Contract No. 019718 (SES)

PERFORMANCE

A science base on photovoltaics performance for increased market transparency and customer confidence

Integrated Project

Priority 6.1.ii – Sustainable Energy Systems

D5.7.1
Methodology for service life prediction based on accelerated testing

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (incl. the Commission Services)	
CO	Confidential, only for members of the consortium (incl. the Commission Services)	

The stresses temperature, humidity and UV-radiation are modelled by appropriate mathematical procedures based on measured time series of loads and climates at 4 different outdoor test sites, which represent a tropical (Indonesia), arid (Israel), alpine (Germany) and urban (Germany) climate. All data were recorded every minute. One year data were used for the evaluation of the stresses.

Data evaluation and modelling

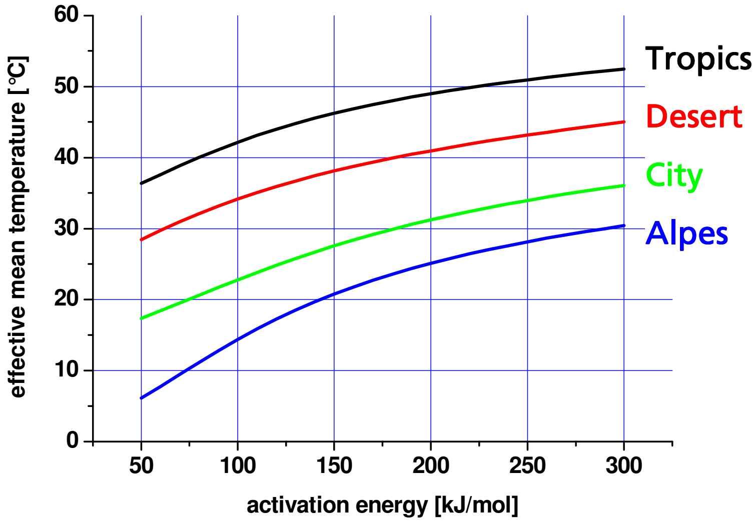
Service life estimation needs to determine the degradation reaction kinetics of the degradation rate dominating processes and the correlation between outdoor exposure and accelerated testing. Deterministic models are usually applied for the extrapolation of the degradation data to the design end of life time [1,2]. Their parameters have to be evaluated from the results of lab tests under well defined and well-controlled conditions, usually called “screening testing”.

$$\Delta P_j = \Sigma^j_{i=1} \{\Sigma_p (A_p\ I_i^n\ \Delta t_i \exp[-E_p /RT_i] \exp [C_p * rF_i])\} \qquad (1)$$

Where P is the considered performance property, p is the number and A, E, C, n are the parameters of the relevant degradation processes, Δt is a time interval, during which the Irradiation I, the temperature T and the relative humidity (or TOW) is assumed to be constant.

Temperature

The temperature loads depend on the climatic conditions. One way to get an idea about the different stresses at different locations is the calculation of the effective temperature load (see equation 2) according to the deterministic degradation model shown in equation 1. We did so for the 4 different locations.



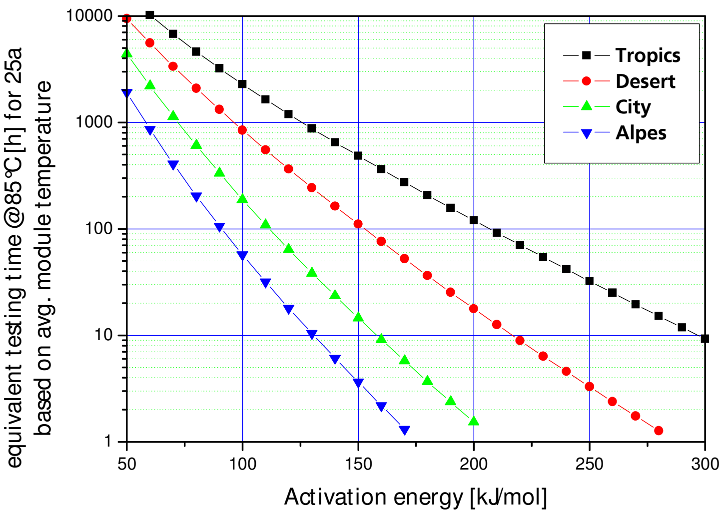


Figure 5.7.1: Effective mean temperature load as function of the activation energy of the rate dominating degradation process for the different test sites (top) and the corresponding testing times at 85°C for 25 years lifetime.

The integration of the measured module-temperature for a given time period (one year, e.g.) is assumed to result the same changes of the performance as a constant temperature load Teff during the same time period, if the simple Arrhenius model can be applied.

$$\exp[-E_p / RT_{eff}] = 1/(t_{max}-t_{min}) \Sigma^{tmax}{}_{tmin} \exp[-E_p / RT(t)] \Delta t \qquad (2)$$

The activation energy as the remaining parameter determines, how much a degradation process could be accelerated by temperature increase.
The effective temperature can be used as characterization of climatic locations with respect to the thermal stress. It is the base for further time – and temperature transformations for the design of appropriate conditions for service life testing [2,3].

UV- radiation

The maximum observed UV-load was 120 kWh/m²a in the desert. It sums up to 3000 kWh/m² for a lifetime of 25 years. That is a factor of about 200 more than the 15 kWh/m²a required in the IEC 61215 standard for module type approval for pre-conditioning. Enhancing the temperature helps accelerating. Therefore the temperature-depending UV-load is the base for evaluating accelerated tests (see figure 5.7.2) by means of eq. 1.

