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Experimental Analysis of Nano Additive Thermal Storage in Central Receiver Tube

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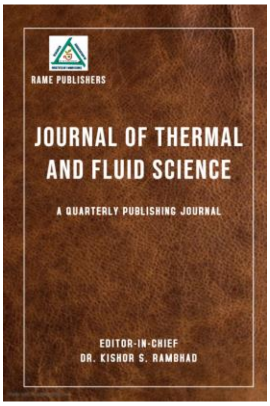

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Abstract: This project aims to investigate the efficiency of Nano additive thermal storage within central receiver tubes. This project works with the help of concentrated solar power on the central receiver tube. Nowadays the demand for the sustainable energy resource is increasing day by day. So, the technology of concentrated solar power system has emerged as the useful form of renewable energy generation. However, it is challenging to enhance the efficiency and the storage capabilities of concentrated solar power system. This study focuses on integrating Nano-additives into the thermal storage medium within central receiver tube to improve the efficiency of heat transfer and also the storage capacity. Nano-additive material such as Nanoparticles will be used in this project by incorporating it into the heat transfer fluid to understand its impact on thermal storage performance. In this project experimental analysis will be carried out considering thermal conductivity, heat capacity and stability of Nano additive thermal storage. Comparative studies will be conducted to assess the effectiveness of the Nano additives in enhancing heat transfer and storage capabilities compared to conventional thermal storage medium. In short, the experimental analysis of the Nano additive thermal storage in the central receiver tubes represent a significant step towards enhancing the performance and viability of concentrated solar power system.

Keywords: solar; Nano additives; thermal storage; central receiver tube; heat transfer; experimental analysis

1. Introduction

A parabolic trough is a type of solar thermal collector that is straight in one dimension a curved as a parabola in the other two dimensions which is lined with a polished metal finish [1]. The sunlight which enters the metal surface parallel to its plane of symmetry is focused along the focal line, where the central receiver tube is positioned so that it is intended to be heated. In this project a tube containing a fluid runs the length of the parabolic trough collector at its focal line [2]. The sunlight is concentrated on the tube with help of the parabolic trough collector and the fluid inside the tube is heated at high temperature with the help of the solar energy [3]. The hot fluid can be piped to a heat engine, which uses the heat energy to drive machinery or to generate electricity [4]. The parabolic trough collector is one of the most commonly used power generation system [5]. The field of solar thermal power energy has emerged as a promising avenue, offering the potential to harness the abundant and renewable power of the sun [5]. One critical aspect of enhancing the efficiency and viability of parabolic trough collector lies in optimizing their thermal storage system. Over recent years, the integration of nanotechnology has opened up exciting possibilities for revolutionizing thermal storage capabilities [6].

This experiment analysis aims to delve into the application of Nano additives within the central receiver tubes of parabolic trough collectors [7]. Nano additives with their unique properties stemming from the diminutive scale, offer the potential to significantly enhance thermal conductivity, heat capacity and the overall performance of the thermal storage medium [8]. The central receiver tube acting as a focal point of the solar concentration plays an important role in this setup [9]. This experimentation holds promise for not only improving energy capture and utilization but also for extending the operational capabilities of parabolic trough systems [10].

Through this experimentation and analysis, the study seeks to provide valuable insights into the thermal characteristics, stability and performance of Nano enhanced thermal storage system within central receiver tubes [11]. The findings generated from this research have the potential to inform the future advancements in solar thermal technology, to get the most efficient and sustainable energy solutions [12]. In short this research represents a significant step to get full potential of parabolic trough collectors by harnessing the transformative power of nanotechnology to optimize thermal storage capabilities [13].

