PERFORMANCE EVALUATION OF PHOTOVOLTAIC THERMAL SYSTEMS USING FUNCTIONALIZED MULTI-WALLED CARBON-BASED NANO-ENHANCED PHASE CHANGE MATERIAL

REJI KUMAR RAJAMONY

DOCTOR OF PHILOSOPHY

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and, in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

(Supervisor's Signature)

Full Name : Ir. Ts. Dr. Mahendran Samykano

Position : Associate Professor

Date : 08 Feb 2023

(Co-supervisor's Signature)

Full Name : Dr. Adarsh Kumar Pandey

Position : Professor

Date : 08 Feb 2023

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : Reji Kumar Rajamony

ID Number : PSM19005

Date : 08 Feb 2023

PERFORMANCE EVALUATION OF PHOTOVOLTAIC THERMAL SYSTEMS USING FUNCTIONALIZED MULTI-WALLED CARBON-BASED NANO-ENHANCED PHASE CHANGE MATERIAL

REJI KUMAR RAJAMONY

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Doctor of Philosophy

Faculty of Mechanical and Automotive Engineering Technology

UNIVERSITI MALAYSIA PAHANG

FEBRUARY 2023

ACKNOWLEDGEMENTS

I am highly indebted to my Main Supervisor, Associate Professor Ir. Ts. Dr. Mahendran Samykano and Field supervisor, Professor Dr. Adarsh Kumar Pandey, for their thorough support and constant encouragement throughout this research journey. Their contribution in giving ideas has helped me to complete my research and thesis writing successfully.

I am grateful to the Universiti Malaysia Pahang for the financial and facility support through research grants RDU192208, RDU192218 and UIC211506 and Research Centre for Nanomaterials and Energy Technology (RCNMET), Sunway University for providing their solid support in all possible ways throughout my study. I would like to extend my thanks to all the group members, colleagues, lab-mates and friends, Atikah Aini, Nor Akmal and everyone who directly or indirectly, helped me in possible ways which ensured the successful completion of my Ph.D. work.

I express my warm regards and heartful appreciation to my all-supportive wife, Mrs. I. Sahila, my beloved parents – Mr. N. Rajamony (Late) and Mrs. Chellathangam, my daughters - R. Manu Suruthi and R. Hanu Suruthe, for their forbearance and unconditional support till the completion of my Ph.D.

Last but not the least, I am always thankful to God Almighty for bestowing his choicest blessings upon me, without which this work would not have got accomplished.

ABSTRAK

Teknologi fotovoltaik (PV) membolehkan penukaran tenaga suria kepada elektrik secara langsung untuk digunakan terus. Kecekapan penukaran fotovoltaik kebiasaannya berkurangan dengan peningkatan suhu sistem PV; oleh itu pengurusan suhu adalah isu utama dalam rekacipta sistem PV. Sistem hibrid fotovoltaik haba (PVT) merupakan penambahbaikan yang menjanjikan pengekstrakan tenaga haba dan tenaga elektrik secara serentak berlaku dengan mudah. Sementara itu, cabaran menggunakan system konvensional PVT berasaskan air ialah ia hanya boleh digunakan pada waktu siang. Integrasi bahan perubahan fasa (PCM) dengan sistem PVT untuk mengawal suhu serta memudahkan penyimpanan tenaga haba adalah pilihan yang popular dan berdaya maju. Walau bagaimanapun, PCM mengalami pengaliran haba yang lebih rendah menyebabkan keupayaan penyimpanan tenaga dan kadar pemindahan haba menjadi lebih rendah. Penyerakan zarah nano secara seragam ke dalam PCM meningkatkan pengaliran haba. Walau bagaimanpun, terdapat masalah yang berkaitan dengan kestabilan penyebaran zarah nano; selepas beberapa kitaran, ia semakin tergumpal. Objektif utama penyelidikan ini adalah untuk mensintesis dan mencirikan bahan perubahan fasa penambah baik nano (NePCM); membangunkan sistem PVT, menganalisa prestasi tenaga dan eksergi sistem PVT dan menilai prestasi sistem PVT bersepadu NePCM menggunakan. Kaedah dua-langkah digunakan untuk mensintesis NePCM menggunakan garam hidrat dengan suhu peralihan fasa pada 50°C sebagai PCM dan tiub nano karbon berbilang dinding berfungsi (FMWCNT) sebagai zarah nano. Nanokomposit yang disediakan telah dicirikan menggunakan spektrum inframerah transformasi fourier, analisis termo-gravimetrik, kalorimetri pengimbasan berbeza, spektrum cahaya nampak ultraviolet, Penganalisis pengaliran haba dan Kitaran haba untuk memastikan sifat fizik haba. Analisis tenaga dan eksergi dijalankan untuk menilai prestasi sistem PVT. Sistem PVT dianalisa menggunakan saluran aliran paip selari seperti yang dicadangkan dalam penganalisaan penyelidikan ini dimana ia bertindak sebagai pengumpul haba untuk mengekstrak tenaga haba khususnya. Untuk menjalankan analisis perbandingan dengan sistem PV konvensional, tiga konfigurasi baharu iaitu PVT, PVT-PCM, dan PVT-NePCM dengan kadar alir 0.4, 0.6 dan 0.8 LPM, telah dikaji. Keputusan yang diperolehi menunjukkan kestabilan kimia, fizikal dan terma daripada NePCM yang disediakan. FMWCNT pada kepekatan berat 0.7% menunjukkan peningkatan aliran haba sebanyak 100% dan pengurangan dalam penghantaran cahaya sebanyak 93.49% jika dibandingkan dengan PCM tulen. Tambahan pula, nanokomposit ini adalah stabil dari segi kimia dan haba; selepas 300 kitaran haba. NePCM yang dinyatakan di atas dengan ciri-ciri yang dipertingkat telah diintegrasikan dengan sistem PVT untuk penyelidikan terkini. Keputusan kajian menunjukkan bahawa penghasilan dan kecekapan kuasa elektrik meningkat sebanyak 29.1% dan 21.9% untuk sistem PVT-NePCM. Kecekapan haba maksimum untuk system PVT-NePCM yang diperolehi ialah 75.42%. Keseluruhan kecekapan tenaga untuk sistem PVT, PVT-PCM dan PVT-NePCM yang dihitung ialah 81.9%, 84.54%, dan 85% masing-masing pada kadar alir yang dioptimumkan. Sebaliknya, kecekapan eksergi maksimum adalah 12.37% untuk sistem PVT-NePCM. Sistem yang dibangunkan menjana kedua-dua tenaga elektrik dan tenaga haba, yang boleh digunakan di kawasan terpencil. Selanjutnya, kajian eksperimen masa nyata ke atas sistem PVT bersepadu NePCM diperlukan untuk menyiasat prestasi masa nyata sistem PVT.

ABSTRACT

Photovoltaic (PV) technology enables direct conversion of solar energy to electricity for direct consumption. Photovoltaic conversion efficiency mostly decreases with increase in temperature of the PV system; henceforth temperature management is a key issue in PV system design. A hybrid photovoltaic thermal (PVT) system is a promising development, which facilitates extraction of heat energy and electrical energy simultaneous. Meanwhile, the challenge of using conventional water-based PVT systems is that they can only be used during the daytime. Integration of phase change materials (PCM) with PVT systems to regulate the temperature as well as to facilitate thermal energy storage is a popular and viable choice. However, the PCMs suffer from lower thermal conductivity which causes lower energy storage capabilities and lower heat transfer rates. Uniform dispersion of nanoparticles into the PCM enhances the thermal conductivity. Though, there are problems pertaining to dispersion stability of the nanoparticles; after a few cycles, they get agglomerated. The main objective of the present research is to synthesize and characterize the nano-enhanced phase change materials (NePCM); develop a PVT system, analyse the energy and exergy performance of the PVT system and to evaluate the performance of NePCM-integrated PVT system. A two-step method is used to synthesize the NePCMs using salt hydrate with a phase transition temperature of 50°C as PCM and functionalize multi-walled carbon nanotubes (FMWCNT) as nanoparticle. The prepared nanocomposites were characterized using fourier transform infrared spectrum, thermo-gravimetric analysis, differential scanning calorimetry, ultraviolet visible spectrum, thermal property analyser and thermal cycler to ensure their thermo physical properties. Energy and exergy analysis is carried out to evaluate the performance of the PVT system. PVT system is investigated using a parallel pipe flow channel as proposed in the current research investigation which acts as thermal collector for extracting the heat energy. To make a comparative analysis with the conventional PV systems, three new configurations namely PVT, PVT-PCM, and PVT-NePCM with flowrates (0.4, 0.6 and 0.8 liter per minute (LPM), have been studied. Results obtained ensures chemical, physical and thermal stability of the prepared NePCM. FMWCNT at a weight concentration of 0.7% depicts thermal conductivity enhancement by 100% and light transmission decrement by 93.49% when compared with pure PCM. Furthermore, the nanocomposites were chemically and thermally stable, after 300 thermal cycles. Aforementioned NePCM with enhanced characteristics were integrated with PVT system for real time investigation. Results show that the electrical power output and efficiency to improve by 29.1% and 21.9% for the PVT-NePCM system. The maximum thermal efficiency of PVT, PVT-PCM and PVT-NePCM systems were found to be 73.1%, 74.99% and 75.42% at 0.4 LPM, respectively. Overall energy efficiency of the PVT, PVT-PCM and PVT-NePCM system were calculated to be 81.9%, 84.54%, and 85 % respectively at the optimized flowrate. On the contrary, the maximum exergy efficiency was found to be 12.37% for PVT-NePCM system. The developed system generates both electrical energy and thermal energy, which can be used for the remote areas. Further, Real time experimental study on NePCM integrated PVTsystem is needed to investigate the real time performance of PVT system.

