Research Article

Evaluation of a Solar Heat Gain with Phase Change Material for a House

Authors: Fatih YİĞİT

To cite to this article: Yiğit, F. (2024). Evaluation of a Solar Heat Gain with Phase Change Material for a House, International Journal of Engineering and Innovative Research, 6(1), p 48-63.

DOI: 10.47933/ijeir.1406173

To link to this artice: https://dergipark.org.tr/tr/pub/ijeir/archive

International Journal of Engineering and Innovative Research

http://dergipark.gov.tr/ijeir

Evaluation of a Solar Heat Gain with Phase Change Material for a House

Fatih YİĞİT[1*]

[1]Isparta University of Applied Sciences, Faculty of Technology, Department of Mechanical Engineering, Isparta, Türkiye.

[*]Corresponding Author: fatihyigit@isparta.edu.tr

(**Received:** 17.12.2023; **Accepted:** 19.01.2024)

https://doi.org/10.47933/ijeir.1406173

Abstract: In the study, actual solar radiation measurements were used to determine the solar heat gains that affect the daily heating and cooling requirements. The study investigated the advantages of the PureTerm 23 PCM in indoor temperature control using data from the 2021-2022 solar radiation records. The results show that the PCM is inefficient in meeting the heating demands in January and February. In March, it was found that the PCM can save energy by meeting 16% of the daily heating demand. In April, a 57% reduction in heating demand is achieved with PCM and in May it can provide full heating and cooling with solar gains. With the use of PCM, the cooling requirement can be reduced by 69%, 56% and 59% in June, July and August, respectively. In September, it is calculated that heating and cooling needs can be eliminated by storing solar energy gains. In October and November, the heating demand can be reduced by 49% and 3% respectively, while in December there is not enough solar gain for PCM storage. PureTerm 23 PCM shows significant potential for seasonal energy storage supporting sustainable energy management for indoor temperature control.

Keywords: Phase change materials, solar gains, heating-cooling demand, energy efficiency

1.Introduction

In the early 21st century, the need for innovative energy production and consumption approaches has been brought to the forefront due to global warming and depleting fossil fuel reserves. This has driven the transition towards sustainable energy and the use of low-carbon renewable energy sources. In this context, the employment of solar energy as a sustainable and eco-friendly substitute in systems like heating, cooling, and power generation is increasingly prevalent. There are essentially two methods of utilizing solar energy: active and passive systems. The primary disparity between these two systems lies in their methods of gathering and transforming energy. Active solar energy systems operate mechanical or electrical devices to convert light into electricity or heat. These systems typically comprise technologies like solar panels, solar thermal collectors, and solar hot water systems. Passive solar systems directly convert sunlight into heat energy without any mechanical or electrical devices. Passive systems collect and store sunlight and heat naturally in the design and building materials of structures. Both systems are renewable energy sources and eco-friendly, but their suitability depends on varying needs and conditions. Active systems usually provide better efficiency and control, while passive systems generally require less maintenance and are usually less expensive.

The efficiency of passive solar systems is reliant on advancements in energy storage technologies. Solar heat gain systems are used to heat edifices by converting sunlight into thermal energy, which, when stored, allows for the provision of heat even in the absence of sunlight [1]. Phase change materials (PCMs) are crucial components in this area due to their immense energy storage density and heat release capacity. PCMs have the ability to store and release energy during the transition between solid and liquid states. These materials can effectively store energy by undergoing a phase change at a specific temperature [2]. They can store a significant amount of energy in a small volume and release it at a constant temperature. In addition to this, PCMs can be utilized to enhance energy efficiency and decrease energy expenses. PCM has a wide range of applications, from controlling the internal temperature of buildings to storing solar energy. The use of PCMs in the heating and cooling systems of buildings leads to decreased energy consumption and improved comfort levels [3].

PCM have significant potential to improve the performance of solar energy systems [4]. PCM can be classified into three categories, namely organic, inorganic, and eutectic [5]. Technical grade paraffins or paraffin mixtures made from oil are utilized in organic PCMs to achieve dependable phase change points [6]. Paraffins are also easily accessible as they are available in a broad range of temperatures, which makes them ideal owing to their extended freeze-thaw cycle. Organic PCMs are widely available and can be classified as either paraffinic or non-paraffinic, including salt hydrates, fatty acids, esters, and glycols (Figure 1) [6,7]. Each category has its own particular advantages and disadvantages stemming from its various properties (Table 1) [8]. PCM properties are an essential consideration when evaluating their use in buildings. These properties are primarily associated with the melting temperature, heat release, thermal conductivity, and density of PCMs [9]. PCMs are predominantly employed for heating in cold regions through two mechanisms: absorbing heat during the daytime and releasing it during chilly nights. Moreover, they serve to prevent heat from escaping from warm indoor spaces to the colder outdoors due to varying temperatures. Phase change materials have the ability to absorb a considerable amount of solar energy during daylight hours and release it during the night, thanks to the temperature contrast. Consequently, they can be utilized to provide heat when enclosing the building envelope during cold weather conditions [10].

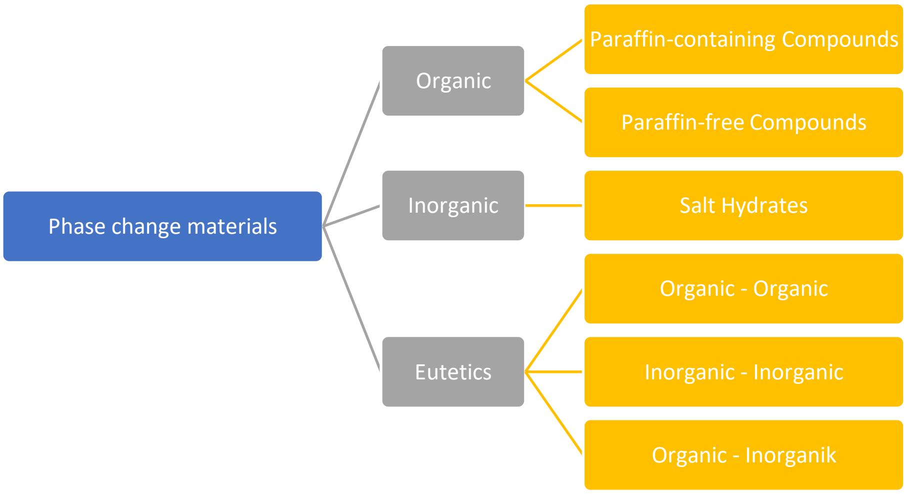


Figure 1. Classification of phase change materials [11]

Table 1. Principal advantages and disadvantages of organic, inorganic, and eutectic PCMs [4].

