

Overview of Photovoltaics Industry

Richard T. Stuebi
BP Fellow for Energy and Environmental Advancement
The Cleveland Foundation

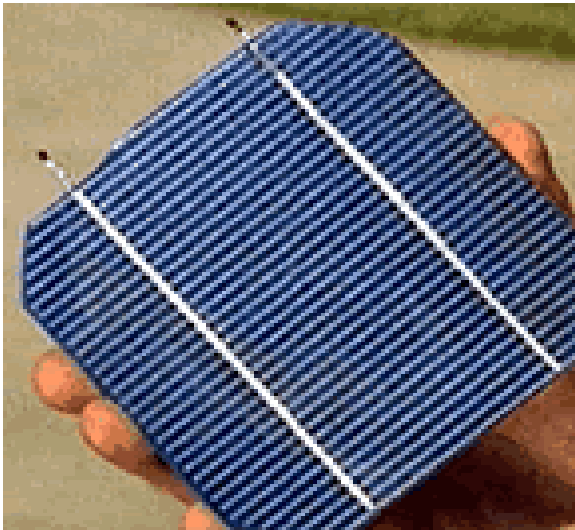
February 3, 2009

Solar Energy

- **People love the idea of solar (“free” energy, no emissions), and it works everywhere (cloudless skies not required)**
- **Main types of solar energy:**
 - **Conversion of sunlight directly to electricity: photovoltaics (PV)**
 - Crystalline-silicon (90% of market)
 - Thin-film (second-generation)
 - 3rd generation also thin-film, but largely based on nanomaterials
 - **Solar thermal heating**
- **Solar economics:**
 - **Minimal ongoing costs, but substantial up-front costs**
 - **Subsidies generally required to make cost-effective relative to conventional energy**
- **Solar markets growing rapidly:**
 - **PV market nearly \$20 billion annually worldwide (mostly non-U.S.), growing at 30+% annually, major manufacturers (Sharp, BP, etc.)**
 - **Solar thermal market smaller, more fragmented, no household names**

Photovoltaics

Cell (crystalline)



Module

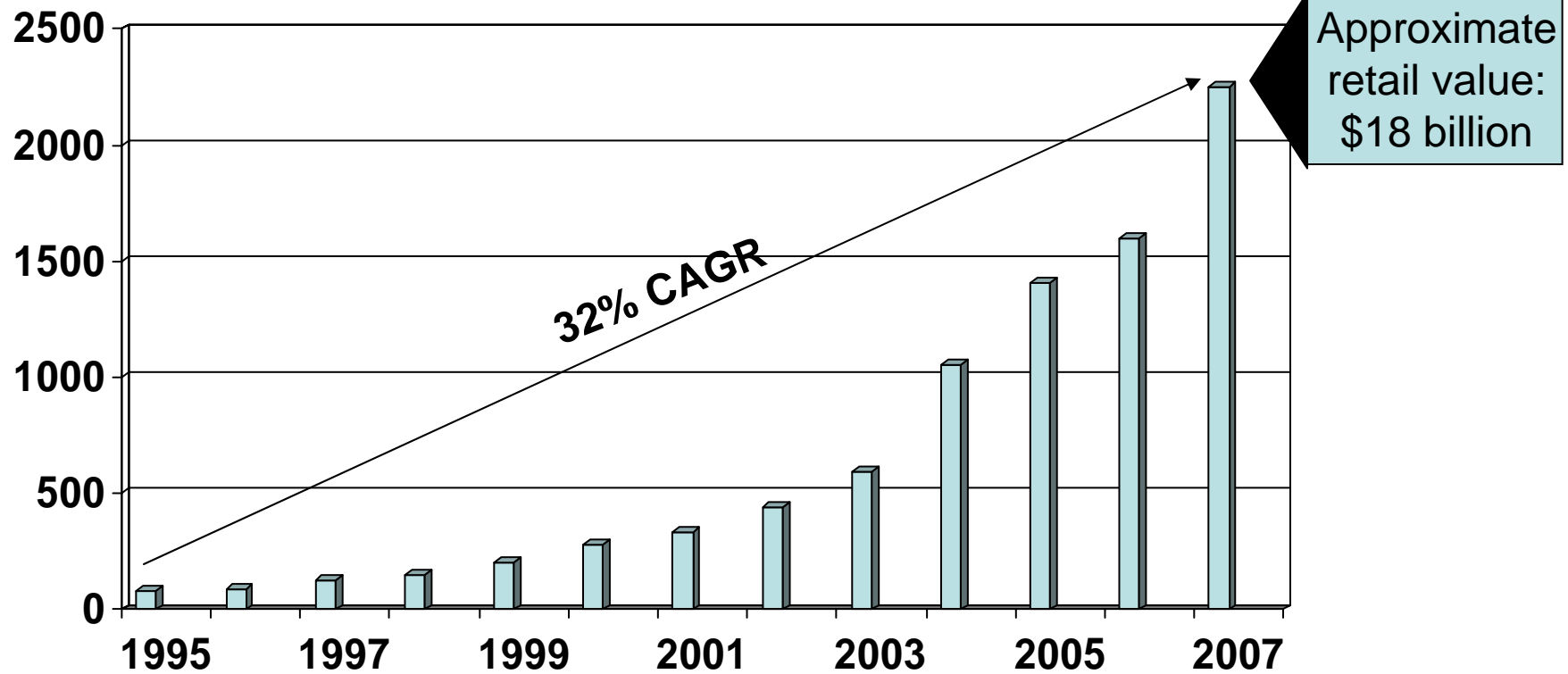


...plus balance of plant

- Mounting racks
- Electrical harnesses
- Power inverter (DC → AC)

