ASES SOLAR 2017
Building a 100% Renewable Energy Community
46th Annual National Solar Conference
AMERICAN SOLAR ENERGY SOCIETY | DENVER October 9-12

Conference Proceedings

ASES National Solar
Conference 2017

Denver, Colorado 9-12 October 2017

Analysis of Solar Updraft Tower Using Compost Waste Heat and Transpired Solar Collectors

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Abstract

This paper explores the use of ways to enhance the convection heat transfer processes in Solar Updraft Towers (SUT) by using compost waste heat and transpired solar collectors (TSC) in unison. Previous work has shown the using compost waste heat harvesting enhances the natural convection set-up with a SUT. The current paper presents results for using the SUT with roof and walls constructed from TSC materials which lead to enhance temperature difference in the SUT and thus leading to increased turbine velocity speed and ultimately increased SUT system power output.

Keywords: *SUT, TSC, Solar Energy, Renewable Energy, Convective Heat Transfer*

1. Introduction

The concept of Solar Updraft Tower (SUT) has been around for decades. The concept of the SUT is shown in Figure 1, whereby a greenhouse constructed on the ground supports a solar chimney.

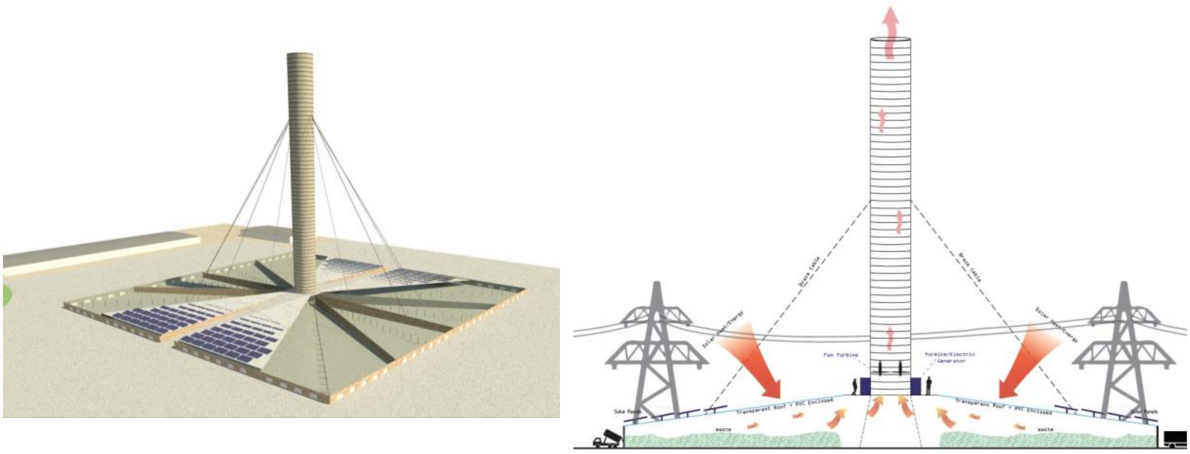

Fig. 1: SUT Configuration (cf. Anderson et al. 2016a)

Figure 1 shows the SUT building, which is typically fabricated from plastic or corrugated type of roofing material. The floors of the SUT building can be used as real estate to house green houses, thus providing sustainable food resources to a community. Turbines located at the base on the chimney are used to produce electricity via the natural convection updraft set up by the solar chimney which causes a wind velocity on the order of 4 m/s to spin the turbine blades. The validity of using SUT is an on-going concept of renewable energy research as evidenced by the recent review of SUT technologies by Zhou et al. (2016). The recent work of Ohya et al. (2016) presents results of numerical heat transfer analysis and experiment results of a SUT using divergent cylindrical wall construction. The validity of using compost waste heat harvesting to enhance SUT power output has been recently outlined (Anderson et al. 2016a, 2016b, 2016c).In our research, the floor plan of the SUT building is used for composting. The additional heat release from the composting is directed to the solar chimney in order to enhance the natural convection set-up by the solar irradiation incident on the walls and roof of the SUT.

The concept of transpired solar collectors pioneered Kutscher et al. (1993) has become a viable candidate for building energy heating as evidenced by the recent work of Croitoru et al. (2016) and Tajdaran et al. (2016). Figure 2 shows the operation of a TSC system used to supply hot air to the HVAC system of a building.

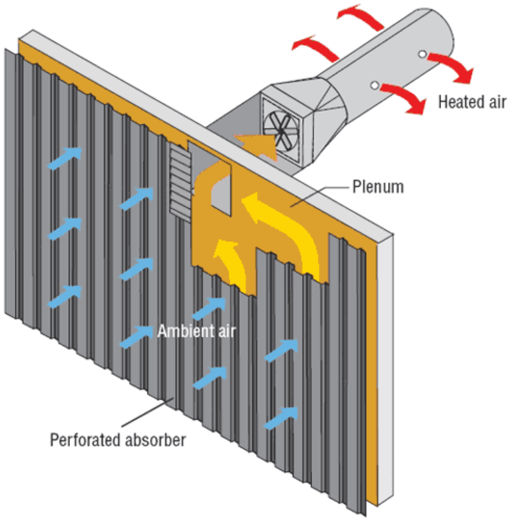

Fig. 2: TSC Configuration (cf. http://solarairheating.org/media/transpired-collector.gif)

The heat transfer characteristics of a functional engineering prototype TSC system is detailed in the work of Ereyner and Akhan (2016). The current paper examines the use of TSC in SUT construction to assess the impact of each technology on the overall temperature difference on the SUT system. From Ereyner (2017), the TSC can afford heat transfer coefficients on the order of 15 W/m^2-K corresponding to horizontal radiation of 600 W/m^2. Typical TSC systems are used to harness hot air and route it to ductwork systems. In our current proposed research, the hot air from the TSC is to be mixed with the air in the SUT, thus serving to enhance the natural convection of the overall system. The concept proposed in the current paper is to construct a SUT using TSC walls and roofs. The TSC walls and roofs will allow heated air into the SUT. The SUT is also to be augmented with compost waste heat removal. Thus the hybrid renewable, sustainable energy system being proposed will be comprised of an SUT fabricated from TSC walls and roofs and using composting as latent heat energy storage and removal. To the author's knowledge this synergy of the three technologies of SUT, TSC and compost waste heat has not yet been addressed in the literature.