	Organics	Inorganics	Eutectics
Advantages	Not corrosive Minimal or nonexistent undercooling Stability in terms of chemicals and thermal	Higher enthalpy of phase change Higher porosity	Sharp melting point
Disadvantages	Lower phase change enthalpy Low thermal conductivity Flammability	Undercooling Corrosion Phase division Phase separation and insufficient thermal stability	İnsufficient of data

There is a vast body of literature exploring the use of PCMs in solar energy systems and their ability to enhance energy efficiency. Akeiber et al. (2016) conducted a review that established the effectiveness of PCMs in passive cooling applications for buildings and their potential for high-density thermal energy storage. Gassar and Yun (2017) undertook a study on the energy-saving capabilities of PCMs in buildings operating under future climate conditions. The study demonstrates that PCMs enhance the energy efficiency of buildings during the heating and cooling seasons in regions including Seoul, Tokyo, and Hong Kong. Subbiah (2017) conducted an experimental investigation where he built a test room with PCM walls, covered with novel triple glazing to exploit solar thermal energy for heating, and assessed the PCM wall's solar heat gains and environmental impact. The study led to the discovery that the CO_2 level in the room with PCM walls reduced from 70% to 4% monthly between October and March and 14% annually. Al-Absi et al. (2019) conducted research to examine the implementation of PCMs in constructing walls. Their findings highlighted that PCMs can be integrated into walls as pre-prepared PCM-enhanced elements, resulting in improved thermal performance as well as reduced heating and cooling loads. In their recent study, Ismail et al. (2022) investigated the potential applications of PCMs in building design and construction. Their findings demonstrated a clear correlation between PCM implementation and significant improvements in thermal performance for buildings. Many certified PCM-based products are currently available on the market, making this technology a promising solution for more sustainable and energy-efficient construction practices. Additionally, Wang et al. (2022) provided a critical review of the main characteristics of PCMs, their design and integration methods, and their impact on energy consumption and construction reliability. In an experiment conducted by Han, Zhou et al (2022), a solar heating setup incorporating PCMs was devised and found to reduce energy consumption by 45% for building heating. Vanaga et al. (2023) undertook a comparative assessment of two-phase change materials, varying in melting temperatures of 21 °C and 28 °C, utilizing experimental and numerical approaches to identify their suitability for deployment in a dynamic solar building envelope. In their experiments, it was demonstrated that RT21HC outperforms RT28HC in storing thermal energy in the PCM and releasing it into the indoor environment. Conversely, in the numerical simulations, RT28HC exhibited an advantage in thermal storage capacity, preventing room overheating in Southern European climates. These findings demonstrate the potential of PCMs in solar energy systems and make a compelling case for their broader implementation.

This study presents pioneering thermal management solutions for sustainable residential areas by comprehensively analyzing the role of solar energy recovery systems and PCMs in improving the energy efficiency of buildings. Incorporating PCMs can substantially lower energy usage by proficiently retaining solar heat, which can be accessed when required. This methodology will bolster sustainable architecture, positioning structures at the vanguard of limiting their carbon emissions and tackling climate change. The study seeks to ascertain solar energy's energy-saving potential in buildings' heating and cooling systems with PCMs. In this context, the total amount of solar heat gain in a house will be assessed based on actual measurements of solar radiation. The impact of solar heat gains on the heating and cooling requirements of the house at different times of the day will be disclosed. Any excess solar energy will be stored in PCMs for future use in order to maintain a constant indoor temperature and ensure optimal thermal comfort. The potential energy savings from storing excess energy with PCMs and utilizing it as required will be ascertained.

2.Materials and Methods

Calculating solar gains via transparent surfaces is crucial for assessing a building's energy performance and indoor comfort. Solar radiation yields solar gains when it enters a building's interior through transparent surfaces and converts into heat energy. This phenomenon significantly impacts a building's heating and cooling loads and plays a vital role in energy efficiency [20]. To calculate solar gains accurately, measurement or calculation of the solar radiation available during the day is necessary. For this study, extracted I_i instantaneous solar radiation data for the years 2021 - 2022 from a measurement station located in Isparta province. This data enables the calculation of solar gains through transparent surfaces during insolation. To determine solar gains, it is necessary to obtain information regarding the transparent surface's area, level of solar radiation exposure, angle in relation to the sun, and solar transmittance. The amount of solar energy (measured in J/day) that impacts transparent surfaces on a daily basis is then calculated using the following equations:

$$E_{i,d} = \int I_i(t) A_s dt \tag{1}$$

where $I_i(t)$ is the instantaneous solar radiation (W/m^2) incident on the transparent surfaces and A_s is the area of the transparent surface. The solar energy gain (SEG) is calculated daily as follows:

$$E_{g,d} = \int \dot{Q}_g\,(t) dt \tag{2}$$

$$\dot{Q}_g = I_i(t) A_s g \tag{3}$$

where $\dot{Q}_g$ is the total heat gain (J or Wh) and g is the solar transmittance coefficient of the glass (usually a value between 0 and 1). The monthly SEG (J/month) and the solar energy incident on the transparent surface (J/month) are calculated as follows:

$$E_{i,m} = \sum_{İ=1}^{N} E_{i,d} \tag{4}$$

where N is the number of days in each relevant month. After knowing the monthly solar gain, it is necessary to calculate the storage capacity of the material with its properties such as specific heat capacity, phase change enthalpy and density to determine how much of it can be stored depending on the nature and amount of phase change material to be used.

$$Q_s = m \Delta H_f \tag{5}$$

where Q_s is the total amount of energy that can be stored (j or Wh), m is the mass of the phase changing substance and ΔH_f is the enthalpy of phase change (j/kg). The enthalpy of phase change is the amount of heat given off or absorbed by a substance as it passes from one phase to another. This value represents the amount of energy that keeps the substance at a constant temperature during the transition from solid to liquid or from liquid to gas.

In this study, it is planned to store heat gains with phase change materials and use them in the time period when there is a need for heating. In this context, PureTemp 23 paraffin was used, which performs phase change at a temperature of approximately 22 ℃, which is considered as comfort conditions. The properties of PureTemp 23 are given in Table 2.

Table 2. Thermophysical properties of PureTemp 23 phase change material

PCM type	Category	Melting temperature (PC)	Heat of fusion (kJ/kg)	Thermal conductivity (W/m.K)	Density (kg/m^3)
PureTemp 23	Paraffin	22.23-24.17	170.71	0.15 (Liquid) 0.25 (Solid)	830 (Liquid) 910 (Solid)

Radiation alone is not a sufficient parameter for determining the heat loss and gain of a house. In addition, average outdoor temperatures, thermophysical properties of the building material and the building layers in contact with the outdoor environment should be known. In this study, heat loss gains are considered for a sample house and the use of phase change materials is examined. Heat loss gains due to outdoor temperatures can be calculated by the following formula.

$$\dot{Q}_K = UA\Delta T \tag{7}$$

Here, U (W/m^{2}K) is the total heat transfer coefficient. Total heat transfer coefficient for a wall;

$$U = \frac{1}{R_i} + \frac{1}{R_w} + \frac{1}{R_{is}} + \cdots + \frac{1}{R_o} \tag{8}$$

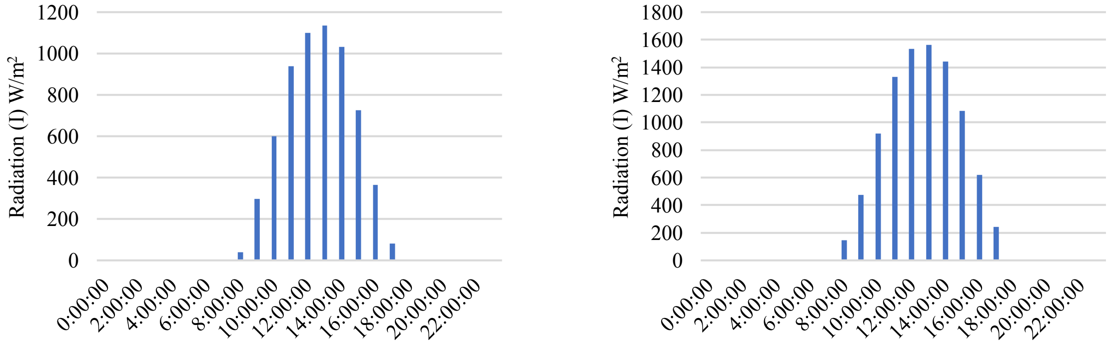
where R_i and R_o are the thermal resistance of the inner and outer surface, R_w is the thermal resistance of the wall and R_{is} is the thermal resistance of the insulation material. The thermal resistances of the inner and outer surfaces of the wall are found by a convection coefficient that depends on the air velocity with which the surfaces are in contact. In addition, the thermal resistance of the materials in the layers inside the wall is the ratio of the thickness of the material to the thermal conductivity of the material.

