2019 NIST/UL Workshop on Photovoltaic Materials Durability
December 12 – 13
Session 2: PV Module Field Survey

Mitsui Chemicals

Energy Yield Reduction of PV Power Plant with CIS Thin-Film PV Modules Installed in Japan

December 12th 2019

Tsuyoshi Shioda
Mitsui Chemicals, Inc.

Mitsui Chemicals' contribution to healthy PV market

Mitsui Chemicals

Analyze aged PV modules
Develop accelerated test

2009~2013

*Shared at the workshops on 2011 and 2013

Know PV modules installed in PV plants

2014~

launch services business

warning as needed

*Shared at the workshop on 2015

Understand what happens in PV plants under operation

2016~

through services

*Shared at the workshop on 2017

Feedback to accelerated test conditions accordingly

Outline

1. Mitsui Chemicals' adviser services for PV project
2. Energy Yield (EY) reduction for 5 PV plants with CIS thin-film PV modules in Japan
3. Influence of encapsulant on the EY reduction
4. Summary

1. Mitsui Chemicals' adviser services for PV project
Since 2014

Mitsui Chemicals

Project Phases

Planning → Construction → Commissioning → Operation → Secondary -Transaction-

Service Menu

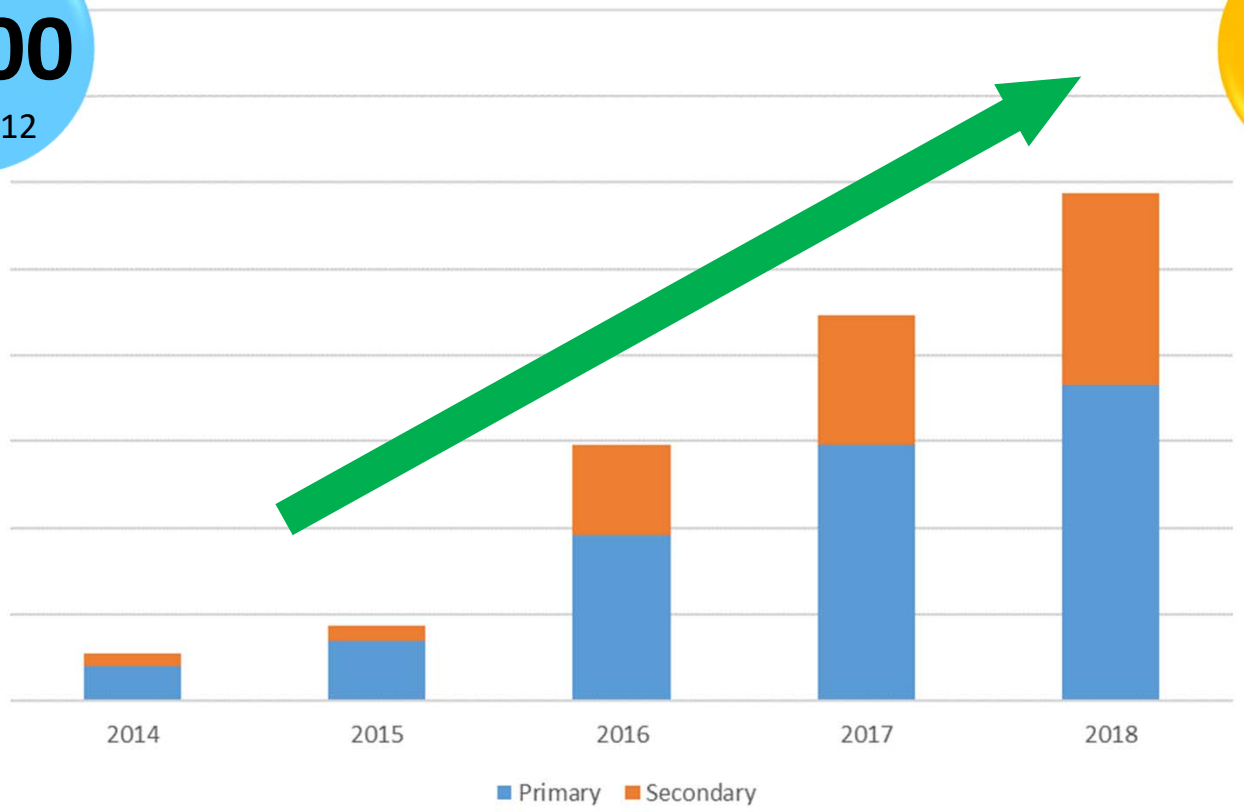
	One- Stop Solution	Best Practice	Technical Due Diligence
PV Modules	• Quality Assurance • Factory Visit • Acceptance Inspection for Module Installation	IR/EL Analysis (on-site)	Yield Assessment for the remaining period of FIT based on: • Yield Performance • Plant Inspection • Evaluation of O&M Performance/costs
For Power Plant	• Yield Assessment • Design Evaluation • Contract Review • Compliance Check with laws and Regulations Plant Construction Site • Supervision During Construction • Inspection Upon Work Completion	• Plant Inspection • Periodical Yield Performance Assessment • Evaluation of O&M Performance	

Track record of our services in Japan

Mitsui Chemicals

Achieved **1,000** 2019.12

Achieved **4**GW 2019.12



Snapshot of my site visit last month

- ✓ Mitsui Chemicals have already evaluated over 300 operating PV plants in Japan.
- ✓ 10 of them were PV plants with CIS thin-film PV modules.
- ✓ Mitsui Chemicals have had additionally monitoring data for over 30 PV plants with CIS thin-film PV modules, collaborating with our client.

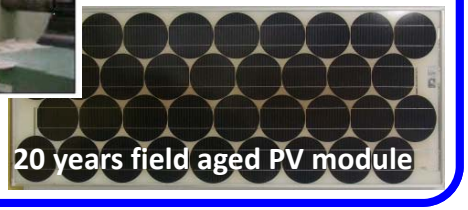
Mitsui Chemicals Expertise in PV Industry

Mitsui Chemicals

Manufacturer of PV encapsulant

- <Subsidiary> Manufacturer and global supplier of competitive encapsulant sheets for over 30 years,
- 20 years of degradation study of PV modules and encapsulants.


EVA encapsulant roll


20 years field aged PV module

Investor/Owner of PV plants

- Possess and manage several PV plants in Japan,
- Continuous improvement of technical skills and knowledge by studying various data and records from several plants including possessed plants.


