RadCool: a Web-enabled Simulation Tool for Radiative Cooling

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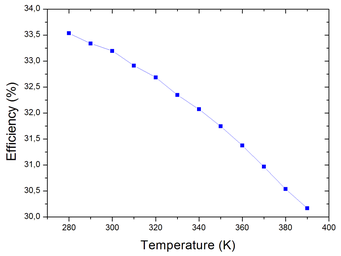
Introduction

Thermophotovoltaic (TPV) systems
- Convert heat to electricity [1]
- Alternative renewable energy source

Challenge of TPV systems:
- Thermal management of PV cells



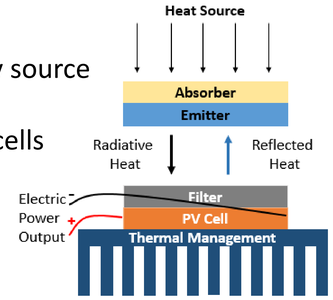


Figure 1. Schematic of the TPV systems

Figure 2. Efficiency of a PV cell as a function of temperature [2].

Approach: Developing a simulation tool, RadCool, to manage the temperature of the TPV system via radiative cooling.
Radiative cooling is a passive technique that dissipates heat into remote space via thermal radiation [4].

Motivation

- Help gather meaningful data using less computational time
- Potential to increase the overall PV efficiency by 1% [3]
- Benefit other applications requiring outdoor cooling that doesn't consume energy

Existing Tool

- TPVexpt
  - Can model TPV system fairly accurately
  - Lack of temperature management of the PV cell

Applications

- Solar cell cooling
- Infrared detectors
- Sensitive electronic devices
- Automobile cooling

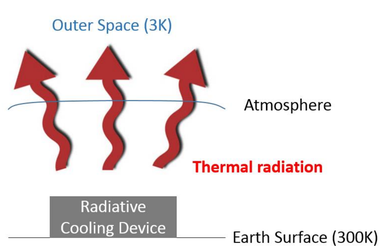


Figure 3. Radiative cooling concept

System Overview

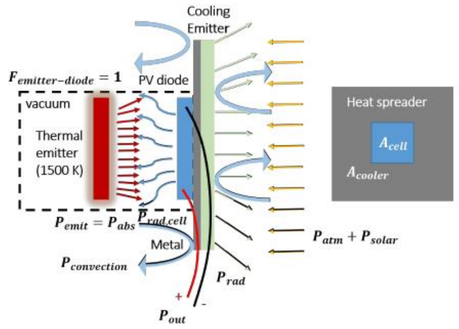
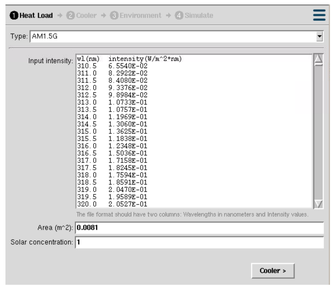


Figure 4. Schematic of the TPV systems with a radiative cooler. The arrow shows the heat flow between the system and the environment [4].

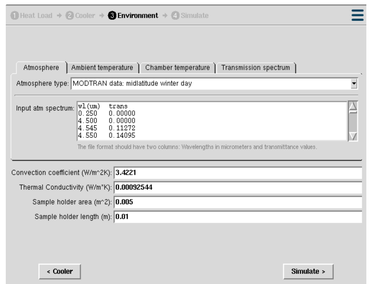
Simulation Tool

Heat balance equation [5]:

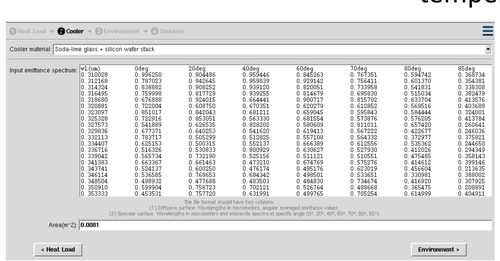
$$P_{atm} + P_{sun} = P_{rad} + P_{convection} + P_{conduction}$$



Heat Load Phase
- Solar absorption



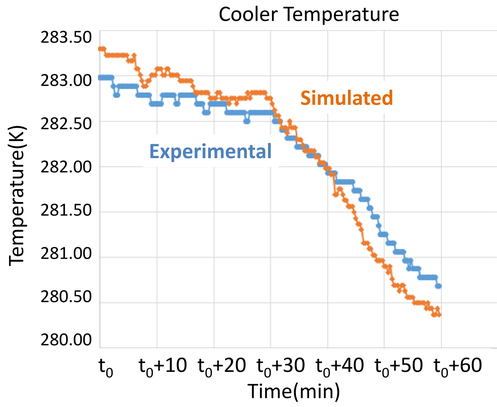
Environment Phase
- Atmospheric spectrum
- Transmission spectrum
- Ambient/Chamber temperature



Cooler Phase
- Emissive spectrum of the cooler

Experimental Verification

Experimental data
- Area ratio of the heat load and the cooler: 1
- Cooling material: Silicon wafer with soda-lime glass
- Transmission spectrum: polyethylene film
- Ambient Temperature: ~290K



Analysis
- RMS value: 0.2552 K
- Below-ambient cooling
- Total decrease in temperature from ambient is ~10K
- Discrepancy may be due to using average convection coefficient

Figure 5. Temperature of the cooler as a function of time.

Conclusions and Future Goals

- Tool can be found at https://nanohub.org/tools/radcool/
- RadCool successfully models radiative cooling system in a graphical interface
- More verification with experimental results
- Can connect with existing TPV model

References

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