In this study, a sample house is taken into consideration to calculate heat loss gains. In order to perform the calculations, the indoor heat convection coefficient is assumed to be 8 W/m^{2}K and the outdoor heat convection coefficient is assumed to be 23 W/m^{2}K.The walls of the house considered in the study consist of internal plaster (thickness 0.02 m, conductivity 1 W/mK), brick (thickness 0.3 m, conductivity 2.5 W/mK), external plaster (thickness 0.02 m, conductivity 1.6 W/mK), insulation (thickness 7 m, conductivity 0.04 W/mK) and exterior paint (thickness 0.006 m, conductivity 0.35 W/mK), total wall area 84 m^2 and wall heat transfer coefficient 0.479 W/m^{2}K. In addition, in this study, it is assumed that multilayer glass (thickness 0.02 m, conductivity 0.042 W/mK) is used on the transparent surfaces of the house, the radiation transmission coefficient is 0.75, the heat transfer coefficient is 2.1 W/m^{2}K and the total transparent surface area is 30 m^2.

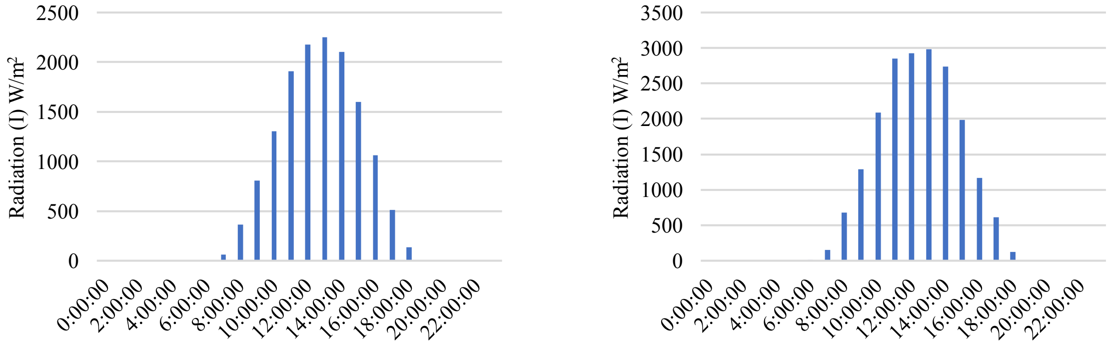
In this paper, the total amount of PureTemp 23 paraffin phase change agent that should be used was determined by considering the solar gains in May. Thus, it was calculated how much of the solar gains in other months could be stored with PCM by using the determined amount of phase change agent. In addition, if the solar gains occurring according to the months are stored with the PCM, it has been determined how long this heat can be used in the house during the period when there is no solar gain.

3.Results and Discussion

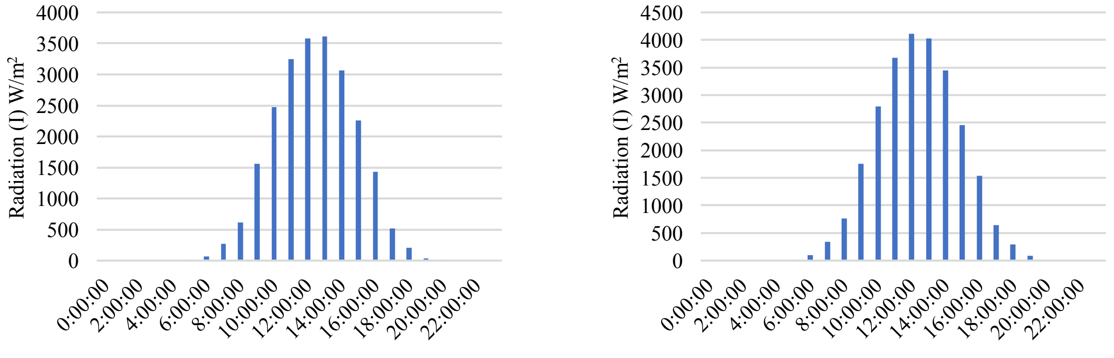
In this study, the solar gains of a house are determined using solar data from the measuring station for Isparta province. After the determination of the relevant solar gains, the use PureTemp 23 paraffin PCM for energy storage and protection of heat fluctuations during the day is investigated. The average daily hourly irradiance by month Figure 2 and the monthly average solar radiation is given in Figure 3.



