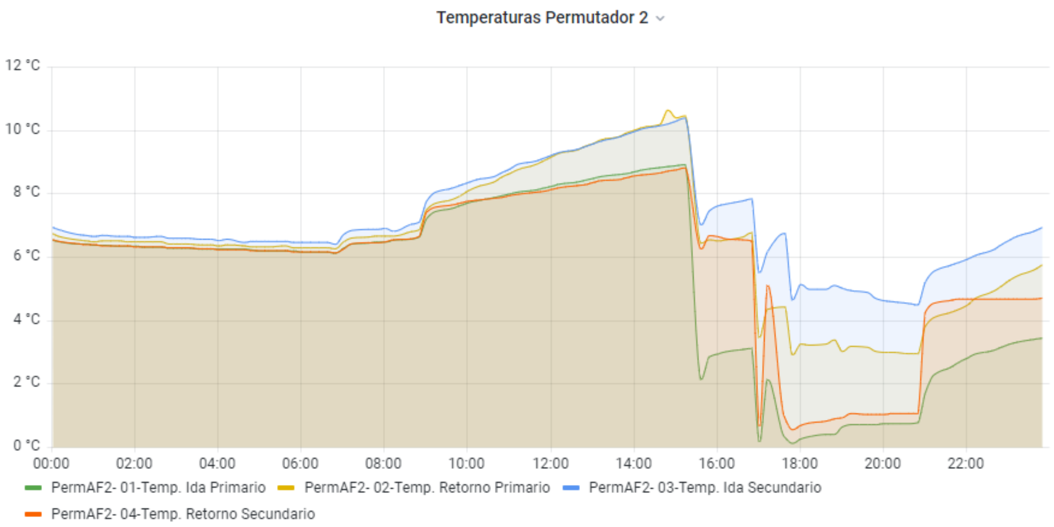


Figure 25- Heat exchanger 2 between Ice Bank and Chilled water reservoirs.

To conclude, it´s expected this procedure to have the following results, Chiller 3 output power in subfreezing setpoint, time of charging and discharging, and verify the temperatures on the heat exchangers aren´t too low. The difference in temperature in the heat exchangers and the discharge on the bank is not very meaningful because they highly depend on the cooling load of the building during the time that the test was performed, however, it´s important to check for abnormalities.

4.2 Stage 2-Strategy of Operation and Economic Evaluation

In this section, it will be described how the economic study was conducted, what considerations were taken into account, and what scenarios were tested. This economic evaluation consists of a hypothetical strategy of operation and a real strategy of operation adjusted to this installation and considering the building´s cooling and heating loads of the previous year to this study, i.e., 2022. The hypothetical strategy of operation serves as a reference to the real strategy. Both strategies are simulated with two different electric prices since the building's management recently changed the electricity contract, so it was enriching for this study to compare both electric contracts. The first step is to understand the main difficulties in the application of an ITES system in this specific building. Followed by the consideration and results drawn from Stage 1. Lastly, simulate cost reduction with both strategies.

This ITES system was never used due to disbelief that it would bring advantages to an already effective installation. As mentioned earlier, the installation is equipped with three chillers, chillers 1 and 2 are 4-pipe chillers. After a careful analysis of the datasheet, it is possible to conclude that these chillers are at their best efficiency when they are producing the same amount of heat and cold, reaching an EER of nearly 7. At this building, there is a constant need for DHW, so it is unrewarding to shift cooling loads to the nighttime when during peak hours the Chillers have DHW demands and can produce, at the same time, chilled water with almost no electricity costs. So, when chillers 1 and 2 are producing hot and chilled water, the cooling loads that exceed the heating loads have a similar EER to Chiller 3/ITES. This means that it can be rewarding to shift the difference between cooling and heating loads.

Another conclusion was the maximum quantity of energy that could be provided by the ITES. This data relies on the first tests conducted on the ice bank, where the bank is charged for 7 hours, mimicking the nighttime period.

The hypothetical strategy consists of using the ITES to meet the building's cooling load during peak hours. If the ice bank is still capable of providing cooling power after peak hours, it will continue meeting the loads during the next period, i.e., the standard period. This strategy is only simulated to serve as a comparison since it is the maximum theoretical reduction cost that it is possible to obtain with ITES installed. However, the most rentable strategy for the installation is shifting only the cooling loads that exceed the heating loads, so the ITES will work as partial storage if there are heating loads or full storage if there aren´t. But to apply this strategy, it is necessary to understand how chillers 1 and 2 work.

Table 5-Chiller 1 and 2 cooling, heating, and combined partial loads.

PART LOAD DATA

COOLING PARTIAL LOADS

Load	%	100,0	90,0	80,0	70,0	60,0	50,0	40,0	30,0	20,0	10,0
Outdoor air temperature	°C	32,0	32,0	32,0	32,0	32,0	32,0	32,0	32,0	32,0	32,0
Cooling load	kWh	823	740	658	576	494	411	329	247	165	82
Fans power input (cooling mode)	kW	19,20	19,20	18,96	16,85	14,74	14,40	14,40	14,40	5,33	3,03
Total power input	kW	254,0	221,4	190,3	170,0	149,7	126,3	102,2	78,10	54,40	30,90
Temp. evaporator inlet	°C	12,00	11,50	11,00	10,50	10,00	9,51	9,01	8,51	8,41	8,41
Temp. evaporator outlet	°C	7,00	7,00	7,00	7,00	7,00	7,00	7,00	7,00	7,00	7,00
Evaporator water flow	l/s	39,44	39,44	39,44	39,44	39,44	39,44	39,44	39,44	39,44	39,44
EER	kW/kW	3,240	3,340	3,460	3,390	3,300	3,260	3,220	3,160	3,020	2,660

HEATING PART LOAD

Load	%	100,0	90,0	80,0	70,0	60,0	50,0	40,0	30,0	20,0	10,0
Outdoor air temp.	°C	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0
Heating load	kWh	714	642	571	499	428	357	285	214	143	71
Total power input	kW	235,4	214,2	193,0	176,7	160,4	134,7	109,0	83,10	58,20	33,20
Condenser input temperature	°C	40,00	40,50	41,00	41,50	42,00	42,51	43,01	43,51	43,52	43,52
Condenser output temperature	°C	45,00	45,00	45,00	45,00	45,00	45,00	45,00	45,00	45,00	45,00
Condenser fluid flow	l/s	37,03	37,03	37,03	37,03	37,03	37,03	37,03	37,03	37,03	37,03
COP	kW/kW	3,030	3,000	2,960	2,830	2,670	2,650	2,620	2,570	2,450	2,150

PART LOAD DATA INTEGRA

Refrigeration load	%	0,0	10,0	20,0	30,0	40,0	50,0	60,0	70,0	80,0	90,0	100,0
Heating load	%	100,0	90,0	80,0	70,0	60,0	50,0	40,0	30,0	20,0	10,0	0,0
Air temp.	°C	4,0	6,8	9,6	12,4	15,2	18,0	20,8	23,6	26,4	29,2	32,0
Cooling capacity	kW	0,000	82,30	164,5	246,8	329,1	411,4	493,6	575,9	658,2	740,4	822,7
Heating capacity	kW	713,5	642,1	570,8	499,4	428,1	356,7	285,4	214,0	142,7	71,30	0,000
Total power input	kW	235,4	187,6	159,1	131,0	109,4	118,3	127,1	143,6	166,8	201,2	254,0
TER	kW/kW	3,030	3,860	4,620	5,700	6,920	6,490	6,130	5,500	4,800	4,030	3,240

In the simulation period, the chiller produces more cooling power than heating power. In a simplified way, the difference between producing only cooling power and cooling power and a smaller percentage of heating power is that the overall electric consumption decreases between 10-20 kW. The fans´ power is turned off in this situation, and the heating power comes without an increase in the electric consumption, in other words, as free energy. That´s the reason the plan is only to shift the exceeding cooling power. To complete the simulation, it´s necessary to attribute a single EER to chiller 3 and another to chillers 1 and 2. These values will be based on the data collected and on the information provided by the datasheet regarding the situation where cooling and heating power is being produced. It´s also necessary to assume the maximum energy output of the ITES. This value will be based on the study in Stage 1 and the information provided by the manufacturer of the ice bank.

Finally, after having all the parameters, we can proceed with the calculations necessary to simulate both strategies. The input data is the thermal energy output of the different chillers over periods of half an hour. This data will provide us with information regarding cooling loads.

Hypothetical Operating Strategy

In this simulation, there are three different scenarios: weekdays, Saturdays, and Sundays. During the weekdays, the totality of the cooling loads during peak hours is shifted to the nighttime if it doesn´t surpass the energy capacity of the ice bank defined; otherwise, the energy shifted is the assumed ice bank´s energy capacity. If the cooling loads during peak hours don´t consume all of it, the remaining will be used to meet the cooling loads during the following hours. On Saturdays, there aren´t hours at the peak, so energy is shifted from the standard hours to the nighttime. On Sundays, the ITES will not be used due to the non-existence of the two most expensive tariffs. The different periods can be checked in Figure 7. Once again, it is important to reinforce that in this building, this strategy is not appropriate due to the equipment installed and the constant DHW needs. Nevertheless, it has value because is the best theoretical result, only considering the maximum storage capacity of the ITES. In Figure 26 a diagram exemplifies the process of calculation. I.B.C. being ice bank capacity, peak loads are the sum of the energy used in peak hours, and standard loads are the sum of energy used in the following hours.

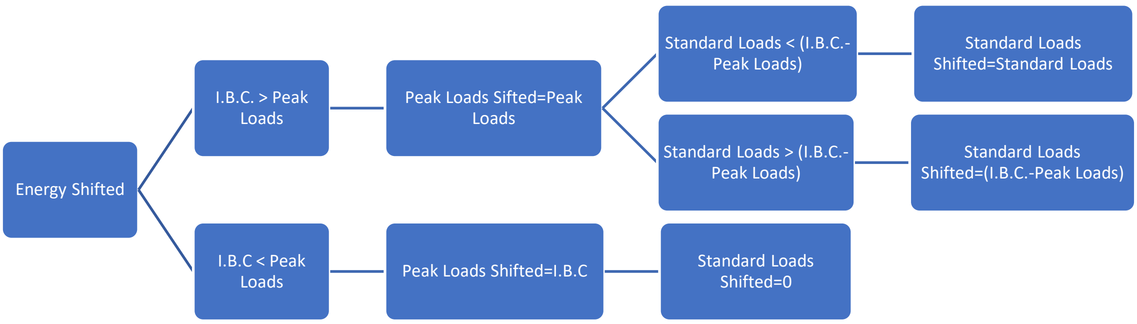


Figure 26- Logic Diagram Hypothetical Strategy of Operation.

Operating Strategy

In this simulation, the heating and cooling loads during peak hours are compared. If the cooling loads are higher, the difference between them will be shifted to nighttime; if not, nothing is shifted. In the standard hours following the peak hours, the strategy is the same, i.e., shifting only the exceeding cooling energy. Note that only the standard hours after the peak hours are fed by the ice bank, and the standard hours before are neglected. This happens to prevent the ice bank from running out before the peak hours, which is the period with the highest benefit. The energy in these periods is always compared to the energy stored in the ice bank and to simulate this strategy is only shifted the energy that ITES can provide. The differentiation between the days of the week is the same as in the previous strategy. In Figure 27 a diagram exemplifies the process of calculation. I.B.C. stands for ice bank capacity; peak loads are the sum of the energy used in peak hours; and standard loads are the sum of energy used in the following hours. C.P.L. and H.P.L. are cooling and heating peak loads, and C.S.L. and H.S.L. are cooling and heating standard loads, respectively.

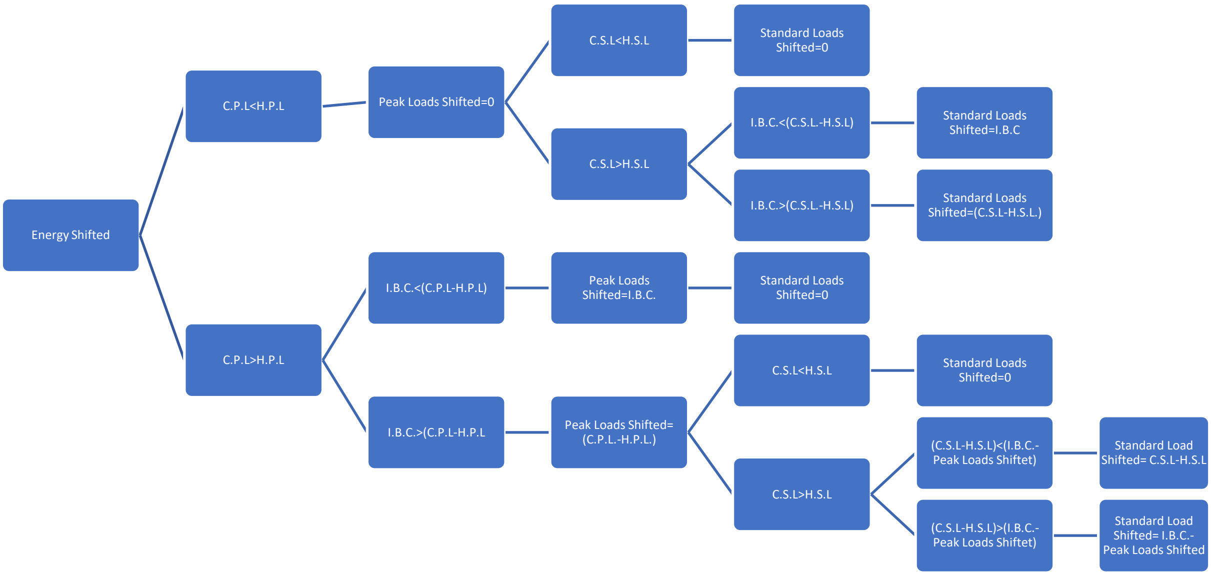


Figure 27- Logic Diagram Strategy of Operation.

After applying both strategies, the output data will be **energy shifted during peak** hours and energy **shifted during standard hours**; both are shifted to off-peak hours, also referred to as nighttime. Now, this data is processed to obtain the cost reduction, but first, it is important to understand how this energy is invoiced. The first parcel influences the price of the kWh in different periods, so it´s possible to sum them up and have an equivalent price per period. The other parcel is the price per kWh on-peak, which currently represents a big share of electricity costs. The monetary value of the power at peak can be calculated using equation (2).

$$Cost\ reduction = \frac{Energy\ consumed\ on{-}Peak\ per\ month\ [kWh]}{Number\ of\ monthly\ Peak\ Hours} \times Power\ price\ \left[\frac{€}{kWh}\right] \times 30\ Days \tag{2}$$

Table 6- 2022 Electricity Prices.

2022

	Active Energy	Reg. Res. Band	Grid Access Energy	∑ Prices	Power on Peak
Peak	0,190956	0,001171	-0,02870	0,192127	
Standard	0,190502	0,001163	-0,0293	0,191665	
Off-Peak	0,171878	0,001147	-0,0308	0,173025	0,2189€/kW
Super Off-Peak	0,172210	0,001140	-0,0308	0,173350	

Table 7- April´s 2023 Electricity Prices.

2023

	Active Energy	Reg. Res. Band	Grid Access Energy.	Pass pool (multi)	∑ PRICES	Power on Peak
Peak	0,005831	0,002864	-0,050400	0,074800	0,033095	0,2284€/kW
Standard	0,006052	0,002846	-0,050900	0,085000	0,042998	
Off-Peak	0,006511	0,002812	-0,052000	0,066000	0,023323	
Super Off-Peak	0,007117	0,002792	-0,052400	0,089900	0,047409	

In terms of electricity tariffs, in this simulation, we are using the electricity prices of 2022 and 2023 since the building´s management changed the contract. However, the 2022 electricity prices are fixed, the 2023´s new contract is where the prices can fluctuate according to the supply and demand in the electricity market, so it can be unpredictable. To resolve this issue, it was used the most recent electricity invoice, April 2023, to calculate the prices per kWh for the different hourly periods. Assuming that the electricity price stays the same as in April can deviate the study from reality; however, that is the only data available, so it´s necessary to keep this decision in mind when analyzing the results.

