Portable Air Cooling and Air Conditioning Technologies: A Review

[1]Prabuddha Kr Verma, [2]Abhishek Sarkar, [3]Adarsh Singh, [4]Shadan Kamal, [5]Mrs.Garima Singh

[1,2,3,4] *Students, Mechanical Engineering, BBDITM, Lucknow, Uttar Pradesh*
[5]*Asst. Professor, Mechanical Engineering, BBDITM, Lucknow, Uttar Pradesh*

---***---

Abstract - *This paper presents a review of portable air cooler and air condition technologies. The purpose of the research is to summarize the type of air conditioning system and the principle of evaporative cooling. This paper also summarizes the recent development in the field of portable air-cooling system, challenges, and opportunities. This portable cooler is environmentally friendly. Being small in size, the portable air cooler fits easily in our kitchen, drawing room, and bedroom.*

Key Words: latent heat of fusion, enthalpy change, direct evaporative cooling, indirect evaporative cooling, peltier effect, thermoelectric cooling

1.INTRODUCTION

The average temperature in India is around 26°C (78.8°F), and various appliances such as air conditioners and fans are used to maintain a suitable temperature for humans in India. Such equipment comes at a high price. During the summer everyone needs cool air. So, to maintain a comfortable temperature, we will need to purchase air-conditioning equipment. This utility will also require space to be installed. The major goal of this research study is to provide an alternate means of cooling and to do it at a reasonable cost. This device is suitable for usage in hostels, houses, offices, and other settings. There is no scientific relevance to the ambient temperature that we can precisely evaluate. Greatly from person to person, weather conditions, and other factors, the room temperature is comfortable and appropriate. A comfortable living room temperature for humans is 21°C (70°F), However, in other locations near the equator, this temperature may well not be adequate. The room temperature will be around 30°C (86°F) when the temperature is higher.

Temperature control is a process in which the change of temperature of a space (and objects collectively there within) is measured or otherwise detected, and the passage of heat energy into or out of the space is adjusted to achieve a desired average temperature. Air-conditioners, space-heaters, refrigerators, water heaters, etc. are examples of devices that perform temperature control. There are several types of air conditioner systems which are mentioned below:

1.1 Types of air conditioning systems

(a) Window air conditioner

(b) Split air conditioner

(c) Air conditioning(central)

(d) Portable air conditioners

(e) Unitary air conditioning systems

(f) Built-up systems

2. LATENT HEAT OF FUSION

When heat energy is delivered to a specified quantity of a substance under constant conditions, the enthalpy change of the substance, also known as latent heat of fusion, happens. pressure to change its state from solid to liquid. For example, 1 kg of ice melting at 0°C under various pressures absorbs 333.55 kJ of energy with no change in temperature. The heat of solidification is equal and opposing when a substance changes from liquid to solid. This energy comprises the effort required to make room for any corresponding volume change by displacing the environment against ambient pressure. The melting point or freezing point, depending on the context, is the temperature at which the phase transition occurs. Unless otherwise specified, the pressure is considered to be 1 atm (101.325 kPa) by convention. the heat energy required to turn a solid into a liquid at atmospheric pressure is called the latent heat of fusion because the temperature remains constant during the process, The latent heat of fusion is the enthalpy change of any amount of substance when it melts. When the heat of fusion is linked to a unit of mass, the specific heat of fusion is the enthalpy change per amount of substance in moles, whereas the molar heat of fusion is the enthalpy change per amount of substance in moles.

The internal energy of the liquid phase is higher as compared to the solid phase of the same substance. This means that energy must be supplied to a solid to melt it, and energy must be withdrawn from a liquid to freeze it, because the molecules in the liquid have feeble intermolecular interactions and as a consequence have larger potential energy (a kind of bond-dissociation energy for intermolecular forces).

When liquid water is chilled, its temperature gradually decreases until it reaches slightly below the freezing point of 0 °C. While the water crystallizes, the temperature remains at the freezing point. Once water is completely frozen, its temperature continues to decline.

The enthalpy of fusion is almost usually positive; the sole known exception is helium. At temperatures below 0.3 K, helium-3 exhibits a negative enthalpy of fusion. Below 0.77 K (272.380 °C), helium-4 has a slightly negative enthalpy of fusion. This means that when heat is added to these substances at proper constant pressures, they freeze. This pressure range for Helium lies between 24.992 and 25.00 atm (2,533 kPa).

