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Office of Energy Efficiency & Renewable Energy

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Comparison of Degradation Rates of Individual Modules Held at Maximum Power

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Outline

- Purpose
- Published degradation rates
- NREL measurement procedure
- Degradation rate results
- Discussion and conclusions

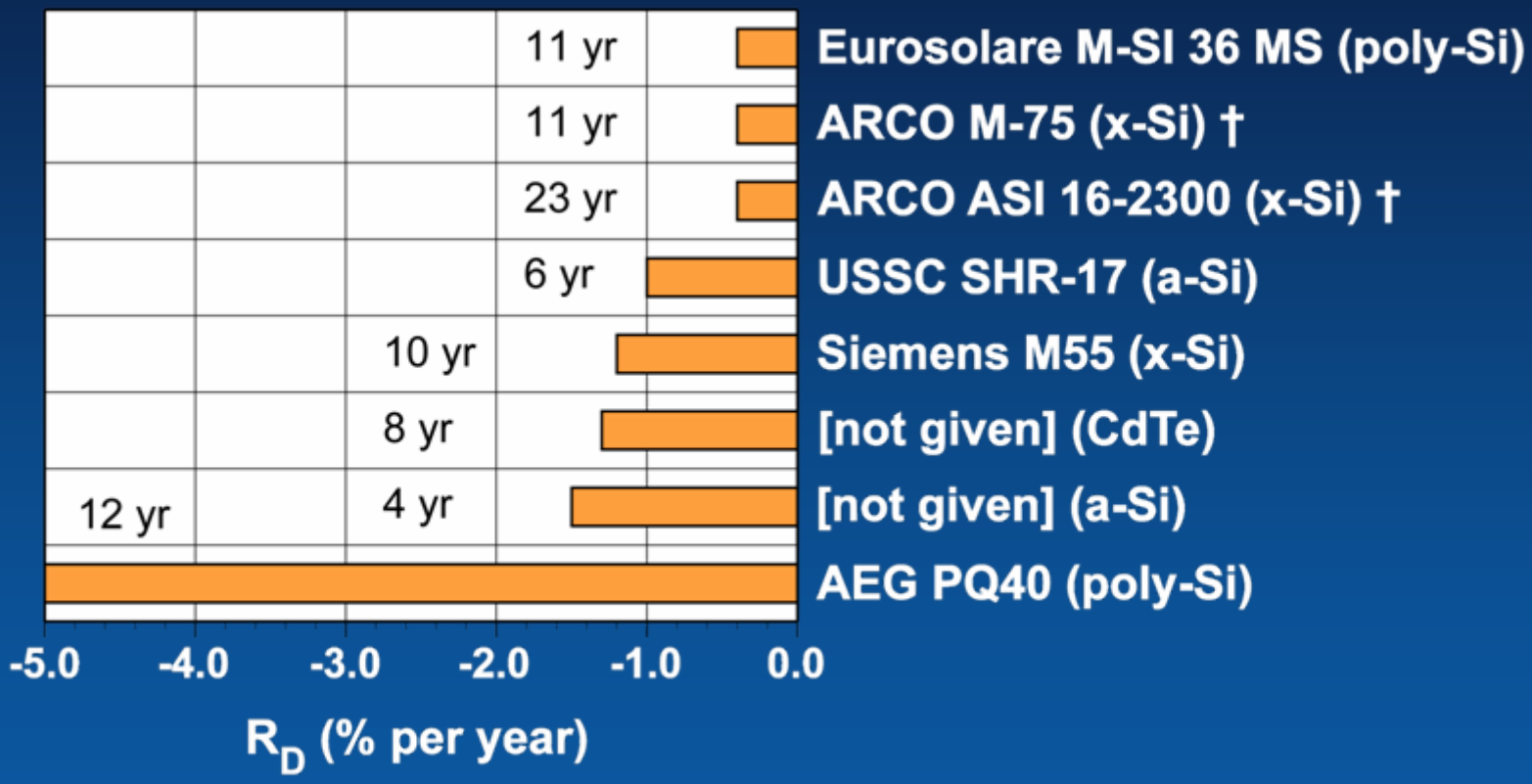
Purpose

- Module degradation rates (R_D) needed for accurate PV system energy delivery calculations
- Time-consuming measurement
- R_D data are generally unavailable