After analyzing the electricity prices, it´s possible to calculate the cost reduction. The cost reductions are done by three different equations; the energy transferred from peak and standard hours to off-peak can be done using equation 3.

$$Cost´s\ Reduction = \left(\frac{p_2 - p_1}{EER}\right) \times Energy\ shifted \qquad (3)$$

Where p_1 and p_2 are the prices of the energy in the period where the energy is being shifted from and the period where the energy is being shifted to, and EER is the energy efficiency ratio of the chiller. This equation is used for the energy transfers in the peak and standard periods. After that, the sum of all the peak hours shifted during a month is used in equation (2). Lastly, the sum of the three equations represents the cost reduction for each month. The simulation will be carried out in the months when most of the time the cooling loads exceed the heating loads. When this does not happen, this strategy can´t be applied for the reasons described previously.

After obtaining the results, it will be possible to draw conclusions about the feasibility of this ITES system and how to improve it.

5 Analysis and Results

As referred to previously, this chapter will be divided into two parts. In the first stage, numerous tests were conducted on the ITES to ensure proper function, optimize the system, and assess charging and discharging times, and capable power output. The second stage consists of a new economic study adjusted to current electric tariffs where a new strategy is adopted to maximize cost reductions.

5.1 Stage 1-Commissioning

5.1.1 Basic Requirements and programmed logic

The first step to start the ITES commissioning was to ensure that all the parts involved were still operational, is important to take into consideration that the ice bank was made fully operational three years ago but has never been used. After ascertaining the state of the water, it was notorious that the water was contaminated by algae and other forms of residue. Upon further research, the advised method to clean an ice bank is using a biocide that doesn´t contain Chlorin and doesn´t change the freezing point of the water.

Figure 28- Interior pipes of the ice bank before using biocide.

After cleaning the water, it was noticed that the ice bank had an ice level equal to -4%, so, as instructed by the installation and operation manual provided by the manufacturer, more water was added to the ice bank. However, due to the contraction of water when approaching negative temperatures, the tank must be refilled in the first charging when the temperature is close to 0^{o} C until it reaches the 0% mark.

Before starting the first test all the valves and pumps were activated during the night to verify that they work and to run all the hydraulic circuits of the chiller 3/ ITES to check for irregularities. The following morning ITES was ready to be charged. The objective of this first charge was to only evaluate the pressures and programmed logic of the system. The ice bank was charged with no problem. the required conditions are:

- Chiller 3 Setpoint -5/-1ºC
- VM6; VM5 and VM1; VM2 closed and VM3; VM4 open.
- BPF5.3/3R pump on

Since all the "cold" produced by Chiller 3 is being used to charge the bank, the pumps, BPBG1.1/1R; BSBG1.2/2R; BSBG1/1R, are off. To get a clearer idea of the location of the valves and pump, consult the Figure 29.

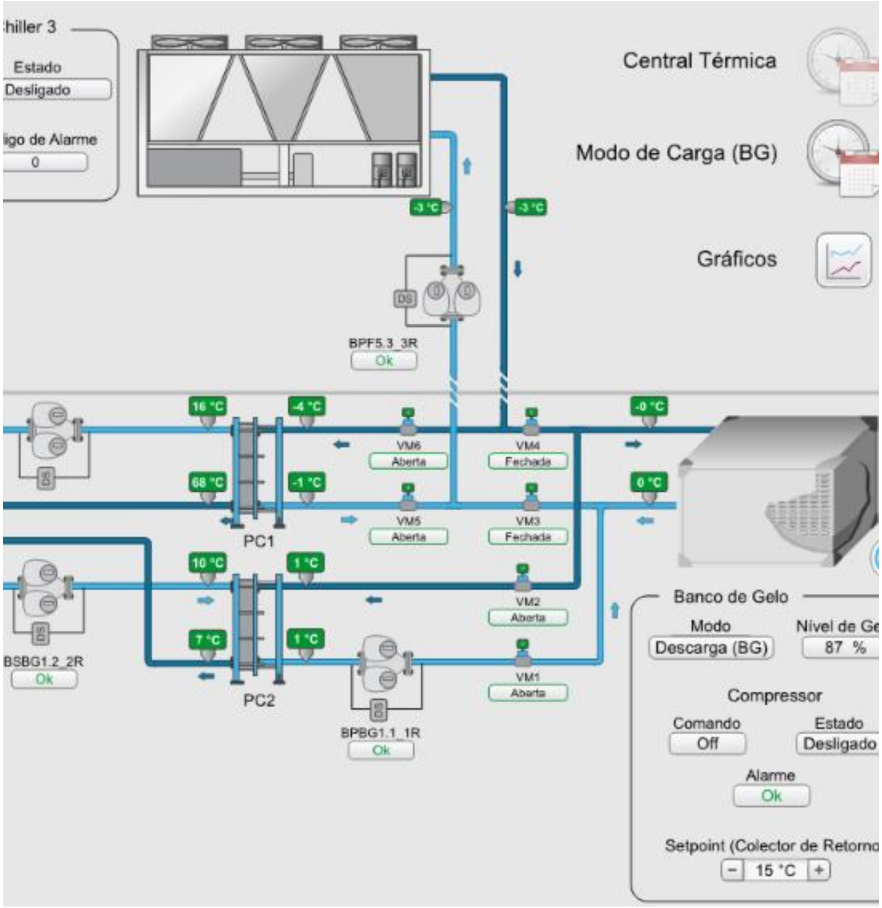


Figure 29- ITES image from the BMS.

In the discharging phase, the required conditions are:

- VM3; VM4 closed and VM1; VM2 open.
- BPBG1.1/1R pump on.
- BSBG1.2/2R pump on.

These conditions were met; however, during discharge, the pumps of the primary circuit of Chiller 3 and the pump of the secondary circuit of Chiller 3 were turned on. In this case, the ice bank was in charge of meeting the loads, and the chiller 3 was off, so there was no reason for these pumps to be on; it was a waste of electricity. To have a clear picture of the events, Table 8 shows what went wrong.

Table 8- State of valves and pumps of Chiller 3/ITES Logic.

	VM1	VM2	VM3	VM4	VM5	VM6	BPF5.3/3R	BPG1.1/1R	BSBG1/1R	BSBG1.2/2R
Conventional Chiller Use	0	0	0	0	1	1	1	0	1	0
Charging	0	0	1	1	0	0	1	0	0	0
Storage	0	0	0	0	0	0	0	0	0	0
Discharging	1	1	0/1	0/1	0/1	0/1	1	1	1	1

The two pumps should not be on. So, a logic command was put into practice, the only time these pumps are turned on during discharging is when we are using the partial storage strategy, where both the chiller and the ice bank contribute to meet the loads(very rarely), or during the moments where we switch from charging to discharging because the Chiller 3 circuit will still have useful cooling power that can be used by the building. In this case, the pump will be turned off when the temperature of this circuit reaches a not-useful temperature, of around 12ºC.

5.1.2 Temperatures and cycle time evaluation

Starting with the charging of the Ice Bank, this procedure was divided into three days, the full charge could be done continuously, but it was opted to perform the test during the working hours of the technicians to prevent irreversible malfunctions. Regarding the charging process, it´s important to analyze the output and input power of the chiller 3 and the ice bank, respectively, and the inlet and outlet temperatures.

Chiller 3´s performance in the subfreezing setpoint was worse than expected. To have a clearer and more objective view of the collected data it´s wise to separate the charging test into three stages: day 1, day 2, and day 3.

Day 1

On day 1, the charging had a duration of roughly 7 hours. Figure 30 displays the inlet and outlet temperatures of Chiller 3.

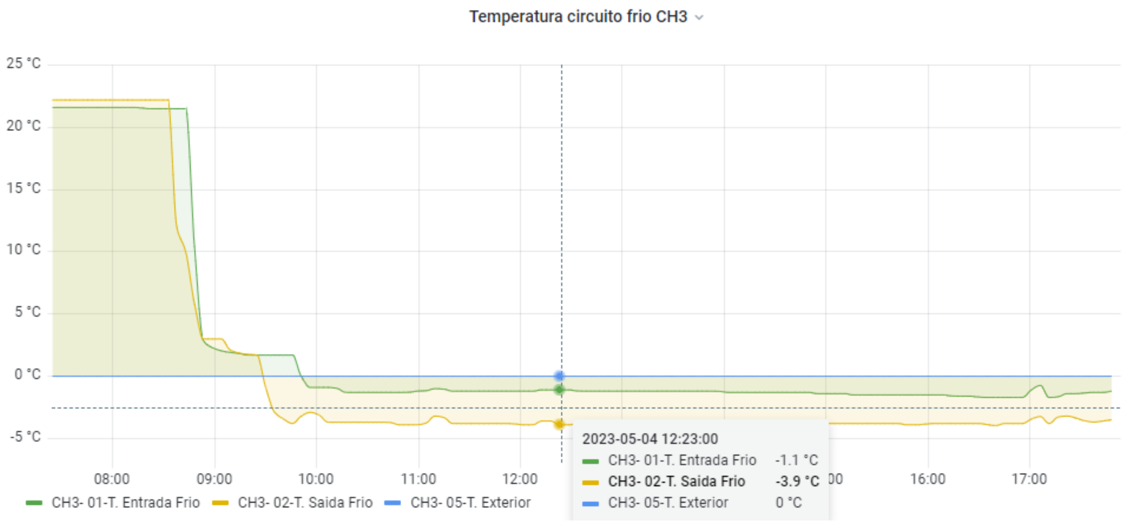


Figure 30 - Inlet and outlet temperature of Chiller 3 during charging.

The expected ΔT of 4º C was not achieved, the average ΔT was roughly -2.8º C. We can compare the temperature difference to the temperature difference in the Ice Bank, Figure 31.

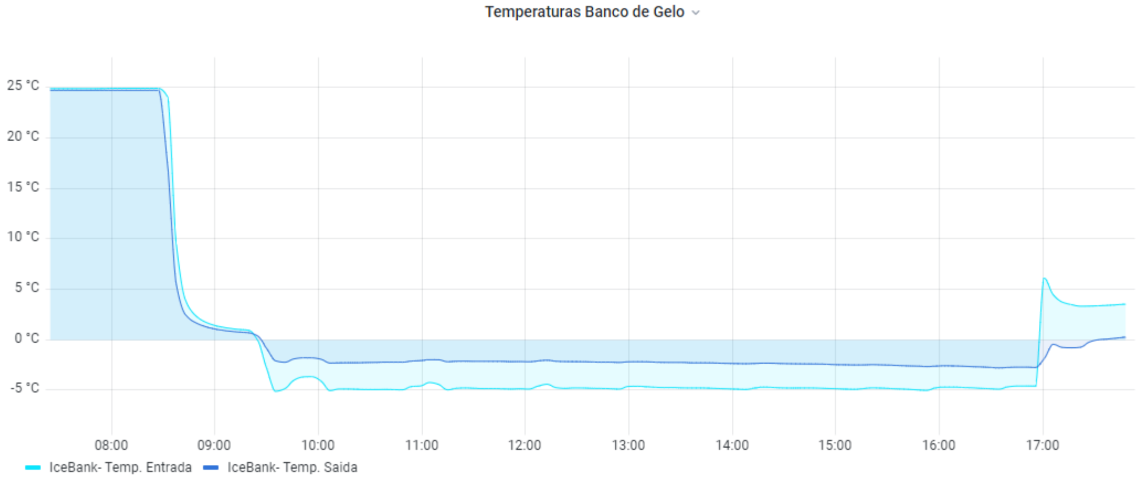


Figure 31- Inlet and outlet temperatures of the Ice Bank while charging.

The ΔT is essentially the same as in the chiller, but the temperatures are lower in the Ice bank, which is impossible. This happens due to some possible miscalibration in the temperature probes; however, the most important factor is the ΔT which is the same, so there is some assurance that the cooling power is being delivered with no problem. In terms of power, as expected, after analyzing the ΔT, is lower than the expected value of performance at this setpoint.

Figure 32- Chiller 3 Power output in subfreezing setpoint.

The maximum power output was 644 kW, and the expected value for this setpoint according to the datasheet given by the manufacturer was 800 kW. The reasons for this underperformance of the chiller 3 transcend this study and should be a target of a thorough investigation. Nevertheless, the EER achieved and the ratio between output power and power consumption were satisfactory. The power consumption can be consulted in Figure 33.

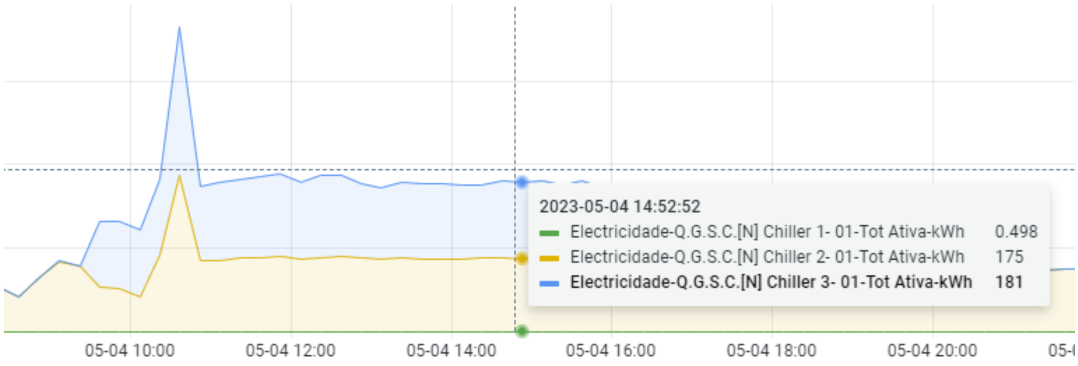
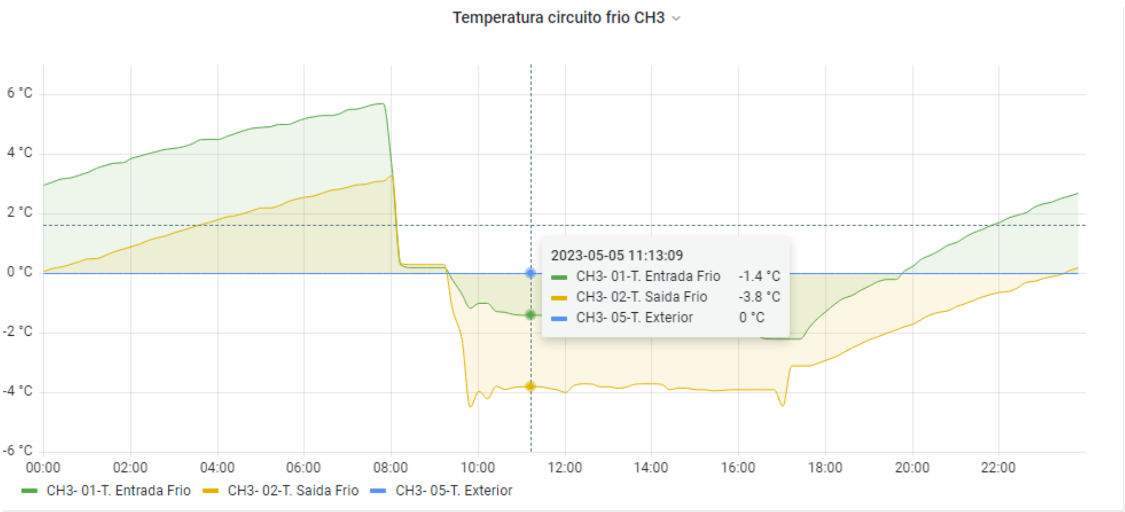


Figure 33- Power consumption by the chiller 3 in blue.

