The New Era of Photovoltaic Technology

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think it. apply it.™

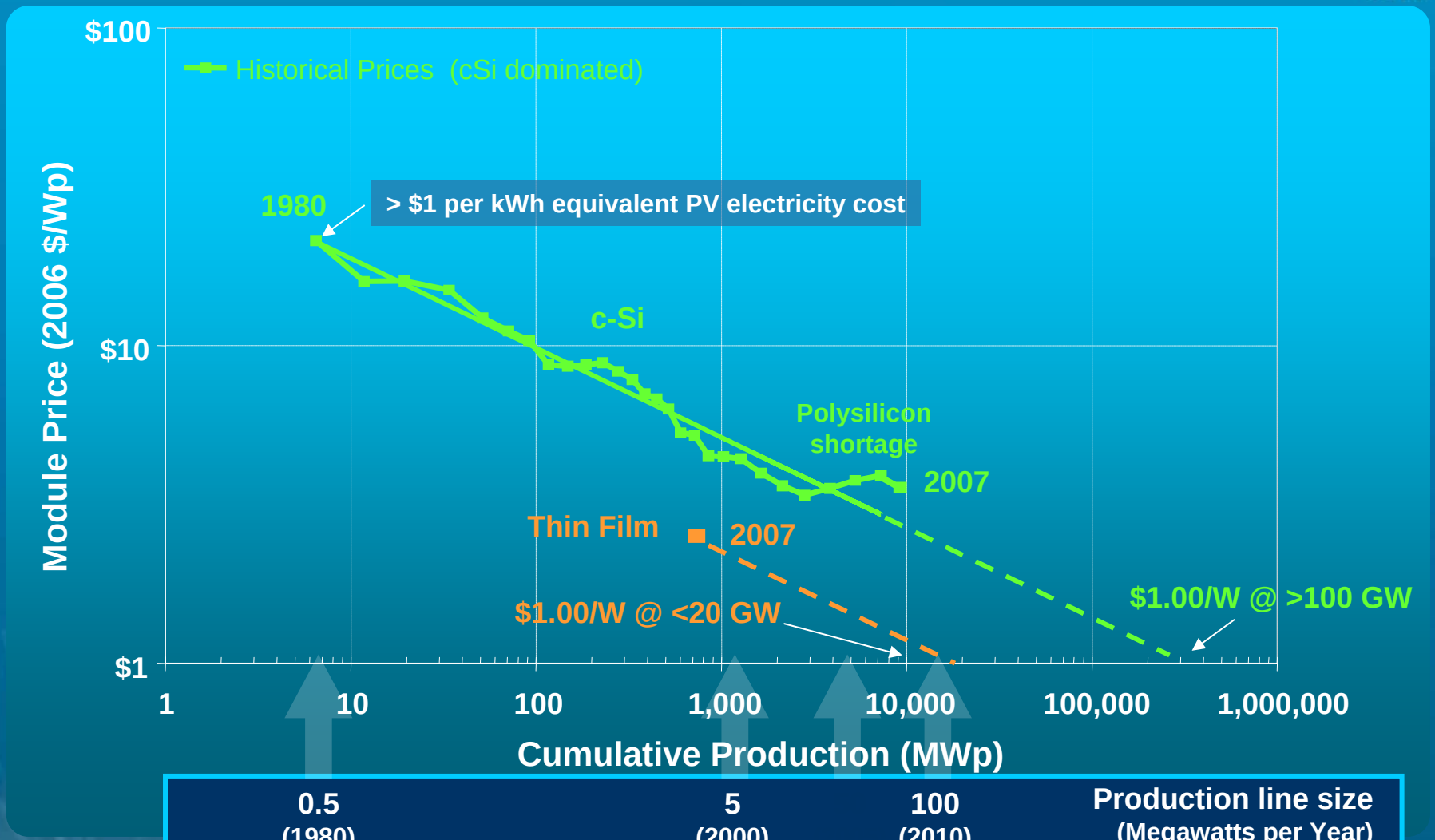
APPLIED MATERIALS.

The New Era…25 Years Later

"If a guy took out a piece of glass, poured some fluid on it, held it up to the sun and got some voltage off it, he made a headline and got funds. Those days are over. It's time for big money commitments."

– J. Robert Maxwell, Westinghouse Director of Solar Programs as quoted in an article by Thomas L. Friedman in The New York Times, August 1981.

