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The Super Highway to Grid Parity

Progress on e-Modules Research and Production

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Canadian Solar Inc.

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OUTLINE

Abstract

SoG-Si vs. conventional Si

Ingot growth and e-Wafers

e-Cells and reverse breakdown voltage

e-Modules performance

Summary

Selected projects of e-Module PV power plant

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ABSTRACT

Low cost, high conversion efficiency and fast energy payback time are the key focusing directions for PV industry. Since Canadian Solar first introduced e-Modules that made from 100% low cost solar grade Si (SoG-Si) into PV market in the middle of 2008, great progresses in the production improvement have been achieved in the past two years. This presentation reports the results of an average e-cell conversation efficiency of 15.93%, an high yield of SoG-Si ingot growth and wafering comparable to conventional Si ingot growth and wafering, a less than 2% of light induced degradation and an average of 0.56% annual long term degradation for e-modules.

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Solar Grade Si vs. Conventional Poly Si

	Conventional poly-Si	Solar grade Si
Energy consumption (KWh/kg)	80-200	10-20
Environmental impact	High	Very low
Impurity levels* of currently available commercial supply	1) 7N-8N; 2) 8N-9N; 3) better than 9N	~6N
Product cost ($/kg)	25-50	15-25
Investment $(USD)M/1000MT	~100	~15
Factory construction period	~2Years	<1Year
Typical multi-crystalline cell efficiency	15.5-16.5%	15-16%

Solar grade Si: Low cost, fast energy payback, environmentally friendly

* Not including O and C

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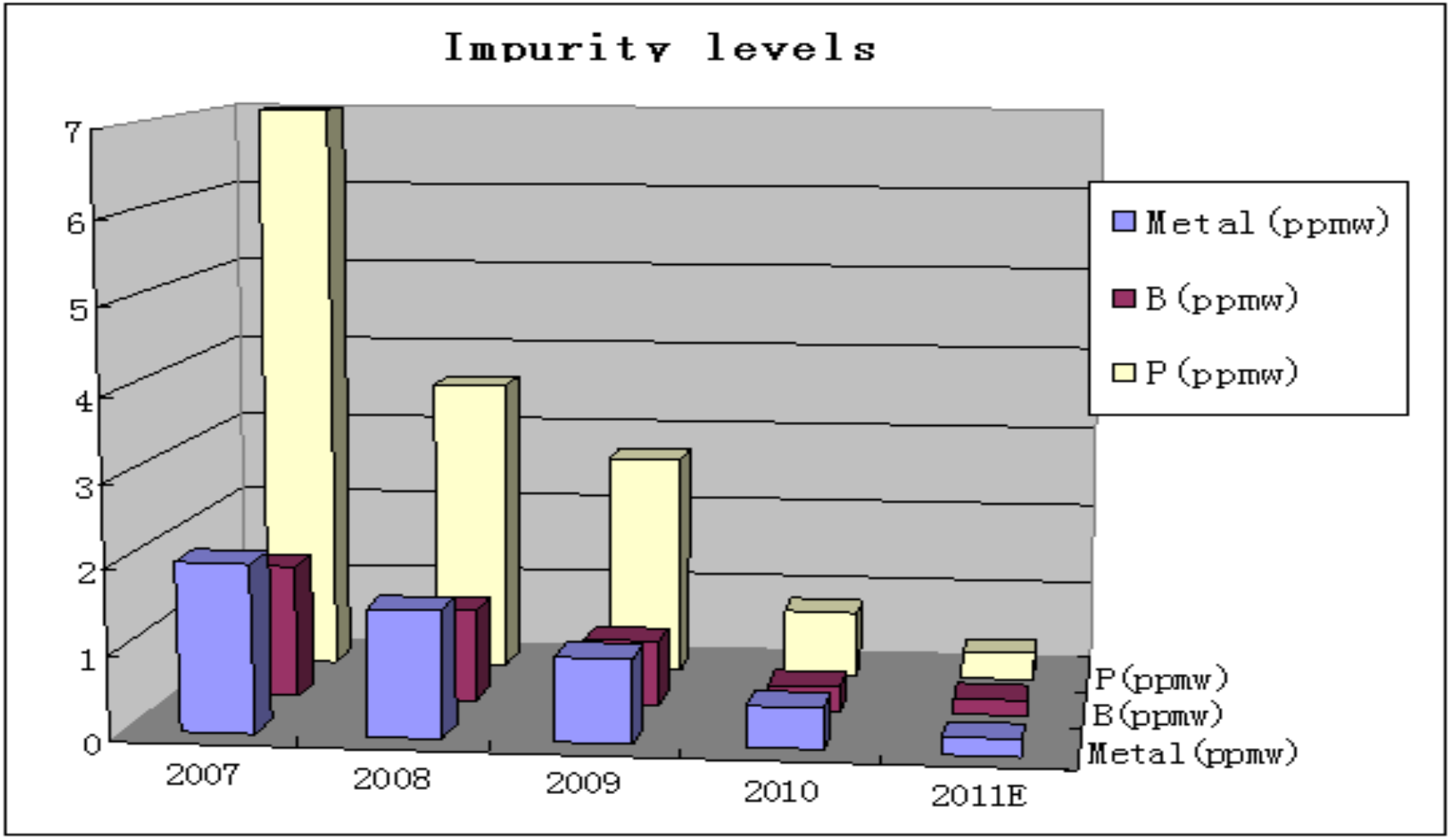
UMG/SoG Si Impurity level Footprint



UMG-Si (5-6N) has improved into SoG-Si (better than 6N)