The power consumption was always some units below the nominal power of 217 kW, averaging 180 kW.

The power output during the charging hours matches the percentage of ice achieved when considering that some cooling power was used to meet the sensible power necessary to lower the temperature of the ice bank from ambient temperature to phase-changing temperature. The Ice percentage achieved in 7 hours of charging was 45%, which corresponds to 3600 kWh of energy stored in latent heat. There´s even more cooling capability stored in sensible heat. This energy is enough to meet the cooling loads of the building during peak hours. 2022 data provided by DTWay showed that on the hottest day of 2022, the combined output power of the chillers during peak hours was 1200 kW. The peak hour during the summer season for medium voltage has a duration of 3 hours. So, 3600 kW covers the expected demand in the limit situation. However, it´s always possible to charge for more than 7 hours if necessary.

On day 2, the charging of the Ice bank was resumed. The temperatures of the chiller 3 and the ice bank inlet and outlet had a small decrease as well, according to ΔT.



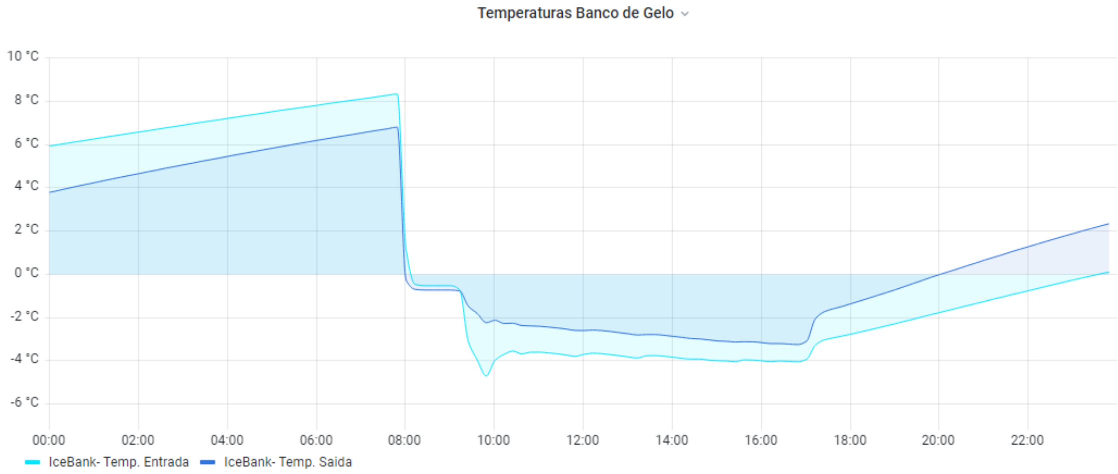


Figure 34- Inlet and outlet temperatures of chiller 3 and Ice Bank on day 2

As the difference in temperature decreases the cooling power transferred to the Ice Bank also decreases. This phenomenon can be explained by the thickening of the ice around the coil inside the Ice Bank. The ice has a lower heat conductivity than water so the overall heat transfer coefficient decreases.

The output power of chiller 3 confirms the decrease in heat transfer.

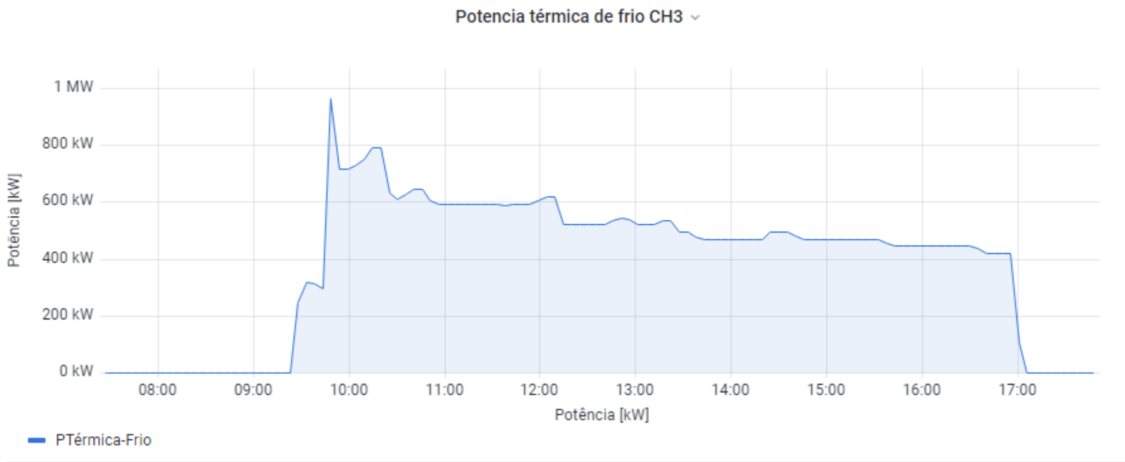


Figure 35- Output power of Chiller 3 on day.

As shown in Figure 35, the average cooling power produced by the Chiller 3 during the charging process had a noticeable decrease when compared to Day 1. Which is expected, as referred to in the state-of-the-art chapter. It´s also noticeable that the power consumption also decreases as expected. The EER had a slight increase. The percentage of Ice obtained in the Ice bank on day 3 was around 68%.

On Day 3, the decrease in the charging rate was substantial. The difference in temperatures was lower as well as the actual temperatures; since the ice bank was not able to absorb all the cooling power provided by the chiller 3, the working fluid starts to decrease in temperature.

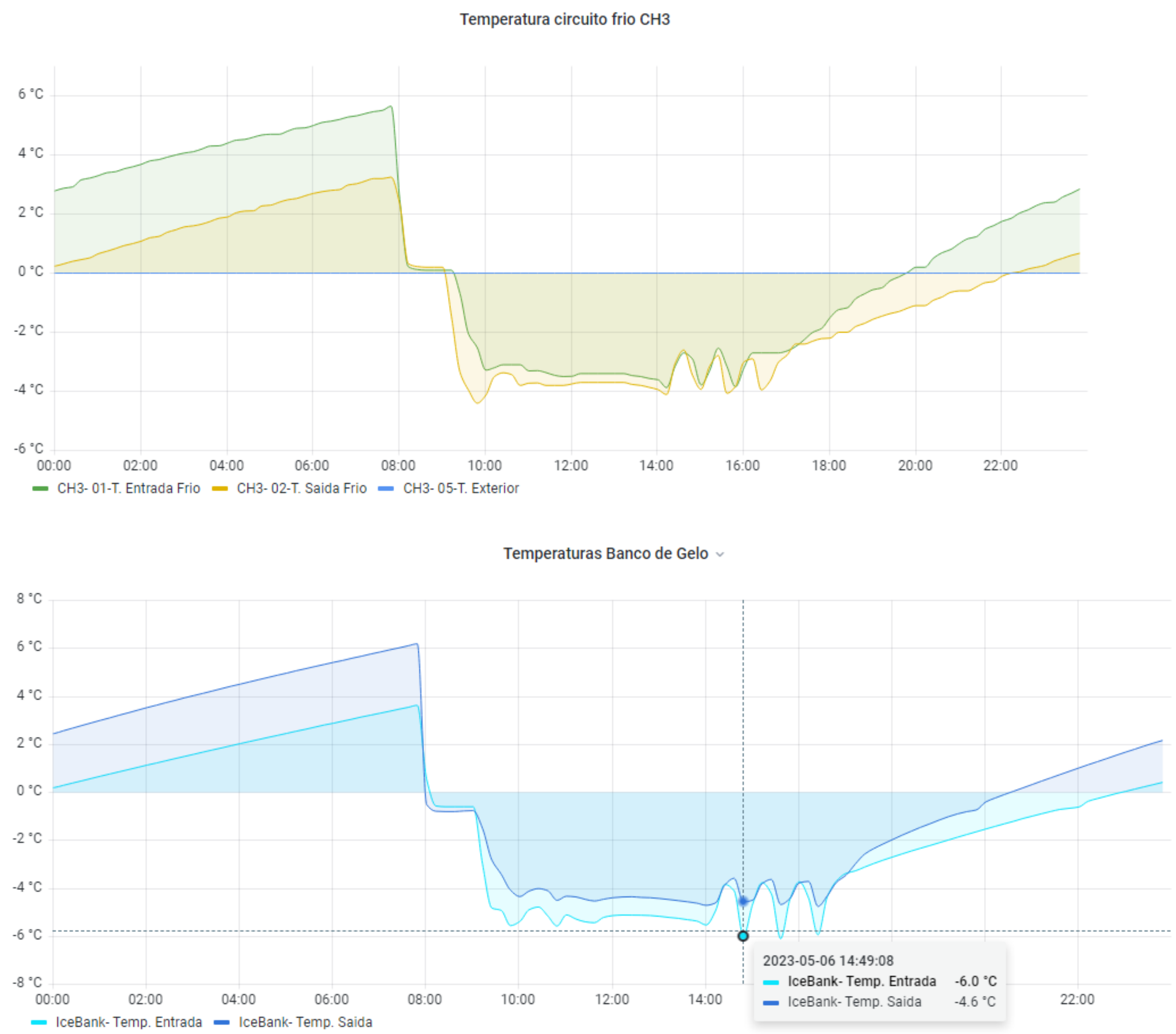


Figure 36- Inlet and outlet temperature in the chiller 3 and Ice bank.

As the Ice bank reaches its maximum capability, the ice thickness negatively impacts heat transfer. Once again, the power output of chiller 3 is lower and decreases during day 3. The percentage reached on day 3 was around 85 %.

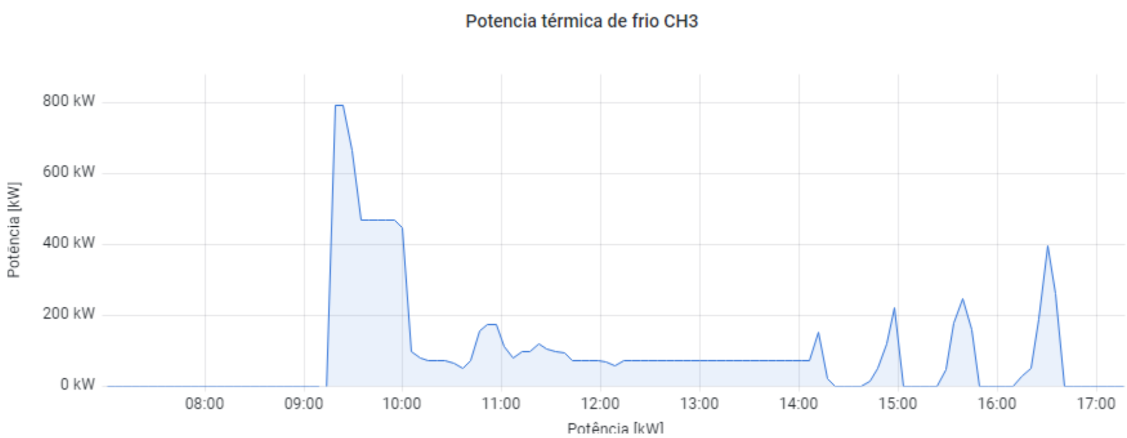


Figure 37- Chiller 3 Power output during Day 3.

After completing the charging tests, which were intended to test the discharging process, the information taken out of this test must be analyzed with critical thinking since the cooling power output provided by the Ice bank is heavily dependent on the building cooling loads. So, the main objective of this test is to evaluate the process in terms of malfunctions rather than energy transfer. Shortly after the discharging process began, it was possible to notice that the output power was very low, and the temperatures were also lower than the design temperatures since it was tested on a day with low cooling needs. However, an important observation was made. As we can see in Figure 38, the temperature in the heat exchanger 2 on the secondary side crossed the phase-changing temperature of water for a moment, and then the test was stopped immediately. The negative temperature on the secondary side can bring tremendous problems to the installation; there´s a risk that the water solidifies or turns into a slurry mixture of ice and water that can negatively impact the water pumps or even break the heat exchanger by water expansion when changing to ice.

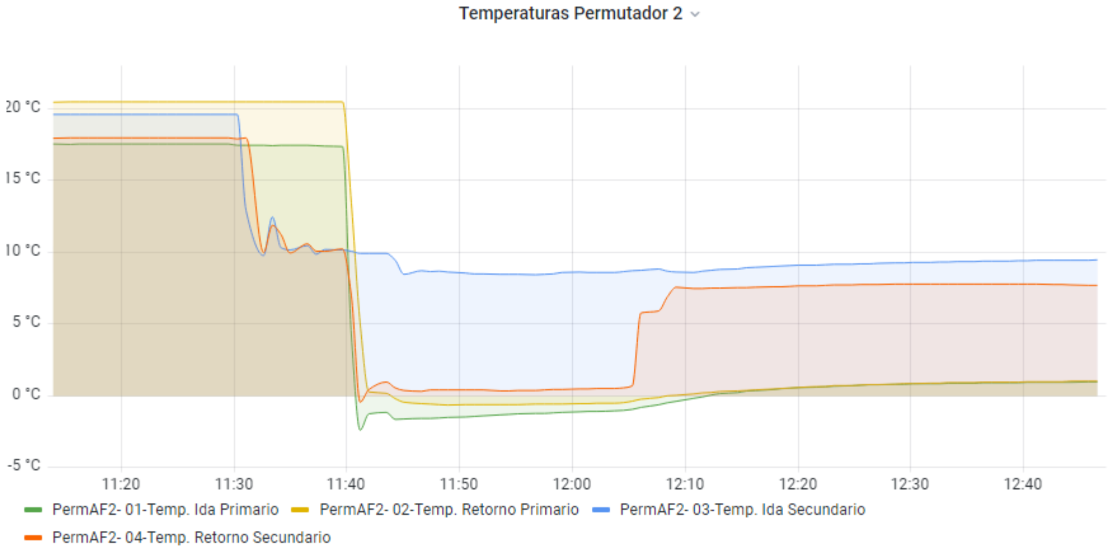


Figure 38- Heat exchanger 2 for Ice bank discharge.

The red line represents the outlet flow temperature on the secondary side of the heat exchanger. The secondary side does not have this problem since the working fluid is a mixture of water and glycol, which has a lower freezing point. There were two solutions to this problem: the first was to shut down the primary pump every time the temperature on the secondary side was lower than 2ºC, and the second was to add a flow controller on the primary side that allows the pump to lower or increase the flow, which can control the cooling power transferred in the heat exchanger 2. The second solution is better because extreme days can help deliver higher cooling power to the building by increasing the flow. The technicians of the building opted for the second solution. Nevertheless, more programmed safety measures were added to the BMS.

To summarize the important results extracted from these tests, a graph of the percentage of ice during the time in question and all the data that is going to be used in the Strategy of Operation and Economic Evaluation.

