African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 83-95
Website: https://aaasjournals.com/index.php/ajapas/index

ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62

Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

Evaluation Techno-economic of Ice Thermal Energy Storage for Office Building in Libya

Mohamed Mustafa M. Abdulgalil [1 *], Ali M. Abdoulha Massoud [2]
[1] Department of Electrical Engineering, Higher Institute of Science and Technology, Sirte, Libya
[2] Department of Mechanical Engineering, College of Technical Sciences, Sebha, Libya

التقييم الفني والاقتصادي لتخزين الطاقة الحرارية الجليدية لمباني الإدارية في ليبيا

محمد مصطفى محمد عبدالجليل[1*]، على محمد عبد الله مسعود[2]
[1] قسم الهندسة الكهربائية، المعهد العالي للعلوم والتقنية سرت، سرت، ليبيا
[2] قسم الهندسة الميكانيكية، كلية العلوم التقنية سبها، سبها، ليبيا

[*]Corresponding author: alsewe7803@yahoo.com

Received: July 14, 2024	Accepted: October 30, 2024	Published: November 12, 2024

Abstract:
This study evaluates the Techno-economic of ice thermal storage (ITS) system for office building in Libya for decreasing power consumption. The (ITS) is integrated into the conventional air conditioning system to reduce the cost of cooling an office building. The Techno-economic of the partial ice thermal storage cooling system was studied by comparing the cost savings of this system to the conventional systems assuming several economic scenarios in which the costs of conventional and backup energy were considered. Results presented in the term of saving energy amount, consumption energy and payback period. Based on the results obtained, it was found that the cooling cost decreased with increasing storage capacity. In addition, the most amount of the stored energy should be used in electricity peak hours as much as possible to increase cooling costs. To achieve great results in a payback period for alternative systems, the price of electricity in Libya between day and night should be increased by four times from the current level during the day time and the demand charges should be taken in account in tariff electricity.

Keywords: Ice Thermal Storage System, Electricity Consumption, Electric Tariff Structure, Air Conditioning System, Payback Period.

الملخص
في هذه الدراسة تقيم تقني واقتصادي لنظام تخزين الطاقة الحرارية بالجليد للمباني الإدارية في ليبيا لتقليل استهلاك الطاقة. تم دمج نظام تخزين الطاقة الحرارية بالجليد مع نظام تكييف الهواء التقليدي لتقليل تكلفة تبريد المباني الإدارية. تمت دراسة التقنية والاقتصادية لنظام تبريد التخزين الحراري الجزئي للجليد من خلال مقارنة لتكلفة لهذا النظام مع الأنظمة التقليدية بافتراض عدد من السيناريوهات الاقتصادية التي تم فيها أخذ تكاليف الطاقة التقليدية والاحتياطية في الاعتبار. تم تقديم النتائج من حيث كمية الطاقة الموفرة واستهلاك الطاقة وفترة الاسترداد. بناءً على النتائج التي تم الحصول عليها، وجد أن تكلفة التبريد تنخفض مع زيادة سعة التخزين. بالإضافة إلى ذلك، يجب استخدام أكبر قدر من الطاقة المخزنة في ساعات الذروة للكهرباء قدر الإمكان لزيادة تكلفة التبريد الموفرة. لتحقيق نتيجة جيدة في فترة

African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 83-95
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62
Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

الاسترداد للنظام البديل، يجب زيادة سعر الكهرباء في ليبيا بين النهار والليل بمقدار أربعة أضعاف عن المستوى الحالي خلال النهار ويجب أخذ رسوم الطلب في الاعتبار في تعريفة الكهرباء.

الكلمات المفتاحية: أنظمة تخزين الثلج الحراري، استهلاك الكهرباء، هيكل التعرفة الكهربائية، أنظمة تكييف الهواء، فترة الاسترداد.

