# nanosolar KEEPING THE WATER OUT FOR 25 YEARS

## NANOSOLAR UTILITY PANEL

DESIGN FOR DAMP HEAT RELIABILITY

- Glass/glass package
- Water resistant junction-box
- Edge-seal embedded with desiccant

## MODELING

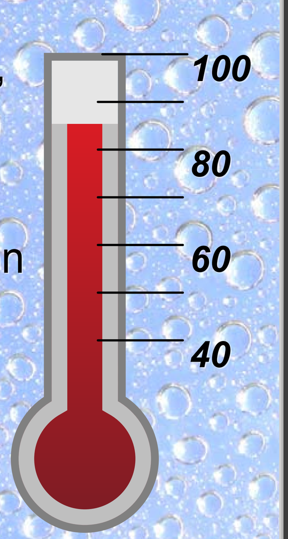
To define the appropriate width of edge-seal that would protect the CIGS from moisture degradation over the panel lifetime, a 1-D diffusion process has been used. Nanosolar edge-seal has been modeled as a finite volume of a Fickian material filled with a desiccant to immobilize water until it saturates. The results of this model have been validated against experimental data sets (Figure 1).

Using real environmental data, simulations of water penetration over 25 years can be run for various edge seal thicknesses and various climates. Based on the Nanosolar model, 7.5 mm is the absolute minimum edge seal width allowable for 25 year lifetime (Figure 2) but based on damp-heat experimental data, 9 mm is a more realistic width.

Therefore, after taking into account process variations and adding a 1 mm safety margin, Nanosolar edge-seal width specification has been set to 11 mm ±1 mm.

## CONTEXT

From 2005 to 2007, 70% of the thin film panels and 28% of the crystalline silicon panels tested for qualification failed 1000 hours damp heat test. [1]




## BACKGROUND

Damp heat exposure is particularly harmful to CIGS devices with humidity being the primary cause of degradation. The challenge for Nanosolar was to design and manufacture a robust package that could keep moisture out during 25 years.

Glass/glass packages which restrict potential moisture ingress to the edge of the panel and through the junction-box was an obvious choice but this design still has significant moisture ingress through its edges [2]. The preferred way to prevent moisture ingress over the lifetime of the panel is by adding a low-diffusivity edge-seal embedded with an active moisture absorber.

### Water penetration in the edge-seal in HALT

No water breakthrough observed yet in panels after 6000 hours of damp-heat.