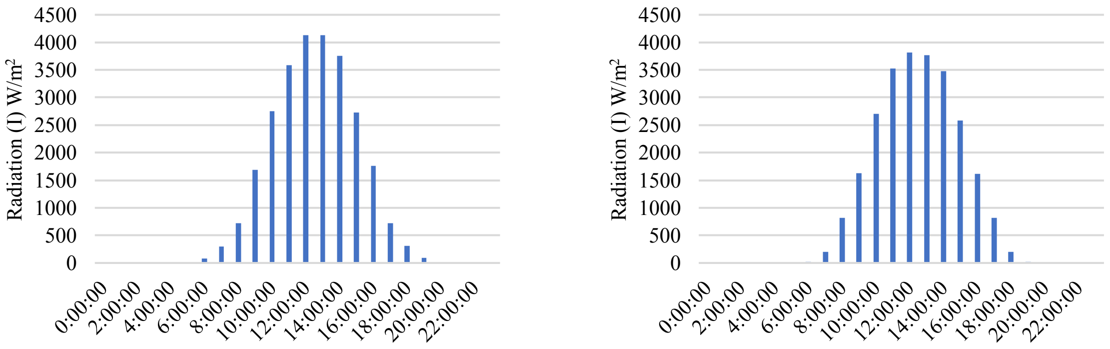
a) January
b) February



c) March
d) April

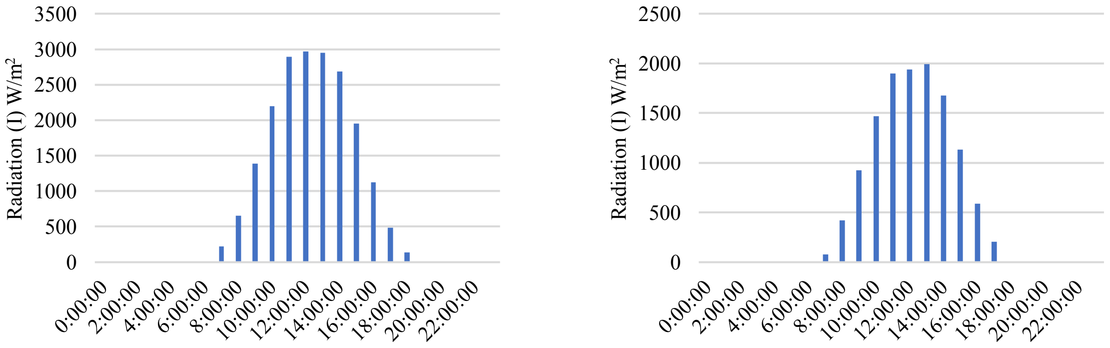


e) May
f) June



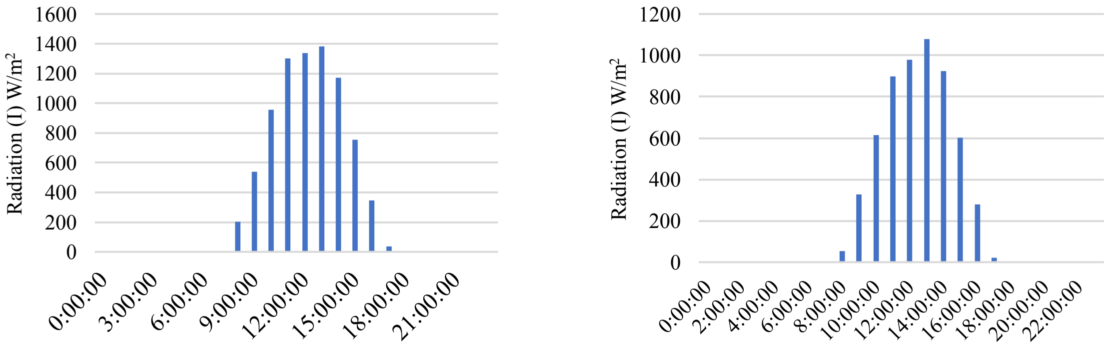
g) July

h) August



i) September

j) October



k) November

l) December

Figure 2. Average daily hourly irradiance by month

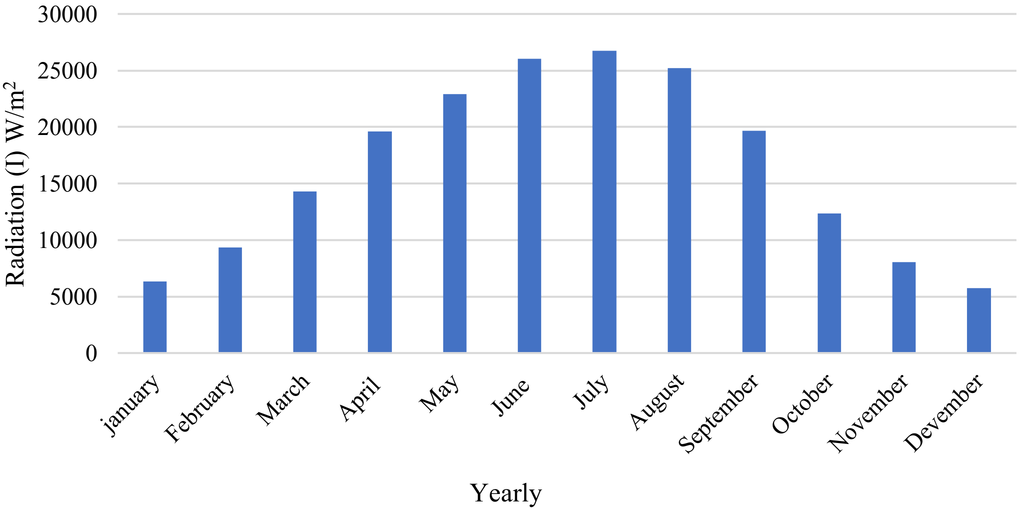


Figure 3. Average monthly irradiance

Considering the irradiation in May, the daily solar gain of the house is calculated to be approximately 69325 kJ. Considering the specifications for PureTemp 23 PCM given in Table 1, it is determined that an average of 406 kg PureTemp 23 PCM is needed to store the solar gain in May. If 406 kg PCM is used, the total solar gain storage rates by month are given in Figure 4. In this study, the storage rate is taken as 100% for the months with more solar gain than the energy that 4006 kg can store during phase change.

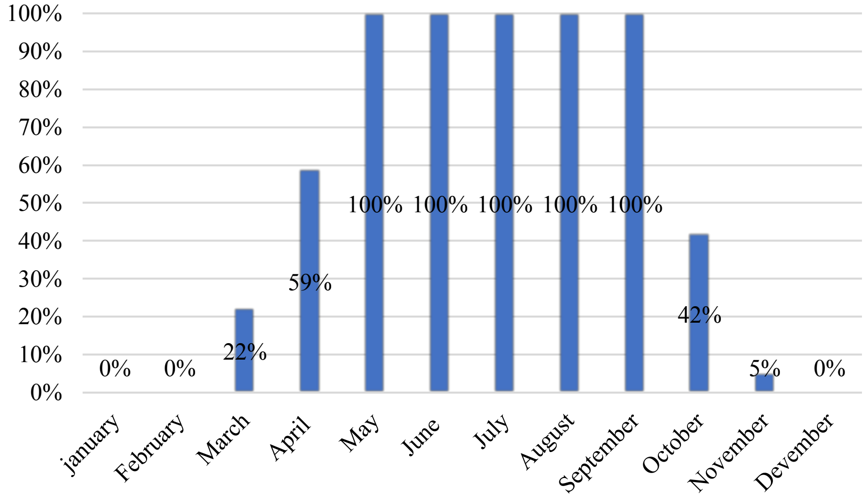


Figure 4. Proportion of energy stored in the PCM

As a result of the calculations, it was determined how much of the solar gains can be stored and how long these gains can be used in the following periods during the day if 406 kg PureTemp 23 PCM is used. Figures 4 to 15 show the storage and utilization of solar gains according to the months. Since the solar gains in January and February were not sufficient to raise the indoor temperature above 22°C, there was no energy storage by phase change in the PCM. The data shown in blue in Figure 5 and Figure 6, which are in the positive part, show that only heating energy is needed. Since energy cannot be stored with PCM during these months, PCM did not contribute.

