Safeguarding Solar PV Revenues

Light Induced Degradation (LID) & Light- and Elevated Temperature-Induced Degradation (LETID) challenges for PERC modules

What are LID & LETID and what do they mean for your financials?

Insights from

Tara Doyle

PVEL

MAKE DATA MATTER.

Dr. Alison Ciesla

UNSW SYDNEY

Marcello Passaro

kiwa

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Executive Summary

Risk Profile

1. **Frequency & Impact:** Without effective treatment PERCmodules can experience LID rates up to 3% in the firstmonths and up to 6% LETID in the first few years.
2. **Root cause:** Degradation rates depend on temperature, irradiance and manufacturer process.
3. **Concern:** LID and LETID are key concerns for solar assets that are often overlooked, impacting yield and in turn revenue over time.

Every 1% degradation equates to
10% of revenue loss

Mitigation Measures

See slide 14 for more

1. IEC61215/61730 Certification
2. Product Qualification Program
3. Batch Testing

Minimizing degradation
due to LETID & LID up to 1%

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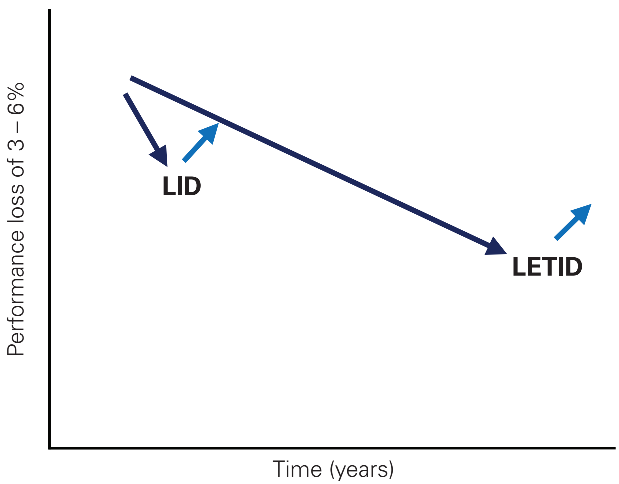
LID & LETID in a nutshell



LID
LID caused by boron-oxygen defects occurs within weeks and recovers within months.

LETID
LETID exact defect unknown but likely hydrogen related occurs over many years and then recovers over decades.

What are LID and LETID?

For untreated cells, Light Induced Degradation (LID) usually occurs when PV modules are first exposed to light and reduces performance up to 3%. Light and Elevated Temperature Induced Degradation (LETID) occurs over a longer period and can reduce performance by up to 3% and in worst cases up to 6%.

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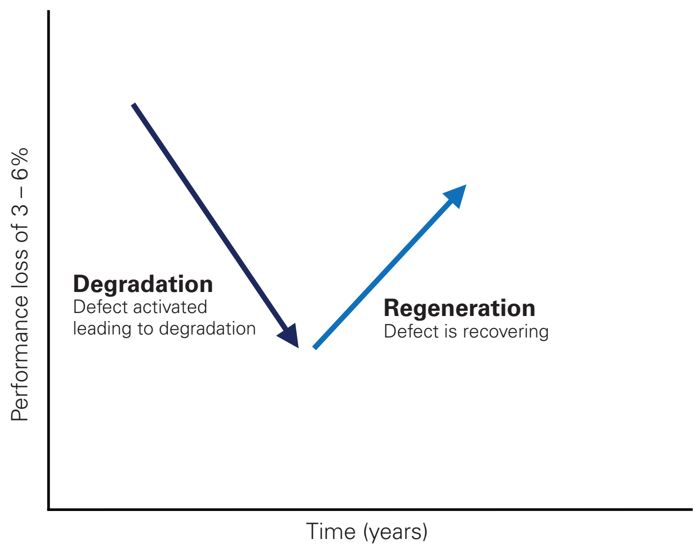
Typical timeline of LID/LETID



Typically LID & LETID have a period of degradation and then regeneration
Degradation rates can vary greatly depending on temperature, irradiance, manufacturing process and cell architecture.

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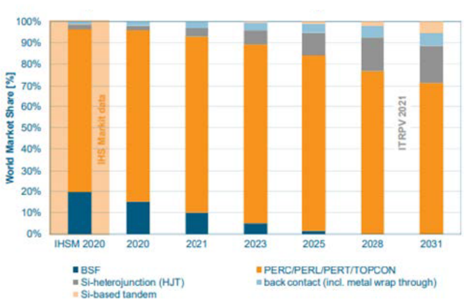
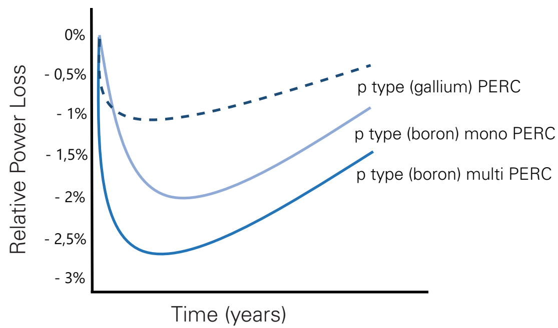
Which technology suffers the most LID & LETID?