Introduction

During the last four decades, there has been a growing awareness of the importance to reduce energy consumption worldwide due to several problems associated with environmental impact, increasing cost and scarcity of conventional fuel resources. Nevertheless, the energy demand for the building sector is increasing rapidly each year especially in the developing nations, like North Africa regions. [1]. A significant part of this increase is caused by the enormous increase in the installations of air conditioning equipment in hot areas, which was probably affected most by the climate and living standards changes that the region has witnessed recently. In most cases, the demand for air-conditioned space is satisfied using a variety of systems based on electric vapor compression chillers. Consequently, as the energy consumption of air conditioning systems is relatively high, further growth of electricity consumption is produced [2]. To reverse this trend, the changes in market penetration of efficient cooling technologies powered by the ITS as renewable energy is required in order to limit the expected growth in electricity consumption. A sustainable form of air conditioning operates by storing thermal energy in the form of ice when energy demand is low during the night. Later, it uses the stored thermal energy during the day to cool the indoor air temperature of the building the next day, thus storing thermal energy in ice and therefore ITS is considered a type of renewable energy. The significant issue of the (ITS) system to reduce cooling cost in building sector. Based in working principle of (ITS) is produced the ice at off peak hours when the electricity is cheaper and used the stored ice to cooling the building at on peak hours when the electricity is expensive. Thus, air conditioning utilization is shifted to off-peak hours and cooling cost is decreased. Besides decreased electricity consumption cost [3,4]. The (ITS) system is one of the necessary types in the application of renewable energy, because it can solve the problem of instability and mismatch between supply and demand [5]. The growth in both population and economy put increasing pressure on energy generation and demand all over Libya. This electric demand requires further significant investments in electricity generation including power lines and power stations. New power plants built to meet peak demand are operated at full capacity only during the short peak periods and remain idle most of the time. This gives strong demand to study evaluation techno-economic of using ice thermal energy storage systems with conventional air conditioning systems in Libya. The previous work briefly designed and analysis of the mathematical model where the phase change phenomena on ice formation around a horizontal tube in a rectangular tank was investigated to reach the optimal design of ice storage tank and analyzing of ice formation behavior during the latent charging process [6]. In areas with variable market price of electricity, day to night electricity costs can vary significantly and the use of electricity during night versus peak daytime hours can lead to significant savings [7]. Because of that, the dynamic electricity price schemes should be used in Libya to reduce the peak load and balance the grid load. In addition, the high prices normally appear in the daytime which match the (ITS) system [8]. Therefore, the (ITS) systems, which can shift energy consumptions, have attracted more and more attentions [8,9]. In the last ten-year price changes of the fuels used for heating in Turkey, the change in the real electricity consumption of a province over time, the electricity tariffs were examined and cost calculations were made in case of heating a space. It is seen that fuel prices have increased significantly in recent years, and thermal energy storage systems (TES) are 20-40% less costly than other systems until 2020, and 40-55% less costly than natural gas in 2021 and 2022 [10]. According to the data obtained from the General Electric Company of Libya, Libya's electric energy demand is expected to grow extremely rapidly. Libyan government organizations expect that demand

African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 83-95
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62
Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

for electrical power will double by 2014 and it will be more than half times bigger by the end of the year 2020 [6]. Basically, there are 9 customer categories in the electricity tariff structure in Libya, namely; Residential, Residential paid bank, Commercial, Heave Industrial, Light Industrial, Public facilities, Street lighting, Agricultural (large) and Agricultural (small). Unfortunately, in Libya static electricity price schemes is used for all customers' bills except residential customer used the dynamic electricity price schemes. Moreover, the demand charges structure of the electricity is not accounting in the pill of electricity consumption. However, the demand charges are additional fees that electric company charge from customers for maintaining constant supply of electricity. This a specific amount of money for each kWh of Demand which occurred in period of the time bill. Demand in a given period is the highest point of consumption for that period. Because of that many countries around the world have adopted time of use tariff, which encourages investors for the use of cold thermal storage systems. There are many researchers are studying for cold thermal storage systems appropriate for specific type of buildings that maximize the net annual savings [13, 14]. In addition, (ITS) systems can reduce the highest point of the demand to decrease the total amount of money when this structure accounting in the bill of electricity. The main purpose of this paper is to evaluate the techno-economic of the ice thermal storage system with different price of electricity and demand charge for the office building in Libya

.

Cooling load estimation method

The cooling load calculation was carried out using Carrier's Hourly Analysis Program (HAP). In the Energy Simulations, loads are computed for all 8,760 hours in the year using simulation weather data, operating schedules for the different days of the week, and the ASHRAE Transfer Function load method. Weather data refer to the temperature, humidity and solar radiation conditions according to the building geographical location. These conditions have a significant effect on building load and system operation. The location of building which will be analyzed in this study is decided to be in Tripoli, the building plan is selected considering the common office building in Libya. It has a rectangle geometry shape and the building's façade with more glazing is oriented to the East and West. The considered building has three story with each surface floor area 1152 m2 and 3.2 m of height. an extremely hot city, due to its specific climate condition which is sunny during the most of the year. Therefore, it is an appropriate location for studying and evaluation techno-economic of ice thermal storage cooling technologies.

