Heat Generated using Luminescent Solar Concentrators for Building Energy Applications

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Supplementary Information

Determining the dye absorption spectra

The absorption for the clear, green, yellow, orange, and red panels was determined using measurements of the total transmission and reflection as well as the specular transmission. These measurements were taken using a UV-Vis Spectrometer (Shimadzu UV-2600). The total transmission and reflection spectra, which includes both the specular and diffuse components, were measured using an integrating sphere, and the incident angle for the diffuse reflectance spectra was 4°. The absorption spectra for each panel is determined using the equation $A = 1 – T_t – R_t$, where T_t and R_t are the total transmission and reflection, respectively. For the clear panel, T_t and R_t are given by the UV-Vis measurements taken with the integrating sphere. However, for the LSC panels, the T_t and R_t spectral include the emission losses from the LSC. That is, for the measurements for the LSC panels taken using the integrating sphere, T_t and R_t can be broken down into three components as given in the equations below:

$$T_t = T_d + T_s + E$$

$$R_t = R_d + R_s + E$$

Where T_d, R_d, T_s, and R_s are the diffuse transmission and reflection, and specular transmission and reflection, respectively. Further, E is the photons emitted from the dye that escaped the LSC and were detected during the UV-Vis measurements. For the diffuse transmittance measurements, E represents the emitted photons that exited the LSC from the surface opposite to the surface the light was incident onto. For the diffuse reflectance measurements, E represents the emitted photons that exited the LSC from the surface that the light was incident onto during the UV-Vis measurements. Thus, for the LSCs the absorption spectra were determined using the equation below:

$$A_{LSC} = 1 – T_t – R_t + 2E$$

The value of E was estimated by subtracting the specular transmittance from the diffuse transmittance. The LSCs have flat surfaces and exhibit minimal light scattering, and the majority of the diffuse component measured during the transmittance measurements are comprised of photons that were emitted from the dye, rather than incident light that was scattered while passing through the LSC. To take into account the small portion of the light that is scattered while passing through the LSC, the diffuse reflectance from the clear panel was also subtracted from the diffuse reflectance in the estimate of *E*. The final equation used to estimate *E* is then given as:

$$E = T_t - T_s - T_{tc}$$

Where T_{tc} is the total transmittance spectra measured for the clear acrylic panel using the integrating sphere accessory.