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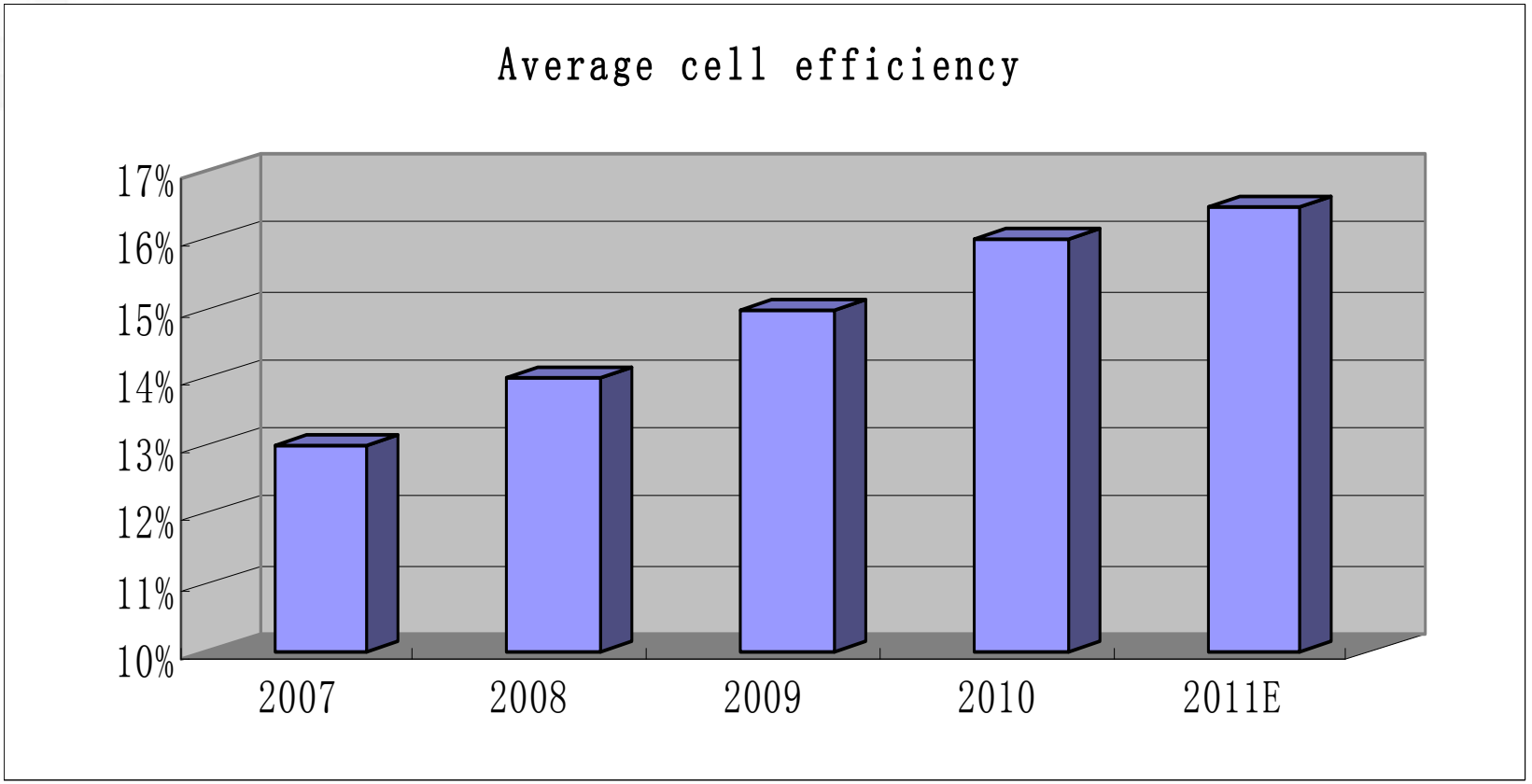
e-Cell Efficiency Footprint & Roadmap



e-Cell efficiency will catch up the conventional Si cell efficiency in next 1-2 years

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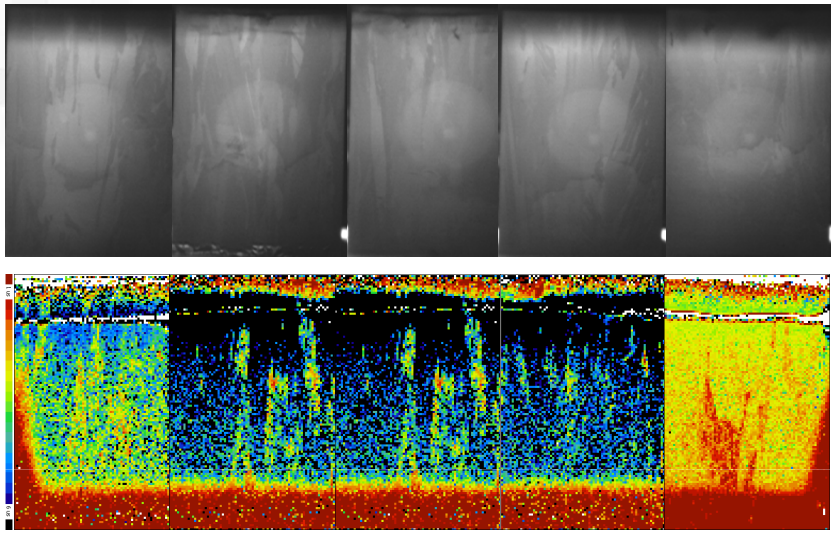
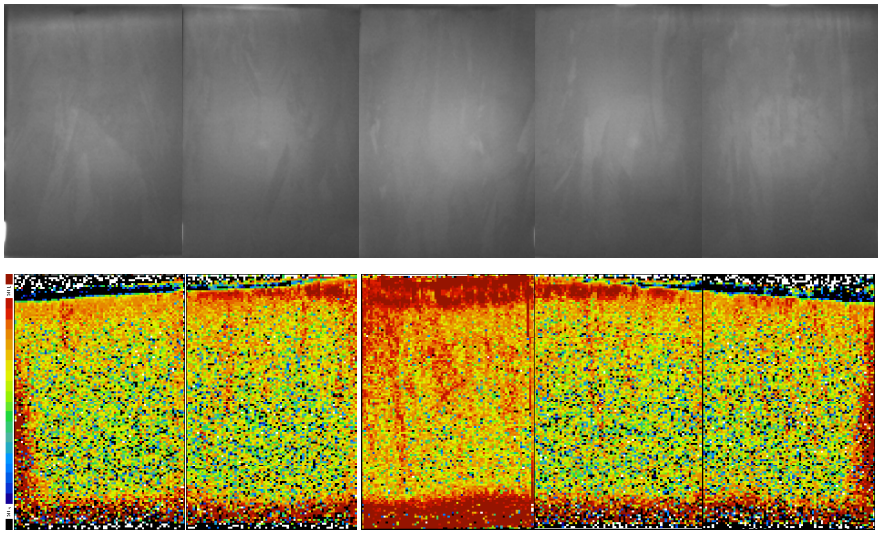
Brick IR Images and Lifetime Mapping