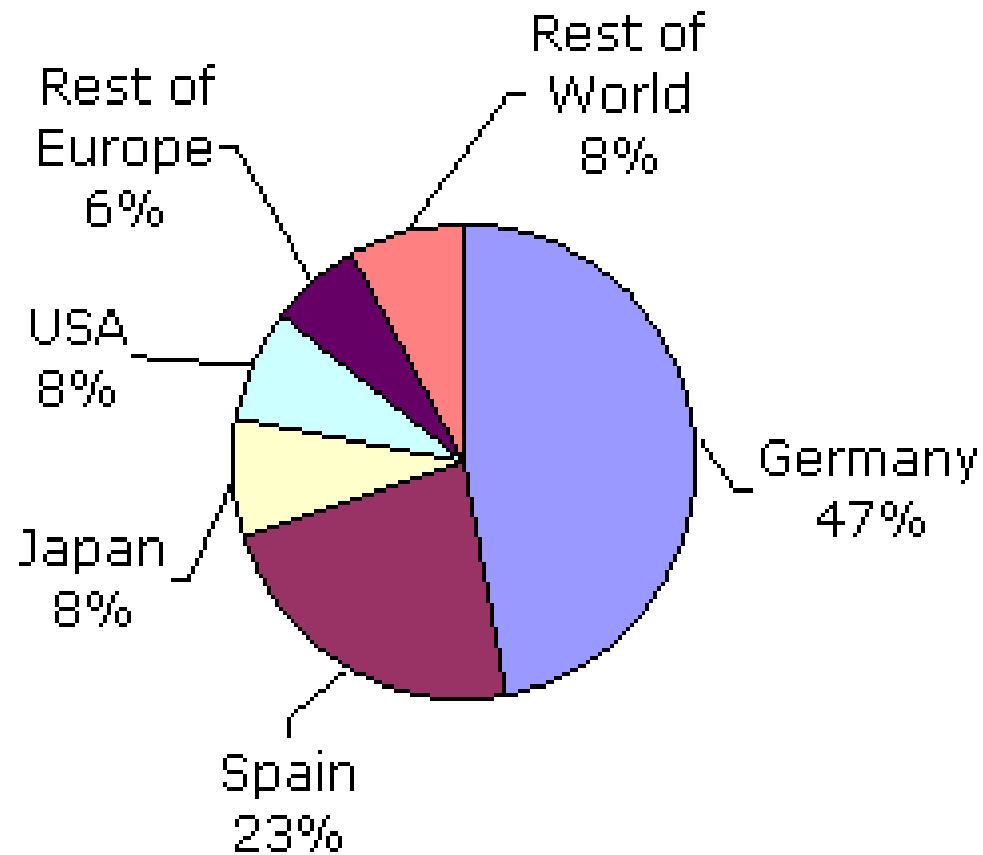
New PV Installations

Megawatts



Source: EPIA

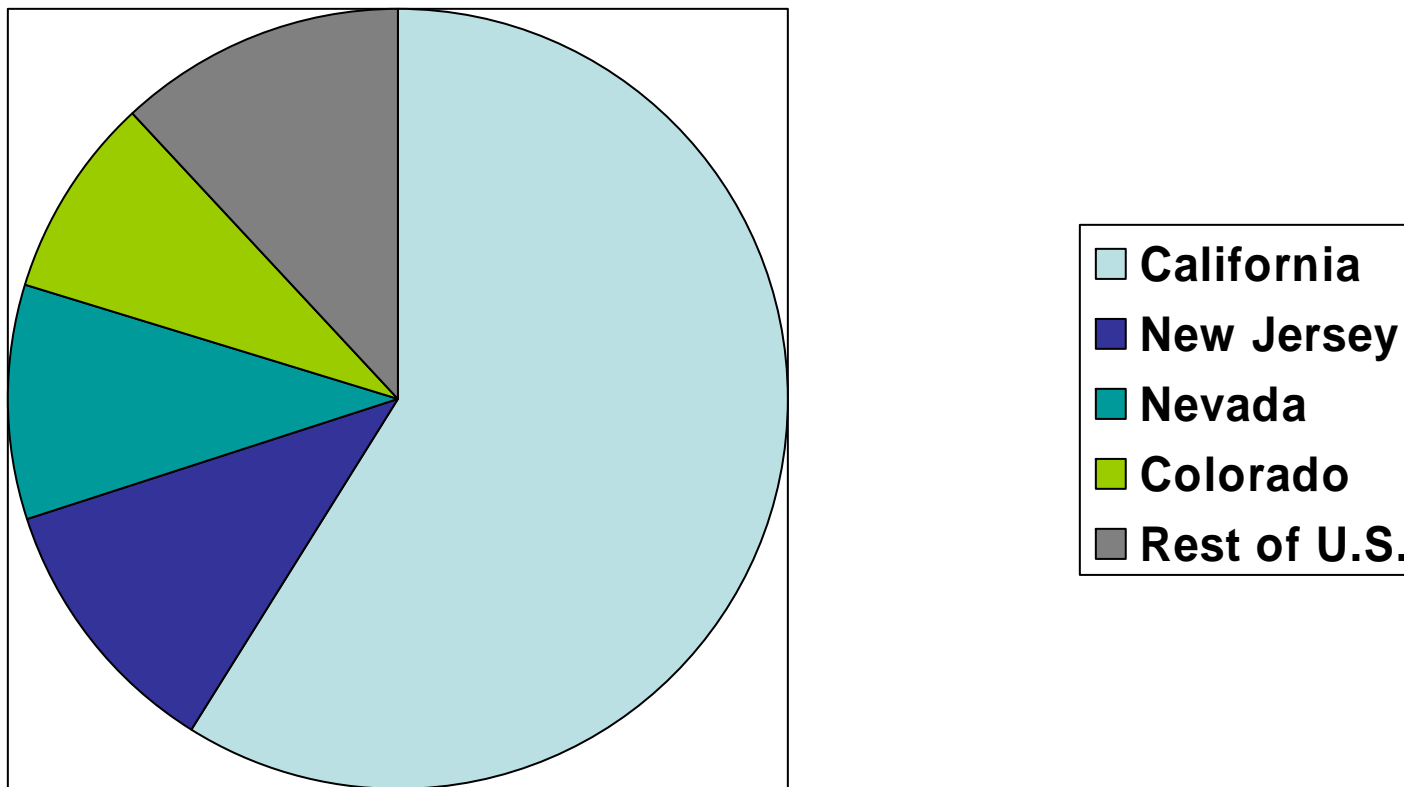
World Photovoltaic Market in 2007 2826 Megawatts



Copyright: Solarbuzz LLC

2007 U.S. Grid-Tied PV Market

100% = 150 Megawatts



Source: SEIA/Prometheus "2007 US Solar Industry Year in Review"