Tahara PV plant with 50MWp

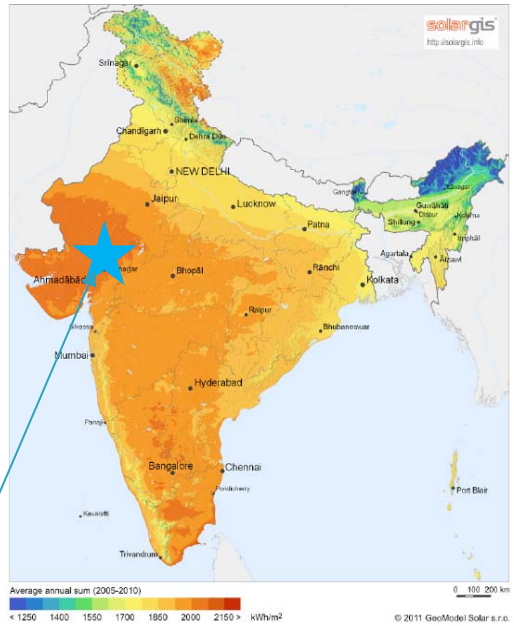

Mobara PV plant with 335kWp


Sodegaura R&D center /mini- site

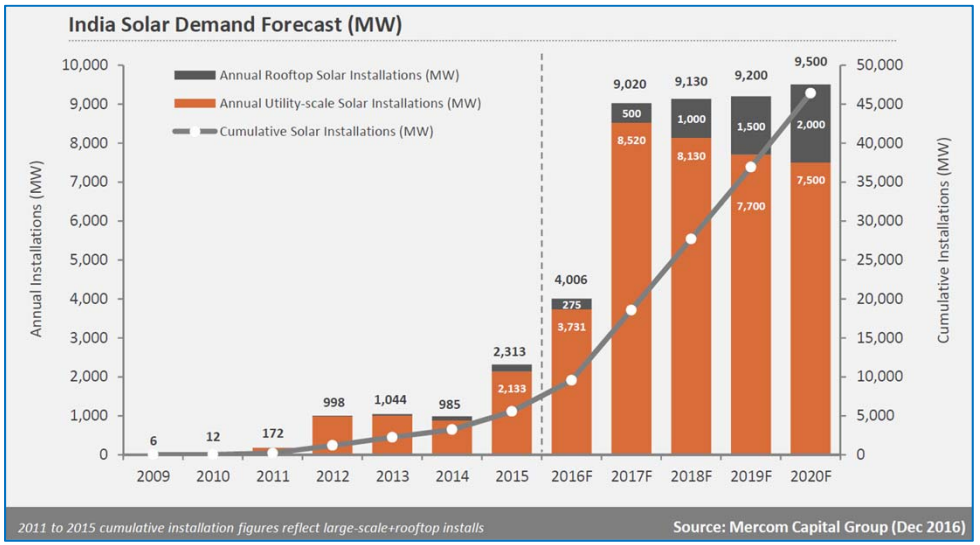
Experiences worldwide through PI

- Part of our solid field inspection and laboratory testing is derived from expertise of an accredited lab, PI Berlin.

Accredited Testing Lab. and TDD services in India



Ahmedabad, Gujarat state

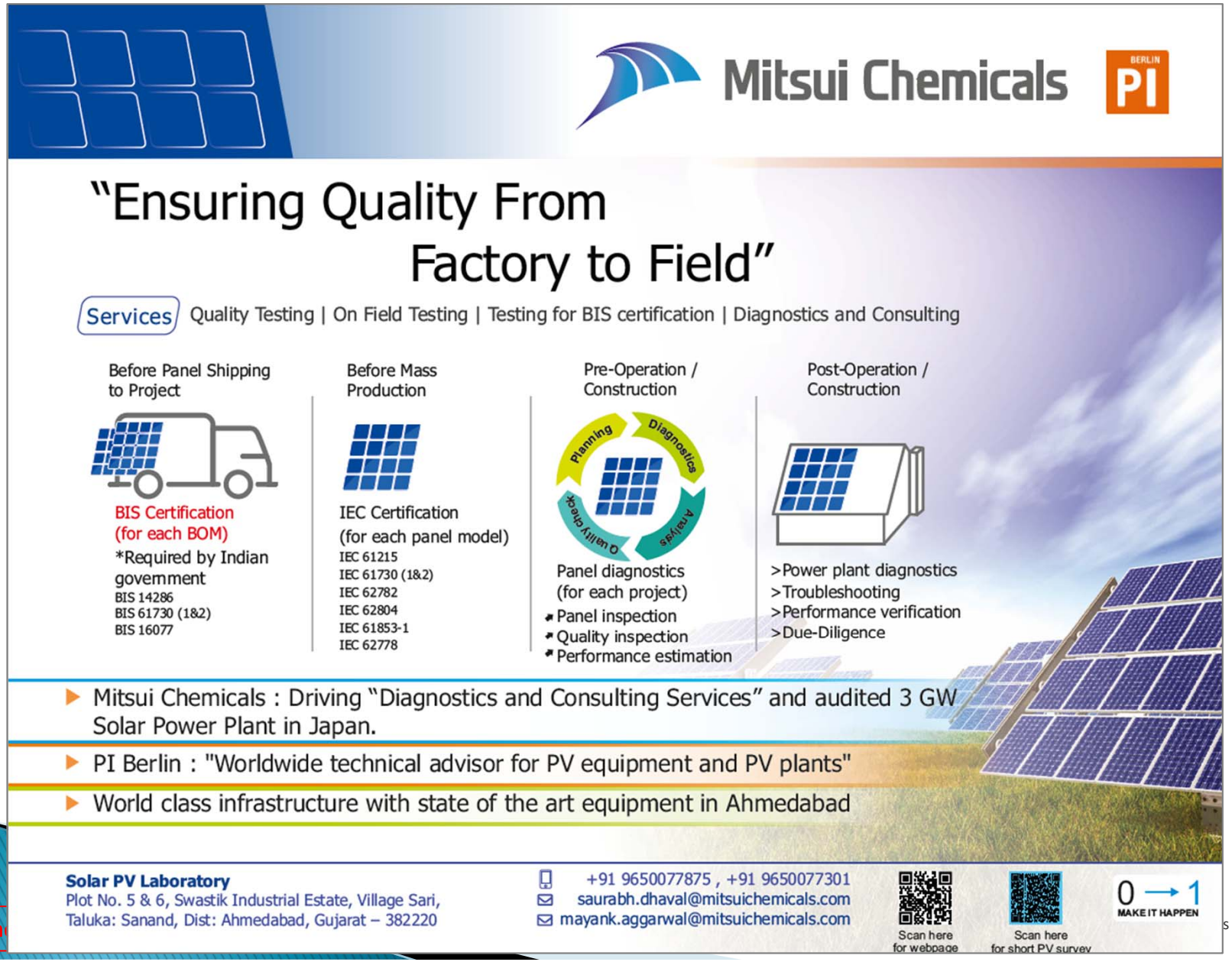


Indian government policy: 100GW @ 2022
300GW @ ~2030
*32GW @Oct. 2019

- ✓ BIS (Bureau of Indian Standards) certification, conducted by the lab accredited by NABL, for the PV modules to be installed has been mandatory since 2018, in order to avoid installation of low quality PV modules.
- ✓ Mitsui Chemicals will launch BIS / IEC certification services in Ahmedabad on January 2020.

Accredited Testing Lab. and TDD services in India

Mitsui Chemicals



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Energy Yield of PV plant with CIS thin-film PV modules

