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Utilization of phase changing materials as air conditioning alternatives in eco-green systems

Nurfi Hikma[1,*], Ade Fitri[1], Ramy Fitrah Izzah[2], Romi Fadli Syahputra[3], Zulkarnain[1,4]
[1]Department of Physics, Universitas Riau, Pekanbaru 28293, Indonesia
[2]Department of Physics, Institut Teknologi Bandung, Bandung 40132, Indonesia
[3]Department of Physics, Universitas Muhammadiyah Riau, Pekanbaru 28294, Indonesia
[4]Department of Physics, Universitas Indonesia, Depok 16424, Indonesia

ABSTRACT

Prevention of global warming due to high energy consumption and greenhouse gases is a priority for local governments, especially in Pekanbaru City, Indonesia. The use of air conditioning has become a community habit of reducing the temperature of a hot room, but unexpected things can have a negative impact on the surrounding environment. Therefore, this paper provides a simple new idea by using a phase change material (PCM) in the form of an eco-green air cooler system (EGACY) application as a free and passive cooler. EGACY consists of salt hydrates, PCM boxes, iron pipes, fans, solar panels, and batteries as the main components and several other supporting components. The EGACY system works by absorbing cold air and stored by the PCM at night through pipes connected to the outside, then expelled during the day through indoor ceiling vents. The resulting temperature in the room can be controlled at a comfortable temperature from 25°C to 28°C. EGACY is believed to be able to provide the potential for environmentally friendly technology with renewable energy sources.

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* **Corresponding Author**
E-mail address: nurfihikma9998@gmail.com

1. INTRODUCTION

The average air temperature in Pekanbaru City, Riau Province, based on information from the Indonesian Central Statistics Agency in 2019 ranged between 21.0°C to 35.9°C. Temperatures that reach 35.9°C make local residents feel quite hot, especially during the day. This temperature is a relatively hot temperature so that the Pekanbaru area became the hottest city in Indonesia in 2019 [1-3]. Such hot temperatures will certainly interfere with human activities themselves because the comfortable air conditions for Indonesian people are in the temperature range of 24.9°C to 28°C [4, 5].

One way that is often done to get thermal comfort is by mechanical air conditioning (AC). The AC cooling mechanism uses a minimum of 340 – 2000 Watts of energy [6, 7]. In addition, the use of air conditioning will certainly have a negative impact on the environment and the existing energy supply, especially in Indonesia. In developing countries, this cooling can account for more than half of the electricity consumption for a single residence [8-10]. However, its use cannot be suppressed because there are no other alternatives that are environmentally friendly and more effective in dealing with changes in average temperature [11, 12]. Therefore, one of the energy-saving alternatives that can be used is the use of energy storage methods. Thermal energy storage (TES) systems can help reduce a building's energy, contribute to efficient energy management, and improve occupant comfort indoors [13-15]. Therefore, the development of TES systems can be achieved by simple heat storage, latent heat storage, and chemical energy storage [16, 17]. However, compared to the other two methods, the latent heat storage method with the application of phase change materials (PCM) has been increasingly

investigated in recent decades due to the potential benefits of high volumetric heat capacity and narrow temperature variations during the phase transition process [18-20].

Passive and free cooling methods have been studied by previous researchers. The TES system actively integrates PCM into HVAC systems, such as air conditioning units, floor heating systems, and domestic ground heat pumps to reduce high energy demand and annual energy consumption. An air distribution system with an adequate number of PCMs in the air ducts for peak load transfer purposes, suggests that a constant room temperature can be maintained without operating a cooling source [21-23]. So the main purpose of writing this idea is to analyze a more effective method of room cooling with PCM in the form of an eco-green air cooler system (EGACY) that is environmentally friendly and renewable energy.

2. MATERIALS AND METHOD

EGACY is a material utilization method that can convert latent heat with PCM components. Inorganic PCM is divided into hydrates and metal salts. Hydrate salt itself is a dehydration process, namely the change of state from solid to liquid. The salt hydrate consists of a mixture of inorganic salts and water to form the crystalline solid MnH_2O. This material is widely used in research because of its properties, namely high latent heat of smelting, small volume at the time of melting, high conductivity, not too corrosive, and relatively cheap price. The EGACY system is installed above the ceiling with the design of the second-floor building in Figure 1 below.

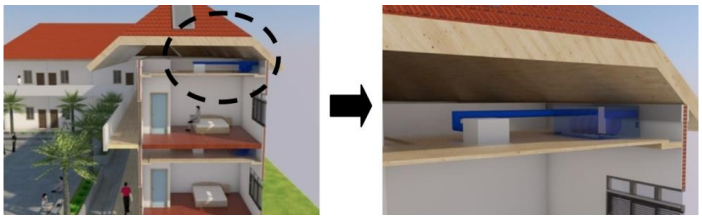

Figure 1. Illustration of the placement of the EGACY design inside the building.