2. Literature Review

Francis Agyenim(2009), Neil Hewitt(2009) paper named " A review of accoutrements , heat transfer and phase change problem expression for idle heat thermal energy storehouse systems(LHTESS) " This paper reviews the development of heat thermal energy storehouse systems studied detailing colorful phase change accoutrements (PCMs) delved over the last three decades, the heat transfer and improvement ways employed in PCMs to effectively charge and discharge idle heat energy and the expression of the phase change problem [14]. It also examines the figure and configurations of PCM holders and a series of numerical and experimental tests accepted to assess the goods of parameters similar as the bay temperature and the mass inflow rate of the heat transfer fluid (HTF) [15]. It's concluded that utmost of the phase change problems have been carried out at temperature suitable for domestic heating operations [16]. In terms of problem expression, the common approach has been the use of enthalpy expression. Heat transfer in the phase change problem was preliminarily formulated using pure conduction approach but the problem has moved to a different position of complexity with added convection in the melt being reckoned for[17]. The first study in this field was conducted in 2010 by Kasaein and Sokhansefat. They conducted a CFD Simulation to study the effect of Al2O3 in PTC at 1- 5 volume of Al2O3 [18]. They set up that the heat transfer measure enhances by nanomaterial volume bit increased by nanomaterial volume bit increase (roughly 14 improvement, at 5 Al2O3 volumetric attention). Accordingly, they concluded that adding temperature (from 300K to 500K) demolishes the effect of nanoparticle attention on enhancing heat transfer measure in constant inflow rate [19].

Mohammad Zadeh proposed an optimized model coupled with CFD analysis through which they delved the effect of using Al2O3/ synthetic oil painting (with 0 –6.5 vol. Attention) as working fluid on the thermal improvement of PTC. They showed that using the proposed model, the maximum convection heat transfer measure of nanofluid could be enhanced by 36 at 300K [20]. Also, they showed that adding the temperature (from 300 K to 500 K) decreases the heat transfer measure. Eventually, they proposed optimum nanofluid attention is6.5 vol., for their studied range. In Reference, they used Al2O3/ synthetic oil painting nanofluid as working fluid with the volume bit of over to 8 to probe the improvement of convection heat transfer measure as well as thermal effectiveness [21]. The results showed at 8 volume attention 76 and7.6 increase can be attained for convection heat transfer and maximum thermal effectiveness, independently. Also the heat transfer measure at 6 and 4 volume attention increased by 54 and 35, independently. A significant increase in pressure drop is also reported by the authors, as the volume attention is reached beyond 4 vol., which in turn emphasized the necessity of further pumping power. This pressure drop increases up to roughly 40 at 4 vol. of Al2O3 in a nanofluid. The effect of temperature increase was on the favor of pressure drop as it causes lower pressure drop along the tube with temperature adding. Still, this effect demolishes the effect of nanofluid in adding thermal effectiveness and heat transfer measure. In reference the maximum heat transfer measure and thermal effectiveness improvement of 38 and 15 were set up at 6 volume attention of CuO in CuO/ syltherm 800 nanofluid. Analogous to them reported an increase of in pressure drop. Fresh simulations were conducted in Reference on Al2O3/ water nanofluid to minimize entropy generation and find optimum Reynolds number for different volume fragments of Al2O3 located at different sections of a indirect tube. They showed that at a given Reynolds number the performance of heat transfer (Nusselt number) and the value for disunion factor is nearly the same anyhow of the volume bit. Also, it was proven that there.

