Thermal Influence of Adhesive-Mounted PV on Underlying Roof

Nitin Shukla, Ph.D.
Alliston Watts
Christian Honeker, Ph.D.
Jan Kosny, Ph.D.

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Residential Photovoltaic (PV) has huge potential, but…

- Residential building rooftops have 731 GW of installed capacity potential
  - equivalent to 25% of national annual electric sales
- 2 GW of residential PV was installed in the US in 2015, a growth of 66% over 2014
- Although PV module price has decreased in recent years, total installed costs remain high in the US
- Non-hardware “soft” costs are higher in the US than in most other countries

Conventional Rack-Mounting is time-intensive and expensive

Ordinary Racking

Framed modules mounted on rails which are connected to mounts fixed to rafters.
Adhesively-Mounted rooftop PV has several benefits...

High-performance Adhesive  +  Lightweight Module  =  Plug and Play Project

<table>
<thead>
<tr>
<th></th>
<th>Lightweight Module Adhesively mounted</th>
<th>Conventional PV Conventional rack-mounting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation Time</td>
<td>30 min/3 kW</td>
<td>75 min/3 kW</td>
</tr>
<tr>
<td>Penetrations</td>
<td>None</td>
<td>2+/module</td>
</tr>
<tr>
<td>Skill Level</td>
<td>Minimal</td>
<td>Roofer or trained installer</td>
</tr>
<tr>
<td>Grounding</td>
<td>None</td>
<td>Yes (exposed metal)</td>
</tr>
</tbody>
</table>
Risk of Heat Build-up under Adhesive-Mounted PV

- Small gap may act as a dead air space causing an increase in roof shingle temperature which may result in reduced lifetime of the shingle.
Objectives

- Investigate the effect of adhering peel-n-stick rooftop PV panels on the temperature of the roof shingle
- Are the shingles heated by the presence of the adhered module as compared to the exposed (uncovered) shingles during the daytime?
- How heat transfer through the roof is affected?
Strategy – Comparative outdoor test hut study

- Field Measurements: Instrument two identical Test Huts in ABQ, NM with conditioned interior space
- One w/ and one w/out adhered rooftop PV (PV and Reference Huts, respectively)
- Measure and compare temperature and heat flux through the shingle/roof deck/ceiling under adhered panels and exposed shingle
- Experiment duration: 5 weeks of summer period
As-Constructed Test Hut

- Built according to standard construction practices; 2.44 m x 3.66 m base
- South-facing roof with 4:12 slope
- Asphalt fiberglass shingles – 3-Tab
- Used standard level of thermal insulation in different envelopes
- Conditioned space was set to same temperature
PV Hut contained adhesive-attached rooftop PVs

- PV Roof contained six lightweight (glassless, frameless PV panels)
  - PV coverage of ~70% of the total roof area
  - Glassless, frameless monocrystalline Si PV (155W rating from Lumeta Solar)
- Elastomeric butyl adhesive; peel and stick solution
- Adhesive tape thickness = 1.5 mm
Identical sensor layout in attic and conditioned-space
Sensor layout on the roof envelope

Reference Hut

PV Hut

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Heat Flux Sensor
TC Array
TC on Shingle Surface

PV Module
Adhesive Patch
Shingle
OSB Roof Deck
Hut interior (Conditioned Space) are matched to 1°F precision.
Shingle Temperature: Shingle under PV is cooler than exposed shingle
Peak Shingle Temperature: Exposed > Under PV panel

- Average daily peak temperature of shingles under PV is 12.5°C lower compared to exposed shingles on reference hut.
Histogram of Shingle Temperature: Exposed > Under PV panel
Heat Flux through Ceiling: Reference > PV Hut

![Graph showing heat flux through the ceiling over a period from Aug 15 to Aug 22, comparing PV Hut and Reference Hut.]
PV Hut shows lower daily peak heat flux

- A reduction of between 45% and 55% in the ceiling heat flux of the PV hut is noted relative to the reference hut.
- Average reduction in peak daily heat flux through the ceiling over the Aug.-Sept. monitoring period is 49%.
Roof cooling load is significantly reduced in PV Hut

Roof – generated Cooling Demand = \int_{t=0}^{t_f} Q''(t) dt

- 49% reduction in cooling load of PV hut w.r.t. Reference hut
- For 69% PV coverage on roof, whole-building scale cooling load reduction = 49%*14% = 6.9%
- Equivalent to addition of R-8 insulation to the walls

<table>
<thead>
<tr>
<th>Component</th>
<th>Load (quads)</th>
<th>Percent of Total Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>0.16</td>
<td>14%</td>
</tr>
<tr>
<td>Walls</td>
<td>0.11</td>
<td>10%</td>
</tr>
<tr>
<td>Foundation</td>
<td>-0.07</td>
<td>-</td>
</tr>
<tr>
<td>Infiltration</td>
<td>0.19</td>
<td>16%</td>
</tr>
<tr>
<td>Windows (conduction)</td>
<td>0.01</td>
<td>1%</td>
</tr>
<tr>
<td>Windows (solar gain)</td>
<td>0.37</td>
<td>32%</td>
</tr>
<tr>
<td>Internal Gains</td>
<td>0.31</td>
<td>27%</td>
</tr>
<tr>
<td>Net Load</td>
<td>1.08</td>
<td>100%</td>
</tr>
</tbody>
</table>
Summary and Conclusions

- Adhesive-applied PV module does not cause any heating of the underlying roof shingle during the daytime of summer season.
- Presence of adhered module causes daytime peak temperature of underlying shingle to reduce by around 12.5°C during summer months.
- Daily peak heat flux is reduced by almost half by the presence of adhered modules.
- Roof cooling load is reduced by almost 50% for PV hut compared to Reference hut.
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Thank You!

Presenter: Nitin Shukla, Ph.D.
nshukla@cse.fraunhofer.org
Ph: +1-617-714-6519