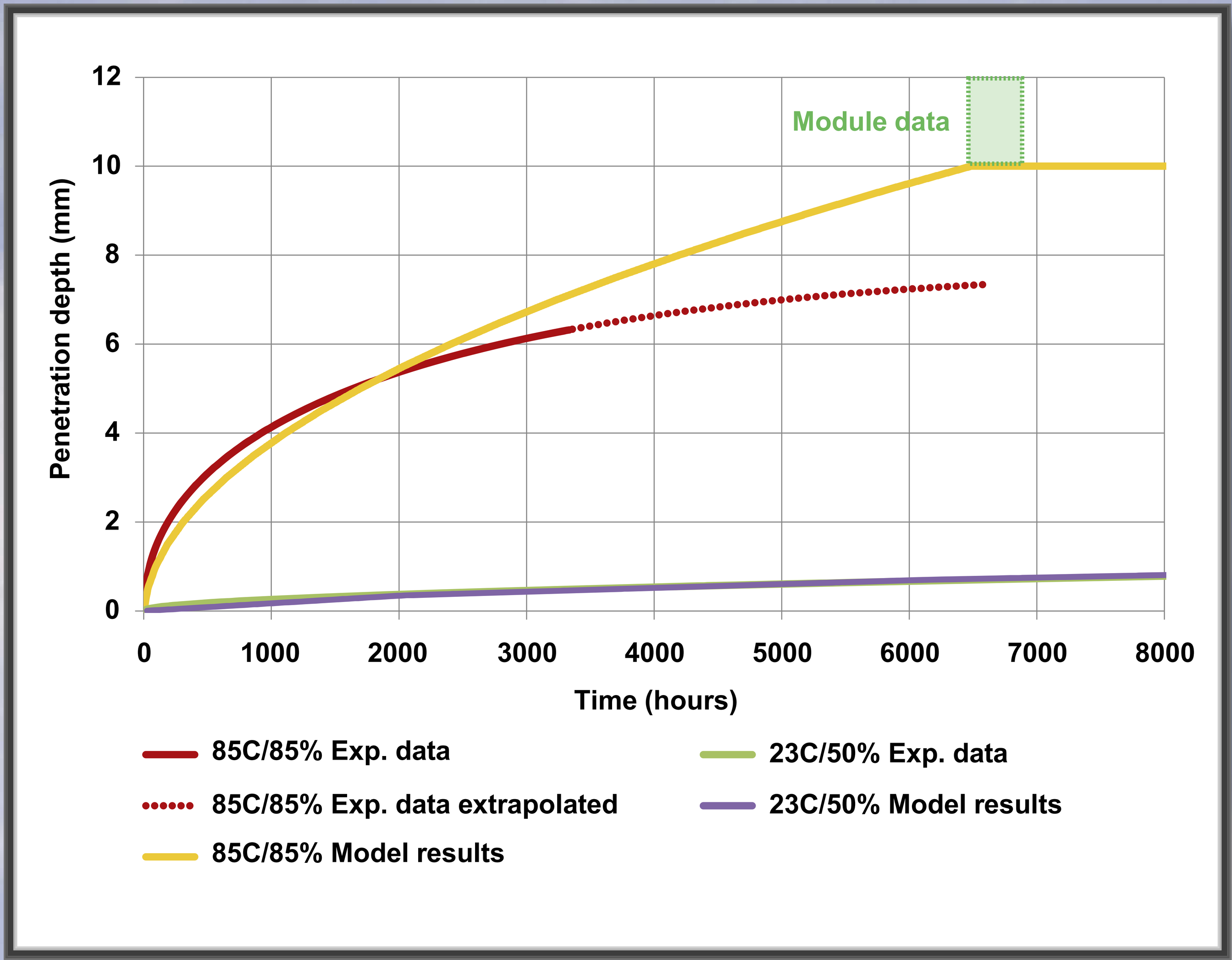



Figure 1

### Damp Heat

Nanosolar panel withstands more than 3000 hours of damp heat with less than 5% change in power and no wet-leakage failures.

