Testing Solar Modules for use in BIPV/AIPV Applications

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Abstract

Solar powered cars are a sustainable alternative to gas powered cars. However, solar modules on a car in the sun tend to get hot which reduces power output. We want to understand the performance of a variety of solar modules on a car roof in a variety of environments. We will test gallium arsenide solar modules side by side with silicon solar modules by mounting them on a black box test stand, simulating the roof of a car, and quantify the difference in operating temperatures and power outputs. We aim to quantify the performance of various solar modules as a function of operating conditions.

Objective

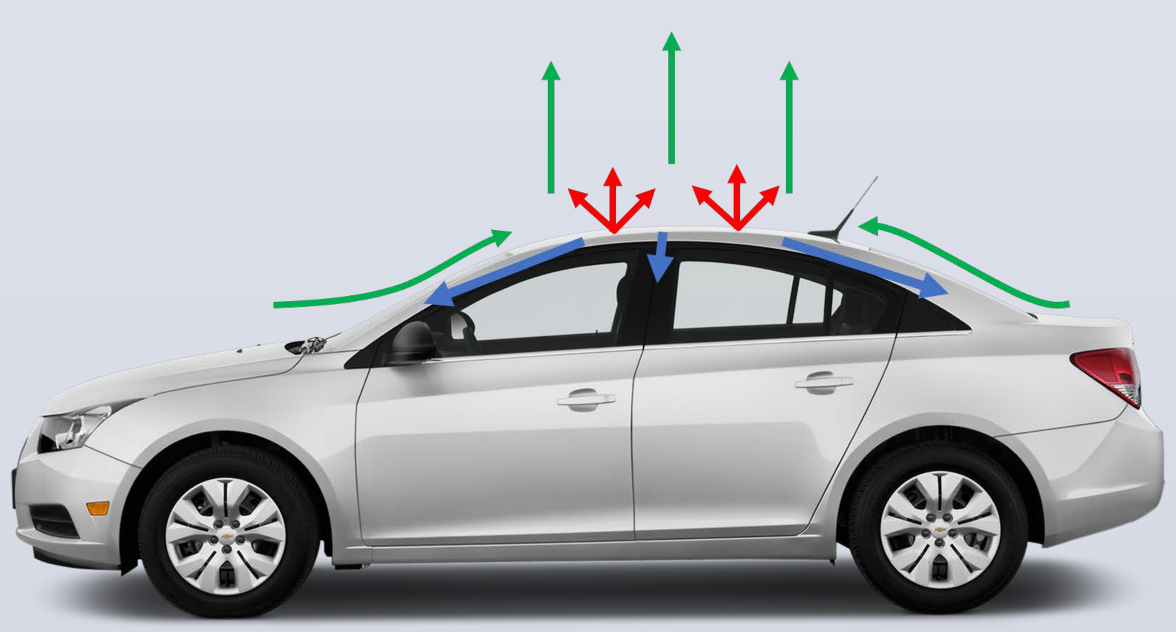
In our research, we aim to collect data on different solar modules set in an environment similar to the roof of a car. We will be testing a variety of Si and GaAs solar modules.

Background Information

BIPV (Building - Integrated Photovoltaic) and AIPV (Automotive - Integrated Photovoltaic) technologies provide thermal environments that we are interested in studying. These environments limit the effectiveness of convective cooling.

3 types of heat transport mechanisms:

- Radiative
- Convective
- Conductive.

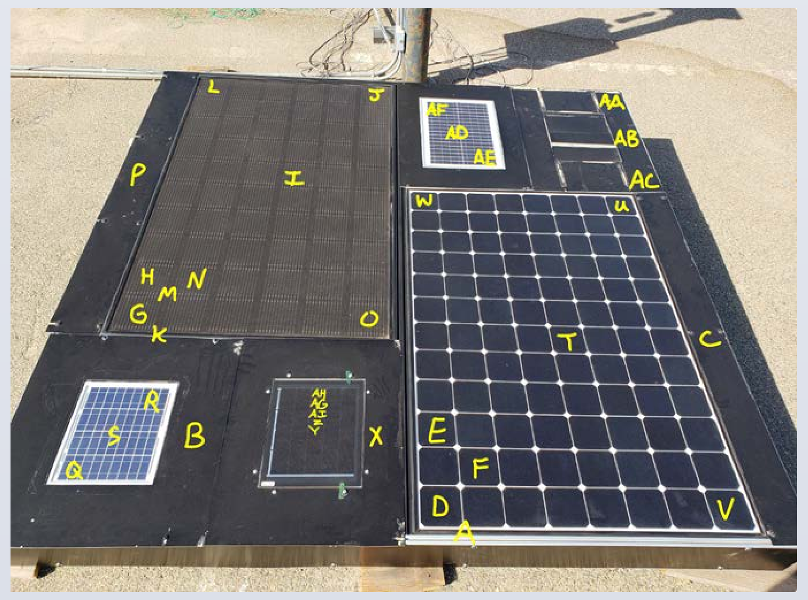


T. Silverman et al compared outdoor performance of single junction Gallium-Arsenide (GaAs) and Silicon (Si) modules in traditional open rack mounting configuration. They showed that "due to its fundamentally different cell technology" the GaAs was less effected by increased temperature than the Si modules. "The low operating temperature and small temperature coefficient of GaAs give it an energy production advantage in warm weather."