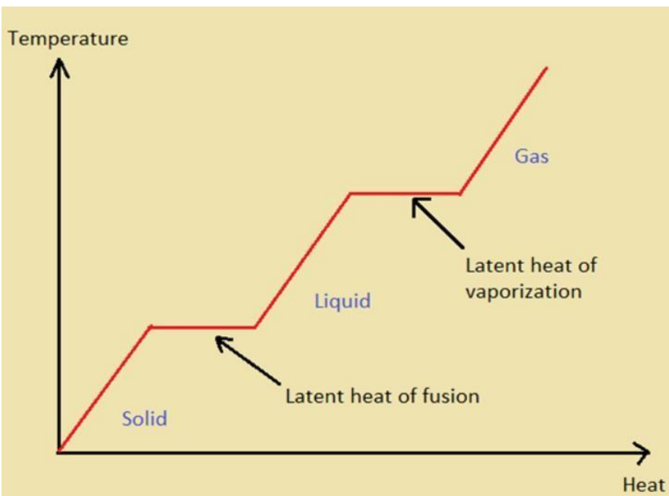

Fig 1: Latent heat of fusion

3. PRINCIPAL OF EVAPORATIVE COOLING

3.1 Principal of Direct Evaporative Cooling

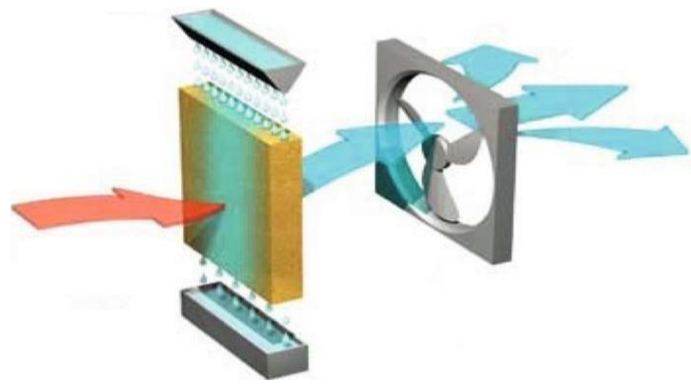

Fig 2: Direct evaporative cooling

Evaporative air coolers are generally referred to as desert coolers. Nowadays it is very popular for space cooling providing a cheap alternative to standard air conditioning systems. It operates without the ozone harming hydro-chlorofluorocarbons (HCFCs) which are used by refrigeration-based systems as compared to air conditioning (AC) units. Northern regions of India are very good locations for the execution of this device when a sufficient amount of water is available, low installation and operating costs in this region than the AC units. Despite the fact that using desert coolers for space air conditioning is a cost-effective alternative to compressor-based air conditioning systems, the evaporative cooling-based desert cooler's poor performance in humid climatic conditions is one of the reasons for its loss in popularity.

Still, it is suitable in many parts of the country due to favorable climatic conditions; it may be categorized as a direct evaporative cooling system and an indirect evaporative cooling system. Direct evaporative cooling puts water into the supply airstream directly. Water absorbs heat from supply air; it evaporates and cools the air By using some form of heat exchangers, indirect evaporative cooling decreases the temperature of the air; secondary air is cooled by water and then gradually cools the main air.

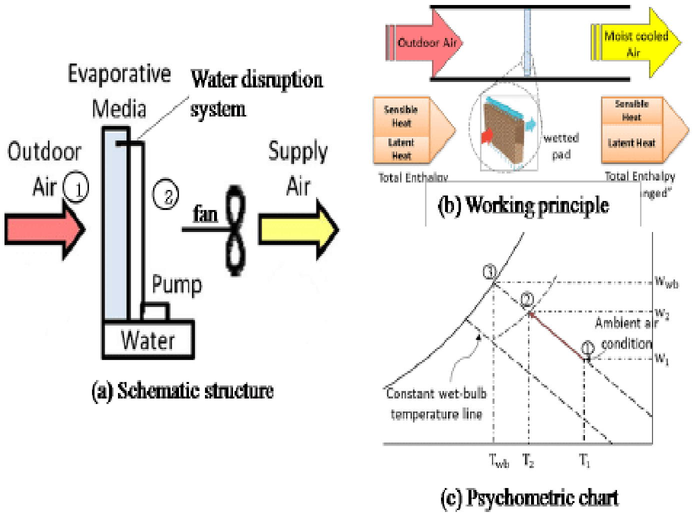

Fig 3: Direct evaporative cooling (a. Schematic structure, b. working principle c. psychometric chart)

