

## **Advanced PV/T Systems**

**Dhanashree Deokar, Gopal Kshirsagar, Pradip Pawar, Akash Dongardive, Avinash Bangale**

Pankaj Laddhad Institute of Technology and Management Studies, Yelgaon, Buldhana, Maharashtra, India  
danashreedeokar@gmail.com, kshirsagargopal48@gmail.com, pradiprpawar981@gmail.com,  
akash.spd10@gmail.com, avipatil1942@gmail.com

**Abstract:** *A significant amount of research and development work on the photovoltaic/thermal (PVT) technology has been done since the 1970s. Many innovative systems and products have been put forward and their quality evaluated by academics and professionals. A range of theoretical models has been introduced and their appropriateness validated by experimental data. Important design parameters are identified. Collaborations have been underway amongst institutions or countries, helping to sort out the suitable products and systems with the best marketing potential. This article gives a review of the trend of development of the technology, in particular the advancements in recent years and the future work required..*

**Keywords:** Hybrid solar system, Photovoltaic/thermal collector, Energy conversion, Exergy analysis, Technology review

### **REFERENCES**

- [1] W. Lin, Z. Ma, M.I. Sohel, P. Cooper, Development and evaluation of a ceiling ventilation system enhanced by solar photovoltaic thermal collectors and phase change materials, *Energy Convers. Manag.* 88 (2014) 218–230, <https://doi.org/10.1016/j.enconman.2014.08.019>.
- [2] M.I. Sohel, Z. Ma, P. Cooper, J. Adams, R. Scott, A theoretical investigation of a solar photovoltaic thermal system integrated with phase change materials, in: *Proceedings of the 12th International Conference Sus. Energy Tech. China 2013* 1265–1272.
- [3] M. Nouira, H. Sammouda, Numerical study of an inclined photovoltaic system coupled with phase change material under various operating conditions, *Appl. Therm. Eng.* 141 (2018) 958–975, <https://doi.org/10.1016/j.applthermaleng.2018.06.039>.
- [4] T. Wongwuttanasatian, T. Sarikarin, A. Suksri, Performance enhancement of a photovoltaic module by passive cooling using phase change material in a finned container heat sink, *Sol. Energy* 195 (2020) 47–53, <https://doi.org/10.1016/j.solener.2019.11.053>.
- [5] M. Fiorentini, P. Cooper, Z. Ma, Development and optimization of an innovative HVAC system with integrated PVT and PCM thermal storage for a net-zero energy retrofitted house, *Energy Build.* 94 (2015) 21–32, <https://doi.org/10.1016/j.enbuild.2015.02.018>.
- [6] N. Choubineh, H. Jannesari, A. Kasaeian, Experimental study of the effect of using phase change materials on the performance of an air-cooled photovoltaic system, *Renew. Sustain. Energy Rev.* 101 (2019) 103–111, <https://doi.org/10.1016/j.rser.2018.11.001>.
- [7] S. Sharma, A. Tahir, K.S. Reddy, T.K. Mallick, Performance enhancement of a building-integrated concentrating photovoltaic system using phase change material, *Sol. Energy Mater. Sol. Cells* 149 (2016) 29–39, <https://doi.org/10.1016/j.solmat.2015.12.035>.
- [8] S. Khanna, S. Newar, V. Sharma, K.S. Reddy, T.K. Mallick, J. Radulovic, R. Khusainov, D. Hutchinson, V. Becerra, Electrical enhancement period of solar photovoltaic using phase change material, *J. Clean. Prod.* 221 (2019) 878–884, <https://doi.org/10.1016/j.jclepro.2019.02.169>.
- [9] H. Ren, Z. Ma, W. Lin, W. Fan, W. Li, Integrating photovoltaic thermal collectors and thermal energy storage systems using phase change materials with rotary desiccant cooling systems, *Sustain. Cities Soc.* 36 (2018) 131–143, <https://doi.org/10.1016/j.scs.2017.10.021>.

