IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 3, Issue 2, March 2023
Impact Factor: 7.301

A Review of Recent Photovoltaic/Thermal (PV/T) System Development

Prof. Fahim R. Sheikh[1] and Mr. Lakshman S. Rajguru[2]
Professor, Department of Mechanical Engineering[1]
PG Student, Department of Mechanical Engineering[2]
Pankaj Laddhad Institute of Technology and Management Studies, Buldana, Maharashtra, India

Abstract: *Hybrid photovoltaic/thermal systems have become an essential energy technology since they can produce electricity and heat simultaneously, are easy to install in buildings, and work well overall. Conventional photovoltaic (PV) systems waste energy in the form of heat as they turn sunlight into electricity. It has been established that as the temperature of a PV cell goes up, the panels' efficiency goes down. So, this heat can be reduced to improve the performance of PV. The most frequent ways to get rid of heat are through air and water, and the energy can subsequently be used to heat structures. Over the past 50 years, scientists worldwide have tested, simulated, and used numbers to model many PV/T systems. In addition to water and air, other ways to eliminate heat have been looked at. These include refrigerants, PCM, heat pumps, and nanofluids. This article overviews and discusses the research done over the last five years on the different PV/T thermal control systems. The current study looks at the most essential parts of the various techniques, such as how well they perform overall, their parameters and settings, the type of system, the sort of work, where they were developed, and how they are used. Based on this study, it was decided that PV/T systems are a good idea and that further effort should be made to make them look better so that they are more widely used and their efficiency improves.*

Keywords: Photovoltaic, Thermal, Efficiency, Air-Based, And Water-Based

REFERENCES

[1]. Adeli, M, et al. 2012. 'Experimental Performance Evaluation of a Photovoltaic Thermal (PV/T) Air Collector and Its Optimization'. Strojniški vestnik-Journal of Mechanical Engineering, 58: 309–318. DOI: https://doi.org/10.5545/sv-jme.2010.007

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

[3]. Akshayveer, et al. 2020. 'Effect of natural convection and thermal storage system on the electrical and thermal performance of a hybrid PV-T/PCM systems'. Materials Today: Proceedings. Elsevier. DOI: https://doi.org/10.1016/j.matpr.2020.08.010

[4]. Arslan, E, Aktaş, M and Can, ÖF. 2020. 'Experimental and numerical investigation of a novel photovoltaic thermal (PV/T) collector with the energy and exergy analysis'. Journal of Cleaner Production, 276: 123255. Elsevier Ltd. DOI: https://doi. org/10.1016/j.jclepro.2020.123255

[5]. Aste, N, et al. 2016. 'Performance monitoring and modeling of an uncovered photovoltaicthermal (PVT) water collector'. Solar Energy, 135: 551–568. Pergamon. DOI: https://doi. org/10.1016/j.solener.2016.06.029

[6]. Aste, N, del Pero, C and Leonforte, F. 2014. 'Water flat plate PV–thermal collectors: A review'. Solar Energy, 102: 98–115. Pergamon. DOI: https://doi. org/10.1016/j.solener.2014.01.025

[7]. Bhattarai, S, et al. 2012. 'Simulation and model validation of sheet and tube type photovoltaic thermal solar system and conventional solar collecting system in transient states'. Solar Energy Materials and Solar Cells, 103: 184–193. North-Holland. DOI: https://doi.org/10.1016/j.solmat.2012.04.017

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 3, Issue 2, March 2023
Impact Factor: 7.301

[8]. Choi, HU, et al. 2020. 'Experimental study on the performance of heat pump water heating system coupled with air type PV/T collector'. Applied ThermEngineering, 178: 115427. Elsevier Ltd. DOI: https:// doi.org/10.1016/j.applthermaleng.2020.115427

[9]. Das, D, et al. 2020. 'Performance investigation of a rectangular spiral flow PV/T collector with a novel form-stable composite material'. Applied Thermal Engineering. Pergamon. p. 116035. DOI: https://doi. org/10.1016/j.applthermaleng.2020.116035

[10]. Dean, J, et al. 2015. Photovoltaic-Thermal New Technology Demonstration, National Renewable Energy Laboratory. Available at: https://www.nrel.gov/docs/ fy15osti/63474.pdf (Accessed: 6 March 2019).