TABLE OF CONTENT

DECLARATION	
TITLE PAGE	
ACKNOWLEDGEMENTS	**ii**
ABSTRAK	**iii**
ABSTRACT	**iv**
TABLE OF CONTENT	**v**
LIST OF TABLES	**ix**
LIST OF FIGURES	**x**
LIST OF SYMBOLS	**xiv**
LIST OF ABBREVIATIONS	**xvi**
LIST OF APPENDICES	**xix**
CHAPTER 1 INTRODUCTION	**1**
1.1 Background	1
1.2 Problem Statement	5
1.3 Research Objectives	6
1.4 Scope of Research	7
1.5 Significance of Research	8
1.6 Organization of the Thesis	9
CHAPTER 2 LITERATURE REVIEW	**10**
2.1 Introduction	10
2.2 Photovoltaic Thermal System with Thermal Energy Storage	10
2.3 Phase Change Materials	13
2.3.1 Nano-enhanced Phase Change Materials	17
2.4 PVT System	27

2.4.1 Air Based PVT System 27
2.4.2 Water Based PVT System 29
2.4.3 Bi-Fluid Based PVT System 31
2.4.4 Jet Impingement Based PVT System 33
2.4.5 Thermoelectric Based PVT System 33
2.4.6 Heat Pipe Based PVT System 35
2.4.7 Nanofluid-Based PVT System 37
2.5 PCM/NePCM Integrated PVT System 39
2.5.1 Air Based PCM Integrated PVT Systems 40
2.5.2 Water Based PCM/NePCM Integrated PVT Systems 45
2.6 Research Gap 57
2.7 Summary 60

CHAPTER 3 METHODOLOGY 61

3.1 Introduction 61
3.2 Materials Selection 61
3.3 Preparation of NePCMs 64
3.4 Characterization Techniques 66
3.5 Development of PVT System 68
3.5.1 PVT System Configuration 68
3.5.2 Fabrication of PVT System 69
3.6 Performance Analysis of PVT System 75
3.6.1 Energy Analysis 76
3.6.2 Exergy Analysis 77
3.6.3 Performance Analysis of NePCM Integrated PVT 79
3.7 Summary 84

CHAPTER 4 RESULTS AND DISCUSSION **85**

4.1 Introduction 85

4.2 Characterization of MWCNT and FMWCNTs 85

4.3 Characterization and Thermophysical Analysis 87

4.3.1 Physical Characterization 87

4.3.2 Chemical Characterization 92

4.3.3 Thermal Characterization 93

4.3.4 Thermal Cycling 103

4.3.5 Comparative Analysis of Nanocomposites PCM 105

4.4 Performance Analysis of PVT System 107

4.4.1 Temperature Variation of PVT System 107

4.4.2 Inlet and Outlet Water Temperature of PVT System 108

4.4.3 Average Electrical Performance PVT System 109

4.4.4 Average Thermal Performance of PVT System 111

4.4.5 Overall Efficiency of PVT System 113

4.5 Exergy Analysis of PVT System 115

4.5.1 Average Exergy Output of PVT System 115

4.5.2 Average Exergy Efficiency of PVT System 116

4.5.3 Exergy Loss 117

4.5.4 Entropy Generation 118

4.5.5 Comparative Analysis of Energy and Exergy Performance of PV and PVT Systems 120

4.6 Performance Analysis of NePCM Integrated PVT System 121

4.6.1 Temperature Variations Against Various Flowrates and Irradiations 121

4.6.2 Average Cooling Fluid Temperature 123

4.6.3 Average Electrical Performance 124

4.6.4 Average Thermal Performance 126
4.6.5 Overall Energy Efficiency 129
4.7 Exergy Analysis 130
4.7.1 Average Electrical Exergy efficiency 130
4.7.2 Thermal Exergy Efficiency 131
4.7.3 Exergy Loss 133
4.7.4 Entropy Generation 134
4.7.5 Overall Exergy Efficiency 135
4.7.6 Overall Energy and Exergy Performance 136
4.7.7 Performance of Present PVT System and Previous Studies 138
4.7.8 Model Validation 139
4.8 Summary 141

CHAPTER 5 CONCLUSION AND RECOMMENDATION 142

5.1 Introduction 142
5.2 Summary of Findings 142
5.3 Contribution to Knowledge 144
5.4 Recommendations for Future Works 144

REFERENCES 147

APPENDICES 169

REFERENCES

Abdallah, S. R., Elsemary, I. M. M., Altohamy, A. A., Abdelrahman, M. A., Attia, A. A. A., & Abdellatif, O. E. (2018). Experimental investigation on the effect of using nano fluid (Al2O3-Water) on the performance of PV/T system. *Thermal Science and Engineering Progress*, *7*, 1–7. https://doi.org/10.1016/j.tsep.2018.04.016

Abdallah, S. R., Saidani-Scott, H., & Abdellatif, O. E. (2019). Performance analysis for hybrid PV/T system using low concentration MWCNT (water-based) nanofluid. *Solar Energy*, *181*, 108–115. https://doi.org/10.1016/j.solener.2019.01.088

Abdelrahman, H. E., Wahba, M. H., Refaey, H. A., Moawad, M., & Berbish, N. S. (2019). Performance enhancement of photovoltaic cells by changing configuration and using PCM (RT35HC) with nanoparticles Al_2O_3. *Solar Energy*, *177*, 665–671. https://doi.org/10.1016/j.solener.2018.11.022

Abdelrazik, A. S., Al-Sulaiman, F. A., Saidur, R., & Ben-Mansour, R. (2018). A review on recent development for the design and packaging of hybrid photovoltaic/thermal (PV/T) solar systems. *Renewable and Sustainable Energy Reviews*, *95*, 110–129. https://doi.org/10.1016/j.rser.2018.07.013

Abdollahi, N., & Rahimi, M. (2020). Potential of water natural circulation coupled with nano-enhanced PCM for PV module cooling. *Renewable Energy*, *147*, 302–309. https://doi.org/10.1016/j.renene.2019.09.002

Abdulmunem, A. R., Mohd, P., Abdul, H., Hussien, H. A., & Ghazali, H. (2021). A novel thermal regulation method for photovoltaic panels using porous metals filled with phase change material and nanoparticle additives. *Journal of Energy Storage*, *39*, 102621. https://doi.org/10.1016/j.est.2021.102621

Aberoumand, S., Ghamari, S., & Shabani, B. (2018). Energy and exergy analysis of a photovoltaic thermal (PV/T) system using nanofluids: An experimental study. *Solar Energy*, *165*, 167–177. https://doi.org/10.1016/j.solener.2018.03.028

Abuilaiwi, F. A., Laoui, T., Al-Harthi, M., & Atieh, M. A. (2010). Modification and functionalization of multiwalled carbon nanotube (MWCNT) via fischer esterification. *Arabian Journal for Science and Engineering*, *35*(1), 37–48.

Afandi, N. S., Khavarian, M., & Mohamed, A. R. (2019). Effect of synthesis condition on the structural features of Ni-Ce bimetallic catalysts supported on functionalized multi-walled carbon nanotubes. *Sains Malaysiana*, *48*(6), 1209–1219. https://doi.org/10.17576/jsm-2019-4806-08

Agrawal, B., & Tiwari, G. N. (2010). Optimizing the energy and exergy of building integrated photovoltaic thermal (BIPVT) systems under cold climatic conditions. *Applied Energy*, *87*(2), 417–426. https://doi.org/10.1016/j.apenergy.2009.06.011

Ahmadi, R., Monadinia, F., & Maleki, M. (2021). Passive/active photovoltaic-thermal (PVT) system implementing infiltrated phase change material (PCM) in PS-CNT foam. *Solar Energy Materials and Solar Cells*, *222*. https://doi.org/10.1016/j.solmat.2020.110942

Akeiber, H., Nejat, P., Majid, M. Z. A., Wahid, M. A., Jomehzadeh, F., Zeynali Famileh, I., Calautit, J. K., Hughes, B. R., & 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. https://doi.org/10.1016/j.rser.2016.03.036

Al-Ahmed, A., Sarı, A., Mazumder, M. A. J., Hekimoğlu, G., Al-Sulaiman, F. A., & Inamuddin. (2020). Thermal energy storage and thermal conductivity properties of Octadecanol-MWCNT composite PCMs as promising organic heat storage materials. *Scientific Reports*, *10*(1), 1–15. https://doi.org/10.1038/s41598-020-64149-3

Al-Jethelah, M., Ebadi, S., Venkateshwar, K., Tasnim, S. H., Mahmud, S., & Dutta, A. (2019). Charging nanoparticle enhanced bio-based PCM in open cell metallic foams: An experimental investigation. *Applied Thermal Engineering*, *148*, 1029–1042. https://doi.org/10.1016/j.applthermaleng.2018.11.121

Al-Shamani, A. N., Yazdi, M. H., Alghoul, M. A., Abed, A. M., Ruslan, M. H., Mat, S., & Sopian, K. (2014). Nanofluids for improved efficiency in cooling solar collectors - A review. *Renewable and Sustainable Energy Reviews*, *38*, 348–367. https://doi.org/10.1016/j.rser.2014.05.041

Al-Waeli, A. H. A., Chaichan, M. T., Kazem, H. A., Sopian, K., Ibrahim, A., Mat, S., & Ruslan, M. H. (2018). Comparison study of indoor/outdoor experiments of a photovoltaic thermal PV/T system containing SiC nanofluid as a coolant. *Energy*, *151*, 33–44. https://doi.org/10.1016/j.energy.2018.03.040

Al-Waeli, A. H. A., Chaichan, M. T., Sopian, K., Kazem, H. A., Mahood, H. B., & Khadom, A. A. (2019). Modeling and experimental validation of a PVT system using nanofluid coolant and nano-PCM. *Solar Energy*, *177*, 178–191. https://doi.org/10.1016/j.solener.2018.11.016

Al-waeli, A. H. A., Kazem, H. A., Chaichan, M. T., & Sopian, K. (2019). Experimental investigation of using nano-PCM / nanofluid on a photovoltaic thermal system (PVT): Technical and economic study. *Thermal Science and Engineering Progress*, *11*, 213–230. https://doi.org/10.1016/j.tsep.2019.04.002

Al-Waeli, A. H. A., Kazem, H. A., Chaichan, M. T., & Sopian, K. (2020). A review of photovoltaic thermal systems: Achievements and applications. *International Journal of Energy Research*, 45(2), 1–40. https://doi.org/10.1002/er.5872

Al-Waeli, A. H. A., Kazem, H. A., Yousif, J. H., Chaichan, M. T., & Sopian, K. (2020).