U.S. Standing in 2007 PV Market

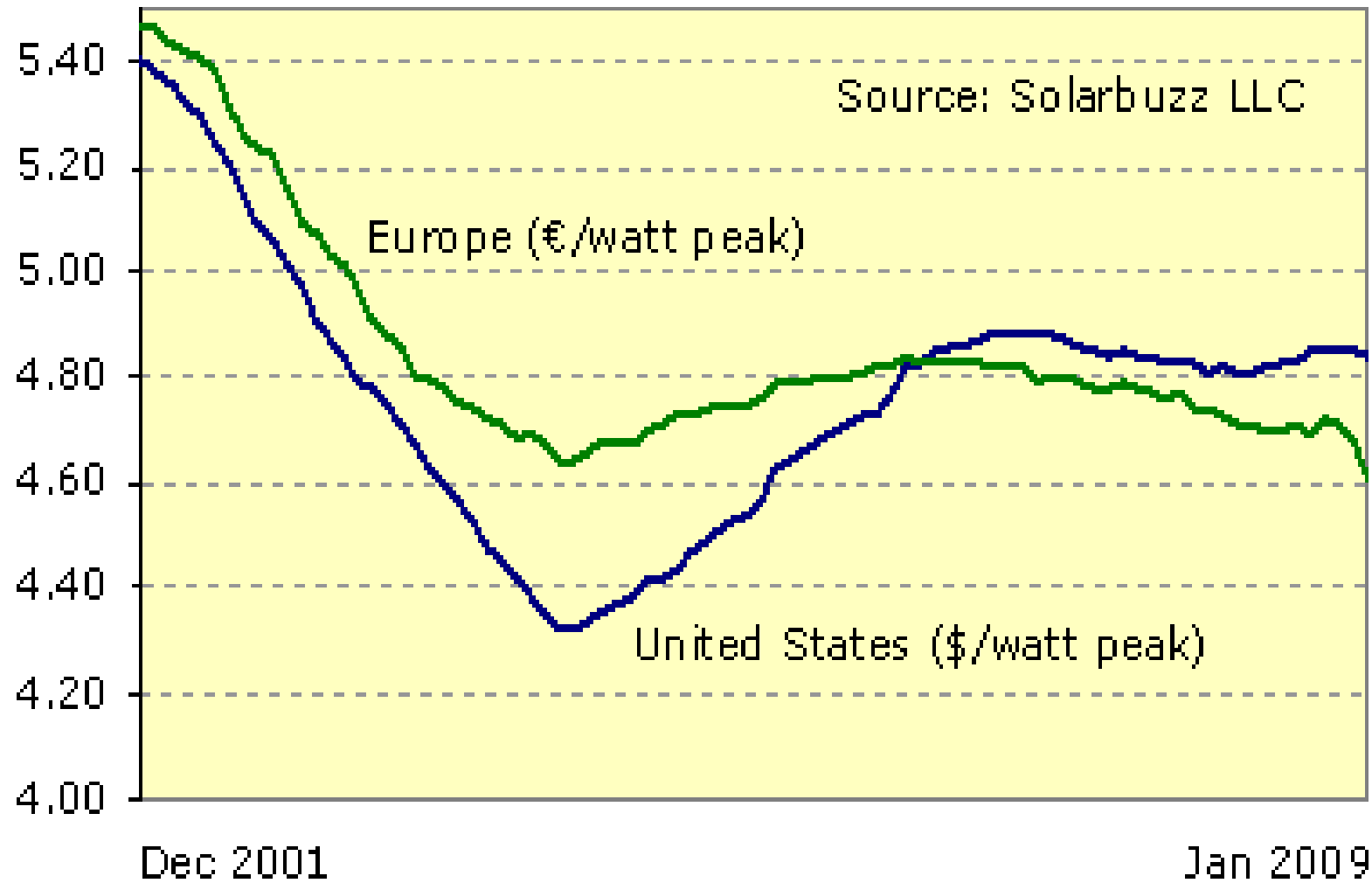
<u>Total Installed Base (MW)</u>			<u>New Installations (MW)</u>			<u>Manufacturing (MW/Year)</u>		
1	Germany	3,800	1	Germany	1,100	1	Japan	920
2	Japan	1,938	2	Spain	512	2	China	820
3	USA	750*	3	Japan	230	3	Germany	780
4	Spain	632	4	USA	190	4	Taiwan	368
5	Italy	100	5	Italy	50	5	USA	266