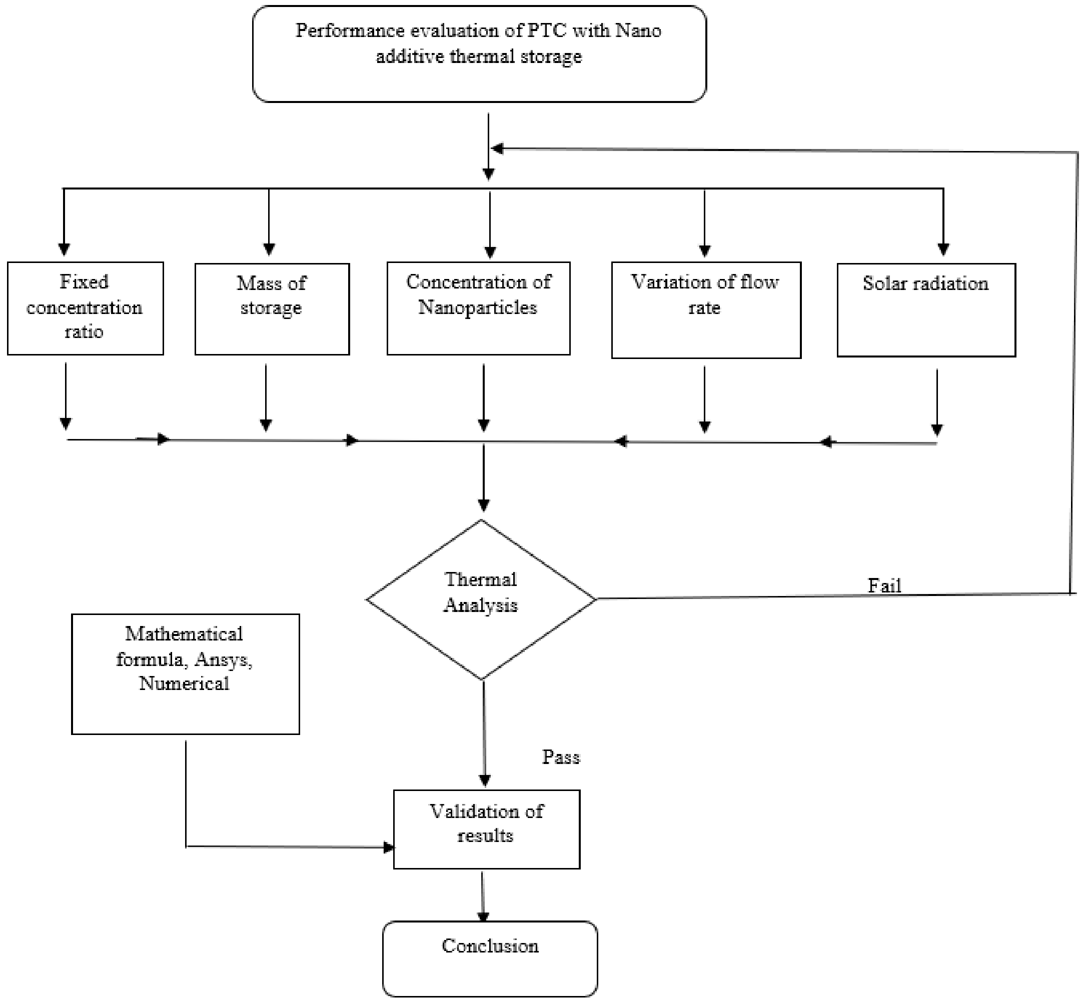
Recent research efforts have been focused on analyzing and optimizing the performance of PTC systems with central receiver tubes. Smith et al. (2020) undertook a thorough investigation into the efficiency of such systems within solar power plants. Their study aimed at achieving higher thermal efficiencies while also optimizing critical system parameters such as the materials used for receiver tubes and the mechanisms employed for tracking the sun. Their findings emphasized the potential for significant improvements in overall system efficiency through the adoption of novel receiver tube materials and advanced tracking systems.

Furthermore, studies have explored the selection and utilization of heat transfer fluids in PTC systems. Johnson et al. (2019) conducted a comparative analysis of various heat transfer fluids utilized in conjunction with central receiver tubes. Their research underscored the importance of selecting the most suitable fluid to ensure maximum thermal efficiency and minimal heat losses within the system. Additionally, Patel et al. (2018) investigated the integration of thermal energy storage with PTC systems, recognizing the pivotal role of storage mediums such as phase change materials and sensible heat storage in enhancing system flexibility and reliability.