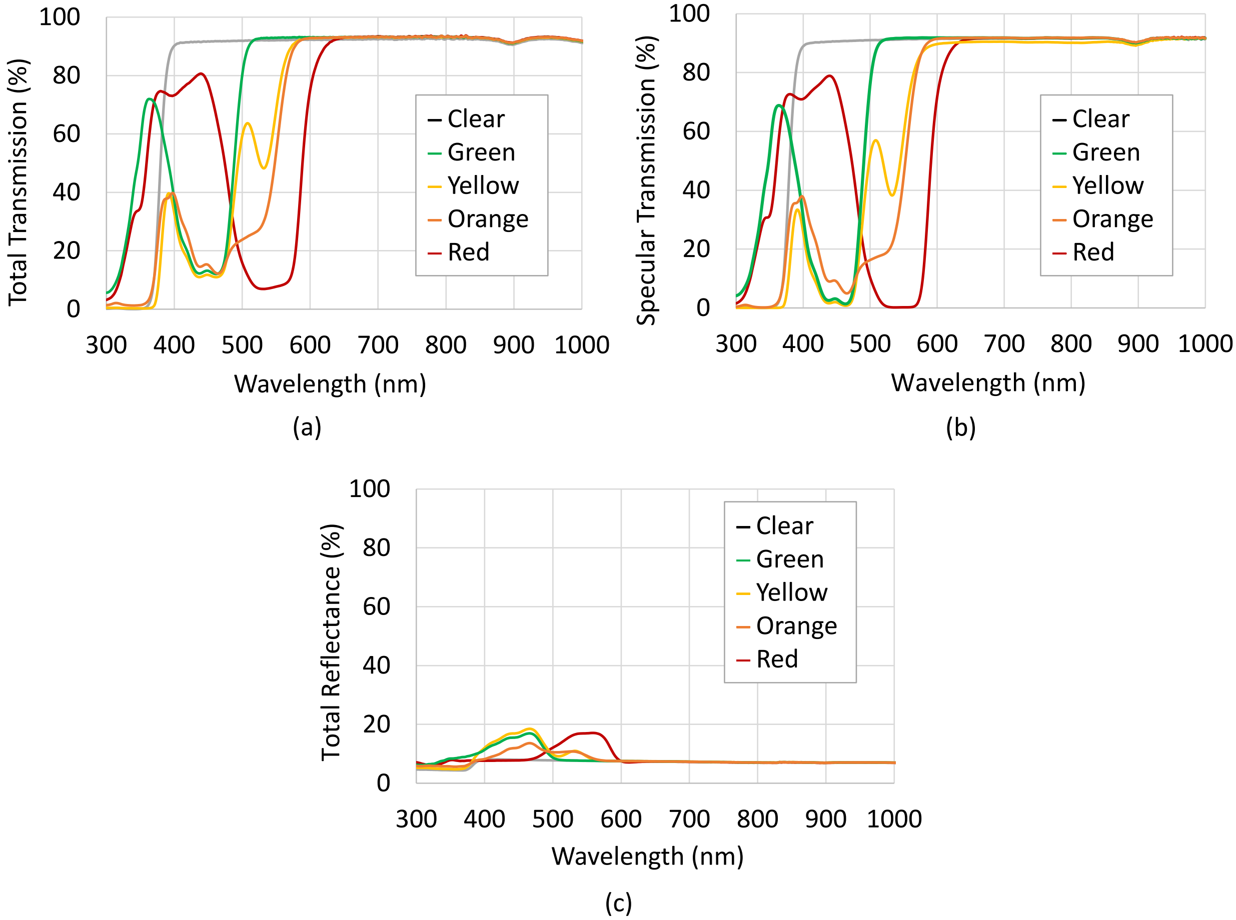

Figure S1: (a) Total transmission, including the specular and diffuse components, (b) specular transmission, and (c) total reflectance, including specular and diffuse components, for the LSCs investigated in this work.

Light spectra for the 1000 W Sunmaster FullNova MH lamps

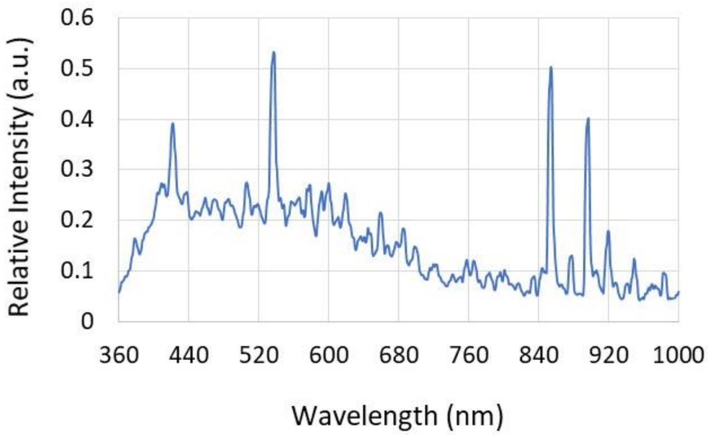

Figure S2: Relative intensity spectra for the 1000 W Sunmaster FullNova MH lamps

Estimate of the annual thermal energy generation from LSC modules

To estimate the amount of thermal energy that could be generated by an LSC module annually, we first estimated the amount of solar irradiance that would provide the same amount of incident light that the solar simulator (i.e. the two 1000 W Sunmaster FullNova MH lamps) provided over the spectral region absorbed by the dye during the experiments.

During the experiments, the average incident intensity over the spectral region between 360 and 1000 nm was 23.95 mW/cm^2. The absorption spectra of the dyes within the LSCs are within this spectral region. Given that 72% of the AM1.5 solar irradiance is in the spectral region between 360 nm and 1000 nm,[1] if the solar irradiance were to provide 23.95 mW/cm^2 of radiant energy within the region between 360 and 1000 nm, then the total solar irradiance would be 33 mW/cm^2, or 330 W/m^2.

The average power generated at thermocouple positions one, two, and three for the red LSC is 4.48 W. The area of this panel is 0.25 m^2, and 17.9 W/m^2 is used in the estimate. It is estimated that the dye in the red panel enabled (17.9 W/m^2)/(330 W/m^2) = 5.4% of the solar irradiance to generate thermal energy within the aluminum frame. Assuming* a mean daily insolation of 5 kWh/m^2 (or a mean daily insolation of 3 kWh/m^2 for a vertical surface) the dye in the red LSC would produce 99 kWh/m^2 (or 59.4 kWh/m^2 for the vertical surface) annually.

* The annual average global horizontal solar insolation depends on location and climate and ranges from ~ 3 kWh/m^2 – 6.5 kWh/m^2 for between the equator and locations at a latitude of 50°. See, for example: NREL, Solar Resource Data, Tools and Maps. Available online: https://www.nrel.gov/gis/solar.html (accessed on 09-10-2020)

[1] NREL, N.R.E.L. 2015. Reference Solar Spectral Irradiance: Air Mass 1.5. Available online: https://www.nrel.gov/grid/solar-resource/spectra.html (accessed on 26-08-2020)