Electrical Efficiency Improvement by Using Phase Change Materials in Photovoltaic Systems: A Review

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Abstract

This paper described a detailed study of the literature review, focused on the use of a Phase Change Materials (PCM) for photovoltaic (PV) system, electrical efficiency and thermal regulation improvement. The different PV cooling methods have been discussed and then, the present investigation carried out in the phase change material. There are different types of PCM studied such as paraffin, stearic acid, cobalt sulphate Hypthydrate, yellow petroleum jelly etc. the result shows that organic paraffin has a better performance 9.07% compared with other PCMs.

Key words: Photovoltaic Panel, Phase Change Materials, Operating Temperature, Application, Panel Performance.

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Nomenclature

Abbreviation	**Description**
AC	Alternative current
CHS	Clathrate Hydrate Slurry
DC	Direct Current
MPP	Maximum Power Point
COP	Coefficient of Performance
PCM	Phase Change Material
PCMS	Phase Change Material Slurry
PV	Photovoltaic
STC	Standard Test Condition
TES	Thermal Energy Storage
LHS	Latent Heat Storage
HDPE	High density polyethylene

Introduction

The worldwide is, in many countries are to start using the renewable energy source. PV cell is one of the most important products of renewable energy conversion, it can be converts the clean electricity directly from the solar radiation. Here, the major drawback of solar PV panel due to temperature rises electrical energy will be reduced so we focused on alternative methods for avoiding energy reduced.

Shivangi Sharma et.al(2015) they initial investigation into an in-house developing test BICPV-PCM prototype system has shown applicable results with providing15.9% electrical efficiency improvement in BICPV.an absolute electrical power conversion efficiency of without PCM cooling module resulted in 7.82% while, with PCM use in the system is increased to 9.07%. The experiment could be iterated for longer durations to explore PCM cooling characteristics and with various organic and inorganic PCM with different melting characteristic, to test their efficacies.

R. Rajaram D.B. Sivakumar(2015) experimentally proved that the phase change materials [cobalt,sulphate hepthahydrate] situated in the back of the solar panel can maintain the panel's operating temperature around two hours in under 40°C a constant solar radiation of 1000 W/ sq. m. The implementation of the phase change material under the solar panel has increase the performance of the solar panel by 5.02% and an increase in power production by 7.92%.

Ahmad hasan et.al(2016) The tested PV-PCM system has reduced heat losses by up to 435KWh/day which, resulted an increased thermal energy storage capacity by the same amount compared to the PV without PCM. They proposed better electrical performance increased in PV-PCM, this system ~6 % (equivalent to an increase in PV efficiency of ~1%) and thermal performance by ~41% compared to the available global solar irradiation.

Yuli Setyo indartono et.al(2014) In this research found that average power and efficiency increased for PV on roof condition is 22.6 and 21.2% respectively; while PV on stand average power and efficiency increase by 6%and 7.3 respectively. It can be concluded that passive cooling for PV, by using PCM is more suitable to be applied in BIPV.

Pascal Biwole et.al(2011) In this paper describe to maintain the temperature of the panel by the use of phase change materials (PCM), close to the CFD modelling of heat and mass transfer in a systems composed of an impure phase change materials situated in the back of a solar panel. It can maintain the panel's operating temperature under 40^{o}C for around two hours under a constant solar radiation of 1000W/m^2.

Marta Kuta et.al(2015) they found solid- solid phase change materials based on polyethylene glycol and cellulose have been synthesized. Chosen material will be tested by the thermal stabilisation of electronic devices. Preliminary results of test on the material confirmed possibility of its use for mentioned application.

Christopher J.Smith et.al(2014)shows that energy output improvements without PCM over the system everywhere positive and in some locations in remain of 6% on an annualised basis, with many regions of the world experiencing a potential total energy gain of 23 KWh m^{-2} based on reference cell efficiency of 15.6% the best results are seen where an ideal PCM melting temperature for the location in question is used and PCM melts fully over the course of the day and solidifies in the evening

Y S Indartono et.al(2014)They found simulation result, the optimum thickness of the PCM is at 80mm, and crude palm oil (CPO) has better performance than coconut oil in ambient temperature around 27-30^{o}C meanwhile from experiment, the biggest temperature difference between reference PV and PV/PCM occurred at 102mm PCM thickness i.e. 9.6°C. With 102mm PCM thickness output power and efficiency of the PV are higher than the reference i.e. 2.1% respectively.