Mathematical and neural network modeling for predicting and analyzing of nanofluid-nano PCM photovoltaic thermal systems performance. *Renewable Energy*, *145*, 963–980. https://doi.org/10.1016/j.renene.2019.06.099

Al-Waeli, A. H. A., Sopian, K., Chaichan, M. T., Kazem, H. A., Hasan, H. A., & Al-Shamani, A. N. (2017). An experimental investigation of SiC nanofluid as a base-fluid for a photovoltaic thermal PV/T system. *Energy Conversion and Management*, *142*, 547–558. https://doi.org/10.1016/j.enconman.2017.03.076

Al-Waeli, A. H. A., Sopian, K., Chaichan, M. T., Kazem, H. A., Ibrahim, A., Mat, S., & Ruslan, M. H. (2017). Evaluation of the nanofluid and nano-PCM based photovoltaic thermal (PVT) system: An experimental study. *Energy Conversion and Management*, *151*, 693–708. https://doi.org/10.1016/j.enconman.2017.09.032

Al-Waeli, A. H. A., Sopian, K., Kazem, H. A., & Chaichan, M. T. (2017). Photovoltaic/Thermal (PV/T) systems: Status and future prospects. *Renewable and Sustainable Energy Reviews*, *77*, 109–130. https://doi.org/10.1016/j.rser.2017.03.126

Al-Waeli, A. H. A., Sopian, K., Kazem, H. A., Yousif, J. H., Chaichan, M. T., Ibrahim, A., Mat, S., & Ruslan, M. H. (2018). Comparison of prediction methods of PV/T nanofluid and nano-PCM system using a measured dataset and artificial neural network. *Solar Energy*, *162*, 378–396. https://doi.org/10.1016/j.solener.2018.01.026

Al-Waeli, A. H. A., Sopian, K., Yousif, J. H., Kazem, H. A., Boland, J., & Chaichan, M. T. (2019). Artificial neural network modeling and analysis of photovoltaic/thermal system based on the experimental study. *Energy Conversion and Management*, *186*, 368–379. https://doi.org/10.1016/j.enconman.2019.02.066

Al Imam, M. F. I., Beg, R. A., Rahman, M. S., & Khan, M. Z. H. (2016). Performance of PVT solar collector with compound parabolic concentrator and phase change materials. *Energy and Buildings*, *113*, 139–144. https://doi.org/10.1016/j.enbuild.2015.12.038

Alous, S., Kayfeci, M., & Uysal, A. (2019). Experimental investigations of using MWCNTs and graphene nanoplatelets water-based nanofluids as coolants in PVT systems. *Applied Thermal Engineering*, *162*, 114265. https://doi.org/10.1016/j.applthermaleng.2019.114265

Ami Eitan, Kuiyang Jiang, Doug Dukes, Rodney Andrews, and, & Linda S. Schadler. (2003). Surface Modification of Multiwalled Carbon Nanotubes: Toward the Tailoring of the Interface in Polymer Composites. *Chemistry of Materials*, *15*, 3198–3201. https://doi/abs/10.1021/cm020975d

Amin, M., Afriyanti, F., & Putra, N. (2018). Thermal properties of paraffin based nano-phase change material as thermal energy storage. *IOP Conference Series: Earth and Environmental Science*, *105*(1), 0–6. https://doi.org/10.1088/1755-1315/105/1/012028

Antonanzas, J., del Amo, A., Martinez-Gracia, A., Bayod-Rujula, A. A., & Antonanzas-Torres, F. (2015). Towards the optimization of convective losses in photovoltaic-thermal panels. *Solar Energy*, *116*, 323–336. https://doi.org/10.1016/j.solener.2015.04.013

Asadi, A., Pourfattah, F., Miklós Szilágyi, I., Afrand, M., Żyła, G., Seon Ahn, H., Wongwises, S., Minh Nguyen, H., Arabkoohsar, A., & Mahian, O. (2019). Effect of sonication characteristics on stability, thermophysical properties, and heat transfer of nanofluids: A comprehensive review. *Ultrasonics Sonochemistry*, *58*. https://doi.org/10.1016/j.ultsonch.2019.104701

Asbik, M., Ansari, O., Bah, A., Zari, N., Mimet, A., & El-Ghetany, H. (2016). Exergy analysis of solar desalination still combined with heat storage system using phase change material (PCM). *Desalination*, *381*, 26–37. https://doi.org/10.1016/j.desal.2015.11.031

Aste, N., Leonforte, F., & Del Pero, C. (2015). Design, modeling and performance monitoring of a photovoltaic-thermal (PVT) water collector. *Solar Energy*, *112*, 85–99. https://doi.org/10.1016/j.solener.2014.11.025

B.N. Egorov, M.P.Revykina, N.N.Trokhinin, S.N.Trushevskii, T. M. F. (1979). Investigation of crystal hydrates thermophysical properties in respect to heat storage problems. *Applied.Solor.Energy*, *16*(3), 61–64.

Babapoor, A., Karimi, G., & Sabbaghi, S. (2016). Thermal characteristic of nanocomposite phase change materials during solidification process. *Journal of Energy Storage*, *7*, 74–81. https://doi.org/10.1016/j.est.2016.05.006

Babu, C., & Ponnambalam, P. (2018). The theoretical performance evaluation of hybrid PV-TEG system. *Energy Conversion and Management*, *173*, 450–460. https://doi.org/10.1016/j.enconman.2018.07.104

Bahiraei, F., Fartaj, A., & Nazri, G. A. (2017). Experimental and numerical investigation on the performance of carbon-based nanoenhanced phase change materials for thermal management applications. *Energy Conversion and Management*, *153*, 115–128. https://doi.org/10.1016/j.enconman.2017.09.065

Belusko, M., Saman, W., & Bruno, F. (2008). Performance of jet impingement in unglazed air collectors. *Solar Energy*, *82*(5), 389–398. https://doi.org/10.1016/j.solener.2007.10.005

Boldoo, T., Ham, J., & Cho, H. (2019). Comparison study on photo-thermal energy conversion performance of functionalized and non-functionalized MWCNT nanofluid. *Energies*, *12*(19). https://doi.org/10.3390/en12193763

Boopalan, N., Kalidasan, B., Raj Kumar, D., Ragupathi, E., Gurumoorthy, M., & Praveenraj, S. (2021). Experimental study and analysis of single slope solar still integrated with Phase Change Material. *IOP Conference Series: Materials Science and Engineering*, *1059*(1).

https://doi.org/10.1088/1757-899X/1059/1/012010

Bozorgan, N., & Shafahi, M. (2015). Performance evaluation of nanofluids in solar energy: a review of the recent literature. *Micro and Nano Systems Letters*, *3*(1), 1–15. https://doi.org/10.1186/s40486-015-0014-2

Browne, M. C., Lawlor, K., Kelly, A., Norton, B., & Cormack, S. J. M. (2015). Indoor Characterisation of a Photovoltaic/ Thermal Phase Change Material System. *Energy Procedia*, *70*, 163–171. https://doi.org/10.1016/j.egypro.2015.02.112

Browne, M. C., Norton, B., & McCormack, S. J. (2016). Heat retention of a photovoltaic/thermal collector with PCM. *Solar Energy*, *133*, 533–548. doi.org/10.1016/j.solener.2016.04.024

Carmona, M., Palacio Bastos, A., & García, J. D. (2021). Experimental evaluation of a hybrid photovoltaic and thermal solar energy collector with integrated phase change material (PVT-PCM) in comparison with a traditional photovoltaic (PV) module. *Renewable Energy*, *172*, 680–696. https://doi.org/10.1016/j.renene.2021.03.022

Choubineh, N., Jannesari, H., & Kasaeian, A. (2019). Experimental study of the effect of using phase change materials on the performance of an air-cooled photovoltaic system. *Renewable and Sustainable Energy Reviews*, *101*, 103–111. https://doi.org/10.1016/j.rser.2018.11.001

Chow, T. T., Pei, G., Fong, K. F., Lin, Z., Chan, A. L. S., & Ji, J. (2009). Energy and exergy analysis of photovoltaic-thermal collector with and without glass cover. *Applied Energy*, *86*(3), 310–316. https://doi.org/10.1016/j.apenergy.2008.04.016

Colla, L., Fedele, L., Mancin, S., Danza, L., & Manca, O. (2017). Nano-PCMs for enhanced energy storage and passive cooling applications. *Applied Thermal Engineering*, *110*, 584–589. https://doi.org/10.1016/j.applthermaleng.2016.03.161

Diallo, T. M. O., Yu, M., Zhou, J., Zhao, X., Shittu, S., Li, G., Ji, J., & Hardy, D. (2019). Energy performance analysis of a novel solar PVT loop heat pipe employing a microchannel heat pipe evaporator and a PCM triple heat exchanger. *Energy*, *167*, 866–888. https://doi.org/10.1016/j.energy.2018.10.192

Diani, A., & Campanale, M. (2019). Transient melting of paraffin waxes embedded in aluminum foams: Experimental results and modeling. *International Journal of Thermal Sciences*, *144*, 119–128. https://doi.org/10.1016/j.ijthermalsci.2019.06.004

Dimri, N., Tiwari, A., & Tiwari, G. N. (2019). Comparative study of photovoltaic thermal (PVT) integrated thermoelectric cooler (TEC) fluid collectors. *Renewable Energy*, *134*, 343–356. https://doi.org/10.1016/j.renene.2018.10.105

Diwania, S., Agrawal, S., Siddiqui, A. S., & Singh, S. (2019). Photovoltaic–thermal (PV/T) technology: a comprehensive review on applications and its advancement. *International Journal of Energy and Environmental Engineering*. doi.org/10.1007/s40095-019-00327-y

Doran, H. (2021). Bringing data to life. *Biochemist*, *43*(5), 3–3. https://doi.org/10.1042/bio_2021_180

Du, Y., Zhou, T., Zhao, C., & Ding, Y. (2022). Molecular dynamics simulation on thermal enhancement for carbon nano tubes (CNTs) based phase change materials (PCMs). *International Journal of Heat and Mass Transfer*, *182*, 122017. https://doi.org/10.1016/j.ijheatmasstransfer.2021.122017

Eanest Jebasingh, B., & Valan Arasu, A. (2019). A comprehensive review on latent heat and thermal conductivity of nanoparticle dispersed phase change material for low-temperature applications. *Energy Storage Materials*. 24, 52-74. https://doi.org/10.1016/j.ensm.2019.07.031