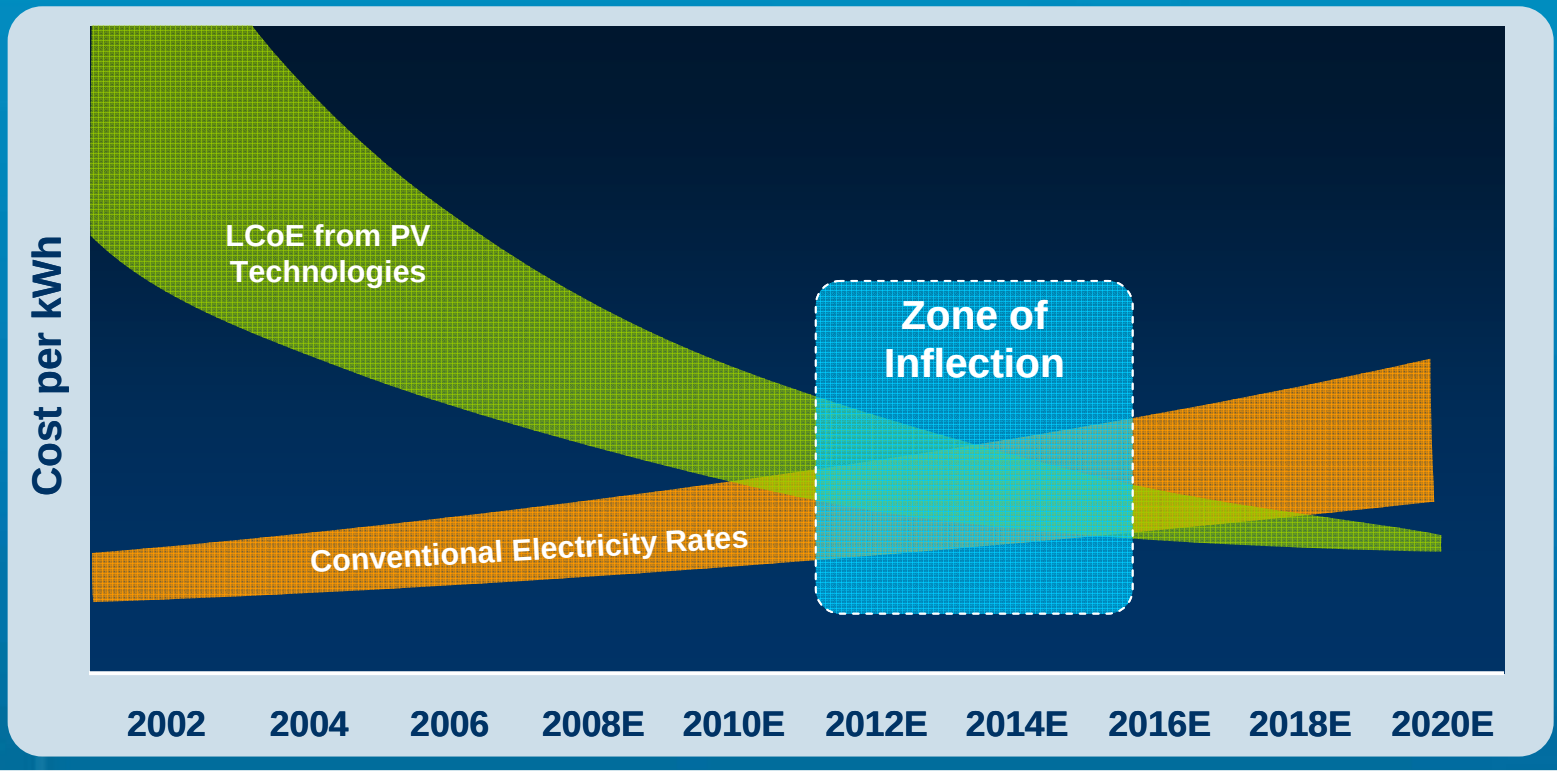
Solar Learning Curve: Module Cost/Watt



0.5 (1980)	5 (2000)	100 (2010)	Production line size (Megawatts per Year)
2	3	10	Lines Per Factory

Source: Adapted from NREL

Grid Parity: The Inflection Zone



$.20/KWhr	$.15/KWhr	$.10/KWhr
▪ 10% of world total ▪ Oil, off grid diesel ▪ Japan, Hawaii, Peak CA	▪ Average price in CA today ▪ DoE US price forecast in 2015	▪ >50% of world total ▪ 300TWh/Yr added
<$4.00/Wp Installed Price ▪ Possible today with TF	**<$3.00/Wp Installed Price** ▪ Possible today through 8-10 year project based off-take	**<$2.00/Wp Installed Price** ▪ Possible today with FIT, other incentives

