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THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Experimental Investigation of a Photonic Radiative Cooler under Sub-tropical Climate

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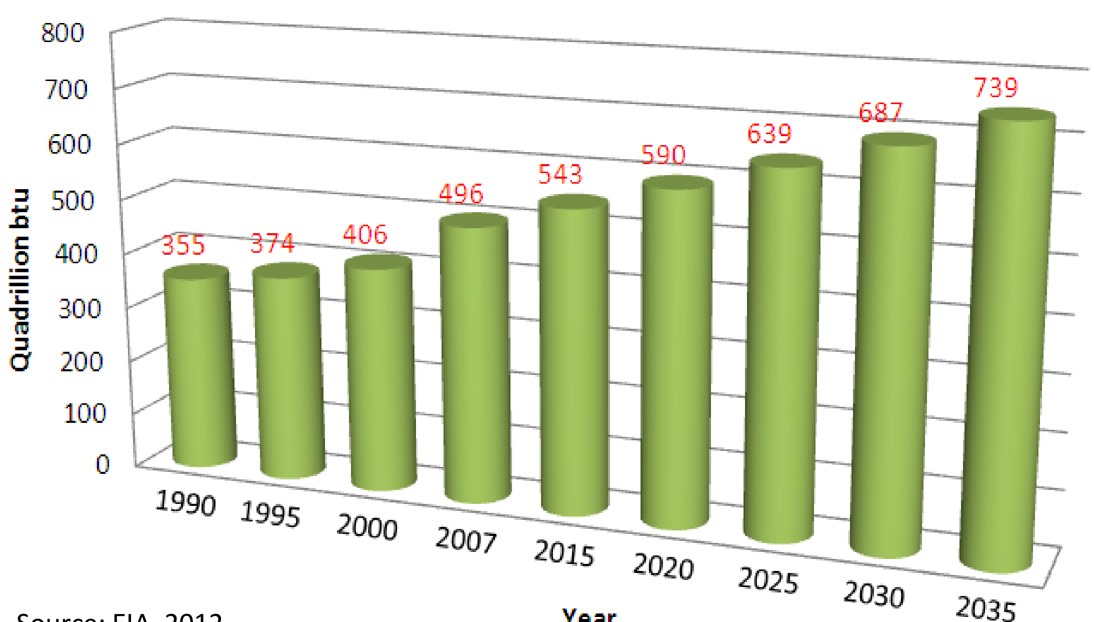
Introduction

Current Status of Global Energy Usage

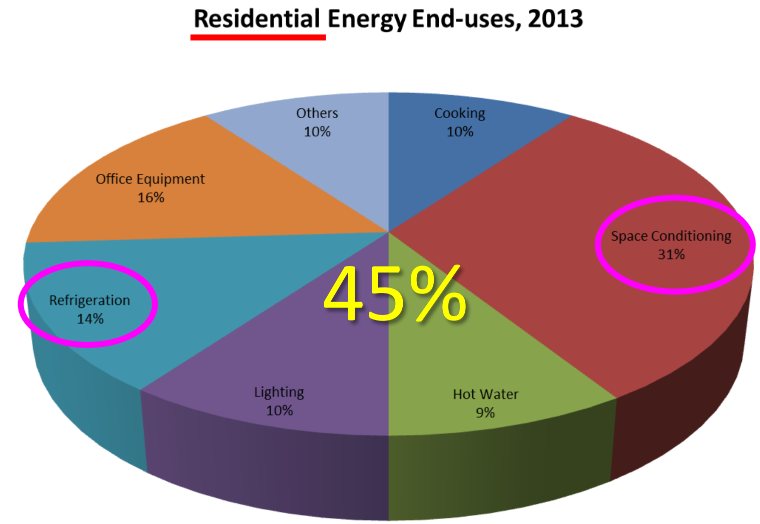
- High Energy Consumption → Worldwide Problem
  - Total Worldwide primary energy consumption
    - 355EJ in 1990
    - 406EJ in 2000
    - 590EJ in 2020
    - 687EJ in 2030

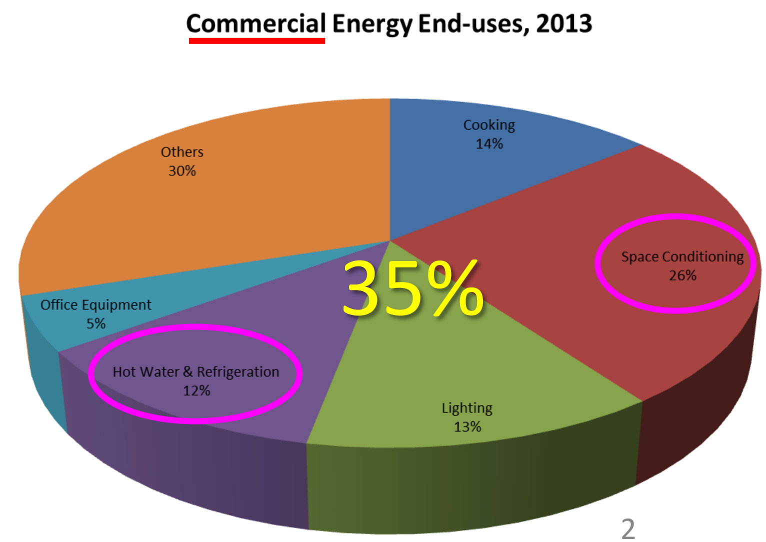
World Marketed Energy Consumption, 1990-2035