Design load profiles

The main purpose of hourly analysis program calculations is to obtain the cooling load profiles for all zones and therefore for the whole building; this helps to size different components of the air conditioning systems including Air Handling Unit system (AHUs), pumps, and chillers, and fan coil units. The maximum cooling load that reaches 484 kW at 04:00 pm and outdoor temperatures for the design day in July is illustrated in Figure (1) [6].

African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 83-95
Website:
https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62
Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

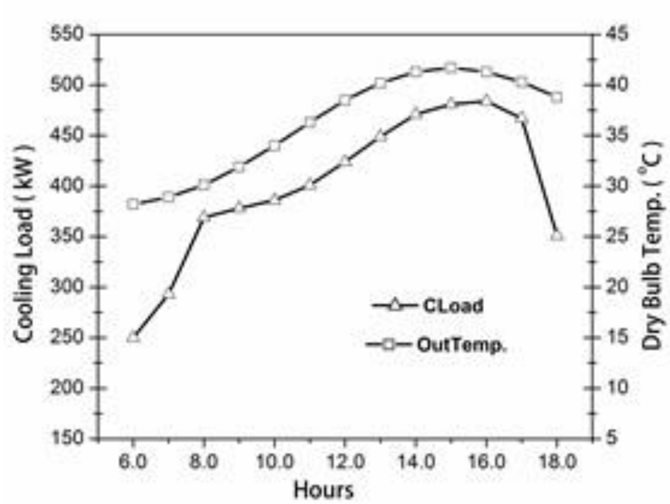

Figure 1: Maximum cooling load and outdoor temperatures for design day in July**.**

System description and modeling

In this study, the size of the equipment for the HVAC system are determined by cooling load profiles of the office building to reach the comfort levels for all zones inside the building. In this paper, three cases are studied, including the conventional AC system without energy storage (scenario 1), with an ice thermal storage (scenario 2), and an ice thermal storage system with different price of electricity and demand charge (scenario 3).

Scenario 1:

In common practice sizing of chillers is selecting equal to maximum cooling load obtained for the considered building. An Air-cooled screw packaged chiller with a nominal cooling capacity of 500 kW installed in the central chiller plant is dedicated for extended hours of operation. The chiller is working with four semi-hermetic screw compressors with a nominal capacity of 125 kW for each, at 46 °C outdoor temperature. Basically, the chiller is coupled with two chilled water distribution systems (7/12 °C) which operated by chilled water pumps to serve both terminal devices (fan coil units) and primary air cooling coil in the air handling unit (AHU) [6].

Scenario 2:

The external ice thermal storage (EITS) system considered in this study is demonstrated in fig.2. This system includes two streams: one goes to refrigeration cycle equipment with an ice storage tank, and others goes to air handling unit (AHU), heat exchanger, ice storage tank and circulating pumps for ice and chilled water. In this system, R134a refrigerant is used as the heat transfer fluid and it is circulated in the pipes throughout the tank with temperatures from -2.5 to - 6.5°C during operating strategies. The capacity cooling and design of the storage tank were studied to provide the required cooling for this system [11]. Based on energy consumption comparison for the operating strategies of the ice thermal storage it was founded that the 60% case of partial storage demand limiting strategy achieves the lowest energy consumption. [6]. Therefore, evaluation techno-economic of the (ITS) for the office building in this study will be based on this type with current level price of the electricity in Libya.

Scenario 3:

African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 83-95
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62
Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

In this scenario, the 60% partial storages demand limiting strategy is chosen as scenario 2, As well as the assumption of the price for electricity in Libya is considered for this scenario to obtain the value of changing price that achieved the profit in economic analysis.

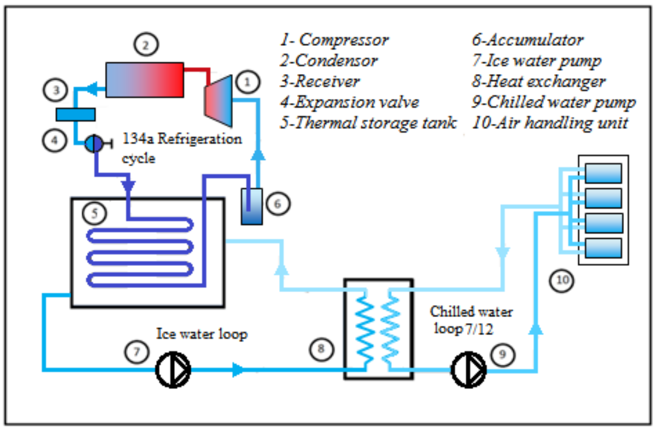

Figure 2. Schematic diagram of the external ice thermal storage system

Estimation of energy consumption for systems

The estimation of the energy consumption and economic analysis for conventional A/C and the (ITS) system requires the use of detailed computer tools. To address this problem, a typical office building cooling load file was used to investigate the impact of (ITS) cooling system and conventional system on the energy consumption through summer months based on the building cooling load, which was estimated using building energy simulation program HAP 4.2.