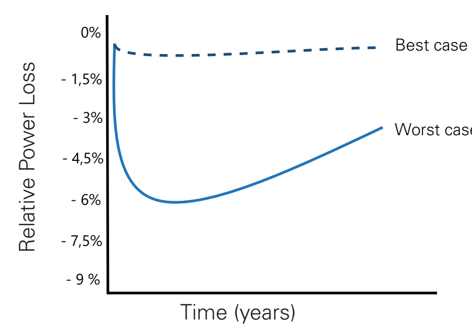
Adoption of advanced cell types 1



LID



LETID 2



Mostly effects Si mono and multi crystalline PERC modules.

Though cells with a PERC architecture are impacted, other architectures (n type, TOPCON, IBC, HJT) also show some varying degree of impact by LID. This paper focuses solely on PERC LID & LETID.

Read more 1 ITRPV https://itrpv.vdma.org/en/ 2 Fraunhofer CSP https://www.csp.fraunhofer.de/en/news/LeTID-Benchmark.html

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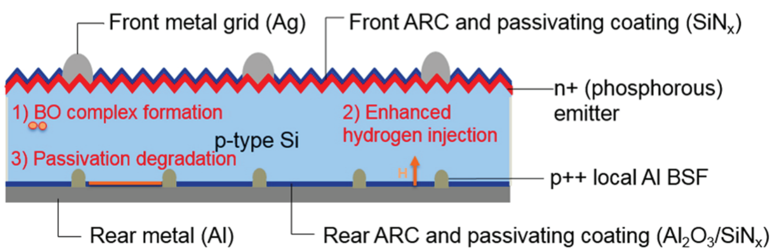
What are the main known root causes for PERC LID & LETID?



1. **Boron Oxygen (BO) Complex formation**
Chemical reactions occur in the cell between boron & oxygen content in the cell forming boron oxygen complexes under temperature & irradiance leading to degradation. Similar light activated defects can form with boron and iron (FeB) and copper precipitates.

2. **Hydrogen Mobilisation**
Hydrogen trapped during cell processing interacts with complexes creating weak bonds, which under illumination & temperature "break" leading to degradation

3. **Passivation Degradation**
Passivation layers degrade under UV exposure outdoors, further accelerated by higher temperatures which leads to degradation

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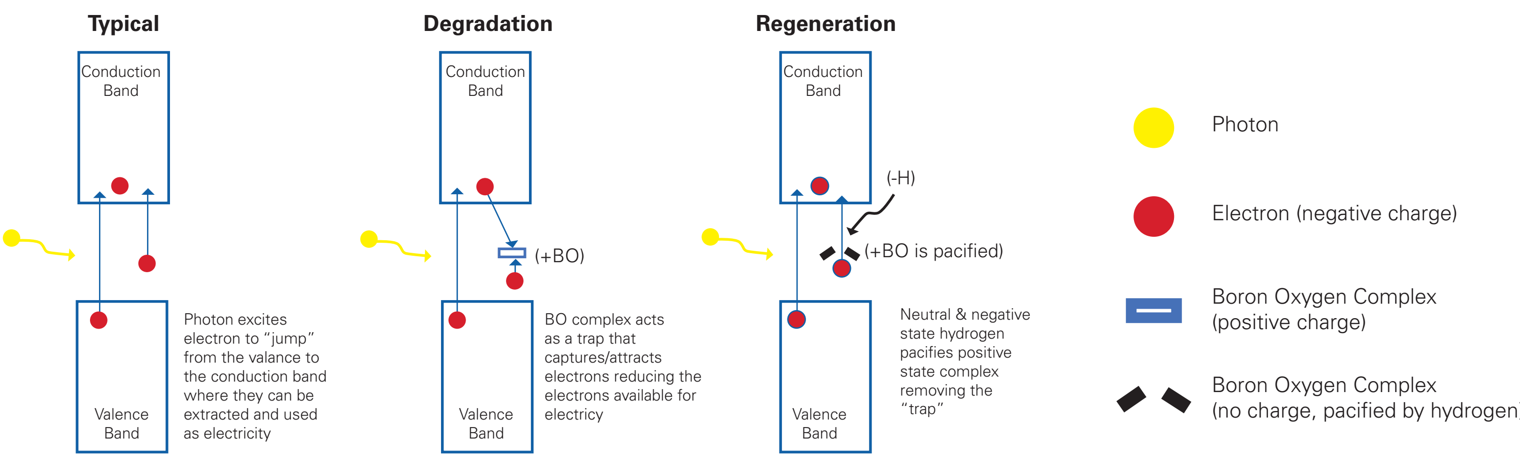
Role of complexes in relative power loss (LID)