3.2 Principal of Indirect Evaporative Cooling

The working principle scheme of the IEC equipment is presented on the left side of figure 3. Warm primary (or product) air (1) circulates inside the dry channels, transferring heat to the wet channels through the heating surface. At the outlet, the primary (or product) air (2) will have a lower temperature than at the inlet, due to the transferred heat. The secondary (working) air (3) circulates with the water inside the wet channels. The behavior of the air and water in the wet channel is similar to the DEC process. The water temperature is equal to the secondary air's WB temperature. The heat transported via the surface between the dry and wet channels is absorbed as latent heat by the water, and a portion of the water is evaporated and embedded in the secondary air through diffusion, increasing the moisture content of this air.

If the secondary air reaches saturation, the heat from the main air is divided into latent heat absorbed by the water and sensible heat absorbed by the secondary air from this point on. As a result, the secondary air temperature at the output (4) might be one of the following:

a. The temperature of the secondary air at the inflow is lower than the WB temperature (no saturation);

b. Equal to the WB temperature of the secondary air at the inlet (saturation is obtained at the outlet);

c. greater than the WB temperature of the secondary air at the inlet (saturation before the outlet).

As can be seen on the psychrometric chart, the main air's working process (1-2) is realized at constant moisture content, whereas the secondary air's working process (3- 4) is realized at constant enthalpy. At the limit, the cooling process of the primary air could continue until the WB temperature of the secondary air at the inlet.

The IEC's key benefit is that it cools primary air without changing its moisture content. The IEC's principal drawback is that the primary air-cooling process is constrained by the WB temperature of the secondary air at the input. This sort of equipment is also known as wet- bulb IEC because of this constraint.

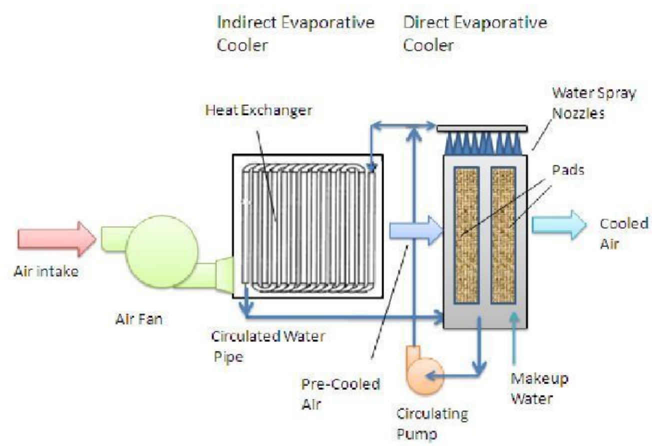

Fig 4: In-Direct evaporative cooling (Schematic structure)

4. PRINCIPAL OF THERMOELECTRIC COOLING

The Peltier effect is used in thermoelectric cooling to produce a heat flux at the intersection of two distinct material types. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump in which heat is transferred from one side of the device to the other while using electrical energy. Peltier devices, Peltier heat pumps, solid state refrigerators, thermoelectric coolers (TEC), and thermoelectric batteries are various names for the same device. It may be used for both heating and cooling, while cooling is the most widely used application. It may also be used to adjust the temperature of a room, either by heating or cooling.

This technology is used for refrigeration significantly less frequently than vapor-compression refrigeration. When compared to a vapor-compression refrigerator, the Peltier cooler has the following advantages: no moving components or circulating liquid, extremely long life, leak resistance, tiny size, and flexible shape. Its primary drawbacks are its high cost per cooling capacity and its low power efficiency (a low COP). Many researchers and businesses are working to build low-cost, high-efficiency Peltier coolers.

A thermoelectric generator can be made from a Peltier cooler. When used as a cooler, a voltage is delivered across the device, causing a temperature difference to form between the two sides. When used as a generator, one face of the device is heated to a higher temperature than the other, causing a voltage differential to develop between both two sides (the Seebeck effect). Due to various design and packaging considerations, a well-designed Peltier cooler will be a mediocre or substandard thermoelectric generator and vice versa.