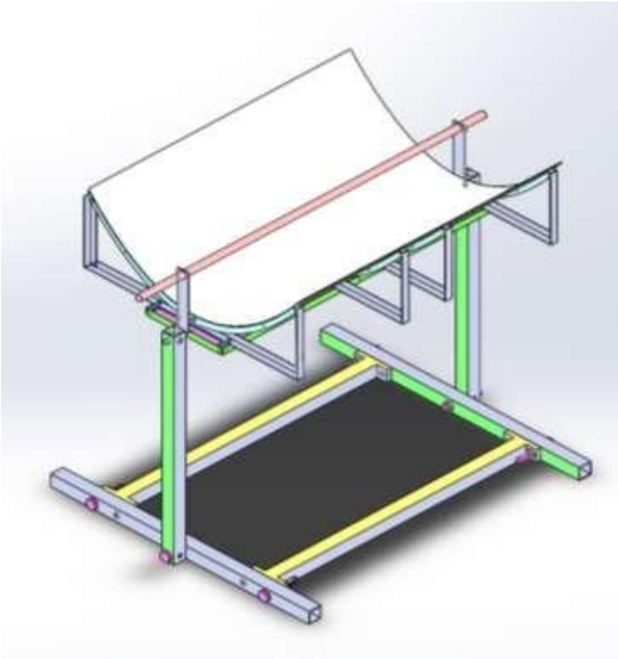
Another area of focus has been the enhancement of optical design and tracking mechanisms in PTC systems. Lee et al. (2022) directed their efforts towards improving the optical characteristics and tracking precision of these systems to optimize solar concentration and energy capture. Their study explored advanced mirror coatings and sophisticated tracking algorithms, revealing promising avenues for increasing reflectivity and refining sunlight focusing capabilities. It was observed that advancements in tracking systems could significantly augment overall system performance, particularly under varying solar conditions.

Moreover, economic and environmental considerations have been central to recent research endeavors in the field of PTC technology. Wang et al. (2020) conducted a comprehensive life cycle assessment (LCA) to evaluate the environmental impacts associated with PTC systems featuring central receiver tubes. Their findings underscored the importance of integrating sustainability considerations into the design and operation of CSP systems. In a similar vein, Martinez et al. (2019) performed an economic analysis to assess the cost-effectiveness of PTC technology, particularly concerning its applicability in industrial settings. Their study provided valuable insights into the leveled cost of energy (LCOE) and identified potential strategies for cost optimization.

