Appendix A: In-situ Dark Voltage

During CID experiments, either dark IV characteristics of the PV modules were measured in-situ, or the voltage in the point of operation at constant current was monitored.
Fig. 16 shows the relative voltage change of module M09, which was subjected to LETID testing at 75 °C and 2 x (I_{SC} - I_{MPP}), during the first LETID test interval. All voltage values were temperature corrected using a temperature coefficient, which was derived from dark IV measurements on module M13. Hourly average values (orange) were calculated following 2 PfG 2689/04.19 and the IEC TS draft.
A local voltage minimum can be located between 30 h and 60 h of LETID testing. Since only low voltage increase is observed before the first intermediate measurement after 96 h of testing time, the power loss measured at STC after 96 h is close to the maximum power loss during the test.
Equivalent to the dark voltage, the relative change of the voltage at I_{SC} - I_{MPP} was extracted from the dark IV characteristics of module M13, which were measured in-situ during a dark storage experiment at 75 °C without intentional carrier injection (see Fig. 17). A continuous voltage drop can be observed during all dark storage intervals with dark IV monitoring.

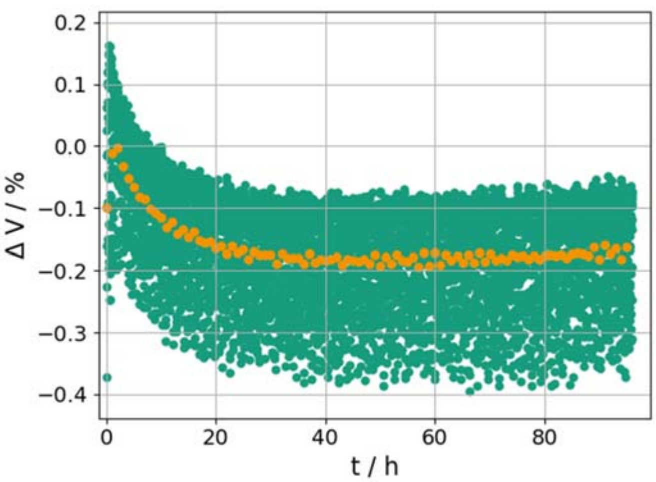

Fig. 16. Dark Voltage Monitoring of M09 during the first LETID test interval

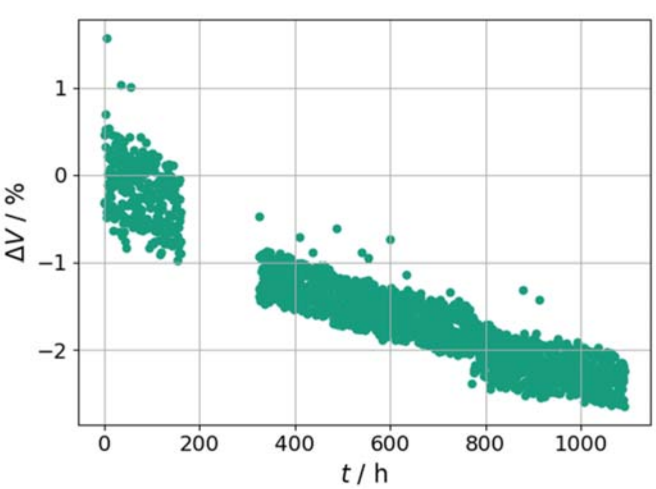

Fig. 17. Relative voltage change at I_{SC} - I_{MPP} in the dark IV characteristic of module M13 during dark storage at 75 °C without carrier injection (Intervals 1, 3-6).

Appendix B: Module temperature during outdoor exposure

The distribution of the average module temperature of two mono-crystalline and two multi-crystalline PV modules during outdoor exposure intervals between indoor characterization measurements are shown in Fig. 18 and Fig. 19. Only temperature values at times, when the in-plane irradiation was above 10 W/m², were included in the graphs. The average temperature values of the mono-crystalline PV modules were calculated on the basis of temperature measurements of three PT100 sensors which were attached to different positions on each module's rear side (top, middle, bottom). In case of the multi-crystalline PV modules, the same method was used for the intervals 1 to 8 (April 18, 2019 to June 22, 2020). After the installation of the mono-crystalline PV modules only one PT100 sensor was available for each multi-crystalline module, which was attached to the middle of the module rear side.