Source: EIA, 2012

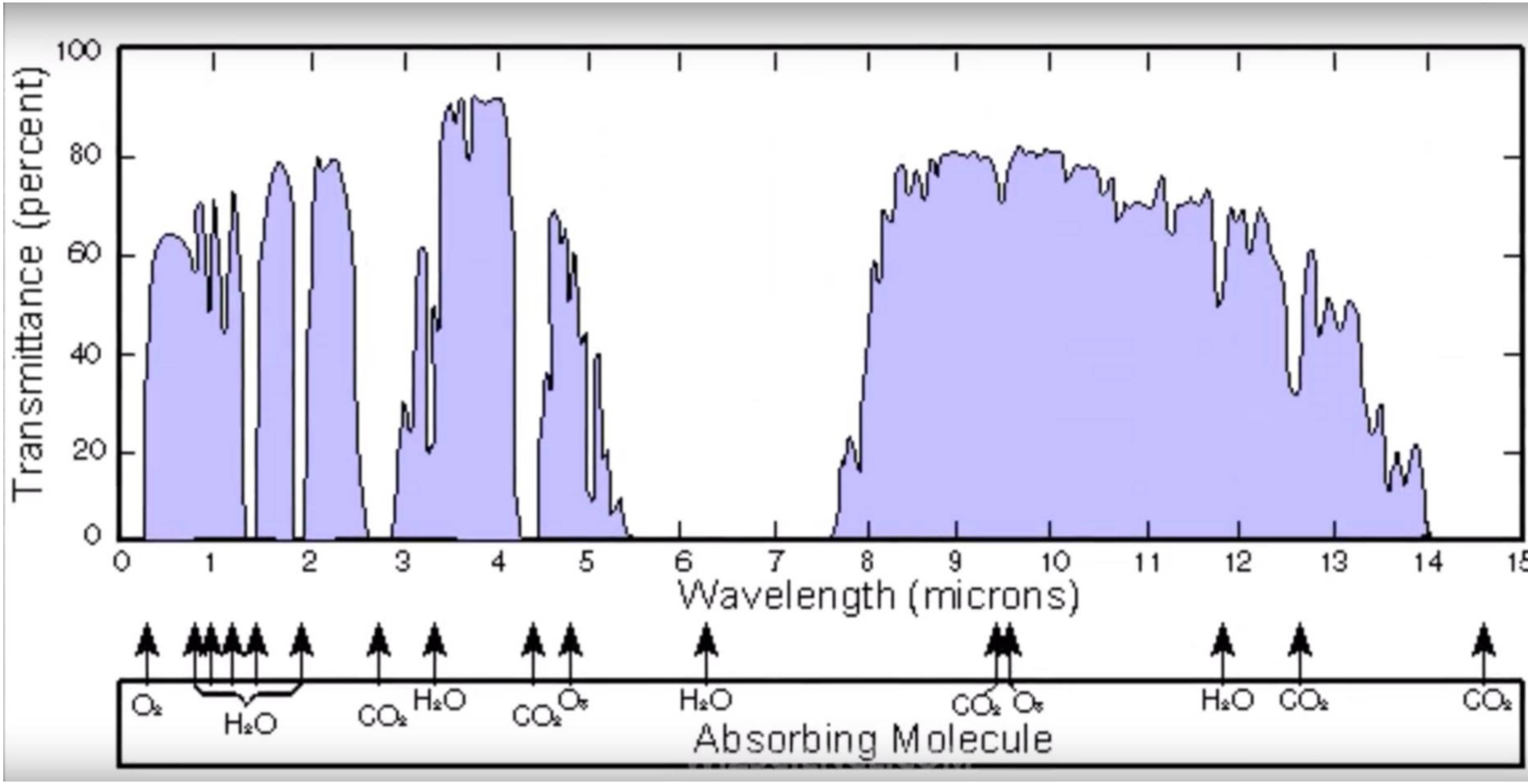
Energy Usage in Hong Kong Buildings





Source: EMSD Data 2015

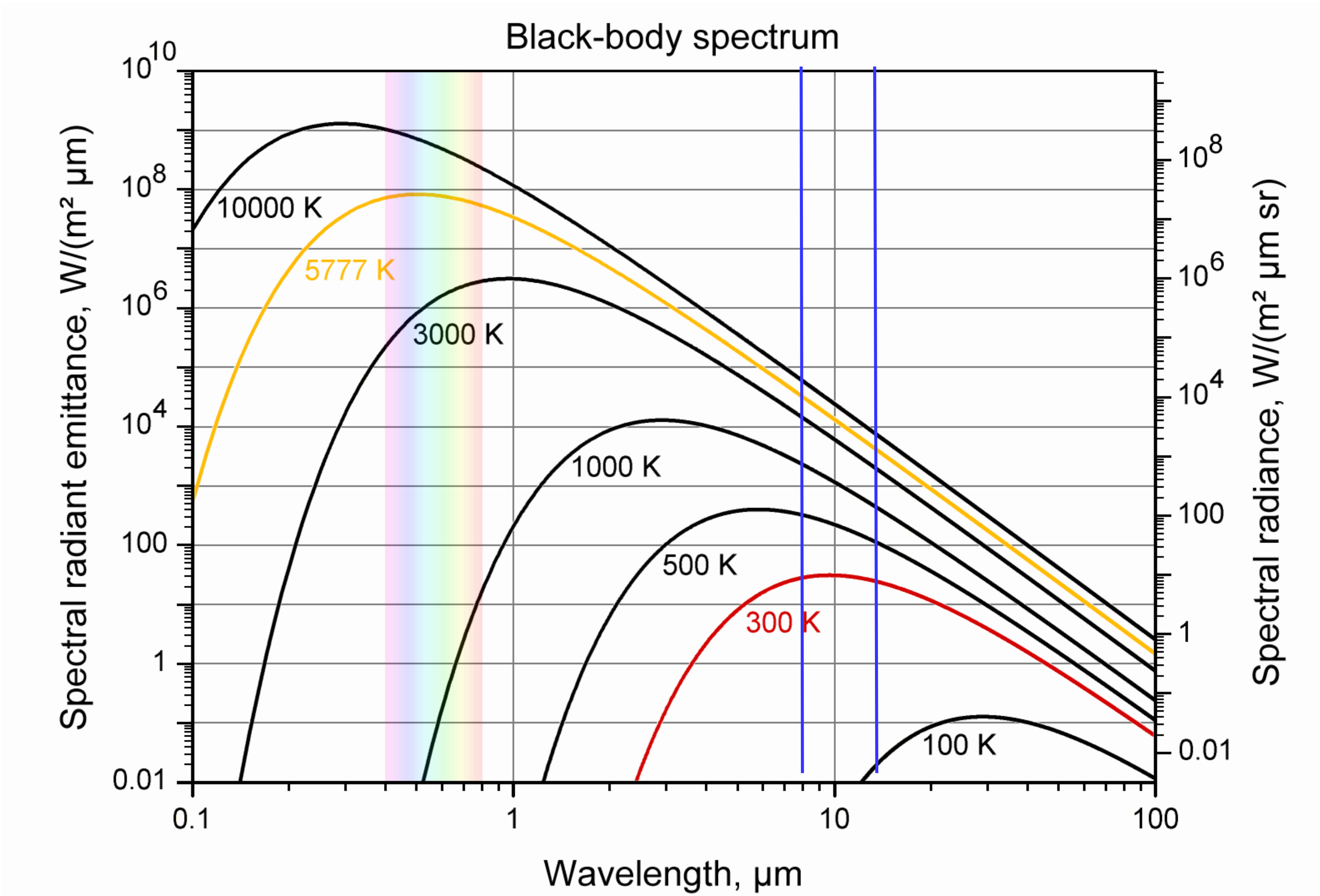
Working Principle of Photonic Passive Radiative Coolers



By analyzing the spectral characteristics, electromagnetic (EM) waves with different wavelengths have different transmittance in the atmosphere. There is a high transmittance band called "atmospheric window", for example: 0.3 - 2.5 μm, 3.2 - 4.8 μm, 8 – 13 μm, etc.

The <u>8-13 μm</u> band is the one people most are interested in, because blackbody radiation is concentrated in this range at room temperature.