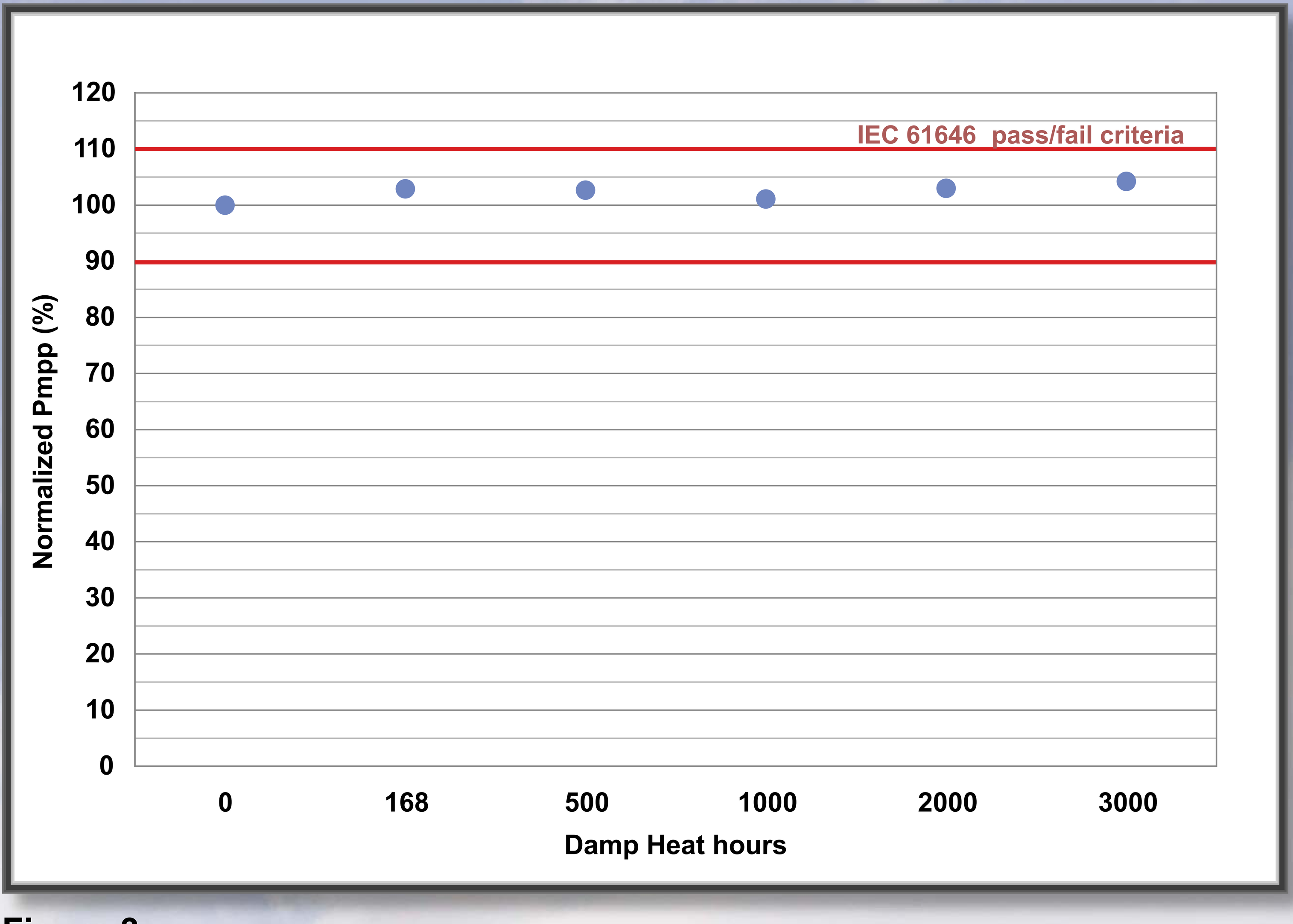



Figure 3

### Water penetration in the edge-seal in Hawaii

Simulation of the water penetration depth for different edge-seal thicknesses in Honolulu, Hawaii.