Elhab, B. R., Sopian, K., Mat, S., Lim, C., Sulaiman, M. Y., Ruslan, M. H., & Saadatian, O. (2012). Optimizing tilt angles and orientations of solar panels for Kuala Lumpur, Malaysia. *Scientific Research and Essays*, *7*(43), 3758–3767. https://doi.org/10.5897/SRE12.241

Evangelisti, L., Vollaro, R. D. L., & Asdrubali, F. (2019). Latest advances on solar thermal collectors : A comprehensive review. *Renewable and Sustainable Energy Reviews*, *114*, 109318. https://doi.org/10.1016/j.rser.2019.109318

Fan, L., & Khodadadi, J. M. (2012). An experimental investigation of enhanced thermal conductivity and expedited unidirectional freezing of cyclohexane-based nanoparticle suspensions utilized as nano-enhanced phase change materials (NePCM). *International Journal of Thermal Sciences*, *62*, 120–126. https://doi.org/10.1016/j.ijthermalsci.2011.11.005

Fayaz, H., Rahim, N. A., Hasanuzzaman, M., Nasrin, R., & Rivai, A. (2019). Numerical and experimental investigation of the effect of operating conditions on performance of PVT and PVT-PCM. *Renewable Energy*, *143*, 827–841. https://doi.org/10.1016/j.renene.2019.05.041

Fayaz, H., Rahim, N. A., Hasanuzzaman, M., Rivai, A., & Nasrin, R. (2019). Numerical and outdoor real time experimental investigation of performance of PCM based PVT system. *Solar Energy*, *179*, 135–150. https://doi.org/10.1016/j.solener.2018.12.057

Fiorentini, M., Cooper, P., & Ma, Z. (2015). Development and optimization of an innovative HVAC system with integrated PVT and PCM thermal storage for a net-zero energy retrofitted house. *Energy and Buildings*, *94*, 21–32. https://doi.org/10.1016/j.enbuild.2015.02.018

Fiorentini, M., Cooper, P., Ma, Z., & Robinson, D. A. (2015). Hybrid model predictive control of a residential HVAC system with PVT energy generation and PCM thermal storage. *Energy*

Procedia, *83*, 21–30. https://doi.org/10.1016/j.egypro.2015.12.192

Gaur, A., Ménézo, C., & Giroux-Julien, S. (2017). Numerical studies on thermal and electrical performance of a fully wetted absorber PVT collector with PCM as a storage medium. *Renewable Energy*, *109*, 168–187. https://doi.org/10.1016/j.renene.2017.01.062

George, M., Pandey, A. K., Abd Rahim, N., Tyagi, V. V., Shahabuddin, S., & Saidur, R. (2020). A novel polyaniline (PANI)/ paraffin wax nano composite phase change material: Superior transition heat storage capacity, thermal conductivity and thermal reliability. *Solar Energy*, *204*, 448–458. https://doi.org/10.1016/j.solener.2020.04.087

George, N., Julie, J. C., Mathiazhagan, A., & Joseph, R. (2015). High performance natural rubber composites with conductive segregated network of multiwalled carbon nanotubes. *Composites Science and Technology*, *116*, 33–40. https://doi.org/10.1016/j.compscitech.2015.05.008

Gharzi, M., Arabhosseini, A., Gholami, Z., & Rahmati, M. H. (2020). Progressive cooling technologies of photovoltaic and concentrated photovoltaic modules: A review of fundamentals, thermal aspects, nanotechnology utilization and enhancing performance. *Solar Energy*, *211*, 117–146. https://doi.org/10.1016/j.solener.2020.09.048

Graham, M., Shchukina, E., Castro, P. F. De, & Shchukin, D. (2016). Nanocapsules Containing Salt Hydrate Phase Change Materials for Thermal Energy Storage, 43,1-18, *Materials Chemistry A*. https://doi.org/10.1039/C6TA06189C

Gueymard, C. A. (2004). The sun's total and spectral irradiance for solar energy applications and solar radiation models. *Solar Energy*, *76*(4), 423–453. https://doi.org/10.1016/j.solener.2003.08.039

Hamdoon, O. M., Alomar, O. R., & Salim, B. M. (2019). Performance Analysis of Hybrid Photovoltaic Thermal Solar System in Iraq Climate Condition. *Thermal Science and Engineering Progress*, 100359. https://doi.org/10.1016/j.tsep.2019.100359

Hameed Jaaz, A., Hasan, H. A., Sopian, K., Kadhum, A. A. H., Gaaz, T. S., & Al-Amiery, A. A. (2017). Outdoor Performance analysis of a photovoltaic thermal (PVT) collector with Jet impingement and compound parabolic concentrator (CPC). *Materials*, *10*(8). https://doi.org/10.3390/ma10080888

Harikrishnan, S., Imran Hussain, S., Devaraju, A., Sivasamy, P., & Kalaiselvam, S. (2017). Improved performance of a newly prepared nano-enhanced phase change material for solar energy storage. *Journal of Mechanical Science and Technology*, *31*(10), 4903–4910. https://doi.org/10.1007/s12206-017-0938-y

Hasan, A., McCormack, S. J., Huang, M. J., & Norton, B. (2010). Evaluation of phase change materials for thermal regulation enhancement of building integrated photovoltaics. *Solar*

Energy, *84*(9), 1601–1612. https://doi.org/10.1016/j.solener.2010.06.010

Hasan, H. A., Sopian, K., & Fudholi, A. (2018). Photovoltaic thermal solar water collector designed with a jet collision system. *Energy*, *161*, 412–424. https://doi.org/10.1016/j.energy.2018.07.141

Hashempour, S., & Vakili, M. H. (2018). Preparation and characterisation of nano enhanced phase change material by adding carbon nano tubes to butyl stearate. *Journal of Experimental Nanoscience*, *13*(1), 188–198. https://doi.org/10.1080/17458080.2018.1502480

Hassan, A., Wahab, A., Qasim, M. A., Janjua, M. M., Ali, M. A., Ali, H. M., Jadoon, T. R., Ali, E., Raza, A., & Javaid, N. (2020). Thermal management and uniform temperature regulation of photovoltaic modules using hybrid phase change materials-nanofluids system. *Renewable Energy*, *145*, 282–293. https://doi.org/10.1016/j.renene.2019.05.130

He, M., Yang, L., Lin, W., Chen, J., Mao, X., & Ma, Z. (2019). Preparation, thermal characterization and examination of phase change materials (PCMs) enhanced by carbon-based nanoparticles for solar thermal energy storage. *Journal of Energy Storage*, *25*, 100874. https://doi.org/10.1016/j.est.2019.100874

He, W., Zhou, J., Chen, C., & Ji, J. (2014). Experimental study and performance analysis of a thermoelectric cooling and heating system driven by a photovoltaic/thermal system in summer and winter operation modes. *Energy Conversion and Management*, *84*, 41–49. https://doi.org/10.1016/j.enconman.2014.04.019

Herrando, M., Ramos, A., Freeman, J., Zabalza, I., & Markides, C. N. (2018). Technoeconomic modelling and optimisation of solar combined heat and power systems based on flat-box PVT collectors for domestic applications. *Energy Conversion and Management*, *175,* 67–85. https://doi.org/10.1016/j.enconman.2018.07.045

Herrando, M., Ramos, A., Zabalza, I., & Markides, C. N. (2019). A comprehensive assessment of alternative absorber-exchanger designs for hybrid PVT-water collectors. *Applied Energy*, *235*, 1583–1602. https://doi.org/10.1016/j.apenergy.2018.11.024

Hossain, M. S., Pandey, A. K., Selvaraj, J., Abd Rahim, N., Rivai, A., & Tyagi, V. V. (2019). Thermal performance analysis of parallel serpentine flow based photovoltaic/thermal (PV/T)system under composite climate of Malaysia. *Applied Thermal Engineering*, *153*, 861–871. https://doi.org/10.1016/j.applthermaleng.2019.01.007

Hossain, M. S., Pandey, A. K., Selvaraj, J., Rahim, N. A., Islam, M. M., & Tyagi, V. V. (2019). Two side serpentine flow based photovoltaic-thermal-phase change materials (PVT-PCM) system: Energy, exergy and economic analysis. *Renewable Energy*, *136*, 1320–1336. https://doi.org/10.1016/j.renene.2018.10.097

Hosseinzadeh, M., Sardarabadi, M., & Passandideh-Fard, M. (2018). Energy and exergy analysis of nanofluid based photovoltaic thermal system integrated with phase change material. *Energy*, *147*, 636–647. https://doi.org/10.1016/j.energy.2018.01.073

Hu, M., Zheng, R., Pei, G., Wang, Y., Li, J., & Ji, J. (2016). Experimental study of the effect of inclination angle on the thermal performance of heat pipe photovoltaic/thermal (PV/T) systems with wickless heat pipe and wire-meshed heat pipe. *Applied Thermal Engineering*, *106*, 651–660. https://doi.org/10.1016/j.applthermaleng.2016.06.003

Iqbal, S., Khatoon, H., Hussain Pandit, A., & Ahmad, S. (2019). Recent development of carbon based materials for energy storage devices. *Materials Science for Energy Technologies*, *2*(3), 417–428. https://doi.org/10.1016/j.mset.2019.04.006

Islam, M. M., Hasanuzzaman, M., Rahim, N. A., Pandey, A. K., Rawa, M., & Kumar, L. (2021). Real time experimental performance investigation of a NePCM based photovoltaic thermal system: An energetic and exergetic approach. *Renewable Energy*, *172*, 71–87. https://doi.org/10.1016/j.renene.2021.02.169

Islam, M. M., Pandey, A. K., Hasanuzzaman, M., & Rahim, N. A. (2016). Recent progresses and achievements in photovoltaic-phase change material technology: A review with special treatment on photovoltaic thermal-phase change material systems. *Energy Conversion and Management*, *126*, 177–204. https://doi.org/10.1016/j.enconman.2016.07.075

Jamil, F., Ali, H. M., & Janjua, M. M. (2021). MXene based advanced materials for thermal energy storage: A recent review. *Journal of Energy Storage*, *35*, 102322. https://doi.org/10.1016/j.est.2021.102322

Jamil, N., Kaur, J., Pandey, A. K., Shahabuddin, S., Hassani, S., Saidur, R., Ali, R. R., Sidik, N. A. C., & Naim, M. (2019). A review on nano enhanced phase change materials: An enhancement in thermal properties and specific heat capacity. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *57*(1), 110–120.

