PV-ROCK-ROOF
Annex A report
Diode and junction box experiments

DANISH TECHNOLOGICAL INSTITUTE

PV-ROCK-ROOF

Diode and junction box experiments

Prepared for:
EUDP, project no. 64019-0029

Prepared by:
Danish Technological Institute
Gregersensvej 2, DK-2630 Taastrup
Refrigeration and Heat Pump Technology
Energy and Climate
www.dti.dk

Project consortium:
Rockwool International A/S
Danish Solar Energy
DTU Fotonik
Solar City Denmark
Kombibyg A/S
EFFEKT Arkitekter ApS
Danish Technological Institute (project manager)

August 2021

Authors:
Ivan Katic, Danish Technological Institute

Content

Introduction

The current report is an annex to the final report from the PV-Rock-Roof project.

The PV-ROCK-ROOF project is using PV modules as roof cladding material, and as such the back side of the modules is not ventilated as efficiently as they would be in a free-standing PV system. The overall module temperature, including junction box and bypass diodes, will thus be higher than usual. Failure of bypass diodes are known as a relatively common fault in PV systems, and replacement with a new diode is often difficult, if possible at all. As part of WP5 Test & certification, DTI has therefore conducted a series of experiments to investigate heat dissipation from bypass diodes with different mounting options and technologies.

The PV modules used in the PV-ROCK-ROOF project consist of monocrystalline solar cells which require a bypass diode for every 24 series connected cells or less. If bypass diodes are not used, there is a risk of hot-spot failure in case of partial module shading and a consequential reduction of power output.

The PV modules hitherto produced by Danish Solar Energy use traditional junction boxes and cylindrical Schottky type bypass diodes. Such diodes have a small voltage drop of about 0.4 Volt when conducting a current, so at a typical maximum current of 10A, they release 4 W of heat. If there is proper ventilation around the junction box this is not an issue, but in case of full integration with a Rockwool layer, almost all this heat must be conducted through the front of the PV module. The question is if this leads to unacceptable temperatures, and if there are pathways to overcome the problem.

Experiments with different types of bypass diodes

A series of tests has been conducted to see how the risk of critical overtemperature could be minimized. The test included three different diode types:

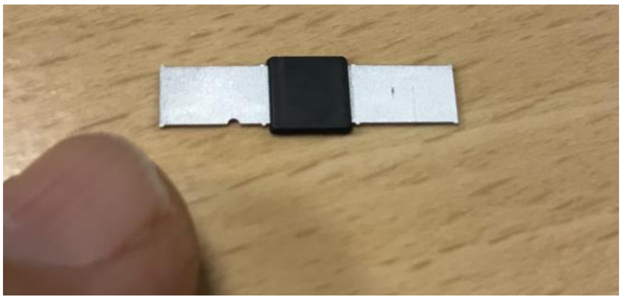
1. Standard cylindrical Schottky diode 10A rated current.
2. Low profile Schottky diode 12A rated current.
3. Active diode (a special circuit with lower loss) 15A rated current.

The experiments were set up in the laboratory or outdoor using a PV glass Tedlar laminate and an adjustable power supply. Two tests were conducted:

a) Comparison of standard diode and active diode power loss.
b) Thermal behaviour of standard cylindrical diode, flat diode and active diode.

Standard diode:

Low profile diode:



SBR12U45LH1

12A SBR®
SUPER BARRIER RECTIFIER
POWERDI®5SP-B

Product Summary

V_{RRM} (V)	I_O(A)	$V_{F(typ)}$ @ +125°C (V)	$I_{R(MAX)}$ @ V_{RRM} (mA)
45	12	0.38	0.3

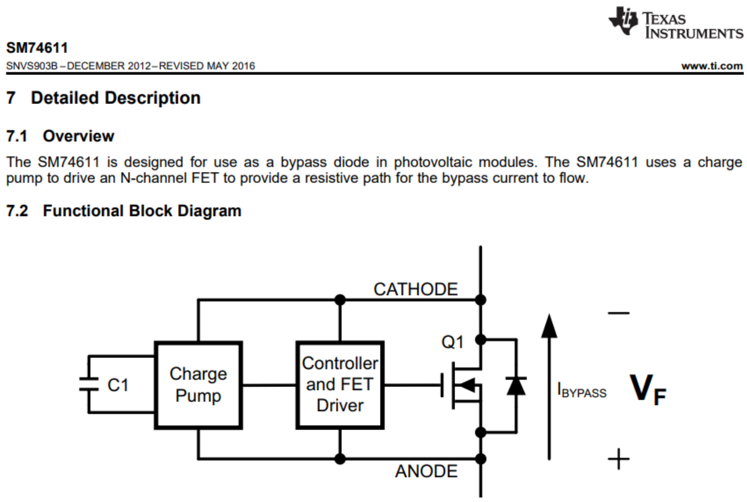
Description

The SBR12U45LH1 uses SBR patented technology that offers ultra-low V_F to reduce forward power loss and improve efficiency. Encapsulated in the new PDI-5SP package with a 0.75mm low height profile and protruding leads for easy soldering, it is especially suited for use as a bypass diode in solar panels.

Features

- Designed as bypass diodes for solar panels
- Low profile height (0.75mm) and 7.6mm protruding leads, enabling the package to be integrated within the solar glass panel
- Selectively rated for +200°C maximum junction temperature for high thermal reliability and excellent high temperature stability
- Patented Super Barrier Rectifier technology
- Ultra low forward voltage drop to minimize forward power losses
- Very low reverse leakage to ensures maximum efficiency of solar panel
- **Lead-Free Finish; RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**

Microsemi active diode:



TEXAS INSTRUMENTS

SM74611

SNVS903B – DECEMBER 2012 – REVISED MAY 2016

www.ti.com

7 Detailed Description

7.1 Overview

The SM74611 is designed for use as a bypass diode in photovoltaic modules. The SM74611 uses a charge pump to drive an N-channel FET to provide a resistive path for the bypass current to flow.

7.2 Functional Block Diagram

“Smart Diode” TO-263-3 and function diagram.

Electrical performance

In this first test, the standard diode and the active diode were measured in open air with respect to their voltage drop in forward current condition. Sense wires for voltage were applied as near to the connector pins as possible. The current was adjusted from 0 - 10A.

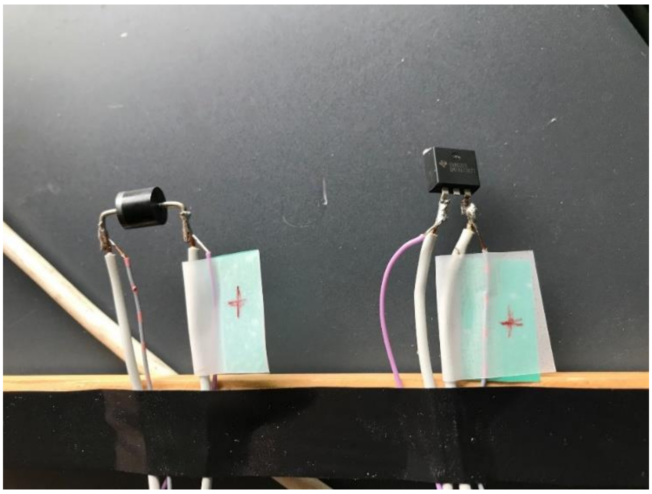


Figure 1 Diodes in free air connected with power and sense wires.

The voltage drop over the sense wires shows very different behavior for the two types:

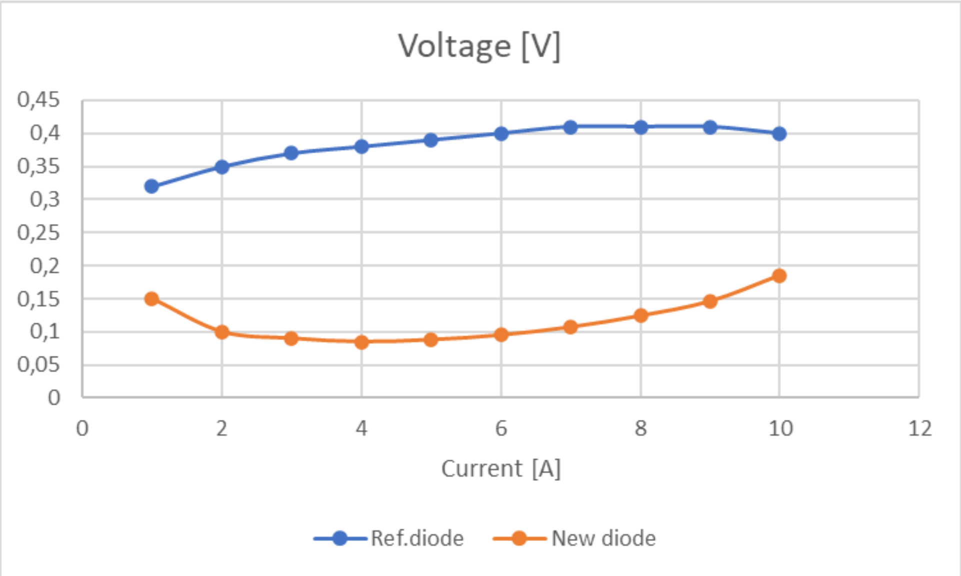


Figure 2 Comparison of voltage drop. The standard diode shows a fairly constant value of 0.35 - 0.4 V. The smart diode has its minimum voltage drop at medium load.

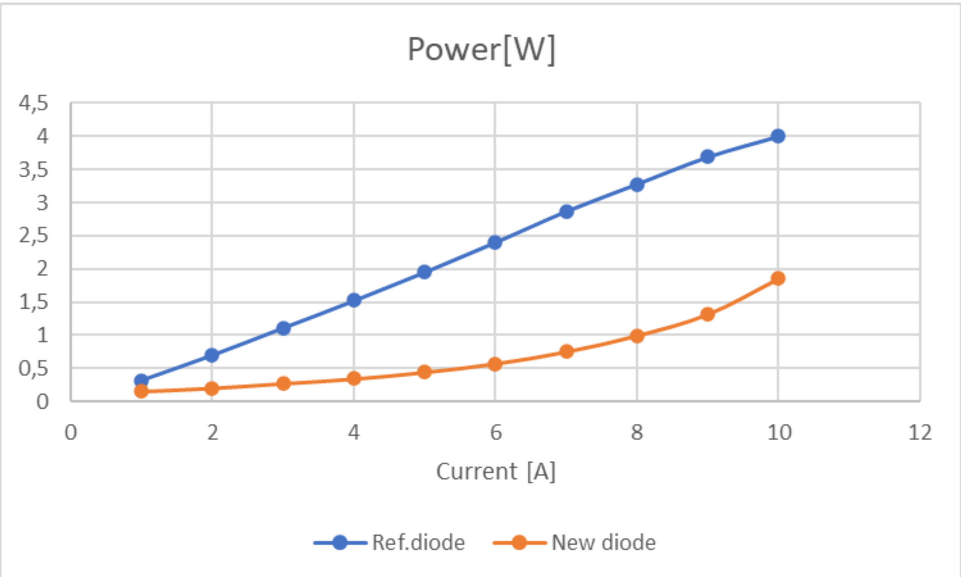


Figure 3 Comparison of power loss. The active diode has much lower loss, but it increases sharply at high current.

The measurements confirm that the smart diode dissipate much less power than a traditional diode, and therefore the smart diode is a good option for BIPV modules.

Thermal performance

In the next experiment, all three diodes were mounted on a dummy PV module from DSE. At first, they were just sticked to the surface with tape.