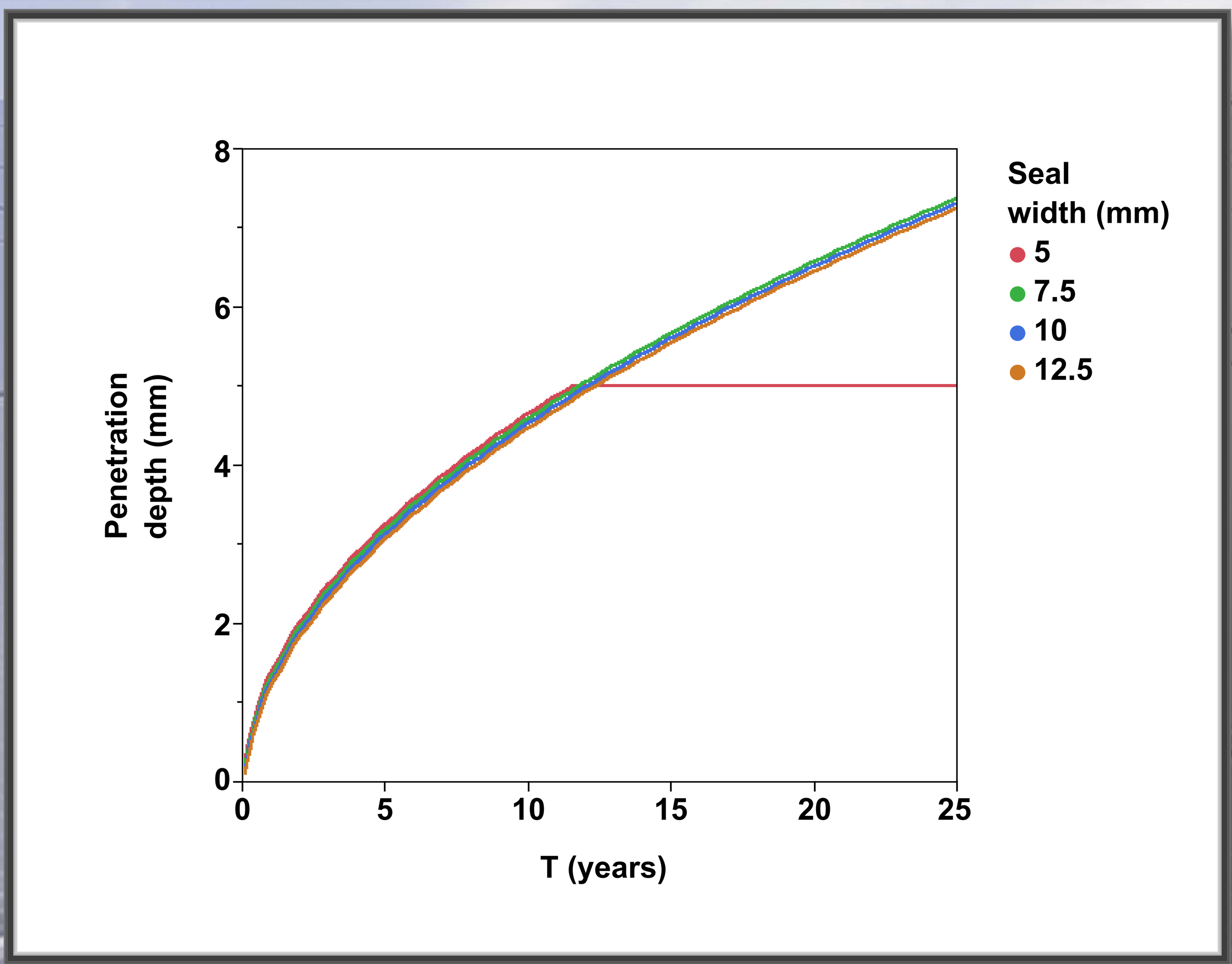



Figure 2

### Damp Heat and High Voltage

Nanosolar panel withstands 1000 hours of damp heat and 1500V test with less than 5% change in power and without structural damage.