Source: [EPIA/Greenpeace](#) and SEIA*

Source: [EPIA/Greenpeace](#)

Source: [PV News \(3/08\)](#)

Solar Module Retail Price Index 125 watts and higher

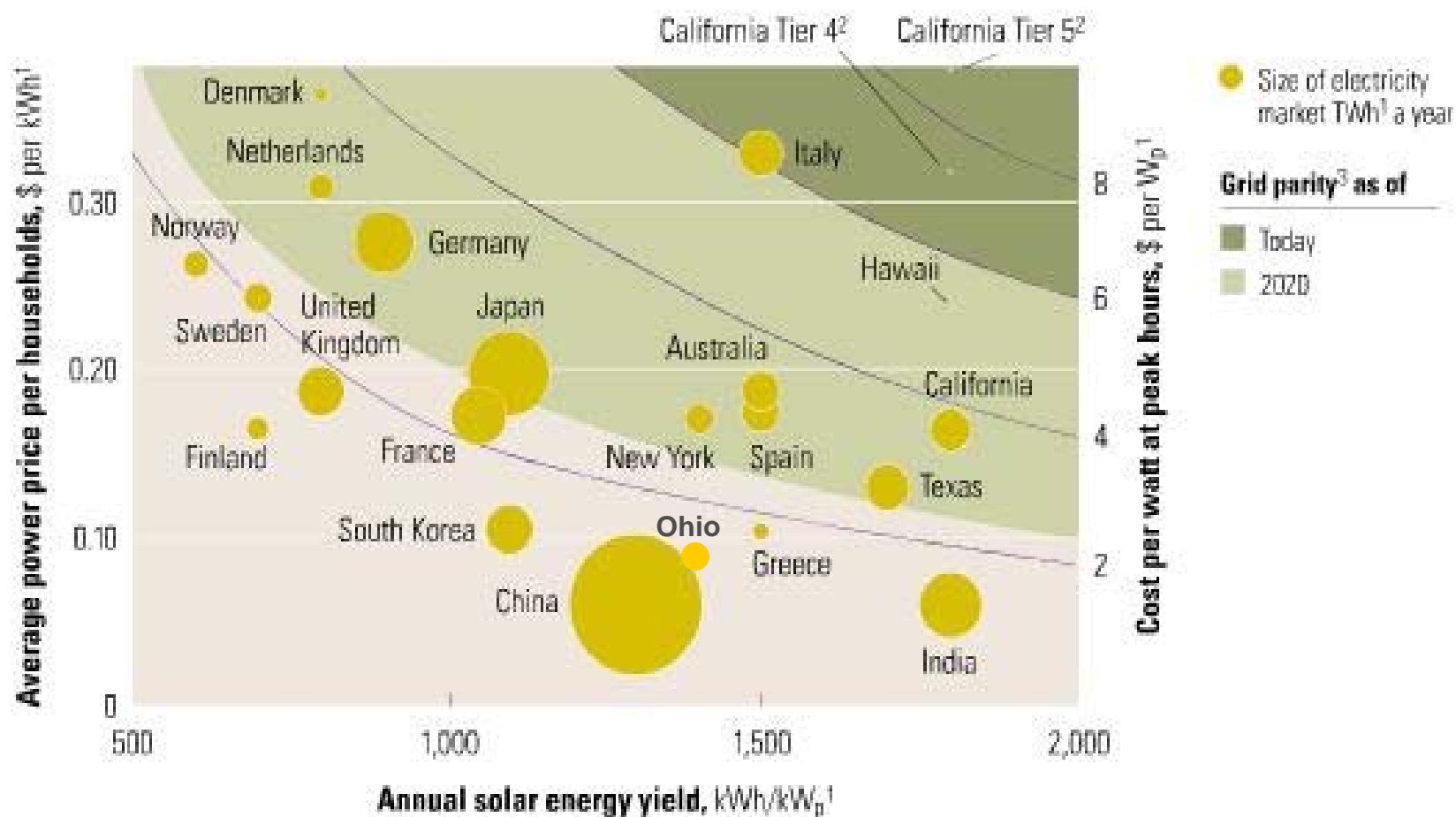


Cost of Electricity from PV

Table showing average cost in cents/kWh over 20 years for solar power panels									
	Insolation								
Cost	2400 kWh/kWp•y	2200 kWh/kWp•y	2000 kWh/kWp•y	1800 kWh/kWp•y	1600 kWh/kWp•y	1400 kWh/kWp•y	1200 kWh/kWp•y	1000 kWh/kWp•y	800 kWh/kWp•y
\$0.20/Wp	0.8	0.9	1.0	1.1	1.3	1.4	1.7	2.0	2.5
\$0.60/Wp	2.5	2.7	3.0	3.3	3.8	4.3	5.0	6.0	7.5
\$1.00/Wp	4.2	4.5	5.0	5.6	6.3	7.1	8.3	10.0	12.5
\$1.40/Wp	5.8	6.4	7.0	7.8	8.8	10.0	11.7	14.0	17.5
\$1.80/Wp	7.5	8.2	9.0	10.0	11.3	12.9	15.0	18.0	22.5
\$2.20/Wp	9.2	10.0	11.0	12.2	13.8	15.7	18.3	22.0	27.5
\$2.60/Wp	10.8	11.8	13.0	14.4	16.3	18.6	21.7	26.0	32.5
\$3.00/Wp	12.5	13.6	15.0	16.7	18.8	21.4	25.0	30.0	37.5
\$3.40/Wp	14.2	15.5	17.0	18.9	21.3	24.3	28.3	34.0	42.5
\$3.80/Wp	15.8	17.3	19.0	21.1	23.8	27.1	31.7	38.0	47.5
\$4.20/Wp	17.5	19.1	21.0	23.3	26.3	30.0	35.0	42.0	52.5
\$4.60/Wp	19.2	20.9	23.0	25.6	28.8	32.9	38.3	46.0	57.5
\$5.00/Wp	20.8	22.7	25.0	27.8	31.3	35.7	41.7	50.0	62.5