* Assumes good sunshine (1800 Hrs), 7.5% per year cost/W reduction for PV

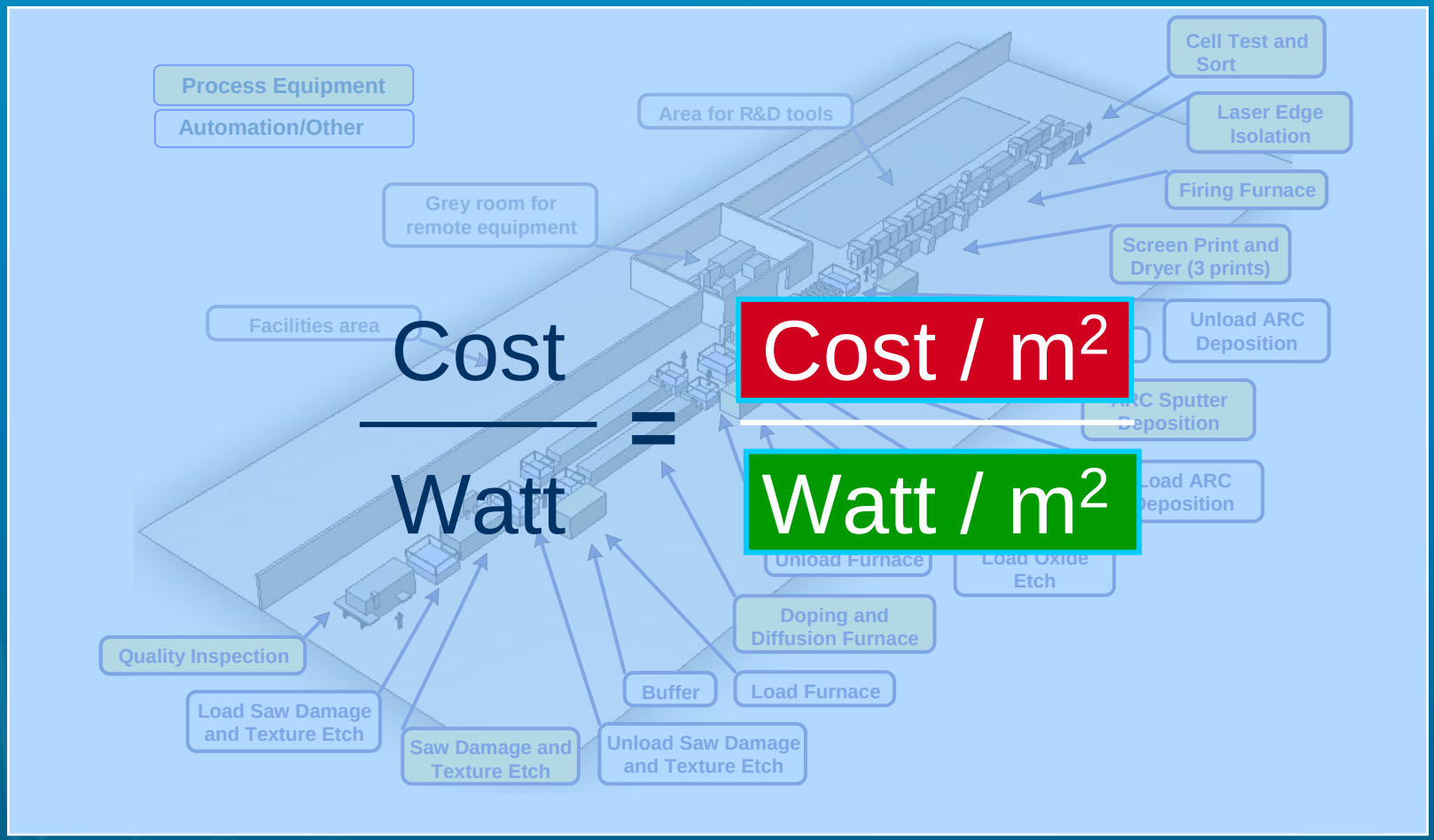
Components of PV Cost

+

- Materials cost
- Process cost
- Module efficiency

- Module efficiency
- Module size
- Module weight
- Labor cost
- Site costs

PV Module Production Cost



Significant leverage available from lower process cost

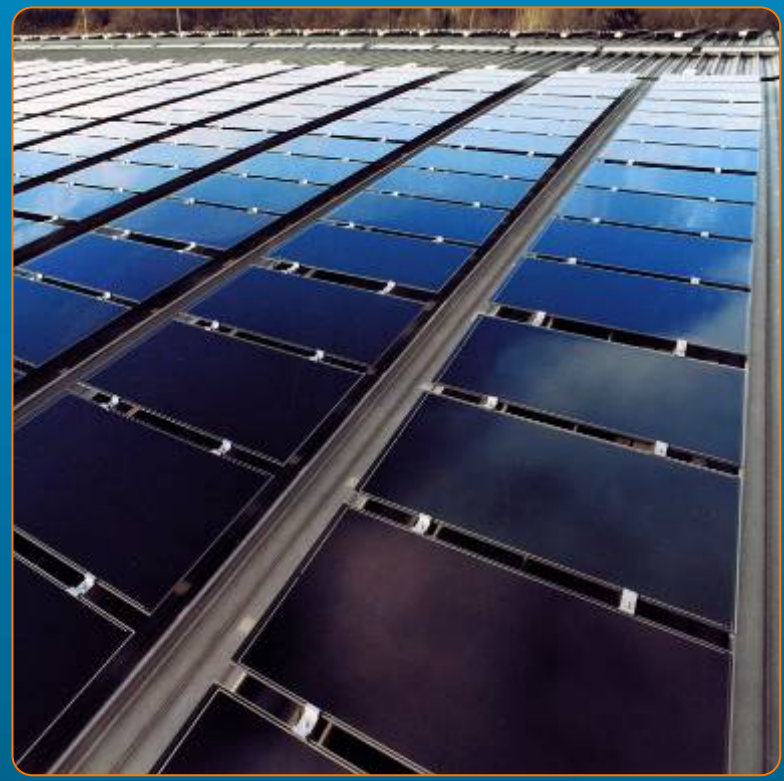
Key PV Technologies and Markets

Crystalline Silicon

Preferred for residential applications

Thin Film

Preferred for large scale applications



Common focus to drive down cost per watt

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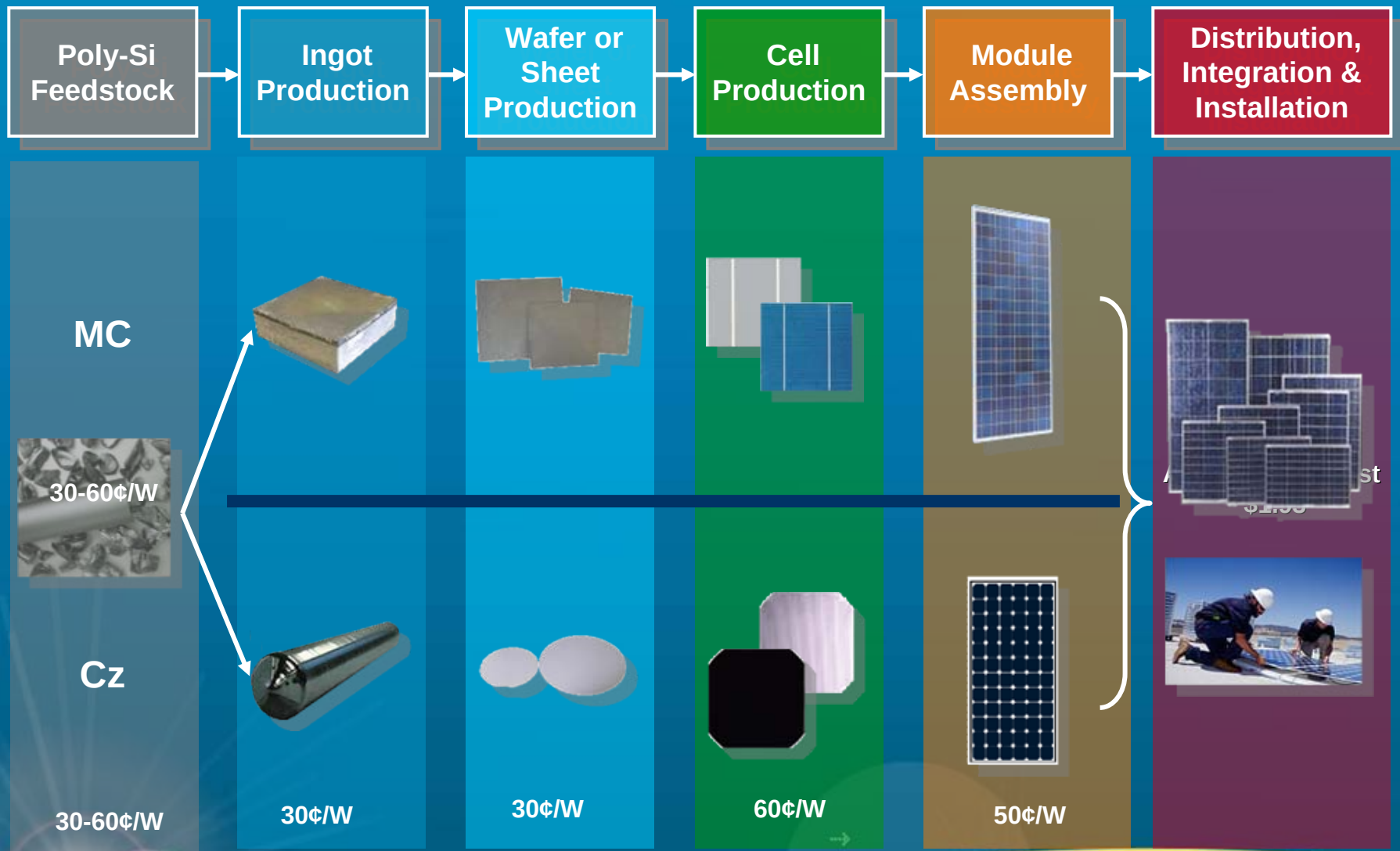
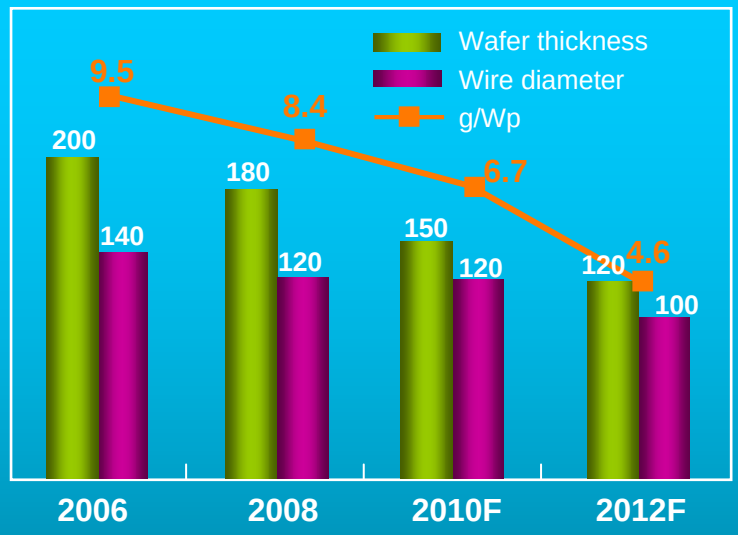
Common focus to drive down cost per watt