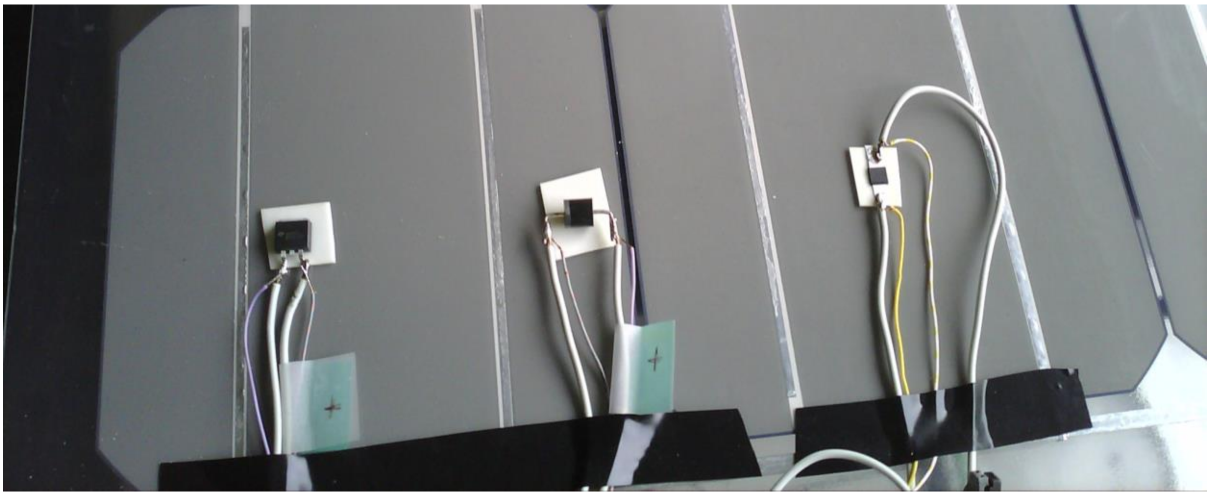


Figure 4 Mounting of three different diodes on a glass/Tedlar PV laminate. From left, it is active diode, standard diode, and flat diode (also Schottky). They are mounted on the module with double adhesive tape.

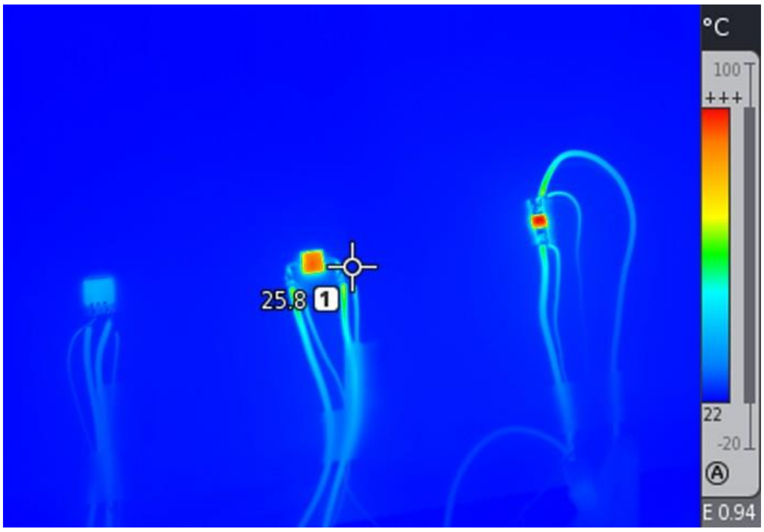


Figure 5 Thermal image seen from the back. Highest surface temperature is more than 100 degC. Current = 5A.

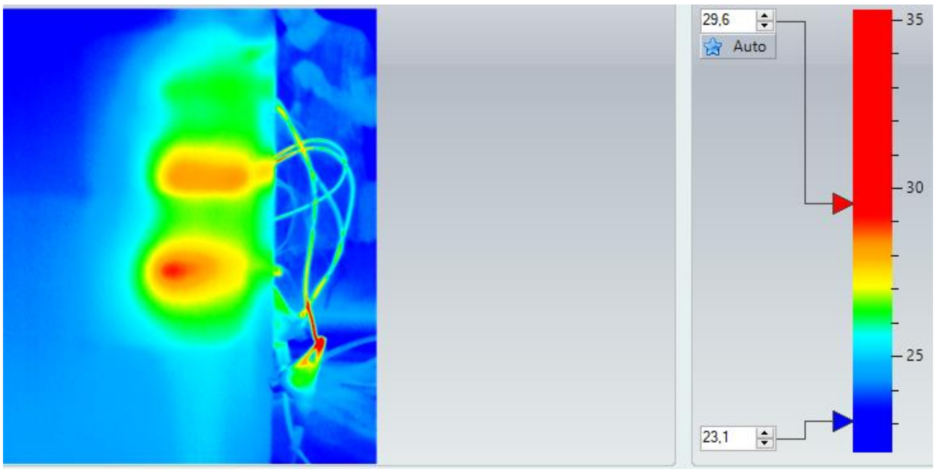


Figure 6 Thermal image seen from the front. The glass is warmest in front of the flat Schottky diode.