Pooja Shukla et.al(2016) in this research have been study the possibility of storing solar energy and heat use as phase change materials(PCM), purpose of reduce the solar PV panel temperature as much as increase the electrical efficiency up to possible. Clearly such systems are financially viable in higher temperature and higher solar irradiation environment also, with cheapest PCM mixture and totally pollution free without any maintenance cost with minimum accommodation.

Ahmad Hassan et.al(2014) have been evaluate the effectiveness of PCM in temperature regulation and electrical performance enhancement of PV panel. When a temperature drop of 12^0C and associated voltage gain is also observed. The result obtained for testing PCM in higher temperature climate shows a promise for PV temperature regulation and power enhancement in the mild season of February when it always get back to solid.

Hassan mahamudul et.al(2016) this work modulate the solar PV panel, based on Malaysian weather condition with integrating the phase change materials. Through the numerical analysis and experimental investigation it has been shown that if PCM layer width 0.02m of RT35 is used as cooling arrangements the PCM can be used the problem will be solved. This will be the future step of this work

Taieb nehari et.al(2016) In this investigation we tried to maintain the PV's temperature at a low values by incorporating a solid-liquid PCM and inner fins. The aim of this work is to investigate numerically the melting behaviours and performance under the effects of the angle of inclination. The commercial CFD code was been used to solve the conservation equation is mass, momentum and energy.

M.J Haung et.al(2008) In this research was found that natural convection started during the early stages of the melting process and increases in magnitude with the melting process. A better fundamental understanding of the process within a PV/PCM system can be used to improve the optimum PV /PCM system design.

Marta Kuta et.al(2016) the research contains a summary of well-studied and known, previously used solution based on phase change materials as well as novel possibilities, which are under development and investigate of highly effective solutions. This work focused on selective applications of PCMs technologies based on renewable energy sources.

Definition of PCM

The PCM defined as the storing thermal energy device to make use of latent heat of PCMs, usually between the solid to the liquid state. Since a phase change materials involve a large amount of latent heat energy at small temperature changes, PCMs are used for temperature stabilization and for storing heat with large energy densities in combination with rather small temperature difference. The latent thermal energy storage is the less thermal conductivity of the materials used as PCMs, this is the main drawback of these process and limited electrical energy only extract from the energy storage(A.Heinz, w.streicher 2001).

PCM Types

The number of PCMs, which can be classified based on different criteria, such as their melting temperature and latent heat of fusion, the changing of phases, or their source material (Abdullah I 2016).figurer.1 gives details of The melting temperature range suitable for applications in buildings, a variety of organic and inorganic PCM have been identified as well as eutectic mixtures. A Eutectic mix is a blend of two or more components, each of which melts and freezes congruently, forming a mixture of the component crystals during crystallization. Selecting one or another type of PCM depends on the characteristics and specific needs of each application (Edwin Rodriguez-Ubinas 2012)