SoG-Si from supplier A:
B and P high
Effective ingot length low
Metals impurity low
Brick lifetime high (>3us)

SoG-Si from supplier B:
B and P lower,
Effective ingot length high
Metals high
Brick lifetime low (>2us)

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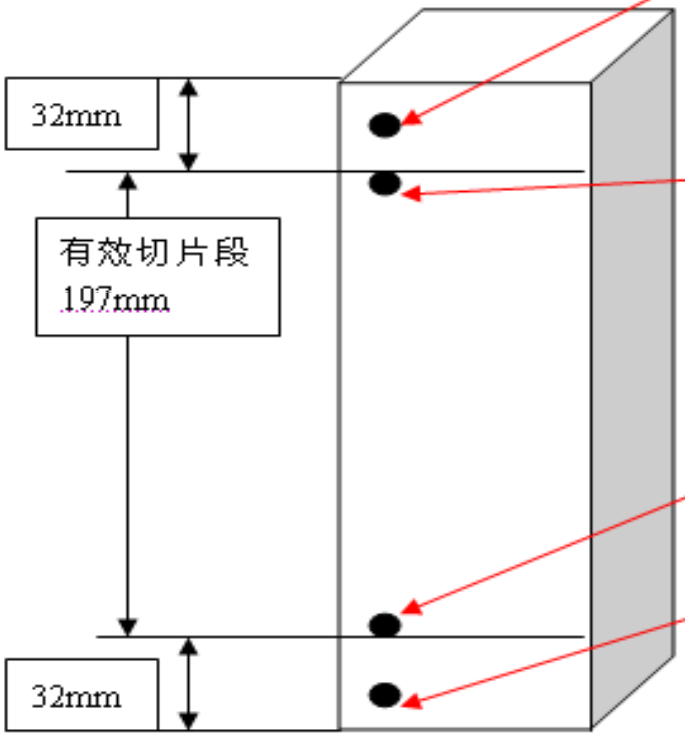
SIMS Analysis of Brick Impurity

Ingot grown from Supplier B
SoG-Si with relative high metals



距顶部 15mm 处，

C： 5.71E+17 (atoms/cm3)　　O： 5.12E+16 (atoms/cm3)

Cr：< 2.00E+13 (atoms/cm3)　　Fe：< 1.00E+14 (atoms/cm3)

Ni： < 2.00E+14 (atoms/cm3)　　Cu：< 1.00E+14 (atoms/cm3)

Zn：< 5.00E+14 (atoms/cm3)　　Al： 2.04E+15 (atoms/cm3)

有效切片段顶部处，

C： 3.97E+17 (atoms/cm3)　　O： <5.0E+16 (atoms/cm3)

Cr：< 2.00E+13 (atoms/cm3)　　Fe：< 1.00E+14 (atoms/cm3)

Ni： < 2.00E+14 (atoms/cm3)　　Cu：< 1.00E+14 (atoms/cm3)

Zn：< 5.00E+14 (atoms/cm3)　　Al： 9.86E+14 (atoms/cm3)

有效切片段底部处，

C： 3.41E+17 (atoms/cm3)　　O： 1.85E+17 (atoms/cm3)

距底部 10mm 处，

C： 3.27E+17 (atoms/cm3)　　O：3.70E+17 (atoms/cm3)

SoG-Si ingot effective length (197mm) has achieved 97.5%
of conventional ingot effective length (202mm)

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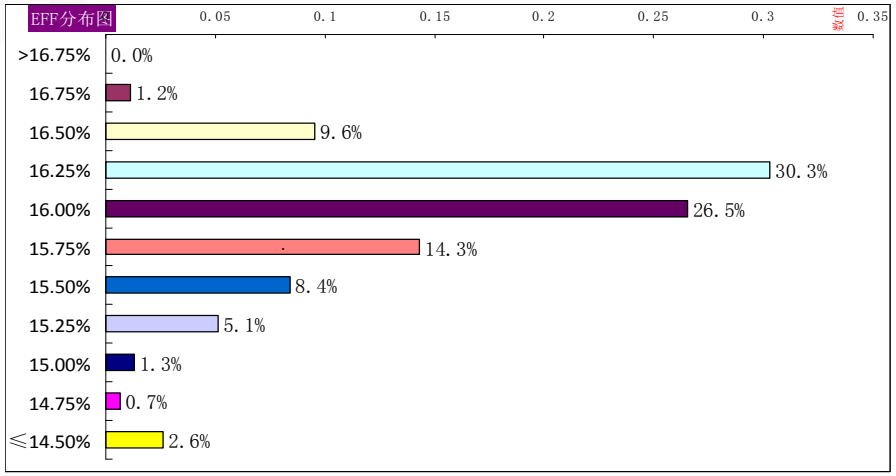
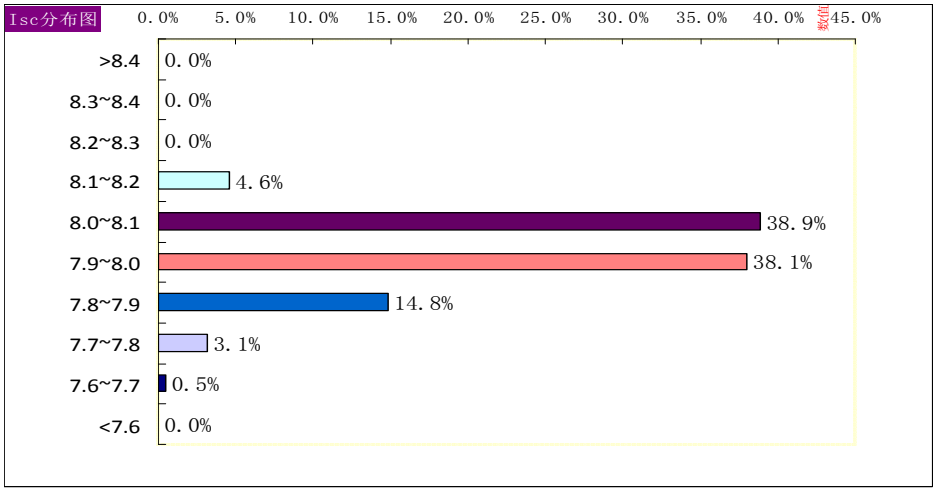
e-Cell Process Results