- System sizing software PVWATTS:
  - Has an input for aging loss, but defaults to no loss
  - Recommends using the common rule-of-thumb 1% per year
- Attempt to quantify PV module R_D

Published Degradation Rates

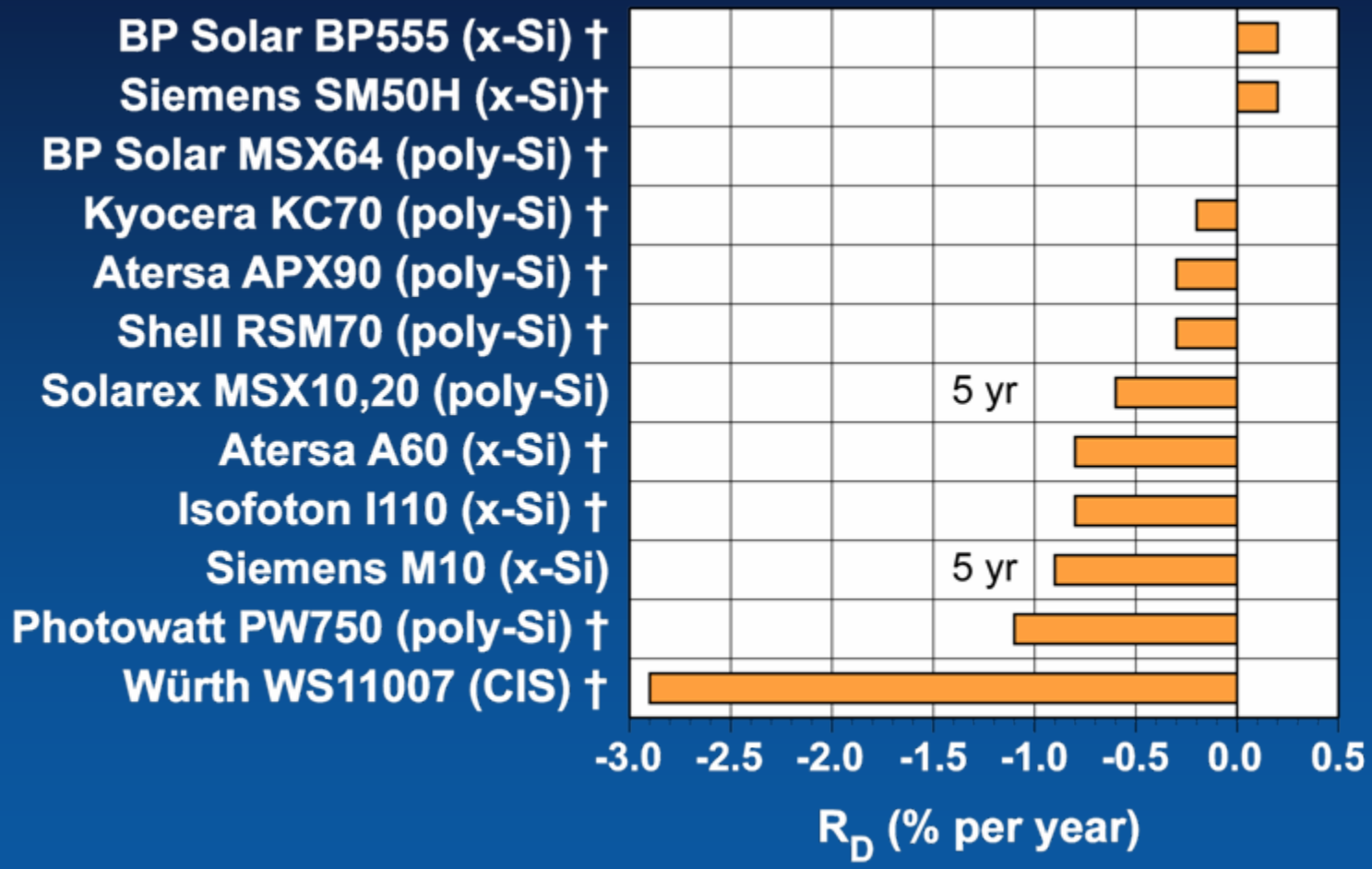
- PV literature search for published R_D values
- Only nine references since 2000 found
- Indication of measurement difficulties
- All but two are from modules exposed in systems
- R_D values derived from system data can include factors unrelated to modules, such as:
  - Inverter operation; max. power tracking
  - Wiring degradation
- System exposures provide more statistics