Jarimi, H., Abu Bakar, M. N., Othman, M., & Din, M. H. (2016). Bi-fluid photovoltaic/thermal (PV/T) solar collector: Experimental validation of a 2-D theoretical model. *Renewable Energy*, *85*, 1052–1067. https://doi.org/10.1016/j.renene.2015.07.014

Jha, P., Das, B., & Gupta, R. (2019). Energy and exergy analysis of photovoltaic thermal air collector under climatic condition of North Eastern India. *Energy Procedia*, *158*, 1161–1167. https://doi.org/10.1016/j.egypro.2019.01.299

Ji, P., Sun, H., Zhong, Y., & Feng, W. (2012). Improvement of the thermal conductivity of a phase change material by the functionalized carbon nanotubes. *Chemical Engineering Science*, *81*, 140–145. https://doi.org/10.1016/j.ces.2012.07.002

Kalidasan, B., Pandey, A. K., Saidur, R., Samykano, M., & Tyagi, V. V. (2022). Nano additive enhanced salt hydrate phase change materials for thermal energy storage. *International*

Materials Reviews, 1–44. https://doi.org/10.1080/09506608.2022.2053774

Kandilli, C. (2019). Energy, exergy, and economical analyses of a photovoltaic thermal system integrated with the natural zeolites for heat management. *International Journal of Energy Research*, *43*(9), 4670–4685. https://doi.org/10.1002/er.4605

Kazem, H. A., Al-Waeli, A. H. A., Chaichan, M. T., & Sopian, K. (2021). Numerical and experimental evaluation of nanofluids based photovoltaic/thermal systems in Oman: Using silicone-carbide nanoparticles with water-ethylene glycol mixture. *Case Studies in Thermal Engineering*, *26*, 101009. https://doi.org/10.1016/j.csite.2021.101009

Kazemian, A., Hosseinzadeh, M., Sardarabadi, M., & Passandideh-Fard, M. (2018a). Effect of glass cover and working fluid on the performance of photovoltaic thermal (PVT) system: An experimental study. *Solar Energy*, *173*, 1002–1010. https://doi.org/10.1016/j.solener.2018.07.051

Kazemian, A., Hosseinzadeh, M., Sardarabadi, M., & Passandideh-Fard, M. (2018b). Experimental study of using both ethylene glycol and phase change material as coolant in photovoltaic thermal systems (PVT) from energy, exergy and entropy generation viewpoints. *Energy*, *162*, 210–223. https://doi.org/10.1016/j.energy.2018.07.069

Kazemian, A., Taheri, A., Sardarabadi, A., Ma, T., Passandideh-Fard, M., & Peng, J. (2020). Energy, exergy and environmental analysis of glazed and unglazed PVT system integrated with phase change material: An experimental approach. *Solar Energy*, *201*, 178–189. https://doi.org/10.1016/j.solener.2020.02.096

Kenisarin, M., & Mahkamov, K. (2016). Salt hydrates as latent heat storage materials:Thermophysical properties and costs. *Solar Energy Materials and Solar Cells*, *145*, 255–286. https://doi.org/10.1016/j.solmat.2015.10.029

Khanna, S., Newar, S., Sharma, V., Reddy, K. S., Mallick, T. K., Radulovic, J., Khusainov, R., Hutchinson, D., & Becerra, V. (2019). Electrical enhancement period of solar photovoltaic using phase change material. *Journal of Cleaner Production*, *221*, 878–884. https://doi.org/10.1016/j.jclepro.2019.02.169

Kibria, M. A., Anisur, M. R., Mahfuz, M. H., Saidur, R., & Metselaar, I. H. S. C. (2015). A review on thermophysical properties of nanoparticle dispersed phase change materials. *Energy Conversion and Management*, *95*, 69–89. https://doi.org/10.1016/j.enconman.2015.02.028

Kim, S., Tserengombo, B., Choi, S. H., Noh, J., Huh, S., Choi, B., Chung, H., Kim, J., & Jeong, H. (2018). Experimental investigation of dispersion characteristics and thermal conductivity of various surfactants on carbon based nanomaterial. *International Communications in Heat and Mass Transfer*, *91*, 95–102. https://doi.org/10.1016/j.icheatmasstransfer.2017.12.011

Kumar, A., Kothari, R., Sahu, S. K., & Kundalwal, S. I. (2021). Thermal performance of heat sink using nano-enhanced phase change material (NePCM) for cooling of electronic components. *Microelectronics Reliability*, *121*, 114144. https://doi.org/10.1016/j.microrel.2021.114144

Kumar, P. M., Karthick, A., Richard, S., Vijayakumar, M., Joseph, P. M., Kumar, D. G., Aswanth, G., Aswath, M., & Kumar, V. (2021). Materials Today : Proceedings Investigating performance of solar photovoltaic using a nano phase change material. *Materials Today: Proceedings*, https://doi.org/10.1016/j.matpr.2021.04.615

Lari, M. O., & Sahin, A. Z. (2018). Effect of retrofitting a silver/water nanofluid-based photovoltaic/thermal (PV/T) system with a PCM-thermal battery for residential applications. *Renewable Energy*, *122*, 98–107. https://doi.org/10.1016/j.renene.2018.01.034

Le, V. T., Ngo, C. L., Le, Q. T., Ngo, T. T., Nguyen, D. N., & Vu, M. T. (2013). Surface modification and functionalization of carbon nanotube with some organic compounds. *Advances in Natural Sciences: Nanoscience and Nanotechnology*, *4*(3), 2–7. https://doi.org/10.1088/2043-6262/4/3/035017

Leong, K. Y., Abdul Rahman, M. R., & Gurunathan, B. A. (2019). Nano-enhanced phase change materials: A review of thermo-physical properties, applications and challenges. *Journal of Energy Storage*, *21*, 18–31. https://doi.org/10.1016/j.est.2018.11.008

Li, D., Xuan, Y., Li, Q., & Hong, H. (2017). Exergy and energy analysis of photovoltaic-thermoelectric hybrid systems. *Energy*, *126*, 343–351. https://doi.org/10.1016/j.energy.2017.03.042

Li, J. F., Lu, W., Zeng, Y. B., & Luo, Z. P. (2014). Simultaneous enhancement of latent heat and thermal conductivity of docosane-based phase change material in the presence of spongy graphene. *Solar Energy Materials and Solar Cells*, *128*, 48–51. https://doi.org/10.1016/j.solmat.2014.05.018

Lin, S. C., & Al-Kayiem, H. H. (2016). Evaluation of copper nanoparticles - Paraffin wax compositions for solar thermal energy storage. *Solar Energy*, *132*, 267–278. https://doi.org/10.1016/j.solener.2016.03.004

Lin, W., Ma, Z., Cooper, P., Sohel, M. I., & Yang, L. (2016). Thermal performance investigation and optimization of buildings with integrated phase change materials and solar photovoltaic thermal collectors. *Energy and Buildings*, *116*, 562–573. https://doi.org/10.1016/j.enbuild.2016.01.041

Lin, W., Ma, Z., Ren, H., Gschwander, S., & Wang, S. (2019). Multi-objective optimisation of thermal energy storage using phase change materials for solar air systems. *Renewable Energy*, *130*, 1116–1129. https://doi.org/10.1016/j.renene.2018.08.071

Lin, W., Ma, Z., Sohel, M. I., & Cooper, P. (2014). Development and evaluation of a ceiling ventilation system enhanced by solar photovoltaic thermal collectors and phase change materials. *Energy Conversion and Management*, *88*, 218–230. https://doi.org/10.1016/j.enconman.2014.08.019

Lin, Y., Jia, Y., Alva, G., & Fang, G. (2018). Review on thermal conductivity enhancement, thermal properties and applications of phase change materials in thermal energy storage. *Renewable and Sustainable Energy Reviews*, *82*, 2730–2742. https://doi.org/10.1016/j.rser.2017.10.002

Lin, Z., Wei, Z., Shuang, L., & Xiangyu, J. (2018). Experimental study on improving stability of PCM and MEPCM slurry with different surfactants. *International Journal of Low-Carbon Technologies*, *13*(3), 272–276. https://doi.org/10.1093/ijlct/cty027

Liu, Y., Yu, K., Gao, X., Ren, M., Jia, M., & Yang, Y. (2020). Enhanced thermal properties of hydrate salt/poly (acrylate sodium) copolymer hydrogel as form-stable phase change material via incorporation of hydroxyl carbon nanotubes. *Solar Energy Materials and Solar Cells*, *208*, 110387. https://doi.org/10.1016/j.solmat.2019.110387

Liu, Z., Zhang, Y., Zhang, L., Luo, Y., Wu, Z., Wu, J., Yin, Y., & Hou, G. (2018). Modeling and simulation of a photovoltaic thermal-compound thermoelectric ventilator system. *Applied Energy*, *228*, 1887–1900. https://doi.org/10.1016/j.apenergy.2018.07.006

Lo Piano, S., & Smith, S. T. (2022). Energy demand and its temporal flexibility: Approaches, criticalities and ways forward. *Renewable and Sustainable Energy Reviews*, *160*, 112249. https://doi.org/10.1016/j.rser.2022.112249

Lu, S., Liang, R., Zhang, J., & Zhou, C. (2019). Performance improvement of solar photovoltaic/thermal heat pump system in winter by employing vapor injection cycle. *Applied Thermal Engineering*, *155,* 135–146. https://doi.org/10.1016/j.applthermaleng.2019.03.038

Ma, Z., Lin, W., & Sohel, M. I. (2016). Nano-enhanced phase change materials for improved building performance. *Renewable and Sustainable Energy Reviews*, *58*, 1256–1268. https://doi.org/10.1016/j.rser.2015.12.234

Maatallah, T., Zachariah, R., & Al-Amri, F. G. (2019b). Exergo-economic analysis of a serpentine flow type water based photovoltaic thermal system with phase change material (PVT-PCM/water). *Solar Energy*, *193,* 195–204. https://doi.org/10.1016/j.solener.2019.09.063