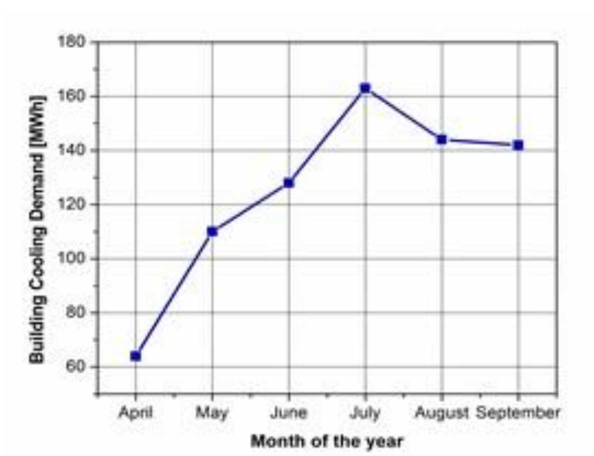

Figure 3: Monthly cooling energy demands in (MWh) for the office building in Tripoli.

African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 83-95
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62
Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

For scenario 1, the sizing of a chiller for a conventional air conditioning system was based on a result of the building's maximum cooling load profiles generated by an hourly analysis program (HAP 4.2). The building is modeled and simulated for the entire summer season based on the climate condition weather data of Tripoli. Both sensible and latent loads are considered in cooling load calculations. The estimated energy demand for cooling of the building space on monthly bases through summer months (April- September) is given in Figure 3. In order to ensure satisfactory comfort condition within the investigated building, the total seasonal cooling load of 687 MWh/seasonal was assumed to be covered by a conventional system or ice thermal storage system and the associated energy consumptions for both systems. The maximum load value 163 MWh appeared in July, while in June, August and September it is very close to total load values of 128, 144 and 142 MWh, respectively. The above results and discussion show the extent of a need and importance of a cooling necessity to the building under climatic conditions in Libya during the summer season. These loads follow the outdoor ambient air temperature distribution throughout the year.

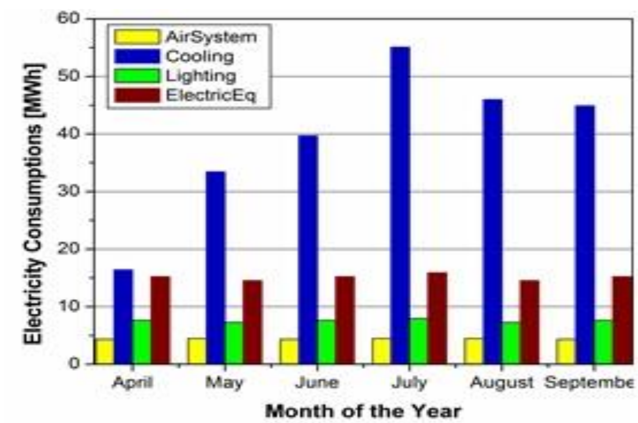

Figure 4: Seasonal building distributions of electricity consumptions

The total seasonal building distribution of electricity consumption including HVAC systems, air system fans, pumps, lights and electrical equipment as illustrates in Figure (4). It is evident from the figure that the air conditioning system for the considered office building in this study is the dominating electrical consumer, which accounts for proximately half of the total building electricity consumption as illustrates in Figure (5). The total power input required for the air conditioning system depends on numerous factors such as cooling load, condensing temperature (a function of outdoor temperature), and control strategy of the system. However, the chiller is the major part of air conditioning system responsible for the highest power consumptions. The cooling load of the building changes throughout its occupied period which causes the chillers to operate frequently at part load.