The heat dissipation to the glass is limited due to poor thermal contact. There is a distinct difference in surface temperature of the diodes, the cylindrical diode being the warmest. It also has the lowest contact area to the tape.

Mounting with plastic filler

In the next experiment, a non-hardening mastic was used to improve the heat conduction from the diodes to the PV laminate. The current was again 5A.

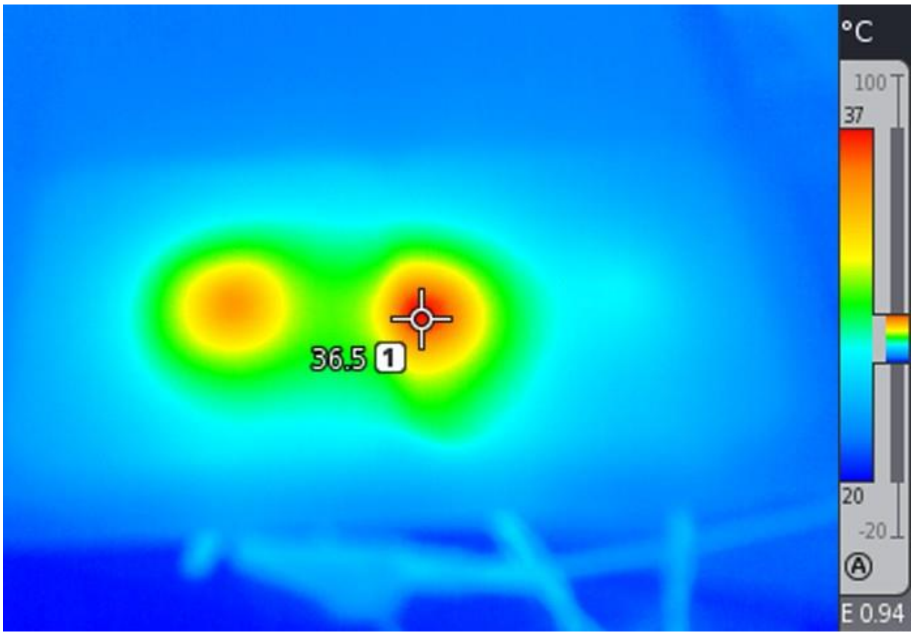


Figure 7 Thermal image from the glass side. Now the standard diode is warming the glass via the thermally conductive filler. The temperature rise of the active diode to the right is hardly seen compared to the others.

Test of junction boxes

Besides the diodes, junction boxes are also exposed for high temperature if there is no ventilation under the modules. It was therefore relevant to compare a junction box with ventilation with an insulated junction box of the same type and assess the difference in real working conditions.

On 10-09-2021, two junction boxes were tested on a small PV laminate at DTI. The junction boxes have been glued to the back with silicone like on a real PV module. A current of 5A was sent through both boxes, each containing 6 diodes. The total voltage drop was 1.9V and the dissipated power therefore approximately 10W. One half of the module was laid directly on a rigid piece of stone wool (with a cavity for the junction box to minimize cooling from the back side), and the other was uncovered. The laminate was mounted on a sloped surface pointing south.

After a preliminary indoor test, the test item was placed outdoor in sunny conditions, estimated 8-900 W/m^2 on the surface and 25 °C ambient temperature. After one hour, the temperature difference was remarkable both on the front and on the back side. The diode surface was more than 100 °C on the insulated half. The surface of the plastic box reached more than 70 °C.