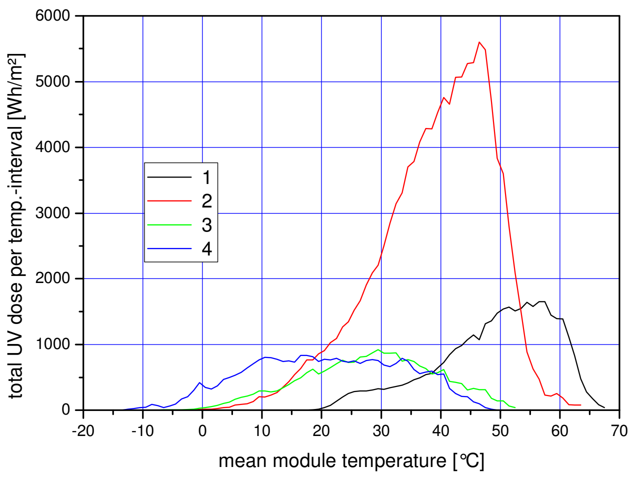


Figure 5.7.2: Frequency distribution of the UV dose as a function of the average PV-module temperature for the different test sites (note that the UV-sensors at site 1, 3, 4 have to be recalibrated).

UV-testing of PV-modules is performed at 60°C sample temperature according to the PV-module type approval standard IEC 61215. A higher sample temperature can shorten the testing times drastically, as can be clearly seen in figure 5.7.2 and allow service life testing in less than 1 year or even less than some weeks, depending on the activation energy of the photo-degradation process.

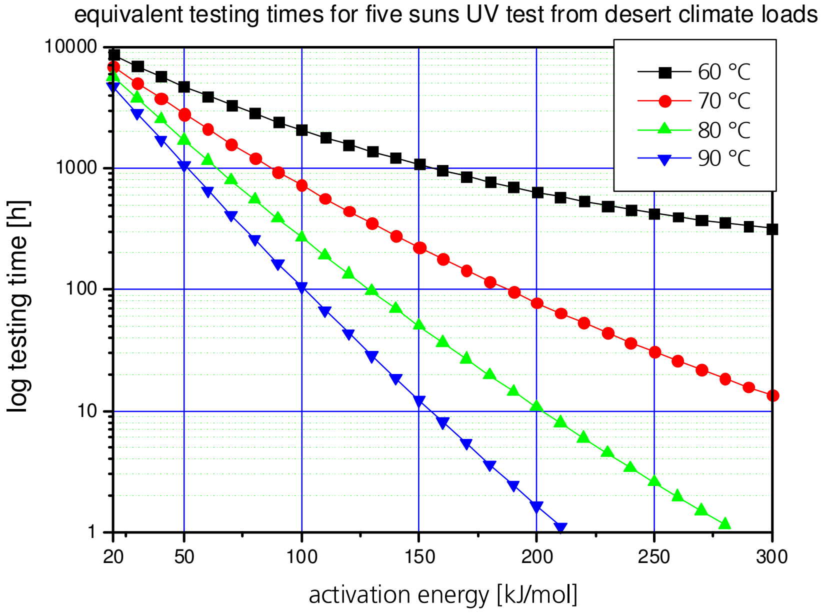


Figure 5.7.3: Estimated testing times as a function of the activation energy for 5X UV-intensity and different sample temperature for 25 years exposure at the desert site

Humidity

A similar approach for the evaluation of the test procedures for the dry temperatures was used for the TOW. Here we made a complete time-transformation to the well-known damp-heat-conditions (85%RH @85°C) for which figure 5.7.2 shows the testing times corresponding to the fluctuation of temperature and humidity at the real test sites. The standardized 1000h damp-heat test might be appropriate for 25 years lifetime at a dry mountain climate for degradation processes with activation energies down to 50 kJ/mol, but for tropical humid climates the limit is 70 kJ/mol. The activation energy of the dominating degradation process is due to the permeation of the water vapour through the back-sheet and the encapsulation material. The activation energy of the diffusion coefficient of water in EVA was determined to be about 34 kJ/mol. Figure 5.7.4 shows that in this case the damp-heat test of about 4000h might be corresponding to a service life of 25 years at the dryer test sites, but for tropical climate a life-test duration of 12000 h (about 1.5 years) might be required.

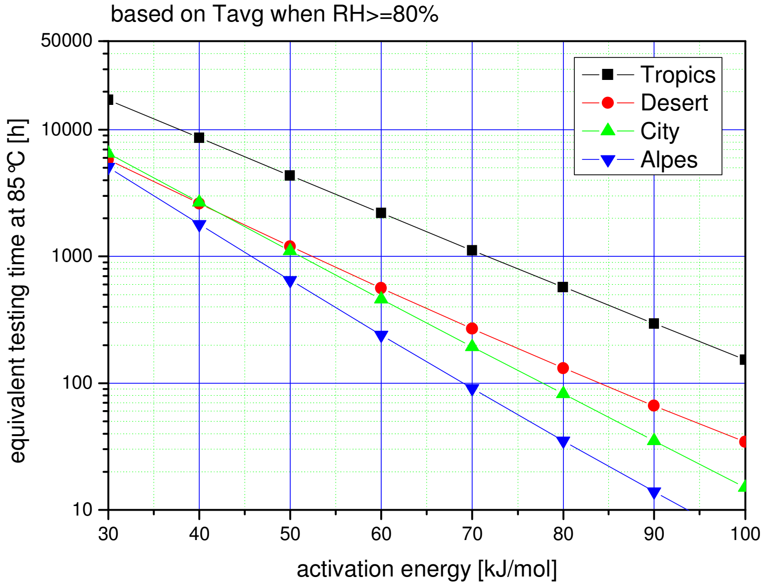


Figure 5.7.4: Equivalent constant testing times for a damp-heat test (85%RH @ 85°C) for a service life of 25 years as function of the activation energy for the monitored one-year exposure data at the 4 different test sites.

Disclaimer
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