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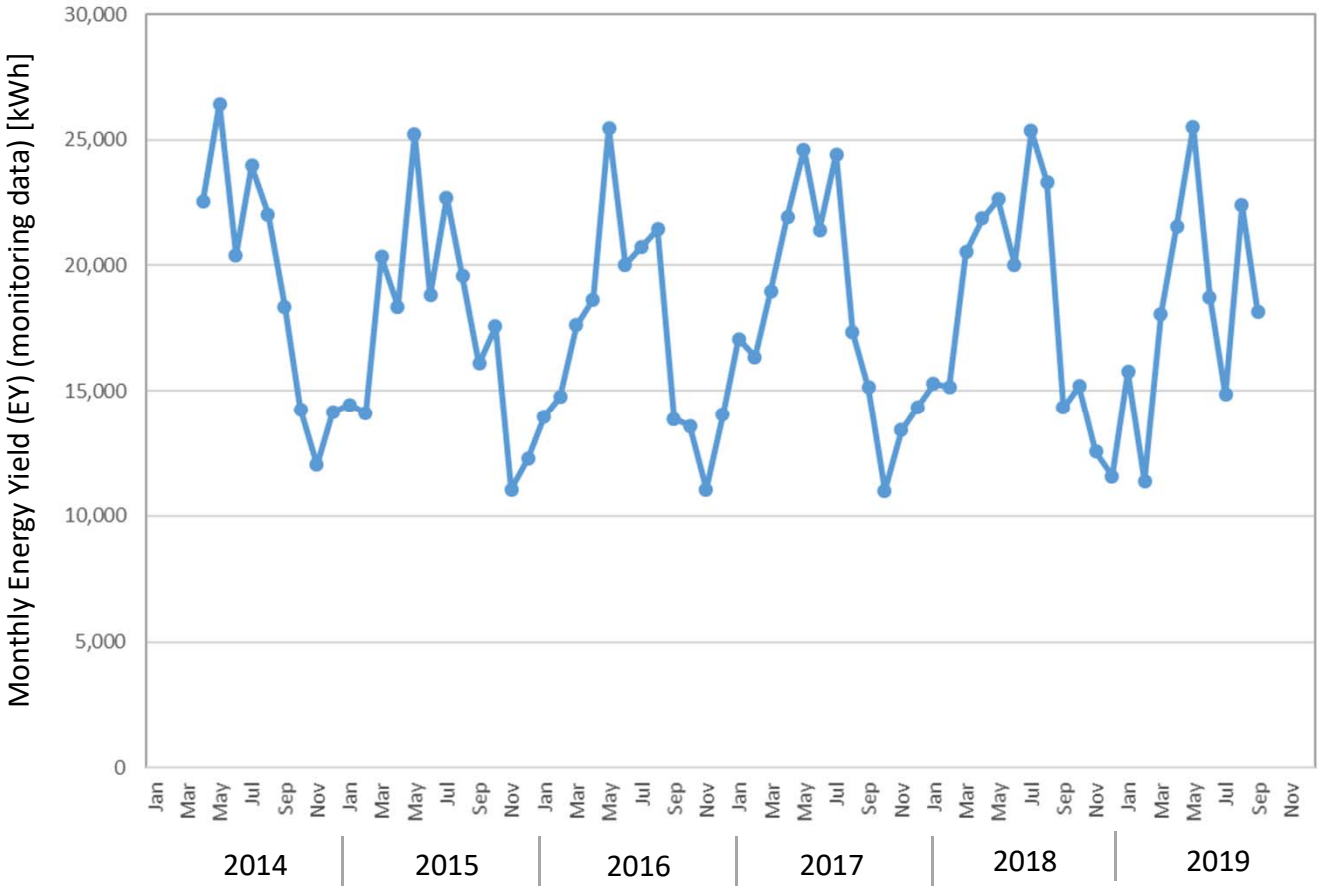
Location	Type	Average of annual irradiance (inclined) for the duration [kWh/m^2]	COD (Operation started)
A		1,429	
B		1,627	
C		1,334	
D		1,465	
E		1,445	
F (our lab)		1,493	

Over 4 years operating PV plants have been chosen.

Location “A”

Energy Yield of PV plant with CIS thin-film PV modules



Location “A”

✓ Monthly energy yield data have seasonal variation which makes our understanding of the degradation harder.

Energy Yield of PV plant with CIS thin-film PV modules

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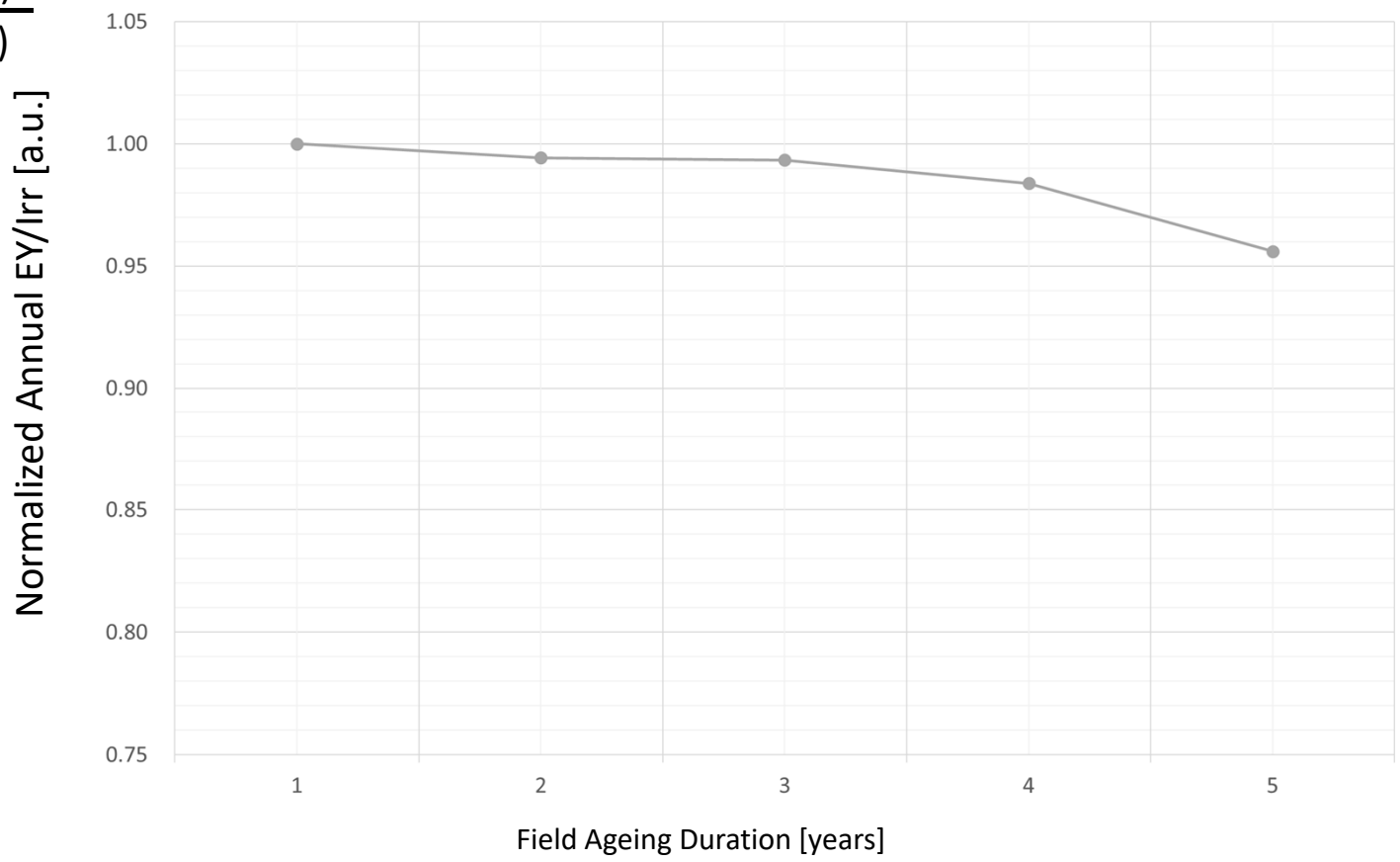
$$\frac{\text{EY (annual)}}{\text{Irr.(annual)}}$$