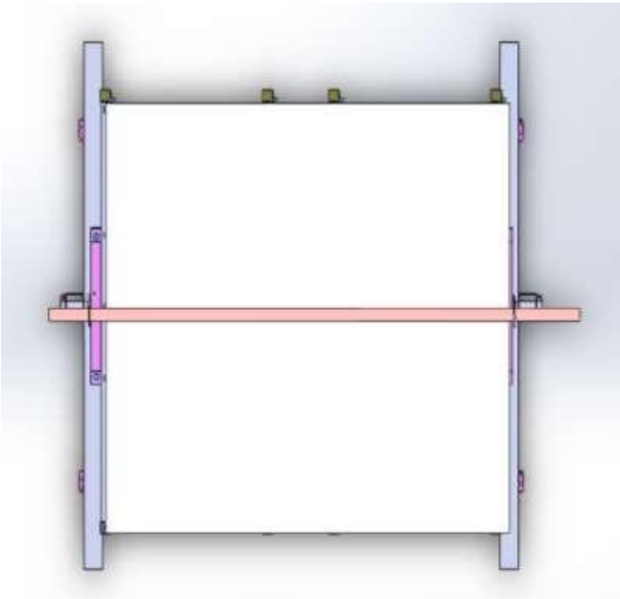
3. Methodology



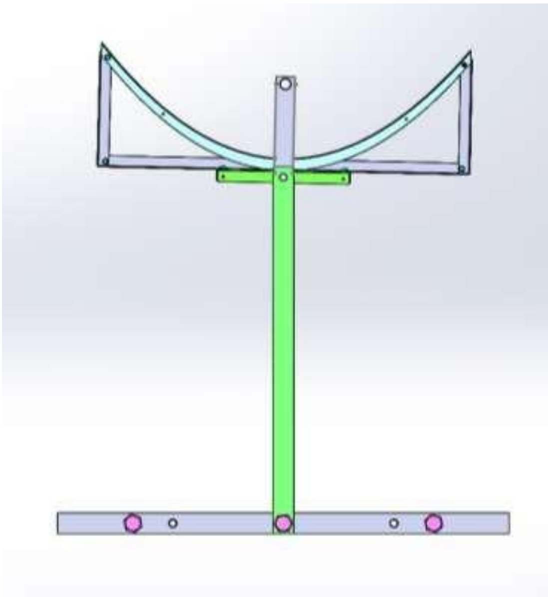
4. Cad Model



Front View



Top View



Side View

Figure 1. CAD Model of the setup in front, top and side view

5. Experimental Setup

Figure 2. Experimental Setup of Parabolic Trough Collector

Figure 3. Experimental Setup of Parabolic Trough Collector

6. Results

Observation **Table 1**: Temperature Readings without using Titanium Dioxide in PCM

Time	Radiation	Inlet water	Wax	Glass tube	Outlet water	Aluminium tube	Ambient
10:00	585	26	37	45	26	46	32
10:15	600	27	37	46	27	46	32
10:30	630	27	38	46	27	47	32
10:45	750	27	38	47	28	47	33
11:00	790	28	38	48	28	47	33
11:15	810	28	39	50	29	48	33
11:30	828	29	39	50	29	48	34
11:45	848	29	40	51	30	49	34
12:00	855	29	41	52	30	51	34
12:15	858	30	41	52	30	51	34
12:30	860	30	43	54	31	53	34
12:45	868	30	43	54	31	53	35
13:00	874	30	44	55	31	53	36
13:15	870	30	45	55	32	53	36
13:30	864	31	45	53	32	52	36
13:45	854	31	44	53	32	50	34
14:00	850	31	44	52	33	50	34
14:15	855	31	43	50	34	49	34
14:30	852	30	43	50	35	49	35
14:45	853	30	43	50	35	49	35
15:00	855	31	43	49	37	48	34
15:15	848	30	43	49	38	47	33
15:30	845	30	42	48	39	47	33