African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 83-95
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62
Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

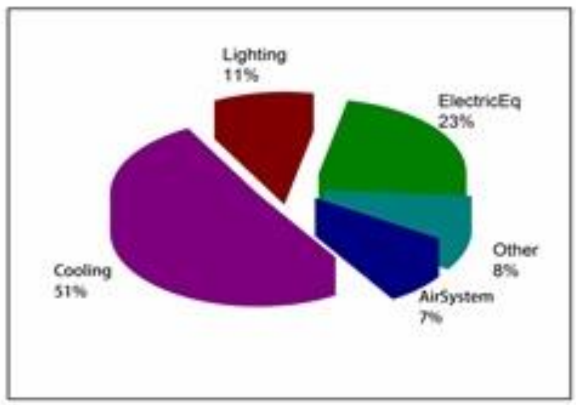

Figure 5: Energy consumption breakdowns for office building

The temperature thermostat set point in space and cooling supply temperature of the primary air were fixed at 26°C and 16°C respectively. The change of the cooling load throughout the building and condensing temperature are effected in a required power input for the compressors of the chiller. The sizing of the selected chiller is equal to the maximum cooling load of 484 kW. At each hour, the capacity ratio of the chiller was simulated by HAP 4.2 program at the given outdoor temperature and corresponding building's cooling load.

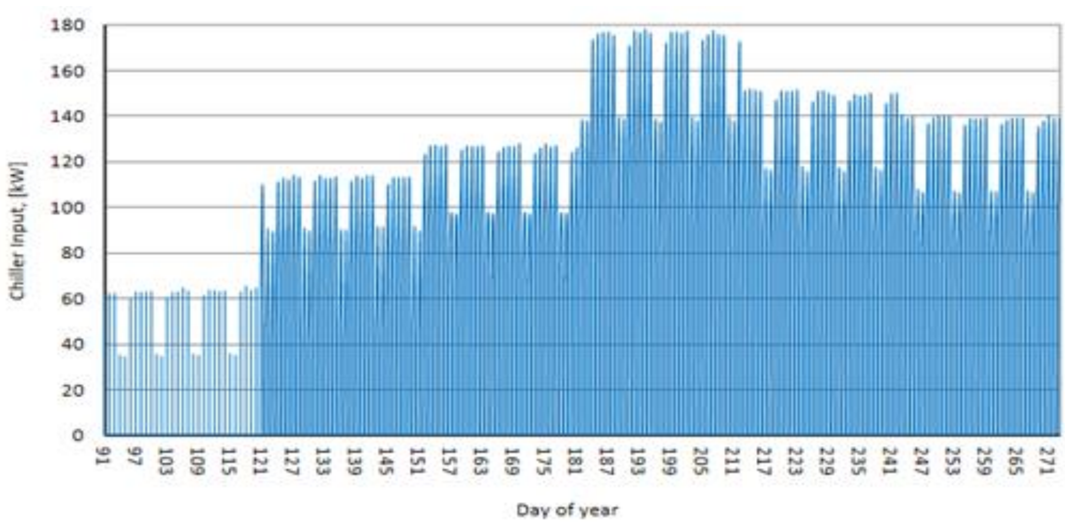

Figure 6: Hourly Simulation Results for Tuesday, April 1 (day 91) through Tuesday, September 30 (day 273).

African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 83-95
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62
Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

The obtained results of daily power input for the chiller during summer months from (April-September) is presented in Figure (6). The simulated electricity consumptions of conventional system are overall and include also the air conditioning (vapor compression chiller). In order to evaluate the electricity consumption, the cooling load values are based on average data of climatic conditions of Tripoli at each hour of each day for all the summer months, which refers to the mean cooling power. The seasonal energy input and output for the chiller of the conventional A/C system in each month, are illustrated in the table 1. The total electricity consumption for conventional air conditioning system is estimated to be 235418kW h/seasonal.

Table 1: Seasonal energy input/output of the conventional chiller.

Month	April	May	June	July	August	September	Sum
Energy input [kWh]	6383	33430	39666	55076	44964	45898	235418
Energy output [kWh]	4138	109913	128332	162732	144094	142265	751474

For scenario 2, the partial demand limiting 40-60 % operating strategy achieved the lowest energy consumption at maximum cooling load when compared to other operating strategies, which was about 1823 kWh [6]. Therefore, this operating strategy is considered for further comparison study with conventional A/C system. The rate of operating strategy in this study refers that 60% of the load met by chiller during the day and the rest met by the storage. Based on this operating strategy, the seasonal energy input and output for the system are illustrated in the table 2. It can be seen from the table that the maximum energy input occurred in July 54460 kWh, while the lowest one occurred in April 5802 kWh. This variation in input power is due to a variation in energy output through months. The total electricity consumption for the demand 40-60% (ITS) system is estimated to be 228705kW h/seasonal. 02% of this value was added referring to storage losses to the environment. Thus, the total value of energy input becomes 233279 kWh. The seasonal reduction in energy consumption by more than 1% was achieved when this operating strategy was applied.