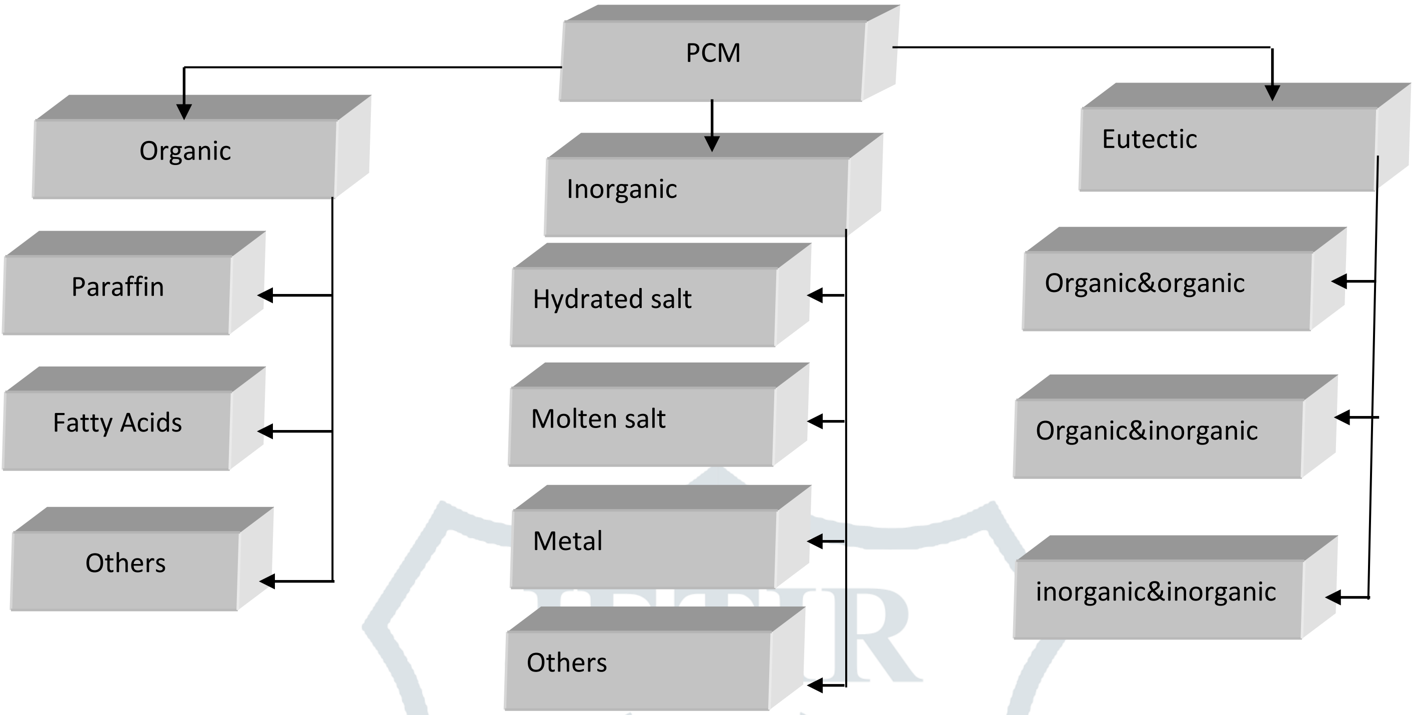

Figure 1.Types of PCMs according to their sources (Abdullah I.Abuzaid 2016)

PCM Materials and Their Characteristics

Inthisresearchvarietyofmaterialswereusedas PCM.Inprincipalmaterialsshouldfulfildifferentcriteria in order to be suitable to serve as a PCM(A.Heinz, w.streicher 2001).

Suitable melting temperature
High melting enthalpy per volume unit[KJ/m^3]
High specific heat [KJ/kg.K]
Low volume change due to the phase change
High thermal conductivity
Cycling stability
Not flammable, not poisonous
Not corrosive (A.Heinz, w.stricher 2001)
Minimal changes in volume, Substances expand or contract when they change state, because PCMs in construction need to be contained within a cassette, large changes in volume could create problems.
Congruent melting, this means that the composition of the liquid is the same as that of the solid (nader A. Bandar bulshalaibi)

PCM Properties

Abdullah I.Abuzaid (2016) explained about that PCMs have different thermo-physical properties, chemical properties, and kinetic properties. High thermal conductivity, solid and liquid phases and acceleration time of charging and discharging of energy, are examples of PCMs' thermo- physical properties. They also list some examples of chemical properties, such as chemical stability and absence of degradation after a large number of freezing and melting cycles. Nucleation rate, which is beneficial for avoiding super cooling of the liquid phase, is an example of kinetic properties.

The PCMs core property is based on their latent heat storage capability around their melting points, because more amount of energy can be stored in a comparatively small volume of PCMs.

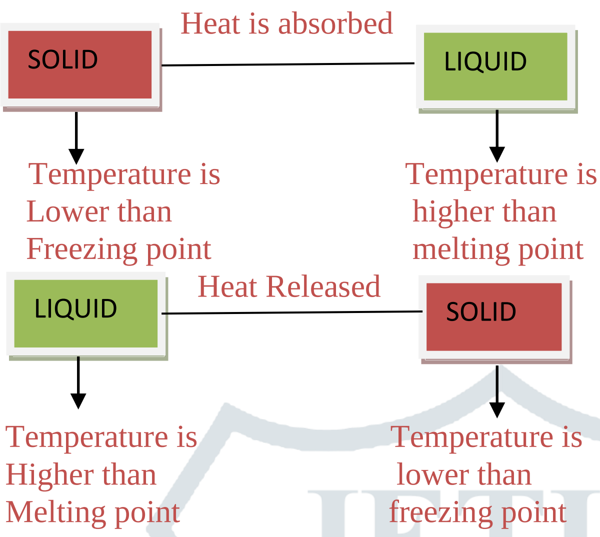

Figure2. Cooling and heating effects on PCMs Abdullah I.Abuzaid (2016)