2. Heat Transfer and Power Generation Analysis

Based upon experience (Anderson et al. 2016a, 2016b, 2016c) with SUT heat transfer and guided by the CFD analysis of Anderson et al. (2015), the following estimates of the temperature drop (ΔT) and average system heat transfer coefficient (HTC) shown in Table 1 for the following configurations i) SUT baseline (no composting, no TSC), ii) SUT with composting (no TSC) and iii) SUT with composting and TSC have been compiled

Tab. 1: Temperature Differential ΔT and HTC Summary

Configuration		ΔT (K)	Avg. HTC (W/m^2-K)
i)	SUT Baseline	20	7.5
ii)	SUT with Composting	30	10
iii)	SUT with Composting and TSC Construction	35	15

Using the data of Table 1, and the theory of Schlaich et al. (2005), power profiles were generated per Equation (1)

$$P = c_p \rho K A \sqrt{2gh \frac{\Delta T}{T_o}} \Delta T \qquad \text{(eq. 1)}$$

where P = power, K is flow coefficient, h is tower height, c_p denotes air heat capacity, ρ is air density, T_o is reference inlet state temperature, and ΔT is temperature delta set up in SUT. Figure 3 shows the expected trends for i) SUT baseline, ii) SUT with composting, and iii) SUT with composting and TSC.

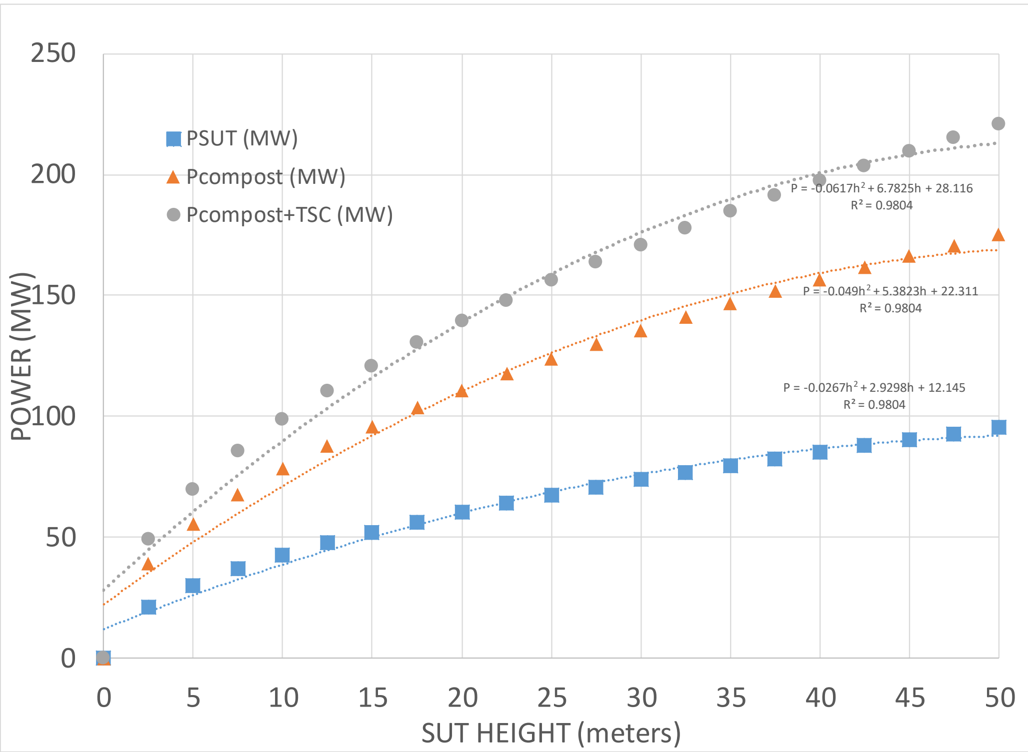

Fig. 3: Power vs. Height of SUT

Figure 3 shows that the power of the SUT system is a function of the height of the chimney. For a moderate power of 100 MW and a diameter of 30 m the chimney must be 10 m, a configuration typical for a housing commune's centralized plant. For larger power demands the tower height can be increased pursuant to limits on structural engineering. Using this example of 10 m, it is seen from Figure 3 that the power for i) SUT baseline, ii) SUT with composting, and iii) SUT with composting and TSC is 40 MW, 75, MW, and 100 MW, respectively. Thus, the use of composting and TSC affords an factor of 2.5 increase in power with respect to the baseline. Thus, the use of TSC is viable for enhancement of the SUT concept.

3. Conclusions

This paper has presented the results of a feasibility study of implementing TSC walls in a SUT using compost waste heat recovery. The background of SUT and TSC have been presented Typical temperature differential and heat transfer coefficients for SUT/TSC systems have been summarized. This paper has presented a very elementary analysis of the SUT/TSC/Composting system. Results indicate the by using TSC walls in SUT construction with composting waste heat harversting, the power output for SUT can be increased up to an order of 2.5, depending on the height of the tower. Future work would entail detailed Numerical heat transfer modeling, and the construction of an engineering prototype such to demonstrate the overall feasibility of the current proposal.

4. Acknowledgments

This research was funded by: COMPO ENERGY INC.
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