Uoc	Isc	Rs	Rsh	FF	EFF
0.632	7.98	0.00387	21	76.87	15.93%

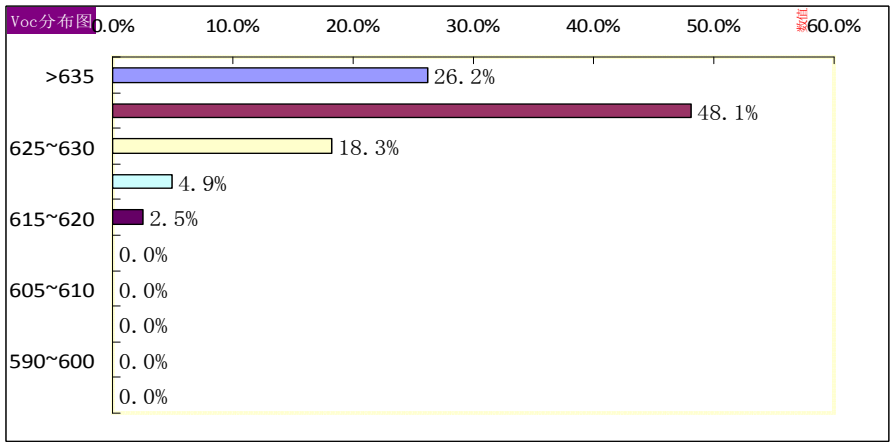
EFF



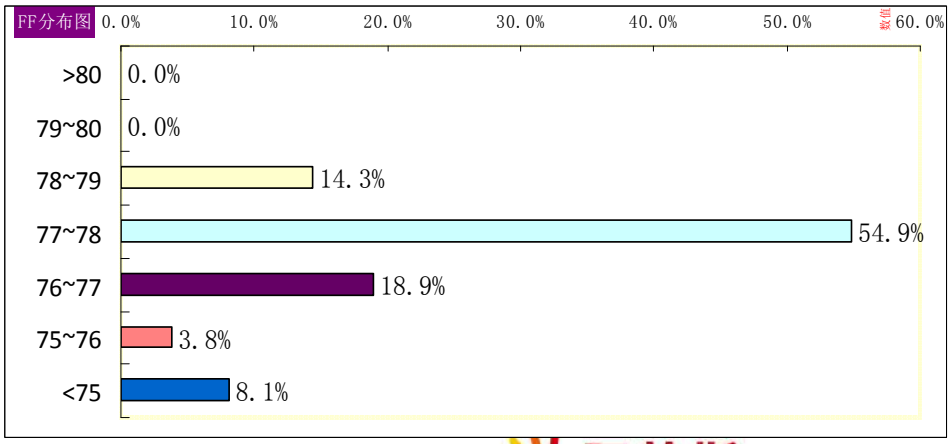
Isc



Voc



FF



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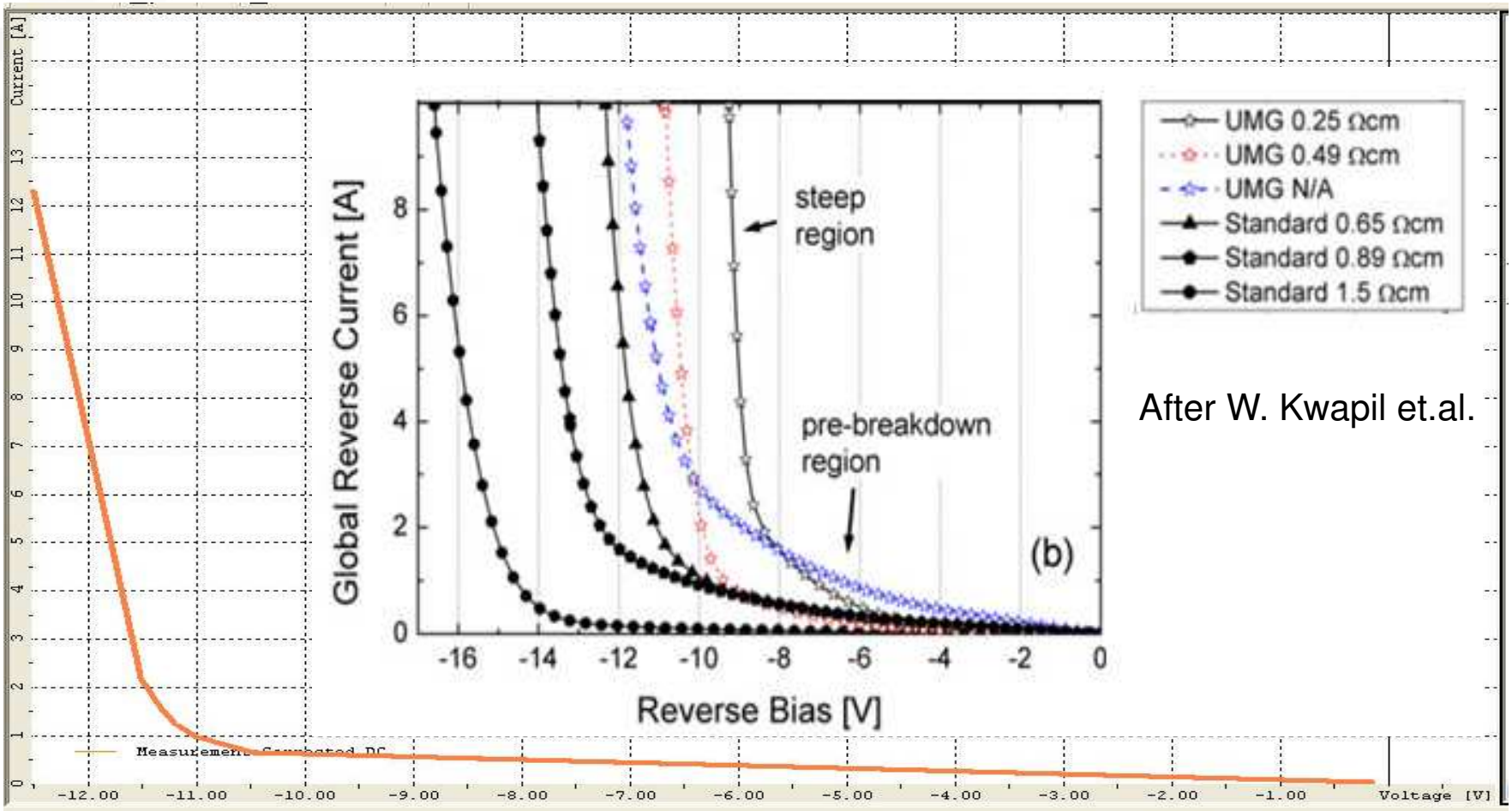
e-Cell Reverse Breakdown Voltage