- [10] M.A. Kibria, R. Saidur, F.A. Al-Sulaiman, M.M.A. Aziz, Development of a thermal model for a hybrid photovoltaic module and phase change materials storage integrated in buildings, *Sol. Energy* 124 (2016) 114–123, <https://doi.org/10.1016/j.solener.2015.11.027>.
- [11] A. Hasan, S.J. McCormack, M.J. Huang, B. Norton, Evaluation of phase change materials for thermal regulation enhancement of building integrated photovoltaics, *Sol. Energy* 84 (2010) 1601–1612, <https://doi.org/10.1016/j.solener.2010.06.010>.
- [12] O.B. Kazanci, M. Skrupskelis, P. Sevela, G.K. Pavlov, B.W. Olesen, Sustainable heating, cooling and ventilation of a plus-energy house via photovoltaic/thermal panels, *Energy Build.* 83 (2014) 122–129, <https://doi.org/10.1016/j.enbuild.2013.12.064>.
- [13] W. Lin, Z. Ma, P. Cooper, M.I. Sohel, L. Yang, Thermal performance investigation and optimization of buildings with integrated phase change materials and solar photovoltaic thermal collectors, *Energy Build.* 116 (2016) 562–573, <https://doi.org/10.1016/j.enbuild.2016.01.041>.
- [14] H. Ren, W. Lin, Z. Ma, W. Fan, Thermal performance evaluation of an integrated photovoltaic thermal-phase change material system using Taguchi method, *Energy Procedia* 121 (2017) 118–125, <https://doi.org/10.1016/j.egypro.2017.08.008>.
- [15] Z. Ma, W. Lin, M.I. Sohel, Nano-enhanced phase change materials for improved building performance, *Renew. Sustain. Energy Rev.* 58 (2016) 1256–1268, <https://doi.org/10.1016/j.rser.2015.12.234>.
- [16] S. Sharma, L. Micheli, W. Chang, A.A. Tahir, K.S. Reddy, T.K. Mallick, Nanoenhanced phase change material for thermal management of BICPV, *Appl. Energy* 208 (2017) 719–733, <https://doi.org/10.1016/j.apenergy.2017.09.076>.
- [17] T. Maatallah, R. Zachariah, F.G. Al-Amri, Exergo-economic analysis of a serpentine flow type water based photovoltaic thermal system with phase change material (PVT-PCM/water), *Sol. Energy* 193 (2019) 195–204, <https://doi.org/10.1016/j.solener.2019.09.063>.
- [18] M.F.I. Al Imam, R.A. Beg, M.S. Rahman, M.Z.H. Khan, Performance of PVT solar collector with compound parabolic concentrator and phase change materials, *Energy Build.* 113 (2016) 139–144, <https://doi.org/10.1016/j.enbuild.2015.12.038>.
- [19] C.S. Malvi, D.W. Dixon-Hardy, R. Crook, Energy balance model of combined photovoltaic solar-thermal system incorporating phase change material, *Sol. Energy* 85 (2011) 1440–1446, <https://doi.org/10.1016/j.solener.2011.03.027>.
- [20] M.C. Browne, K. Lawlor, A. Kelly, B. Norton, S.J.M. Cormack, Indoor characterization of a photovoltaic/thermal phase change material system, *Energy Procedia* 70 (2015) 163–171, <https://doi.org/10.1016/j.egypro.2015.02.112>.
- [21] Y. Zhou, X. Liu, G. Zhang, Performance of buildings integrated with a photovoltaic-thermal collector and phase change materials, *Procedia Eng.* 205 (2017) 1337–1343, <https://doi.org/10.1016/j.proeng.2017.10.109>.
- [22] S. Mousavi, A. Kasaeian, M.B. Shafii, M.H. Jahangir, Numerical investigation of the effects of a copper foam filled with phase change materials in a water-cooled photovoltaic/thermal system, *Energy Convers. Manag.* 163 (2018) 187–195, <https://doi.org/10.1016/j.enconman.2018.02.039>.
- [23] M.R. Salem, M.M. Elsayed, A.A. Abd-Elaziz, K. Elshazly M., Performance enhancement of the photovoltaic cells using Al<sub>2</sub>O<sub>3</sub>/PCM mixture and/or water cooling techniques, *Renew. Energy* 138 (2019) 876–890, <https://doi.org/10.1016/j.renene.2019.02.032>.
- [24] N. Abdollahi, M. Rahimi, Potential of water natural circulation coupled with nanoenhanced PCM for PV module cooling, *Renew. Energy* 147 (2020) 302–309, <https://doi.org/10.1016/j.renene.2019.09.002>.
- [25] A.S. Abdelrazik, R. Saidur, F.A. Al-Sulaiman, Thermal regulation and performance assessment of a hybrid photovoltaic/thermal system using different combinations of nano-enhanced phase change materials, *Sol. Energy Mater. Sol. Cells* 215 (2020), 110645, <https://doi.org/10.1016/j.solmat.2020.110645>.
- [26] M.M. Islam, M. Hasanuzzaman, N.A. Rahim, A.K. Pandey, M. Rawa, L. Kumar, Real time experimental performance investigation of a NePCM based photovoltaic thermal system: an energetic and exergetic approach, *Renew. Energy* 172 (2021) 71–87,
- [27] M. Sardarabadi, M. Passandideh-Fard, M.J. Maghrebi, M. Ghazikhani, Experimental study of using both ZnO/water nanofluid and phase change material (PCM) in photovoltaic thermal systems, *Sol. Energy Mater. Sol. Cells* 161 (2017) 62–69, <https://doi.org/10.1016/j.solmat.2016.11.032>.

- [28] M. Hosseinzadeh, M. Sardarabadi, M. Passandideh-Fard, Energy and exergy analysis of nanofluid based photovoltaic thermal system integrated with phase change material, *Energy* 147 (2018) 636–647, <https://doi.org/10.1016/j.energy.2018.01.073>.
- [29] A. Hassan, A. Wahab, M.A. Qasim, M.M. Janjua, M.A. Ali, H.M. Ali, T.R. Jadoon, E. Ali, A. Raza, N. Javaid, Thermal management and uniform temperature regulation of photovoltaic modules using hybrid phase change materialsnanofluids system, *Renew. Energy* 145 (2020) 282–293, <https://doi.org/10.1016/j.renene.2019.05.130>.
- [30] M.M. Sarafraz, M.R. Safaei, A.S. Leon, I. Tlili, T.A. Alkanhal, Z. Tian, M. Goodarzi, M. Arjomandi, Experimental investigation on thermal performance of a PV/TPCM (photovoltaic/thermal) system cooling with a PCM and nanofluid, *Energy* 12 (2019) 1–16, <https://doi.org/10.3390/en12132572>.
- [31] A.H.A. Al-Waeli, M.T. Chaichan, K. Sopian, H.A. Kazem, H.B. Mahood, A. A. Khadom, Modeling and experimental validation of a PVT system using nanofluid coolant and nano-PCM, *Sol. Energy* 177 (2019) 178–191, <https://doi.org/10.1016/j.solener.2018.11.016>.
- [32] A. Kazemian, M. Khatibi, S.R. Maadi, T. Ma, Performance optimization of a nanofluid-based photovoltaic thermal system integrated with nano-enhanced phase change material, *Appl. Energy* 295 (2021), 116859, <https://doi.org/10.1016/j.apenergy.2021.116859>.