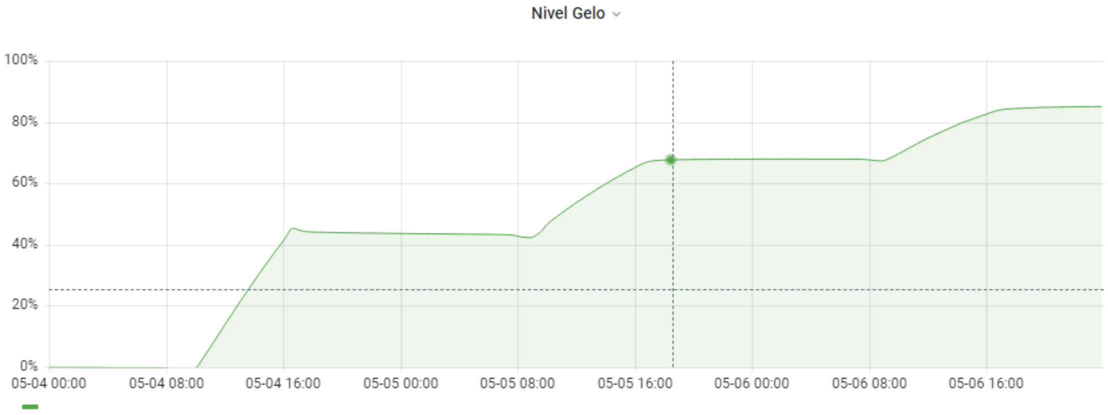


Figure 39- Level of Ice throughout the days of testing.

Main Results

- Energy stored in 7 hours is enough to meet the building cooling loads in the limit situation (3600 kWh).
- The EER was always superior to 3.
- The losses in energy stored for 24 hours are negligible (below 0.5%).

5.2 Stage 2- Strategy of Operation and Economic Evaluation

In this section, the results obtained from the different solutions will be discussed, as well as any considerations that were made. Starting by explaining the EER, the electricity tariffs, and the time schedule used in the simulation. Then, all the different results will be analyzed in an objective and clear way.

After carefully analyzing the datasheet and the data from 2022, it was possible to conclude that the average EER of chiller 3 is identical to the EER of chillers 1 and 2. So a constant EER of 3 is used throughout the study. This assumption may bring a small error to the results; however, using different EERs for every possible situation is counterproductive.

To recall, the schedule can be found in Figure 7, where there are 3 hours on-peak, which is the energy reduction priority, followed by a period of standard hours. The objective is to reduce the maximum amount of energy consumed during these periods.

Starting with the analysis of the hypothetical strategy and the strategy of operation with the 2022 electricity prices, the data from both strategies can be found on Table 9 and Table 10, respectively.

Table 9- Hypothetical Strategy Summarized 2022.

Hypothetical Strategy Summarized								
Month	Cooling Energy demand on Peak [kWh]	Energy provided by the ITES on Peak Hours [kWh]	Cooling Energy demand on the following standard hours (flat preiod) [kWh]	Energy provided by the ITES in standard hours (flat hours] [kWh]	Cost reductions on Peak 2022 Tariff [€]	Cost reductions Standard hours 2022 Tariff [€]	Power on Peak Reduction costs 2022 [€]	Sum of the costs reductions 2022 Tariff €
April	22854,29	22854,29	50158,21	49482,87	143,05	302,09	797,36	1242,50
May	39761,73	39761,73	85913,34	54892,34	248,87	335,12	1324,19	1908,17
June	51740,15	51740,15	116483,67	44459,85	323,84	271,43	1723,10	2318,37
July	63412,11	62249,24	144507,47	33853,61	389,62	206,68	2171,81	2768,10
August	58622,72	58622,72	105353,13	40778,31	366,92	248,95	1867,43	2483,30
September	54079,24	54079,24	91475,43	37799,85	338,48	230,77	1801,00	2370,25
October	38920,59	38920,59	60278,90	46855,08	243,60	286,05	1296,17	1825,83
November	27019,71	27019,71	41028,52	34942,39	169,12	213,32	899,84	1282,28
Sum	356410,55	328227,96	654170,15	308121,91	2223,50	2094,41	11880,90	16198,81

Only 8 months (from May to October) were tested since in April and November, most of the days the heating loads are higher than the cooling loads, so the main strategy can´t be applied. If this strategy could be applied without increasing the costs of DHW production, it would be promising. Another interesting point is the fact that the second column is equal to the first column in every month except April and July. This means that the energy that the ice bank can charge in a day is compatible with the peak demands. However, the same cannot be said regarding standard hours; in this case, it´s clear that the ice bank wasn't able to respond to this period´s loads, as shown in columns 3 and 4.

In this situation, all the energy that the ice bank can store is shifted, resulting in a cost reduction of 16 198€.

Table 10- Strategy 1 Summarized 2022.

Strategy 1 Summarized								
Month	Difference between Cooling and Heating Energy during Peak Hours [kWh]	Energy provided by the ITES on Peak Hours [kWh]	Difference between Cooling and Heating Energy during off-Peak Hours [kWh]	Energy provided by the ITES in standard hours (flat hours] [kWh]	Cost reductions on Peak 2022 Tariff [€]	Cost reductions Standard hours 2022 Tariff [€]	Cost reductions Peak Power 2022 Tariff [€]	Sum of the costs reductions 2022 Tariff €
April	1050,33	1050,33	980,29	980,29	6,57	5,98	36,64	0,00
May	17284,34	17284,34	35165,20	30013,04	108,18	183,23	575,62	867,03
June	26474,95	26474,95	52558,60	42531,45	165,71	259,65	881,70	1307,06
July	50507,99	49520,08	112001,50	42389,34	309,95	258,79	1727,70	2296,43
August	48395,05	48395,05	73131,29	47684,76	302,90	291,12	1541,63	2135,65
September	43492,75	43492,75	56263,55	37849,06	272,22	231,07	1448,44	1951,73
October	25603,04	25603,04	16973,49	16973,49	160,25	103,62	852,66	1116,53
November	1010,43	5948,40	1045,56	1045,56	37,23	6,38	207,53	0,00
Sum	213818,88	217768,94	348119,48	219466,99	1363,02	1339,85	7271,92	9674,43

Now, applying the realistic strategy, the reduced costs for the 6 months where the strategy can be applied are 9 674 € (Table 10). This isn´t desirable; most of this reduction comes from the power consumption on the peak parcel, as observed in the column "cost reductions Peak power 2022 Tariff [€]". Since the different prices per period are very close to each other, the energy transferred in both peak hours and standard hours does not have a great impact on cost reduction, making the return on investment greater than 10 years. In this case, it´s possible to conclude that energy stored in the ice bank during nighttime is more than enough to cover the peak hour periods, and it´s not far from covering the standard periods, as we can see from the column covering the standard hours.

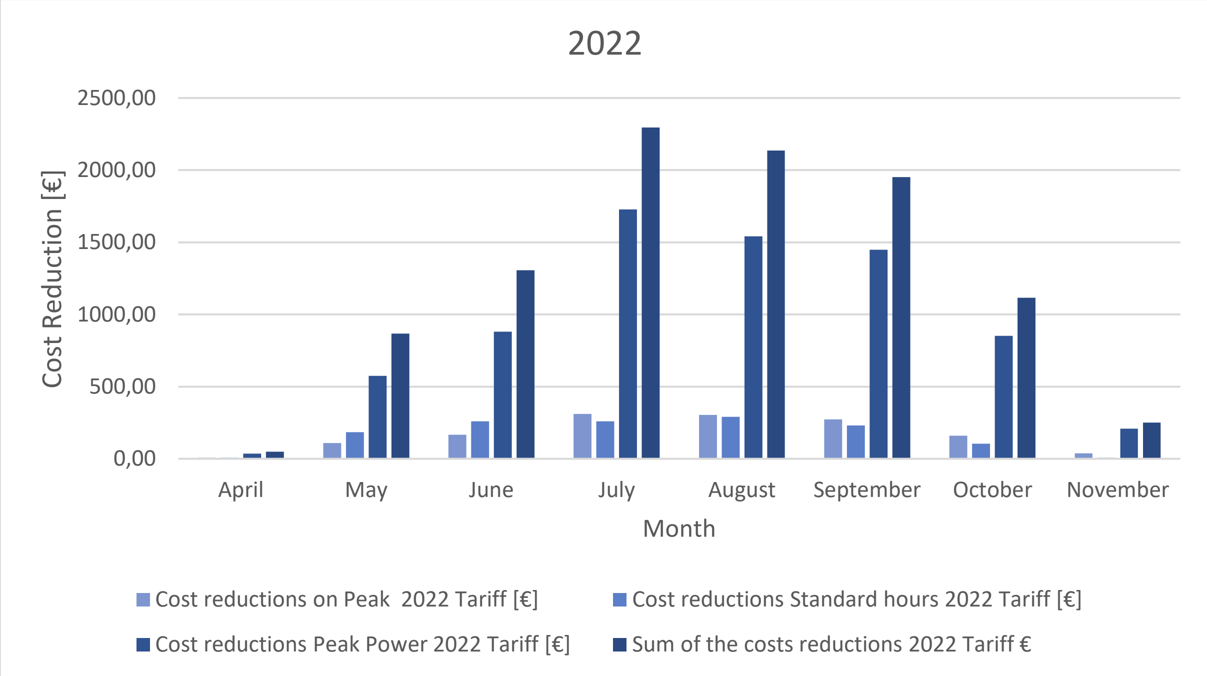


Figure 40- Contribution of costs reduction by each parcel and their sum.

As explained previously, this graph shows the weight of each parcel, and the difference between electricity prices across the day doesn´t represent a big share in the total costs' reductions due to the proximity in prices of the different time periods. Now, comparing the two strategies, it is possible to notice that the strategy of operation 1 reached roughly 65% of the amount in the hypothetical strategy of operation. As expected, the months that have the highest contribution are the ones that typically have the highest temperatures.

Table 11- Hypothetical Strategy Summarized 2023.

Hypothetical Strategy Summarized								
Month	Cooling Energy demand on Peak [kWh]	Energy provided by the ITES on Peak Hours [kWh]	Cooling Energy demand on the following standard hours (flat preiod) [kWh]	Energy provided by the ITES in standard hours (flat hours) [kWh]	Cost reductions on Peak 2023 Tariff [€]	Cost reductions Standard 2023 Tariff [€]	Power on Peak Reduction costs 2023 [€]	Sum of the costs reductions 2023 Tariff €
April	22854,29	22854,29	50158,21	49482,87	-109,05	-72,76	828,56	646,8
May	39761,73	39761,73	85913,34	54892,34	-189,72	-80,71	1376,00	1105,6
June	51740,15	51740,15	116483,67	44459,85	-246,87	-65,37	1790,52	1478,3
July	63412,11	62249,24	144507,47	33853,61	-297,01	-49,78	2298,94	1952,2
August	58622,72	58622,72	105353,13	40778,31	-279,71	-59,96	1940,50	1600,8
September	54079,24	54079,24	91475,43	37799,85	-258,03	-55,58	1871,47	1557,9
October	38920,59	38920,59	60278,90	46855,08	-185,70	-68,89	1346,89	1092,3
November	27019,71	27019,71	41028,52	34942,39	-128,92	-51,38	935,05	754,7
Sum	356410,55	328227,96	654170,15	308121,91	-1695,01	-504,42	12387,92	9433,75

When using the 2023 electricity prices, it is noticeable the decrease in costs reduction. With this electricity tariff, the prices during the day are lower than the prices during the night; however, the power price at the peak is similar, making this strategy not optimal for this tariff but very close. The optimal strategy for 2023 is similar, but the ice bank stops feeding the building after peak hours. This strategy rules out the column "cost reductions standard 2023 Tariff [€], making the cost reductions go from 9 434 € to 9 938 €.

Table 12- Strategy 1 Summarized 2023.

Strategy 1 Summarized								
Month	Difference between Cooling and Heating Energy during Peak Hours [kWh]	Energy provided by the ITES on Peak Hours [kWh]	Difference between Cooling and Heating Energy during off-Peak Hours [kWh]	Energy provided by the ITES in standard hours (flat hours] [kWh]	Cost reductions on Peak 2023 Tariff [€]	Cost reductions Standard hours 2023 Tariff [€]	Cost reductions Peak Power 2023 Tariff [€]	Sum of the costs reductions 2023 Tariff €
April	1050,33	1050,33	980,29	980,29	-5,01	-1,44	38,08	0,00
May	17284,34	17284,34	35165,20	30013,04	-82,47	-44,13	598,14	471,54
June	26474,95	26474,95	52558,60	42531,45	-126,32	-62,54	916,19	727,34
July	50507,99	49520,08	112001,50	42389,34	-236,28	-62,33	1795,30	1496,70
August	48395,05	48395,05	73131,29	47684,76	-230,91	-70,11	1601,95	1300,92
September	43492,75	43492,75	56263,55	37849,06	-207,52	-55,65	1505,11	1241,94
October	25603,04	25603,04	16973,49	16973,49	-122,16	-24,96	886,02	738,90
November	1010,43	5948,40	1045,56	1045,56	-28,38	-1,54	205,85	0,00
Sum	213818,88	217768,94	348119,48	219466,99	-1010,67	-321,15	7546,64	5977,35

Now applying the realistic strategy, the costs of the reductions for the 6 months where the strategy can be applied are 5977 €, which is not desirable and results in a return-on-investment superior to 15 years. However, this is not the most optimal strategy as well; the ice bank working in the standard hours does not bring any value and decreases the cost reductions. So, applying the strategy without the column "cost reductions standard hours 2023 Tariff [€] "results in a final value of 6 298 €, still making it a bad investment. For this strategy of only covering the peak hours, the stored energy in the ice bank is adequate, and there is no value in increasing the energy stored since the standard hours are no longer supplied by the ITES.

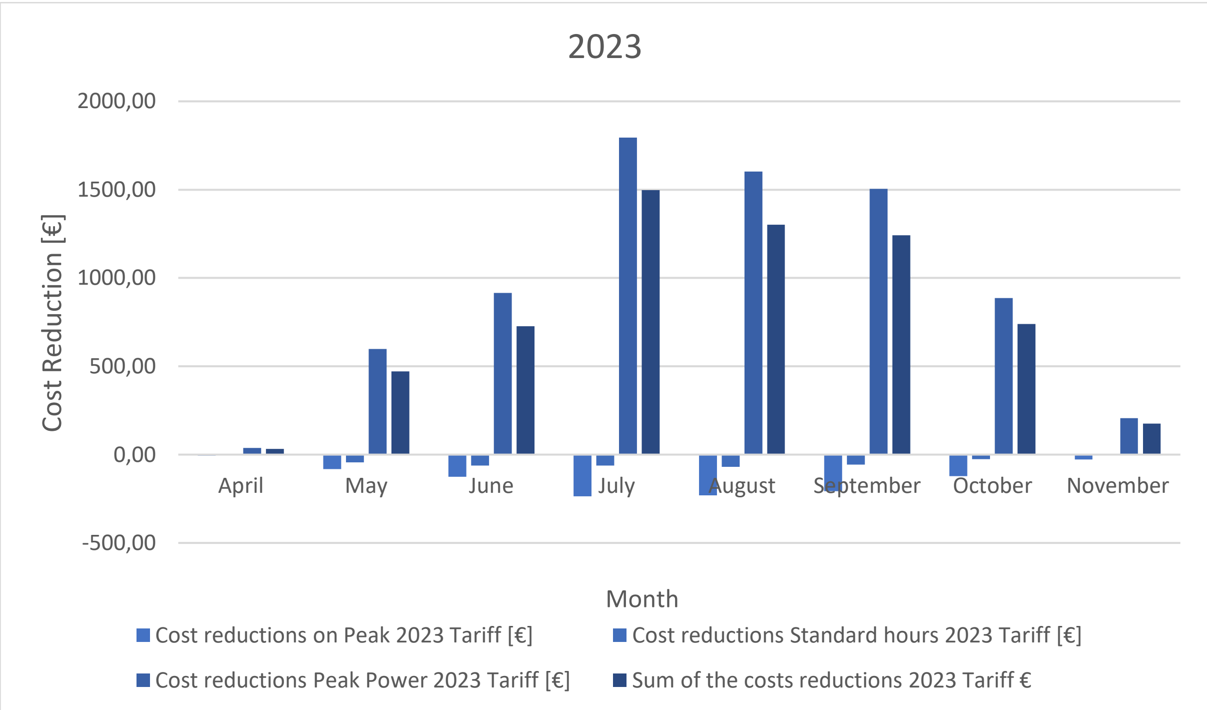


Figure 41- Contribution of each parcel in the cost's reductions 2023.