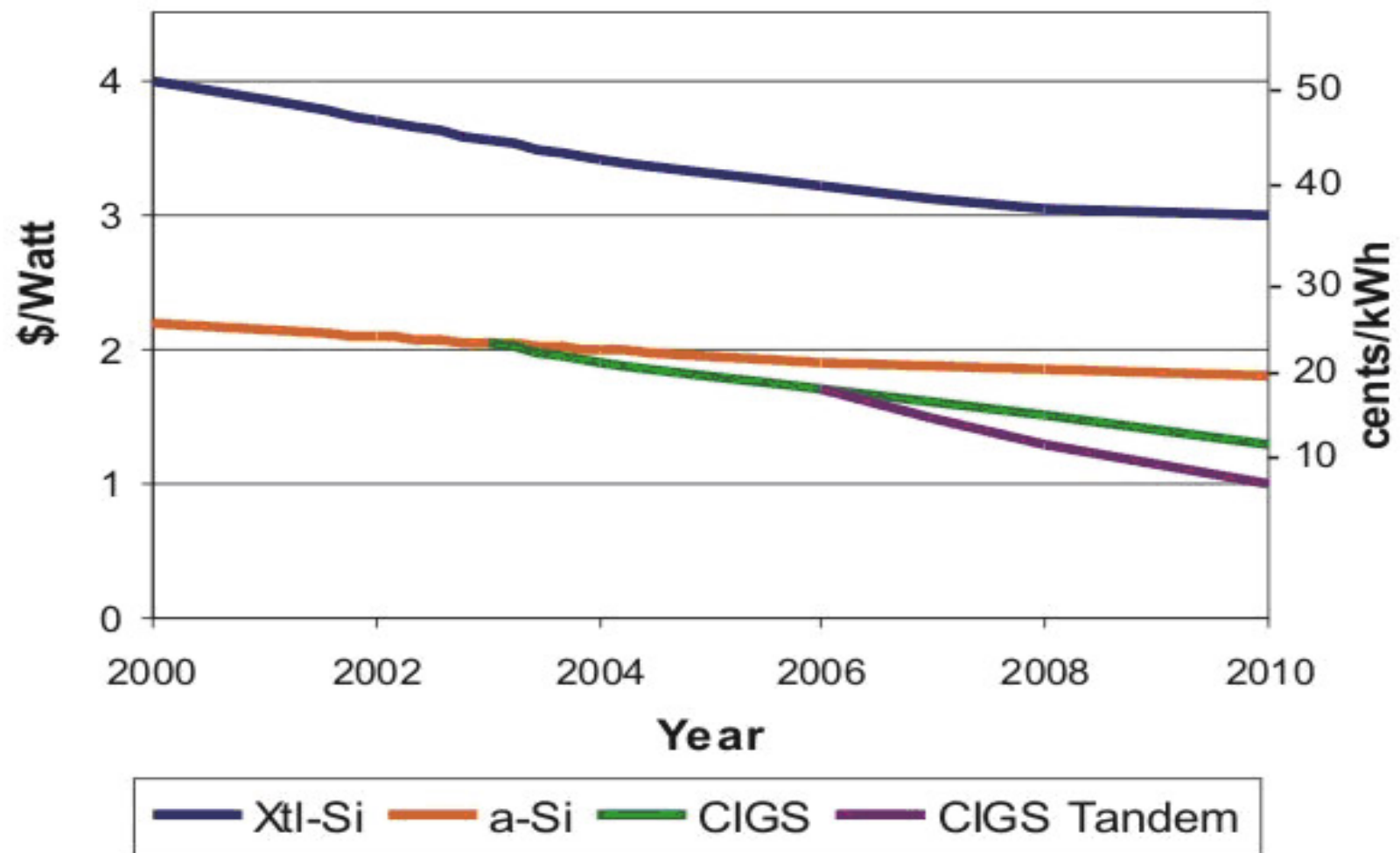
Source: Wikipedia

PV Economics vs. Grid