Application of Phase Change Materials

PCMs as an efficient way of storing thermal energy by the latent heat storage materials that can be used as temperature-controllers in construction and architecture (Abdullah I. Abuzaid2016).

These materials provided for active and passive solar applications during the 1980s. In addition, (Abdullah I. Abuzaid2016) they investigates the PCM was melted by direct solar radiation, when the encapsulated commercial PCM products at that time were inadequate for delivering heat to the building passively. This can be clearly seen in the buildings' envelopes, which offer large areas for passive heat transfer. The most important one, the building construction applications to create thermal comfort in buildings. The required for proper building materials with high performance insulation is considered (Abdullah I. Abuzaid2016).

When the air temperature rise or falls beyond the PCM melting point, the heat or cold were automatically stored or released. The passive systems can take advantage of the internal thermal gains. On the opposite, of the active application, the PCM thermal energy charging and dis-charging is achieved with the help of mechanical equipment (Edwin Rodriguez-Ubinas 2012).

More than 500 natural and niminypiminy(synthetic) PCMs are known in addition to water. The phase change temperature ranges and their heat storage capacities, they could be differ from each other. Besides Other properties of PCM for a high efficient cooling system with thermal energy system (TES) (nader A. nader 2015). The figure.3 shown that different types of PCM and its components, storage unit etc.. Mentioned below.