Published R_D — Systems



† Based on individual module performance measurements

Published R_D — Modules



† N. Cereghetti, et. al., 3rd WCPEC, Osaka, May 2003

NREL R_D Measurements

- Performance & Energy Ratings Testbed (PERT) on roof of Outdoor Test Facility
- Operational since 1994
- Currently 35 modules under test

PERT Data Acquisition

- 3 Raydec Multi-Tracer II max-power tracking loads
- 15 module channels each
- I-V curves every 15 min.
- Irradiance and back-of-module temperature measurements

PTC Power Rating Calculations

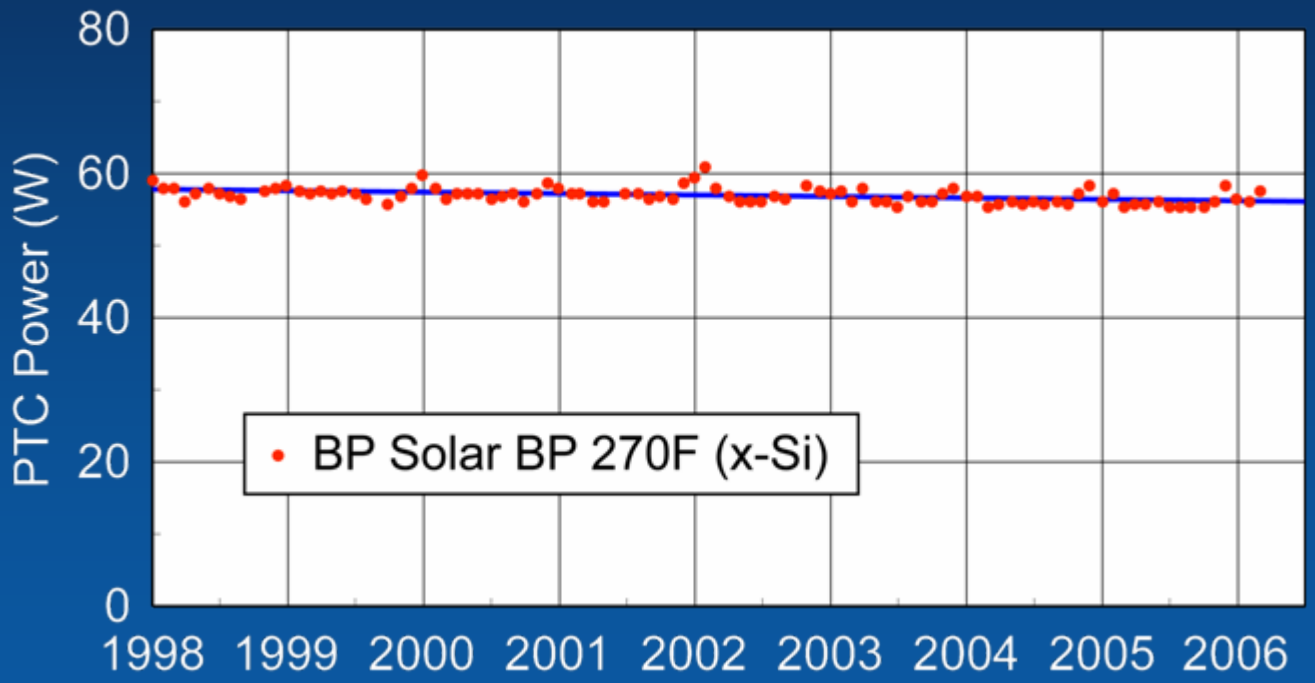
- P_{max} extracted from I-V curves and combined with E, T, and s
- For E > 800 W/m^2, 1 month of data fit to Performance Test Conditions (PTC)
- Using regression results, power rating @ STC calculated

