ENERGY

Degradation

Wearing away the confusion surrounding PV degradation rates.

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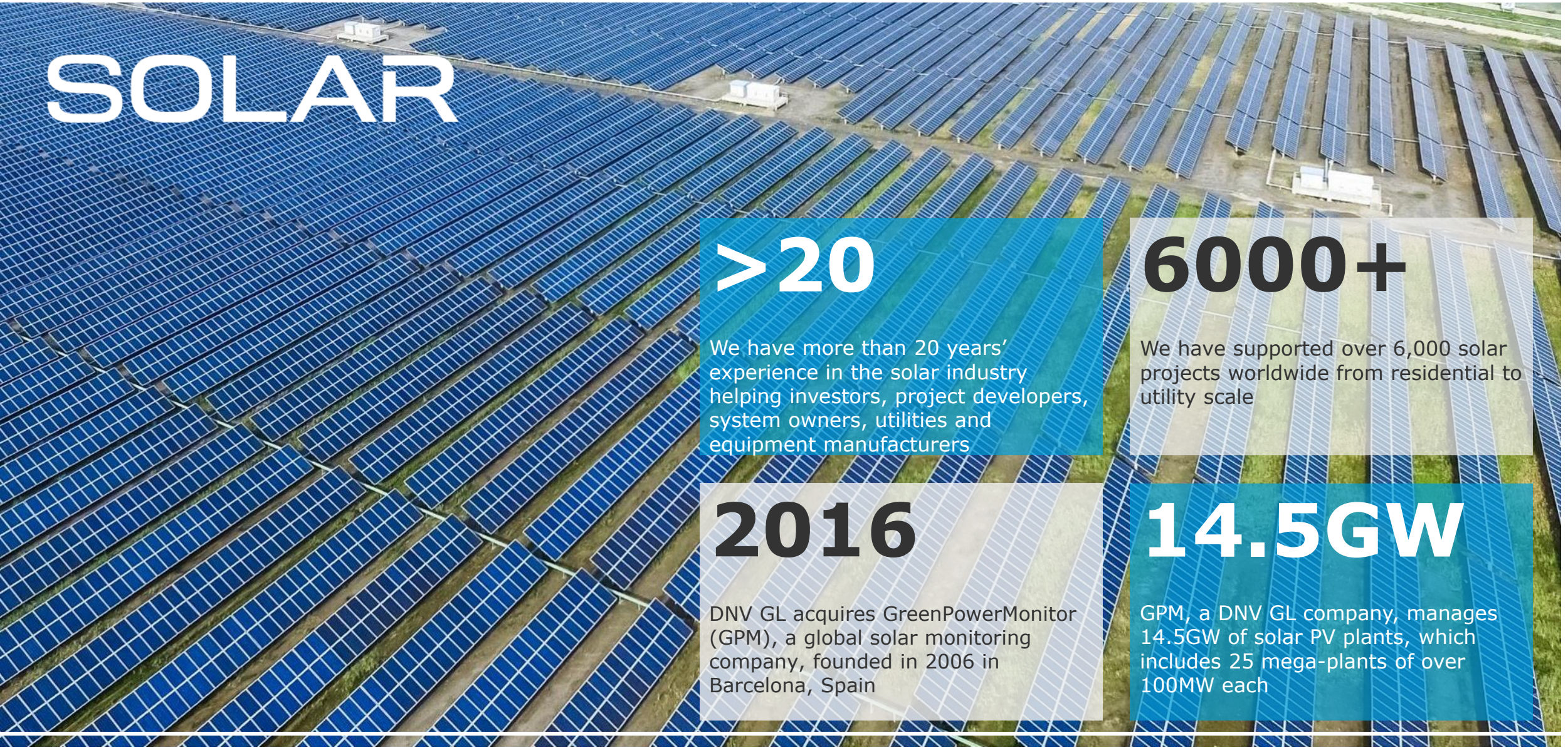
15 May 2019

SOLAR



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We have more than 20 years' experience in the solar industry helping investors, project developers, system owners, utilities and equipment manufacturers

6000+

We have supported over 6,000 solar projects worldwide from residential to utility scale