Table 2: Seasonal energy input/output of the ice thermal storage chiller.

Month	April	May	June	July	August	September	Sum
Energy input [kWh]	5802	31427	39311	54460	48595	43244	228705
Energy output [kWh]	4138	109913	128332	162732	144094	142265	751474

Results and dissections

The economics of ice thermal storage systems are particularly complex with much inevitable uncertainty due to several factors. The principal reason for using the (ITS) for heating or cooling is to reduce the energy cost associated with office building. Therefore, an economic analysis must be carried out to determine whether a particular ice thermal storage system is economically advantageous for a particular project. In order to analyses the financial and economic viability of the (ITS) cooling system, it is economically compared to the conventional A/C system. The comparison of alternatives deals with situations in which one has more than

African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 83-95
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62
Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

one choice, and using engineering economic principles, one needs to decide between the alternatives so as to select for the one that is economically. In this study, the economics of conventional A/C and the (ITS) are assessed. The assessment is based on the actual and subsidized costs of electricity consumption and connected electrical power. Also discusses the procedures for computing the total life cycle cost for each A/C system alternatives to evaluate the total cost of each system over its complete lifetime and hence to compare the results in order to select the most economical alternative. The life cycle cost (LCC) principally comprises of the capital cost (C investment) and the annual operation and maintenance cost (CO&M) is given by (1).

$$LCC = C_{investment} + C_{O\&M} \quad (1)$$

The investment cost is assumed to include the purchase cost and the installation cost, which is further assumed as 10% of the purchase cost for conventional air conditioning system while it is 10% from the cost of chiller and 30% from the costs of all equipment for ITS system [9]. An overview of the investment costs for both systems are illustrated in the Table 3. The net present value (NPV), the payback period (PBP), and the return rate of return (IRR) have been chosen as the key economic indicators. NPV represents the net value of all lifetime expenses and revenues, which is discounted back to the beginning of the investment. NPV can be calculated as follows.

$$NPV = -ICC + \sum_{t=1}^{N} \frac{CF_t}{(1+i)^t} \quad (2)$$

Where, CFt is the saving in financial operating cost registered from year 1 to year t, -ICC representing the difference in investment casts between alternatives systems, and i is the discount rate. PBP can be calculated as follows.

$$PBP = Y_{NPV>0-1} + \frac{NPV_{t=Y_{NPV>0-1}}}{CF_{t=Y_{NPV>0}}} \quad (3)$$

Where YNPV>0 is the year when the NPV is a positive value. IRR can be calculated as follows.

$$IRR = \frac{CF}{ICC} \quad (4)$$

Methodology

To assess the financial and economic viability of the (ITS) system for the office building the standard cost-benefit methodology framework was used. The conventional cooling system and the (ITS) are considered as two mutually exclusive projects. For the calculation of the financial and economic criteria for the (ITS) project viability the net effect of the project alternatives was used. Net effect of project alternatives is calculated as a difference in the total financial and economic flows between conventional cooling systems and the (ITS) system.

Project costs

Project costs consist of investment and operating costs. Investment costs of conventional cooling systems are given as an aggregate cost of equipment and installation costs of equipment. Investment costs of (ITS) are divided among the cost of equipment (chiller), the cost of heat exchangers, pumps, automatic control, installation costs and other equipment.

African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 83-95
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62
Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

Table 3: Investment costs of project alternatives.

Conventional A/C system	**Value**	**Currency**
Value of Equipment (chiller, Q= 620 kW)	80000	€
Installation costs	8000	€
Total	88000	€
Ice thermal storage system	**value**	**Currency**
Value of equipment [Chiller capacity = 294kW]	45000	€
Ice thermal storage tank 2626kWh	30000	€
Plate heat exchanger 277kW	5000	€
Pumps	5000	€
Automatic control	5000	€
Installation (costs 10% from cost of chiller and 30% from costs of all equipment).	21000	€
Other equipment	10000	€
Total	121000	€

African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 1-10
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62
Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