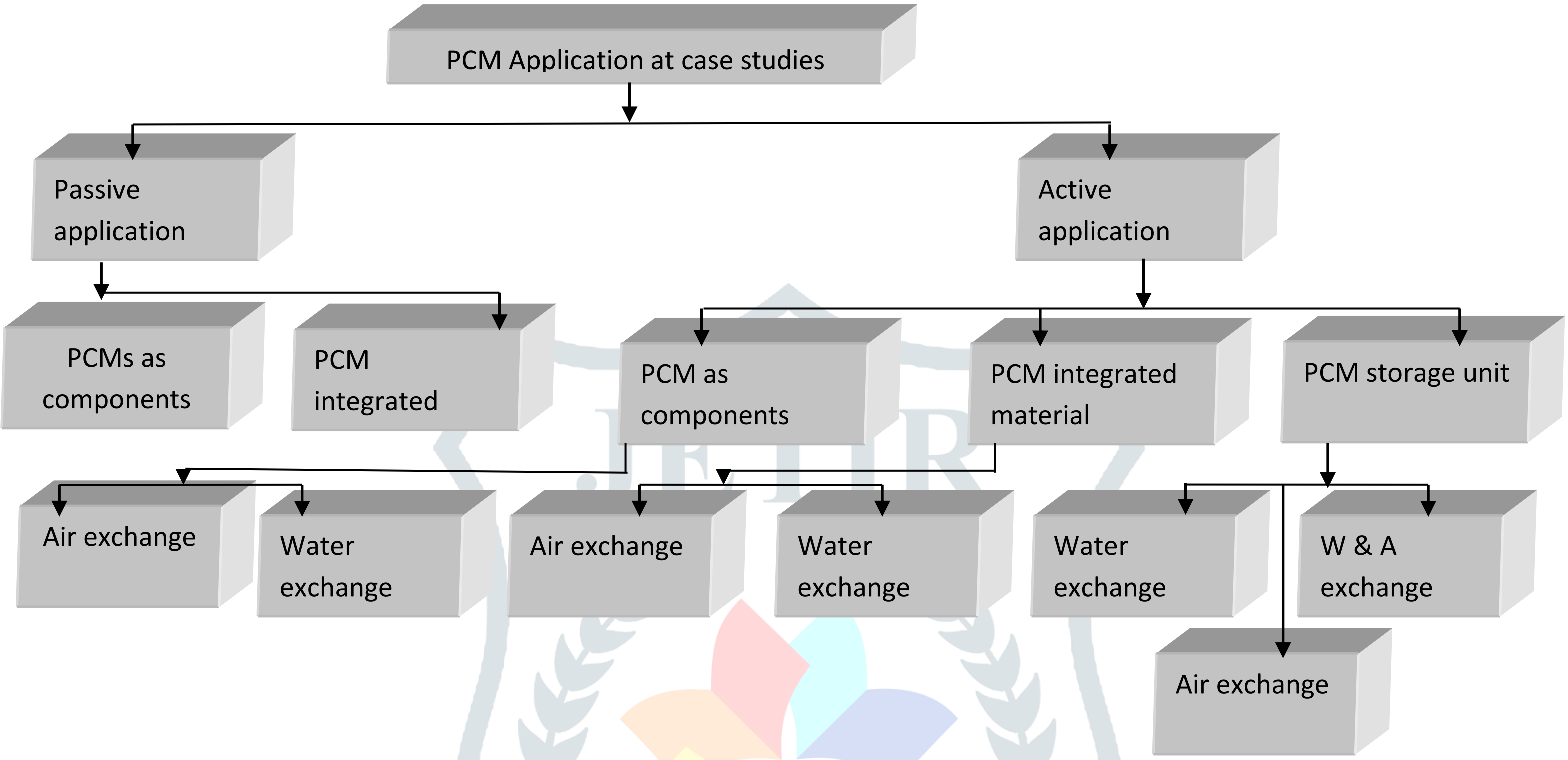

Figure3. PCM application classification diagrams (Edwin Rodriguez-Ubinas 2012).

Passive application: PCM as component

The system designed by macro-encapsulated PCM and integrated into a layer of the floor assembly, beneath the engineered hard-wood flooring as shown in. They used a commercial PCM product, DELTA-COOL 24; it is consists on salt hydrate PCM encapsulated, which is 15 mm thick polypropylene panels.

A heat storage capacity of each panel has an approximately62.6 kWhand, the PCM is designed to melt at 24 ° C and solidify at 22 ° C. A totally installed PCM panels 62.1 m^2, with a melt enthalpy of 158 kJ/kg.

The sunlight falling on the floor, the PCM absorbs the thermal energy directly from the sunlight, the excess of heat inside the house, to use it throughout the night. Otherwise, during the day time when cool is required, the shades automatically block the solar radiation before it reaches the glazing, eliminating unwanted solar gains and the PCM reduces the cooling peak load by taking off the excess heat; the air force night ventilation system is activated at night time, enabling the PCM to release the stored heat into the cool night air. The shades help to maintain the interior temperature between these two extreme operational states, and comfort changing their angles between parallel or perpendicular to the sun's rays as needed. The energy demand of the house is reduced from approximately 2800 kWh/yr to less than 2000kWh/yr by the ESP-r simulations through the addition of PCM.(Edwin Rodriguez-Ubinas 2012).

Active applications: PCM as component

A house equipped with the combination of forced air smart control system. The PCM improve the heat transfer condition in thermal storage system. The Dow Chemical Co., black moulded polyethylene modules (36 cm × 56 cm × 5 cm) designed to fit between the walls. This was one of the first PCM products for building thermal com-fort in the market, the commercialized modules were filled with 8.4 kg of Calcium Chloride Hex hydrate TESC-81, with a shift tem-prelature of 27 ° C and a thermal storage capacity is 386.4 Kcal. Inter phase modules were typically installed within timber stud or masonry cavity back of the wall situated a glazed screen for direct solar collection. (Edwin Rodriguez-Ubinas 2012)

Passive storage in biometric building/architecture (HDPE+paraffin)
Thermal storage of solar energy
Thermal protection of food, transport, the hotel trade, ice-cream, etc.
Cooling use of off-peak rates and reduction of installed power, ice-bank
Safety: temperature maintenance in rooms with computers or electrical appliance
Food agro industry, wine, milk products (absorbing peaks in demand), greenhouse
Thermal protection of electronic devices (integrated with the appliance)
Medical application: transport of blood, operating tables, hot-cold therapies
Engine cooling (electric and combustion)
A comfort in vehicles
Softening of exothermic temperature peaks in chemical reactions
Solar power plants