After W. Kwapil et.al.

With similar wafer resistivity, e-module has achieved a comparable breakdown voltage

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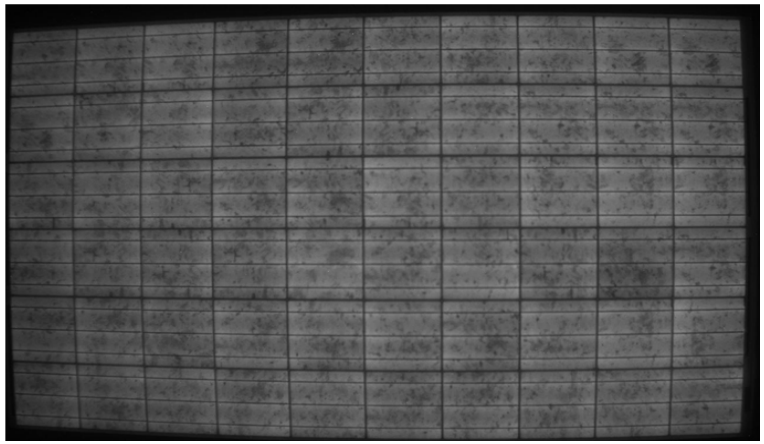
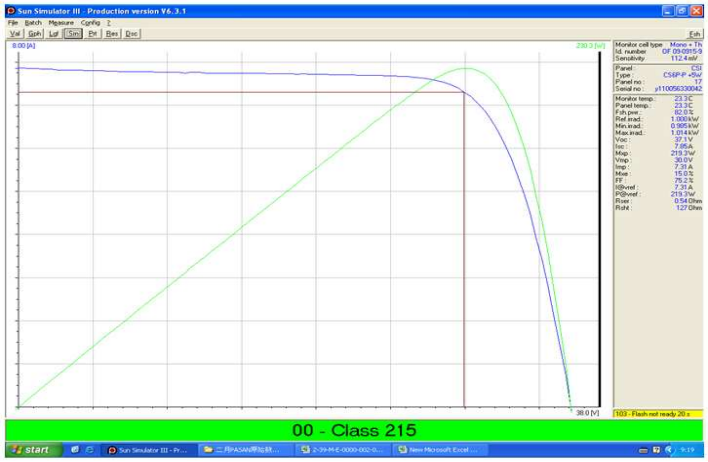
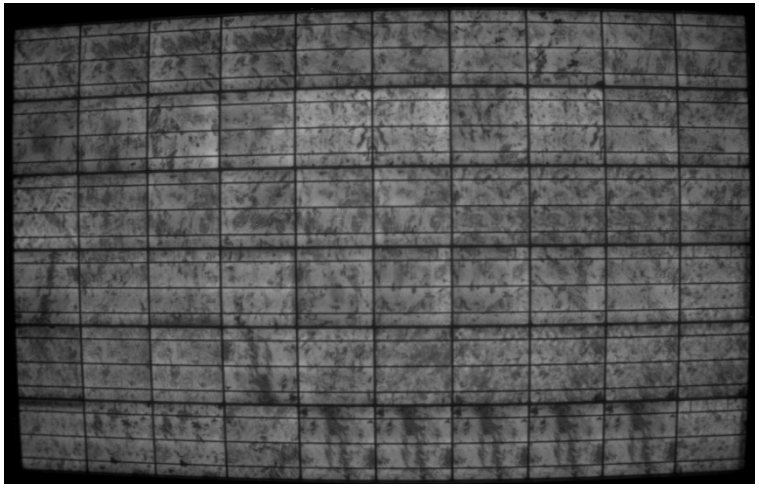
e-Module I-V Testing and EL Image