Wafer Based PV Value Chain

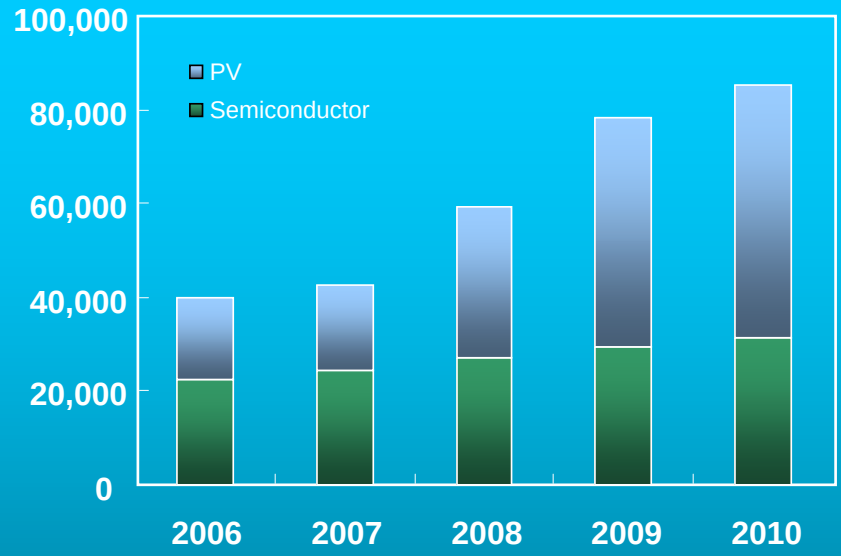


Improve Material Efficiency: Thin Wafers

PV Wafering Roadmap



Polysilicon Production (Mton)



$$\frac{\text{Cost / m}^2}{\text{Watt / m}^2}$$

Data sources:
Wafering: S. Schneeberger, April 2007
Polysilicon: A. Bjørseth, June 2007

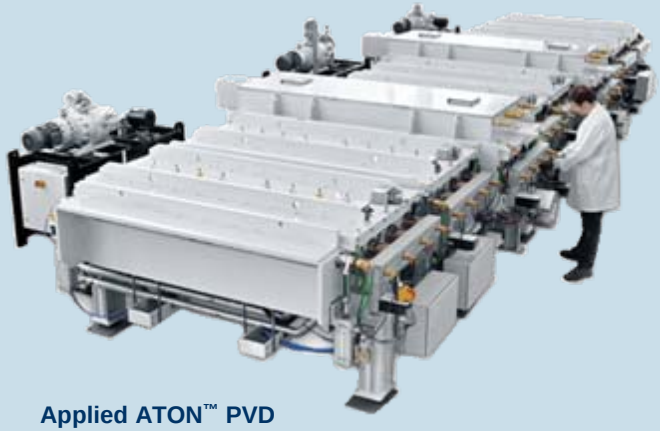
Processes Offering Scale + PV Efficiency