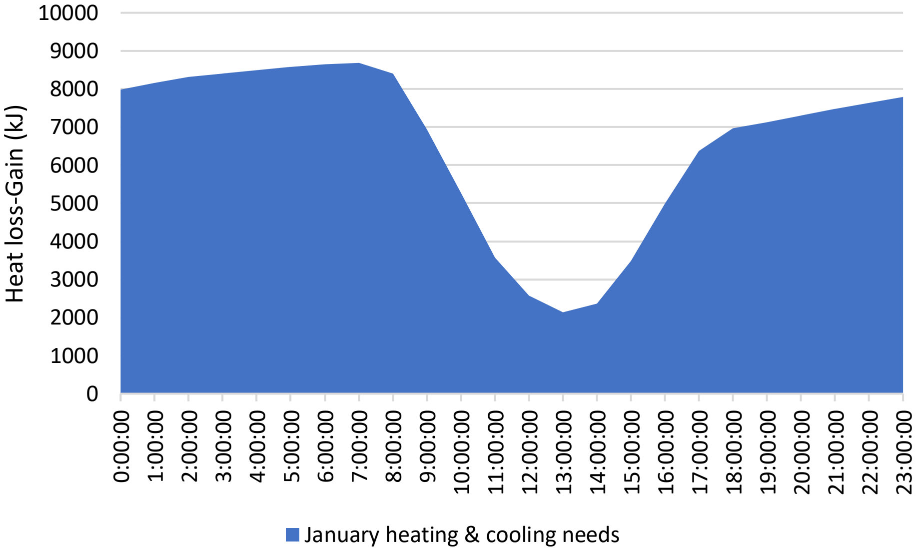


Figure 5. Storing and utilizing solar gains in January

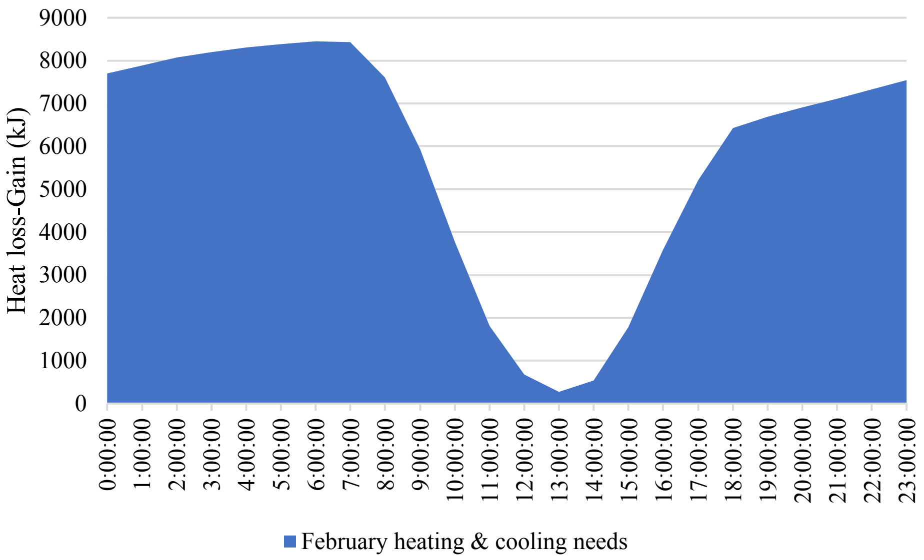


Figure 6. Storing and utilizing solar gains in February

It is calculated that the indoor temperature starts to rise above 22 °C with solar gains at around 10:00 on average in March. In this process, thanks to the storage of solar gains with PCM, the indoor temperature was prevented from rising above 22 °C and this stored energy prevented the indoor temperature from falling below 22 °C after 16:00 until 22:00. Thus, approximately 16% of the daily heating requirement was met thanks to the energy stored with PCM. The orange-colored negative region in Figure 7 represents the process in which solar gains are stored and the orange-colored positive region represents the process in which these gains are used indoors.

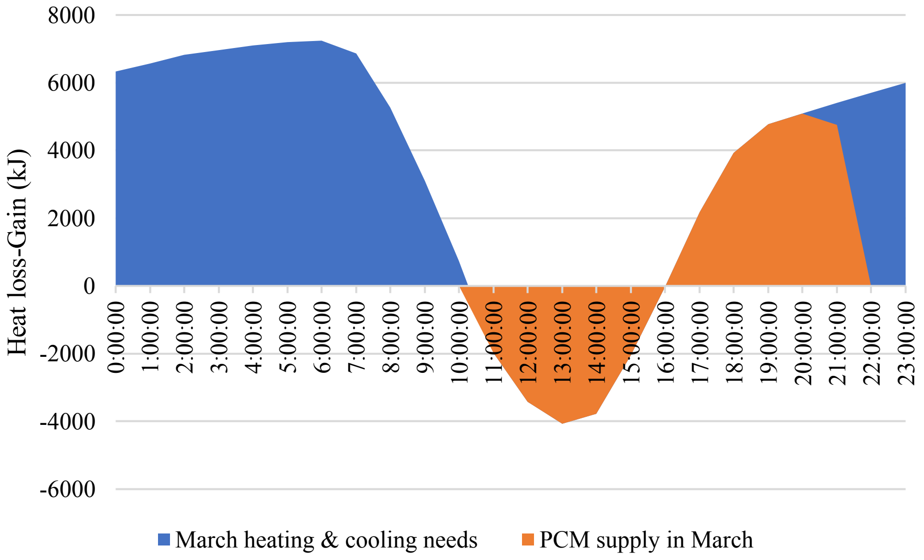


Figure 7. Storing and utilizing solar gains in March

As solar radiation reached higher levels in April, solar gains started at 09:00 on average. Figure 8 shows the process of storing solar gains during the day in the orange-colored negative zone. The energy stored with PCM kept the indoor temperature at about 22 °C for the rest of the day (after 17:00) until about 03:00. With the solar gains stored with the PCM, it was determined that the heating requirement for April was reduced by about 57%.

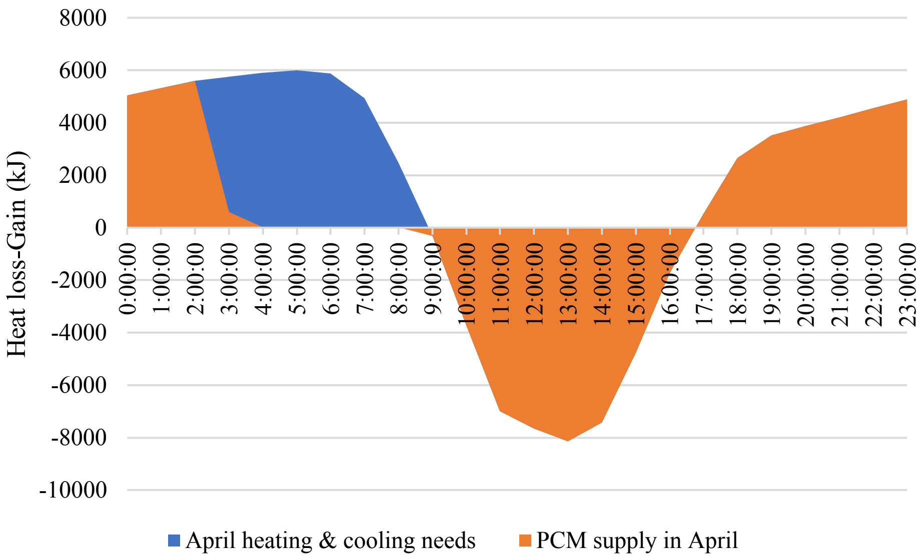


Figure 8. Storing and utilizing solar gains in April

Figure 9 shows the amount of energy stored and used with PCM for the month of May. In this study, the calculations were made by selecting May as a reference month in order to store the solar gains in May and to eliminate the need for cooling. Thus, the solar gains between 08:00 and 18:00 in May were stored by the PCM and kept the indoor temperature constant at approximately 22 °C during the rest of the day.