$$P = E\left[a_1 + a_2 E + a_3 T + a_4 s\right]$$

PTC: E = 1000 W/m^2, T = 20°C, s = 1 m/s

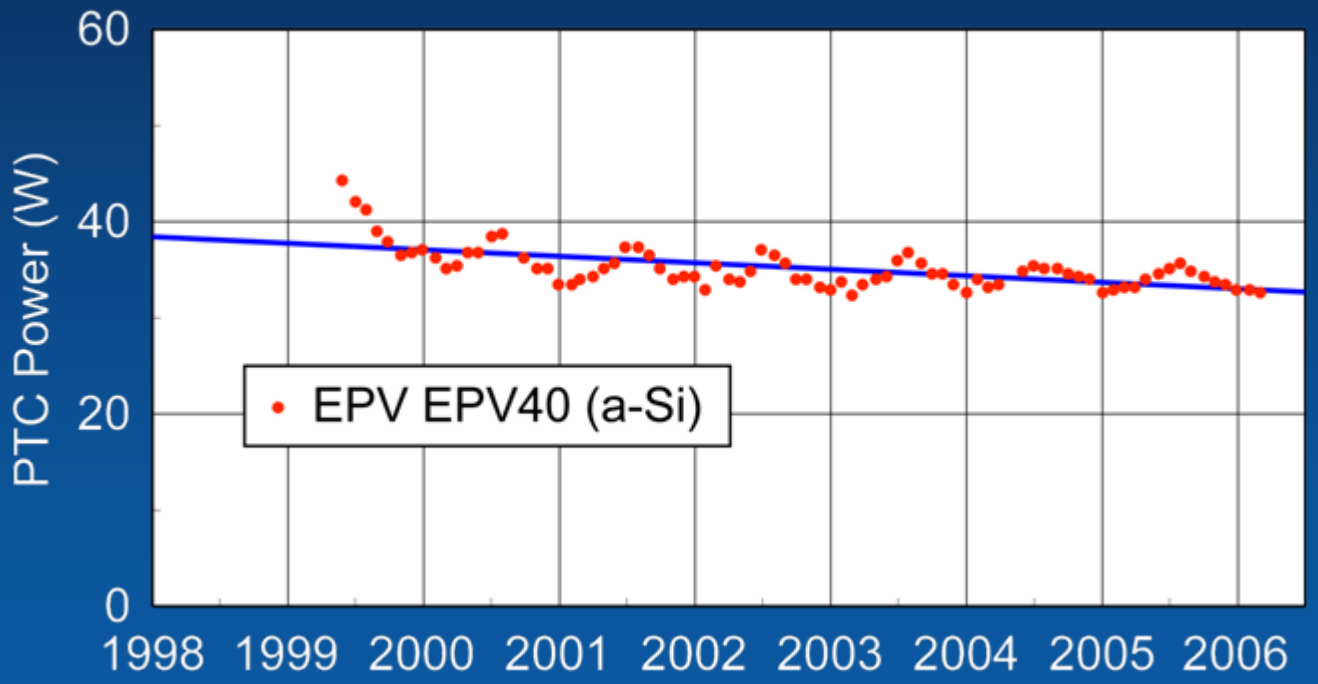
R_D Determination

- PTC ratings plotted versus time
- Slope of linear fit gives R_D (-0.35 %/yr)