From Figure 41, it is possible to observe the contribution of each parcel to the cost reduction. Once again, it is shown that the energy shifted in the standard hours brings a decrease in the cost reductions (see the second column of each month). The energy shifted in peak hours also brings a decrease in cost reductions. However, there is nothing that can be done to prevent this decrease since this energy is also responsible for the decrease in power consumption on peak, which is accountable for the totality of the cost reduction.

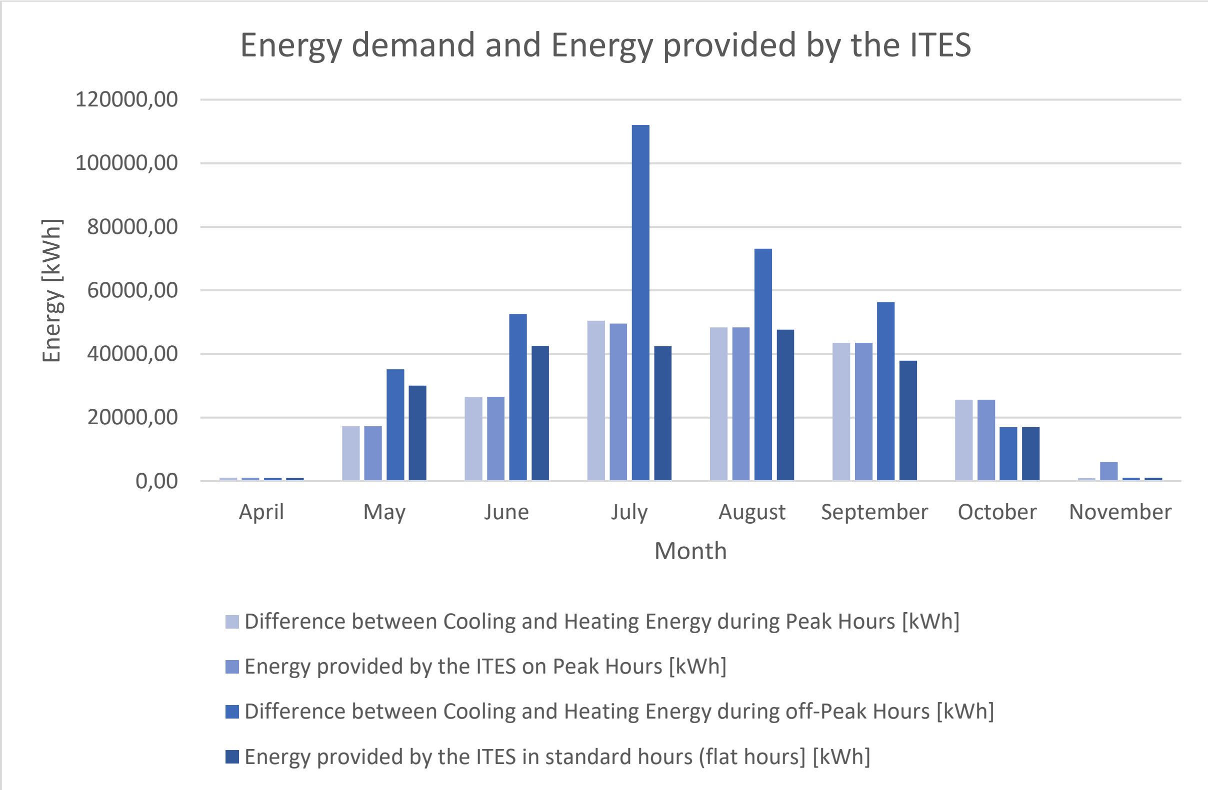


Figure 42- Energy demands and energy provided by the ITES in different periods.

Now in terms of capacity, it is possible to see in Figure 42 the demand of energy and the energy provided by the ITES, and it´s is shown that during the peak period the ITES as enough energy stored to meet the needs, in the standard hours this doesn’t always happen.

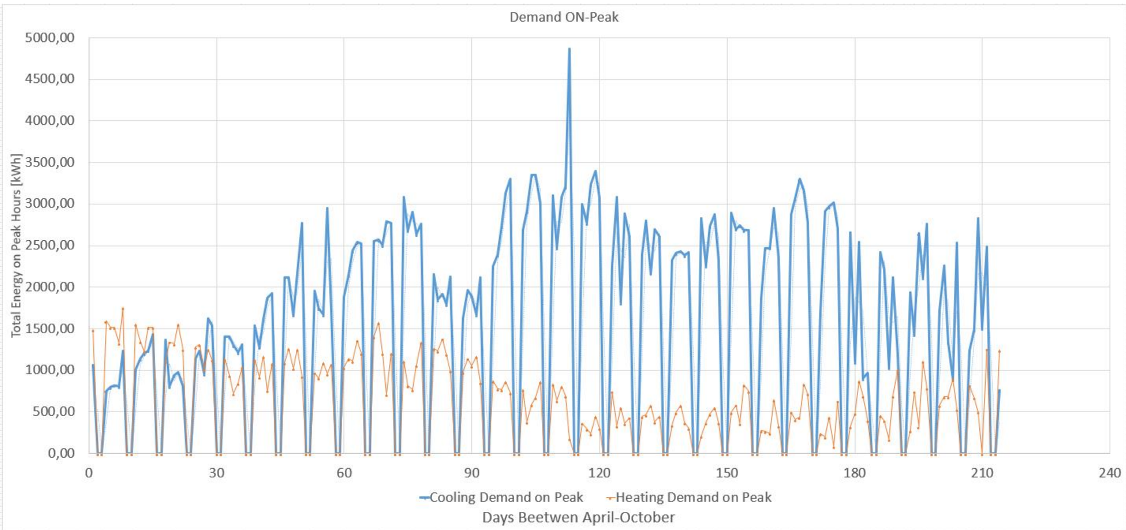


Figure 43- Daily cooling and heating demands peak between April and October.

This ITES is very limited by the installation and the building´s needs. The constant DHW needs and the fact that the chilled water system and domestic water system are connected and depend on each other make the inclusion of ITES on the installation very challenging. The concentration of the electricity prices throughout the day makes it even more challenging. Despite the small cost reduction that this strategy can achieve, the building management must make that decision.

6 Conclusions

This study describes the commissioning and economic assessment of an ITES system, that provides results of the actual function and possible cost reductions of the system. With this data it is possible to draw conclusions. In the commissioning of the ice bank, it was noticed that the time of charging was not what was expected. This had a monetary impact on the simulation with the 2022 tariff because the ice bank was not able to meet the totality of the cooling loads in the standard period. In the 2023 simulation, this lack of storage didn´t have an impact because the optimal strategy was to have the ITES only work during peak hours. The programmed logic of the system was optimized to ensure minimum electricity consumption by the water pumps. The problem regarding the low temperature on the heat exchanger´s secondary side was solved by implementing safety measures and a rate flow controller. Regarding the economic evaluation, if it were needed to decide whether an ITES system should be installed in the building, the decision, according to this study, would be that the ITES is not economically feasible. The ITES brings a low-cost reduction, resulting in a more than 15-year return on investment, mainly due to the current electricity prices, the characteristic of the installation, and the building´s demands. Moreover, it has a cooling system that affects the efficiency of the heating system and vice versa; this aspect should have been considered at the time of design. However, the system is already installed and can add value despite having a low impact on the electricity bill. An ITES system can be very volatile because its feasibility is directly connected to the electricity prices, which can have great fluctuations, even more so in the instable times that we live in. Also, this system requires annual attention to develop new strategies to adjust the system to the electricity tariffs. Overall, this is an investment that should be carefully studied before implementation and needs an occasional review of the operating strategy.

6.1 Perspectives for Future Works

For future works, it would be interesting to study the chiller 3´s low output power when it is on the subfreezing setpoint. This aspect is directly related to the increase in charging time, and this could be a problem with the chiller or the heat exchanger inside the ice bank. Another study could be the development of software that has as input the meteorological information and social events of the following day in the building to predict the amount of energy that must be charged in the ice bank to reduce the losses of storage. Lastly, and with more impact on the cost reduction, study the possibility of also shifting the heat loads of the de building, not necessarily to the nighttime but to the previous hours, with the objective of not having any electric consumption during the peak hours. Since the peak hours have a great monetary impact, this proposal can have higher costs reduction than the hypothetical strategies studied.

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Annexes

Annex 1- Daily Results of Hypothetical Strategy

Hypothetical Strategy											
date	weekday	Cooling Energy demand on Peak [kWh]	Energy provided by the ITES on Peak Hours [kWh]	Cooling Energy demand on the following standard hours (flat preiod) [kWh]	Available Energy in the ITES after Peak hours [kWh]	Energy provided by the ITES in standard hours (flat hours] [kWh]	Cost reductions on Peak 2022 Tariff [€]	Cost reductions off Peak 2022 Tariff [€]	Cost reductions on Peak 2023 Tariff [€]	Cost reductions off Peak 2023 Tariff [€]	Number of Peak Hours
01/04/2022	sexta-feira	1060,15	1060,15	1619,21	2639,85	1619,21	67,89	9,89	-5,058315674	-2,38077726	3
02/04/2022	sábado	0,00	0,00	1590,22	3700,00	1590,22	0,00	9,71	0	-2,33815465	0
03/04/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
04/04/2022	segunda-feira	753,70	753,70	1321,04	2946,30	1321,04	48,27	8,06	-3,596146299	-1,942373264	3
05/04/2022	terça-feira	795,11	795,11	1312,76	2904,89	1312,76	50,92	8,01	-3,793736755	-1,930195375	3
06/04/2022	quarta-feira	819,96	819,96	1362,45	2880,04	1362,45	52,51	8,32	-3,912291029	-2,003262708	3
07/04/2022	quinta-feira	803,39	803,39	1635,77	2896,61	1635,77	51,45	9,99	-3,833254846	-2,405133038	3
08/04/2022	sexta-feira	1234,08	1234,08	1590,22	2465,92	1590,22	79,03	9,71	-5,888195589	-2,33815465	3
09/04/2022	sábado	0,00	0,00	2248,67	3700,00	2248,67	0,00	13,73	0	-3,306296809	0
10/04/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
11/04/2022	segunda-feira	1002,17	1002,17	1913,23	2697,83	1913,23	64,18	11,68	-4,781689035	-2,813092313	3
12/04/2022	terça-feira	1134,69	1134,69	2045,75	2565,31	2045,75	72,67	12,49	-5,413978494	-3,007938534	3
13/04/2022	quarta-feira	1200,95	1200,95	2335,64	2499,05	2335,64	76,91	14,26	-5,730123224	-3,434164642	3
14/04/2022	quinta-feira	1238,22	1238,22	2310,79	2461,78	2310,79	79,30	14,11	-5,907954634	-3,397630975	3
15/04/2022	sexta-feira	1432,86	1432,86	2244,53	2267,14	2244,53	91,76	13,70	-6,836629778	-3,300207865	3
16/04/2022	sábado	0,00	0,00	2617,24	3700,00	2617,24	0,00	15,98	0	-3,848212861	0
17/04/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
18/04/2022	segunda-feira	1366,60	1366,60	1996,06	2333,40	1996,06	87,52	12,19	-6,520485048	-2,934871201	3
19/04/2022	terça-feira	803,39	803,39	1817,99	2896,61	1817,99	51,45	11,10	-3,833254846	-2,673046592	3
20/04/2022	quarta-feira	940,05	940,05	1606,79	2759,95	1606,79	60,20	9,81	-4,485303351	-2,362510427	3
21/04/2022	quinta-feira	973,18	973,18	1776,57	2726,82	1776,57	62,32	10,85	-4,643375716	-2,612157148	3
22/04/2022	sexta-feira	806,54	806,54	1494,97	2893,46	1494,97	51,65	9,13	-3,848288363	-2,198108928	3
23/04/2022	sábado	0,00	0,00	1880,10	3700,00	1880,10	0,00	11,48	0	-2,764380758	0
24/04/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
25/04/2022	segunda-feira	1142,97	1142,97	1619,21	2557,03	1619,21	73,20	9,89	-5,453496586	-2,38077726	3
26/04/2022	terça-feira	1229,94	1229,94	2203,12	2470,06	2203,12	78,77	13,45	-5,868436543	-3,239318421	3
27/04/2022	quarta-feira	956,62	956,62	1768,29	2743,38	1768,29	61,26	10,80	-4,564339534	-2,599979259	3
28/04/2022	quinta-feira	1619,21	1619,21	2240,39	2080,79	2080,79	103,70	12,70	-7,72578683	-3,059456073	3
29/04/2022	sexta-feira	1540,53	1540,53	2675,22	2159,47	2159,47	98,66	13,18	-7,350364963	-3,175146017	3
30/04/2022	sábado	0,00	0,00	2931,97	3700,00	2931,97	0,00	17,90	0	-4,310972635	0
01/05/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
02/05/2022	segunda-feira	1399,73	1399,73	2153,42	2300,27	2153,42	89,64	13,15	-6,678557413	-3,166251088	3
03/05/2022	terça-feira	1399,73	1399,73	1983,63	2300,27	1983,63	89,64	12,11	-6,678557413	-2,916604368	3
04/05/2022	quarta-feira	1296,20	1296,20	2256,95	2403,80	2256,95	83,01	13,78	-6,184581273	-3,318474698	3
05/05/2022	quinta-feira	1217,51	1217,51	2671,07	2482,49	2482,49	77,97	15,16	-5,809159406	-3,65008368	3
06/05/2022	sexta-feira	1308,62	1308,62	2497,14	2391,38	2391,38	83,81	14,60	-6,24385841	-3,516126903	3
07/05/2022	sábado	0,00	0,00	2981,66	3700,00	2981,66	0,00	18,20	0	-4,384039968	0
08/05/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
09/05/2022	segunda-feira	1534,31	1534,31	2401,90	2165,69	2165,69	98,26	13,22	-7,320726395	-3,184279433	3