2016

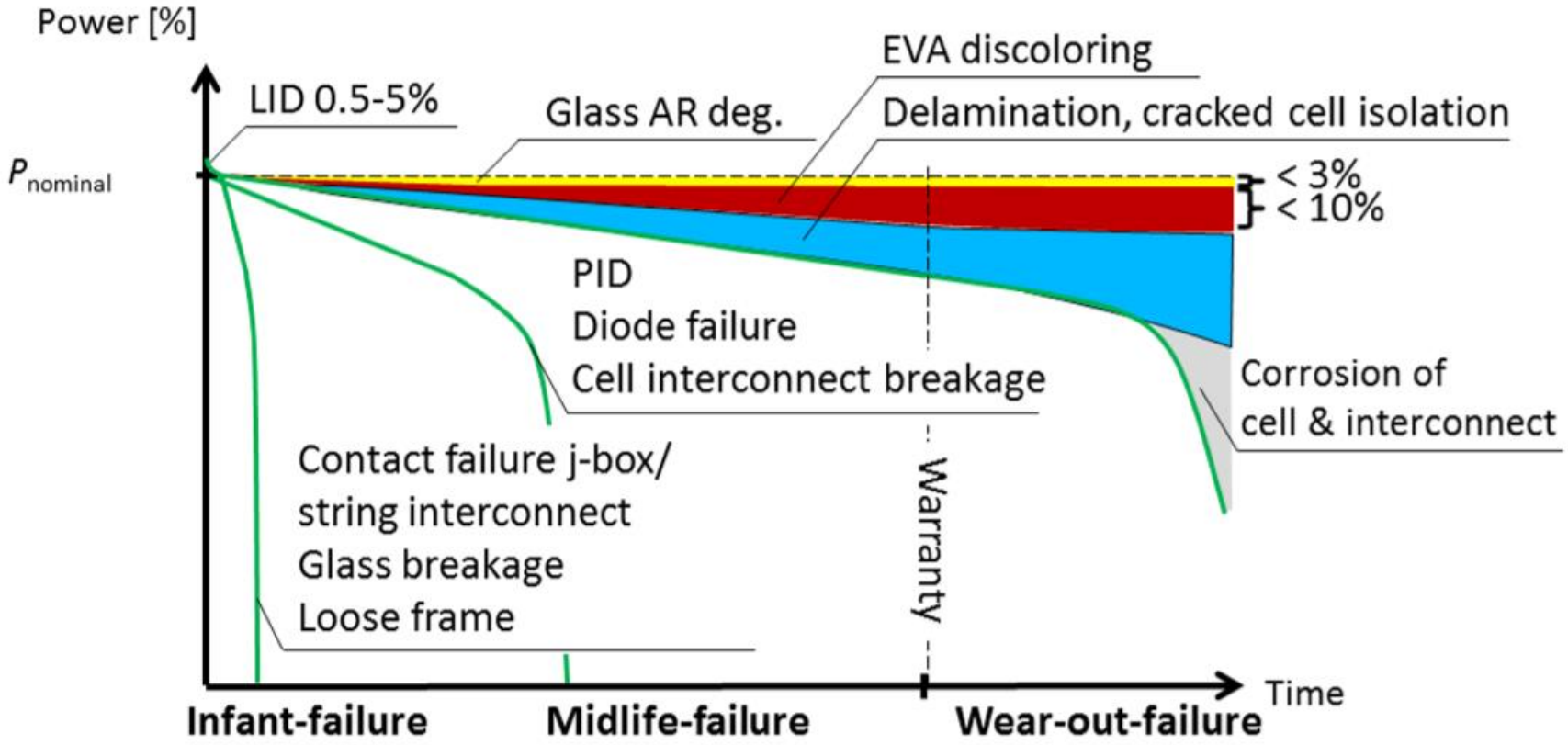
DNV GL acquires GreenPowerMonitor (GPM), a global solar monitoring company, founded in 2006 in Barcelona, Spain

14.5GW

GPM, a DNV GL company, manages 14.5GW of solar PV plants, which includes 25 mega-plants of over 100MW each

*Our testing, certification and advisory services are independent from each other

PV degradation, degradation rates and failure



(Kontges *et al*, 2014, p.4)