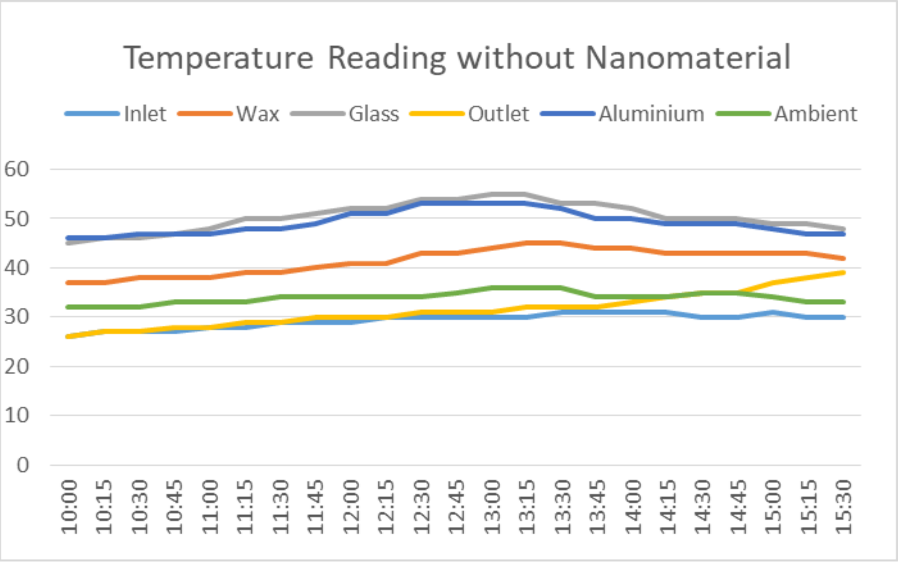


Figure 4. Graph of Temperature Reading without using Nanomaterial

Observation **Table 2:** Temperature Readings using Titanium Dioxide in PCM

Time	Radiation	Inlet water	Wax	Glass tube	Outlet water	Aluminium tube	Ambient
10:00	610	26	37	45	26	46	32
10:15	630	26	37	45	26	46	32
10:30	635	27	38	46	27	47	32
10:45	750	27	39	46	27	47	33
11:00	794	27	41	47	29	48	33
11:15	815	27	42	48	29	48	33
11:30	834	28	43	49	31	49	33
11:45	854	28	45	49	32	50	34
12:00	856	28	47	50	32	50	34
12:15	860	28	49	52	33	51	34
12:30	874	29	51	53	34	52	35
12:45	875	29	51	54	34	52	36
13:00	880	29	50	54	35	53	36
13:15	871	30	50	55	36	53	36
13:30	868	30	50	54	36	52	36
13:45	866	30	49	54	38	51	35
14:00	852	31	49	53	38	50	34
14:15	850	32	48	52	39	50	34
14:30	853	32	47	51	39	49	35
14:45	854	31	47	50	41	49	34
15:00	851	30	47	50	43	48	33
15:15	849	30	46	50	43	48	33
15:30	846	30	46	49	44	47	33