Cost / m^2

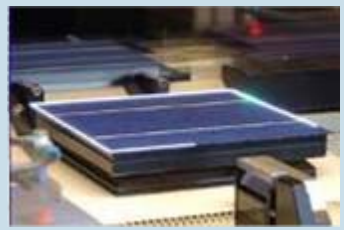
Watt / m^2

- Yield
- Thruput
- Uptime
- Thin wafers
- COC

- Efficiency
- Uniformity



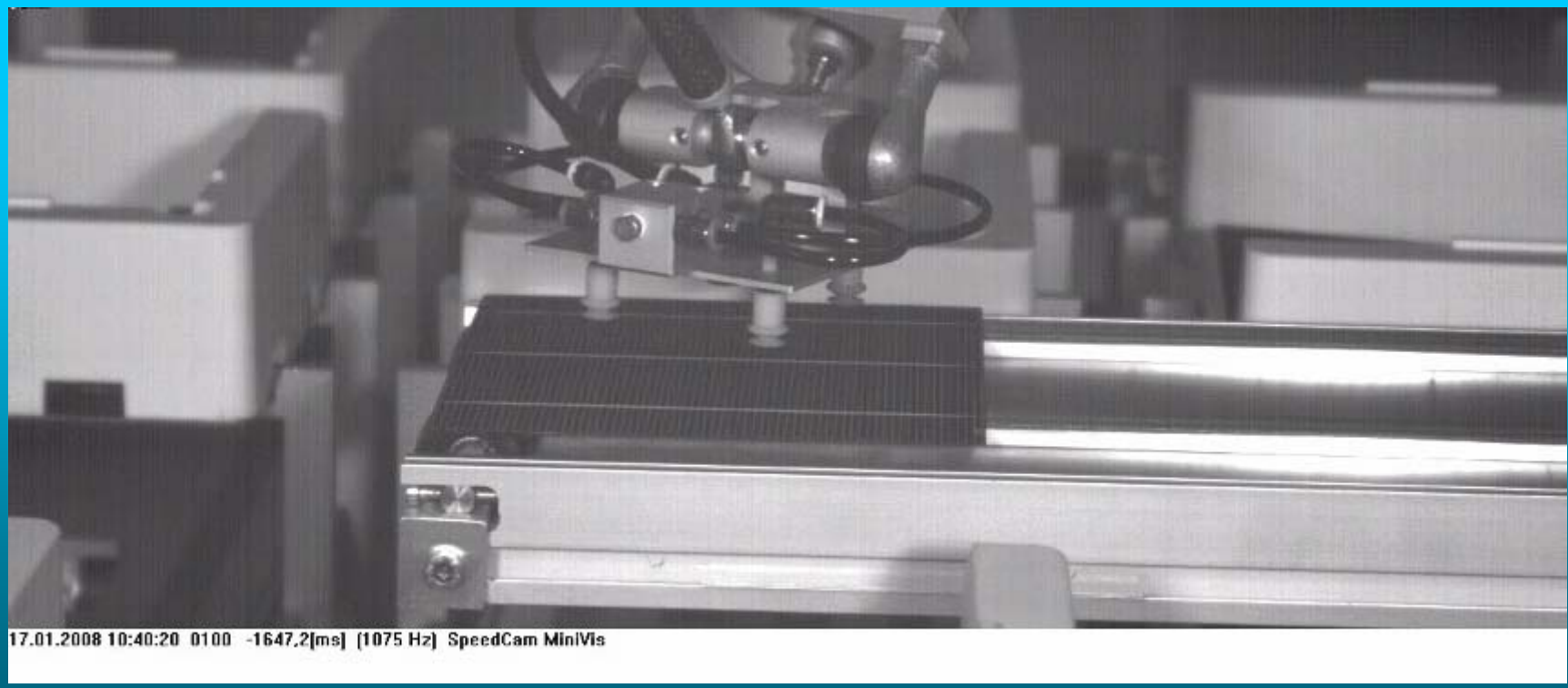
Applied ATON™ PVD



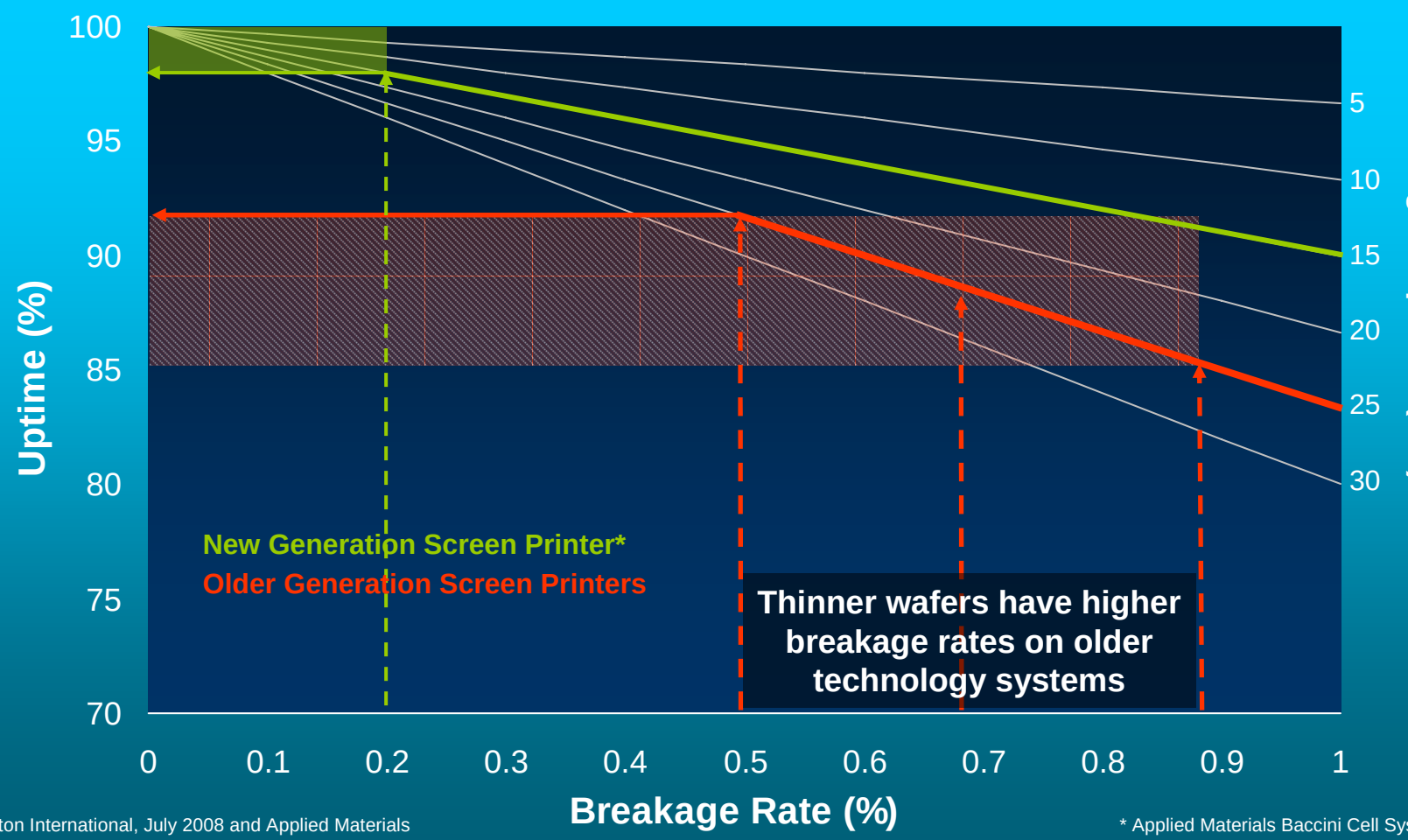
Applied Baccini Cell Systems Metallization Line

Requires throughputs of >1,000 wafers per hour

Enabling Ultra-Thin Wafer Processing



Example of Thin Wafer Processing



Source: Photon International, July 2008 and Applied Materials

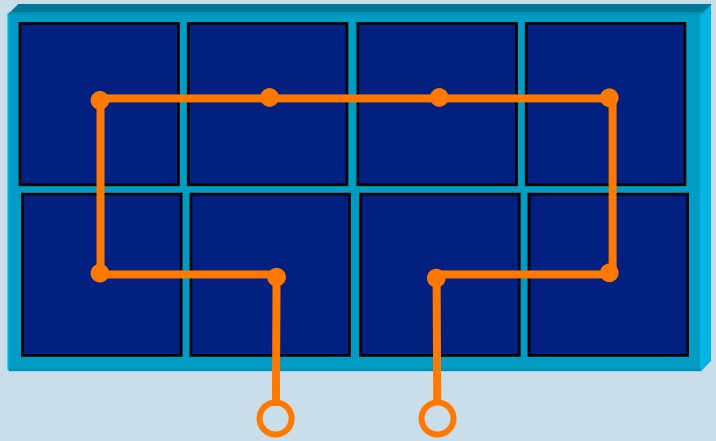
* Applied Materials Baccini Cell Systems