Thermal Energy Storage Application

Table 1. Examples of PCMs application (Abdulla I.Abuzaid 2016)

Field	Examples of Applications
Consumer Products	1) Textile 2) Apparel & Shoes 3) Furniture 4) Car Seats 5) NASA Dive Suit 6)Lunch & Beverage Containers 7) Outdoor Gear (sleeping bags, etc.)
Packaging	1) Medical 2) Pharmaceutical 3) Chilled Food 4) Vaccines 5) Drug & Laboratory Testing 6) Chemicals & Biological samples
Bedding	1) Mattresses 2) Mattress toppers 3) Protectors 4) Pillows 5) Linens 6) Quilting 7) Ticking
Electronics	1) Computer parts 2) Outdoor electronics 3) Laboratory equipment 4) Handheld devices & phones 5) Remote telecom stations

There are different types of PCMs available in the market; in recently, many industries are used in these materials like, textile, ether, furniture, medical laboratory, electronic devices. The PCMs are used in varies types of areas, like, production, packaging, bedding, electronics etc.. Here table.1 briefly explained above, that the application of PCMs and where it is used.

Comparison of Phase Change Materials

(Nader A. Nader 2015) explain that, Ice and gel packs have become extremely popular for keeping materials cold around 0°C. These devices have the advantages of good performance, low cost, nontoxic, not flammable, environmentally friendly and easy to use. Here, only one disadvantage there, these ice and gel pack is maintaining their surroundings or thermal load at 0°C. To obtain a water-based PCM lower than 0°C, then a salt can be added to the water, It will depress the freezing point. However, these significantly decrease the latent heat and broaden the freeze / melt temperature. This technique used by many in applications example, homemade ice cream by salt to ice or to reduce the freezing point of water adding salt to roads during the icy conditions.

The sodium polyacrylate is pre dominate in compound gel packs, and Sodium polyacrylate is the predominant chemical used in diapers. The addition of sodium polyacrylate does change the crystal structure of ice and therefore diminishes the effectiveness of ice as a PCM. (Nader A. Nader 2015)

Salt Hydrates

The salt hydrates is latent heat storage PCM materials. Such soften times the lowest cost PCM behind water and gel packs. Numerous trials and sub-scale tests have been carried out on these compounds. The material comprises M•nH_2O, where M is an inorganic compound.

(Nader A. Nader 2015)They have to explain about the salt hydrates and it' problems related to practical applications Salt hydrates as PCMs. Most notable, is the limited temperature ranges available to salts in meeting specific temperature needs at the desired temperature. Other few salts is there it's melt at between 1 and 150°C. In the absence of salts melting at temperatures between 1 and 150°C, eutectic mixtures and salt hydrates are pursued for these missing temperature ranges.

The thermal storage applications were due to the fact that most salt hydrates melt incongruently specifies the following problem with salt hydrates, "The main thing is, in using salt hydrates as PCMs is that most of them melt incongruently, i.e. Due to density differences, the salt phase settles out and collects at the bottom of the container, they melt to a saturated aqueous phase and a solid phase which is generally a lower hydrate of the same salt, a phenomenon called decomposition. Even some measurements are taken, this process called irreversible process.

The poor nucleating properties that result is, what is termed super cooling of the liquid salt hydrate prior to freezing, this observation was repeated by Varner and by Lane. The salt hydrates using for changing volume, and the nature of the salt hydrates are corrosive and some of the materials are toxicity. A phase change of salt hydrates is up to 10% volume change in the solid to liquid. So this is required to accommodate in special packaging. The required specific type of salt hydrate used for these packaging. Therefore, the safety data sheets must be carefully checked for human toxicity and environmental damage when disposed because some of the salt hydrates are corrosive to metals. (Nader A. Nader 2015).

Paraffin

Paraffin is one of the good thermal energy storage materials it consist of high-molecular-mass hydrocarbons with a waxy consistency at room temperature. Paraffin are made up of straight chain hydrocarbons. The paraffin are classified into two main sub-groups, even chained (n-Paraffin) and odd-chained (iso- Paraffin). Generally, iso-paraffin stearic hindrances in their molecular packing so that, it's not make good PCMs.