10/05/2022	terça-feira	1275,49	1275,49	2468,16	2424,51	2424,51	81,69	14,80	-6,085786045	-3,564838458	3
11/05/2022	quarta-feira	1615,07	1615,07	2368,77	2084,93	2084,93	103,43	12,73	-7,706027784	-3,065545017	3
12/05/2022	quinta-feira	1871,82	1871,82	3279,83	1828,18	1828,18	119,88	11,16	-8,931088611	-2,688030465	3
13/05/2022	sexta-feira	1921,52	1921,52	3408,21	1778,48	1778,48	123,06	10,86	-9,168197158	-2,614963132	3
14/05/2022	sábado	0,00	0,00	3482,75	3700,00	3482,75	0,00	21,26	0	-5,12080224	0
15/05/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
16/05/2022	segunda-feira	2116,15	2116,15	3209,43	1583,85	1583,85	135,52	9,67	-10,0968723	-2,328782745	3
17/05/2022	terça-feira	2116,15	2116,15	3234,28	1583,85	1583,85	135,52	9,67	-10,0968723	-2,328782745	3
18/05/2022	quarta-feira	1664,76	1664,76	3192,87	2035,24	2035,24	106,62	12,43	-7,943136331	-2,992477685	3
19/05/2022	quinta-feira	2161,71	2161,71	3495,17	1538,29	1538,29	138,44	9,39	-10,3142218	-2,261804357	3
20/05/2022	sexta-feira	2774,60	2774,60	5164,08	925,40	925,40	177,69	5,65	-13,23856055	-1,360640585	3
21/05/2022	sábado	0,00	0,00	4729,25	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
22/05/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
23/05/2022	segunda-feira	1954,65	1954,65	3064,49	1745,35	1745,35	125,18	10,66	-9,326269523	-2,566251577	3
24/05/2022	terça-feira	1747,59	1747,59	3002,37	1952,41	1952,41	111,92	11,92	-8,338317243	-2,870698797	3
25/05/2022	quarta-feira	1673,04	1673,04	2931,97	2026,96	2026,96	107,15	12,37	-7,982654422	-2,980299796	3
26/05/2022	quinta-feira	2948,53	2948,53	5027,42	751,47	751,47	188,83	4,59	-14,06844047	-1,104904921	3
27/05/2022	sexta-feira	1739,30	1739,30	5603,04	1960,70	1960,70	111,39	11,97	-8,298799152	-2,882876685	3
28/05/2022	sábado	0,00	0,00	4455,93	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
29/05/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
30/05/2022	segunda-feira	1880,10	1880,10	3010,65	1819,90	1819,90	120,41	11,11	-8,970606702	-2,675852576	3
31/05/2022	terça-feira	2145,14	2145,14	3838,89	1554,86	1554,86	137,38	9,49	-10,23518562	-2,286160134	3
01/06/2022	quarta-feira	2439,17	2439,17	3462,04	1260,83	1260,83	156,21	7,70	-11,63807786	-1,853845082	3
02/06/2022	quinta-feira	2542,70	2542,70	4174,33	1157,30	1157,30	162,84	7,07	-12,132054	-1,701621472	3
03/06/2022	sexta-feira	2521,99	2521,99	4344,12	1178,01	1178,01	161,51	7,19	-12,03325877	-1,732066194	3
04/06/2022	sábado	0,00	0,00	4865,91	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
05/06/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
06/06/2022	segunda-feira	2555,12	2555,12	4418,66	1144,88	1144,88	163,64	6,99	-12,19133114	-1,683354639	3
07/06/2022	terça-feira	2567,54	2567,54	4716,83	1132,46	1132,46	164,43	6,91	-12,25060827	-1,665087805	3
08/06/2022	quarta-feira	2501,28	2501,28	4244,73	1198,72	1198,72	160,19	7,32	-11,93446354	-1,762510916	3
09/06/2022	quinta-feira	2791,17	2791,17	5321,44	908,83	908,83	178,75	5,55	-13,31759673	-1,336284808	3
10/06/2022	sexta-feira	2774,60	2774,60	5975,75	925,40	925,40	177,69	5,65	-13,23856055	-1,360640585	3
11/06/2022	sábado	0,00	0,00	6327,75	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
12/06/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
13/06/2022	segunda-feira	3085,19	3085,19	6191,09	614,81	614,81	197,58	3,75	-14,72048897	-0,903969755	3
14/06/2022	terça-feira	2679,36	2679,36	5292,45	1020,64	1020,64	171,59	6,23	-12,7841025	-1,500686307	3
15/06/2022	quarta-feira	2902,98	2902,98	6157,96	797,02	797,02	185,91	4,87	-13,85109097	-1,171883309	3
16/06/2022	quinta-feira	2637,94	2637,94	5371,14	1062,06	1062,06	168,94	6,48	-12,58651205	-1,561575751	3
17/06/2022	sexta-feira	2758,04	2758,04	5321,44	941,96	941,96	176,63	5,75	-13,15952437	-1,384996363	3
18/06/2022	sábado	0,00	0,00	5006,71	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
19/06/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
20/06/2022	segunda-feira	2153,42	2153,42	4062,52	1546,58	1546,58	137,91	9,44	-10,27470371	-2,273982245	3
21/06/2022	terça-feira	1846,98	1846,98	3652,54	1853,02	1853,02	118,28	11,31	-8,812534338	-2,724564131	3
22/06/2022	quarta-feira	1917,38	1917,38	3722,94	1782,62	1782,62	122,79	10,88	-9,148438113	-2,621052076	3
23/06/2022	quinta-feira	1793,14	1793,14	3722,94	1906,86	1906,86	114,84	11,64	-8,555666745	-2,803720408	3
24/06/2022	sexta-feira	2124,44	2124,44	3710,52	1575,56	1575,56	136,05	9,62	-10,13639039	-2,316604856	3
25/06/2022	sábado	0,00	0,00	3872,02	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
26/06/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
27/06/2022	segunda-feira	1619,21	1619,21	3288,11	2080,79	2080,79	103,70	12,70	-7,72578683	-3,059456073	3
28/06/2022	terça-feira	1967,07	1967,07	3515,88	1732,93	1732,93	125,98	10,58	-9,38554666	-2,547984743	3
29/06/2022	quarta-feira	1892,53	1892,53	2758,04	1807,47	1807,47	121,20	11,03	-9,029883839	-2,657585743	3

30/06/2022	quinta-feira	1668,90	1668,90	2985,81	2031,10	2031,10	106,88	12,40	-7,962895377	-2,98638874	3
01/07/2022	sexta-feira	2116,15	2116,15	3739,50	1583,85	1583,85	135,52	9,67	-10,0968723	-2,328782745	3
02/07/2022	sábado	0,00	0,00	3602,84	3700,00	3602,84	0,00	22,00	0	-5,297381628	0
03/07/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
04/07/2022	segunda-feira	2244,53	2244,53	3731,22	1455,47	1455,47	143,74	8,89	-10,70940272	-2,140025469	3
05/07/2022	terça-feira	2393,61	2393,61	3785,06	1306,39	1306,39	153,29	7,98	-11,42072836	-1,92082347	3
06/07/2022	quarta-feira	2733,19	2733,19	5300,74	966,81	966,81	175,04	5,90	-13,0409701	-1,421530029	3
07/07/2022	quinta-feira	3130,75	3130,75	6593,89	569,25	569,25	200,50	3,48	-14,93783847	-0,836991367	3
08/07/2022	sexta-feira	3304,68	3304,68	6671,47	395,32	395,32	211,64	2,41	-15,76771839	-0,581255702	3
09/07/2022	sábado	0,00	0,00	6365,02	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
10/07/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
11/07/2022	segunda-feira	2683,50	2683,50	5064,69	1016,50	1016,50	171,86	6,21	-12,80386155	-1,494597362	3
12/07/2022	terça-feira	2915,40	2915,40	6741,87	784,60	784,60	186,71	4,79	-13,9103681	-1,153616476	3
13/07/2022	quarta-feira	3344,32	3344,32	6465,32	355,68	355,68	214,18	2,17	-15,95684211	-0,522975365	3
14/07/2022	quinta-feira	3350,23	3350,23	6323,61	349,77	349,77	214,56	2,14	-15,98506789	-0,514277314	3
15/07/2022	sexta-feira	3006,51	3006,51	6013,02	693,49	693,49	192,54	4,23	-14,34506711	-1,019659699	3
16/07/2022	sábado	0,00	0,00	5797,68	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
17/07/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
18/07/2022	segunda-feira	3101,76	3101,76	5317,30	598,24	598,24	198,64	3,65	-14,79952515	-0,879613978	3
19/07/2022	terça-feira	2472,30	2472,30	5325,58	1227,70	1227,70	158,33	7,50	-11,79615022	-1,805133527	3
20/07/2022	quarta-feira	3081,05	3081,05	5188,92	618,95	618,95	197,32	3,78	-14,70072993	-0,9100587	3
21/07/2022	quinta-feira	3205,29	3205,29	5304,88	494,71	494,71	205,27	3,02	-15,29350129	-0,727390368	3
22/07/2022	sexta-feira	4862,87	3700,00	5430,65	0,00	0,00	236,96	0,00	-17,65393333	0	3
23/07/2022	sábado	0,00	0,00	4017,91	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
24/07/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
25/07/2022	segunda-feira	2995,47	2995,47	6463,43	704,53	704,53	191,84	4,30	-14,29238188	-1,035895169	3
26/07/2022	terça-feira	2770,91	2770,91	6312,30	929,09	929,09	177,46	5,67	-13,22094897	-1,366067768	3
27/07/2022	quarta-feira	3234,02	3234,02	6179,98	465,98	465,98	207,11	2,84	-15,43059916	-0,685142312	3
28/07/2022	quinta-feira	3394,21	3394,21	6411,17	305,79	305,79	217,37	1,87	-16,19489809	-0,449616073	3
29/07/2022	sexta-feira	3071,35	3071,35	6210,66	628,65	628,65	196,70	3,84	-14,65444513	-0,924321815	3
30/07/2022	sábado	0,00	0,00	6148,74	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
31/07/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
01/08/2022	segunda-feira	2252,25	2252,25	5338,13	1447,75	1447,75	144,24	8,84	-10,74624343	-2,128672639	3
02/08/2022	terça-feira	3083,66	3083,66	5102,04	616,34	616,34	197,48	3,76	-14,71315782	-0,906228923	3
03/08/2022	quarta-feira	1813,85	1813,85	4427,69	1886,15	1886,15	116,16	11,51	-8,654461973	-2,773275686	3
04/08/2022	quinta-feira	2887,64	2887,64	4049,74	812,36	812,36	184,93	4,96	-13,77789577	-1,194439129	3
05/08/2022	sexta-feira	2613,06	2613,06	3703,10	1086,94	1086,94	167,35	6,64	-12,4677763	-1,598165339	3
06/08/2022	sábado	0,00	0,00	4037,83	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
07/08/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
08/08/2022	segunda-feira	2390,14	2390,14	3146,41	1309,86	1309,86	153,07	8,00	-11,40417453	-1,925924694	3
09/08/2022	terça-feira	2797,09	2797,09	3628,17	902,91	902,91	179,13	5,51	-13,34583086	-1,327584184	3
10/08/2022	quarta-feira	2167,23	2167,23	3444,69	1532,77	1532,77	138,79	9,36	-10,34057276	-2,253684049	3
11/08/2022	quinta-feira	2693,56	2693,56	3498,01	1006,44	1006,44	172,50	6,14	-12,85185472	-1,479807794	3
12/08/2022	sexta-feira	2606,87	2606,87	3843,94	1093,13	1093,13	166,95	6,67	-12,43823181	-1,607269765	3
13/08/2022	sábado	0,00	0,00	3201,03	3700,00	3201,03	0,00	19,54	0	-4,706581625	0
14/08/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
15/08/2022	segunda-feira	2322,11	2322,11	3274,19	1377,89	1377,89	148,71	8,41	-11,0795614	-2,025957425	3
16/08/2022	terça-feira	2411,33	2411,33	3462,00	1288,67	1288,67	154,43	7,87	-11,50526326	-1,894773207	3
17/08/2022	quarta-feira	2433,49	2433,49	3158,99	1266,51	1266,51	155,85	7,73	-11,61098599	-1,862193708	3
18/08/2022	quinta-feira	2383,95	2383,95	3719,75	1316,05	1316,05	152,67	8,03	-11,37463004	-1,93502912	3
19/08/2022	sexta-feira	2419,21	2419,21	4187,11	1280,79	1280,79	154,93	7,82	-11,54286415	-1,883186123	3

20/08/2022	sábado	0,00	0,00	4771,77	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
21/08/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
22/08/2022	segunda-feira	2831,87	2831,87	4536,19	868,13	868,13	181,36	5,30	-13,51180718	-1,276436948	3
23/08/2022	terça-feira	2254,15	2254,15	4251,16	1445,85	1445,85	144,36	8,83	-10,75532457	-2,125874196	3
24/08/2022	quarta-feira	2730,71	2730,71	3636,29	969,29	969,29	174,88	5,92	-13,02912168	-1,425181235	3
25/08/2022	quinta-feira	2871,08	2871,08	3861,81	828,92	828,92	183,87	5,06	-13,69885959	-1,218794907	3
26/08/2022	sexta-feira	2326,17	2326,17	3701,05	1373,83	1373,83	148,97	8,39	-11,09894415	-2,019984441	3
27/08/2022	sábado	0,00	0,00	4115,31	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
28/08/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
29/08/2022	segunda-feira	2891,70	2891,70	3789,59	808,30	808,30	185,19	4,93	-13,79727852	-1,188466145	3
30/08/2022	terça-feira	2698,51	2698,51	3683,97	1001,49	1001,49	172,82	6,11	-12,87549032	-1,472524253	3
31/08/2022	quarta-feira	2743,09	2743,09	3783,16	956,91	956,91	175,67	5,84	-13,08821067	-1,406972382	3
01/09/2022	quinta-feira	2681,17	2681,17	3969,44	1018,83	1018,83	171,71	6,22	-12,79276573	-1,498016647	3
02/09/2022	sexta-feira	2689,45	2689,45	3375,83	1010,55	1010,55	172,24	6,17	-12,83228382	-1,485838758	3
03/09/2022	sábado	0,00	0,00	3849,40	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
04/09/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
05/09/2022	segunda-feira	1863,27	1863,27	3375,99	1836,73	1836,73	119,33	11,21	-8,890299737	-2,700599958	3
06/09/2022	terça-feira	2464,45	2464,45	2949,48	1235,55	1235,55	157,83	7,54	-11,75870846	-1,816671575	3
07/09/2022	quarta-feira	2470,64	2470,64	3558,53	1229,36	1229,36	158,23	7,51	-11,78825295	-1,807567149	3
08/09/2022	quinta-feira	2949,96	2949,96	3777,13	750,04	750,04	188,92	4,58	-14,0752222	-1,102815062	3
09/09/2022	sexta-feira	2350,97	2350,97	3713,77	1349,03	1349,03	150,56	8,24	-11,21724756	-1,983528081	3
10/09/2022	sábado	0,00	0,00	3972,44	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
11/09/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
12/09/2022	segunda-feira	2871,98	2871,98	3632,80	828,02	828,02	183,93	5,06	-13,70318703	-1,217461363	3
13/09/2022	terça-feira	3063,07	3063,07	4312,25	636,93	636,93	196,17	3,89	-14,61492704	-0,936499704	3
14/09/2022	quarta-feira	3301,05	3301,05	4418,19	398,95	398,95	211,41	2,44	-15,75041364	-0,586588332	3
15/09/2022	quinta-feira	3158,21	3158,21	4528,72	541,79	541,79	202,26	3,31	-15,06888336	-0,796608597	3
16/09/2022	sexta-feira	2778,31	2778,31	4073,32	921,69	921,69	177,93	5,63	-13,25625663	-1,355187364	3
17/09/2022	sábado	0,00	0,00	4636,43	3700,00	3700,00	0,00	22,59	0	-5,440233333	0
18/09/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
19/09/2022	segunda-feira	1676,89	1676,89	6115,84	2023,11	2023,11	107,39	12,35	-8,001005686	-2,974644673	3
20/09/2022	terça-feira	2908,27	2908,27	3595,61	791,73	791,73	186,25	4,83	-13,8763147	-1,164110367	3
21/09/2022	quarta-feira	2966,13	2966,13	2093,00	733,87	733,87	189,96	4,48	-14,15237689	-1,079039086	3
22/09/2022	quinta-feira	3015,54	3015,54	4454,41	684,46	684,46	193,12	4,18	-14,38816839	-1,006377614	3
23/09/2022	sexta-feira	2704,56	2704,56	3909,16	995,44	995,44	173,21	6,08	-12,90437827	-1,463622147	3
24/09/2022	sábado	0,00	0,00	3460,66	3700,00	3460,66	0,00	21,13	0	-5,088329757	0
25/09/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
26/09/2022	segunda-feira	2654,35	2654,35	3249,07	1045,65	1045,65	169,99	6,38	-12,66480231	-1,537449835	3
27/09/2022	terça-feira	1102,19	1102,19	1106,17	2597,81	1106,17	70,59	6,75	-5,258919863	-1,626444431	3
28/09/2022	quarta-feira	2544,95	2544,95	2401,52	1155,05	1155,05	162,98	7,05	-12,14278687	-1,69831403	3
29/09/2022	quinta-feira	897,85	897,85	1546,44	2802,15	1546,44	57,50	9,44	-4,283951574	-2,273786397	3
30/09/2022	sexta-feira	965,96	965,96	1399,80	2734,04	1399,80	61,86	8,55	-4,608941003	-2,058179682	3
01/10/2022	sábado	0,00	0,00	3515,66	3700,00	3515,66	0,00	21,46	0	-5,169196706	0
02/10/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
03/10/2022	segunda-feira	2417,00	2417,00	2769,36	1283,00	1283,00	154,79	7,83	-11,53232611	-1,886433525	3
04/10/2022	terça-feira	2212,66	2212,66	2618,42	1487,34	1487,34	141,70	9,08	-10,55735782	-2,186879601	3
05/10/2022	quarta-feira	1036,17	1036,17	1629,31	2663,83	1629,31	66,36	9,95	-4,943904031	-2,395623265	3
06/10/2022	quinta-feira	2111,50	2111,50	1681,21	1588,50	1588,50	135,23	9,70	-10,07467232	-2,335623887	3
07/10/2022	sexta-feira	1195,94	1195,94	2340,71	2504,06	2340,71	76,59	14,29	-5,706226558	-3,441617406	3
08/10/2022	sábado	0,00	0,00	2755,52	3700,00	2755,52	0,00	16,82	0	-4,05152727	0
09/10/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0