Operating costs of project alternatives are considered as financial operating costs and economic operating costs. Financial operating costs of the conventional cooling system and ice thermal storage system cover energy costs, maintenance costs and depreciation costs. In addition, the direct costs of electricity in the operating costs for both project alternatives, and the demand charging power cost (expected of used power kW) of electricity are also included in this study. Maintenance costs for both project alternatives are calculated as a percentage of equipment which is 33%. In the financial operating cost, the depreciation costs for all components of certain equipment provided for linearly 5% of the annual rate cost. It is assumed that the cost of the equipment at the end of its life time (of 20 years) would be fully depreciated. For scenario 1, the direct annual costs of electricity for the conventional cooling system are calculated as multiplying of total amount of electricity consumed (235418 kWh / year) by the daily rates (prices) of electricity. For scenario 2, the direct annual costs of electricity for the ice thermal storage cooling system are calculated as the sum of the amount electricity consumed during the night (128028 kWh / year) multiplied by the night price of the electricity and the amount of electricity consumed during the day (105251kWh/year) multiplied by the daily price of the electricity. The different price of the electricity and the price of the demand charging are applied for scenario 3. The price of electricity only varies with the time of use, not dependent on the amount of electricity consumption. During the day is assumed to be varies price of kWh while during the night is 0.05 euro per kWh to evaluate techno-economic of (ITS) for particular building. The direct annual costs of electricity for the (ITS) cooling system are calculated as the sum of the amount electricity consumed during the night (128028 kWh / year) multiplied by the night price of the electricity and the amount of electricity consumed during the day (105251kWh/year) multiplied by the daily price of the electricity. The cost of demand charging power as part of the operating costs were determined for both project alternatives systems at peak load. In both systems, this part of the operating cost is calculated as multiplying the demand charging power of the unit (chiller) required by the tariff (the cost of demand charging power in the peak load which is assumed to be diverse price of € / kW during 6 months of the cooling season). This part of the operating costs for the conventional system is higher than the part of the operating costs for the (ITS) system. This significant difference in this part of the operating costs is due to large differences in the chiller`s capacity. The total sum of these costs with the direct electricity costs, maintenance costs and depreciation costs leads to an overall financial system for both cooling systems. The financial operating cost per year for the conventional cooling system and the ice thermal storage system were 67404 euros and 40192 euros, respectively.

Financial net effect of the ice thermal storage system

The financial net effect of the ice thermal storage system is calculated as a difference between financial operating costs of project alternatives. This difference is positive for the plant life time with the discount rate of 6%, is 312119 euro.

The financial feasibility of the ice thermal storage system

A criterion for assessing the financial viability of the project is calculated on the basis of the net cash flow, which represents the difference between cash flows of the project (technological) alternatives. The difference of the cash flows of the project alternatives is the difference of investment and operating costs between conventional and ice thermal storage systems. Based on the cash flow net present value (FNPV), the financial internal rate of return (FIRR) and financial return on investment (financial pay-back period) are calculated. Table 2 provides a summary of the results of the financial feasibility of the conventional and ice thermal storage systems.

Table 4: Financial feasibility of the project.

Feasibility criteria	Value	Unit of issue
FNPV	263320	€
FIRR	82,5	%
PAY BACK PERIOD	14,5	months

African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 83-95
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62
Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

The present value of the financial effect (profit) project of the ice thermal storage system during twenty years of plant life time with a discount rate of 6% is 263320 Euros. Based on the previous value, the project is financially very reasonable. The average annual rate of profit viewed as the value of the annual savings in operating costs of 82% and it is unusually high for projects in the energy sector. Payback period is 14.5 months, which is an impressively short time for energy projects. Such impressive financial results are primarily due to the great difference in day and night rate electricity introduced in the assumption, but in relatively low-cost equipment alternative cooling systems as well as great savings on operational costs related to demand charge power of unit (chiller) in ice thermal storage.

Economic feasibility of the ice thermal storage system

The economic analysis of investment of the ice thermal storage system project should assess the project in terms of the investment costs, total energy stability of the country, and measure economic contribution investment aspect of the overall economy. The economic cash flow is the difference between economic processes of project alternatives, which was used to quantify the economic feasibility criteria in this study. Economic flows include the flows of real resources that do not include transfer costs. Given the relative ease, financial flows and real economic flow of financial flow differ only in depreciation costs. Depreciation and amortization as an accounting category does not represent a real waste of resources and is not included in the economic operating costs. The net economic cycle to calculate the criteria for the economic evaluation of the feasibility of project alternatives - the economic net present value (ENPV), economic internal rate of return (EIRR) and economic payback period. Table 3 provides a summary of the values of criteria for economic evaluation of the feasibility of introducing the system cooling ice accumulation.

Table 5: Economic feasibility of the project.