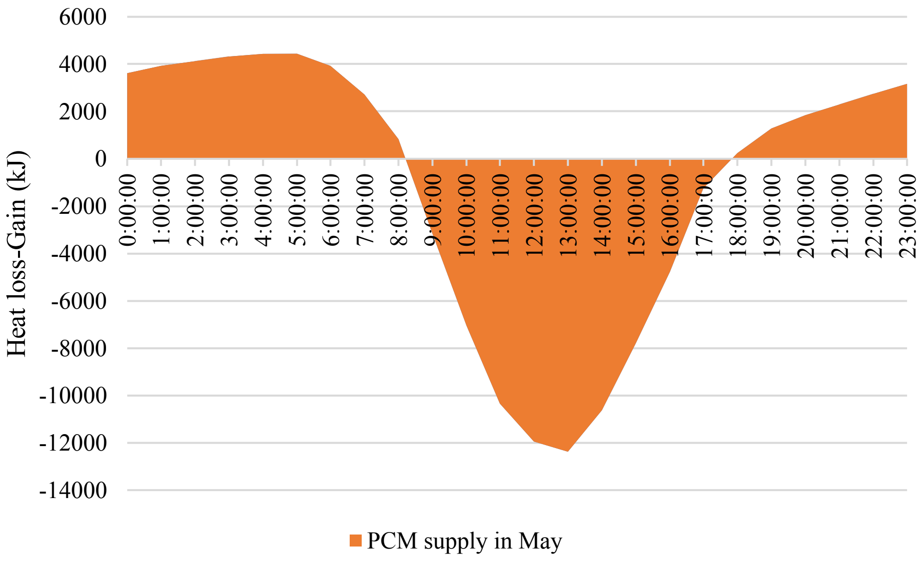


Figure 9. Storing and utilizing solar gains in May

Figure 10 shows the amount and utilization of energy stored with PCM for the month of June. Due to the insufficient phase change enthalpy capacity of the PCM in June, solar gains increased the indoor temperature above 22 °C after 16:00 and cooling was required (Blue colored negative region). As a result of the calculations made for June, it was determined that the cooling requirement was reduced by 69% by storing solar gains with PCM.

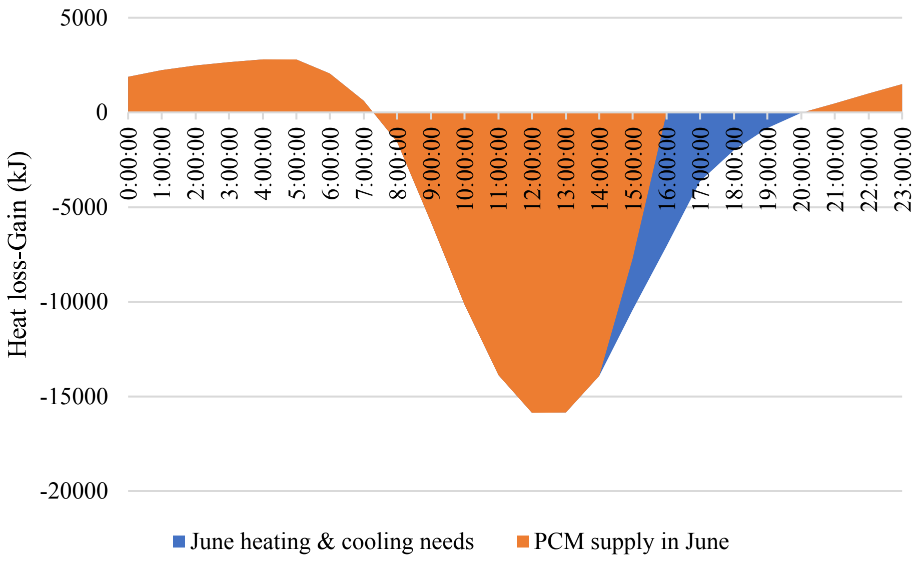


Figure 10. Storing and utilizing solar gains in June

Similar to June, in July, as the solar gains were above the amount of energy that the PCM could store with the storage phase change, the indoor temperature rose above 22 °C after 14:00 on average and cooling was required (Figure 11).The cooling requirement was reduced by approximately 56% by storing solar gains with the PCM in July.

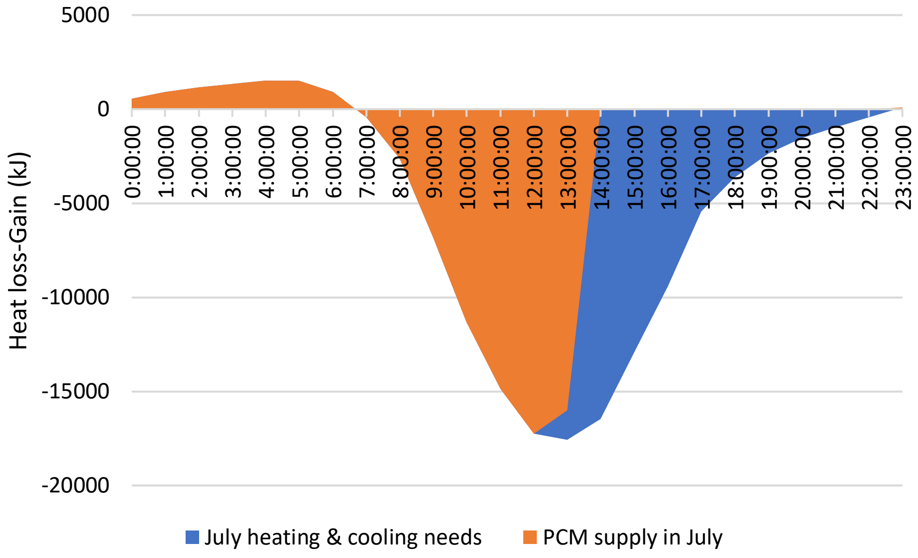


Figure 11. Storing and utilizing solar gains in July

It was observed that with the storage of solar gains in August, there was no cooling need until 14:00, but there was a cooling need after 14:00 (Figure 12). It is calculated that the cooling requirement is reduced by about 59% by storing solar gains in August.

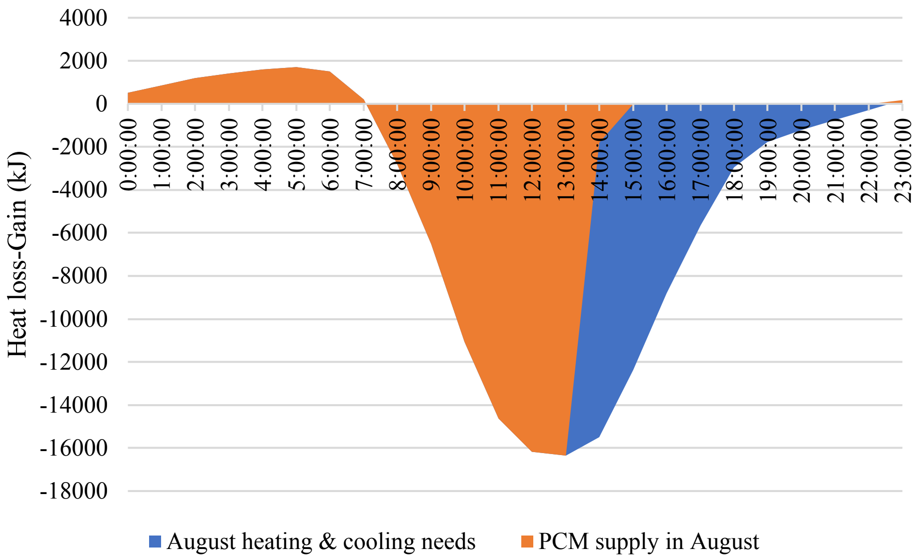


Figure 12. Storing and utilizing solar gains in August

As can be seen in Figure 13, all of the average solar gains for September were stored with PCM and this stored energy could be used during the periods when there was a need for heating. Thus, similar to May, there was no need for heating and cooling in September.