[11]. Diwania, S, et al. 2020. 'Photovoltaic–thermal (PV/T) technology: a comprehensive review on applications and its advancement'. International Journal of Energy and Environmental Engineering, 11(1): 33–54.

[12]. Berlin, Heidelberg: Springer. DOI: https:// doi.org/10.1007/s40095-019-00327-y El-Samie, MMA, et al. 2020. 'Three-dimensional numerical investigation of a hybrid low concentrated photovoltaic/thermal system'. Energy, 190: 116436. Elsevier Ltd. DOI: https://doi.org/10.1016/j. energy.2019.116436

[13]. Florschuetz, LW. 1979. 'Extension of the Hottel-Whillier model to the analysis of combined photovoltaic/thermal flat plate collectors'. Solar Energy, 22(4): 361–366. Pergamon. DOI: https://doi. org/10.1016/0038-092X(79)90190-7

[14]. Gaur, A, Ménézo, C and 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.Pergamon. DOI: https://doi. org/10.1016/j.renene.2017.01.062

[15]. Gholampour, M and Ameri, M. 2016. 'Energy and exergy analyses of Photovoltaic/Thermal flat transpired collectors: Experimental and theoretical study'. Applied Energy, 164: 837–856. Elsevier. DOI: https://doi. org/10.1016/j.apenergy.2015.12.042

[16]. Gude, VG. 2018. Renewable Energy Powered Desalination Handbook: Application and Thermodynamics, Renewable Energy Powered Desalination Handbook: Application and Thermodynamics. Elsevier Inc. DOI: https://doi.org/10.1016/C2017-0-02851-3

[17]. Hall, MR. 2010. Materials for energy efficiency and thermal comfort in buildings. CRC Press. Available at: https:// www.sciencedirect.com/book/9781845695262/ materials-for-energy-efficiency-and-thermal-comfort-in-buildings (Accessed: 14 March 2019). DOI: https://doi.org/10.1533/9781845699277

[18]. Hamdan, MA and Kardasi, KK. 2017. 'Improvement of Photovoltaic Panel Efficiency using Nanofluid'. Int. J. of Thermal & Environmental Engineering, 14(2): 143–151. He, Y, Xiao, L and Li, L. 2017. 'Research on the influence of PV cell to thermal characteristics of photovoltaic/thermal solar system'. International Journal of Energy Research, 41(9): 1287–1294. DOI: https:// doi.org/10.1002/er.3711

[19]. International Energy Agency. 2019. 'World Energy Balances 2019.' World Energy Balances Overview, pp. 1–23. Available at: https://iea.blob.core windows.net/assets/8bd626f1-a403-4b14-964ff8d0f61e0677/World_Energy_Balances_2019_ Overview.pdf.

[20]. IRENA. 2019. Future of Wind: Deployment, investment, technology, grid integration and socio-economic aspects, International Renewable Energy Agency (IRENA). Available at: https://www.irena.org/ documentdownloads/publications/re_technologies_cost_analysis-hydropower.pdf (Accessed: 23 September 2020).

[21]. Jarimi, H, et al. 2016. 'Bi-fluid photovoltaic/thermal (PV/T) solar collector: Experimental validation of a 2-D theoretical model'. Renewable Energy, 85: 1052–1067. Pergamon. DOI: https://doi. org/10.1016/j.renene.2015.07.014

[22]. Jha, P, Das, B and Gupta, R. 2019. 'An experimental study of a photovoltaic thermal air collector (PVTAC): A comparison of a flat and the wavy collector'. Applied Thermal Engineering, 163: 114344. Elsevier Ltd. DOI: https://doi.org/10.1016/j. applthermaleng.2019.114344

[23]. Jia, Y, Alva, G and Fang, G. 2019. 'Development and applications of photovoltaic–thermal systems: A review'. Renewable and Sustainable Energy Reviews, 102: 249–265. Pergamon. DOI: https://doi. org/10.1016/j.rser.2018.12.030 Kern, ECJ and Russell, MC. 1978. Hybrid photovoltaic/thermal solar energy system. DOI: https://doi.org/10.2172/7151726

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 3, Issue 2, March 2023
Impact Factor: 7.301

[24]. Kong, D, et al. 2020. 'Experimental study of solar photovoltaic/thermal (PV/T) air collector drying performance'. Solar Energy, 208: 978–989. Elsevier Ltd. DOI: https://doi.org/10.1016/j. solener.2020.08.067