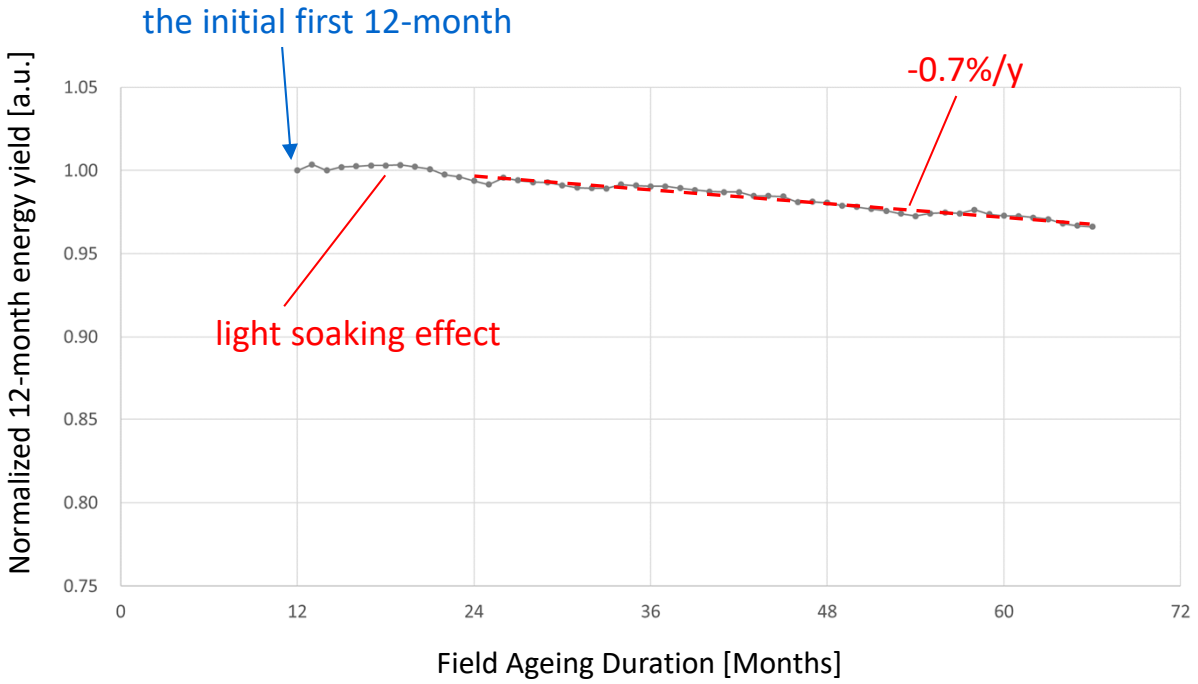


- ✓ Annual energy yield data taking account of variation of irradiance are useful (just like PR).
- ✓ Small number of plots in a graph would sometimes lead to misunderstand the degradation trend, especially future prediction.

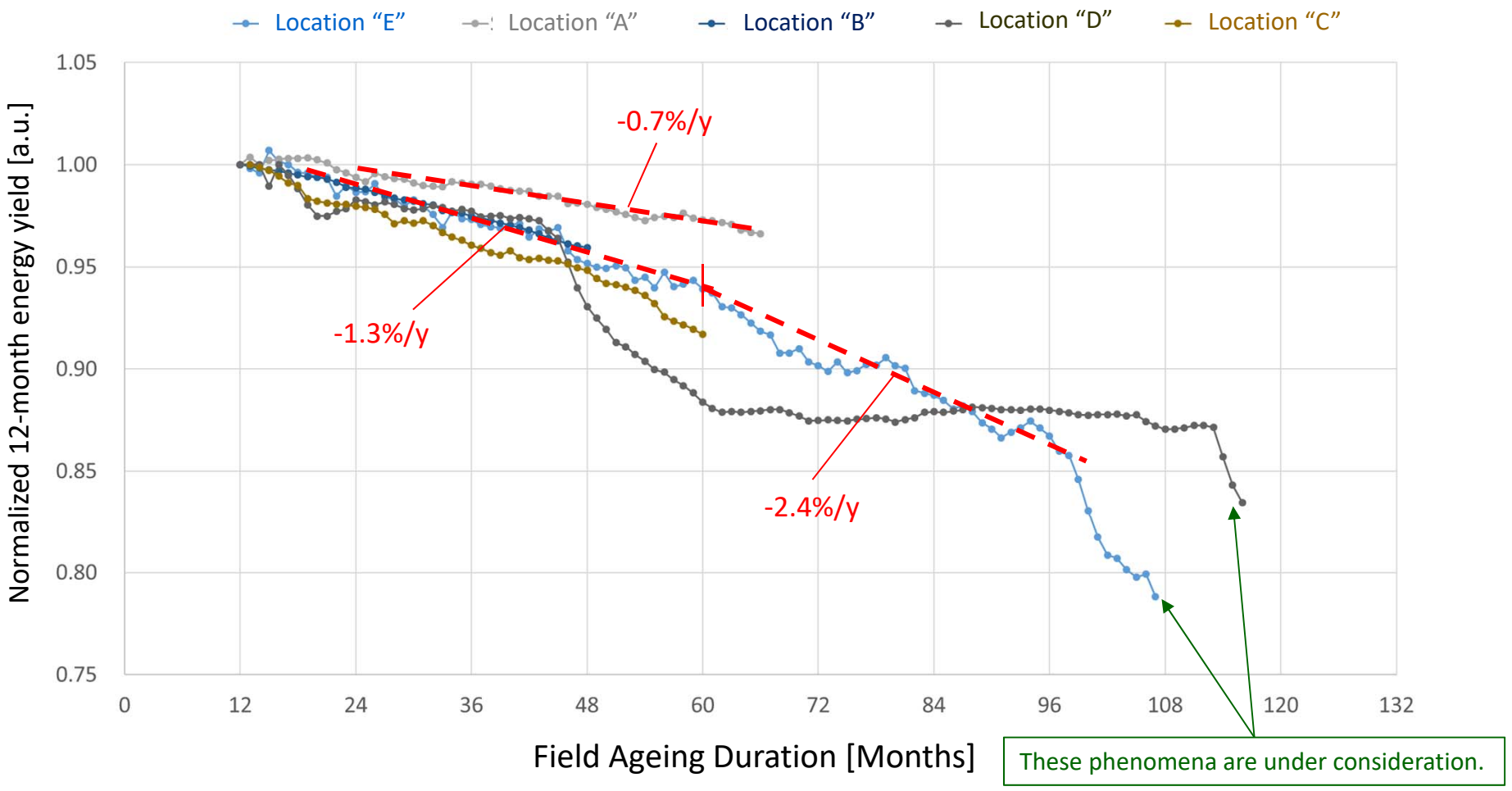
12-month Moving Average Analysis

$$\text{12-month Energy Yield} = \sum_{i=1}^{12} \frac{\text{EY}i\ \text{(monthly)}}{\text{Irr.}i\ \text{(monthly)}}$$

- ✓ The 12-month energy yield is calculated and plotted at one month step.
- ✓ When we found that the PV plant stopped for a duration, corresponding irradiance was removed from the relative monthly irradiance.