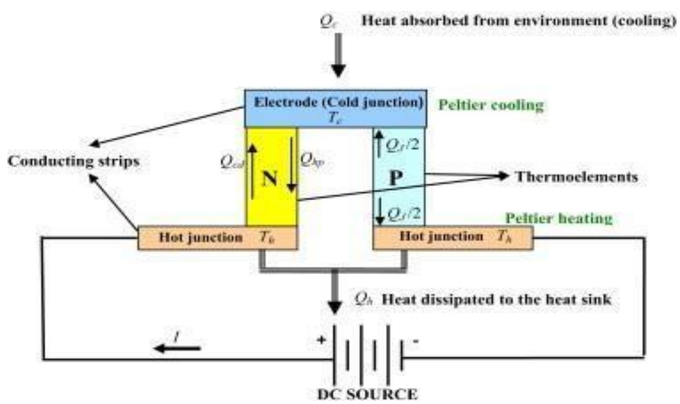

Fig. 5: Thermoelectric Cooling

5. PORTABLE AIR COOLING SYSTEM

A portable air conditioner is an innovative product originally from a standard air conditioner that is limited to being used in a room or inside the building. Then, it is designed to make it easier to move from one place to another. This product is designed to look like a decoration tree which people mostly use as a decoration in an outdoor event such as a wedding and talk. As we all notice that Malaysia has a tropical rainforest climate due to its proximity to the equator. It is a hot and humid country all year round, with an average temperature of 27 °C (80.6 °F) and almost no variability in the yearly temperature. Most Malaysians are finding a way to get comfort, especially during day events. This portable air conditioner can help them to produce a comfortable environment on a hot day.

Besides, they do not have to depend on a conventional fan that still produces warm air but this portable will give cold air the same as a normal air conditioner in a closed room.

This portable air conditioner is equipped with a photosensor that can sense the existence of people in front of it and it will automatically switch off if there are no people and it will turn on back if it detects people crossing or standing in front of it. This will make it easier for people than switching on or off manually, especially in busy events. It is also economizing the electricity when the usage is continuous without people using it which leads to waste of energy. The presence of an air conditioner is difficult to install especially to fit in an outdoor environment. This product is designed with a wheel which makes it easier to move and install. With the simplest installation procedure, anyone can easily install the air conditioner wherever they are desired

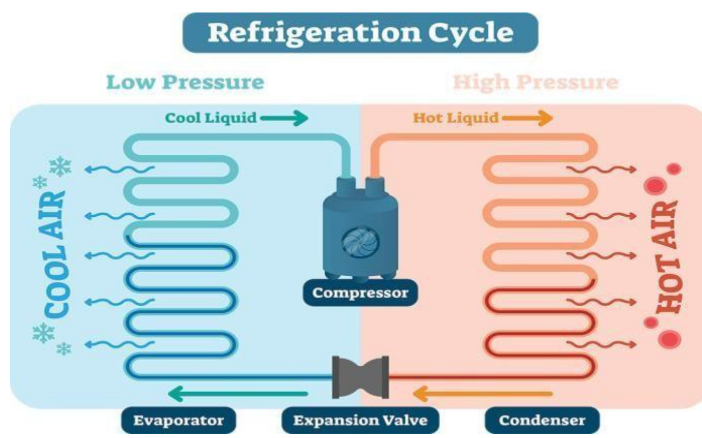

Fig 6: Refrigeration Cycle

The growth of an industry and its influence on society are frequently fascinating topics to research. Take, for example, portable air conditioning: Portable air conditioning was initially introduced to America in 1983 by Denso, a Japanese maker of automotive equipment. It was originally developed to keep employees on the assembly line cool. This was initially sold through the standard air conditioning wholesale supply channel, and it had only limited success in the early years. Only a few firms used this strategy for worker comfort since the American industry was uninterested in such an expensive solution. The majority of sales in those early years were stock orders from the wholesaler. There were only a few orders from end users. Wholesaler reorders were sparse due to surplus inventory on hand. It wasn't long before the distribution method needed to be tweaked in order to kick-start sales. It was decided to create a network of direct-sales stores specializing in portable air conditioning and selling directly to the public. Traditional wholesale distribution proved to be far less effective. Although end- user sales increased, it was superb timing that proved to be the most important factor in the industry's success. This coincides with the minicomputer explosion, which began in the mid-1980s and lasted until the early 1990s.