[25]. Kong, R, et al. 2020. 'Performance and economic evaluation of a photovoltaic/thermal (PV/T)-cascade heat pump for combined cooling, heat and power in tropical climate area'. Journal of Energy Storage, 30. Elsevier Ltd. DOI: https://doi.org/10.1016/j. est.2020.101507

[26]. Koşan, M, et al. 2020. 'Performance analyses of sustainable PV/T assisted heat pump drying system'. Solar Energy, 199: 657–672. Elsevier Ltd. DOI: https:// doi.org/10.1016/j.solener.2020.02.040

[27]. Kubba, S. 2012. Handbook of Green Building Design, and Construction, Handbook of Green Building Design, and Construction. Elsevier Inc. DOI: https://doi. org/10.1016/C2009-0-64483-4

[28]. Lebbi, M, et al. 2020. 'Energy performance improvement of a new hybrid PV/T Bi-fluid system using active cooling and self-cleaning: Experimental study'. Applied Thermal Engineering. Pergamon, p. 116033. DOI: https://doi.org/10.1016/j. applthermaleng.2020.116033

[29]. Li, Z, et al. 2019. 'Experimental study and performance analysis on solar photovoltaic panel integrated with phase change material'. Energy, 178: 471–486. Elsevier Ltd. DOI: https://doi.org/10.1016/j. energy.2019.04.166

[30]. Ma, X, et al. 2020. 'Performance investigation of an iron scrap filled tube-plate PV/T system'. Energy for Sustainable Development, 58: 196–208. Elsevier B.V. DOI: https://doi.org/10.1016/j.esd.2020.08.002

[31]. Makki, A, Omer, S and Sabir, H. 2015. 'Advancements in hybrid photovoltaic systems for enhanced solar cells performance'. Renewable and Sustainable Energy Reviews, 41: 658–684. Pergamon. DOI: https://doi. org/10.1016/j.rser.2014.08.069

[32]. Misha, S, et al. 2019. 'Simulation CFD and experimental investigation of PVT water system under natural Malaysian weather conditions'. Energy Reports. Elsevier Ltd. DOI: https://doi.org/10.1016/j. egyr.2019.11.162

[33]. Olivier, J and Peters, J. 2018. Trends in global CO2 and total greenhouse gas emissions 2018 report. Available at: www.pbl.nl/en. (Accessed: 4 March 2019).

[34]. Othman, MY, et al. 2016. 'Performance analysis of PV/T Combi with water and air heating system: An experimental study'. Renewable Energy, 86: 716–722. Pergamon. DOI: https://doi. org/10.1016/j.renene.2015.08.061

[35]. Preet, S, Bhushan, B and Mahajan, T. 2017. 'Experimental investigation of water based photovoltaic/thermal (PV/T) system with and without phase change material (PCM)'. Solar Energy, 155: 1104–1120. Pergamon. DOI: https://doi. org/10.1016/j.solener.2017.07.040

[36]. Rejeb, O, et al. 2016. 'Numerical and model validation of uncovered nanofluid sheet and tube type photovoltaic thermal solar system'. Energy Conversion and Management, 110: 367–377. Elsevier Ltd. DOI: https://doi.org/10.1016/j. enconman.2015.11.063

[37]. Riaz, A, et al. 2020. 'A review on the application of photovoltaic thermal systems for building façades'. Building Services Engineering Research and Technology, 41(1): 86–107. SAGE Publications Ltd. DOI: https:// doi.org/10.1177/0143624419845117

[38]. Rubbi, F, et al. 2020. 'Performance optimization of a hybrid PV/T solar system using Soybean oil/MXene nanofluids as A new class of heat transfer fluids'. Solar Energy, 208: 124–138. Elsevier Ltd. DOI: https://doi.org/10.1016/j.solener.2020.07.060

[39]. Rukman, NSB, et al. 2019. 'Electrical and thermal efficiency of air-based photovoltaic thermal (PVT) systems: An overview'. Indonesian Journal of Electrical Engineering and Computer Science, 14(3): 1134–1140. DOI: https://doi.org/10.11591/ijeecs. v14.i3.pp1134-1140