Power



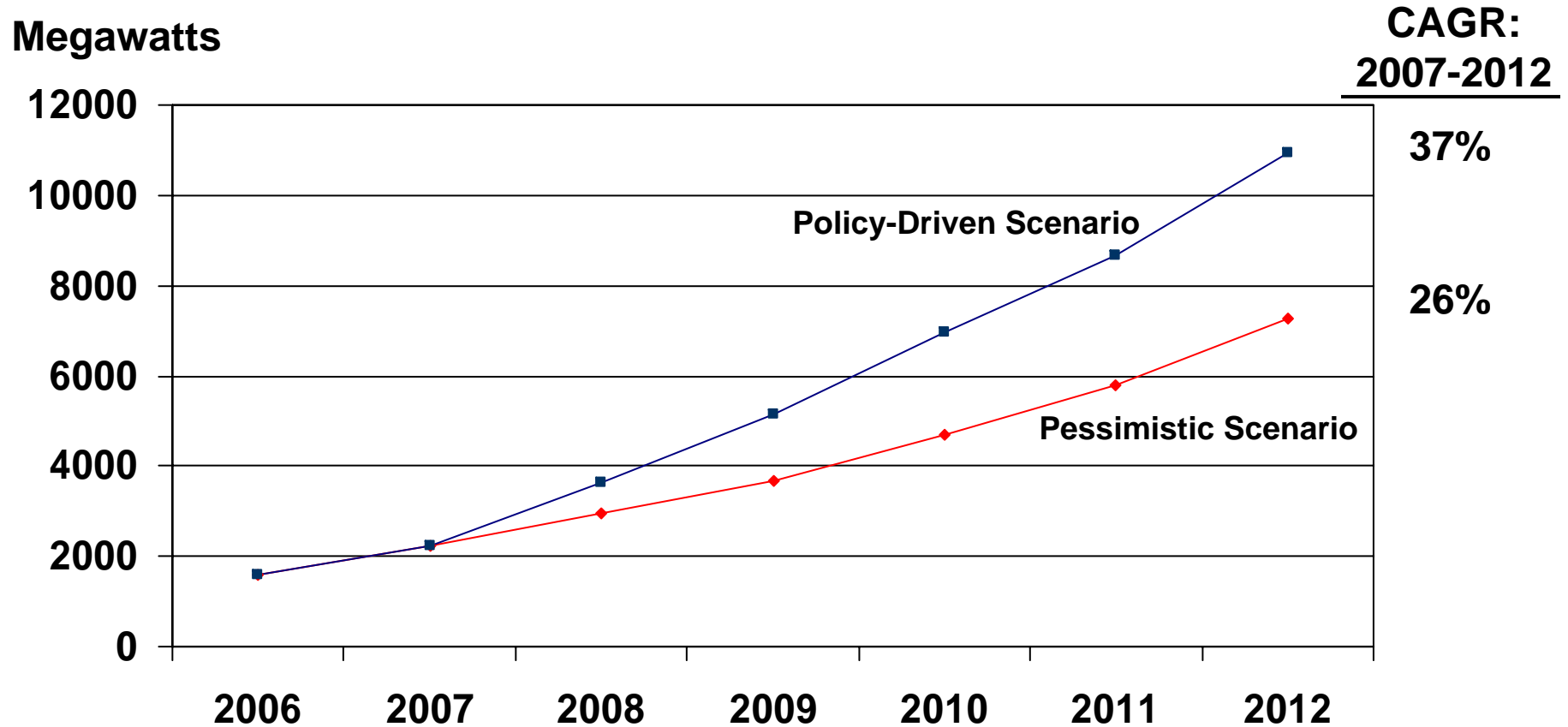
Source: McKinsey & Co.