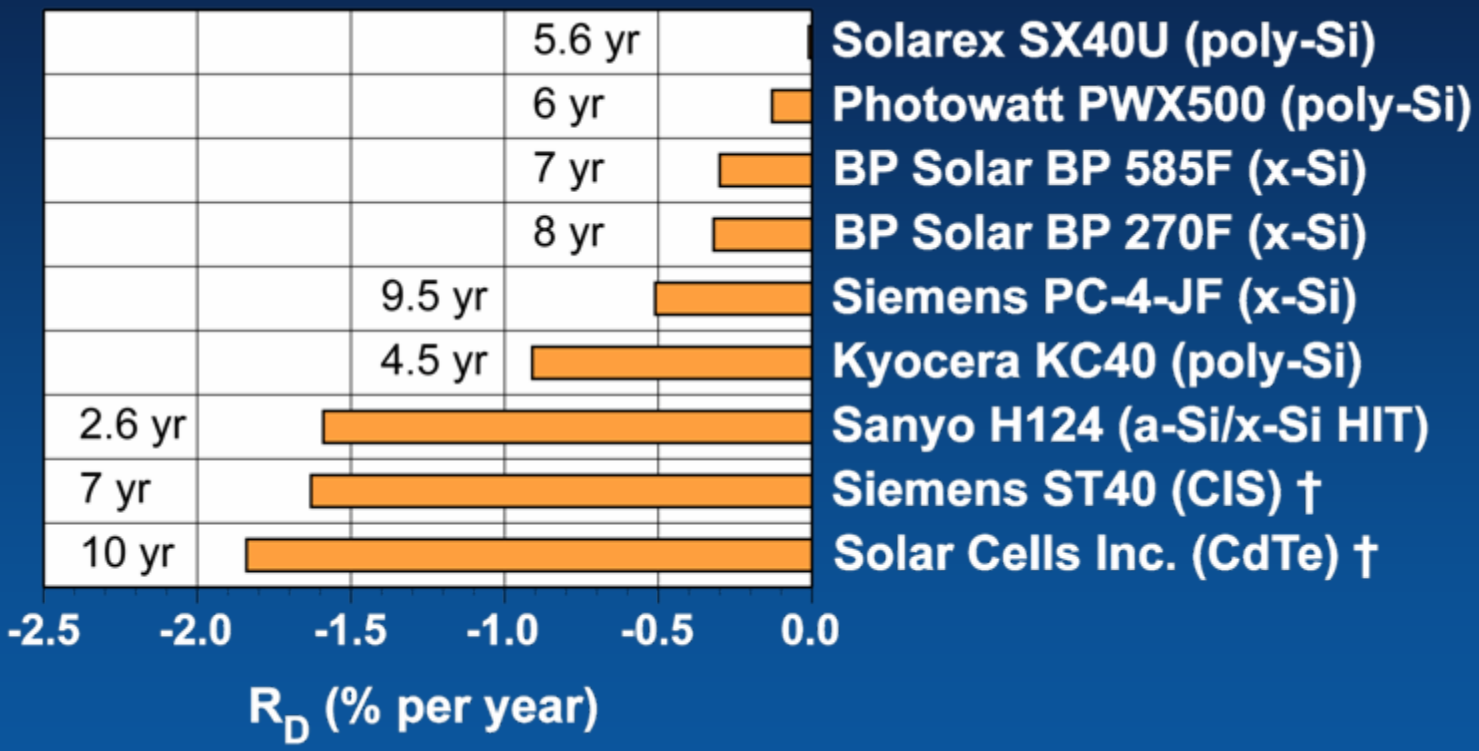


Pitfalls

- a-Si initial stabilization
- Seasonal variations

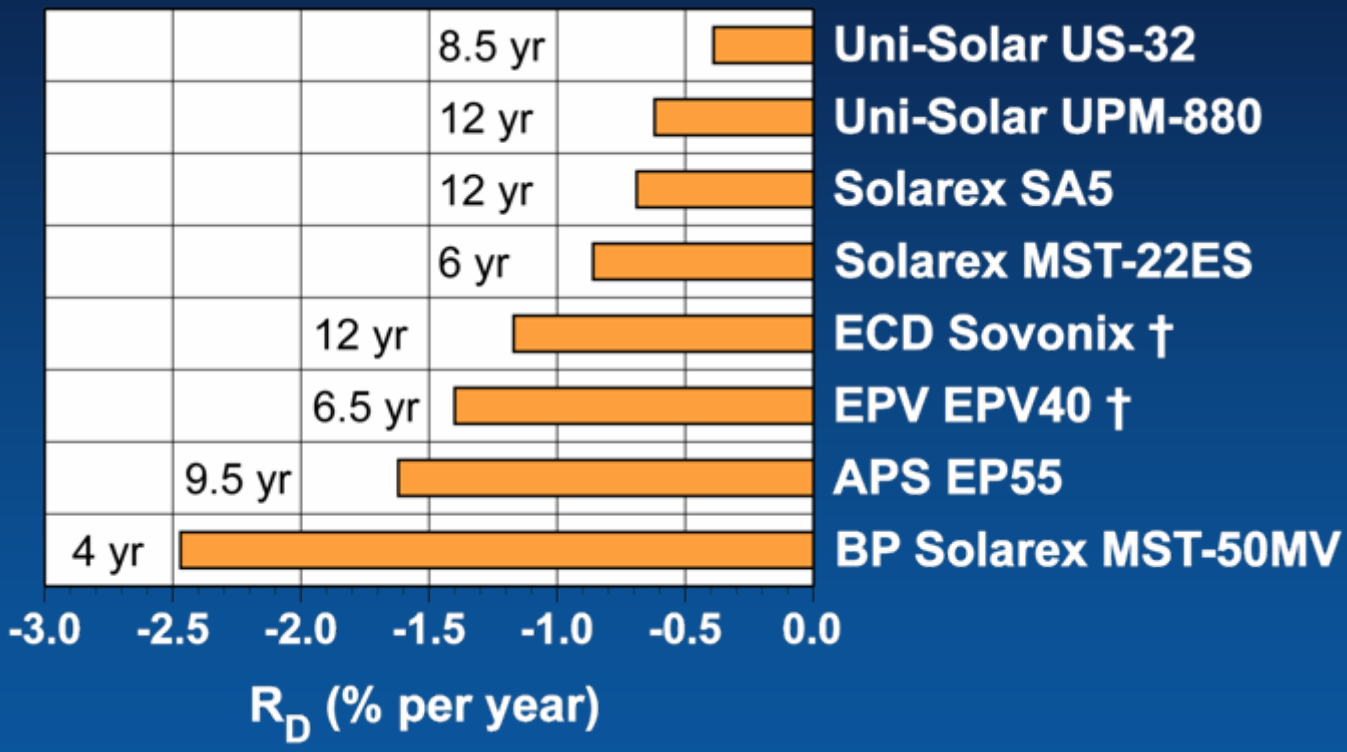


PERT R_D Results — Crystalline



† Non-commercial prototype modules

PERT R_D Results — a-Si



† Non-commercial prototype modules

Discussion and Conclusions

- Many Si R_D values < 1%/year
- Some thin-film R_D values < 1%/year
- Recommend 0.5% per year for Si
- R_D > 2%/year likely indicative of serious module or system problems
- R_D values vary over wide range; accurate data should be available for system designers