10/10/2022	segunda-feira	1936,88	1936,88	1580,62	1763,12	1580,62	124,04	9,65	-9,241517602	-2,324034683	3
11/10/2022	terça-feira	1428,35	1428,35	1902,23	2271,65	1902,23	91,48	11,61	-6,815153831	-2,796913794	3
12/10/2022	quarta-feira	2650,29	2650,29	2497,18	1049,71	1049,71	169,73	6,41	-12,64541956	-1,543422819	3
13/10/2022	quinta-feira	2114,15	2114,15	1905,23	1585,85	1585,85	135,40	9,68	-10,08733425	-2,33172199	3
14/10/2022	sexta-feira	2762,50	2762,50	2820,03	937,50	937,50	176,92	5,72	-13,18081377	-1,378435825	3
15/10/2022	sábado	0,00	0,00	2384,99	3700,00	2384,99	0,00	14,56	0	-3,506733295	0
16/10/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
17/10/2022	segunda-feira	1715,21	1715,21	2651,55	1984,79	1984,79	109,85	12,12	-8,18382473	-2,918307185	3
18/10/2022	terça-feira	2260,11	2260,11	2989,12	1439,89	1439,89	144,74	8,79	-10,78374017	-2,117117651	3
19/10/2022	quarta-feira	1337,49	1337,49	1566,72	2362,51	1566,72	85,66	9,56	-6,38161062	-2,303593337	3
20/10/2022	quinta-feira	893,12	893,12	2846,52	2806,88	2806,88	57,20	17,14	-4,261368614	-4,127050648	3
21/10/2022	sexta-feira	2534,73	2534,73	2657,11	1165,27	1165,27	162,33	7,11	-12,09404778	-1,713333461	3
22/10/2022	sábado	0,00	0,00	2987,66	3700,00	2987,66	0,00	18,24	0	-4,392856038	0
23/10/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
24/10/2022	segunda-feira	1236,37	1236,37	1563,56	2463,63	1563,56	79,18	9,55	-5,899113274	-2,298953897	3
25/10/2022	terça-feira	1492,37	1492,37	2047,13	2207,63	2047,13	95,57	12,50	-7,120599259	-3,009968868	3
26/10/2022	quarta-feira	2826,04	2826,04	2750,59	873,96	873,96	180,99	5,34	-13,48395603	-1,285019553	3
27/10/2022	quinta-feira	1510,87	1510,87	2096,28	2189,13	2096,28	96,76	12,80	-7,208856441	-3,082224479	3
28/10/2022	sexta-feira	2489,22	2489,22	2650,96	1210,78	1210,78	159,42	7,39	-11,87688643	-1,780253869	3
29/10/2022	sábado	0,00	0,00	1954,77	3700,00	1954,77	0,00	11,93	0	-2,874156726	0
30/10/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
31/10/2022	segunda-feira	759,61	759,61	1116,47	2940,39	1116,47	48,65	6,82	-3,624375416	-1,641579822	3

01/11/2022	terça-feira	2099,12	2099,12	2072,41	1600,88	1600,88	13,14	9,77	-10,01558333	-2,35383274	3
02/11/2022	quarta-feira	840,66	840,66	1283,77	2859,34	1283,77	5,26	7,84	-4,011086257	-1,887572764	3
03/11/2022	quinta-feira	575,63	575,63	1229,94	3124,37	1229,94	3,60	7,51	-2,746507338	-1,808416487	3
04/11/2022	sexta-feira	534,21	534,21	1080,85	3165,79	1080,85	3,34	6,60	-2,548916882	-1,589214488	3
05/11/2022	sábado	0,00	0,00	931,77	3700,00	931,77	0,00	5,69	0	-1,37001249	0
06/11/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
07/11/2022	segunda-feira	704,00	704,00	1113,98	2996,00	1113,98	4,41	6,80	-3,359037752	-1,637926044	3
08/11/2022	terça-feira	832,38	832,38	1341,75	2867,62	1341,75	5,21	8,19	-3,971568166	-1,972817986	3
09/11/2022	quarta-feira	753,70	753,70	1122,27	2946,30	1122,27	4,72	6,85	-3,596146299	-1,650103932	3
10/11/2022	quinta-feira	770,26	770,26	1507,40	2929,74	1507,40	4,82	9,20	-3,675182482	-2,216375762	3
11/11/2022	sexta-feira	664,64	664,64	777,84	3035,36	777,84	4,16	4,75	-3,171234414	-1,143677905	3
12/11/2022	sábado	0,00	0,00	2878,31	3700,00	2878,31	0,00	17,57	0	-4,23207907	0
13/11/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
14/11/2022	segunda-feira	2192,00	2192,00	2322,54	1508,00	1508,00	13,72	9,21	-10,45875074	-2,217266342	3
15/11/2022	terça-feira	511,89	511,89	922,62	3188,11	922,62	3,20	5,63	-2,442407522	-1,356559038	3
16/11/2022	quarta-feira	2340,61	2340,61	2456,99	1359,39	1359,39	14,65	8,30	-11,16781859	-1,998760106	3
17/11/2022	quinta-feira	600,63	600,63	1023,82	3099,37	1023,82	3,76	6,25	-2,86581588	-1,505361305	3
18/11/2022	sexta-feira	2024,81	2024,81	1451,19	1675,19	1451,19	12,67	8,86	-9,661049411	-2,133728306	3
19/11/2022	sábado	0,00	0,00	680,30	3700,00	680,30	0,00	4,15	0	-1,00026882	0
20/11/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
21/11/2022	segunda-feira	613,02	613,02	967,98	3086,98	967,98	3,84	5,91	-2,924904867	-1,423247526	3
22/11/2022	terça-feira	2431,46	2431,46	2924,44	1268,54	1268,54	15,22	7,74	-11,60132597	-1,865170537	3
23/11/2022	quarta-feira	848,32	848,32	1360,72	2851,68	1360,72	5,31	8,31	-4,047595625	-2,000711581	3
24/11/2022	quinta-feira	2398,43	2398,43	2762,73	1301,57	1301,57	15,01	7,95	-11,44369263	-1,913746805	3
25/11/2022	sexta-feira	813,25	813,25	1036,44	2886,75	1036,44	5,09	6,33	-3,880302261	-1,523918039	3
26/11/2022	sábado	0,00	0,00	3087,52	3700,00	3087,52	0,00	18,85	0	-4,53968698	0
27/11/2022	domingo	0,00	0,00	0,00	3700,00	0,00	0,00	0,00	0	0	0
28/11/2022	segunda-feira	2037,20	2037,20	1910,95	1662,80	1662,80	12,75	10,15	-9,720138398	-2,444877006	3
29/11/2022	terça-feira	396,29	396,29	779,93	3303,71	779,93	2,48	4,76	-1,890847591	-1,146751367	3
30/11/2022	quarta-feira	2037,20	2037,20	2000,06	1662,80	1662,80	12,75	10,15	-9,720138398	-2,444877006	3

Annex 2- Daily Results of Strategy

Strategy 1									
DATE	WEEKDAY	Difference between Cooling and Heating Energy during Peak Hours [€]	Difference between Cooling and Heating Energy during off-Peak Hours [€]	Energy provided by the ITES on Peak Hours [kWh]	Energy provided by the ITES off Peak Hours [kWh]	Cost reductions on Peak 2022 Tariff [€]	Cost reductions off Peak 2022 Tariff [€]	Cost reductions on Peak 2023 Tariff [€]	Cost reductions off Peak 2023 Tariff [€]
01/04/2022	sexta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
02/04/2022	sábado	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
03/04/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
04/04/2022	segunda-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
05/04/2022	terça-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
06/04/2022	quarta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
07/04/2022	quinta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
08/04/2022	sexta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
09/04/2022	sábado	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
10/04/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
11/04/2022	segunda-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
12/04/2022	terça-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
13/04/2022	quarta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
14/04/2022	quinta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
15/04/2022	sexta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
16/04/2022	sábado	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
17/04/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
18/04/2022	segunda-feira	262,4	0,0	262,4	0,0	1,6	0,0	-1,3	0,0
19/04/2022	terça-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
20/04/2022	quarta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
21/04/2022	quinta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
22/04/2022	sexta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
23/04/2022	sábado	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
24/04/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
25/04/2022	segunda-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
26/04/2022	terça-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
27/04/2022	quarta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
28/04/2022	quinta-feira	371,1	0,0	371,1	0,0	2,3	0,0	-1,8	0,0
29/04/2022	sexta-feira	416,9	626,2	416,9	626,2	2,6	3,8	-2,0	-0,9
30/04/2022	sábado	0,0	354,1	0,0	354,1	0,0	2,2	0,0	-0,5
01/05/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
02/05/2022	segunda-feira	260,5	42,2	260,5	42,2	1,6	0,3	-1,2	-0,1
03/05/2022	terça-feira	458,8	338,9	458,8	338,9	2,9	2,1	-2,2	-0,5
04/05/2022	quarta-feira	576,9	740,6	576,9	740,6	3,6	4,5	-2,8	-1,1
05/05/2022	quinta-feira	369,9	695,9	369,9	695,9	2,3	4,2	-1,8	-1,0
06/05/2022	sexta-feira	270,5	607,5	270,5	607,5	1,7	3,7	-1,3	-0,9
07/05/2022	sábado	0,0	886,0	0,0	886,0	0,0	5,4	0,0	-1,3
08/05/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
09/05/2022	segunda-feira	406,8	648,3	406,8	648,3	2,5	4,0	-1,9	-1,0
10/05/2022	terça-feira	354,0	465,8	354,0	465,8	2,2	2,8	-1,7	-0,7
11/05/2022	quarta-feira	444,7	471,3	444,7	471,3	2,8	2,9	-2,1	-0,7
12/05/2022	quinta-feira	1117,5	1285,2	1117,5	1285,2	7,0	7,8	-5,3	-1,9
13/05/2022	sexta-feira	836,7	1386,4	836,7	1386,4	5,2	8,5	-4,0	-2,0
14/05/2022	sábado	0,0	928,2	0,0	928,2	0,0	5,7	0,0	-1,4
15/05/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
16/05/2022	segunda-feira	1027,5	1385,9	1027,5	1385,9	6,4	8,5	-4,9	-2,0

17/05/2022	terça-feira	856,4	1200,8	856,4	1200,8	5,4	7,3	-4,1	-1,8
18/05/2022	quarta-feira	638,3	996,1	638,3	996,1	4,0	6,1	-3,0	-1,5
19/05/2022	quinta-feira	909,7	1111,7	909,7	1111,7	5,7	6,8	-4,3	-1,6
20/05/2022	sexta-feira	1841,4	3274,4	1841,4	1858,6	11,5	11,3	-8,8	-2,7
21/05/2022	sábado	0,0	2120,3	0,0	2120,3	0,0	12,9	0,0	-3,1
22/05/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
23/05/2022	segunda-feira	982,6	747,2	982,6	747,2	6,2	4,6	-4,7	-1,1
24/05/2022	terça-feira	841,6	436,2	841,6	436,2	5,3	2,7	-4,0	-0,6
25/05/2022	quarta-feira	580,5	622,4	580,5	622,4	3,6	3,8	-2,8	-0,9
26/05/2022	quinta-feira	1992,0	2659,5	1992,0	1708,0	12,5	10,4	-9,5	-2,5
27/05/2022	sexta-feira	666,2	5062,6	666,2	3033,8	4,2	18,5	-3,2	-4,5
28/05/2022	sábado	0,0	4455,9	0,0	3700,0	0,0	22,6	0,0	-5,4
29/05/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
30/05/2022	segunda-feira	845,9	914,9	845,9	914,9	5,3	5,6	-4,0	-1,3
31/05/2022	terça-feira	1005,9	1681,0	1005,9	1681,0	6,3	10,3	-4,8	-2,5
01/06/2022	quarta-feira	1331,0	1070,8	1331,0	1070,8	8,3	6,5	-6,4	-1,6
02/06/2022	quinta-feira	1181,8	1930,9	1181,8	1930,9	7,4	11,8	-5,6	-2,8
03/06/2022	sexta-feira	1316,7	1999,6	1316,7	1999,6	8,2	12,2	-6,3	-2,9
04/06/2022	sábado	0,0	2257,0	0,0	2257,0	0,0	13,8	0,0	-3,3
05/06/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
06/06/2022	segunda-feira	1147,6	2015,8	1147,6	2015,8	7,2	12,3	-5,5	-3,0
07/06/2022	terça-feira	992,8	2022,3	992,8	2022,3	6,2	12,3	-4,7	-3,0
08/06/2022	quarta-feira	1296,0	1651,3	1296,0	1651,3	8,1	10,1	-6,2	-2,4
09/06/2022	quinta-feira	2079,6	2755,3	2079,6	1620,4	13,0	9,9	-9,9	-2,4
10/06/2022	sexta-feira	1569,3	3491,2	1569,3	2130,7	9,8	13,0	-7,5	-3,1
11/06/2022	sábado	0,0	3788,8	0,0	3700,0	0,0	22,6	0,0	-5,4
12/06/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
13/06/2022	segunda-feira	1973,2	4037,1	1973,2	1726,8	12,4	10,5	-9,4	-2,5
14/06/2022	terça-feira	1866,7	2979,0	1866,7	1833,3	11,7	11,2	-8,9	-2,7
15/06/2022	quarta-feira	2137,0	3840,6	2137,0	1563,0	13,4	9,5	-10,2	-2,3
16/06/2022	quinta-feira	1576,5	2995,5	1576,5	2123,5	9,9	13,0	-7,5	-3,1
17/06/2022	sexta-feira	1424,4	3113,0	1424,4	2275,6	8,9	13,9	-6,8	-3,3
18/06/2022	sábado	0,0	2059,5	0,0	2059,5	0,0	12,6	0,0	-3,0
19/06/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
20/06/2022	segunda-feira	889,8	1224,2	889,8	1224,2	5,6	7,5	-4,2	-1,8
21/06/2022	terça-feira	610,5	857,0	610,5	857,0	3,8	5,2	-2,9	-1,3
22/06/2022	quarta-feira	537,1	1397,8	537,1	1397,8	3,4	8,5	-2,6	-2,1
23/06/2022	quinta-feira	603,4	1172,3	603,4	1172,3	3,8	7,2	-2,9	-1,7
24/06/2022	sexta-feira	1133,0	1568,1	1133,0	1568,1	7,1	9,6	-5,4	-2,3
25/06/2022	sábado	0,0	955,9	0,0	955,9	0,0	5,8	0,0	-1,4
26/06/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
27/06/2022	segunda-feira	643,3	628,6	643,3	628,6	4,0	3,8	-3,1	-0,9
28/06/2022	terça-feira	824,0	1416,3	824,0	1416,3	5,2	8,6	-3,9	-2,1
29/06/2022	quarta-feira	842,7	327,9	842,7	327,9	5,3	2,0	-4,0	-0,5
30/06/2022	quinta-feira	498,6	1002,8	498,6	1002,8	3,1	6,1	-2,4	-1,5
01/07/2022	sexta-feira	1264,6	1686,6	1264,6	1686,6	7,9	10,3	-6,0	-2,5
02/07/2022	sábado	0,0	1662,7	0,0	1662,7	0,0	10,2	0,0	-2,4
03/07/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
04/07/2022	segunda-feira	1373,6	2071,0	1373,6	2071,0	8,6	12,6	-6,6	-3,0
05/07/2022	terça-feira	1619,9	2187,0	1619,9	2080,1	10,1	12,7	-7,7	-3,1
06/07/2022	quarta-feira	1963,3	3527,7	1963,3	1736,7	12,3	10,6	-9,4	-2,6
07/07/2022	quinta-feira	2267,6	4875,6	2267,6	1432,4	14,2	8,7	-10,8	-2,1
08/07/2022	sexta-feira	2573,7	5197,9	2573,7	1126,3	16,1	6,9	-12,3	-1,7
09/07/2022	sábado	0,0	5494,1	0,0	3700,0	0,0	22,6	0,0	-5,4
10/07/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
11/07/2022	segunda-feira	1917,5	3470,5	1917,5	1782,5	12,0	10,9	-9,1	-2,6
12/07/2022	terça-feira	2538,3	5629,9	2538,3	1161,7	15,9	7,1	-12,1	-1,7
13/07/2022	quarta-feira	2757,2	5153,7	2757,2	942,8	17,3	5,8	-13,2	-1,4