Declining PV Costs



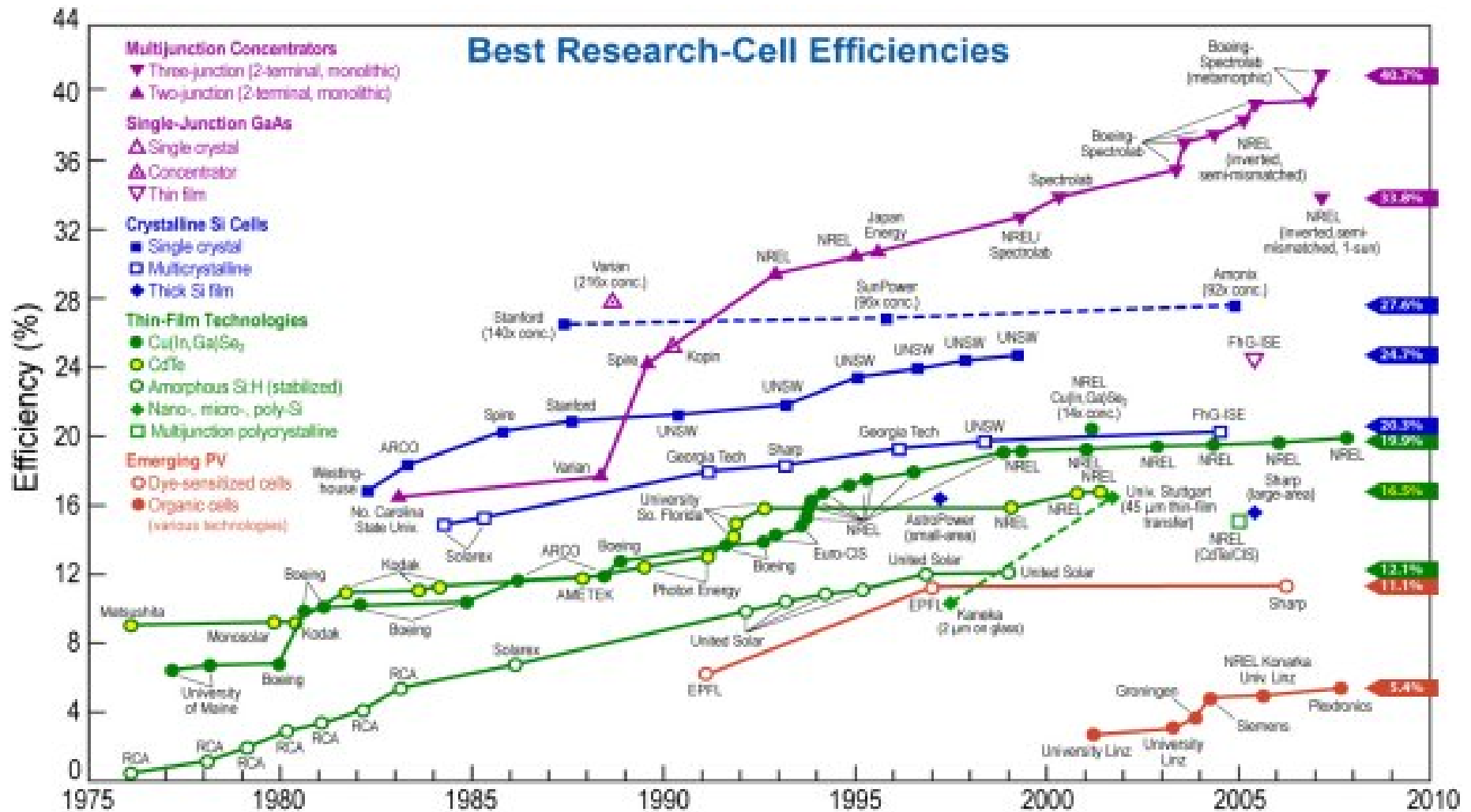
Source: SolarBuzz

Projected PV Market Growth



Source: EPIA

Improving PV Efficiencies



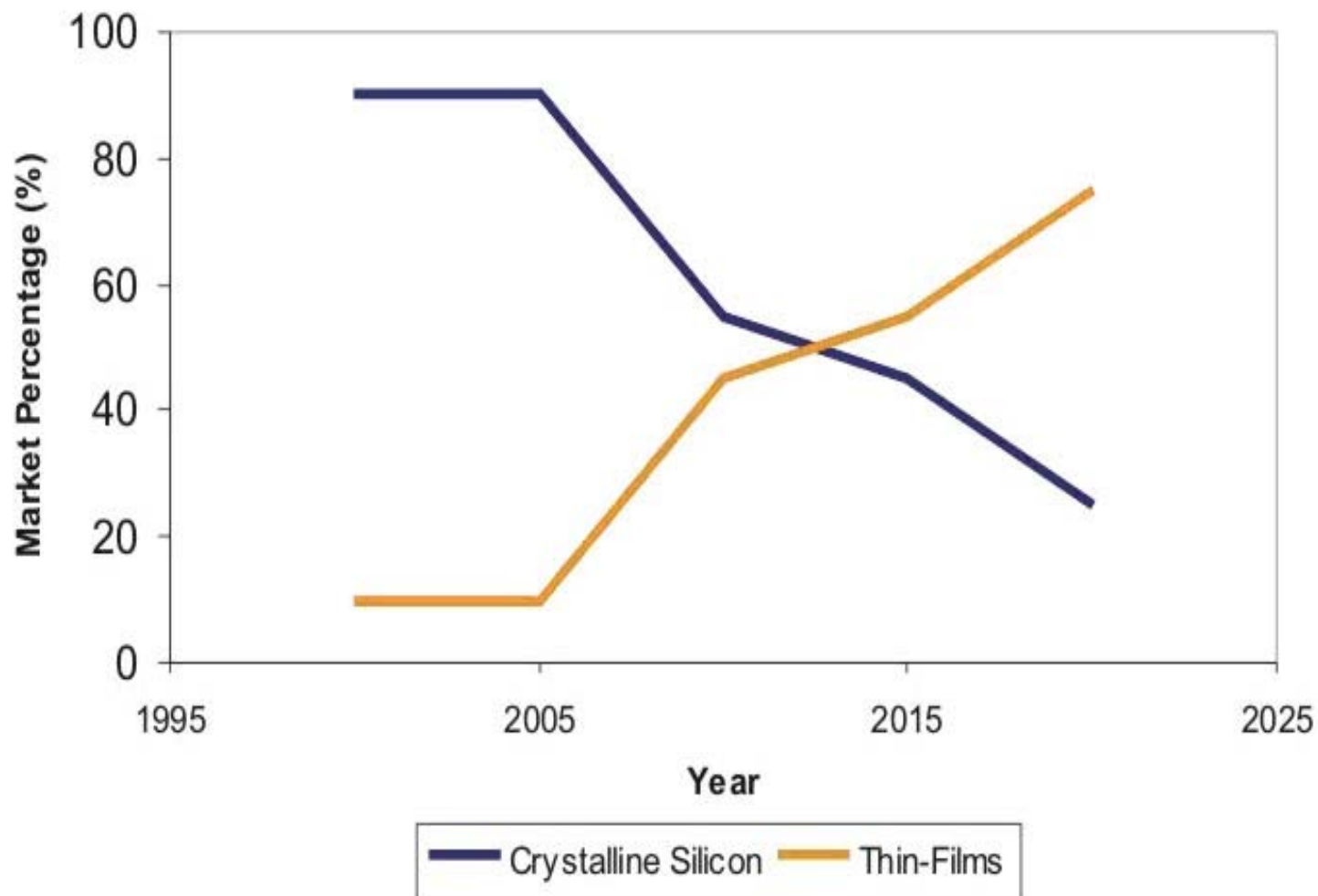
Source: National Renewable Energy Laboratory

Technology Comparison

	Amorphous silicon (a-si)	Cadmium telluride (CdTe)	Cadmium indium selenide (CIS)	a-Si/m-Si	Mono-crystalline	Poly-crystalline
Conversion efficiencies	6-7%	8-10%	10-11%	8%	16-17% (cell), 13-15% (module)	14-15% (cell), 12-14% (module)
Area per kW	15 sq. m.	11 sq. m.	10 sq. m.	12 sq. m.	~7 sq. m.	~8 sq. m.

Source: EPIA/Greenpeace (from Simmons & Co.)

PV Technology Shift



Source: SolarBuzz

Thin-Film Manufacturing Capacity

Megawatts

	<u>2007</u>	<u>2008</u>	<u>2010</u>	<u>2012</u>
CdTe	206	455	1,096	1,173
a-Si	204	434	2,192	5,201
CIGS	27	142	912	3,088