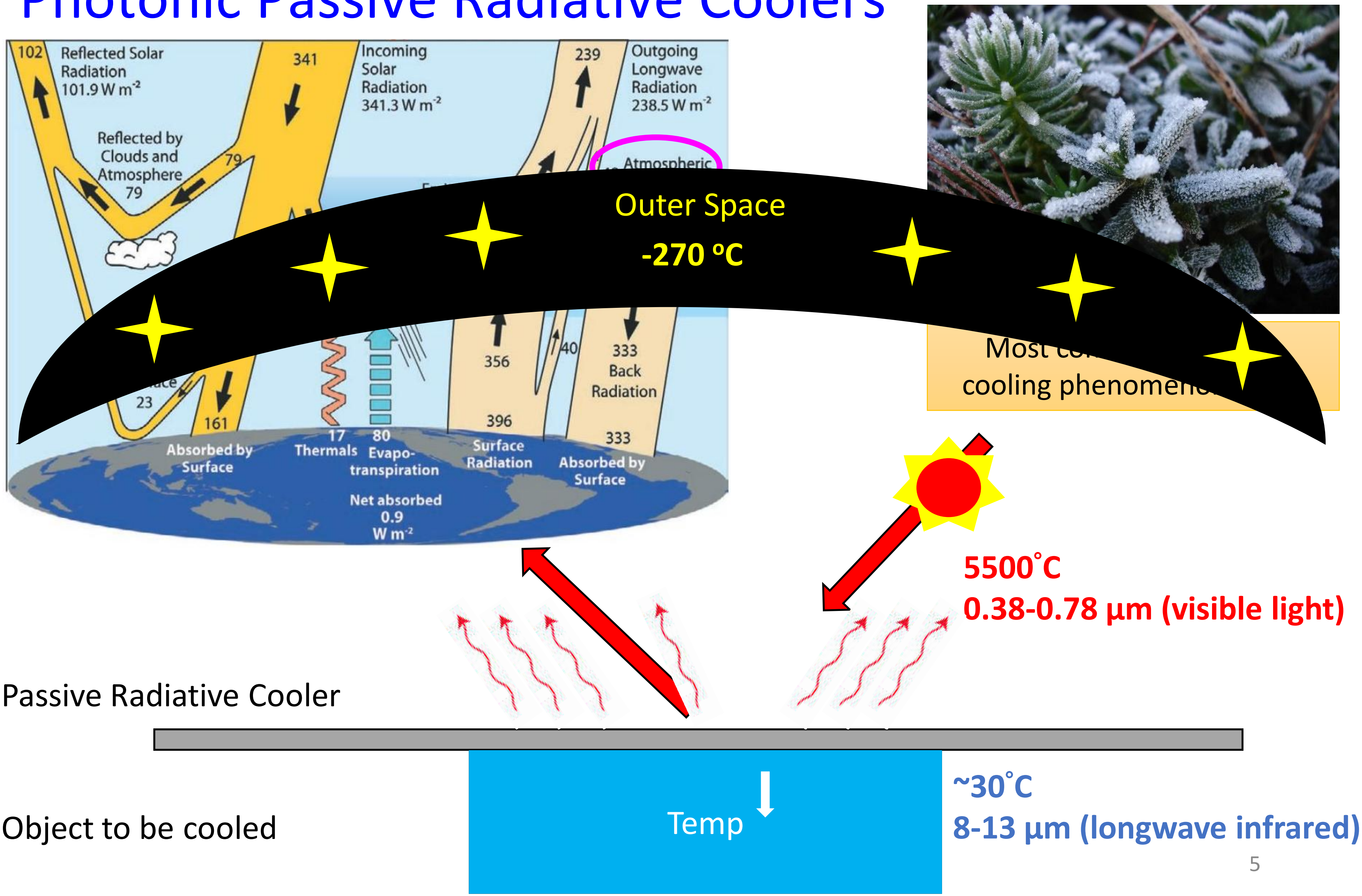
Working Principle of Photonic Passive Radiative Coolers



Working Principle of Photonic Passive Radiative Coolers

Environmentally Friendly

Electricity Free

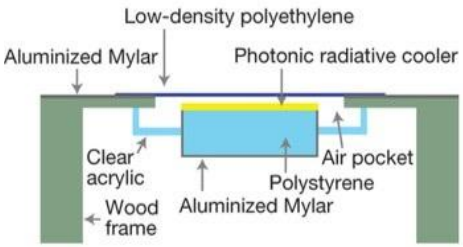


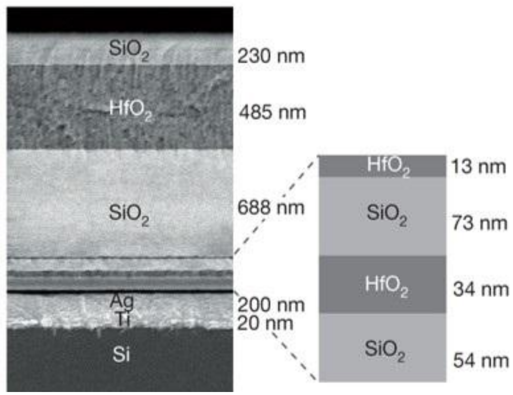
Objectives

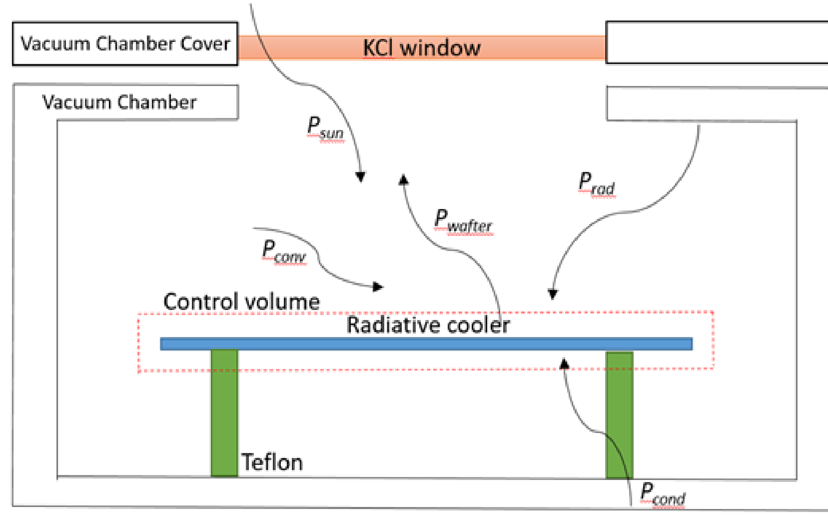
- To experimentally investigate the passive radiative cooler with different thermal designs (i.e. vacuum and non-vacuum configurations);

- To test its cooling performance in the hot and humid environment of Hong Kong.