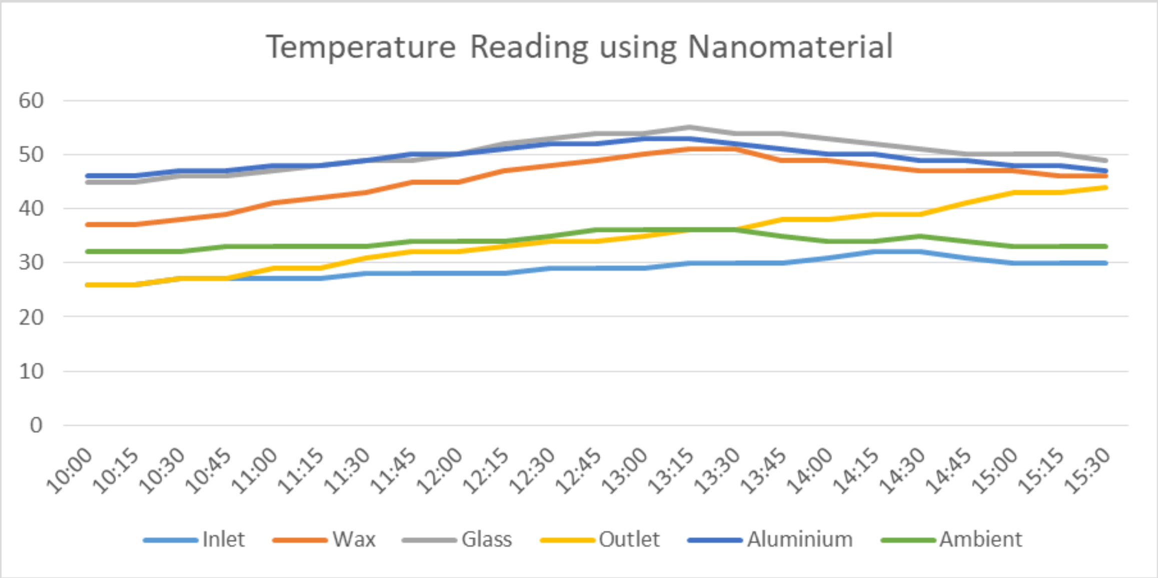


Figure 5. Graph of Temperature Reading by using Nanomaterial

7. Conclusion

In conclusion, the literature reflects a dynamic landscape of research and development in parabolic trough collectors (PTCs) with central receiver tubes, showcasing advancements, challenges, and promising avenues for future exploration. Studies have underscored the importance of optimizing system parameters such as receiver tube materials, heat transfer fluids, and tracking mechanisms to enhance overall efficiency and performance. Furthermore, efforts to integrate thermal energy storage and improve optical design have emerged as key strategies for maximizing the potential of PTC systems. Economic and environmental considerations have also played a significant role, with analyses highlighting the importance of sustainability and cost-effectiveness in the deployment of PTC technology. Life cycle assessments and economic analyses have provided valuable insights into the environmental impacts and economic viability of PTC systems, informing decision-making processes and guiding future research directions. Looking ahead, continued innovation and interdisciplinary collaboration will be essential in driving further advancements in PTC technology. Areas of focus may include the exploration of novel materials and coatings, the integration of PTCs with complementary renewable energy technologies, and the development of advanced control and optimization strategies. By addressing these challenges and capitalizing on emerging opportunities, PTCs with central receiver tubes hold immense promise as a clean and sustainable energy solution, contributing to the global transition towards a low-carbon future.

In summation, the culmination of research and analysis into parabolic trough collectors (PTCs) featuring central receiver tubes presents a tapestry of advancements, challenges, and future trajectories that underscore their pivotal role in the landscape of renewable energy technologies. The multifaceted investigations conducted in recent years have illuminated various facets of these systems, revealing pathways towards enhanced efficiency, improved sustainability, and broader applicability across diverse contexts.

The iterative refinement of PTC systems has been a focal point, with researchers diligently exploring avenues to optimize critical components and operational parameters. Studies have delved into the intricacies of receiver tube materials, heat transfer fluids, and tracking mechanisms, seeking to extract maximal energy yield while minimizing thermal losses and operational inefficiencies. By scrutinizing these elements, researchers have unlocked insights that promise to elevate the performance and reliability of PTC systems, thereby bolstering their attractiveness as a viable renewable energy solution. In tandem with performance optimization, the integration of thermal energy storage has emerged as a strategic imperative in enhancing the versatility and dispatch ability of PTC systems. The ability to store excess thermal energy for later use not only facilitates smoother energy delivery but also enables PTC installations to better align with fluctuating demand patterns and grid requirements. Through innovative storage mediums and system configurations, researchers have charted a course towards greater operational flexibility and resilience, positioning PTCs as integral components of future energy landscapes.

Economic viability and environmental sustainability have remained steadfast considerations throughout this journey of exploration and innovation. Rigorous life cycle assessments and economic analyses have provided critical insights into the true costs and benefits of PTC deployment, informing decision-making processes and guiding resource allocation. By accounting for environmental externalities and assessing long-term economic implications, stakeholders are better equipped to navigate the complexities of energy transition and investment, ensuring that PTCs contribute meaningfully to both environmental stewardship and economic prosperity. As we peer into the horizon of possibilities, it becomes increasingly evident that the journey of PTCs with central receiver tubes is far from reaching its denouement. Rather, it represents an ongoing narrative of discovery, collaboration, and adaptation, wherein each chapter unveils new challenges and opportunities. The road ahead beckons with promises of further innovation, from the exploration of novel materials and coatings to the integration of advanced control systems and the convergence with complementary renewable energy technologies. In this grand tapestry of renewable energy innovation, PTCs with central receiver tubes occupy a prominent and enduring position, offering a beacon of hope amidst the imperatives of climate change and sustainable development. Their journey is intertwined with ours, a testament to human ingenuity and determination to harness the boundless potential of the sun. As we embark on this collective voyage towards a cleaner, greener future, let us embrace the lessons learned and the challenges ahead, knowing that the promise of PTCs shines brightly on the horizon of possibility.