(Nader A. Nader 2015).they gives details about the n-paraffin's and its characteristics, it is directly connection to the number of carbon atoms, within the material structure containing with alkanes 12-40^{0}C at the melting point. Normally. Atoms melting points between 6 and 80 degrees centigrade. These concept are called 'pure paraffin's' even paraffin waxes are different. A Paraffin waxes consist of hydro carbon molecules, different carbon number with low melting points and insufficient latent heat than the pure paraffin.(Nader A. Nader 2015).

(Nader A. Nader 2015) clearly mention that, a cost-effective paraffin are mixtures of alkanes, similarly not having sharp, well-defined melting points. Illustrate, most of the hexadecane latent heat is 230 J/g, melting point at 18°C.a petroleum crude oil consist of less amount of hexadecane it means that 1% of fraction.

A huge amount required for separation process, as high-vacuum, multi-stage distillation; price is over $10 per pound. It is not a commercial product. Through the wax products by used for a variety of applications including uses in. A C20-C24 canning wax has a latent heat of 150 J/g and melts over a 7°C temperature range considerably poorer performance than +98% n-paraffin products found in most literature. Pure paraffin are also limited in their range of melting points that they can target. However, from a practical standpoint, only the even numbered paraffin is in any abundance in crude petroleum. This takes the number of common paraffin for use as PCMs down to 8 commercially viable paraffin.

Paraffin are made from petroleum products, which increases our reliance on crude oil and other concerns with paraffin used as PCMs are social dynamics. Paraffin prices have followed the unstable price of petroleum. Furthermore, paraffin have geopolitical consequences and contribute to the increase in carbon emissions blamed for the global warming crisis (Nader A. Nader 2015).the selective temperature range of Paraffin area good PCM., a researcher select certain types of paraffin. It has an efficient storage capacities, besides proved super cooling. Advantages of paraffin, chemical stability in many hot and cold cycles, huge amount heat fusion, most of the materials and non-reactive encapsulated.

Vegetables-Based PCM

In recently, the paraffin products and salt hydrates has been predominated in the phase change material market. In recent years Paraffin become more popular than the salt hydrates in the market.

The potential vegetable-derived compounds research becoming significant in the PCM market sponsored by The Department of Agriculture and the National Science Foundation. The result of the investigations they were able to generate around 300variety fat-and vegetable oil-based on PCMs ranging from - 90°C to 150°C with latent heats between 150 and 220 J/g. In these PCMs are remarkable greater than those of paraffin because it has been safety and benefits of environmental aspects.

Vegetable-based on PCMs, depends on “food grade” when intake, there is no toxic and laxative effects. Hence paraffin characteristics, opposite of vegetable based PCMs. Under the Department of Agriculture research program Researchers also find out that, less amount of PCMs flash points 10-20% and longer second-rate flame spread temperature comparable, paraffin-based counterparts.

The current environment tissues, when the paraffin is disposed in a landfill. While this is attractive for the life of the PCM. So these vegetable-derived chemical building blocks are available at concentrations considerably greater than any particular n-paraffin is available in crude oil. Because of this, vegetable-based PCMs have a distinct competitive advantage over paraffin and could corner the PCM market (Nader A. Nader 2015).

Table 2.advantages and disadvantages of PCMs(Abdullah I.abuzaid 2016)

Organic	Inorganic	Eutectic
High latent heat	High latent heat	Sharp melting
Non-corrosive	High melting enthalpy	Temperature
Chemically & thermally	High density and latency	High volumetric thermal
Stable	High thermal	storage density
Little sub-cooling	Conductivity	
Durable and recyclable	High heat of fusion	
Efficient for thermal	Sensible heat storage	
comfort	Non-flammable	
High heat of fusion	Low volume change	
Low vapour pressure	Affordable	
	DISADVANTAGES	
Not affordable	Sub-cooling	Lack of test and limited
Low melting enthalpy	Corrosive of container	data of thermo-physical

Low density	Materials	Properties
Low thermal conductivity	Phase separation	
Rare availability	Phase segregation	
Flammability (depending	Lack of thermal stability	
on containment)	Instability of volume after	
Volume change	repeated change cycles	

Table 3, 4. Represents the different diameter capsules 38mm, 58mm, 68mm with variation of charging time and PCM (paraffin, stearic acid). Table.3 shows that 38mm spherical capsule changing time is less than 10% of the 68mm diameter capsule.