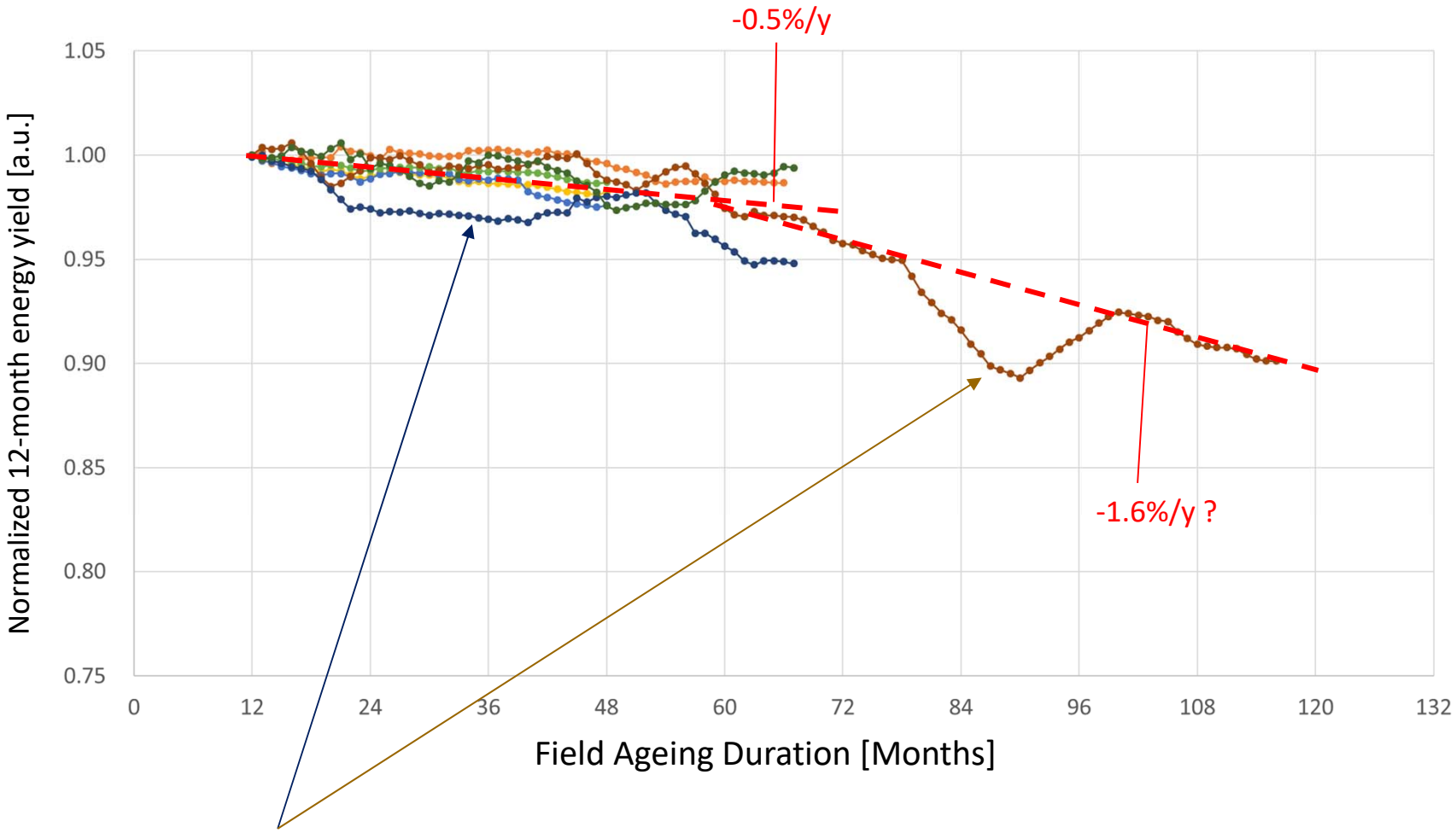


Degradation rate of the EY (CIS)



✓ The large degradation rates, over 1%/y (most plants), and the trend of larger degradation after 5 years operation have been found.

Degradation rate of the EY (c-Si)



- ✓ These would be due to weeding and/or failures of strings/inverters.
- ✓ Further investigation is ongoing.

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Outdoor exposure test of CIS thin-film in our lab.

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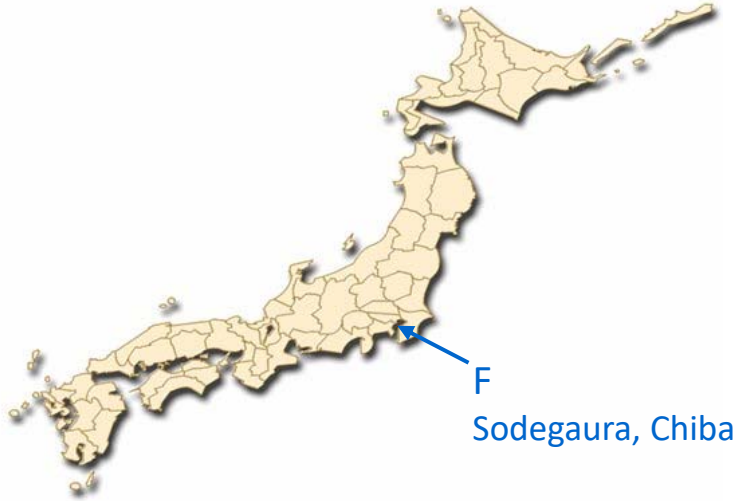
Azimuth: due south (0°)
Tilt angle: 30°
Latitude: 35.450164°N

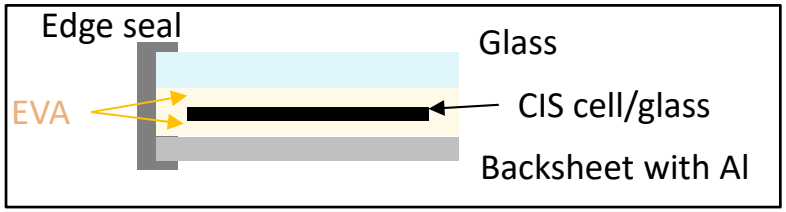
Annual average irradiance (inclined) :
1,493 kWh/m^2



Outdoor exposure test started on April 2011.
We have measured the following items every year.