[40]. Sainthiya, H and Beniwal, NS. 2019. 'Efficiency Enhancement of Photovoltaic/Thermal Module Using Front Surface Cooling Technique in Winter and Summer Seasons: An Experimental Investigation'. Journal of Energy Resources Technology, Transactions of the ASME, 141(9): 1–18. DOI: https://doi. org/10.1115/1.4043133

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 3, Issue 2, March 2023
Impact Factor: 7.301

[41]. Samylingam, L, et al. 2020. 'Thermal and energy performance improvement of hybrid PV/T system by using olein palm oil with MXene as a new class of heat transfer fluid'. Solar Energy Materials and Solar Cells, 218: 110754. Elsevier B.V. DOI: https://doi. org/10.1016/j.solmat.2020.110754

[42]. Sathe, TM and Dhoble, AS. 2017. 'A review on recent advancements in photovoltaic thermal techniques'. Renewable and Sustainable Energy Reviews, 76: 645–672. Pergamon. DOI: https://doi. org/10.1016/j.rser.2017.03.075

[43]. Shubbak, MH. 2019. 'Advances in solar photovoltaics: Technology review and patent trends'. Renewable and Sustainable Energy Reviews. Elsevier Ltd. p. 109383. DOI: https://doi.org/10.1016/j. rser.2019.109383

[44]. Shyam, et al. 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. Pergamon. DOI: https://doi. org/10.1016/j.solener.2016.05.013

[45]. Singh, DB and Tiwari, GN. 2017. 'Performance analysis of basin type solar stills integrated with N identical photovoltaic thermal (PVT) compound parabolic concentrator (CPC) collectors: A comparative study'. Solar Energy, 142: 144–158. Pergamon. DOI: https://doi.org/10.1016/j.solener.2016.11.047

[46]. Slimani, MEA, et al. 2017. 'A detailed thermal-electrical model of three photovoltaic/thermal (PV/T) hybrid air collectors and photovoltaic (PV) module: Comparative study under Algiers climatic conditions'. Energy Conversion and Management, 133: 458–476. Pergamon. DOI: https://doi. org/10.1016/j.enconman.2016.10.066

[47]. Su, D, et al. 2016. 'Dynamic performance analysis of photovoltaic–thermal solar collector with dual channels for different fluids'. Energy Conversion and Management, 120: 13–24. Pergamon. DOI: https://doi. org/10.1016/j.enconman.2016.04.095 Tiwari, S, et al. 2016. 'Thermal modelling of photovoltaic thermal (PVT) integrated greenhouse system for biogas heating'. Solar Energy, 136: 639–649. Pergamon. DOI: https://doi.org/10.1016/j.solener.2016.07.048

[48]. Tsai, HL. 2015. 'Modeling and validation of refrigerant-based PVT-assisted heat pump water heating (PVTA-HPWH) system'. Solar Energy, 122: 36–47. Elsevier Ltd. DOI: https://doi.org/10.1016/j. solener.2015.08.024 Zhou, J, Ma, X, et al. 2020. 'Numerical simulation and experimental validation of a micro-channel PV/T modules based direct-expansion solar heat pump system'. Renewable Energy, 145: 1992–2004. DOI: https://doi.org/10.1016/j.renene.2019.07.049

[49]. Zhou, J, Zhu, Z, et al. 2020. 'Theoretical and experimental study of a novel solar indirect-expansion heat pump system employing mini channel PV/T and thermal panels'. Renewable Energy, 151: 674–686. Elsevier Ltd. DOI: https://doi. org/10.1016/j.renene.2019.11.054

[50]. E. Cuce, T. Bali, S.A. Sekucoglu, Effects of passive cooling on performance of silicon photovoltaic cells. Int. J. Low Carbon Technol. 6(4), 299–308 (2011)

[51]. S.K. Natarajan, T.K. Mallick, M. Katz, S. Weingaertner, Numerical investigations of solar cell temperature for photovoltaic concentrator system with and without passive cooling arrangements. Int. J. Therm. Sci. 50(12), 2514–2521 (2011)

[52]. K. Araki, H. Uozumi, M. Yamaguchi, A simple passive cooling structure and its heat analysis for 500/spl times/concentrator PV module. In Conference Record of the Twenty-Ninth IEEE Photovoltaic Specialists Conference (IEEE, May 2002), pp. 1568–1571