Table 4.shows that the 38mm and 68mm spherical capsules not have much effect on the changing time.

First three hours 10.00a.m. To 1.00p.m. HTF inlet temperature increase from 30^{0}C to 65^{0}C.

Table 3.Variation of PCM temperature atx/l =1.0 for the different capsule diameter

Time (min)	PCM(Paraffin) Temperature ^{0}C		
	38mm	58mm	68mm
0	32	32	32
24	45	43	42
60	53	51	49
96	57	55	52
132	57	57	57
168	62	59	57
204	67	65	61
240	68	65	65
300	-	-	70

Table 4.Variation of PCM temperature at x/l for the different capsule diameter (R.meenakshi Reddy 2012).

Time (min)	PCM(strearic Acid) Temperature ^{0}C		
	38mm	58mm	68mm
0	32	32	32
24	50	49	47
60	54	53	52
96	56	56	56
132	56	56	56
168	62	60	59
204	65	63	61
240	68	65	63
300	-	-	65

Table 5. Summary of the review Phase Change Materials and performance

Researchers [ref.]	Technology Adopted	PCM	performance upsurge
Shivangi Sharma et.al(2015)	Enhancing The Performance of BICPV Systems Using Phase Change Materials	Organic paraffinWax,RT42	9.07%

R. Rajaram D.B. Sivakumar(2015)	Experimental Investigation of Solar Panel Cooling By The Use of Phase Change Material	Cobalt Sulphate Hepthhydrate	7.92%.
Ahmad hasan et.al(2016)	Energy Efficiency Enhancement of Photovoltaic By Phase Change Materials Through Thermal Energy Recovery	Epoxy Resin Glue	6%
Yuli Setyo indartono et.al(2014)	Improving Photovoltaic Performance By Using Yellow Petroleum Jelly As Phase Change Material	Yellow petroleum jelly	7.3%
Pascal Biwole et.al(2011)	Improving The performance of Solar Panels by The Use of Phase Change materials	Fins	-
Marta Kuta et.al (2015)	Phase Change Materials To Improve Solar's performance	Solid-Solid Polyethylene Glycol Cellulose	-
Christopher J.Smith et.al(2014)	Global Analysis of photovoltaic Energy Output Enhanced By phase Change Material Cooling	Salt hydrates, Fatty Acid and Paraffin waxes	15.6%
Y S Indartono et.al(2014)	Simulation and Experimental Study On Effect Of phase Change material Thickness To Reduce Temperature Of Photovoltaic panel	Crude Palm Oil and Coconut Oil	23.8%
Pooja Shukla et.al(2016)	Study of solar PVT-PCM Hybrid System With Possible Modifications To Increase Module and Thermal Efficiency	Paraffin	-
Ahmad Hassan et.al (2014)	Temperature Regulation and Thermal Energy Storage Potential of Phase Change Materials Layer Contained at the back of a building Integrated Photovoltaic Panel	Paraffin Wax Solid-liquid	-
Hassan mahamudul et.al (2016)	Temperature Regulation of Photovoltaic Module Using Phase Change Material: A Numerical Analysis and Experimental Investigation	PCM RT 35	-
Hassan mahamudul et.al (2016)	The Effect of Inclination On The Passive Cooling Of The Solar PV Panel By Using Phase Change material	Paraffin Wax RT25	-
M.J Haung et.al(2008)	The Effect of Phase Change Material Crystalline Segregation On The Building Integrated Photovoltaic System Thermal Performance	Paraffin RT 25,RT 35, RT 27	10%
Marta Kuta et.al (2016)	The Role of Phase Change materials For The Sustainable Energy	Emerest 2326 and Paraffin(Unicere 55S)	54%

Conclusion

The PV/PCM can reduce the average temperature of PV systems. The PCM have more affects the induce temperature rise of the PV surface. In this work analysed different types of PCM and its improving performance, electrical efficiency by using natural resources with less energy consumption. There are different types of Phase Change Materials (PCM) has been studied such as paraffin, stearic acid, cobalt sulphate hypthhydrate and yellow petroleum jelly etc. The result shown that organic paraffin has a better performance 9.07% compared with other PCMs. The future research needs, different fields and explored the possibility of by using Phase Change Materials (PCMs) is different Areas.

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