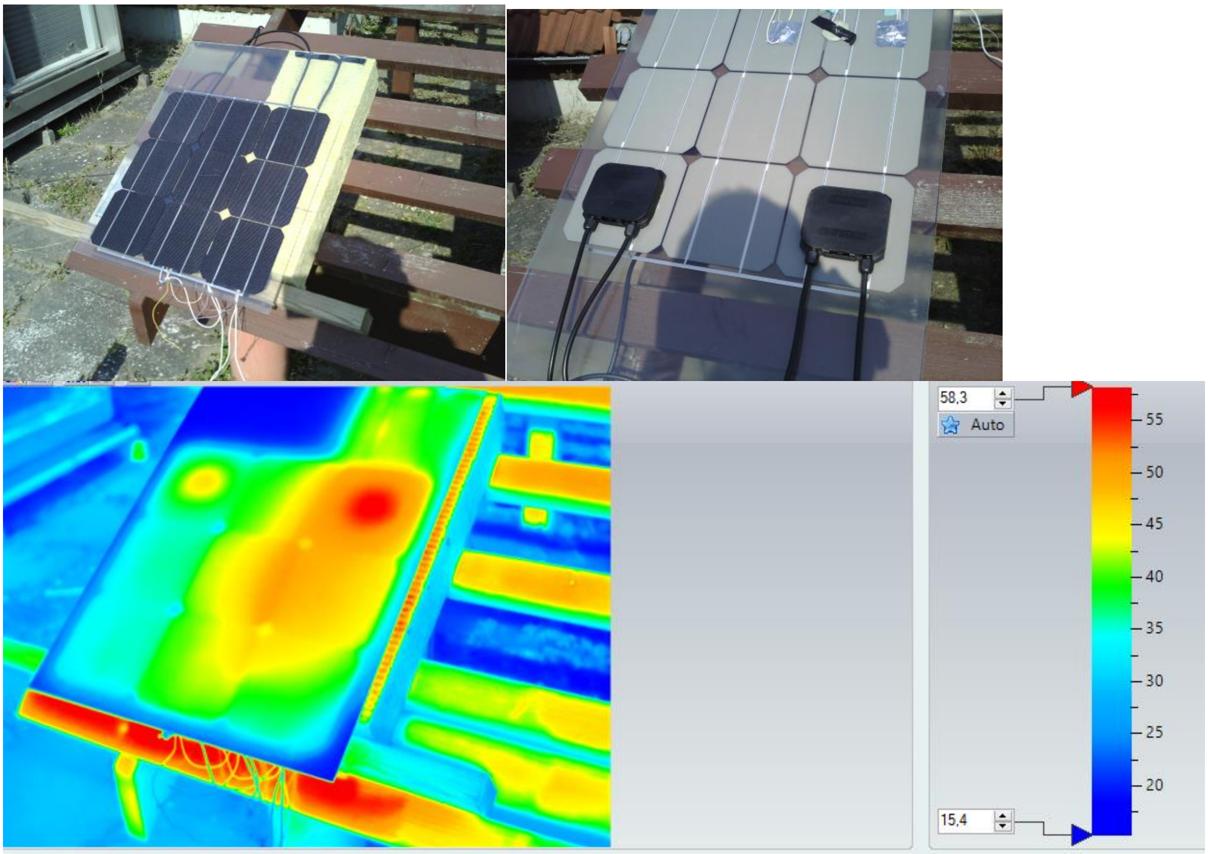


Figure 8 Thermal photo of the front glass (may not be exact but shows remarkable difference).