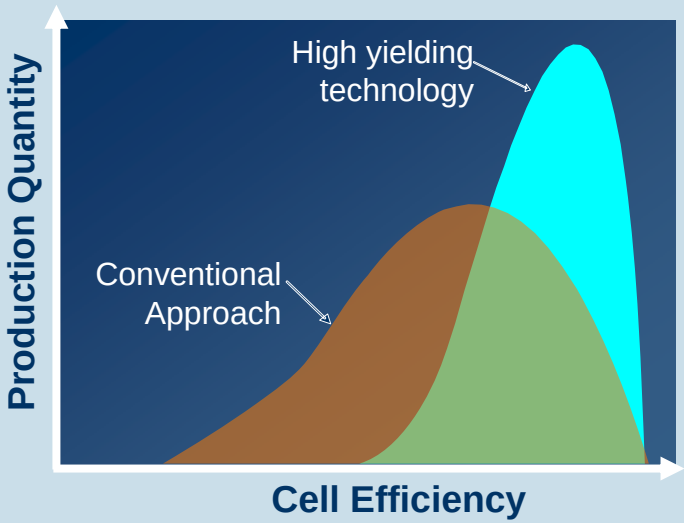
Low Cost = Thin Silicon + High Uptime

Production Uniformity and Wafer Binning

Cost / m^2

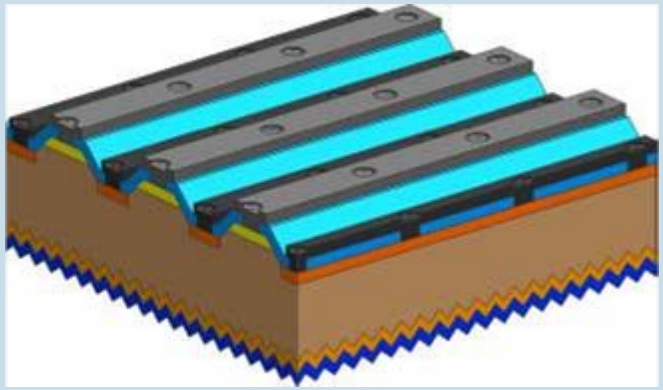
Watt / m^2





High Efficiency Commercial Silicon PV Cells

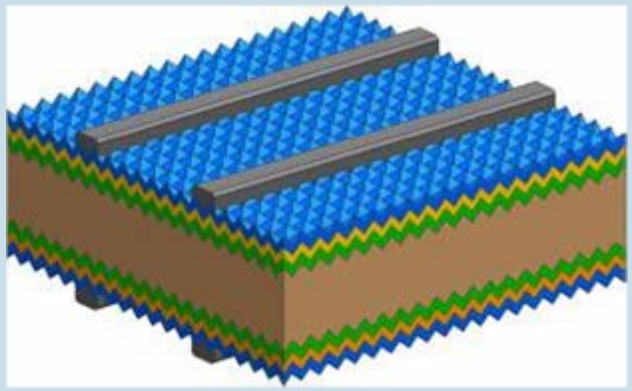
All Back Contact (SunPower)



- Back contact structure minimizes series resistance and recombination loss
- 23.4% cell efficiency achieved

Source: R.Swanson et.al., 33rd IEEE PV Conf, May 2008

HIT Cell (Sanyo)



- Hetero interface creates a minority carrier mirror and improves thermal dependence
- 22.3% cell efficiency achieved

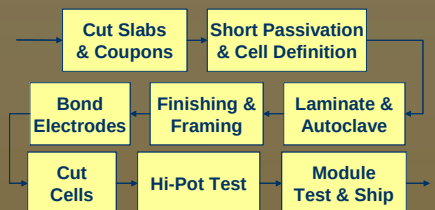
Source: Y. Tsunomura et.al., Intl. PVSEC-17, 2007

Manage Additional Process Complexity

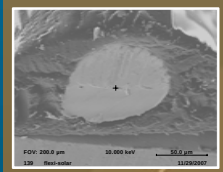
$$\frac{\text{Cost / m}^2}{\text{Watt / m}^2}$$

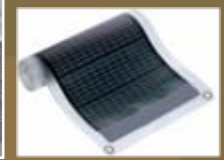
Thin Film PV Value Chain

Wafer or Sheet Production	Cell Production (Si, CdTe, CIS)	Module Assembly	Distribution, Integration & Installation