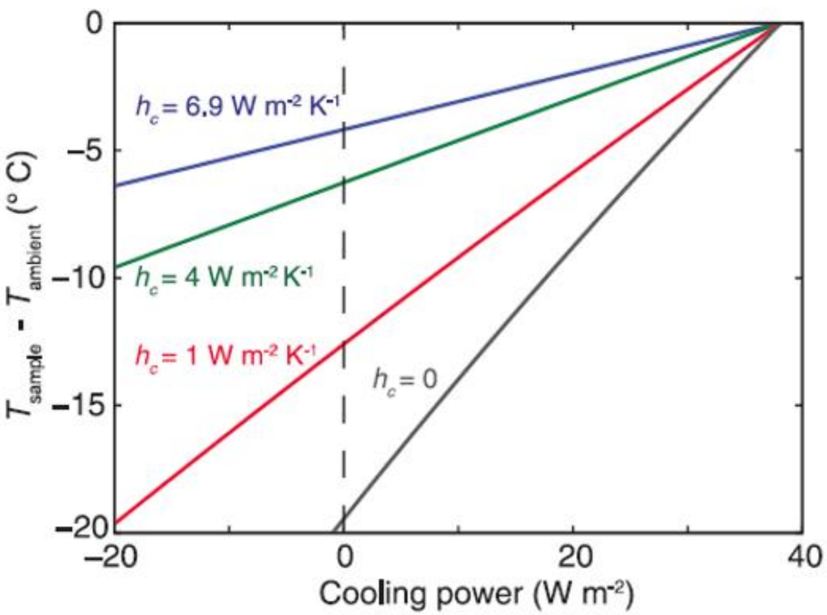
Multi-layer Passive Radiative Cooler

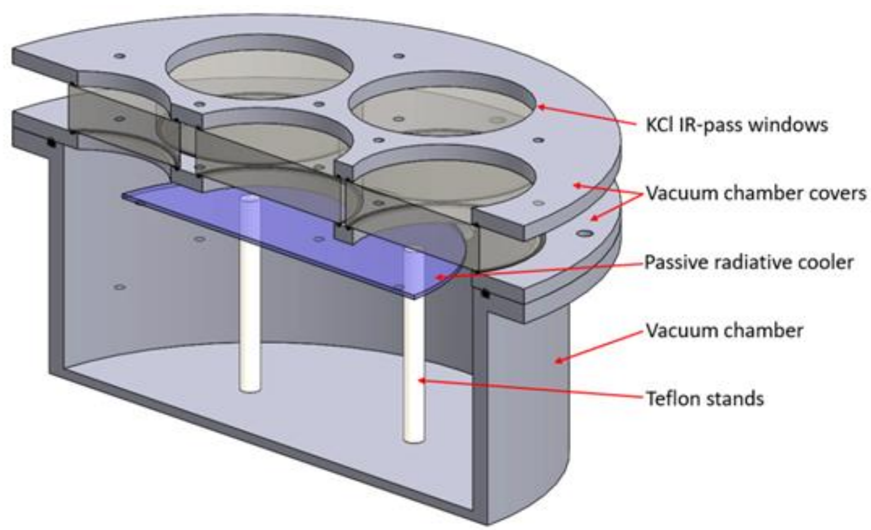






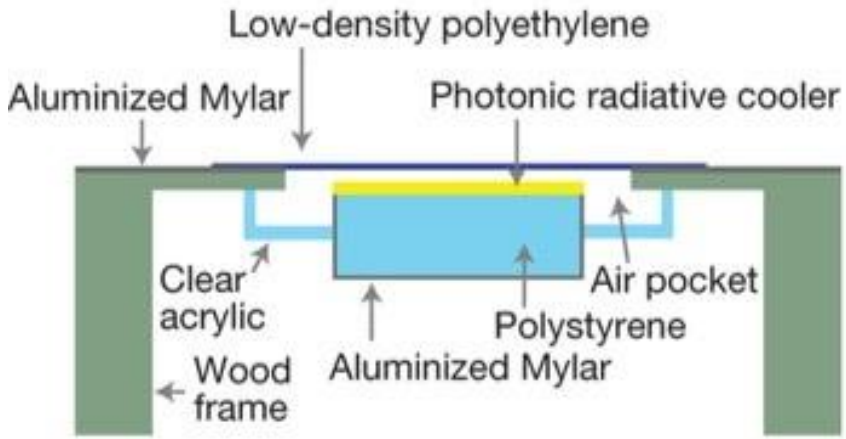
$$P_{cool} = P_{wafer} - P_{sun} - P_{conv} - P_{cond} - P_{rad}$$

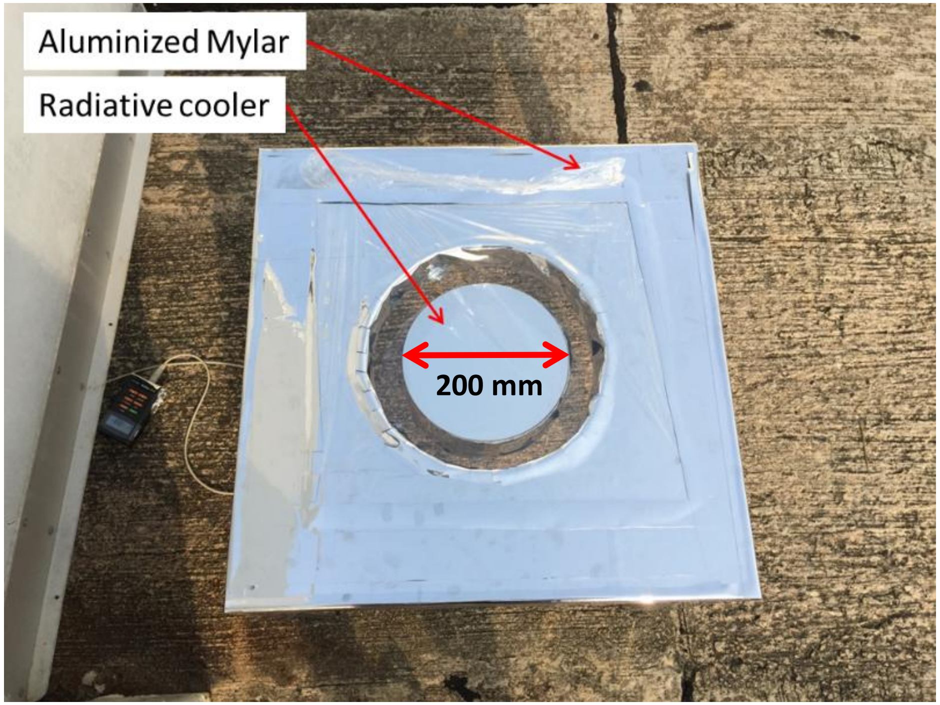


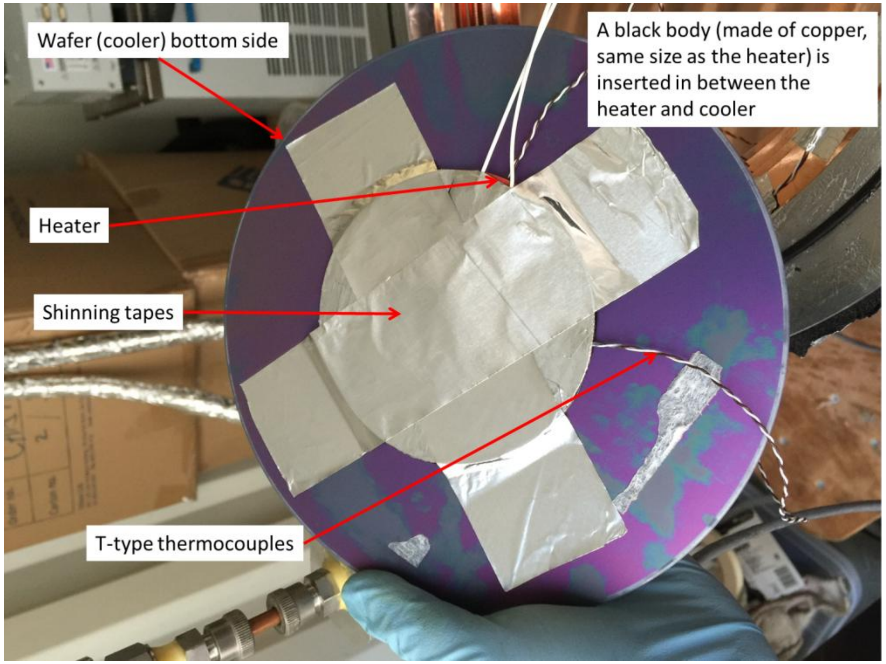


Raman, A. P., Anoma, M. A., Zhu, L., Rephaeli, E., & Fan, S. (2014). Nature, 515(7528), 540-4.