6. LITERATURE REVIEW

Somchai jiajitsawat [1] has fabricated and tested a portable hybrid thermoelectric-direct evaporative air cooling system based on a commercially portable direct evaporative air cooler integrated with a thermoelectric refrigeration system. In this hybrid thermoelectric direct evaporative air cooling system, 12 thermoelectric modules TEC1-12708 are used to cool water by stacking their cool side into layers on one wall of the aluminum container and the hot side on the rectangular fin heat exchanger. This cooled water is then used for a direct evaporative cooling system. This direct evaporative cooling system is used as a main air-cooling system by inducing the hot ambient air in direct contact with the working fluid (water). The testing results show that under the fan operation, the system is unable to cool the inlet air temperature (or 0% cooling effectiveness) When the DEAC system is active, the cooling performance of the prototype increases by 20% and is up to 30% with higher fan speed (or 1.7 C of air temperature drop). The results of TE installation shows that it can improve the cooling performance of the DEAC system by 10% and is up to 20% with higher fan speed (or 2.6 °C of air temperature decrease). Therefore, the concept of applying TEs to cool the water temperature in the container seems to be reliable not only for its additional cooling capacity but also for contributing more convenience to a portable DEAC system in the market. However, due to the low COP of 0.06, the heat exchanger at the hot ends of TE should be redesigned carefully in order to improve the cooling performance of the TE system.

Bogdan Porumba et.al [2] discussed a review of IEC (indirect evaporative cooling technology). Indirect evaporative cooling is an emerging technology that has promising potential to improve air conditioning. The review presents theoretical and practical aspects related to the IEC's development including theory, construction principles, flow schemes, working conditions, and parameters of performance. From a geometric perspective, there are constructions based on horizontal or vertical plates and also horizontal tubes. The different flow schemes let you use outside and inside air as your primary or secondary supply of fresh air. It is a very common practice to regenerate it, which involves recirculating part of the cooled primary supply as secondary. The R-IEC equates to the ratio between Primary (0...100%), Fresh Air, and Secondary.

N. Beemkumar et.al [3] investigated an air cooler with thermal storage, which can be used as an AC backup system when in a room where the AC unit is turned off or not working properly or during power outages. The units are placed inside the air-conditioned room near the main AC and will keep cool until it's needed again. During a normal time of A/C operation, the PCM in the heat exchanger changes from liquid to solid and stores cold energy as latent heat of fusion. In case of power failure, the mobile air cooler with PCM storage uses only the fan operation from DG set for circulating chilled air through it. This cool air is concentrated in the area where occupants are present and cooling can be achieved locally. The phase change material has a phase change temperature of 25°C to 26°C, which makes it appropriate for this application. The use of this air cooler is ideal for restaurants and shopping complexes, where diesel generators cannot run their AC units.

Franck Lucasa et.al [4] developed a method to evaluate the energy performance of buildings cooled by room air conditioners, like split AC systems. These types of small ACs are often installed without proper study of their building envelope's performance just because of their low cost and small size. This isn't a question of whether or not the system is maintained, but rather if it is done according to regulations. Some tradesmen sometimes neglect to comply with these rules and regulations. If maintenance is not carried out properly then eventually the systems will be compromised and energy performance will suffer. This article provides an overview of a practical, global approach to diagnosing the performance of existing small air- conditioning installations in buildings on Reunion Island. One goal for this tropical island is to become self-sufficient with electricity. This approach uses a numerical tool to help you determine the best system for your building and it relies on dynamic simulations of buildings equipped with AC. The simulations, which take account of all aspects including the envelope, as well as users' practices, are based on kernel calculation Energy. In order to help make better decisions, they also take into account climatic conditions and provide an estimate of the annual electricity consumption related to cooling a zone. This global analysis helps to qualify them by assigning an energy label.

T. Wessapan et.al [5] conducted research on the portability of an air conditioning-heat pump unit that uses a helical coil heat exchanger making use of both heating and cooling systems to maximize energy utilization by using the waste heat recovery from an air conditioner, for warming water. In recent years, there have been some scholars who study the use of a helical heat exchanger for recovering waste heat from domestic water-cooled air conditioners. However, there is no evidence that the helical heat exchanger has ever been used with a portable air-conditioning system to improve the cooling performance of a portable A/C unit and enhance its heat recovery performance. The portable air conditioning-heat pump unit was fabricated in the lab and then tested at water flow rates ranging between 0.5 - 2 liters per minute. In the experiments at full load conditions, they measured and evaluated cooling performance, heat recovery, and power consumption for different water flow rates.