1. I-V curve by solar simulator
2. EL image
3. Dark I-V curve

➢ Cross section of the CIS thin-film PV module



I-V curve measurement by solar simulator

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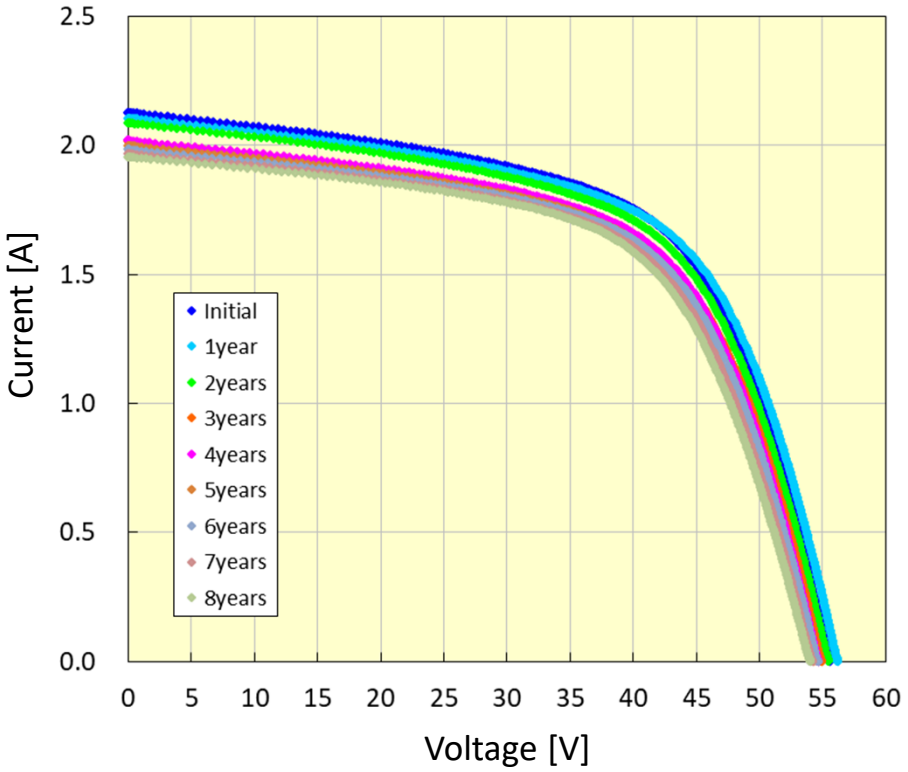
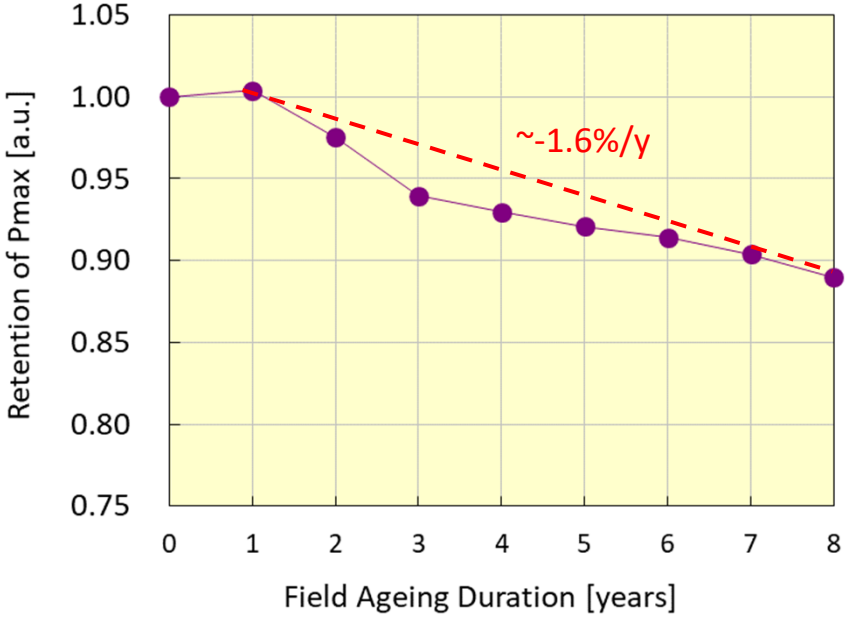
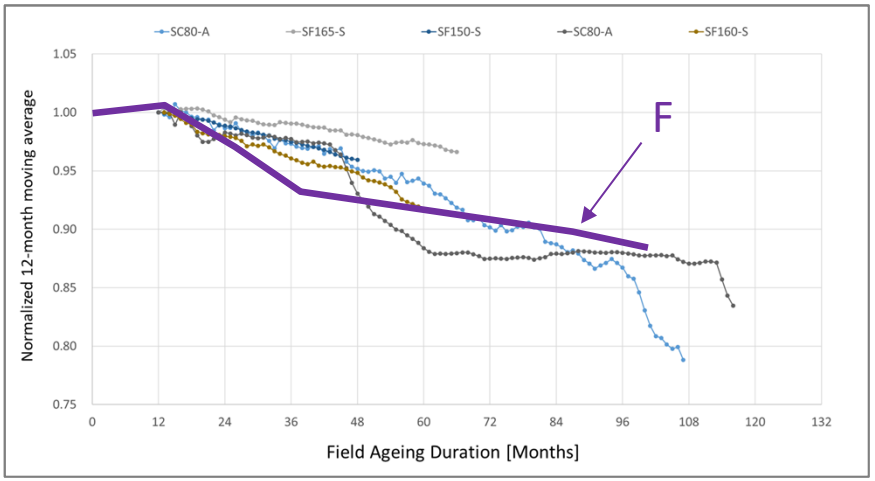


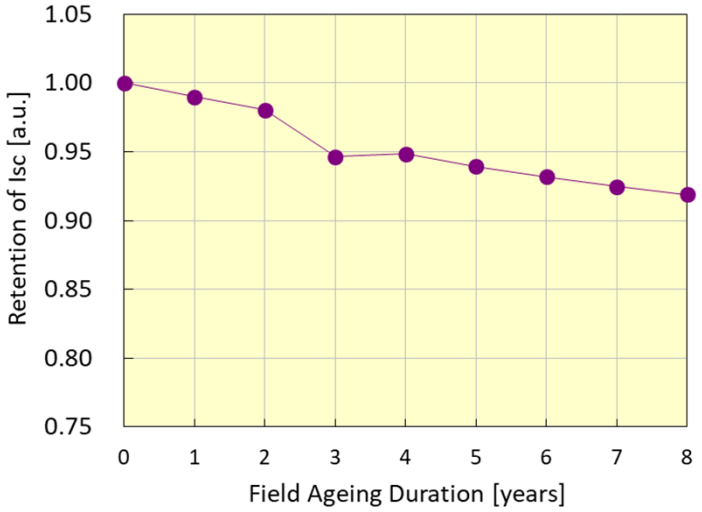


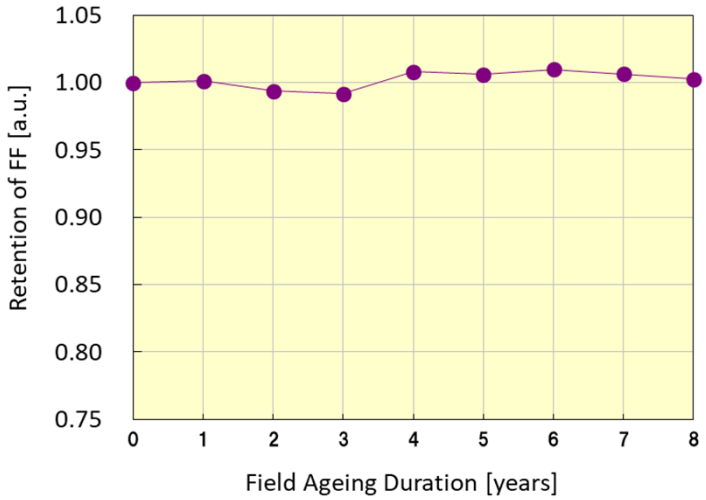


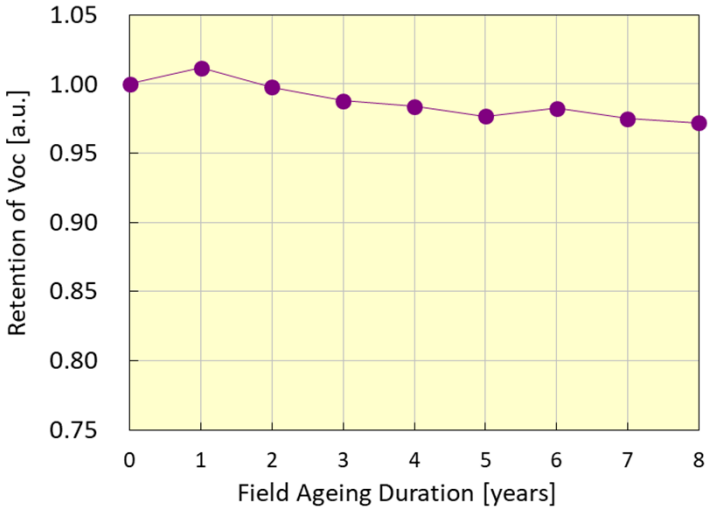
- ✓ The reduction trend is similar to those for EY reductions mentioned.
- ✓ The degradation rate of ~-1.6%/y was found after 1 year field-aged.