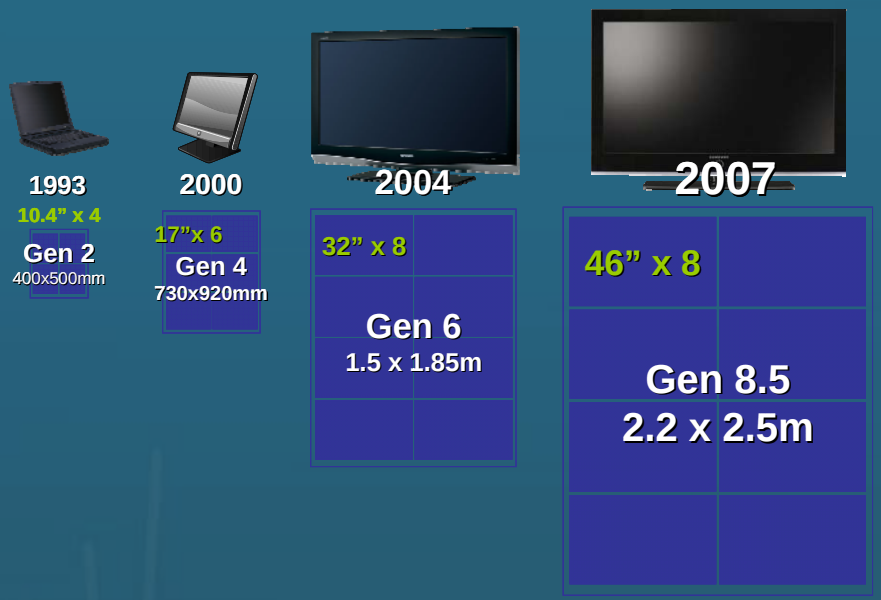
Source: Unisolar



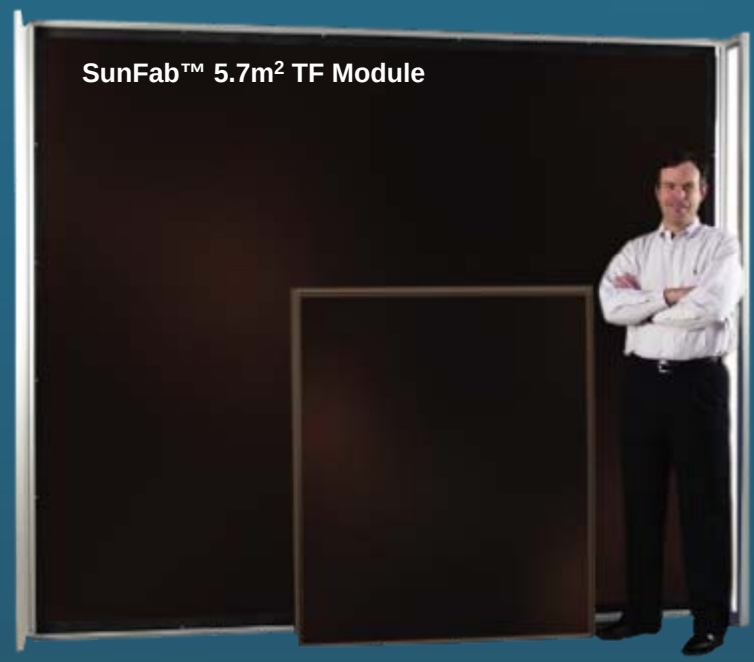


Large Area Processing = Lower Cost Per Area

Demonstrated in 15+ years of flat panel displays



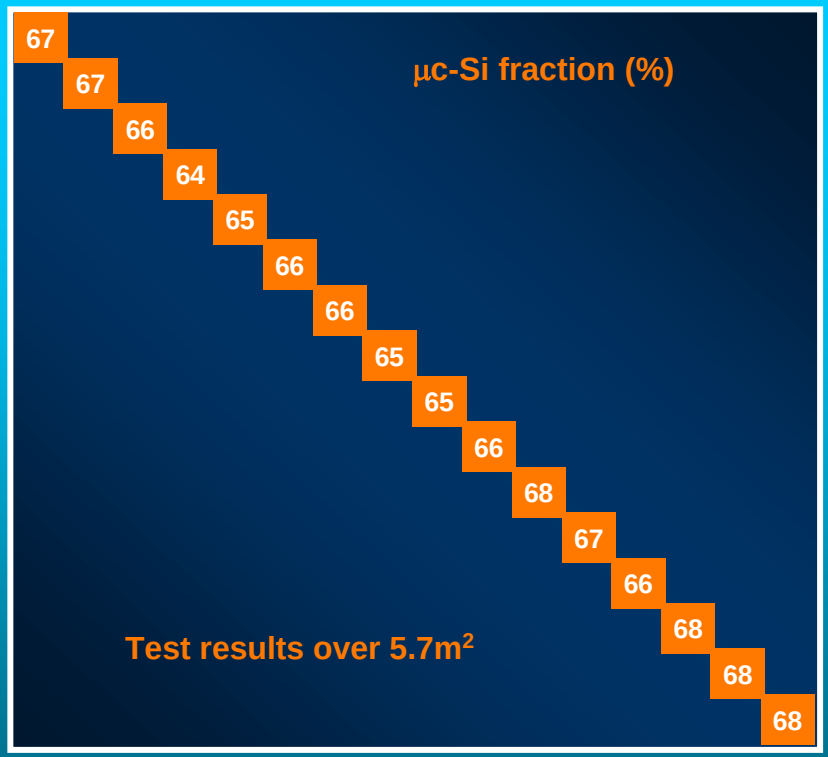
~20X Reduction in Display Cost/Area Due to Large Area Processing

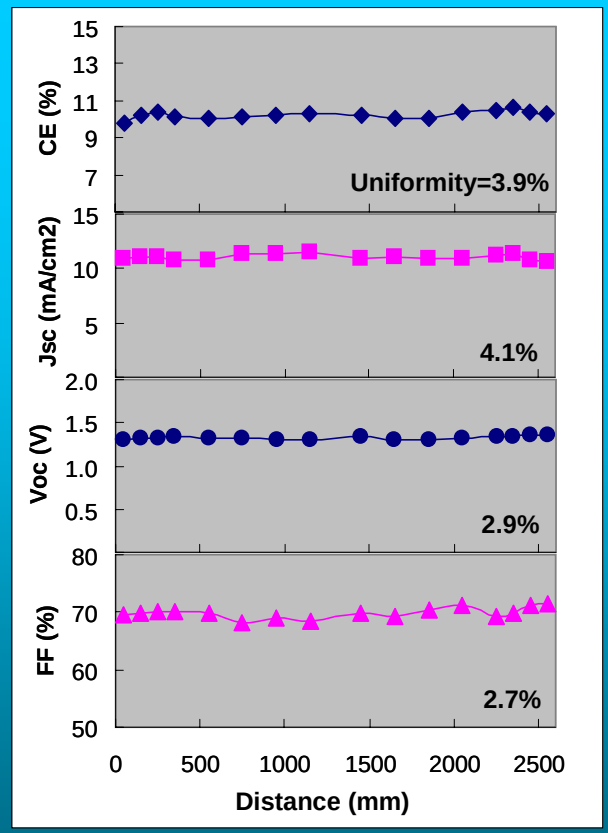


Large Thin Film PV Modules Leverage Low Cost per Area Processing *and* Reduce Installation Costs