Mahian, O., Kianifar, A., Kalogirou, S. A., Pop, I., & Wongwises, S. (2013). A review of the applications of nanofluids in solar energy. *International Journal of Heat and Mass Transfer*, *57*(2), 582–594. https://doi.org/10.1016/j.ijheatmasstransfer.2012.10.037

Makki, A., Omer, S., Su, Y., & Sabir, H. (2016). Numerical investigation of heat pipe-based photovoltaic-thermoelectric generator (HP-PV/TEG) hybrid system. *Energy Conversion and Management*, *112*, 274–287. https://doi.org/10.1016/j.enconman.2015.12.069

Malvi, C. S., Dixon-Hardy, D. W., & Crook, R. (2011). Energy balance model of combined photovoltaic solar-thermal system incorporating phase change material. *Solar Energy*, *85*(7), 1440–1446. https://doi.org/10.1016/j.solener.2011.03.027

Manoj Kumar, P., Mylsamy, K., & Saravanakumar, P. T. (2019). Experimental investigations on thermal properties of nano-SiO_2 /paraffin phase change material (PCM) for solar thermal energy storage applications. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, *0*(0), 1–14. https://doi.org/10.1080/15567036.2019.1607942

Michael, J. J., Selvarasan, I., & Goic, R. (2016). Fabrication, experimental study and testing of a novel photovoltaic module for photovoltaic thermal applications. *Renewable Energy*, *90*, 95–104. https://doi.org/10.1016/j.renene.2015.12.064

Migdał-mikuli, A., Mikuli, E., Dziembaj, R., Majda, D., & Hetma, Ł. (2004). Thermal decomposition of $[Mg(NH_3)_6](NO_3)_2$, $[Ni(NH_3)_6](NO_3)_2$ and $[Ni(ND_3)_6](NO_3)_2$, *Thermochimica Acta 419*(3), 223–229. https://doi.org/10.1016/j.tca.2004.01.035

Mishra, A. K., Lahiri, B. B., & Philip, J. (2018). Thermal conductivity enhancement in organic phase change material (phenol-water system) upon addition of Al_2O_3, SiO_2 and TiO_2 nano-inclusions. *Journal of Molecular Liquids*, *269*, 47–63. https://doi.org/10.1016/j.molliq.2018.08.001

Mishra, A. K., Lahiri, B. B., Solomon, V., & Philip, J. (2019). Nano-inclusion aided thermal conductivity enhancement in palmitic acid/di-methyl formamide phase change material for latent heat thermal energy storage. *Thermochimica Acta*, *678*, 178309. https://doi.org/10.1016/j.tca.2019.178309

Mofijur, M., Mahlia, T. M. I., Silitonga, A. S., Ong, H. C., Silakhori, M., Hasan, M. H., Putra, N., & Ashrafur Rahman, S. M. (2019). Phase change materials (PCM) for solar energy usages and storage: An overview. *Energies*, *12*(16), 1–20. https://doi.org/10.3390/en12163167

Mohamed, N. H., Soliman, F. S., El Maghraby, H., & Moustfa, Y. M. (2017). Thermal conductivity enhancement of treated petroleum waxes, as phase change material, by A nano alumina: Energy storage. *Renewable and Sustainable Energy Reviews*, *70*, 1052–1058. https://doi.org/10.1016/j.rser.2016.12.009

Mojumder, J. C., Chong, W. T., Ong, H. C., Leong, K. Y., & Abdullah-Al-Mamoon. (2016). An experimental investigation on performance analysis of air type photovoltaic thermal collector system integrated with cooling fins design. *Energy and Buildings*, *130*, 272–285. https://doi.org/10.1016/j.enbuild.2016.08.040

Morsy, M., Helal, M., El-Okr, M., & Ibrahim, M. (2014). Preparation, purification and characterization of high purity multi-wall carbon nanotube. *Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy*, *132*, 594–598. https://doi.org/10.1016/j.saa.2014.04.122

Mousavi, S., Kasaeian, A., Shafii, M. B., & Jahangir, M. H. (2018). Numerical investigation of the effects of a copper foam filled with phase change materials in a water-cooled photovoltaic/thermal system. *Energy Conversion and Management*, *163*, 187–195. https://doi.org/10.1016/j.enconman.2018.02.039

Muhammad, H., Furqan, A., & Hamza Babar, J. (2021). *Thermal Energy Storage Storage Techniques, Advanced Materials, Thermophysical Properties and Applications*. Springer, Berlin; Springer nature Singapore; Springer

Naghdbishi, A., Yazdi, M. E., & Akbari, G. (2020). Experimental investigation of the effect of multi-wall carbon nanotube – Water/glycol based nanofluids on a PVT system integrated with PCM-covered collector. *Applied Thermal Engineering*, *178*, 115556. https://doi.org/10.1016/j.applthermaleng.2020.115556

Nasiri, A., Shariaty-Niasar, M., Rashidi, A., Amrollahi, A., & Khodafarin, R. (2011). Effect of dispersion method on thermal conductivity and stability of nanofluid. *Experimental Thermal and Fluid Science*, *35*(4), 717–723. https://doi.org/10.1016/j.expthermflusci.2011.01.006

Nasrin, R., Rahim, N. A., Fayaz, H., & Hasanuzzaman, M. (2018). Water/MWCNT nanofluid based cooling system of PVT: Experimental and numerical research. *Renewable Energy*, *121*, 286–300. https://doi.org/10.1016/j.renene.2018.01.014

Naveenkumar, R., Divakaran, S., Aravinthasamy, P., Eswaraaravinth, R., Ganesan, N., & Ravichandran, M. (2020). Role of phase changing materials and other parameters to enhance the thermal performance of solar still. *Materials Today: Proceedings*, *33*, 3676–3682. https://doi.org/10.1016/j.matpr.2020.05.798

Nazir, H., Batool, M., Bolivar Osorio, F. J., Isaza-Ruiz, M., Xu, X., Vignarooban, K., Phelan, P., Inamuddin, & Kannan, A. M. (2019). Recent developments in phase change materials for energy storage applications: A review. *International Journal of Heat and Mass Transfer*, *129*, 491–523. https://doi.org/10.1016/j.ijheatmasstransfer.2018.09.126

Nazri, N. S., Fudholi, A., Bakhtyar, B., Yen, C. H., Ibrahim, A., Ruslan, M. H., Mat, S., & Sopian, K. (2018). Energy economic analysis of photovoltaic-thermal-thermoelectric (PVT-TE) air collectors. *Renewable and Sustainable Energy Reviews*, *92*, 187–197. https://doi.org/10.1016/j.rser.2018.04.061

Nazri, N. S., Fudholi, A., Mustafa, W., Yen, C. H., Mohammad, M., Ruslan, M. H., & Sopian, K. (2019). Exergy and improvement potential of hybrid photovoltaic thermal/thermoelectric (PVT/TE) air collector. *Renewable and Sustainable Energy Reviews*, *111*, 132–144. https://doi.org/10.1016/j.rser.2019.03.024

Nižetić, S., Jurčević, M., Čoko, D., Arıcı, M., & Hoang, A. T. (2021). Implementation of phase change materials for thermal regulation of photovoltaic thermal systems: Comprehensive analysis of design approaches. *Energy*, *228*. https://doi.org/10.1016/j.energy.2021.120546

Noori, M. M., Ali, H., Arjmand, M., & Jafari, S. H. (2019). Paraffin / CuO nanocomposites as phase change materials : Effect of surface modification of CuO. *Polyer composites* 40, 1–9. https://doi.org/10.1002/pc.25298

Norizan, M. N., Moklis, M. H., Ngah Demon, S. Z., Halim, N. A., Samsuri, A., Mohamad, I. S., Knight, V. F., & Abdullah, N. (2020). Carbon nanotubes: Functionalisation and their application in chemical sensors. *RSC Advances*, *10*(71), 43704–43732. https://doi.org/10.1039/d0ra09438b

Nouira, M., & Sammouda, H. (2018). Numerical study of an inclined photovoltaic system coupled with phase change material under various operating conditions. *Applied Thermal Engineering*, *141*(June), 958–975. https://doi.org/10.1016/j.applthermaleng.2018.06.039

Oró, E., de Gracia, A., Castell, A., Farid, M. M., & Cabeza, L. F. (2012). Review on phase change materials (PCMs) for cold thermal energy storage applications. *Applied Energy*, *99*, 513–533. https://doi.org/10.1016/j.apenergy.2012.03.058

Othman, M. Y., Hamid, S. A., Tabook, M. A. S., Sopian, K., Roslan, M. H., & Ibarahim, Z. (2016). Performance analysis of PV/T Combi with water and air heating system: An experimental study. *Renewable Energy*, *86*, 716–722. https://doi.org/10.1016/j.renene.2015.08.061

Özakin, A. N., & Kaya, F. (2019). Effect on the exergy of the PVT system of fins added to an air-cooled channel: A study on temperature and air velocity with ANSYS Fluent. *Solar Energy*, *184* 561–569. https://doi.org/10.1016/j.solener.2019.03.100

Pang, W., Zhang, Q., Cui, Y., Zhang, L., Yu, H., Zhang, X., Zhang, Y., & Yan, H. (2019). Numerical simulation and experimental validation of a photovoltaic/thermal system based on a roll-bond aluminum collector. *Energy*, *187*, 115990. https://doi.org/10.1016/j.energy.2019.115990

Parameshwaran, R., Jayavel, R., & Kalaiselvam, S. (2013). Study on thermal properties of organic ester phase-change material embedded with silver nanoparticles. *Journal of Thermal Analysis and Calorimetry*, *114*(2), 845–858. https://doi.org/10.1007/s10973-013-3064-9

Phase Change Material Products Limited. (2013). *PlusICE Phase Change Materials Phase*.

Popovici, C. G., Hudişteanu, S. V., Mateescu, T. D., & Chereecheş, N. C. (2016). Efficiency Improvement of Photovoltaic Panels by Using Air Cooled Heat Sinks. *Energy Procedia*, *85*, 425–432. https://doi.org/10.1016/j.egypro.2015.12.223

Prieto, C., Ruiz-cabañas, F. J., Rodríguez-sanchez, A., Rubio, C., Fernández, A. I., Martínez, M., Oró, E., & Cabeza, L. F. (2019). *Eff ect of the impurity magnesium nitrate in the thermal decomposition of the solar salt*. *192*, 186–192.