Mitsui Chemicals Confidential

Changes in parameters



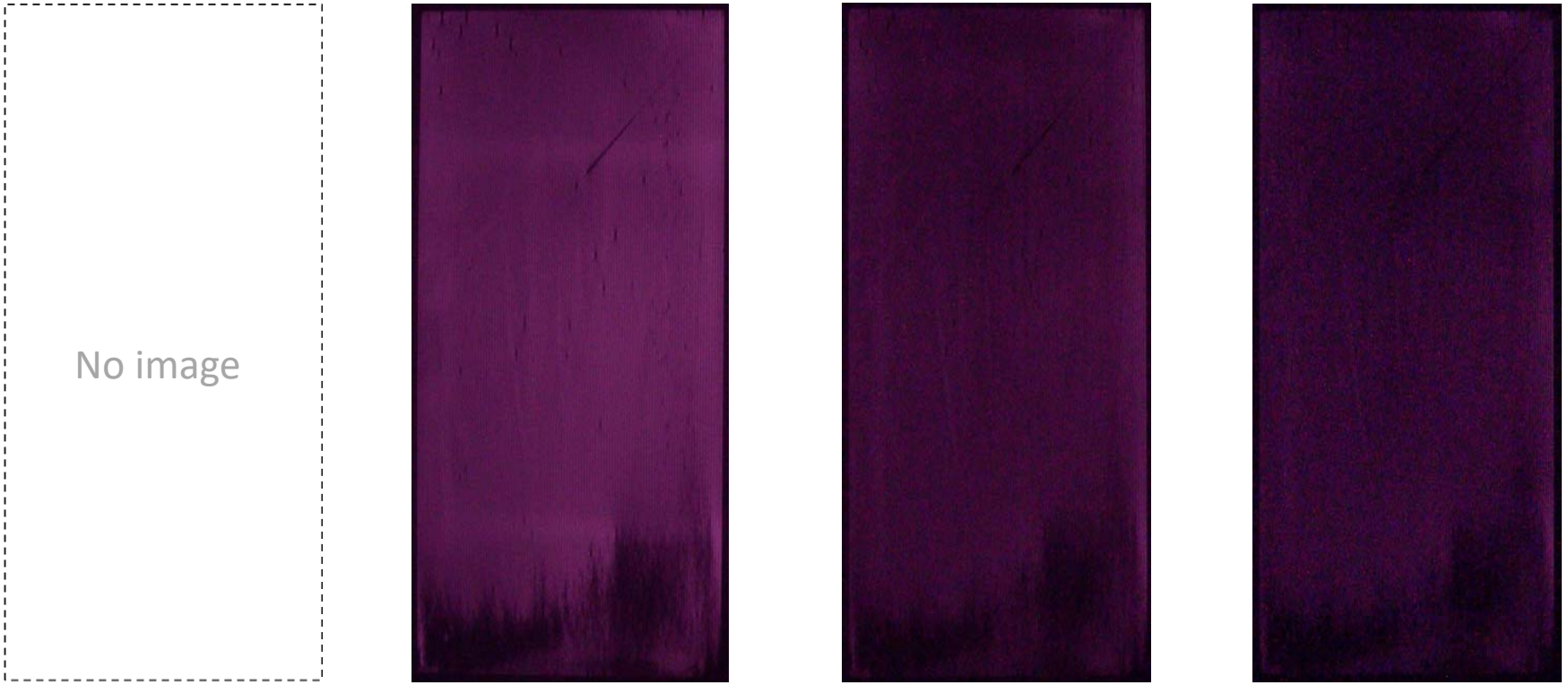




Parameter	Comments
Isc	Decrease by ~-1.0%/y
Voc	Decrease by ~-0.5%/y after 1 year
FF	No change

EL image

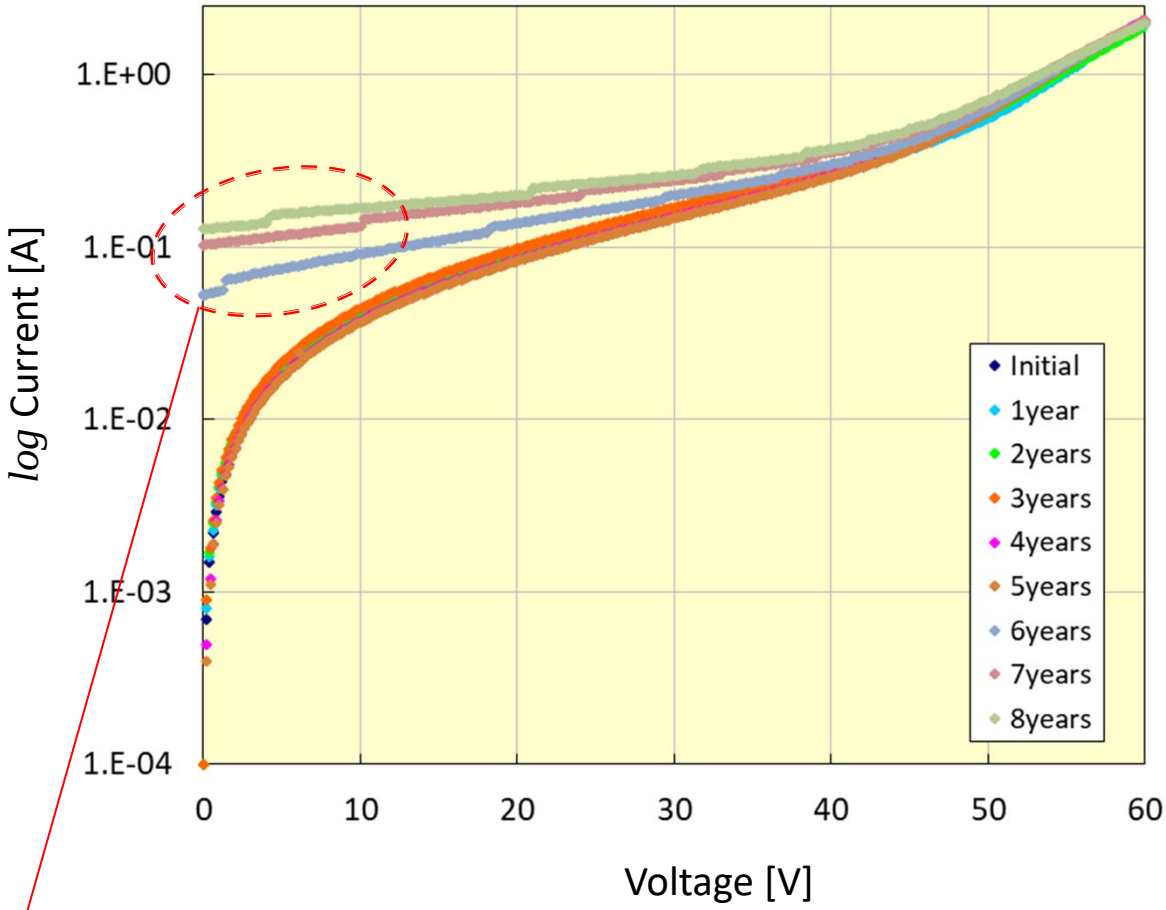
Injection Current: 2.0 [A] (constant)
Voltage: ~59.6 [V] (uncontrolled)
ISO sensitivity: 6400



Initial | 3 years | 5 years | 8 years

✓ EL image became darker gradually.

Dark I-V curve (semi-logarithm)



✓ Diode characteristic of the CIS thin-film has been changed after 6 years field ageing.