The modules were exposed during the following intervals:

1) April 18 – May 21, 2019
2) May 28 – July 2, 2019
3) July 5 – July 31, 2019
4) August 6 – October 1, 2019
5) November 21, 2019 – January 21, 2020
6) January 28 – April 8, 2020
7) April 17 – May 12, 2020
8) May 22 – June 22, 2020
9) June 24 – July 22, 2020
10) July 23 – August 25, 2020
11) September 1 – October 5, 2020
12) October 9 – December 9, 2020
13) December 11, 2020 – January 19, 2021
14) January 22 – March 1, 2021
15) March 2 – April 8, 2021
16) April 9 – May 14, 2021
17) May 14 – June 15, 2021
18) June 18, 2021 - July 27, 2021
19) July 28, 2021 - September 1, 2021

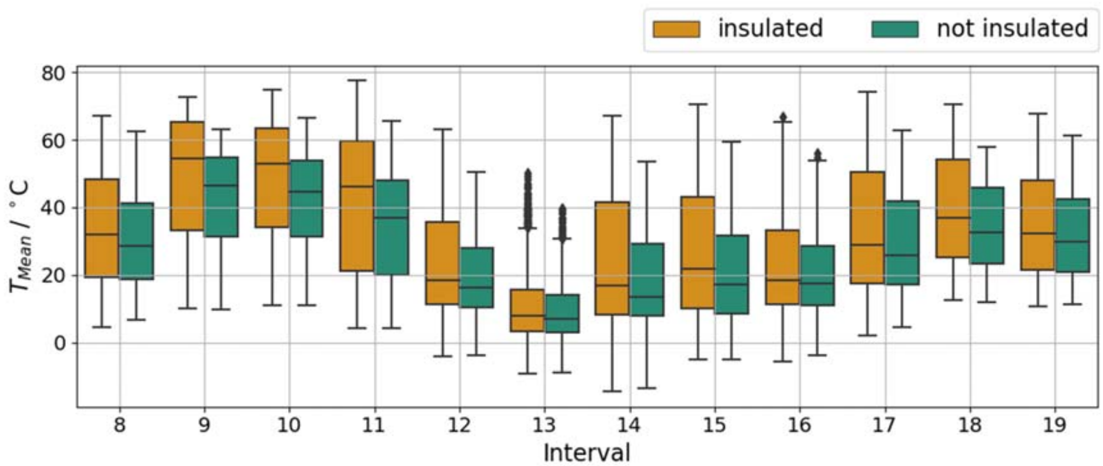

Fig. 18. Distribution of the module temperature of two Mono-PERC modules during outdoor exposure intervals at times with irradiance > 10 W/m².

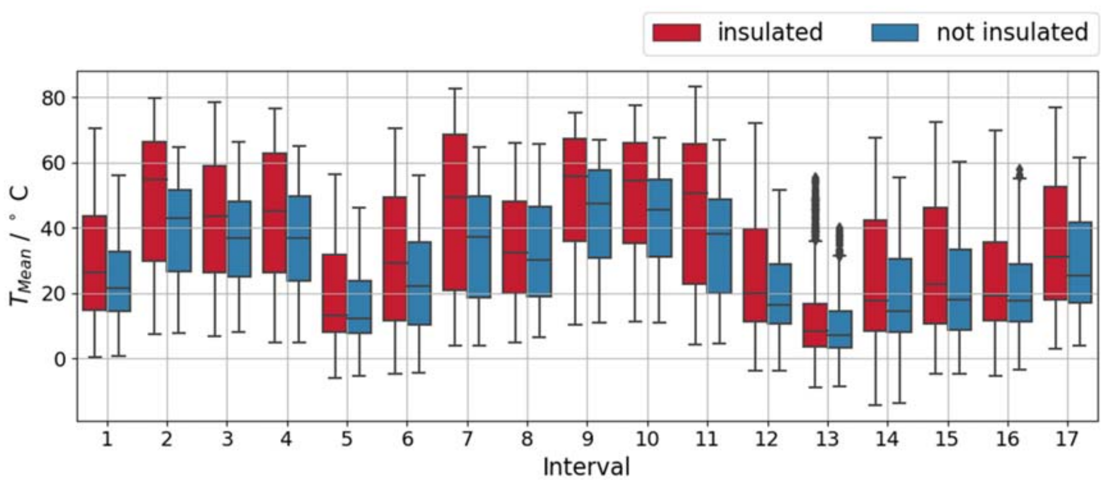

Fig. 19. Distribution of the module temperature of two Multi-PERC modules during outdoor exposure intervals at times with irradiance > 10 W/m²