Preparing Black Box Test Stand

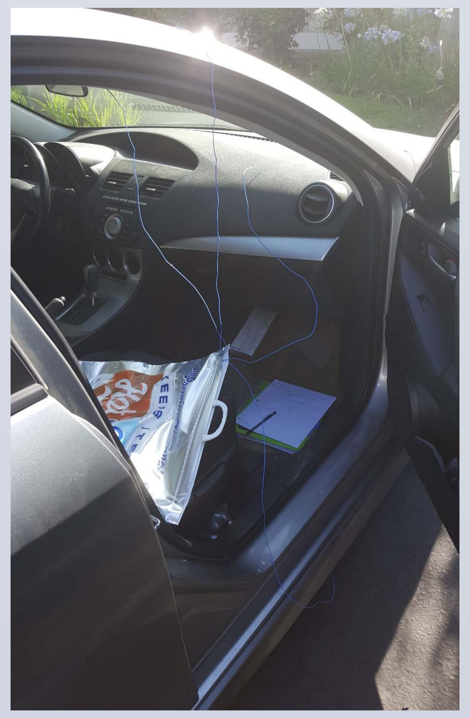
Prepared a black box test stand made of an aluminum frame enclosed by black anodized aluminum sheet. This test stand will create an environment similar to the roof of a car for solar modules. Black box is placed outside next to the shed, where long term tests are taking place.

Current Setup



35 thermocouples inside the box

Car Testing Site



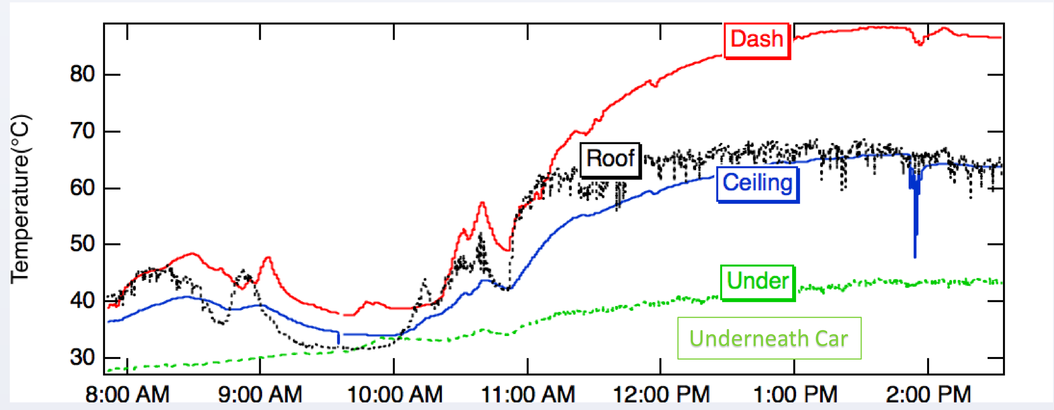
For two cars, we placed the 4 channel meter in a thermal bag with cool rocks.

First Car: A light grey Mazda3 2010 parked in the sun facing east all day.

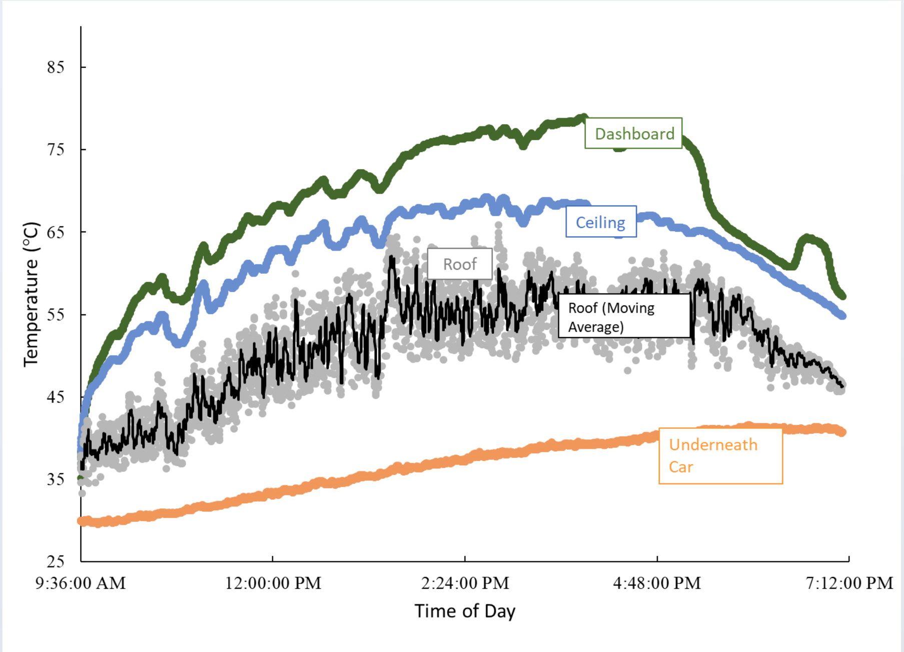
Second Car: A dark charcoal Subaru Impreza parked in the sun facing south all day.