Passive cooling and free cooling components in buildings using PCM consist of inorganic salts (hydrate salts), PCM box, ventilation fans, iron pipes, solar panels, batteries, Kelvin temperature sensors, EnergyPlus v8.3 applications, and anemometers. The data collection method was carried out with a quantitative approach that produced data and synthesis. Then an analysis is carried out by comparing the results of previous studies that can provide new innovations by combining several methods simultaneously. That way, the effectiveness of the methods that have been applied can be further optimized.

3. RESULTS AND DISCUSSIONS

The EGACY concept is the application of two methods at once, namely passive cooling and free cooling. Passive cooling is a method of lowering the room temperature without the use of electronic devices. While free cooling is a method of using outside/external air to help the air conditioner cool the air in the room. Furthermore, this EGACY model will capture cold temperatures at night reaching 23°C and release them during the day. This temperature range is expected to be generated during the day (thermal comfort temperature). The working principle of EGACY in the form of applications in buildings is shown in Figure 2.

Air is circulated through fans mounted on the walls of the building. The fan drive is a solar panel whose energy will be stored by the battery during the day to be used by the fan at night. The cold night temperature will be stored first by the PCM and then released during the day. This PCM storage unit is insulated on all sides at the top to minimize internal and external heat transfer to the PCM case. Therefore, adiabatic boundary conditions were applied to the lower and side walls of the PCM domain as well as the upper temperature limit. Air that enters the room will be circulated throughout the room (free cooling). Cold air will move downwards to replace hot air. Hot air will move up and finally out through the vent (passive cooling). The movement follows the rules of air convection and the cooling circulation events occur repeatedly.

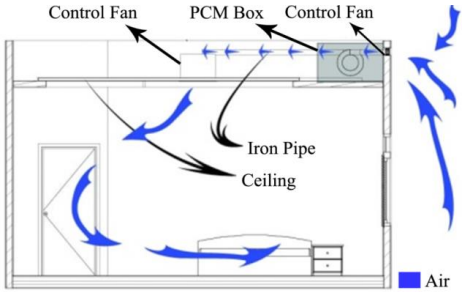

Figure 2. The working principle of EGACY.

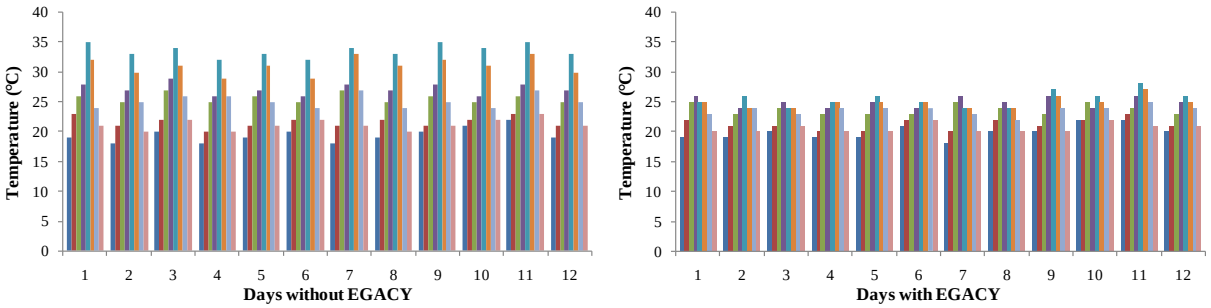

Figure 3. Changes in room temperature before and after using EGACY.

A numerical method of free cooling is carried out by modeling PCM heat exchange using computational fluid dynamics (CFD) and building simulation using EnergyPlus v8.3 applications. The developed CFD model is used to measure heat transfer or temperature changes before and after using EGACY as a room cooler. Figure 3 shows the results of measuring changes in room temperature due to the use of EGACY for approximately two weeks. The room under normal conditions is relatively 35°C during the day and 20°C at night. This situation indicates the weather is quite hot at the peak of the day, but at night the temperature drops dramatically. Except for the last three days, the lowest temperature was 23°C, which means the nighttime weather has very low humidity compared to other days [24, 25]. Fluctuations in room temperature changes are clearly visible when EGACY is activated. The average room temperature which was originally 35°C decreased to 24°C with a percentage decrease of about 17%. In addition, EGACY has the ability to control a comfortable temperature range of 24°C to 28°C. This proves that EGACY is suitable for use as an air conditioner with economical cost, energy saving, and environmentally friendly.

4. CONCLUSION

The use of the PCM method on the EGACY system has been successfully carried out. Changes in room temperature provide better results with a standard of comfort at a temperature of 24°C to maximum control at a temperature of 28°C. With this, the air conditioner that was originally used massively can be replaced with EGACY on a regular basis. So that at night, cold temperatures can be used as a source of cooling energy which is first stored by the PCM and then released during the day. Through the pipes connected to the building, the air will flow into the room and then spread to all parts of the room. If this is implemented, the benefits of cooling that are environmentally friendly, economical, and energy efficient will be obtained.

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