SunFab™ 5.7m² Thin Film PV Factory

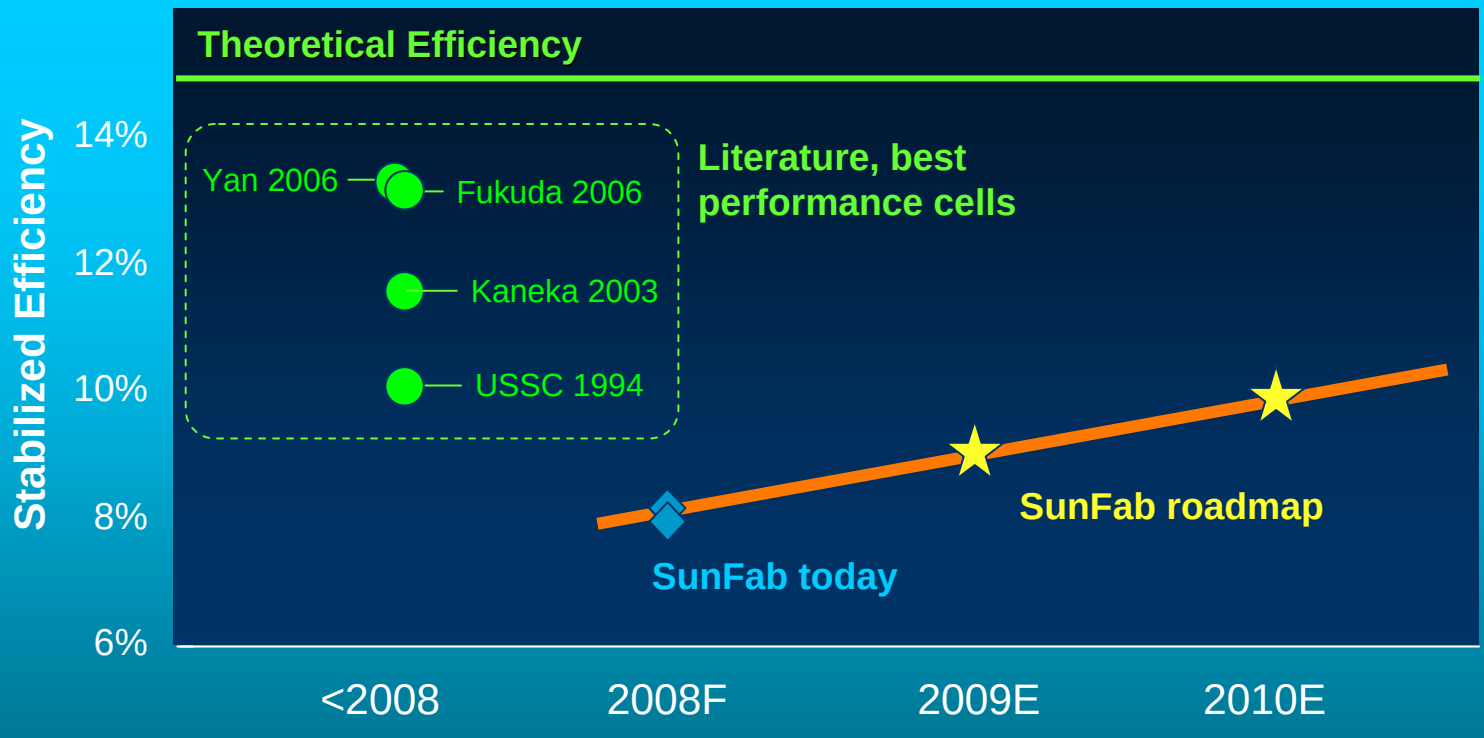
SunFab™ Tandem Junction on 5.7m² Modules

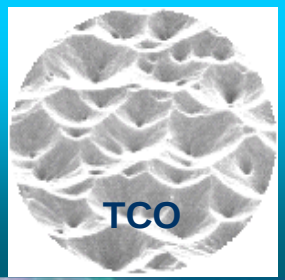




- Achieved TJ average initial cell efficiency >10% with standard deviation of only 0.2% over full 5.7m² module
- Relative variation <5% in µc-Si fraction over entire substrate

Driving Thin Film Silicon Efficiency at Large Scale



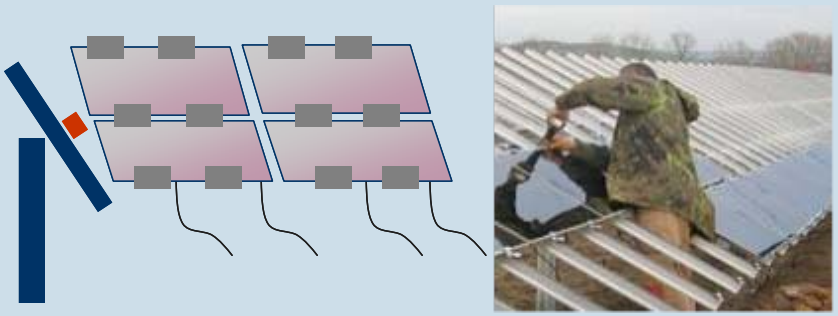


OPTICS: Improved Light Capture
ABSORBER LAYER: PECVD processing
CONTACTS: Reduce resistivity

Module Size Advantage For Installation

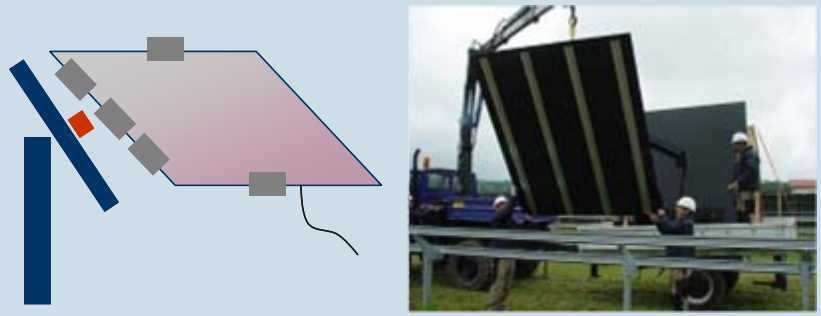
System integrators measure by $/Wp for the whole system

Standard Modules



- More clamps per square meter
- More rails per square meter
- More cabling
- More labor

Large Size Modules



- Efficient mounting structure
- Less cabling, rails, clips

>17% BOS savings with 5.7m² sized glass

Equivalent to > 2 – 3% gain in efficiency!

Source: One of the Top 3 German Installers

Leveraging Scale: GW TF PV Module Factory

- Consumes 500 tons of glass per day
- PV factory (111 acres) is larger than the Magic Kingdom at Disney World (107acres)
- Produces 6,000 modules per day or enough to cover 7 ½ football fields **per day**
  - Equivalent area of 450,000 300mm wafers per day

$$\frac{\text{Cost / m}^2}{\text{Watt / m}^2}$$

20% Cost/Wp reduction translates to 1+ year earlier parity

Summary and Conclusions

- New era of solar has arrived
  - Entering grid parity "inflection zone"
  - Incentives, carbon taxes, climate concerns are catalysts but not fundamental drivers
- Expect wafer-based and TF technologies to co-exist, serving diverse PV market segments
- Key is driving down cost per watt through manufacturing technology & scale
  - TF is nearing $1/Wp production cost
  - GWp (per year) factories are being built

Time to catch some rays…

APPLIED MATERIALS®