Simplified example of the role of complexes in reducing the relative power of a module in LID

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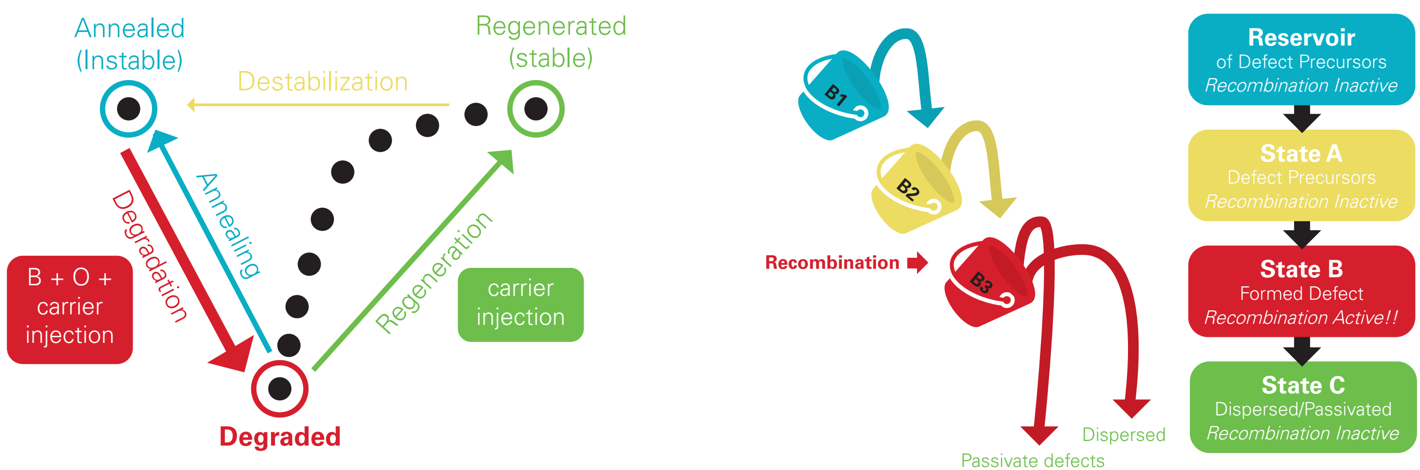
The cyclic effect of all degradation mechanisms leading to LID/LETID



Thermal processes without illumination can reactivate boron, oxygen and hydrogen creating new cycles of degradation, particularly when exposed to temperature and illumination.

Read more UNSW SYDNEY https://www.researchgate.net/publication/326367944_Hydrogen-induced_degradation

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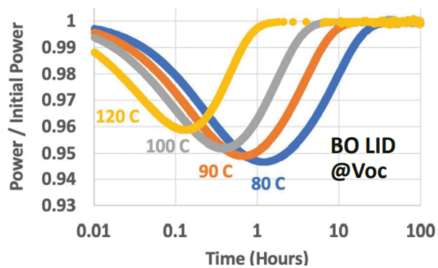
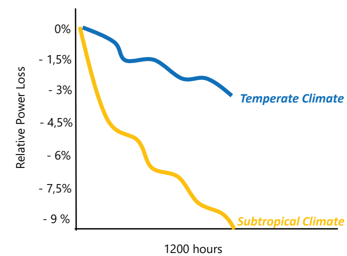
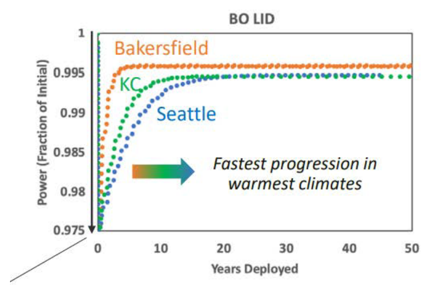
Illumination & temperature (climate) dependance of LID & LETID

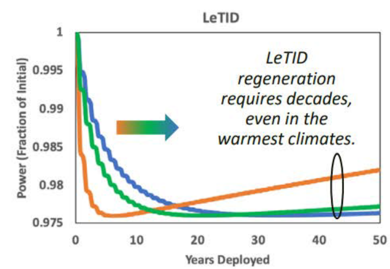
Lab Testing





Field & Simulated Data





LID and LETID rates depend on climate as well as cell technology/architecture.