Vahid Khalajzadeh et.al [6] conducted a study in which researchers conducted a case in Iran's capital city of Tehran. The IEC faced restrictions during certain summer days- so the team chose it as their geographical location to examine the thermal performance of decentralization and centralization systems. Since centralized heating is not always sufficient for comfort conditions, they decided to explore different systems that would provide better results. A temperate, dry climate is found in Tehran. The wet bulb temperature is less than 23℃ and the dry-bulb temperature goes down to less than 40 ℃ Aluminum fins with staggered copper tubes that cool air for a small dwelling air conditioner, where water and air mass flow rate is chosen to be suitable for the type of unit being used. Other CCU specifications are presented. An indirect evaporative heat exchanger is used to provide a cooling performance and increase the efficiency of a hybrid system, which has an air temperature at the exit of each section about 8–11◦ C lower than that inlet. Thus, the ambient air is able to enter IEC with a lower wet-bulb temperature. In this case, the maximum and minimum heat reduction in the GCC are 4.5 kJ/s and 3.1 kJ/s, respectively; while there is maximum cooling effectiveness of 0.73 and minimum cooling effectiveness of 0.59. This process of pre-cooling helps the IEC to achieve higher performance. By integrating an additional cooling device into the unit, its total cooling effectiveness increases significantly. The proposed system's effectiveness is greater than unity, which means that this system can decrease air temperatures below wet-bulb temperature.

Takahiko Miyazaki et. al. [7] have developed a building integrated photovoltaic-thermal (BIPVT) setup, with the goal of developing a passive cooling device that can effectively minimize the cooling load on central air conditioners in hot and humid weather. The authors recommended using a solar chimney and a dew point evaporative cooler to incorporate a passive cooling system into a structure. The cooling performance of the system with a modified design has been simulated in this study. Evaporative cooling is a way of cooling outdoor air before supplying it to an area. Both active and passive systems can benefit from evaporative cooling. Evaporative cooling for passive systems is a field that has been relatively unexplored, and the technology to combine it with building structures is still in the works. The passive system, which consisted of a south wall collector and a roof duct with an evaporative cooling surface, was shown to control temperature fluctuations in the room, keeping it around 30°C during the summer while the ambient temperature reached 42°C at its highest. Chungloo and Limmeechokchai assessed the performance of a solar chimney with a water- sprayed roof, and the results showed that when the two passive measures were combined, the room air temperature dropped by 2.0–6.2 degrees Celsius when compared to the ambient temperature. Maerefat and Haghighi developed a system with a solar chimney and an evaporative cooling chamber by employing a mathematical model to investigate the effects of geometrical dimensions as well as ambient conditions on cooling effectiveness. The results showed that the proposed system could improve indoor conditions with a low solar intensity of 200W/m2 and a high ambient temperature of 40°C. They found that the system produced suitable interior air conditions at a high ambient temperature and relative humidity of less than 50%, but that the relative humidity of the ambient air had a significant effect on room air temperature. Passive cooling is a cooling technique that does not rely on active mechanical equipment, such as pumps and fans, but instead depends on buoyant air movement to provide cooling. Solar chimneys, Trombe walls, and double facades are all examples of devices that rely on the stack effect to stimulate air movement, and the increased natural ventilation provided by those devices will provide cooling. In a hot and humid climate, natural ventilation on the other hand may compromise building thermal comfort, as the temperature and humidity of outdoor air during the day are significantly higher than that of an air-conditioned room. During the summer months, it is not uncommon for outside air temperatures in Japan to exceed 25 degrees Celsius throughout the night.

Jakkula Rajesh et.al.[8] did a detailed study of the vapor compression refrigeration cycle, as well as the classification of condensers and evaporators in refrigeration and air conditioning systems. A portable air conditioner's coefficient of performance (COP) utilizing R22 was calculated and found to be 8.96.

Shahi Satyam et.al [9] researched and developed a portable air conditioner system that meets the users' needs at the lowest possible cost, and the manufacturing and maintenance costs are extremely low. It has comparable cooling power to a wall air conditioner, is easily transportable, and can be moved anywhere. It is small and so would be suitable for our bedroom, living room, and kitchen. It is completely non-toxic.

Garud Akhilesh Ravindra et. al [10] developed a portable A.C. that is extremely simple to install, and it is generally cheaper to implement additional energy-saving measures when retrofitting work is already being performed on a building than when the hospital is in normal operation. They eliminated the need for a centralized air conditioning system.