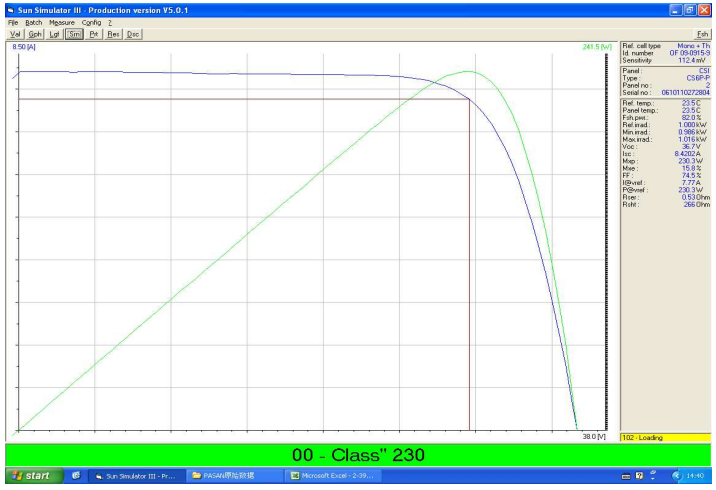
E-module(cell Eff. 15.5%)





P-module(cell Eff. 16%)





Compared with conventional module, e-module has a similar EL image although slightly lower Eff.

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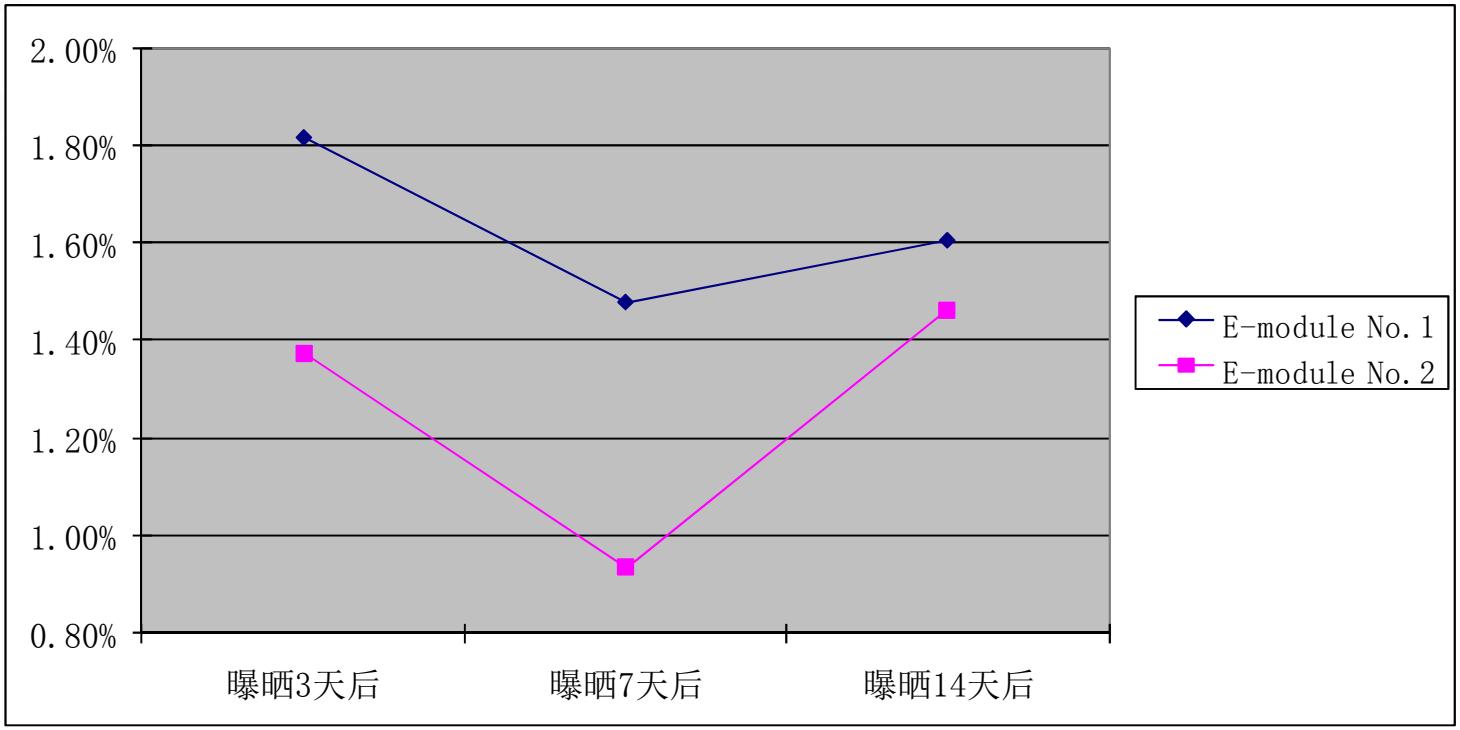
Performance of e-Modules



Initial performance results:

- **Typical LID for e-Modules is less than 2%, which is comparable with the conventional crystalline Si module; stabilized after 3-4 days**
- **LID mainly caused by B-O complex; LID results in a reduction of Isc**
- **New generation of e-Module without LID will be in production soon**