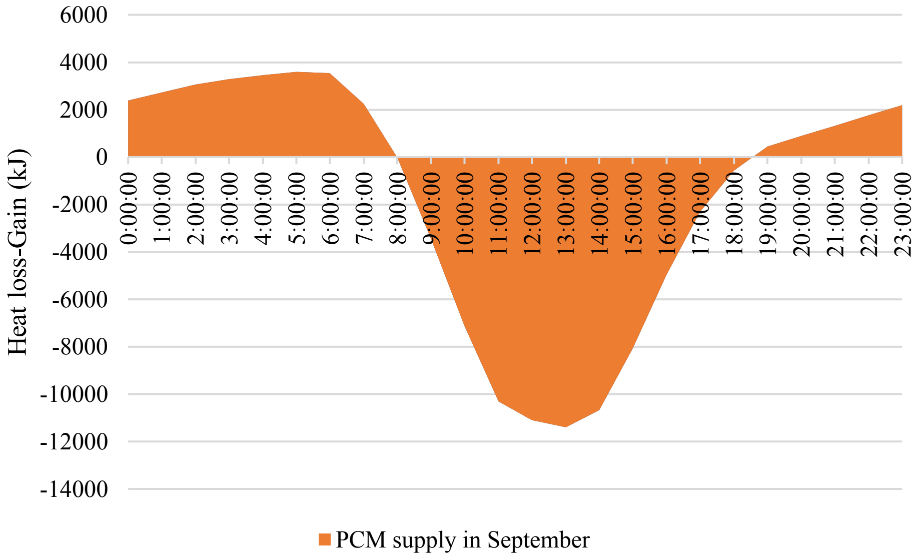


Figure 13. Storing and utilizing solar gains in September

It was observed that in October, with the storage of solar gains and their subsequent utilization, there was only a need for heating between 03:00 and 09:00 (Figure 14). It is calculated that storing the solar gains occurring between 09:00 and 16:00 in October with PCMs reduces the heating demand by approximately 49%.

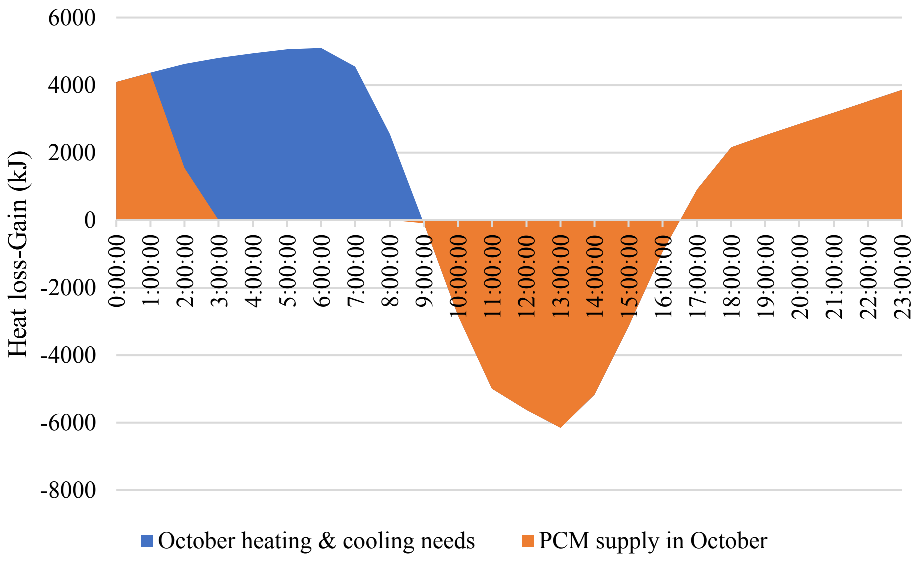


Figure 14. Storing and utilizing solar gains in October

Although solar gains were low in November, it was determined that there was no heating and cooling need between 11:00 and 17:00 with the use of PCM (Figure 15). By storing solar gains with PCM in November, the heating demand is reduced by about 3%.

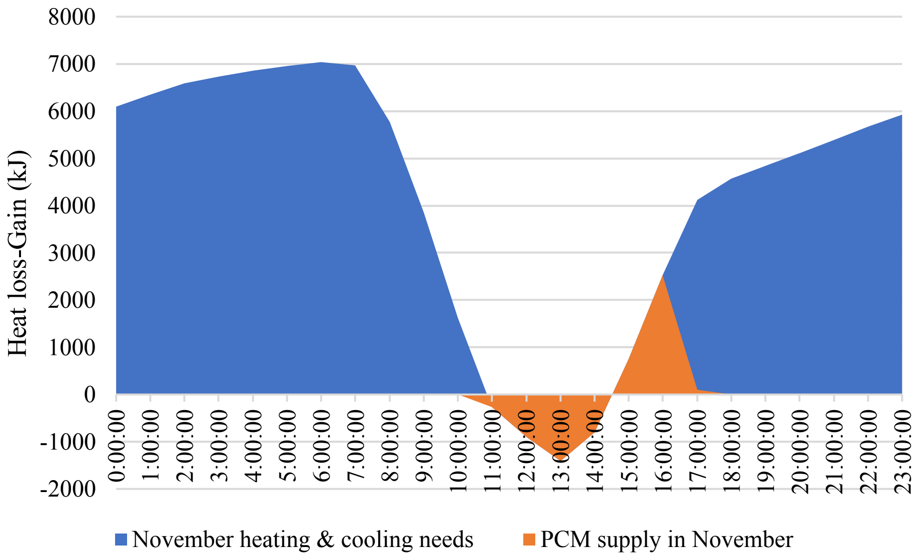


Figure 15. Storing and utilizing solar gains in November

As can be seen in Figure 16, similar to January and February, solar gains could not be stored with PCM in December as solar gains did not allow the indoor temperature to rise above 22 °C.