Feasibility criteria	Value	Unit of issue
ENPV	274141	€
EIRR	85,5	%
PAY BACK PERIOD	14	months

The economic net present value (ENPV) shows the total economic contribution of the project system cooling ice accumulation and increased added value of the energy sector based on energy savings based on this technical solution. Economic Internal Rate of Return (EIRR) of 86% indicates the average mean annual rate of increase of these savings is well above the marginal productivity of assets invested in the energy sector (economic discount rate of 6%). Funds invested in the project return to potential investors, investors in 14 months.

Conclusion

Based on the electricity tariffs fixed by General Electricity Company of Libya (GECOL) the systems are not sufficiently differentiated. Moreover, there is no profit when (ITS) is applied. Considering the fact that the electricity tariffs differ four times between night and day and demand charging kW power as it has been applied in many European countries, a value of 263320 euros was obtained for the financial effect (profit) project of the (ITS) system during twenty years of plant life cycle time with discount rate of 6%. Achieving this value of the project profit proves that the project is financially very reasonable within a life cycle of the system. The financial

African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 3, Issue 5, 2024
Page No: 83-95
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62
Special issue: First International Conference on Technical Science (FICTS-2024), Sabha, Libya

internal rate of return (FIRR) of profit viewed as the value of the annual savings in operating costs is 82%, which is unusually high for projects in the energy sector. The payback period of the (ITS) system in comparison to the conventional systems is the other major concern of the study. A payback period of 14.5 months was obtained, according to the assumptions considered in this study, which is an impressively short time for energy projects. The results of the economic analysis indicate that the economic viability and payback period are highly dependent on the difference between night and day tariffs. As this differences increase, the FIRR increases which in turn decreases the payback period of the system.

References

[1] K. Boubaker. Renewable energy in upper North Africa: Present versus 2025-horizon perspectives optimization using a Data Envelopment Analysis (DEA) framework; Renewable Energy 43 (2012) 364-369.

[2] Musbah, M. H., et al. Solar energy contribution to the energy demand forair conditioning system in an office building undertripoli climate conditions. thermal science, Year 2014, Vol. 18, Suppl. 1, pp.S1-S12.

[3] Kahwaji, g.y, Mohammed, S.A, Modeling and design of an ice-storage module. University of Sharjah Journal of Pure & Applied Sciences, 3, 3, (2006), pp 113- 132.

[4] Ahmed, M.A, An investigation into the current utilization and prospective of renewable energy resources and technologies in Libya, Renewable Energy, 50 (2013), pp. 732-740.

[5] S. Zhang, P. Ocłon, ´ J.J. Klemeˇs, P. Michorczyk, K. Pielichowska, K. Pielichowski, Renewable energy systems for building heating, cooling and electricity production with thermal energy storage, Renew. Sustain. Energy Rev. 165 (2022), 112560, https://doi.org/10.1016/j.rser.2022.112560.

[6] Mohamed M. ABDULGALIL, Franc F. KOSI, Mohamed H. MUSBAH and Mirko S. KOMATIN, Effect of thermal energy storage in energy consumption required for air conditioning system in office building under the African Mediterranean climate," vol. 18, pp. 201-212, November 2014.

[7] Franc Franc Kosi, Dragi Antonijevic, eta, chapter (20) Cold Thermal Energy Storage in Handbook of Research on Advances and Applications in Refrigeration Systems and Technologies, August 2015.

[8] M.J. Sebzali, P.A. Rubini., Analysis of ice cool thermal storage for a clinic building in Kuwait, Energy Conversion and Management,47 (2006), 18-19, pp. 3417-3434.

[9] H.-J. Chen, et al., Optimization of an ice-storage air co9

[10] nditioning system using dynamic rogramming method, Applied Thermal Engineering, 25, (2005), 4, pp. 461-472.

[11] Ahmet Fertelli, Electric tariffs and thermal energy storage systems for buildings, European Mechanical Science (2022), 6(4): pp.257-262.

[12] 10. Mohamed Adulgalil, Imhamed Saleh, Ali Elgalai, Optimal design of the external ice thermal storage tank during charging process, International Conference on Technical Sciences, 04-06 March 2019, pp. 245-249.

[13] J.M. McCullough. Ice thermal storage system selection and design, Consulting. Specifying Engineer 3 (1) (1988) 70-77.

[14] Y.Hongxing, Y.Shijun, Partial ice storage application to air conditioning systems in Hong Kong, Building Services Engineering Research and Technology 20 (4) (1999) 201-203.