[53]. J.K. Tonui, Y. Tripanagnostopoulos, Improved PV/T solar collectors with heat extraction by forced or natural air circulation. Renew. Energy 32(4), 623–637 (2007)

[54]. J.G. Ahn, J.H. Kim, J.T. Kim, A study on experimental performance of air-type PV/T collector with HRV. Energy Procedia 78, 3007–3012 (2015)

[55]. J. Hu, W. Chen, D. Yang, B. Zhao, H. Song, B. Ge, Energy performance of ETFE cushion roof integrated photovoltaic/thermal system on hot and cold days. Appl. Energy 173, 40–51 (2016)

[56]. E.D. Rounis, A.K. Athienitis, T. Stathopoulos, Multiple-inlet Building Integrated Photovoltaic/ Thermal system modelling under varying wind and temperature conditions. Sol. Energy 139, 157–170 (2016)

[57]. J.H. Kim, S.H. Park, J.T. Kim, Experimental performance of a photovoltaic-thermal air collector. Energy Procedia 48, 888–894 (2014)

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 3, Issue 2, March 2023
Impact Factor: 7.301

[58]. G. Ömeroğlu, CFD analysis and electrical efficiency improvement of a hybrid PV/T panel cooled by forced air circulation. Int. J. Photoenergy 2018(12), 1–11 (2018)

[59]. J.C. Mojumder, W.T. Chong, H.C. Ong, K.Y. Leong, An experimental investigation on performance analysis of air type photovoltaic thermal collector system integrated with cooling fins design. Energ. Buildings 130, 272–285 (2016)

[60]. S. Dubey, G.S. Sandhu, G.N. Tiwari, Analytical expression for electrical efficiency of PV/T hybrid air collector. Appl. Energy 86(5), 697–705 (2009)

[61]. G. Jin, H. Ruslan, S. Mat, M.Y. Othman, A. Zaharim, K. Sopian, Experiment study on singlepass photovoltaic-thermal (PV/T) air collector with absorber. In 9th WSEAS International Conference on System Science and Simulation in Engineering, ICOSSSE'10 (October 2010), pp. 435–438

[62]. S.M. Sultan, C.P. Tso, A thermal performance study for different glazed water based photovoltaic thermal collectors. In AIP Conference Proceedings, Vol. 2030, No. 1 (AIP Publishing, November 2018), p. 020307

[63]. L. Lu, X. Wang, S. Wang, X. Liu, Analysis of three different sheet-and-tube water-based flatplate PVT collectors. J. Energy Eng. 143(5), 04017022 (2017)

[64]. A.A. Alzaabi, N.K. Badawiyeh, H.O. Hantoush, A.K. Hamid, Electrical/thermal performance of hybrid PV/T system in Sharjah, UAE. Int. J. Smart Grid Clean Energy 3(4), 385–389 (2014)

[65]. I. Nardi, D. Ambrosini, T. de Rubeis, D. Paoletti, M. Muttillo, S. Sfarra, Energetic performance analysis of a commercial water-based photovoltaic thermal system (PV/T) under summer conditions. In Journal of Physics: Conference Series, Vol. 923, No. 1. (IOP Publishing, November 2017), p. 012040

[66]. R. Liang, J. Zhang, L. Ma, Y. Li, Performance evaluation of new type hybrid photovoltaic/ thermal solar collector by experimental study. Appl. Therm. Eng. 75, 487–492 (2015)

[67]. H. Jarimi, M.N.A. Bakar, N.A. Manaf, M. Othman, M. Din, Mathematical modelling of a finned bi-fluid type photovoltaic/thermal (PV/T) solar collector. In 2013 IEEE Conference on Clean Energy and Technology (CEAT) (IEEE, November 2013), pp. 163–168

[68]. D. Su, Y. Jia, X. Huang, G. Alva, Y. Tang, G. Fang, Dynamic performance analysis of photovoltaic–thermal solar collector with dual channels for different fluids. Energy Convers. Manag. 120, 13–24 (2016)

[69]. A. Tiwari, M.S. Sodha, Performance evaluation of hybrid PV/thermal water/air heating system: A parametric study. Renew. Energy 31(15), 2460–2474 (2006)