Pujiastuti, S., & Wulan, P. P. D. K. (2019). The effect of hydrogen peroxide (H_2O_2) on carbon nanotubes solubility as drug delivery material for cancer with covalent functionalization. *AIP Conference Proceedings*, *2092*. https://doi.org/10.1063/1.5096710

Qian, T., Li, J., Min, X., Guan, W., Deng, Y., & Ning, L. (2015). Enhanced thermal conductivity of PEG/diatomite shape-stabilized phase change materials with Ag nanoparticles for thermal energy storage. *Journal of Materials Chemistry A*, *3*(16), 8526–8536. https://doi.org/10.1039/c5ta00309a

Qu, Y., Wang, S., Tian, Y., & Zhou, D. (2019). Comprehensive evaluation of Paraffin-HDPE shape stabilized PCM with hybrid carbon nano-additives. *Applied Thermal Engineering*, *163*. https://doi.org/10.1016/j.applthermaleng.2019.114404

Qu, Y., Wang, S., Zhou, D., & Tian, Y. (2020). Experimental study on thermal conductivity of paraffin-based shape-stabilized phase change material with hybrid carbon nano-additives. *Renewable Energy*, *146*, 2637–2645. https://doi.org/10.1016/j.renene.2019.08.098

Ranjbar, S., Masoumi, H., Haghighi Khoshkhoo, R., & Mirfendereski, M. (2020). Experimental investigation of stability and thermal conductivity of phase change materials containing pristine and functionalized multi-walled carbon nanotubes. *Journal of Thermal Analysis and Calorimetry*, *140*(5), 2505–2518. https://doi.org/10.1007/s10973-019-09005-x

Rashidi, S., Yang, L., Khoosh-Ahang, A., Jing, D., & Mahian, O. (2020). Entropy generation analysis of different solar thermal systems. *Environmental Science and Pollution Research*, *27*(17), 20699–20724. https://doi.org/10.1007/s11356-020-08472-2

Ren, H., Ma, Z., Lin, W., Fan, W., & Li, W. (2018). Integrating photovoltaic thermal collectors and thermal energy storage systems using phase change materials with rotary desiccant cooling systems. *Sustainable Cities and Society*, *36*, 131–143. https://doi.org/10.1016/j.scs.2017.10.021

Renewable, I., & Agency, E. (2021). Renewable capacity statistics and Renewaable market update, IEA 2021, https://www.iea.org/reports/renewable-energy-market-update-may-2022.

S. Hirano, T.Saitoh, O.Masaaki, Y. M. (2001). Temperature dependence of thermophysical properties of di sodium hydrogen phosphate dodecahydrate. *Journal of . Thermophysics and HeatTransfer*, *15*(3), 340–346. https://doi.org/10.2514/2.6613

S. Sternberg, A. M. (1983). Temperature dependence of thermalconductivity in $Ca(N0_3)_2$.$4H_2O$-nH_2O. *Sytem,Revue.Roumaine de .Chime*, *23*(5), 437–444.doi:10.1007/s10973-006-7526-1

Sadeghi, G. (2022). Energy storage on demand: Thermal energy storage development, materials, design, and integration challenges. *Energy Storage Materials*, *46*, 192–222. https://doi.org/10.1016/j.ensm.2022.01.017

Safari, A., Saidur, R., Sulaiman, F. A., Xu, Y., & Dong, J. (2017). A review on supercooling of Phase Change Materials in thermal energy storage systems. *Renewable and Sustainable Energy Reviews*, *70*, 905–919. https://doi.org/10.1016/j.rser.2016.11.272

Salem, M. R., Elsayed, M. M., Abd-Elaziz, A. A., & Elshazly, K. M. (2019). Performance enhancement of the photovoltaic cells using Al_2O_3/PCM mixture and/or water cooling-techniques. *Renewable Energy*, *138*, 876–890. https://doi.org/10.1016/j.renene.2019.02.032

Sami, S., & Etesami, N. (2017). Improving thermal characteristics and stability of phase change material containing TiO_2 nanoparticles after thermal cycles for energy storage. *Applied Thermal Engineering*, *124*, 346–352. https://doi.org/10.1016/j.applthermaleng.2017.06.023

Sarafraz, M. M., Safaei, M. R., Leon, A. S., Tlili, I., Alkanhal, T. A., Tian, Z., Goodarzi, M., & Arjomandi, M. (2019). Experimental investigation on thermal performance of a PV/T-PCM (photovoltaic/thermal) system cooling with a PCM and nanofluid. *Energies*, *12*(13), 1–16. https://doi.org/10.3390/en12132572

Sardarabadi, M., & Passandideh-Fard, M. (2016). Experimental and numerical study of metal-oxides/water nanofluids as coolant in photovoltaic thermal systems (PVT). *Solar Energy Materials and Solar Cells*, *157*, 533–542. https://doi.org/10.1016/j.solmat.2016.07.008

Sardarabadi, M., Passandideh-Fard, M., Maghrebi, M. J., & Ghazikhani, M. (2017). Experimental study of using both ZnO/ water nanofluid and phase change material (PCM) in photovoltaic thermal systems. *Solar Energy Materials and Solar Cells*, *161*, 62–69. https://doi.org/10.1016/j.solmat.2016.11.032

Sathe, T. M., & Dhoble, A. S. (2017). A review on recent advancements in photovoltaic thermal techniques. *Renewable and Sustainable Energy Reviews*, *76*, 645–672. https://doi.org/10.1016/j.rser.2017.03.075

Scott B.W (1960). The Absorption of Radiation in Bone. *Australasian Radiology*, *4*(2), 129–132. https://doi.org/10.1111/j.1440-1673.1960.tb01091.x

Shah, R., & Srinivasan, P. (2018). Hybrid Photovoltaic and Solar Thermal Systems (PVT): Performance Simulation and Experimental Validation. *Materials Today: Proceedings*, *5*(11), 22998–23006. https://doi.org/10.1016/j.matpr.2018.11.028

Shahsavar, A. (2021). Experimental evaluation of energy and exergy performance of a nanofluid-based photovoltaic/thermal system equipped with a sheet-and-sinusoidal serpentine tube collector. *Journal of Cleaner Production*, *287*, 125064. https://doi.org/10.1016/j.jclepro.2020.125064

Sharma, A., Tyagi, V. V., Chen, C. R., & Buddhi, D. (2009). Review on thermal energy storage with phase change materials and applications. *Renewable and Sustainable Energy Reviews*, *13*(2), 318–345. https://doi.org/10.1016/j.rser.2007.10.005

Sharma, M. K. (2022). Alternative designs and technological advancements of phase change material integrated photovoltaics : A state-of-the-art review. *Journal of Energy Storage*, *48*, 104020. https://doi.org/10.1016/j.est.2022.104020

Sharma, S., Micheli, L., Chang, W., Tahir, A. A., Reddy, K. S., & Mallick, T. K. (2017). Nano-enhanced Phase Change Material for thermal management of BICPV. *Applied Energy*, *208*, 719–733. https://doi.org/10.1016/j.apenergy.2017.09.076

Sharma, Shivangi, Tahir, A., Reddy, K. S., & Mallick, T. K. (2016). Performance enhancement of a Building-Integrated Concentrating Photovoltaic system using phase change material. *Solar Energy Materials and Solar Cells*, *149*, 29–39. https://doi.org/10.1016/j.solmat.2015.12.035

Shehadeh, S. H., Aly, H. H., & El-Hawary, M. E. (2019). Investigation of photovoltaic coverage ratio for maximum overall thermal energy of photovoltaic thermal system. *Renewable Energy*, *134*, 757–768. https://doi.org/10.1016/j.renene.2018.11.080

Sheikholeslami, M. (2018). Numerical simulation for solidification in a LHTESS by means of nano-enhanced PCM. *Journal of the Taiwan Institute of Chemical Engineers*, *86*, 25–41. https://doi.org/10.1016/j.jtice.2018.03.013

Shimoda, Y., Yamaguchi, Y., Iwafune, Y., Hidaka, K., Meier, A., Yagita, Y., Kawamoto, H., & Nishikiori, S. (2020). Energy demand science for a decarbonized society in the context of the residential sector. *Renewable and Sustainable Energy Reviews*, *132*, 110051. https://doi.org/10.1016/j.rser.2020.110051

Shin, D., & Banerjee, D. (2011). Enhancement of specific heat capacity of high-temperature silica-nanofluids synthesized in alkali chloride salt eutectics for solar thermal-energy storage applications. *International Journal of Heat and Mass Transfer*, *54*(5–6), 1064–1070. https://doi.org/10.1016/j.ijheatmasstransfer.2010.11.017

Shukla, A. (2015). Latent heat storage through phase change materials. *Resonance*, *20*(6), 532–541. https://doi.org/10.1007/s12045-015-0212-5

Shukla, K. N. (2015). Heat Pipe for Aerospace Applications—An Overview. *Journal of Electronics Cooling and Thermal Control*, *05*(01), 1–14. https://doi.org/10.4236/jectc.2015.51001

Shyam, Tiwari, G. N., Fischer, O., Mishra, R. K., & Al-Helal, I. M. (2016). Performance evaluation of N-photovoltaic thermal (PVT) water collectors partially covered by photovoltaic module connected in series: An experimental study. *Solar Energy*, *134*, 302–313. https://doi.org/10.1016/j.solener.2016.05.013

Simón-Allué, R., Guedea, I., Villén, R., & Brun, G. (2019). Experimental study of Phase Change Material influence on different models of Photovoltaic-Thermal collectors. *Solar Energy*, *190*, 1–9. https://doi.org/10.1016/j.solener.2019.08.005

Singh, R. P., Sze, J. Y., Kaushik, S. C., Rakshit, D., & Romagnoli, A. (2021). Thermal performance enhancement of eutectic PCM laden with functionalised graphene nanoplatelets for an efficient solar absorption cooling storage system. *Journal of Energy Storage*, *33*, 102092. https://doi.org/10.1016/j.est.2020.102092

Singh, S., Agrawal, S., & Avasthi, D. V. (2016). Design, modeling and performance analysis of dual channel semitransparent photovoltaic thermal hybrid module in the cold environment. *Energy Conversion and Management*, *114*, 241–250. https://doi.org/10.1016/j.enconman.2016.02.023

Sohel, M. I., & Cooper, P. (2013). A theoretical investigation of a solar photovoltaic thermal system integrated with phase change materials. *International Conference on Sustainable Energy technologies-Hong Kong* 1265–1272.