References

[1] Choi, S.; Gray, M.L.; Jones, C.W. Amine-Tethered Solid Adsorbents Coupling High Adsorption Capacity and Regenerability for CO_2 Capture from Ambient Air. ChemSusChem **2011**, 4, 628–635.
[2] Earth's CO_2 Home Page. 2019. Available online: https://www.co2.earth/ Jan23 (accessed on 29 December 2018).
[3] Owusu, P.A.; Asumadu-Sarkodie, S. A review of renewable energy sources, sustainability issues and climate change mitigation. Cogent Eng. **2016**, 3, 1167990.
[4] Lewis, N.S.; Nocera, D.G. Powering the planet: Chemical challenges in solar energy utilization. Proc. Natl. Acad. Sci. USA **2006**, 103, 15729–15735.
[5] Dupeyrat, P.; Ménézo, C.; Fortuin, S. Study of the thermal and electrical performances of PVT solar hot water system. Energy Build. **2014**, 68, 751–755.
[6] Chen, M.; He, Y.; Zhu, J.; Wen, D. Investigating the collector efficiency of silver nanofluids based direct absorption solar collectors. Appl.Energ. **2016**, 181, 65–74
[7] Kalogirou, S.A.; Karellas, S.; Braimakis, K.; Stanciu, C.; Badescu, V. Exergy analysis of solar thermal collectors and processes. Prog. Energy Combust. Sci. **2016**, 56, 106–137Minardi, J.E.; Chuang, H.N. Performance of a "black" liquid flat-plate solar collector. Sol. Energy **1975**, 17, 179–183.
[8] Choi, S.U.; Eastman, J.A. Enhancing Thermal Conductivity of Fluids with Nanoparticles; Argonne National Lab.: Cass Avenue, IL, USA, 1995.
[9] Sokhansefat, T.; Kasaeian, A.; Kowsary, F. Heat transfer enhancement in parabolic trough collector tube using Al2O3/synthetic oil nanofluid. Renew. Sustain. Energy Rev. **2014**, 33, 636–644.
[10] Wang, X.-Q.; Mujumdar, A.S. Heat transfer characteristics of nanofluids: A review. Int. J. Thermal Sci. **2007**, 46, 1–19.
[11] Hordy, N.; Rabilloud, D.; Meunier, J.L.; Coulombe, S. High temperature and long-term stability of carbon nanotube nanofluids for direct absorption solar thermal collectors. Sol. Energy. **2014**, 105, 82–90. Kalogirou, S.A. Solar thermal collectors and applications. Prog. Energy Comb]
[12] Newman, M.D. Flat plate solar collector. U. S. patent 5,653,222, 5 August 1997.
[13] Qiu, S.; Ruth, M.; Ghosh, S. Evacuated tube collectors: A notable driver behind the solar water heater industry in China. Renew. Sustain. Energy Rev. 2015, 47, 580–588.
[14] VP Kalbande, G Fating, M Mohan, K Rambhad, AK Sinha, Experimental and theoretical study for suitability of hybrid nano enhanced phase change material for thermal energy storage applications, Journal of Energy Storage 51, 104431.
[15] VP Kalbande, PV Walke, K Rambhad, Performance of oil-based thermal storage system with parabolic trough solar collector using Al2O3 and soybean oil nanofluid, , International Journal of Energy Research
[16] VP Kalbande, PV Walke, K Rambhad, M Mohan, A Sharma, Performance enhancement of thermal energy storage systems using nanofluid, Energy Storage Systems: Optimization and Applications, 135-149
[17] K Rambhad, J Dane, V Joshi, S Kulkarni, R Ghodke, Simulation and Optimization of Silica Gel and Molecular Sieve Desiccant Wheel for Air Dehumidification Journal of Thermal Engineering and Technology 5 (1), 11-27.
[18] Performance of Solar Collector for Thermal Storage System Using Nanofluids: A Review, VP Kalbande, KS Rambhad, PV Walke, International Journal of Analytical, Experimental and Finite Element Analysis 2 (1), 6-11
[19] V Khond, SM Kondawar, KS Rambhad, Development and investigation of thermal composite insulation from environmentally hazardous waste fly ash, Materials Today: Proceedings
[20] R Jibhakate, N Nirwan, Y Nandanwar, KS Rambhad, Thermal analysis of hybrid nanofluid flowing inside the automobile radiator, Materials Today: Proceedings
[21] K. S. Rambhad, Himanshu Sharma, Anurag Singh Choudhary Solar Thermal Energy In India- A Review, , International Journal for Science and Advance Research In Technology