14/07/2022	quinta-feira	2673,7	5118,3	2673,7	1026,3	16,7	6,3	-12,8	-1,5
15/07/2022	sexta-feira	2143,3	4520,0	2143,3	1556,7	13,4	9,5	-10,2	-2,3
16/07/2022	sábado	0,0	4417,4	0,0	3700,0	0,0	22,6	0,0	-5,4
17/07/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
18/07/2022	segunda-feira	2269,7	3952,6	2269,7	1430,3	14,2	8,7	-10,8	-2,1
19/07/2022	terça-feira	1838,5	3564,3	1838,5	1861,5	11,5	11,4	-8,8	-2,7
20/07/2022	quarta-feira	2272,3	3855,3	2272,3	1427,7	14,2	8,7	-10,8	-2,1
21/07/2022	quinta-feira	2517,1	4130,7	2517,1	1182,9	15,8	7,2	-12,0	-1,7
22/07/2022	sexta-feira	4687,9	4283,6	3700,0	0,0	23,2	0,0	-17,7	0,0
23/07/2022	sábado	0,0	2451,0	0,0	2451,0	0,0	15,0	0,0	-3,6
24/07/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
25/07/2022	segunda-feira	2630,0	5452,5	2630,0	1070,0	16,5	6,5	-12,5	-1,6
26/07/2022	terça-feira	2477,4	5853,5	2477,4	1222,6	15,5	7,5	-11,8	-1,8
27/07/2022	quarta-feira	2999,4	5507,3	2999,4	700,6	18,8	4,3	-14,3	-1,0
28/07/2022	quinta-feira	2951,0	5579,1	2951,0	749,0	18,5	4,6	-14,1	-1,1
29/07/2022	sexta-feira	2772,0	6210,7	2772,0	928,0	17,3	5,7	-13,2	-1,4
30/07/2022	sábado	0,0	6148,7	0,0	3700,0	0,0	22,6	0,0	-5,4
31/07/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
01/08/2022	segunda-feira	1508,3	4898,8	1508,3	2191,7	9,4	13,4	-7,2	-3,2
02/08/2022	terça-feira	2749,3	4285,5	2749,3	950,7	17,2	5,8	-13,1	-1,4
03/08/2022	quarta-feira	1261,7	3403,8	1261,7	2438,3	7,9	14,9	-6,0	-3,6
04/08/2022	quinta-feira	2529,9	2949,4	2529,9	1170,1	15,8	7,1	-12,1	-1,7
05/08/2022	sexta-feira	2181,5	2610,5	2181,5	1518,5	13,7	9,3	-10,4	-2,2
06/08/2022	sábado	0,0	3050,2	0,0	3050,2	0,0	18,6	0,0	-4,5
07/08/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
08/08/2022	segunda-feira	1946,9	1894,4	1946,9	1753,1	12,2	10,7	-9,3	-2,6
09/08/2022	terça-feira	2330,5	2516,2	2330,5	1369,5	14,6	8,4	-11,1	-2,0
10/08/2022	quarta-feira	1587,9	1986,6	1587,9	1986,6	9,9	12,1	-7,6	-2,9
11/08/2022	quinta-feira	2316,4	2246,0	2316,4	1383,6	14,5	8,4	-11,1	-2,0
12/08/2022	sexta-feira	2159,7	2471,4	2159,7	1540,3	13,5	9,4	-10,3	-2,3
13/08/2022	sábado	0,0	1976,3	0,0	1976,3	0,0	12,1	0,0	-2,9
14/08/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
15/08/2022	segunda-feira	1980,0	2076,6	1980,0	1720,0	12,4	10,5	-9,4	-2,5
16/08/2022	terça-feira	1917,0	2124,5	1917,0	1783,0	12,0	10,9	-9,1	-2,6
17/08/2022	quarta-feira	1858,0	1743,7	1858,0	1743,7	11,6	10,6	-8,9	-2,6
18/08/2022	quinta-feira	2014,6	2475,5	2014,6	1685,4	12,6	10,3	-9,6	-2,5
19/08/2022	sexta-feira	2115,9	2923,5	2115,9	1584,1	13,2	9,7	-10,1	-2,3
20/08/2022	sábado	0,0	3197,1	0,0	3197,1	0,0	19,5	0,0	-4,7
21/08/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
22/08/2022	segunda-feira	2621,9	3439,7	2621,9	1078,1	16,4	6,6	-12,5	-1,6
23/08/2022	terça-feira	1880,9	3045,8	1880,9	1819,1	11,8	11,1	-9,0	-2,7
24/08/2022	quarta-feira	2256,4	1995,5	2256,4	1443,6	14,1	8,8	-10,8	-2,1
25/08/2022	quinta-feira	2322,8	2843,1	2322,8	1377,2	14,5	8,4	-11,1	-2,0
26/08/2022	sexta-feira	1956,8	2487,9	1956,8	1743,2	12,2	10,6	-9,3	-2,6
27/08/2022	sábado	0,0	2980,0	0,0	2980,0	0,0	18,2	0,0	-4,4
28/08/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
29/08/2022	segunda-feira	2397,9	2444,3	2397,9	1302,1	15,0	7,9	-11,4	-1,9
30/08/2022	terça-feira	2115,3	2168,2	2115,3	1584,7	13,2	9,7	-10,1	-2,3
31/08/2022	quarta-feira	2385,4	2896,7	2385,4	1314,6	14,9	8,0	-11,4	-1,9
01/09/2022	quinta-feira	1856,9	2472,5	1856,9	1843,1	11,6	11,3	-8,9	-2,7
02/09/2022	sexta-feira	1939,0	2139,4	1939,0	1761,0	12,1	10,8	-9,3	-2,6
03/09/2022	sábado	0,0	2850,1	0,0	2850,1	0,0	17,4	0,0	-4,2
04/09/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
05/09/2022	segunda-feira	1587,2	2435,1	1587,2	2112,8	9,9	12,9	-7,6	-3,1
06/09/2022	terça-feira	2200,1	2129,1	2200,1	1499,9	13,8	9,2	-10,5	-2,2
07/09/2022	quarta-feira	2229,6	1793,3	2229,6	1470,4	14,0	9,0	-10,6	-2,2
08/09/2022	quinta-feira	2304,5	2245,2	2304,5	1395,5	14,4	8,5	-11,0	-2,1
09/09/2022	sexta-feira	2017,9	2384,0	2017,9	1682,1	12,6	10,3	-9,6	-2,5

10/09/2022	sábado	0,0	2654,4	0,0	2654,4	0,0	16,2	0,0	-3,9
11/09/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
12/09/2022	segunda-feira	2374,3	2205,8	2374,3	1325,7	14,9	8,1	-11,3	-1,9
13/09/2022	terça-feira	2654,8	2986,4	2654,8	1045,2	16,6	6,4	-12,7	-1,5
14/09/2022	quarta-feira	2861,7	2664,6	2861,7	838,3	17,9	5,1	-13,7	-1,2
15/09/2022	quinta-feira	2322,3	2747,9	2322,3	1377,7	14,5	8,4	-11,1	-2,0
16/09/2022	sexta-feira	2062,9	2401,4	2062,9	1637,1	12,9	10,0	-9,8	-2,4
17/09/2022	sábado	0,0	3112,3	0,0	3112,3	0,0	19,0	0,0	-4,6
18/09/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
19/09/2022	segunda-feira	1443,6	4710,7	1443,6	2256,4	9,0	13,8	-6,9	-3,3
20/09/2022	terça-feira	2710,0	2783,0	2710,0	990,0	17,0	6,0	-12,9	-1,5
21/09/2022	quarta-feira	2526,8	1268,7	2526,8	1173,2	15,8	7,2	-12,1	-1,7
22/09/2022	quinta-feira	2930,0	3167,4	2930,0	770,0	18,3	4,7	-14,0	-1,1
23/09/2022	sexta-feira	2074,3	2265,3	2074,3	1625,7	13,0	9,9	-9,9	-2,4
24/09/2022	sábado	0,0	2041,5	0,0	2041,5	0,0	12,5	0,0	-3,0
25/09/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
26/09/2022	segunda-feira	2335,5	1783,2	2335,5	1364,5	14,6	8,3	-11,1	-2,0
27/09/2022	terça-feira	616,2	40,8	616,2	40,8	3,9	0,2	-2,9	-0,1
28/09/2022	quarta-feira	1674,0	663,5	1674,0	663,5	10,5	4,1	-8,0	-1,0
29/09/2022	quinta-feira	201,9	317,8	201,9	317,8	1,3	1,9	-1,0	-0,5
30/09/2022	sexta-feira	569,4	0,0	569,4	0,0	3,6	0,0	-2,7	0,0
01/10/2022	sábado	0,0	1976,0	0,0	1976,0	0,0	12,1	0,0	-2,9
02/10/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
03/10/2022	segunda-feira	1958,2	1393,0	1958,2	1393,0	12,3	8,5	-9,3	-2,0
04/10/2022	terça-feira	1820,0	1152,6	1820,0	1152,6	11,4	7,0	-8,7	-1,7
05/10/2022	quarta-feira	869,0	93,5	869,0	93,5	5,4	0,6	-4,1	-0,1
06/10/2022	quinta-feira	1419,4	460,3	1419,4	460,3	8,9	2,8	-6,8	-0,7
07/10/2022	sexta-feira	192,8	548,3	192,8	548,3	1,2	3,3	-0,9	-0,8
08/10/2022	sábado	0,0	620,9	0,0	620,9	0,0	3,8	0,0	-0,9
09/10/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
10/10/2022	segunda-feira	1663,2	291,0	1663,2	291,0	10,4	1,8	-7,9	-0,4
11/10/2022	terça-feira	683,4	415,7	683,4	415,7	4,3	2,5	-3,3	-0,6
12/10/2022	quarta-feira	2331,5	630,9	2331,5	630,9	14,6	3,9	-11,1	-0,9
13/10/2022	quinta-feira	1003,3	290,2	1003,3	290,2	6,3	1,8	-4,8	-0,4
14/10/2022	sexta-feira	1975,6	857,3	1975,6	857,3	12,4	5,2	-9,4	-1,3
15/10/2022	sábado	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
16/10/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
17/10/2022	segunda-feira	1135,9	520,8	1135,9	520,8	7,1	3,2	-5,4	-0,8
18/10/2022	terça-feira	1579,7	971,2	1579,7	971,2	9,9	5,9	-7,5	-1,4
19/10/2022	quarta-feira	657,1	0,0	657,1	0,0	4,1	0,0	-3,1	0,0
20/10/2022	quinta-feira	0,0	455,3	0,0	455,3	0,0	2,8	0,0	-0,7
21/10/2022	sexta-feira	2002,1	1047,4	2002,1	1047,4	12,5	6,4	-9,6	-1,5
22/10/2022	sábado	0,0	1245,8	0,0	1245,8	0,0	7,6	0,0	-1,8
23/10/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
24/10/2022	segunda-feira	416,0	0,0	416,0	0,0	2,6	0,0	-2,0	0,0
25/10/2022	terça-feira	823,6	519,1	823,6	519,1	5,2	3,2	-3,9	-0,8
26/10/2022	quarta-feira	2328,4	1168,1	2328,4	1168,1	14,6	7,1	-11,1	-1,7
27/10/2022	quinta-feira	1510,9	1202,0	1510,9	1202,0	9,5	7,3	-7,2	-1,8
28/10/2022	sexta-feira	1233,3	753,5	1233,3	753,5	7,7	4,6	-5,9	-1,1
29/10/2022	sábado	0,0	360,6	0,0	360,6	0,0	2,2	0,0	-0,5
30/10/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
31/10/2022	segunda-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
01/11/2022	terça-feira	0,0	0,0	1010,4	0,0	6,3	0,0	-4,8	0,0
02/11/2022	quarta-feira	1010,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0
03/11/2022	quinta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
04/11/2022	sexta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
05/11/2022	sábado	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

06/11/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
07/11/2022	segunda-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
08/11/2022	terça-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
09/11/2022	quarta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
10/11/2022	quinta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
11/11/2022	sexta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
12/11/2022	sábado	0,0	382,1	0,0	382,1	0,0	2,4	0,0	-0,6
13/11/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
14/11/2022	segunda-feira	0,0	11,7	1188,9	11,7	7,4	0,1	-5,7	0,0
15/11/2022	terça-feira	1188,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0
16/11/2022	quarta-feira	0,0	282,2	1277,8	282,2	8,0	1,8	-6,1	-0,4
17/11/2022	quinta-feira	1277,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0
18/11/2022	sexta-feira	0,0	155,1	726,2	155,1	4,5	1,0	-3,5	-0,2
19/11/2022	sábado	726,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0
20/11/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
21/11/2022	segunda-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
22/11/2022	terça-feira	0,0	214,4	641,6	214,4	4,0	1,3	-3,1	-0,3
23/11/2022	quarta-feira	641,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0
24/11/2022	quinta-feira	0,0	0,0	983,1	0,0	6,2	0,0	-4,7	0,0
25/11/2022	sexta-feira	983,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0
26/11/2022	sábado	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
27/11/2022	domingo	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
28/11/2022	segunda-feira	0,0	0,0	120,3	0,0	0,8	0,0	-0,6	0,0
29/11/2022	terça-feira	120,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0
30/11/2022	quarta-feira	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0