Supplementary Materials

A. Detail description of the flow dynamics model

The mathematical governing equations used in the CFD model to predict the flow of the Solar updraft tower (SUT) are shown below. These equations are based on a two-dimensional (2D) cylindrical coordinate system [1].

1. Continuity equation

$$\frac{\partial}{\partial t}(\rho) + \frac{1}{r}\frac{\partial}{\partial r}(r\rho u) + \frac{\partial}{\partial z}(\rho w) = 0$$

2. Momentum equations

$$\frac{\partial}{\partial t}(\rho u) + \frac{1}{r}\frac{\partial}{\partial r}(r\rho uu) + \frac{\partial}{\partial z}(\rho uw) = -\frac{dp}{dr} + \frac{1}{r}\frac{\partial}{\partial r}(\mu\, r\frac{\partial}{\partial r}(u)) + \frac{\partial}{\partial z}(\mu\,\frac{\partial}{\partial z}(u)) - 2\mu\frac{u}{r^2}$$

$$\frac{\partial}{\partial t}(\rho w) + \frac{1}{r}\frac{\partial}{\partial r}(r\rho uw) + \frac{\partial}{\partial z}(\rho Vw) = -\frac{dp}{dz} + \frac{1}{r}\frac{\partial}{\partial r}(\mu\, r\frac{\partial}{\partial r}(w)) + \frac{\partial}{\partial z}(\mu\,\frac{\partial}{\partial z}(w)) - (\rho_0 - \rho)$$

3. Energy equation

$$\frac{\partial}{\partial t}(\rho T) + \frac{1}{r}\frac{\partial}{\partial r}(r\rho uT) + \frac{\partial}{\partial z}(\rho VT) = \frac{1}{r}\frac{\partial}{\partial r}(r\frac{\lambda}{C_p}\frac{\partial}{\partial r}(T)) + \frac{\partial}{\partial z}(\frac{\lambda}{C_p}\frac{\partial}{\partial z}(T))$$

4. Standard k-ε model

In standard k-ε model, the turbulent kinetic energy k and its dissipation rate ε are calculated using the following transport equation.

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}[(\mu + \frac{\mu_t}{\sigma_k})\frac{\partial k}{\partial x_j}] + G_k + G_b - \rho\varepsilon - Y_M + S_k \quad \ldots\ldots\ldots\ldots (1)$$

$$\frac{\partial}{\partial t}(\rho\varepsilon) + \frac{\partial}{\partial x_i}(\rho\varepsilon u_i) = \frac{\partial}{\partial x_j}[(\mu + \frac{\mu_t}{\sigma_\varepsilon}) + \frac{\partial\varepsilon}{\partial x_j}] + C_{1\varepsilon}\frac{\varepsilon}{k}(G_k + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} + S_\varepsilon \quad \ldots\ldots\ldots\ldots (2)$$

In equation (1) and (2), where G_k is the generation of turbulence kinetic energy due to the mean velocity gradients, G_b is the generation of turbulence kinetic energy due to buoyancy, Y_M is the contribution of the fluctuating dilatation in compressible turbulence to the overall dissipation rate.

The turbulent (or eddy) viscosity, μ_t, is computed by combining k and ε as follows:

$$\mu_t = \rho C_\mu \frac{k^2}{\varepsilon}$$

The model constants $C_{1\varepsilon}$, $C_{2\varepsilon}$, C_μ, σ_k, σ_ε are given as follows:

Constant	$C_{1\varepsilon}$	$C_{2\varepsilon}$	C_μ	σ_k	σ_ε
Value	1.44	1.92	0.09	1	1.3

B. Validation of CFD model

The grid independence test was performed with three different grid densities (Grid #1: 62,880, Grid #2: 123,720, and Grid #3: 200,720) (Figure S1). The difference of outlet mass flow rates between Grid #2 and Grid #3 is 0.06%, while the difference between Grid #1 and Grid #2 is 0.24%. Therefore, the grid density of Grid #2 was used in all cases to save the computational power.

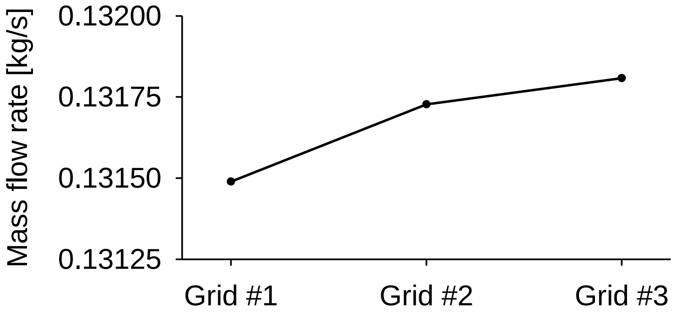

Figure S1. Grid independence test.