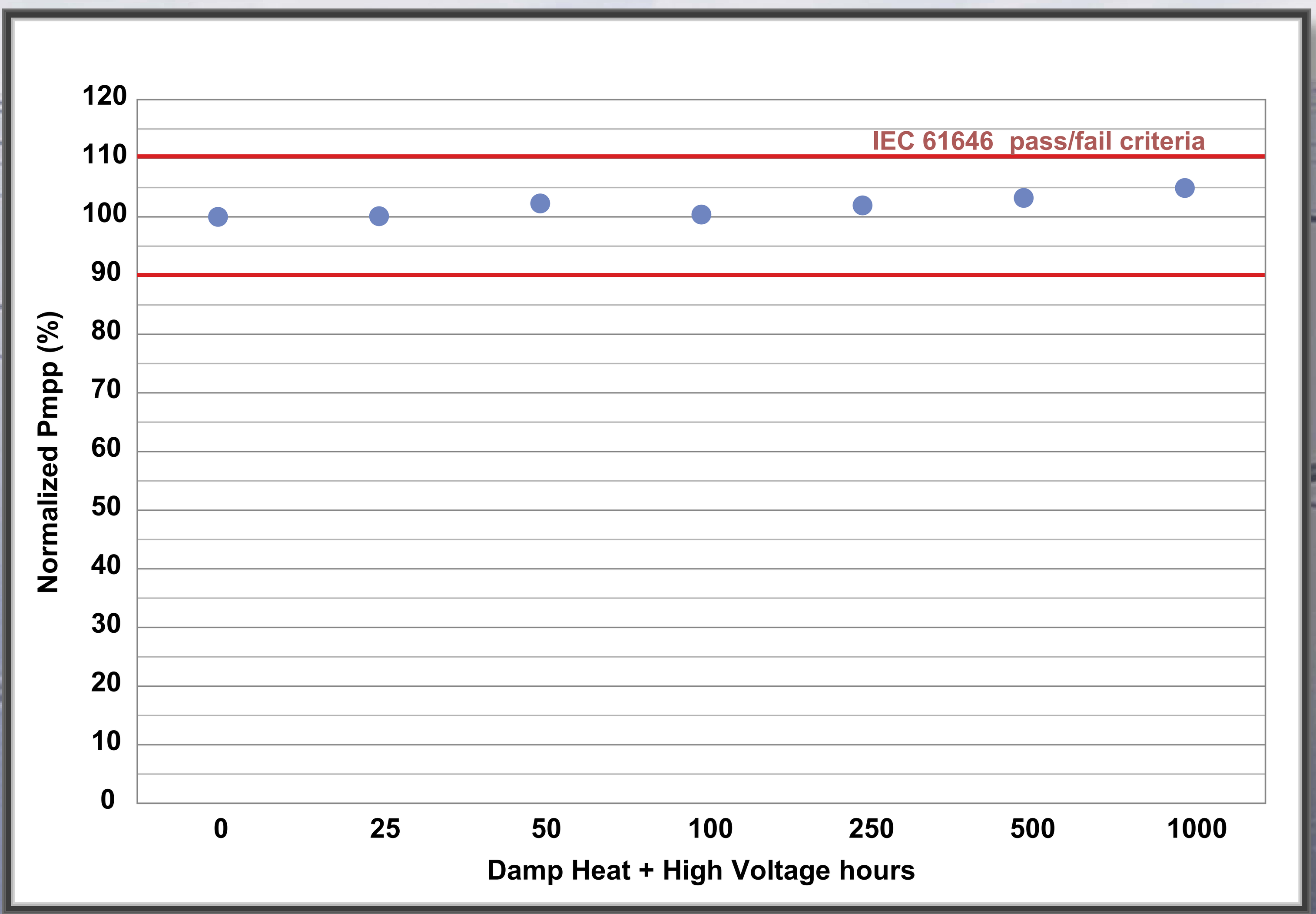



Figure 4

## DAMP-HEAT TESTS

By choosing the right materials and the right design, the Nanosolar panel can withstand more than 3000 hours of damp heat test with less than 5% change in power (Figure 3) and without failure in the wet-leakage test.

As the Nanosolar Utility Panel has been designed for high-power and utility-scale applications, it was important to test its ability to withstand high voltage relative to ground. Therefore, in collaboration with ZSW Photovoltaic Department, Nanosolar performed a damp-heat test with high voltage. During the exposure time in the climate chamber, a voltage of -1500V is connected between the positive pole of the panel and the metallic structure that retains the panel.

As expected and reported in the literature [3], Nanosolar packaging blocked leakage current very effectively in the damp-heat test. After 1000 hours of damp-heat with high-voltage, Nanosolar panels have more than 4% power increase and no structural damage (Figure 4).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[1] G. TamizhMani; B. Li; T. Arends; J. Kuitche; B. Raghuraman; W. Shisler; K. Farnsworth; J. Gonzales; A. Voropayev; P. Symanski; Failure analysis of design qualification testing: 2007 VS. 2005; 2008 33rd IEEE Photovolatic Specialists Conference (May 2008), 2008, pg. 1-4

[2] Kempe, M. D. 2006 “Modeling of Rates of Moisture Ingress into Photovoltaic Modules”, Solar Energy Materials and Solar Cells, Vol. 90, pp. 2720-2738

[3] Hacke, P.; Terwilliger, K.; Glick, S.; Trudell, D.; Bosco, N.; Johnston, S.; Kurtz, S. R. (2010). Test-to-Failure of Crystalline Silicon Modules: Preprint. 10 pp.; NREL Report No. CP-5200-47755