Module and system degradation

System Degradation rate P40-P60 of

0.5-0.75%/year

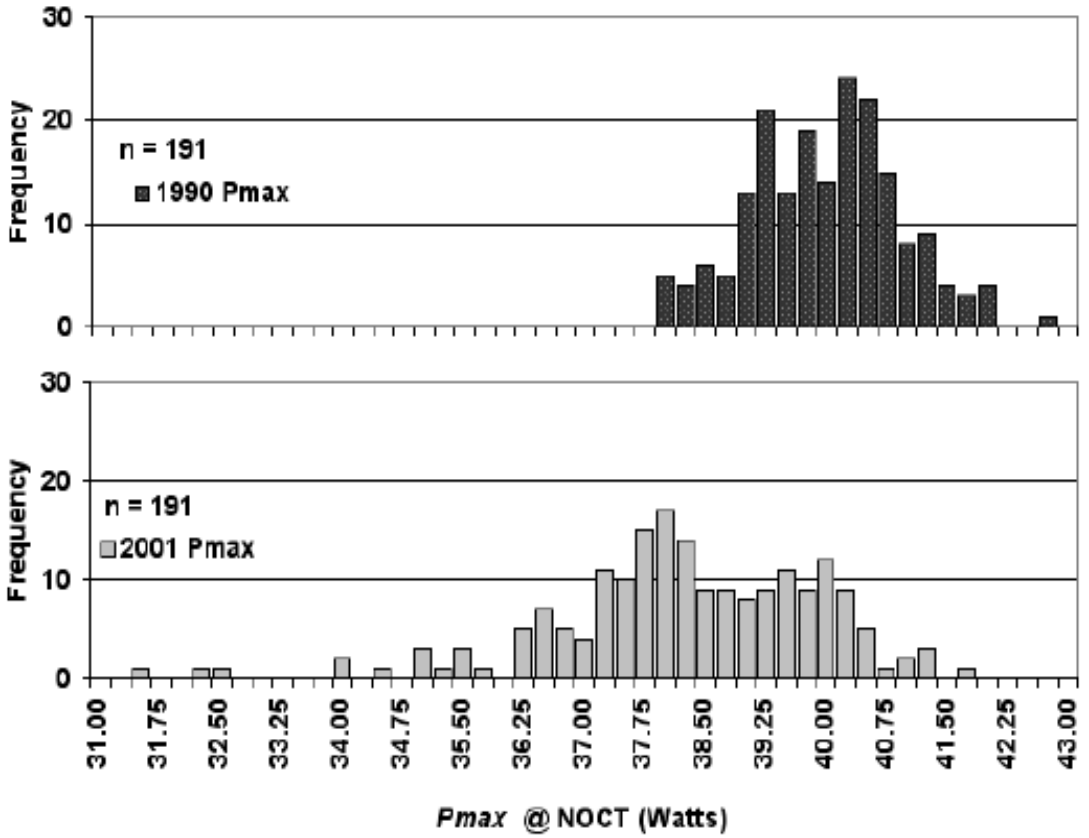
Module Degradation rate P40-P60 of

0.4 to 0.5%/year

Balance of Plant Degradation rate 0.1-0.25%/year

Caused by:

- Non-Recoverable mismatch
- Recoverable mismatch
- Increased terminal resistance



(Reis *et al*, 2002, p.1432-1435)

NREL and DNV GL degradation study

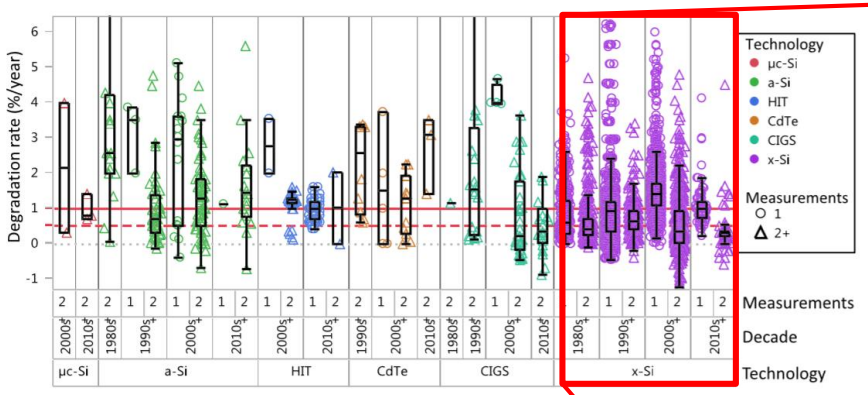
Over 11,000 degradation rates, from almost 200 studies covering 40 countries.