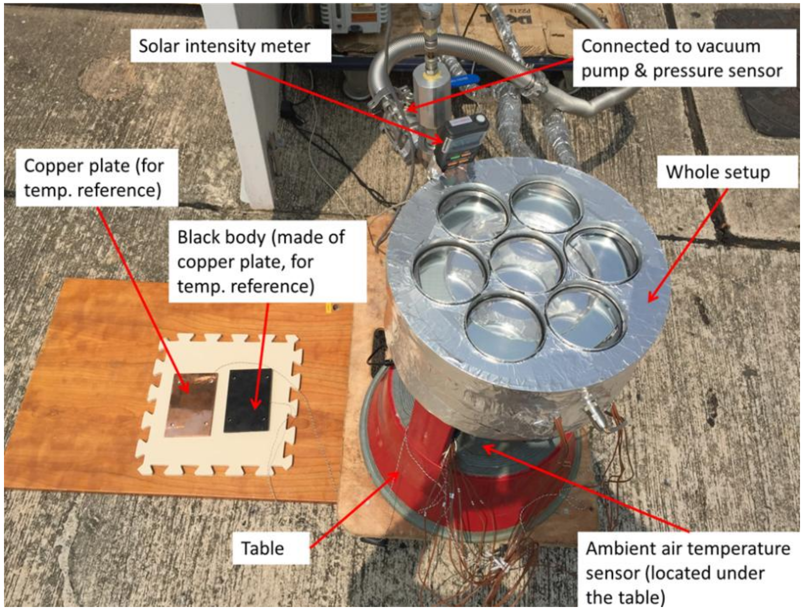
Non-Vacuum Design

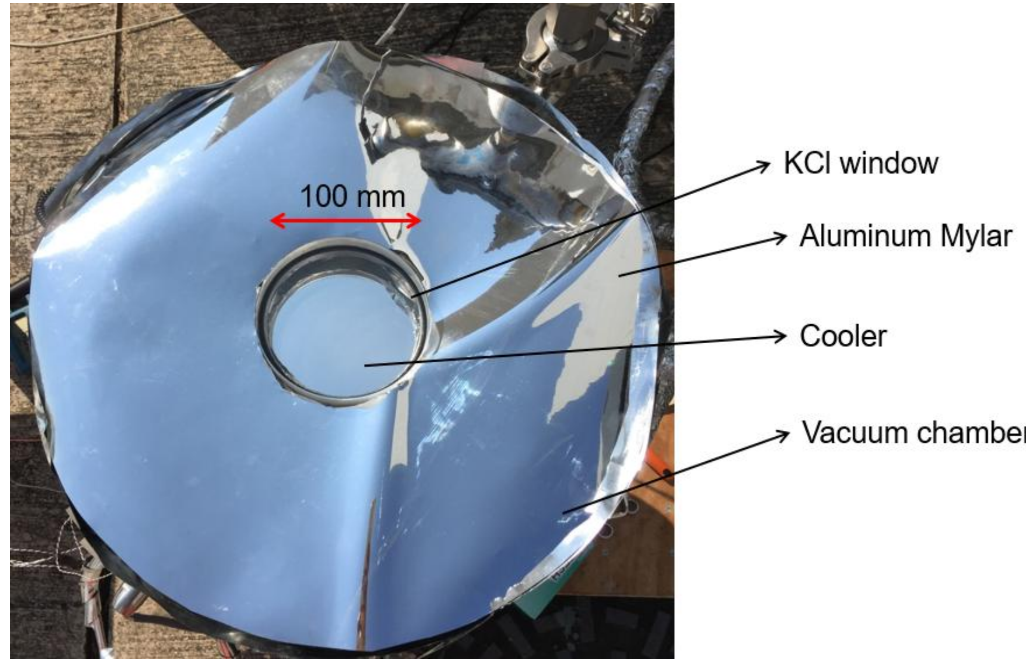


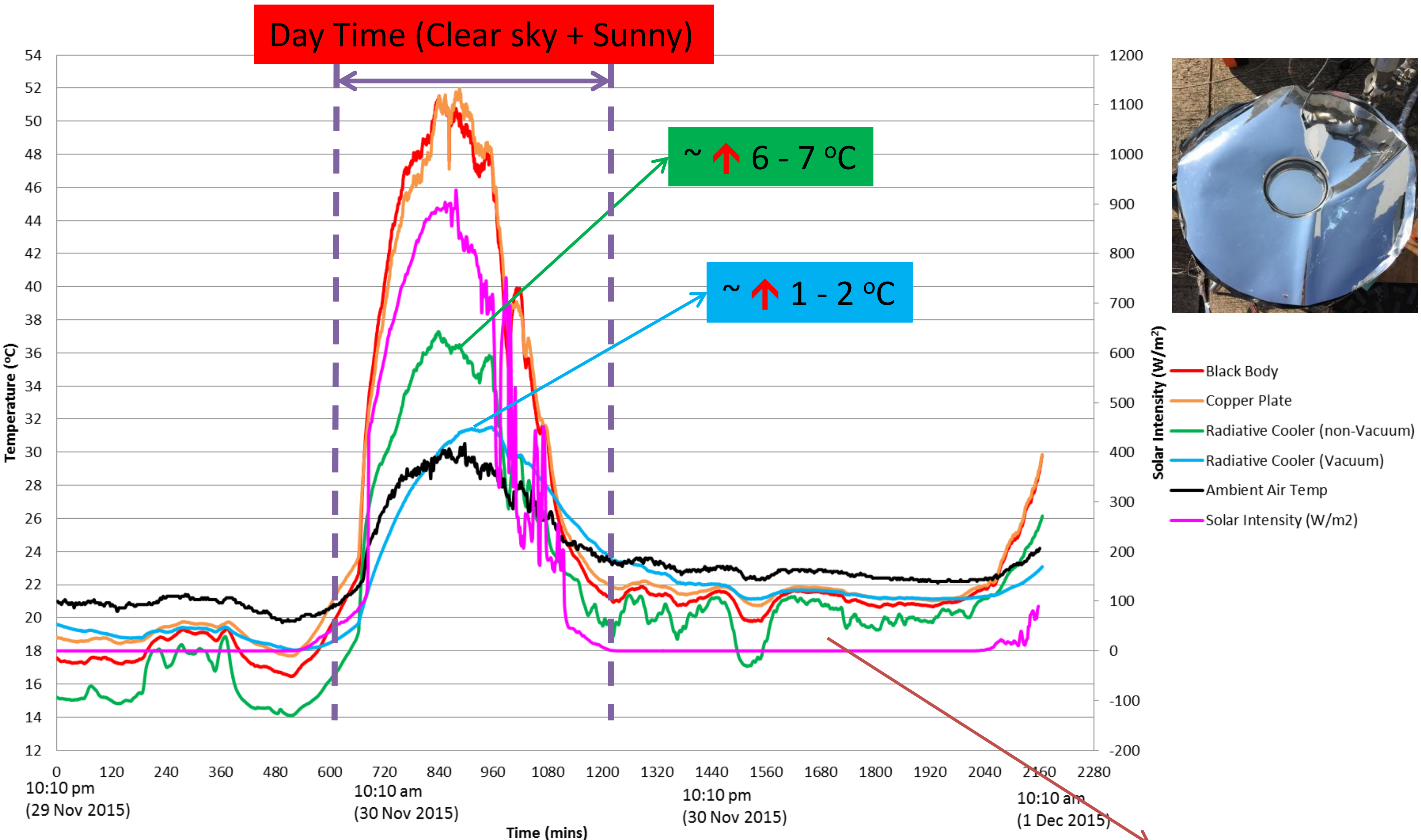




Vacuum Design