The temperature and mass flow rate, which are important parameters for analysis were monitored during the calculating iterations (Figure S2). After the 10,000th iteration, the mass flow rate in the outlet was stable (Figure S2a). The average temperature in the SUT chimney inlet also was monitored. The stabilization of temperature was occurred after the 10,000th iteration (Figure S2b). In this study, the analysis was conducted using the computational result after 30,000 iterations.

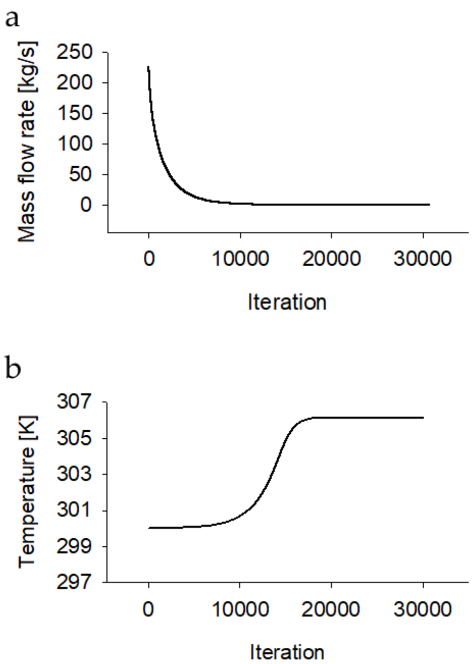

Figure S2. Monitoring the stabilization of temperature and mass flow rate during the iterative calculation.

The validation was performed comparing the temperature profile on the SUT absorber between the CFD results and experimental results (Figure S3) [2]. In both the CFD results and experimental results, the gradual increase of temperature was observed as it approached the center axis. The maximum difference of 3.2% was measured near the SUT inlet (at 0.25 m in the ground radius). This error implies that our CFD model is useful enough to predict the physical phenomena inside the SUT.

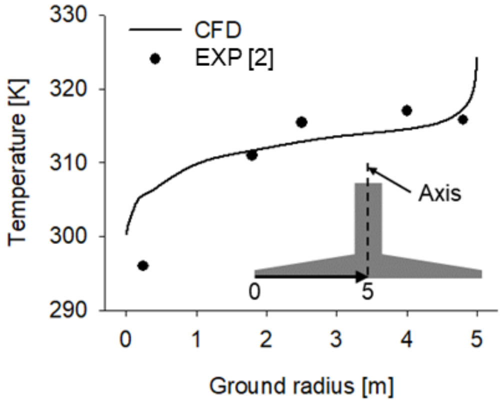

Figure S3. Comparison of the temperature profiles between the CFD results and experiment results [2].

C. Solar updraft tower efficiency

The following graph shows the efficiency trend. Note that the efficiency is boldly calculated based on the ratio of the kinetic power to the heat generation of the absorber.

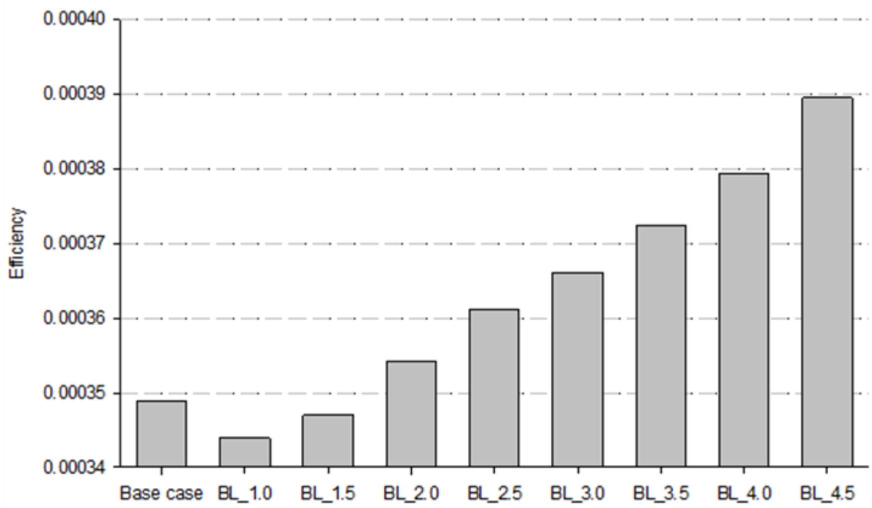

Figure S4. The efficiency of each model.

Reference

1. ANSYS Fluent 19.0 Theory Guide.
2. Nia, E.S.; Ghazikhani, M. Numerical investigation on heat transfer characteristics amelioration of a solar chimney power plant through passive flow control approach. *Energy Conversion and Management* **2015**, *105*, 588–595.