Appendix C: Electroluminescence images of the multi-crystalline PV Modules (Outdoor Test)

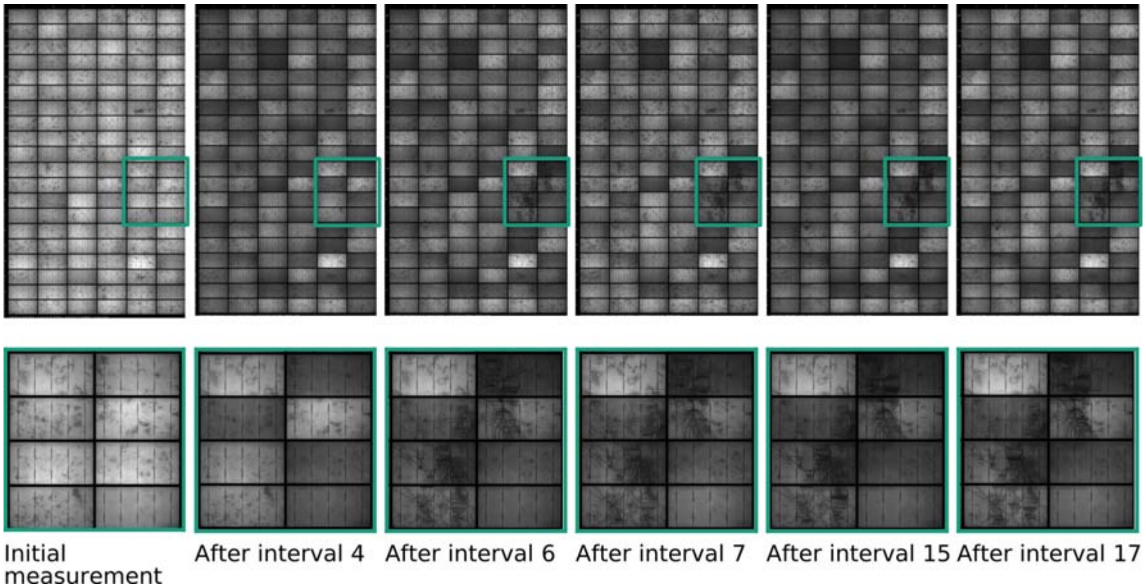

Fig. 20. Electroluminescence images of the thermally insulated multi-crystalline PV module before and after exposure intervals in the outdoor test. The images have been taken at a current of I_{SC} (nameplate value).

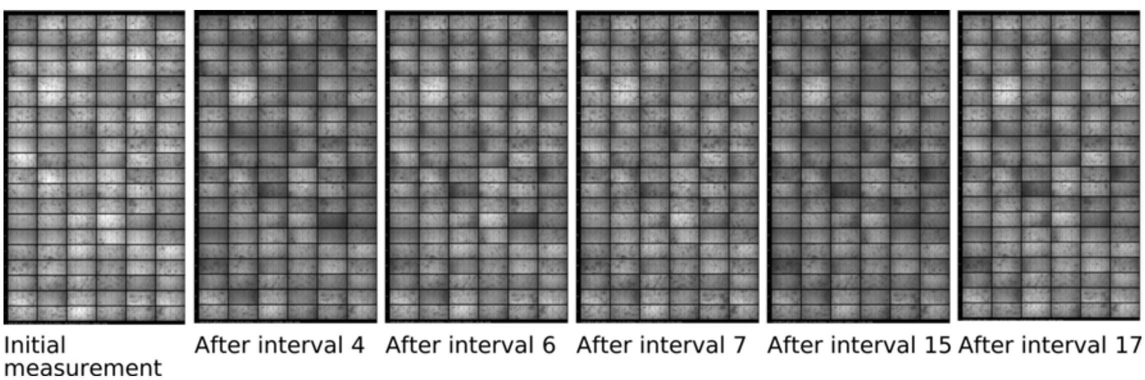

Fig. 21. Electroluminescence images of the non-insulated multi-crystalline PV module before and after exposure intervals in the outdoor test. The images have been taken at a current of I_{SC} (nameplate value).