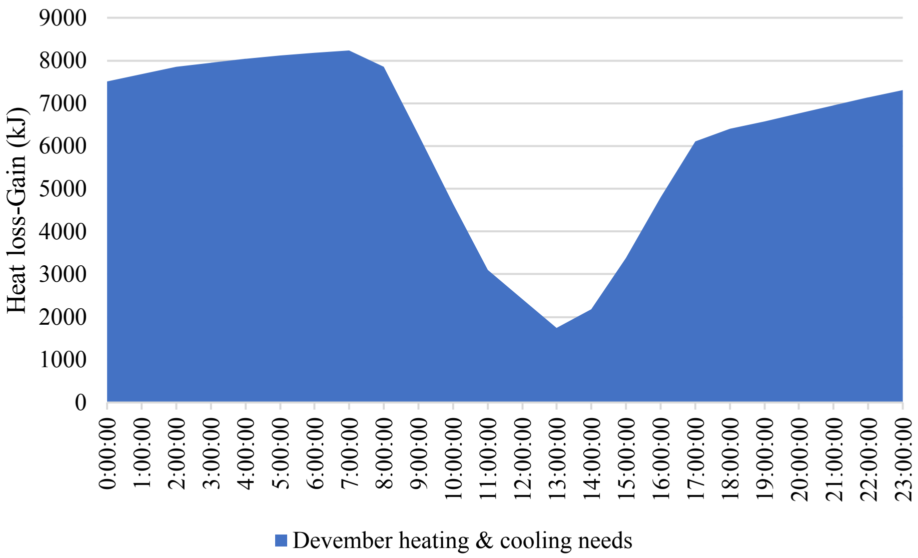


Figure 16. Storing and utilizing solar gains in December

4.Conclusions

This study evaluated the potential advantages of using PureTerm 23 paraffin PCM for indoor temperature control. The processes of storing and using the daily solar gains of a house with PCM to minimize the heating or cooling needs of the house are calculated by considering the average irradiances for each month. The irradiances used in the calculations were obtained from solar radiation data for the years 2021-2022 from a measurement station for Isparta province. According to the results of the study, it was observed that solar gains were not enough to raise the indoor temperature above 22 °C in January and February. During this period, energy storage by phase change of the PCM did not occur, and it was found to be ineffective in meeting the heating energy demand.

In March, the storage of solar gains with PCM prevented the indoor temperature from rising above 22 °C and conserved energy from 16:00 until 22:00. In this case, about 16% of the daily heating demand was met by the PCM. In April, the heating requirement was reduced by about 57% due to the PCM storing solar gains. Since the amount of PCM was determined by considering the solar gains in May in the study, the heating and cooling needs during May were met by solar gains. In June and the following months, it was observed that PCM was effective in reducing the cooling need. Especially in June, the cooling requirement was reduced by 69% thanks to the storage of solar gains with PCM. Similarly, in July and August, the PCM was effective in reducing the cooling demand (56% in July and 59% in August), resulting in energy savings.

In September, it was observed that there was no need for heating and cooling by storing all of the solar gains with the PCM and using this energy stored in the PCM during periods when cooling was needed. In October, it was determined that the heating need was reduced by 49% by storing solar gains by PCM. In November, the use of PCM reduced the heating requirement by 3%. In December, it was observed that solar gains were not enough to raise the indoor temperature above 22 °C and therefore energy storage by PCM was not realized. According to the results obtained in this study. PureTerm 23 paraffin PCM has potential advantages in terms of seasonal energy storage and can support sustainable energy management strategies for indoor temperature control.

References

[1] Wazeer, A., Das, A., & Vidya, S. (2023). Phase Change Materials for Solar Energy Applications. Transactions of the Indian Institute of Metals, 76(5), 1155-1163.

[2] Rashid, F. L., Al-Obaidi, M. A., Dulaimi, A., Mahmood, D. M., & Sopian, K. (2023). A review of recent improvements, developments, and effects of using phase-change materials in buildings to store thermal energy. Designs, 7(4), 90.

[3] Khudhair, A. M., & Farid, M. (2021). A review on energy conservation in building applications with thermal storage by latent heat using phase change materials. Thermal Energy Storage with Phase Change Materials, 162-175.

[4] Al-Yasiri, Q. M., & Szabó, M. (2021). Performance assessment of phase change materials integrated with building envelope for heating application in cold locations. European Journal of Energy Research, 1(1), 7-14.

[5] Juarez, D., Balart, R., Ferrandiz, S., & Peydro, M. A. (2013, June). Classification of phase change materials and his behaviour in SEBS/PCM blends. In Manufaturing Engineering Society International Conference.

[6] Zeinelabdein, R., Omer, S., & Gan, G. (2018). Critical review of latent heat storage systems for free cooling in buildings. Renewable and Sustainable Energy Reviews, 82, 2843-2868.

[7] Faraj, K., Khaled, M., Faraj, J., Hachem, F., & Castelain, C. (2020). Phase change material thermal energy storage systems for cooling applications in buildings: A review. Renewable and Sustainable Energy Reviews, 119, 109579.

[8] Chandel, S. S., & Agarwal, T. (2017). Review of current state of research on energy storage, toxicity, health hazards and commercialization of phase changing materials. Renewable and Sustainable Energy Reviews, 67, 581-596.

[9] Madad, A., Mouhib, T., & Mouhsen, A. (2018). Phase change materials for building applications: a thorough review and new perspectives. Buildings, 8(5), 63.

[10] De Gracia, A. (2019). Dynamic building envelope with PCM for cooling purposes–Proof of concept. Applied energy, 235, 1245-1253.

[11] Bakırhan, E. K. (2023). Faz Değiştiren Malzemelerin Bina Yaşam Döngüsü Evrelerindeki Mevcut Potansiyelleri ve Gelişmeye Açık Yönleri. Mekansal Araştırmalar Dergisi, 1(1), 109-126.

[12] Akeiber, H., Nejat, P., Majid, M. Z. A., Wahid, M. A., Jomehzadeh, F., Famileh, I. Z., & Zaki, S. A. (2016). A review on phase change material (PCM) for sustainable passive cooling in building envelopes. Renewable and Sustainable Energy Reviews, 60, 1470-1497.

[13] Gassar, A. A. A., & Yun, G. Y. (2017). Energy saving potential of PCMs in buildings under future climate conditions. Applied Sciences, 7(12), 1219.

[14] Subbiah, M. (2017). Analysis of solar heat gains and environmental impact of the phase change material (PCM) wall. Innovative Energy & Research, 6, 1-6.

[15] Al-Absi, Z. A. A. S., Isa, M. H. M., & Ismail, M. (2019). Application of phase change materials (PCMs) in building walls: a review. The Advances in Civil Engineering Materials: Selected Papers of the ICACE 2018 held in Batu Ferringhi, Penang Malaysia on 9th-10th May 2018 2, 73-82.

[16] Ismail, K. A., Lino, F. A., Teggar, M., Arıcı, M., Machado, P. L., Alves, T. A., & Benhorma, A. (2022). A Comprehensive Review on Phase Change Materials and Applications in Buildings and Components. ASME Open Journal of Engineering, 1.

[17] Wang, X., Li, W., Luo, Z., Wang, K., & Shah, S. P. (2022). A critical review on phase change materials (PCM) for sustainable and energy efficient building: Design, characteristic, performance and application. Energy and Buildings, 260, 111923.

[18] Han, H., Zhou, H., Dong, O., & Ma, J. (2022). Experimental Study on Phase Change Material with Solar Heater System for Building Heating. Coatings, 12(10), 1476.

[19] Vanaga, R., Narbuts, J., Freimanis, R., Zundāns, Z., & Blumberga, A. (2023). Performance Assessment of Two Different Phase Change Materials for Thermal Energy Storage in Building Envelopes. *Energies*, *16*(13), 5236.

[20] Kutlu, R. (2019). Bir Tasarım Öğesi Olarak Günışığı. Turkish Online Journal of Design Art and Communication, 9(2), 226-233.
of Energy Research, 1(1), 7-14.