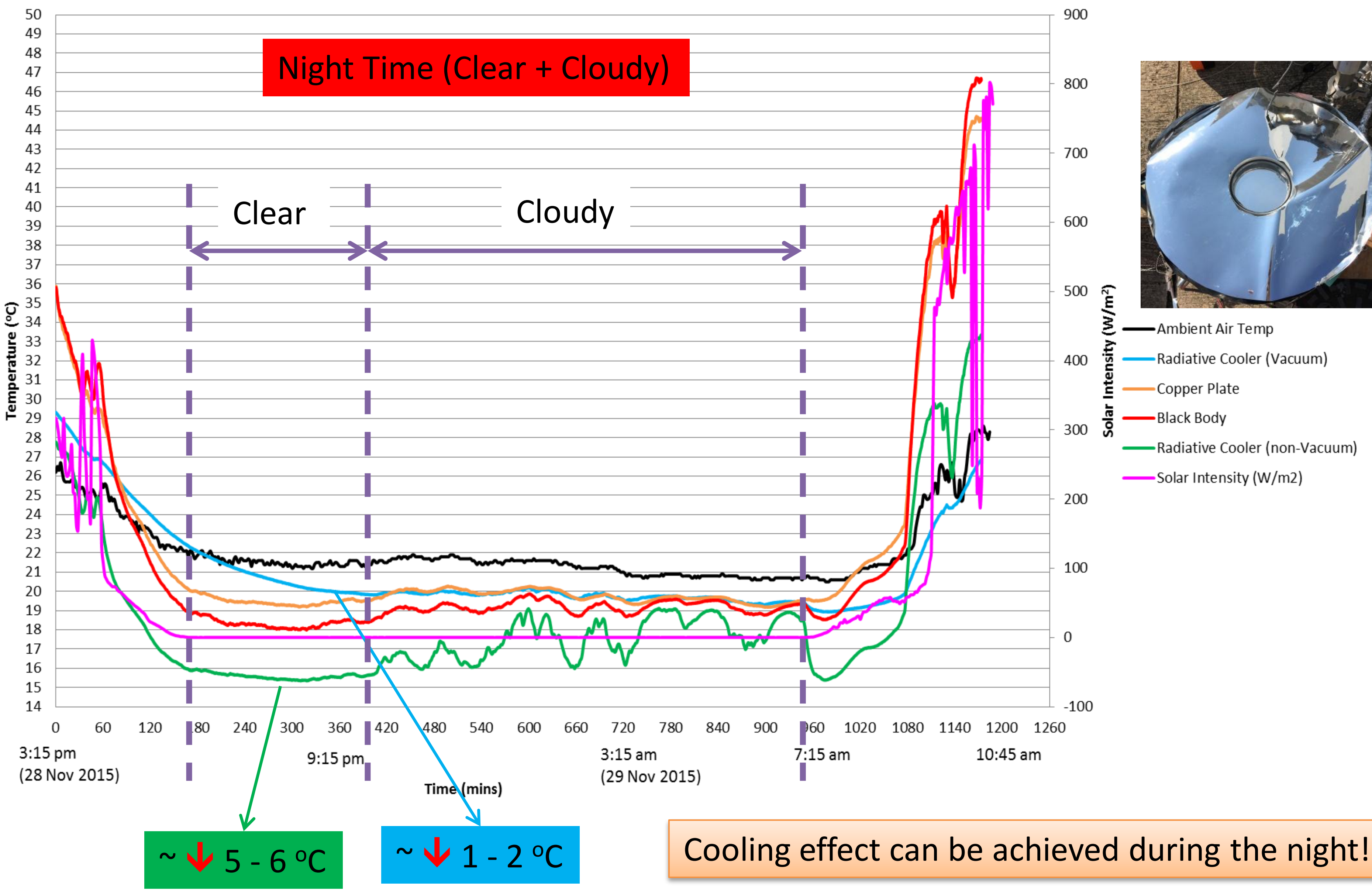






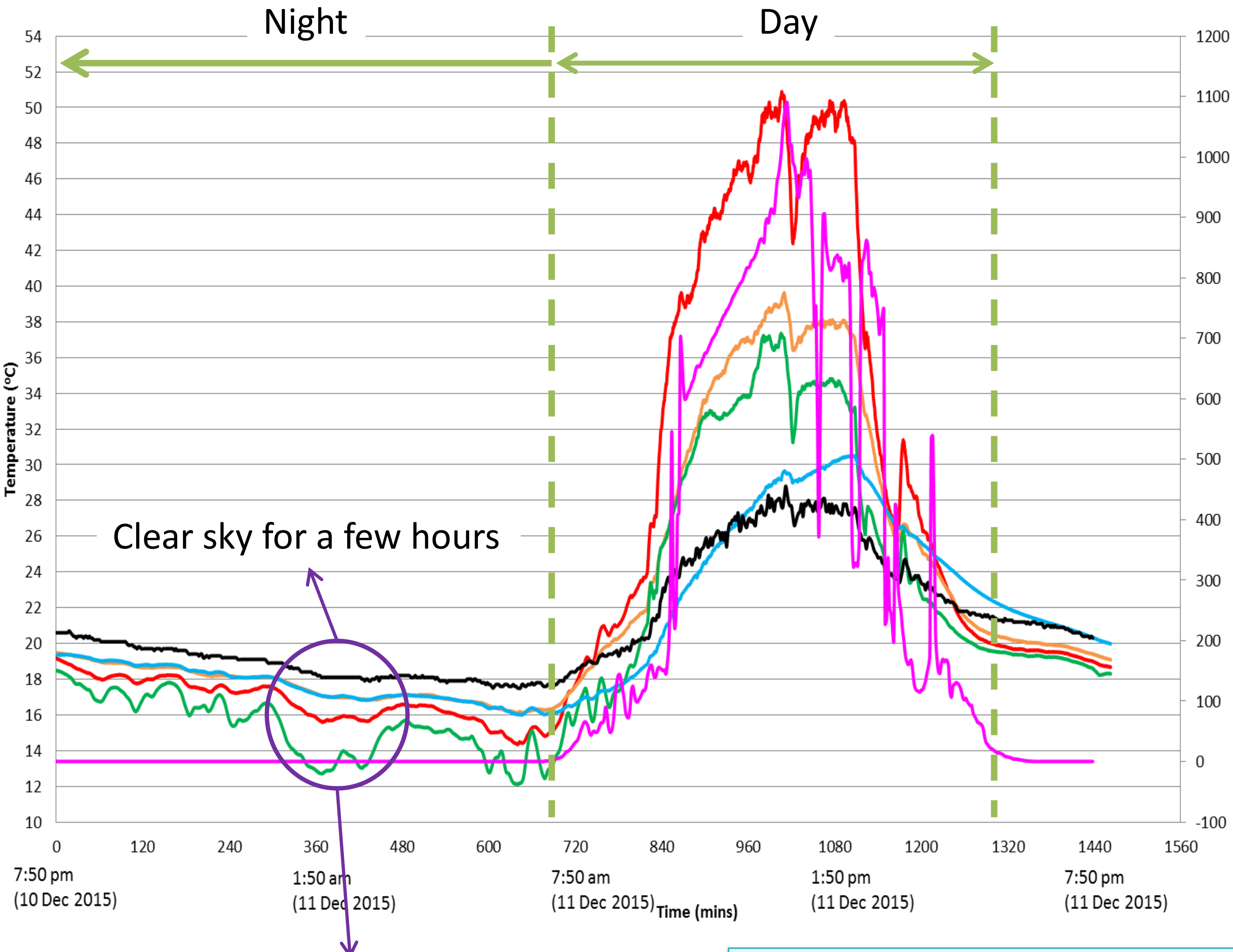
Cooling effect of both radiative coolers (vacuum & non-vacuum) are hardly to be achieved during the day time operation!