Yellowing of EVA in the CIS thin-film PV module

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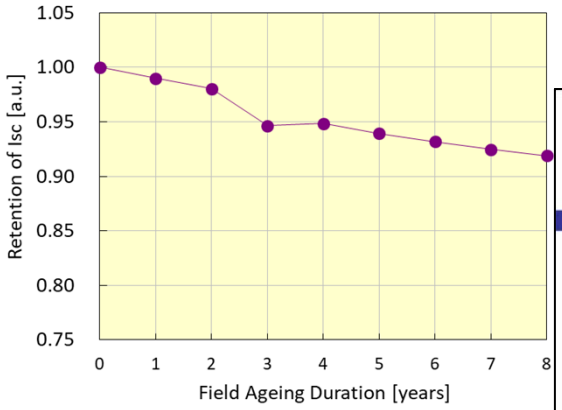

YI change prediction for EVA-1 with Xenon light

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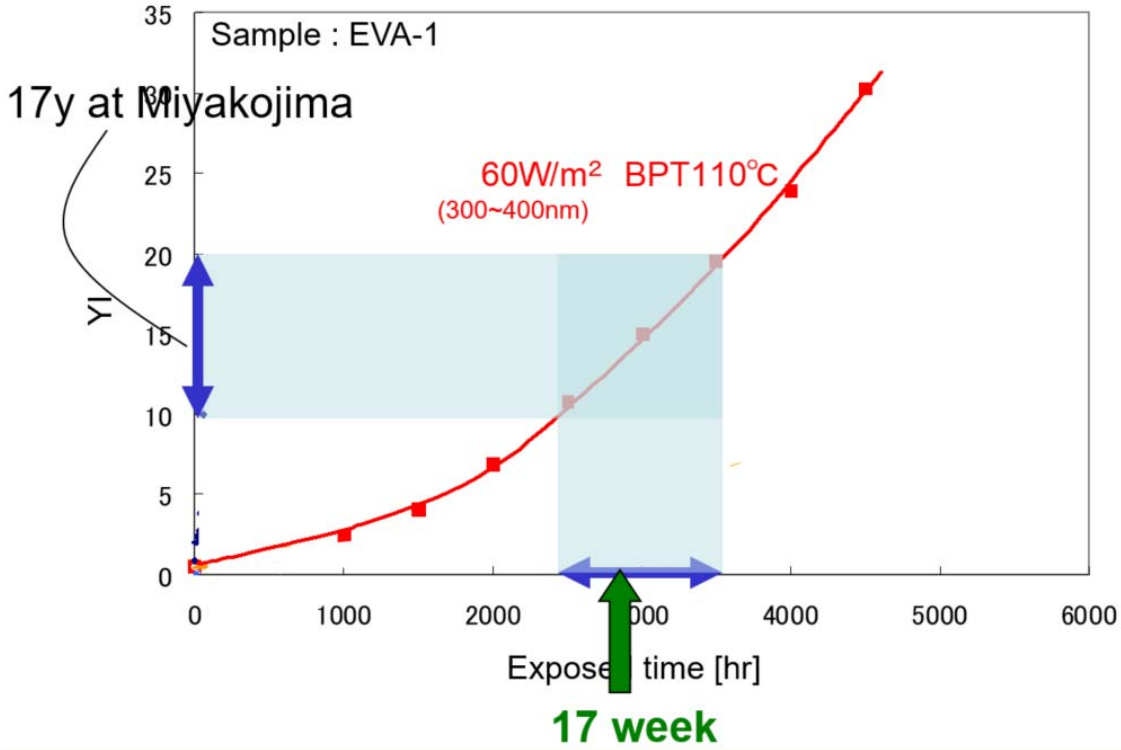
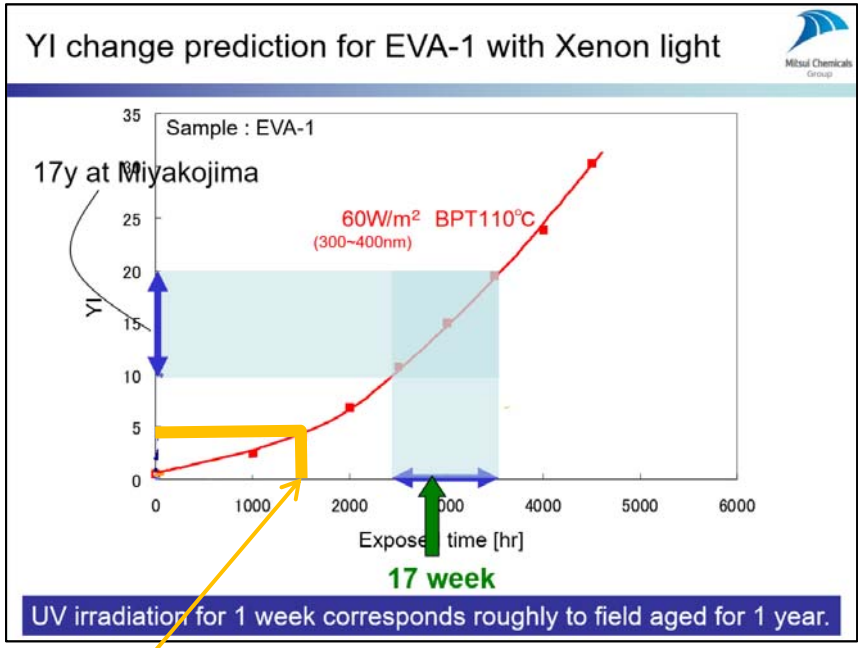
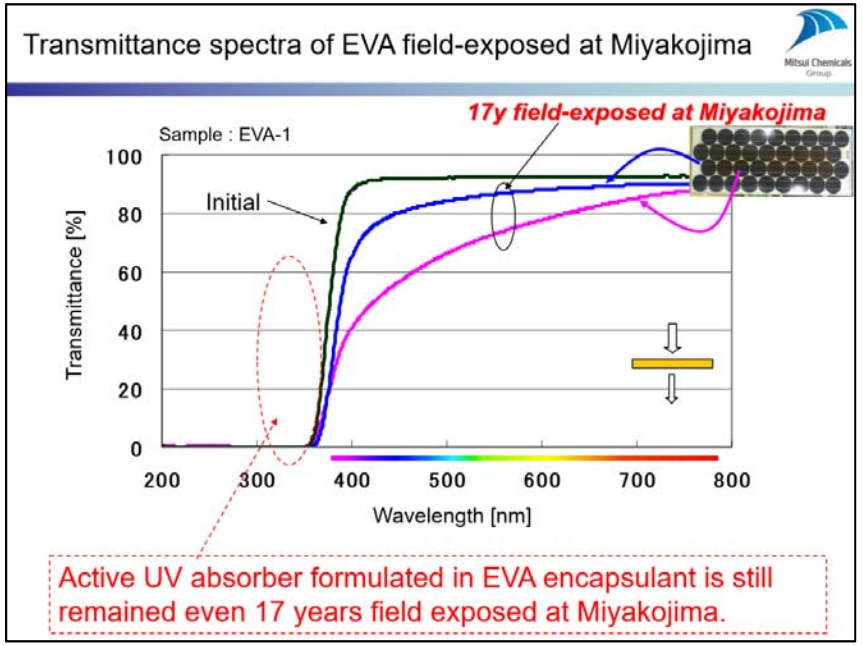


UV irradiation for 1 week corresponds roughly to field aged for 1 year.

T. Shioda: 1st ATLAS/NIST PV material durability workshop 2011

Influence of Yellowing on Isc





T. Shioda: 1st ATLAS/NIST PV material durability workshop 2011

8 weeks Xenon exposure, corresponding to 8 years field ageing, leads to YI of ~5.

- ✓ Yellowness Index (YI) change of the EVA of the CIS thin-film PV modules is similar to that already reported.
- ✓ YI of ~5 would lead to reduction of Isc by ~3%, taking account of the spectra response of the CIS cell and transmittance spectrum change of the EVA.
- ✓ YI change of EVA encapsulant is a part of causes of the 8% reduction of Isc for 8 years field ageing.

4. Summary

- ✓ Actual energy yield data for 5 operating PV plants with CIS thin-film PV modules in Japan have been analyzed.
- ✓ 12-month moving average analysis revealed degradation rate of EY of the PV plants with CIS thin-film PV modules in Japan.
- ✓ The large degradation rates, over 1%/y, have been found. Further the trends showed larger degradation rates after 5 years operation.
- ✓ Further investigation such as effect of inter-row shading in terms of long term reliability is ongoing.
- ✓ The CIS thin-film PV module deployed in our lab have shown similar degradation. Reduction of Isc is main cause of decrease in Pmax, so far. Yellowing of EVA encapsulant is one of causes of the decrease.