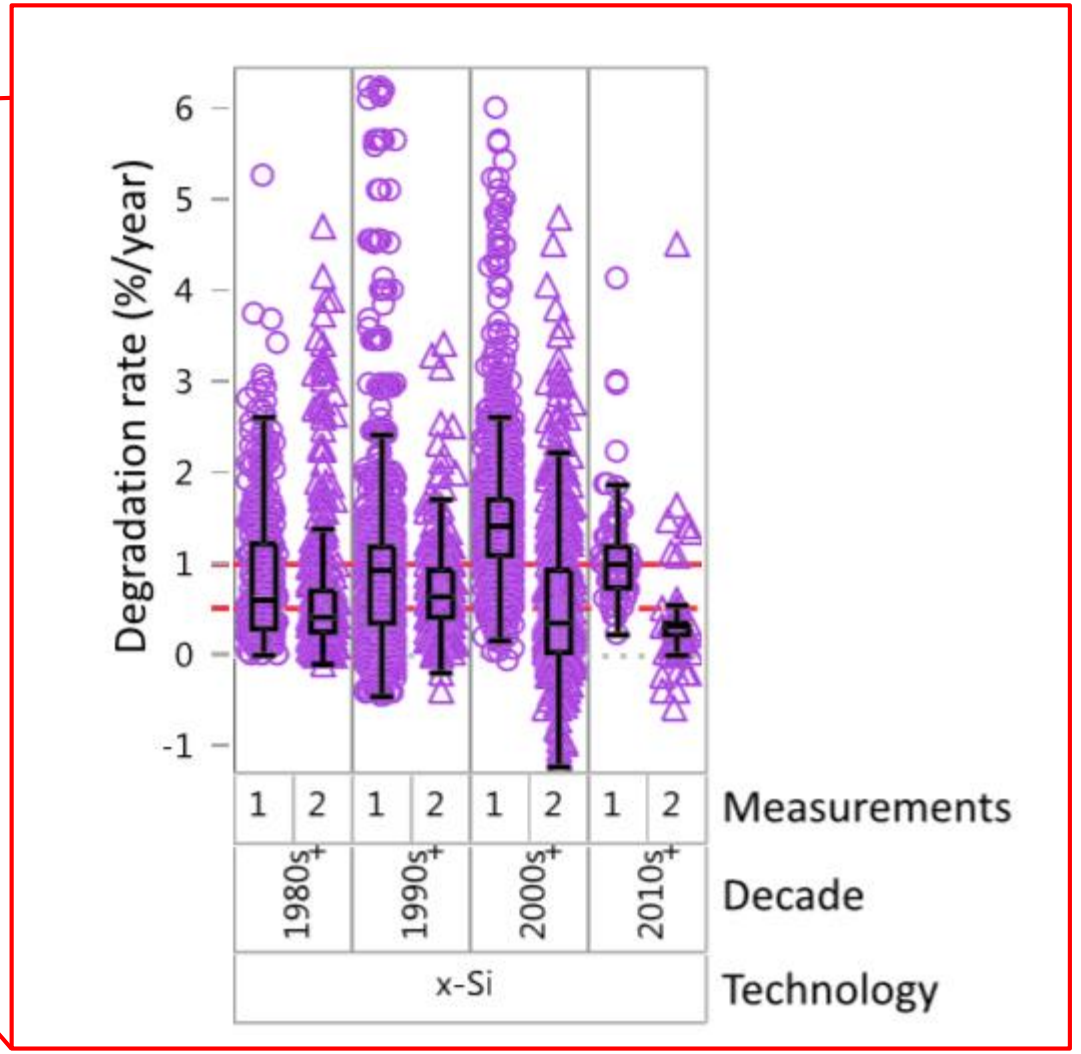
Technology	Study type	System/Module	Median	Mean	Data points
All data	All	All	0.90	0.93	11 029
x-Si	All	All	0.90	0.91	10 572
Thin-film	All	All	1.15	1.38	455
All	Median per study and system	All	0.82	1.09	312
All	2+ measurements	All	0.46	0.69	2792
All	1, outdoor IV	All	1.08	1.06	7238
All	1, indoor IV	All	0.64	0.77	963
All	High quality studies	All	0.49	0.66	2161
x-Si	Median per study and system	Modules	0.67	0.91	127
x-Si	Median per study and system	Systems	0.69	0.79	108
x-Si	High quality, all	Modules	0.40	0.51	1552
x-Si	High quality, all	Systems	0.64	0.81	384
x-Si	High quality, Median per study and system	Modules	0.55	0.59	61
x-Si	High quality, Median per study and system	Systems	0.61	0.69	71
x-Si	High quality, desert	All	0.71	1.19	42
x-Si	High quality, hot and humid	All	0.60	0.80	683
x-Si	High quality, moderate	All	0.42	0.57	1396
x-Si	High quality, snow	All	0.35	0.62	39

Probability	System Degradation
P40	0.5%
P60	0.75%

(Jordan, *et al*, 2016, p.978-989)

Change in x-Si degradation rates with time





(Adapted from:Jordan, *et al*, 2016, p.978-989)

DNV GL degradation data review process

Minimising degradation downside

Before Module Selection

- Accelerated testing of relevant BOM
- Above industry standard warranty
- Manufacturers who implement better quality control measures

During/After Module Manufacture

- Certification batch testing
- Factory witness testing

During Operation

- Aerial imagery
- String level monitoring
- Module level monitoring

References

Köntges, M., Kurtz, S., Packard, C., Jahn, U., Berger, K.A., Kato, K., Friesen, T., Liu, H. and Iseghem, M., 2014. Performance and reliability of photovoltaic systems, subtask 3.2: review of failures of photovoltaic modules. *Report2014*.

Reis, A.M., Coleman, N.T., Marshall, M.W., Lehman, P.A. and Chamberlin, C.E., 2002, May. Comparison of PV module performance before and after 11-years of field exposure. In *Conference Record of the Twenty-Ninth IEEE Photovoltaic Specialists Conference, 2002.* (pp. 1432-1435). IEEE.

Jordan, D.C., Kurtz, S.R., VanSant, K. and Newmiller, J., 2016. Compendium of photovoltaic degradation rates. *Progress in Photovoltaics: Research and Applications*, *24*(7), pp.978-989.