Srimanickam, B., Vijayalakshmi, M. M., & Natarajan, E. (2015). Experimental Study of Exergy Analysis on Flat Plate Solar Photovoltaic Thermal (PV/T) Hybrid System. *Applied Mechanics and Materials*, *787*, 82–87. https://doi.org/10.4028/www.scientific.net/amm.787.82

Su, D., Jia, Y., Huang, X., Alva, G., Tang, Y., & Fang, G. (2016). Dynamic performance analysis of photovoltaic-thermal solar collector with dual channels for different fluids. *Energy Conversion and Management*, *120*, 13–24. https://doi.org/10.1016/j.enconman.2016.04.095

Su, D., Jia, Y., Lin, Y., & Fang, G. (2017). Maximizing the energy output of a photovoltaic–thermal solar collector incorporating phase change materials. *Energy and Buildings*, *153*, 382–391. https://doi.org/10.1016/j.enbuild.2017.08.027

Sun, X., Liu, L., Mo, Y., Li, J., & Li, C. (2020). Enhanced thermal energy storage of a paraffin-based phase change material (PCM) using nano carbons. *Applied Thermal Engineering*, *181*, 115992. https://doi.org/10.1016/j.applthermaleng.2020.115992

Suresh Kumar, K. R., & Kalaiselvam, S. (2017). Experimental investigations on the thermophysical properties of CuO-palmitic acid phase change material for heating applications. *Journal of Thermal Analysis and Calorimetry*, *129*(3), 1647–1657. https://doi.org/10.1007/s10973-017-6301-9

Suresh Kumar, K. R., Parameshwaran, R., & Kalaiselvam, S. (2017). Preparation and characterization of hybrid nanocomposite embedded organic methyl ester as phase change material. *Solar Energy Materials and Solar Cells*, *171*, 148–160. https://doi.org/10.1016/j.solmat.2017.06.031

Tao, Y. B., & He, Y. L. (2018). A review of phase change material and performance enhancement method for latent heat storage system. *Renewable and Sustainable Energy Reviews*, *93*, 245–

259. https://doi.org/10.1016/j.rser.2018.05.028

Tariq, S. L., Ali, H. M., Akram, M. A., Janjua, M. M., & Ahmadlouydarab, M. (2020). Nanoparticles enhanced Phase Change Materials (NePCMs) -A Recent Review. *Applied Thermal Engineering, 208*, 115305. https://doi.org/10.1016/j.applthermaleng.2020.115305

Teng, T. P., & Yu, C. C. (2012). Characteristics of phase-change materials containing oxide nano-additives for thermal storage. *Nanoscale Research Letters*, *7*, 1–10. https://doi.org/10.1186/1556-276X-7-611

Tiwari, S., Tiwari, G. N., & Al-Helal, I. M. (2016). Performance analysis of photovoltaic-thermal (PVT) mixed mode greenhouse solar dryer. *Solar Energy*, *133*, 421–428. https://doi.org/10.1016/j.solener.2016.04.033

Tripathi, R., Tiwari, G. N., & Dwivedi, V. K. (2016). Overall energy, exergy and carbon credit analysis of N partially covered Photovoltaic Thermal (PVT) concentrating collector connected in series. *Solar Energy*, *136*, 260–267. https://doi.org/10.1016/j.solener.2016.07.002

Tyagi, V. V., Pandey, A. K., Kothari, R., & Tyagi, S. K. (2014). Thermodynamics and performance evaluation of encapsulated PCM-based energy storage systems for heating application in building. *Journal of Thermal Analysis and Calorimetry*, *115*(1), 915–924. https://doi.org/10.1007/s10973-013-3215-z

Verma, S. K., & Tiwari, A. K. (2015). Progress of nanofluid application in solar collectors: A review. *Energy Conversion and Management*, *100*, 324–346. https://doi.org/10.1016/j.enconman.2015.04.071

Vivekananthan, M., & Amirtham, V. A. (2019). Characterisation and thermophysical properties of graphene nanoparticles dispersed erythritol PCM for medium temperature thermal energy storage applications. *Thermochimica Acta*, *676*, 94–103. https://doi.org/10.1016/j.tca.2019.03.037

Wang, S. Y. W. H., & Zhu, S. X. D. S. (2012). An investigation of melting / freezing characteristics of nanoparticle-enhanced phase change materials. *Journalof thermal analysis and calorimetry, 110,* 1127–1131. https://doi.org/10.1007/s10973-011-2080-x

Wen, R., Zhu, X., Yang, C., Sun, Z., Zhang, L., Xu, Y., Qiao, J., Wu, X., Min, X., & Huang, Z. (2022). A novel composite phase change material from lauric acid, nano-Cu and attapulgite: Preparation, characterization and thermal conductivity enhancement. *Journal of Energy Storage*, *46*, 103921. https://doi.org/10.1016/j.est.2021.103921

Wong-Pinto, L. S., Milian, Y., & Ushak, S. (2020). Progress on use of nanoparticles in salt hydrates as phase change materials. *Renewable and Sustainable Energy Reviews*, *122*, 109727. https://doi.org/10.1016/j.rser.2020.109727

Wongwuttanasatian, T., Sarikarin, T., & Suksri, A. (2020). Performance enhancement of a photovoltaic module by passive cooling using phase change material in a finned container heat sink. *Solar Energy*, *195*, 47–53. https://doi.org/10.1016/j.solener.2019.11.053

Wu, S. Y., Wang, T., Xiao, L., & Shen, Z. G. (2019). Effect of cooling channel position on heat transfer characteristics and thermoelectric performance of air-cooled PV/T system. *Solar Energy*, *180*, 489–500. https://doi.org/10.1016/j.solener.2019.01.043

Wu, T., Xie, N., Niu, J., Luo, J., Gao, X., fang, Y., & Zhang, Z. (2020). Preparation of a low-temperature nanofluid phase change material: $MgCl_2$–H_2O eutectic salt solution system with multi-walled carbon nanotubes (MWCNTs). *International Journal of Refrigeration*, *113*, 136–144. https://doi.org/10.1016/j.ijrefrig.2020.02.008

Wulan, P. P. D. K., Ulwani, S. H., Wulandari, H., Purwanto, W. W., & Mulia, K. (2018). The effect of hydrochloric acid addition to increase carbon nanotubes dispersibility as drug delivery system by covalent functionalization. *IOP Conference Series: Materials Science and Engineering*, *316*(1). https://doi.org/10.1088/1757-899X/316/1/012013

Xu, H., Wang, N., Zhang, C., Qu, Z., & Karimi, F. (2021). Energy conversion performance of a PV/T-PCM system under different thermal regulation strategies. *Energy Conversion and Management*, *229*, 113660. https://doi.org/10.1016/j.enconman.2020.113660

Yadav, C., & Rekha Sahoo, R. (2020). Experimental analysis for optimum thermal performance and thermophysical parameters of MWCNT based capric acid PCM by using T-history method. *Powder Technology*, *364*, 392–403. https://doi.org/10.1016/j.powtec.2020.02.008

Yang, L., Huang, J. nan, & Zhou, F. (2020). Thermophysical properties and applications of nano-enhanced PCMs: An update review. *Energy Conversion and Management*, *214*, 112876. https://doi.org/10.1016/j.enconman.2020.112876

Yang, X., Sun, L., Yuan, Y., Zhao, X., & Cao, X. (2018). Experimental investigation on performance comparison of PV/T-PCM system and PV/T system. *Renewable Energy*, *119*, 152–159. https://doi.org/10.1016/j.renene.2017.11.094

Yin, H. M., Yang, D. J., Kelly, G., & Garant, J. (2013). Design and performance of a novel building integrated PV/thermal system for energy efficiency of buildings. *Solar Energy*, *87*(1), 184–195. https://doi.org/10.1016/j.solener.2012.10.022

Yu, M., Chen, F., Zheng, S., Zhou, J., Zhao, X., Wang, Z., Li, G., Li, J., Diallo, T. M. O., & Hardy, D. (2019). Experimental Investigation of a Novel Solar Micro-Channel Loop-Heat-Pipe Photovoltaic/Thermal (MC-LHP-PV/T) System for Heat and Power Generation. *Applied Energy*, *256*, 113929. https://doi.org/10.1016/j.apenergy.2019.113929

Yu, W., & Xie, H. (2012). A review on nanofluids: Preparation, stability mechanisms, and applications. *Journal of Nanomaterials*, *2012*. 1-17. https://doi.org/10.1155/2012/435873

Yuan, P., Zhang, P., Liang, T., & Zhai, S. (2019). Effects of surface functionalization on thermal and mechanical properties of graphene/polyethylene glycol composite phase change materials. *Applied Surface Science*, *485*, 402–412. https://doi.org/10.1016/j.apsusc.2019.04.011

Zhang, S., Wu, J. Y., Tse, C. T., & Niu, J. (2012). Effective dispersion of multi-wall carbon nano-tubes in hexadecane through physiochemical modification and decrease of supercooling. *Solar Energy Materials and Solar Cells*, *96*(1), 124–130. https://doi.org/10.1016/j.solmat.2011.09.032

Zhou, Yan, Wang, X., Liu, X., Sheng, D., Ji, F., Dong, L., Xu, S., Wu, H., & Yang, Y. (2019). Multifunctional ZnO/polyurethane-based solid-solid phase change materials with graphene aerogel. *Solar Energy Materials and Solar Cells*, *193*, 13–21. https://doi.org/10.1016/j.solmat.2018.12.041

Zhou, Yuekuan, Liu, X., & Zhang, G. (2017). Performance of buildings integrated with a photovoltaic-thermal collector and phase change materials. *Procedia Engineering*, *205*, 1337–1343. https://doi.org/10.1016/j.proeng.2017.10.109

Zhu, W., Deng, Y., Wang, Y., Shen, S., & Gulfam, R. (2016). High-performance photovoltaic-thermoelectric hybrid power generation system with optimized thermal management. *Energy*, *100*, 91–101. https://doi.org/10.1016/j.energy.2016.01.055