Preliminary Car Temperature Data

First Car Temperature Data



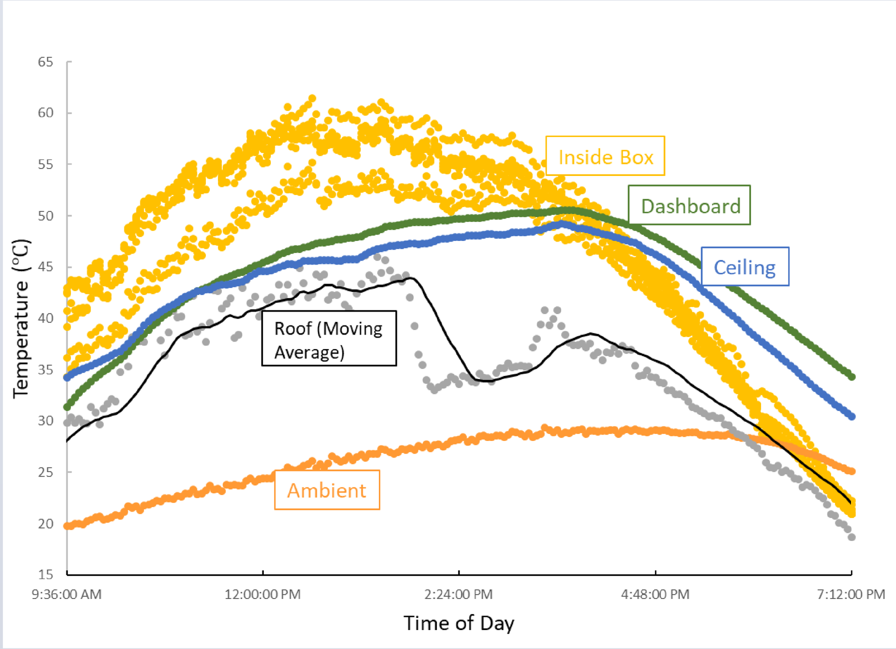
Second Car Temperature Data



Used K type thermocouples and a 4 channel meter to record the temperature on different parts of the car.

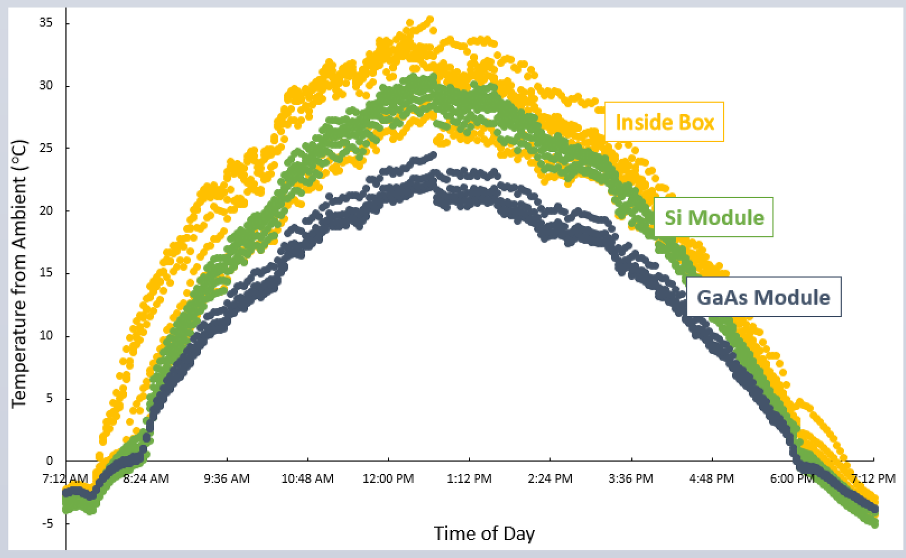
Box Temperature Data

Third Car vs Box Temperature



Tan Prius with reflector in windshield

Temperature Above Ambient for Black Box



Future Steps

- Continue using multi-tracer to collect:
  - IV data
  - Temperatures of box interior, solar modules, and ambient
- Set up multi-tracer to collect the following data:
  - Wind speed and direction
  - Relative humidity
  - Irradiance
- Interpret data and develop a model that predicts the performance of solar modules as a function of operating conditions

Conclusions

- Roof and ceiling temperatures of first and second car tell slightly different stories
- Interior temperature lags behind roof temperature
- Wispy clouds have a measurable effect on temperature of car as seen for the second car

Observed wispy clouds when testing second car, which had an impact on results.

- Black box hotter than tan Prius with sun shade during the day but cools off faster
- Modules operate at different temperatures with GaAs cooler than the box

References

- 1. Silverman, Timothy J. Outdoor Performance of a Thin-Film Gallium-Arsenide Photovoltaic Module. , 2013. Internet resource.

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