[70]. H. Jarimi, M.N.A. Bakar, M. Othman, M. Din, Bi-fluid photovoltaic/thermal PV/T solar collector with three modes of operation: Experimental validation of a theoretical model, in Mediterranean green buildings & renewable energy, (Springer, Cham, 2017), pp. 445–464

[71]. H.L. Tsai, Design and evaluation of a photovoltaic/thermal-assisted heat pump water heating system. Energies 7(5), 3319–3338 (2014)

[72]. J. Ji, H. He, T. Chow, G. Pei, W. He, K. Liu, Distributed dynamic modeling and experimental study of PV evaporator in a PV/T solar-assisted heat pump. Int. J. Heat Mass Transf. 52(5–6), 1365–1373 (2009)

[73]. X. Zhao, X. Zhang, S.B. Riffat, Y. Su, Theoretical study of the performance of a novel PV/e roof module for heat pump operation. Energy Convers. Manag. 52(1), 603–614 (2011)

[74]. M.A.M. Rosli, Y.J. Ping, S. Misha, M.Z. Akop, K. Sopian, S. Mat, A.N. Al-Shamani, M.A. Saruni, Simulation study of computational fluid dynamics on photovoltaic thermal water collector with different designs of absorber tube. J. Adv. Res. Fluid Mech. Therm. Sci. 52(1), 12–22 (2018)

[75]. K. Sopian, G.L. Jin, M.Y Othman, S.H. Zaidi, M.H. Ruslan, Advanced absorber design for photovoltaic thermal (PV/T) collectors. Recent Researches in Energy, Environment, and Landscape Architecture (2011)

[76]. M.M. Sardouei, H. Mortezapour, K.J. Naeimi, Temperature distribution and efficiency assessment of different PVT water collector designs. Sādhanā 43(6), 84 (2018)

[77]. N.A. Manaf, A. Bakar, M. Nazari, H. Jarimi, S. Muhamed, M. Othman, Design of a single-pass bi-fluid photovoltaic/thermal (PV/T) solar collector. Int. J. Chem. Environ. Eng. 4 (2013)

[78]. M.S. Hossain, A.K. Pandey, J. Selvaraj, N.A. Rahim, M.M. Islam, V.V. Tyagi, Two side serpentine flow based photovoltaic-thermal-phase change materials (PVT-PCM) system: Energy, exergy and economic analysis. Renew. Energy 136, 1320–1336 (2019)

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 3, Issue 2, March 2023
Impact Factor: 7.301

[79]. M.A.M. Rosli, S. Misha, K. Sopian, S. Mat, M.Y. Sulaiman, E. Salleh, Parametric analysis on heat removal factor for a flat plate solar collector of serpentine tube. World Appl. Sci. J. 29(2), 184–187 (2014)

[80]. A.H.M.A.D. Fudholi, A. Ibrahim, M.Y. Othman, M. Hafidz, Energy and exergy analyses on water based photovoltaic thermal (PVT) collector with spiral flow absorber. In 2nd International Conference on Energy Systems, Environment, Antalya, Turkey (October 2013), pp. 70–74

[81]. V.N. Palaskar, S.P. DESHMUKH, Study of oscillatory flow heat exchanger used in hybrid solar system fitted with fixed reflectors. Int. J. Ren. Energy Res. 4(4), 893–900 (2014)

[82]. A. Ibrahim, G.L. Jin, Hybrid Photovoltaic Thermal (PV/T) Air and Water Based Solar Collectors Suitable for Building Integrated Applications

[83]. Adnan Ibrahim, Goh Li Jin, Roonak Daghigh, Mohd Huzmin Mohamed Salleh, Mohd Yusof Othman, Mohd Hafidz Ruslan, Sohif Mat and Kamaruzzaman Sopian Solar Energy Research Institute, University Kebangsaan Malaysia, 43600, Bangi, Selangor, Malaysia. Am. J. Environ. Sci. 5(5), 618–624 (2009)

[84]. M.R. Karim, M.A.R. Akhanda, Study of a Hybrid Photovoltaic Thermal (PVT) Solar Systems Using Different Ribbed Surfaces Opposite to Absorber Plate (2011)

[85]. D.İ.L.Ş.A.D. Engin, M.U.S.T.A.F.A. Engin, Simulation modelling of a photovoltaic and thermal collector (PV/T) hybrid system. In 6th International Ege Energy Symposium and Exhibition (June 2012), pp. 28–30