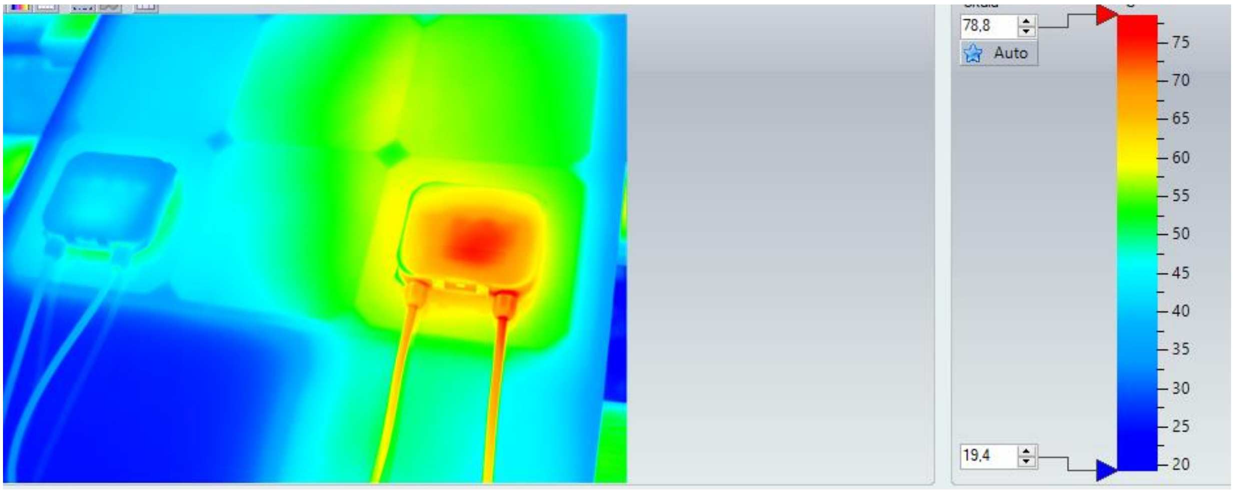


Figure 9 Temperature on the back immediately after removing insulation.

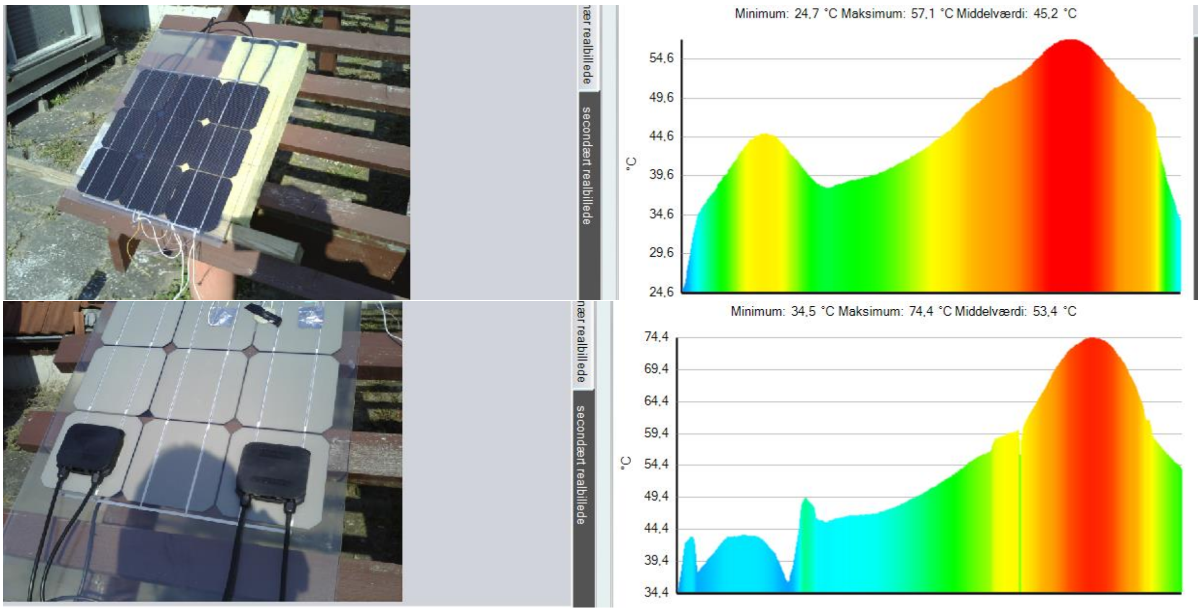


Figure 10 Temperature profile across the two junction boxes from front and rear.

The infrared images clearly show that there is an overtemperature in the range of 40K when the two boxes are compared. The maximum temperature is almost 75 °C and could become higher on hot summer days. It is therefore critical that the junction boxes used in PV-ROCK-ROOF modules are approved for higher temperature than normal.

PS: IR image temperature is indicative only as the surface emissivity and sky radiation can influence the results.

Ideas for improved cooling of junction box and diodes

Given that the ventilation is very limited in the PV-ROCK-ROOF construction, it is important to avoid overheating of diodes and junction boxes. There could be different ways to achieve this:

- Use many diodes in parallel and distributed over a large surface
- Integrate a heat dissipating metal sheet in the laminate

DANISH
TECHNOLOGICAL
INSTITUTE