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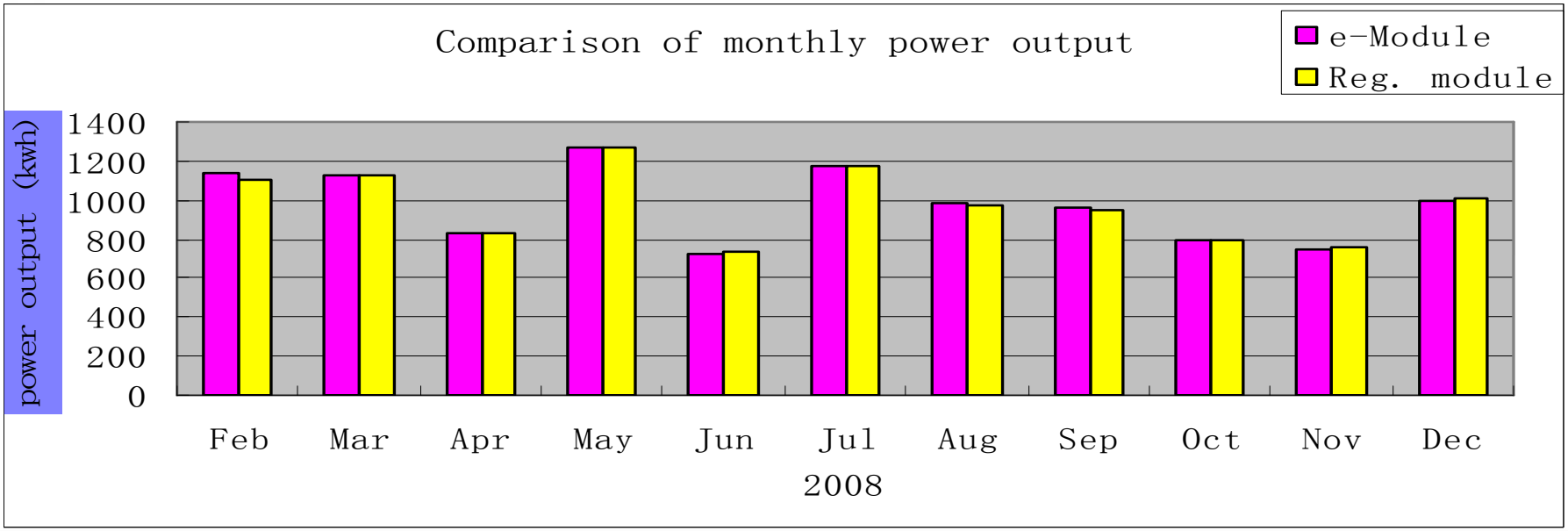
Performance Comparison

e-Modules

Conventional Modules



- **Equal performance to conventional modules, better at high temperatures (peak pricing periods)**
- **long term degradation is about 0.56% per year both of these values are comparable with conventional modules**

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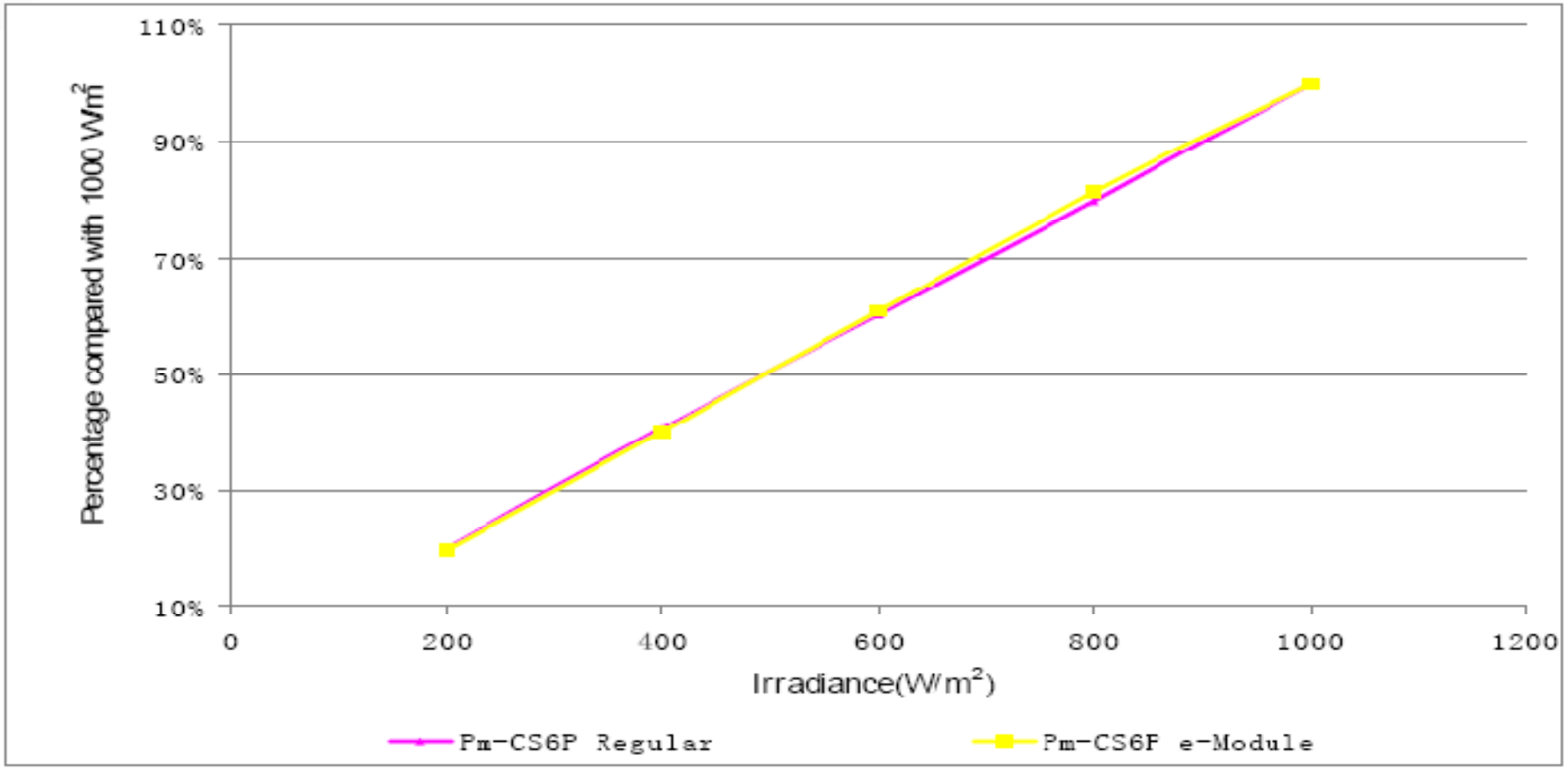
System Output vs. Irradiation