W. N. Fakhira[11] developed a thermoelectric air cooler that is feasible and marketable. The thermoelectric air cooler is based on a Peltier for cooling, and it fulfills the basic air conditioner functions. The thermoelectric air coolers were tested on their functions and reliability of construction. Human factors taught us that people can be uncomfortable because of several factors. Temperature is one of them, as we all know that certain countries, particularly those with a tropical climate, such as South East Asia, have a hot temperature climate. Because of this, a thermoelectric air cooler is one of the most important things that can help a student feel comfortable. This thermoelectric air cooler is a good deal for students because of its shape, which makes it easy for them to carry it everywhere. Some students have limited space for air conditioning, so this smart thermoelectric air cooler can be fitted in a study space near the user to free up that space for an air conditioner. Because it is lightweight and portable, the thermoelectric air coolers could be relocated and set up quicker

Nilesh Ambaji Jadhav [12] noticed the problem of global warming as the conventional air conditioning system gives out Chloro-Fluoro Carbon resulting in depletion of the Ozone layer due to global warming. Nowadays there is a day's power crisis. So, importance should be given to power saving and energy conservation. After noticing all the problems like this he developed a 360° air cooler and heater to reduce the consumption of energy. 360° air cooler and heater is a device used to cool or heat the air according to the requirement of the user. A conventional air conditioning system uses three to five times electricity as compared to the 360° air cooler and heater which results in the emission of a considerable amount of heat resulting in global warming. In this project 360˚ air cooler cum heater will be designed, developed, and fabricated for low operational and overall cost.

Vignesh Ravi et. al [13] has Designed And Fabricated the MINI AIR COOLER in which the cooling of air by using cold water or any other refrigerant is circulated in the copper tube for the purpose of reducing the heat in the surrounding environment, where it is of great importance in widely distributed villages with little or no rural electrification and also in the urban areas where power shortage is often in practice. They identified the problem of poor people and the power shortage problem and worked on this project.

7. CHALLENGES AND OPPORTUNITIES

In India, one of the biggest no. of students is in the hostels and a large no of the population are lower middle-class families and they live as tenants. In India the most vulnerable season to sustain is Summer. The temperature during summer season in India can vary from 25°C to 45°C and this range is getting higher every year due to global warming, these temperatures when paired with excess humidity are a nightmare for Indians. Temperatures in low-lying areas may exceed 50°C during the months of May and June, leading to heat waves that can kill hundreds of Indians that are left without any cooling solutions. The cooling systems present today lack features that are essential for lower-middle-class families and hostel students. For these lower middle-class families and hostel students, the most important features a cooling system must have are affordability, lower running cost, low maintenance cost, compact size to be able to fit in smaller rooms, portability, and the optimum cool air for comfort.

People of today's generation are increasingly interested in technology, as they aim for optimum comfort and well- being while also possessing the technology to attain it. People nowadays prefer smaller air conditioner units and other air regulating appliances, and these types of technologies are constantly created and desired by consumers who wish to manage the air climate in their homes or places of business.

As Refrigerants used in the air conditioner are the main cause and continue to cause serious environmental issues, including ozone depletion and climate change, as several countries have not yet ratified the Kigali Amendment to reduce the consumption and production of hydrofluorocarbons. Currently, almost all the air conditioners use around 20% of energy consumption in buildings globally, and the expected growth of the usage of air conditioning due to climate change and technology uptake will drive significant energy demand growth. As a substitute for continual air conditioning includes passive cooling, passive solar cooling, natural ventilation, operating shades to reduce solar gain, using trees, architectural shades, and windows (and using window coatings) to reduce solar gain.

8. CONCLUSIONS

As a conclusion, we can conclude that the portable air cooler satisfies the needs of the consumer at the most economical cost. The portable air cooler has a very low maintenance cost. It provides the facility of portability and can move anywhere easily. It is smaller in size, hence it would sit nicely in our bedroom, drawing room, and kitchen and it is completely non- polluting because we are using ice as a cooling medium.

REFERENCES

[1] Somchai Jiajitsawat, "A Portable Hybrid Thermoelectric-Direct Evaporative Air Cooling System" Naresuan University Journal 2012.

[2] Bogdan Porumba, Paula Ungureşana, Lucian Fechete Tutunarua, Alexandru Şerbanb & Mugur Bălana, "A review of indirect evaporative cooling technology", Energy Procedia 85,461 – 471,2016.

