Surface Energy Balance Modelling for Industrial Areas

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Abstract

An Urban Heat Island (UHI) describes the phenomena where an urban area has a higher temperature than the surrounding rural areas. Energy from the Sun is stored on various surfaces on Earth, raising temperatures which contributes to the formation of an UHI. UHIs can bring about negative impacts such as increasing energy usage and reducing the quality of life. Many heat reducing strategies have been employed to mitigate these adverse effects. In order to study the phenomena of UHI, the energy balance between the Sun and the surface of the Earth must be understood. Through the Surface Energy Balance System (SEBS), remote sensing data is used to determine the energy balance for an area of land. However, it does not take into account the finer details, such as differentiating the roads, roofs and buildings since they have different thermal properties. Hence, this study will aim to determine the relationship between solar irradiance and surface temperature of different materials. In addition, the effectiveness of UHI management is explored.

Introduction

The Surface Energy Balance System (SEBS) is given as such [2]:

$$R_n = G + H + LE$$

R_n = Net Radiation
G = Ground Heat Flux (Energy stored in objects)
H = Sensible Heat Flux (Energy carried away by wind)
LE = Latent Heat Flux (Energy due to evapotranspiration)

In this study, H and LE terms are minimised, simulating an extreme day with minimal wind and evapotranspiration.

Objectives

1. To explore the relationship between solar irradiance and surface temperature of different materials

2. To determine the effectiveness of UHI reduction strategies by comparing a location which employs such strategies with another location that does not

Experimental Method

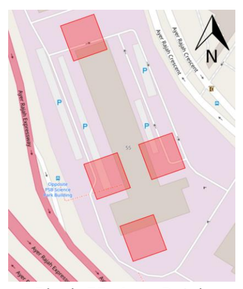
- Two locations: Ayer Rajah Industrial Estate and CleanTech Park. A pyranometer to measure solar irradiance and an air temperature & humidity sensor were deployed on the roof.

- Solar irradiance, air temperature and humidity data taken every 10 seconds

Pyranometer

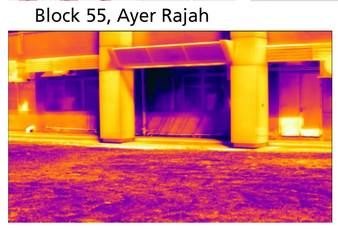
Air Temperature & Humidity Sensor

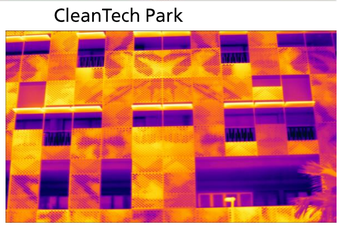
- Thermal images of various surfaces were taken every 20 minutes using a thermal imager. Locations are demarcated in red as seen below:



Block 55, Ayer Rajah

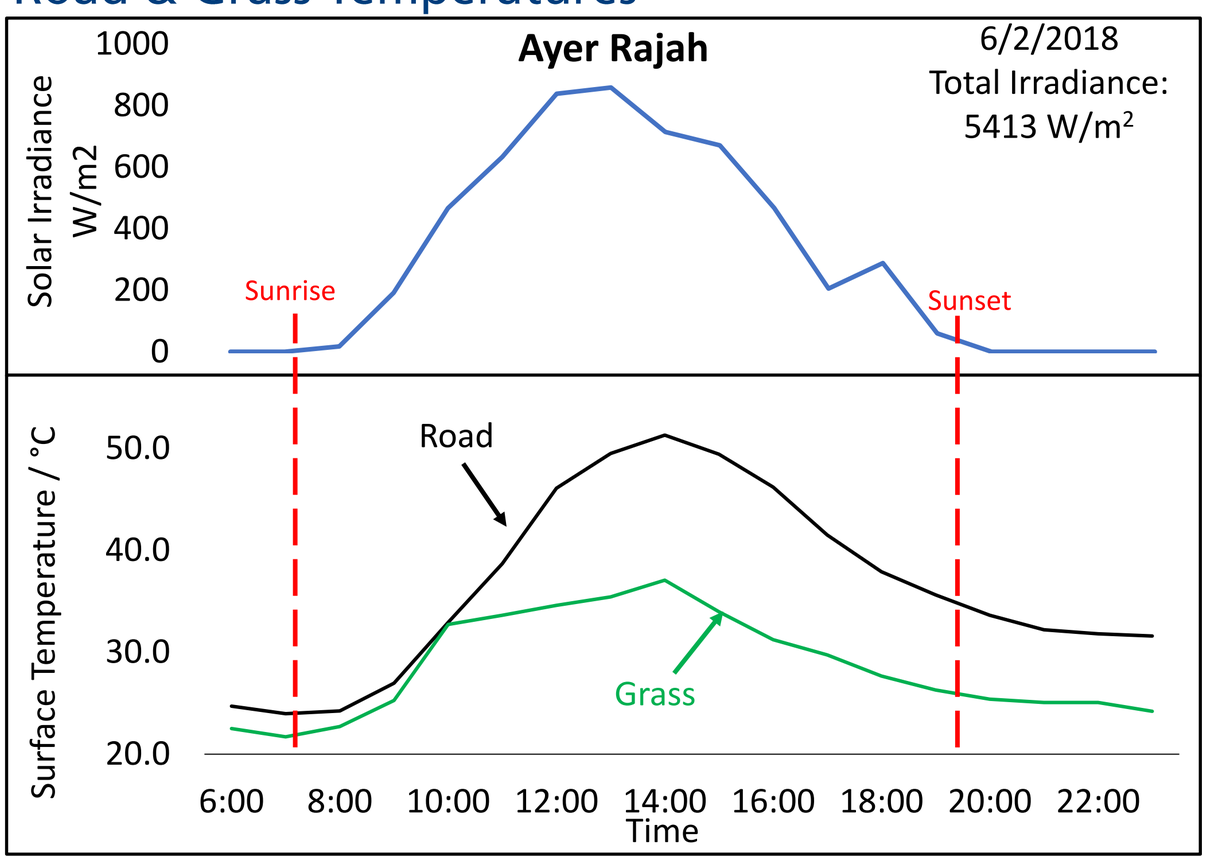
CleanTech Park

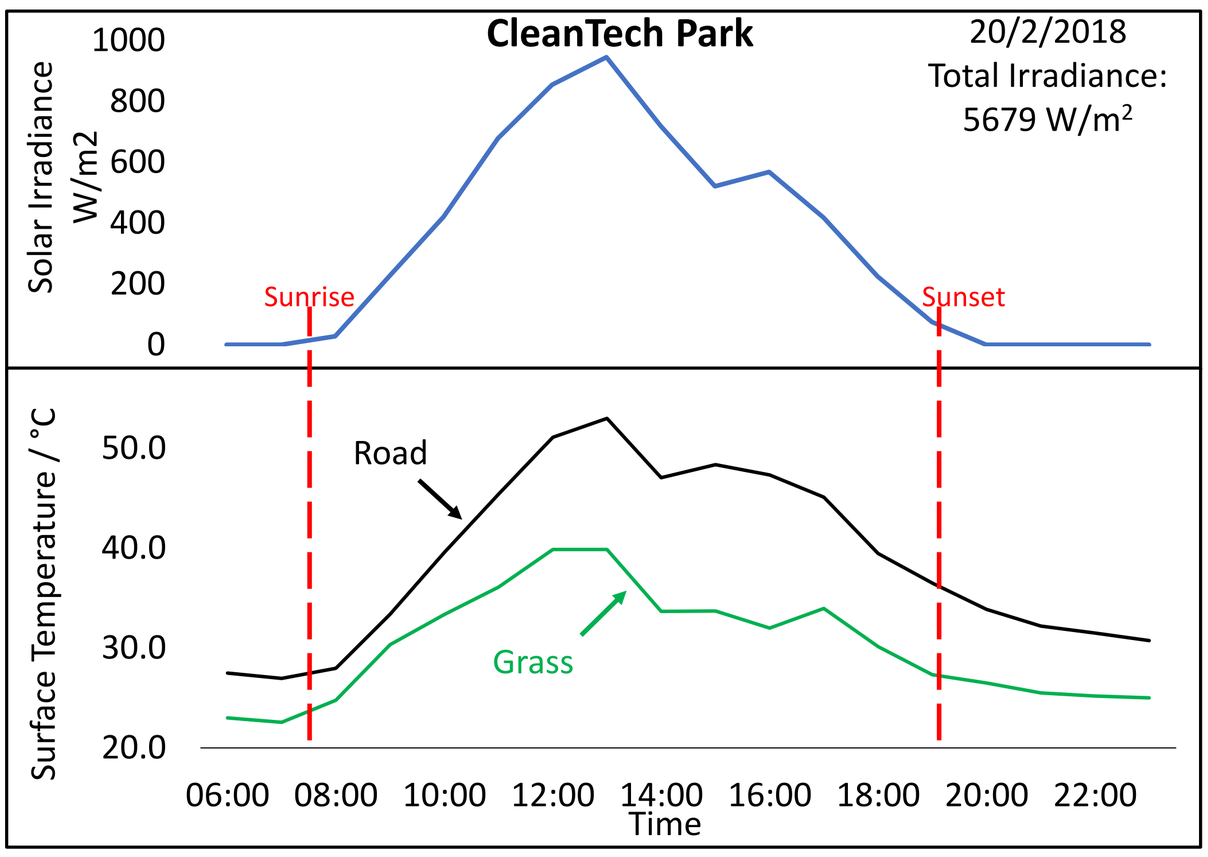




Examples of thermal images obtained

Road & Grass Temperatures

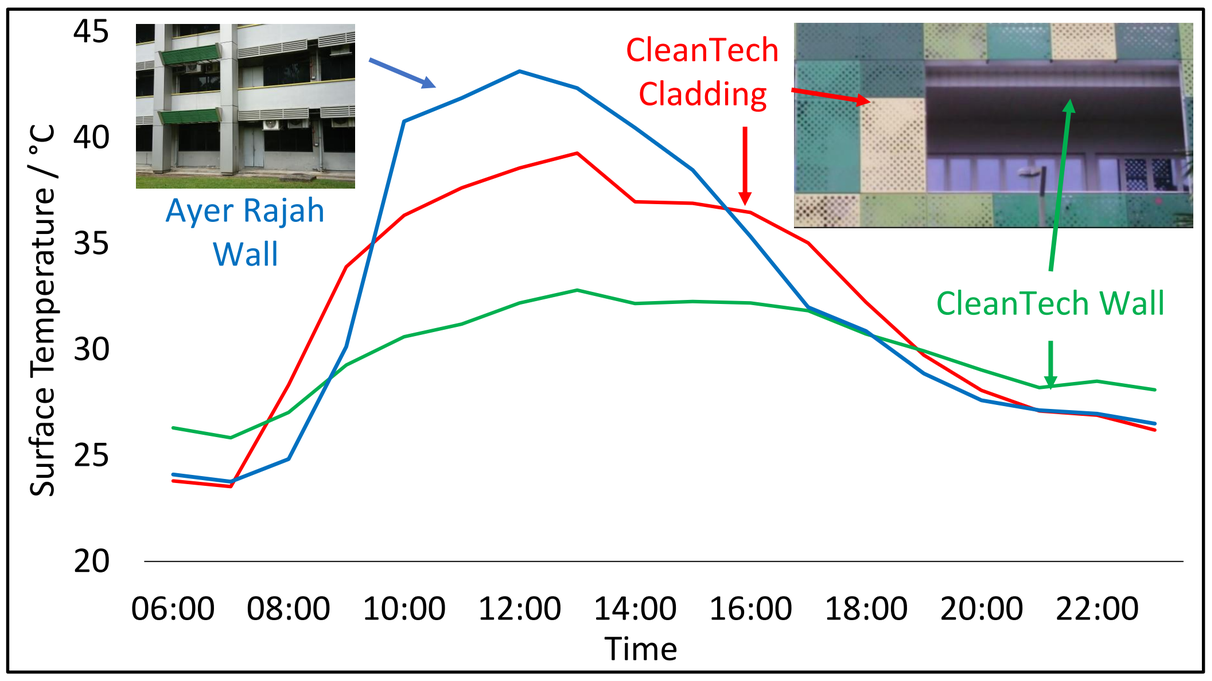




- Correlation between solar irradiance and surface temperatures. The greater the solar irradiance, the more energy is stored in the materials

- However, the road and grass have different temperatures due to different albedos or solar reflectivity. Roads having a lower albedo is able to absorb more heat when compared to grass.