Very cloudy at night → the overall cooling performance is poor no matter which coolers are.



Cooling effect can be achieved during the night!

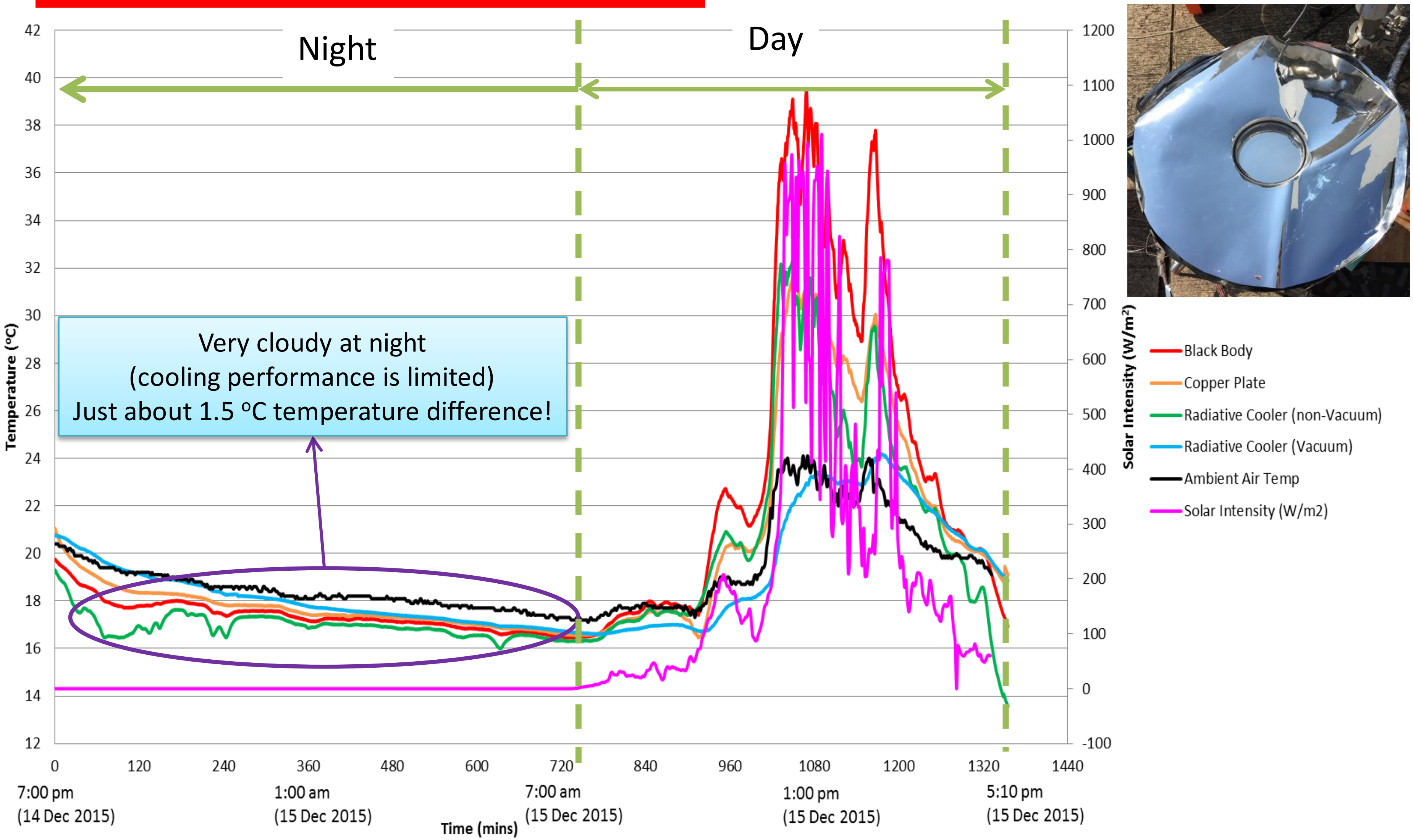
Mostly cloudy at Night & Partly Sunny at Day