[3] N.Beemkumar, D.Yuvarajan, J.Jayaprabakar, Department of mechanical engineering, "Experimental Investigation on Air Cooler with Thermal Storage", pg. 205-211 IEEE,2010

[4] Franck Lucasa, Pascal Ortegaa, Mathieu Davidb, Frantz Sinamab, Boris Brangeonb Fabien Picgirardc, "A Method To Evaluate Energy Performance Of Buildings Cooled By Room Air Conditioners", The 7th International Conference On Applied Energy – Icae, pg. 1275 – 1283,2015

[5] T. Wessapan, T. Borirak, S. Teeksap , "A Development of a Portable Air Conditioning-Heat Pump Unit using Helical Coil Heat Exchanger ",2nd International Conference on Computer Engineering and Technology, v5 186-189, Thailand 2010

[6] Vahid Khalajzadeh, Moien Farmahini-Farahani 1, Ghassem Heidarinejad, "A novel integrated system of ground heat exchanger and indirect evaporative cooler'' Department of Mechanical Engineering, Tarbiat Modares University, P.O. Box 14115-143, Tehran, Iran 13 January 2012.

[7] Jakkula Rajesh, Suresh Akella, K. Sainath, "Portable Air Conditioner Design for Fabrication", International Journal of Research in Engineering, Science and Management, Volume-1, Issue-10, October-2018

[8] Takahiko Miyazaki, Atsushi Akisawaa, Isao Nikai, "The cooling performance of a building integrated evaporative cooling system driven by solar energy'', Engineering Consultant, 5-7-12 Kiminomori-minami, Ooami-shirasatomachi, Sanbugun, Chiba 299-3241, Japan 2011.

[9] Shahi Satyam, Sucheta Jagtap, Sanap Archana, Patil Swapnil, "Design and Development of Portable Air

Conditioner", International Journal for Research in Engineering Application & Management, Vol-02, Issue 07, Oct 2016

[10] Garud Akhilesh Ravindra, Dolas Nikhil Rajendra, Mahajan Sumit Prakash, Jadhav Rahul Devidas, Prof. Thakare Rakesh Balwant, "Review Study of Portable Air Conditioner", International Journal of Engineering and management research, Volume-6, Issue-2, March-April 2016

[11] W N Fakhiraand, M K Fadzly, "Smart Portable Air Cooler Using Thermoelectric Peltier", AIP Publishing,020150-1 to 5, 2019

[12] Nilesh Ambaji Jadhav," DESIGN OF 360° AIR COOLER AND HEATER", Journal of Emerging Technologies and Innovative Research, Volume 6, Issue 1,2019

[13] VIGNESH RAVI, A.SATHISHKUMAR, N.SIVA, R.RAVIKUMAR." DESIGN AND FABRICATION OF MINI AIR COOLER, International Research Journal of

Engineering and Technology (IRJET)", Volume: 03 Issue: 12 Dec -2016

BIOGRAPHIES

Mr. Prabuddha Kr Verma was born in 2001 in Lucknow Uttar Pradesh India. He is currently pursuing his Bachelor of Technology degree in Mechanical Engineering from BBDITM. Lucknow(affiliated to Dr. A.P.J. Abdul Kalam Technical University Lucknow)

Mr. Abhishek Sarkar was born in 2000 in Lucknow Uttar Pradesh India. He is currently pursuing his Bachelor of Technology degree in Mechanical Engineering from BBDITM. Lucknow(affiliated to Dr. A.P.J. Abdul Kalam Technical University Lucknow)

Mr. Adarsh Singh was born in 2000 in Lucknow Uttar Pradesh India. He is currently pursuing his Bachelor of Technology degree in Mechanical Engineering from BBDITM. Lucknow(affiliated to Dr. A.P.J. Abdul Kalam Technical University Lucknow)

Mr. Shadan Kamal was born in 2000 in Lucknow Uttar Pradesh India. He is currently pursuing his Bachelor of Technology degree in Mechanical Engineering from BBDITM. Lucknow(affiliated to Dr. A.P.J. Abdul Kalam Technical University Lucknow)

Mrs. Garima Singh was born in 1986 in Lucknow Uttar Pradesh India. She is an Assistant professor in BBDITM . Lucknow(affiliated to Dr. A.P.J. Abdul Kalam Technical University Lucknow)