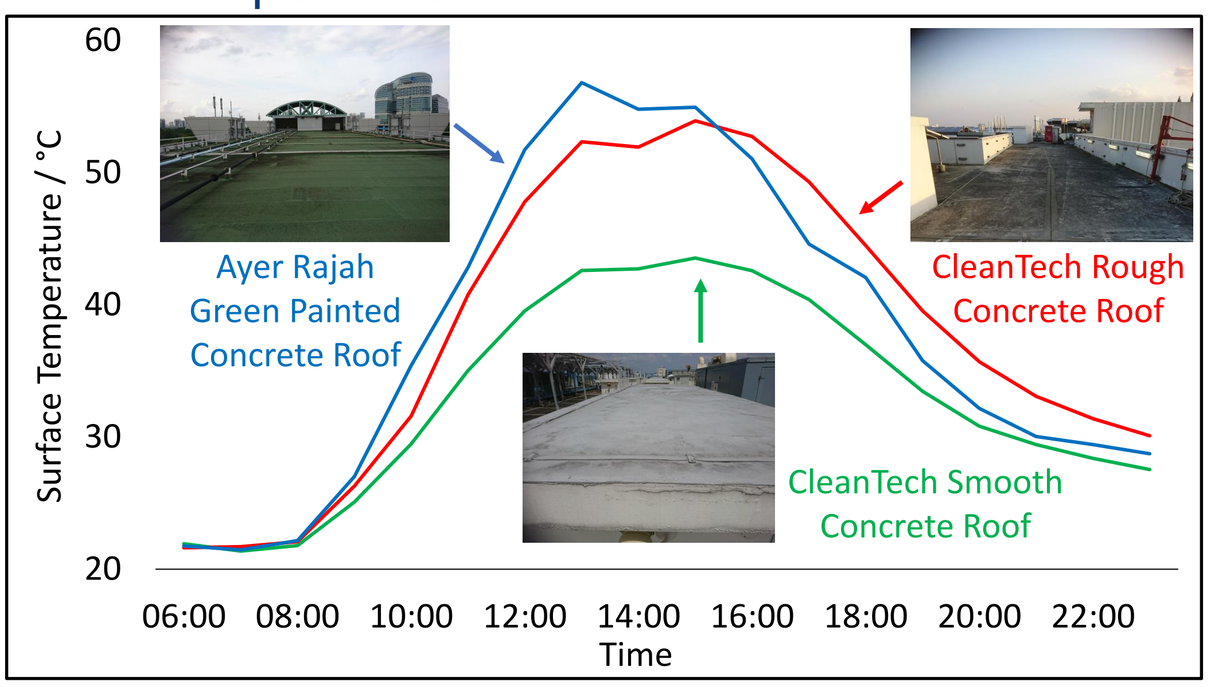
Wall Temperature



- The wall cladding absorbs more energy from the Sun as it shields the actual wall surface, preventing the wall temperature from rising as much as itself. On average, the temperature difference is 6°C

- The shielded wall has a lower temperature than the bare wall

Roof Temperature



- A smooth surface having a higher albedo at 0.6 than a rough surface, reflects more solar radiation than a rough surface with albedo value 0.35.

- On average, the temperature difference is 9°C

Conclusions

- The surface temperature of a material depends on solar irradiance as well as its albedo.

- Urban heat island management utilized at Cleantech Park is effective in reducing temperatures as compared to typical industrial buildings of old industrial estates like Ayer Rajah Industrial Estate. By reducing the surface temperatures by up to 12°C on the building facade, solar heat gain by the building is decreased drastically in the day. The energy usage in cooling down the building is also reduced. This equates to savings on energy bills for the building owner or the tenants.

References

[1] U.S. Environmental Protection Agency. 2008. Reducing urban heat islands: Compendium of strategies
[2] Su, Z. 2006. Estimation of the Surface Energy Balance. Encyclopedia of Hydrological Sciences

Acknowledgements

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