Maximum temperature difference ≈ 5 - 6 °C

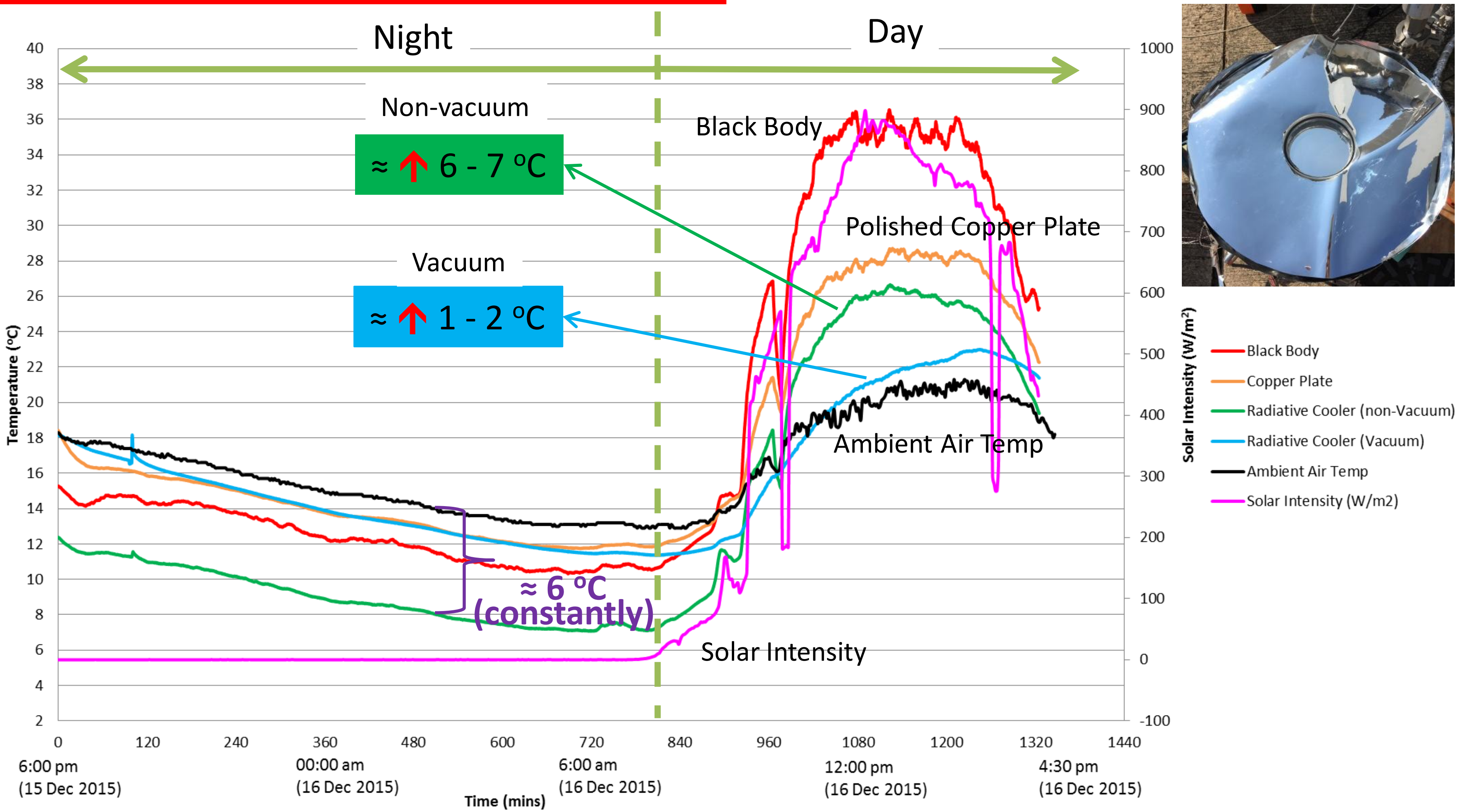
Similar results are obtained comparing to the previous 2 slides!

Very Cloudy at Night & Partly Sunny at Day

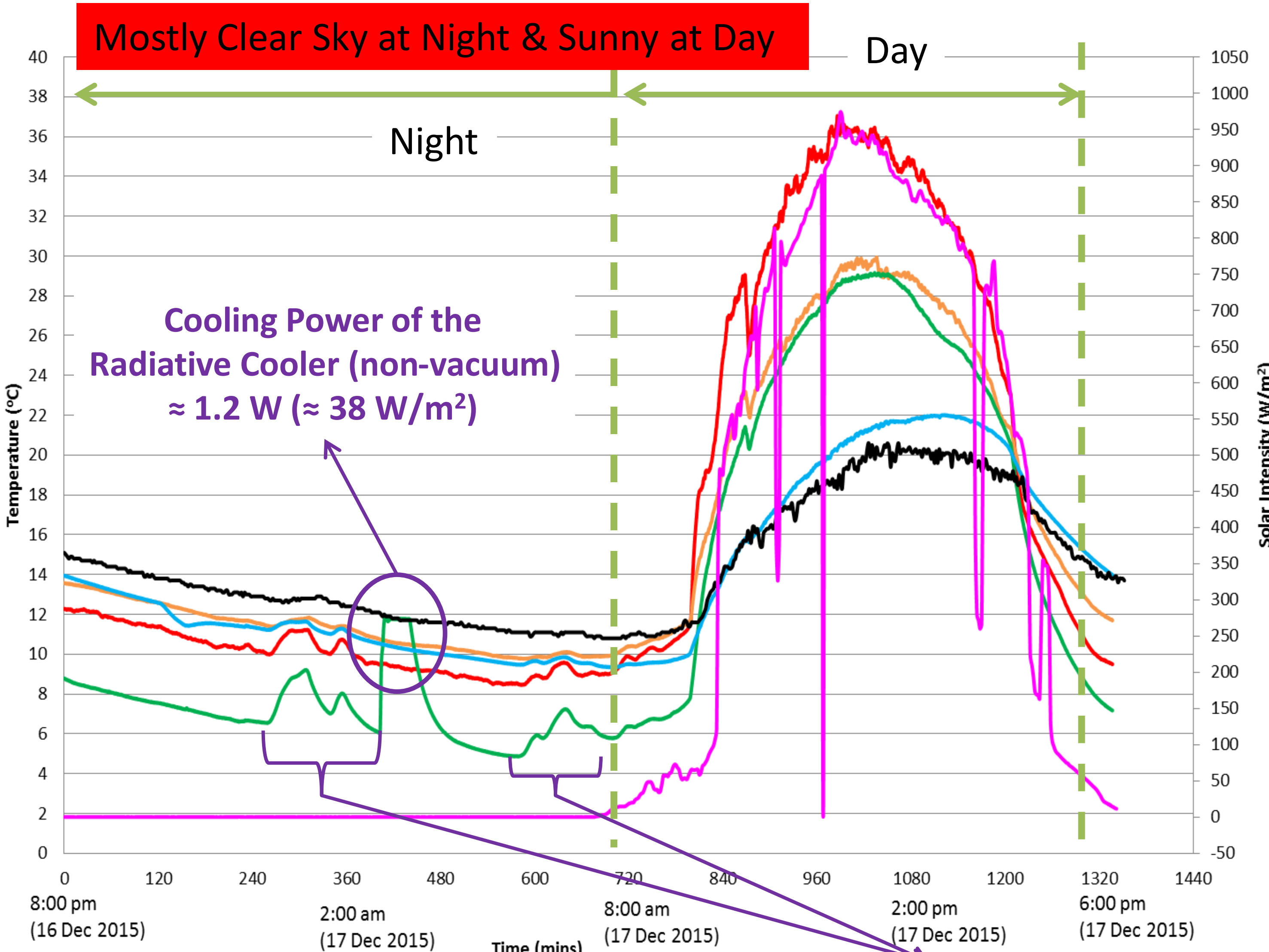


Weather plays a major role on the cooling performance of the passive radiative cooler!

Very Clear Sky at Night & Mostly Sunny at Day



Cooling Capacity



Cloudy during this period → The temperature is increased.

Most of the time, the temperature difference ≈ 6 ºC (radiative cooler non-vacuum Vs ambient air temperature)!

Conclusions

- Both passive radiative coolers with vacuum and non-vacuum design were unable to provide a cooling effect under direct sunlight.
- Although vacuum design cannot provide the cooling effect during the daytime operation, its outcome is much better than that of the non-vacuum design.
- Local weather plays a major role on the cooling performance of the passive radiative cooler.
- The passive radiative cooler with non-vacuum design can cool the ambient air temperature during night time (i.e. reducing the ambient air temperature by about 7 ^{o}C), producing a cooling power of 1.2 W (i.e. 38 W/m^2) under a clear night sky in Hong Kong.
- Cooling by using night radiation technique seemed to be feasible in Hong Kong, but there remains much work to successfully produce the cooling effect under direct sunlight in Hong Kong's climate.


Thank You