Read more DuraMAT Durable Module Materials Consortium NREL Transforming ENERGY https://www.nrel.gov/docs/fy21osti/78629.pdf

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LID/LETID may result in extensive losses

No mitigation measures means lower CAPEX costs, but higher than anticipated OPEX costs & lower yields

=

10% loss in revenue per 1% of LID and/or LETID degradation

Up to 1.2 EUR/MWh(AC) reduction in LCOE possible if implementing mitigation measures at the CAPEX costof 1.2 EUR; ultimately reducing yearly losses of up to 3 EUR/kWp/year.

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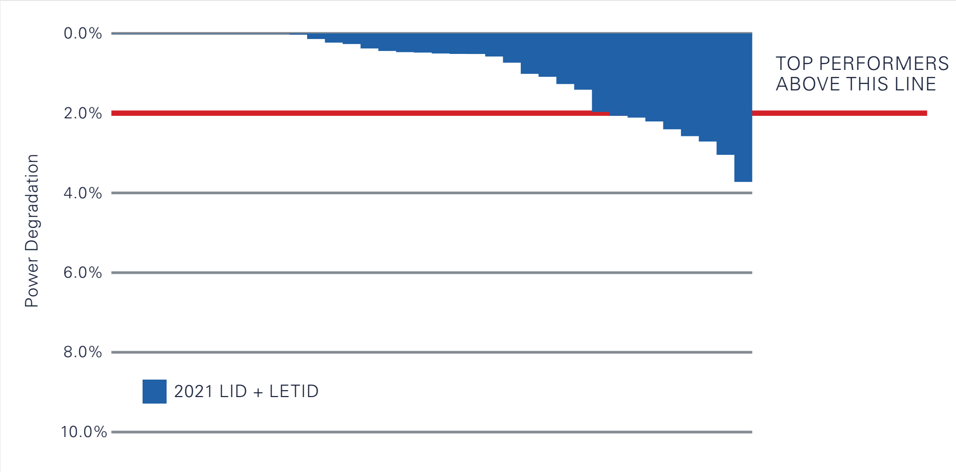
Case Study

In PVEL's 2021 PV Module Reliability Scorecard the majority of modules tested within an 18 month period were Top Performers with a combined power degradation of less than 2%.

This is encouraging, although testing participants are a self-selecting group and it's unknown if this represents a trend for all modules.



Read more PVEL MAKE DATA MATTER. https://modulescorecard.pvel.com/lidletid/

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Mitigate these risks by:

Mitigation Strategies based on 0,1 to 100MWDC Project Size & Testing Budget

IEC61215 & IEC61730 Certificates	IEC61215 & IEC61730 Certificates	IEC61215 & IEC61730 Certificates	IEC61215 & IEC61730 Certificates	IEC61215 & IEC61730 Certificates	IEC61215 & IEC61730 Certificates	IEC61215 & IEC61730 Certificates
PVEL Product Qualification Program Insights	PVEL Product Qualification Program Insights	PVEL Product Qualification Program Insights	PVEL Product Qualification Program Insights	PVEL Product Qualification Program Insights	PVEL Product Qualification Program Insights	PVEL Product Qualification Program Insights
	Contract Optimization	Contract Optimization	Contract Optimization	Contract Optimization	Contract Optimization	Contract Optimization
		Technology & Design Review	Technology & Design Review	Technology & Design Review	Technology & Design Review	Technology & Design Review
			Batch Testing	Batch Testing	Batch Testing	Batch Testing
				Factory Audit	Factory Audit	Factory Audit
					Production Monitoring	Production Monitoring
Site Testing	Site Testing	Site Testing	Site Testing	Site Testing	Site Testing	Site Testing

Each additional phase reduces the project risk from medium - high to low

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Added value of mitigating risks

Up to

3.2

EUR/kWp/year

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Typical loss for a 0,10 EUR/kWh project without mitigation strategies equates to a total loss of 5.4 EUR/kWp/year. Implementing previously stated risk strategiesreduces those total losses to 2.2 EUR/kWp/year.

Read more SOLAR BANKABILITY http://www.solarbankability.org/results.html#c129

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Find out how Kiwa can be your partner in progress for safeguarding long term solar investments

solar@kiwa.com

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Sources:
Solar Bankability, Miniziming Technical Risks in Photovoltaic Projects, 2017
IEA PVPS, Review of Failures of Photovoltaics Modules, 2014
NREL/DuraMat, LID and LeTID Impacts to PV Module Performance and System Economics, 2020
iSFH/PV Tech, Is LeTID degradation in PERC cells another degradation crisis evenworse than PID, 2018
Eternal Sun Spire, Temperature Coefficients of LID in PERC, 2018
ITRPV, Technology Roadmap, 2020
UNSW, Hydrogen Induced Degradation, 2018
Kiwa field experience and data analytics
PVEL data analytics & testing

Co-written with:

PVEL MAKE DATA MATTER.

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