Equal performance to conventional modules

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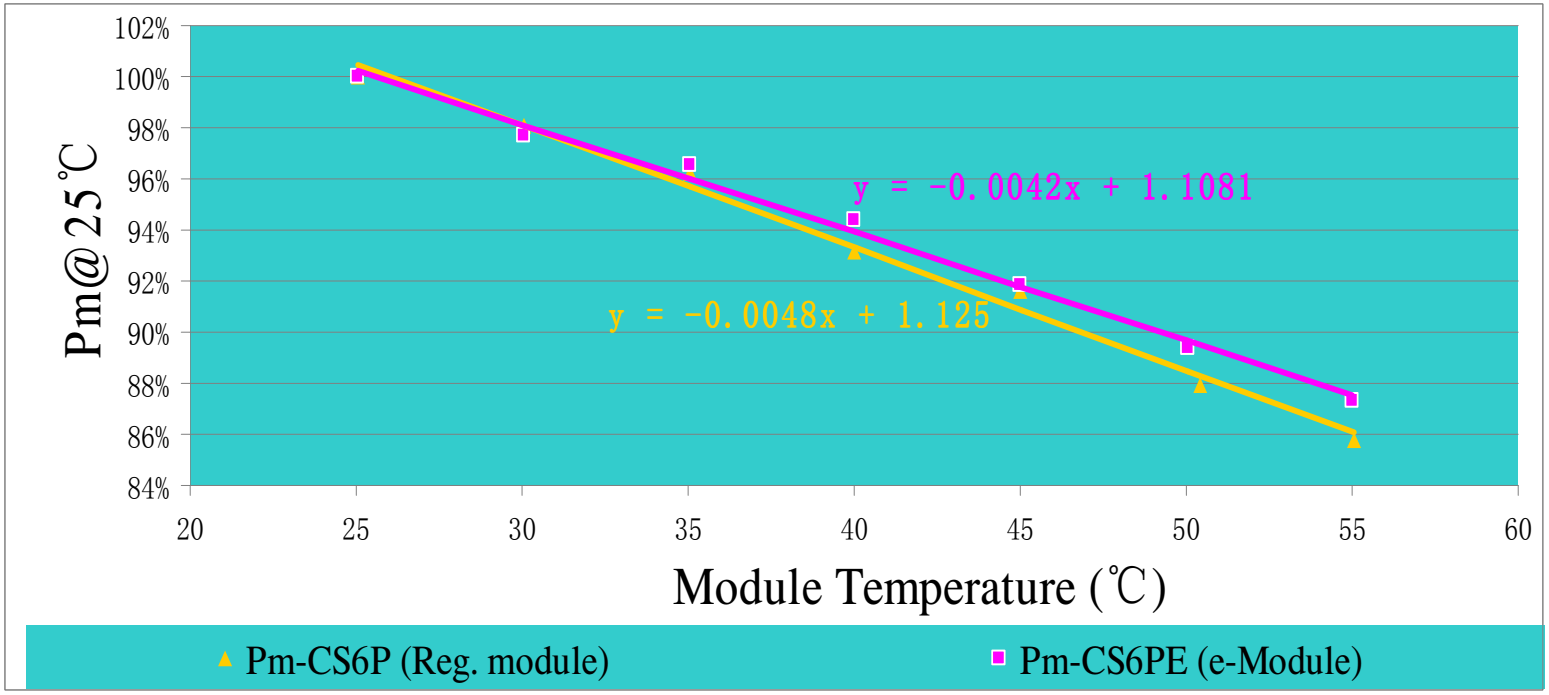
Modules Temperature Coefficients

	α-Isc(%/℃)	β-Voc(%/℃)	γ-Pm(%/℃)
CS6P Reg. module	0.073%	-0.356%	-0.494%
CS6PE e-Module	0.107%	-0.378%	-0.438%



A lower peak power temperature coefficient

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Summary

- SoG Si: low cost, fast energy payback time, and environmental friendly
- CSI's SoG-Si ingot growth and wafering have achieved the similar yield to conventional Si ingot growth and wafering.
- e-Cells average efficiency has reached ~16%, and reverse breakdown voltage has achieved 11.3V
- e-Modules have demonstrate a LID of less than 2% and long term degradation of about 0.56% annually, both values are comparable with conventional modules.
- e-Modules demonstrate excellent potential for fast-pace efficiency improvement and cost reduction
- e-Modules will lead the crystalline modules toward the grid parity.

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Minturn Huller

Location: California, US
Module: CS6P-200PE e-Module

System Size: 540 kW
Activated: Dec. 2009

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Person County Solar Park

Location: North Carolina, US
Module: CS6P 190PE e-Module

System Size: 650 kW
Activated: Aug. 2009

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Concord Truss Company

Location: New Jersey, US	System Size: 117.6 kW
Module: CS6P PE e-Module	Activated: Oct. 2009

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e-Module Project in USA

Project Details			
Location	Visalia, CA	Module Type	e-Module CS6P-PE
System Size	392.645 kWp	Completion	August 2008

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e-Module Project in Germany

Project Details			
Location	Ostfriesland, Germany	Module Type	e-Module CS6A-PE
System Size	111 KWp	Completion	September 2008

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e-Module Project in Korea

Project Details			
Location	Jeong Up-si, Korea	Module Type	e-Module CS6P-PE
System Size	300 KWp	Completion	September 2008

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Thank You !