3 rd Gen	5	15	58	145
Total	442	1,046	4,258	9,607

Source: Greentech Media & Prometheus Institute

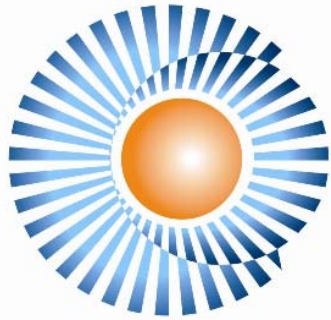
3rd Gen. PV Technology Ventures

Company	Country	Technology	Substrate	Mfrg. Process
G24 Innovations	Wales	DSC	Plastic (flexible)	Printing, roll-to-roll
CSG Solar AG (Pacific Solar)	Germany	CSG	Glass	CVD, laser printing, sputtering
Konarka	US	Organic	Plastic (flexible)	Printing, roll-to-roll, low-temp
Botest Systems	Germany	Organic		
Global Photonic	US	Organic		
Sony	Japan	Organic		
Plextronics	US	Organic	Plastic (flexible)	
Solamer Energy	US	Organic	Plastic (flexible)	Roll-to-roll
Heliatek	Germany	Organic	Plastic (flexible)	
GE	US	Organic		
Sharp	Japan	Organic		
Mitsubishi	Japan	Organic		
Canon	Japan	Organic		
Korea Parts and Fasteners	Korea	Organic	Plastic (flexible)	Roll-to-roll
Innovalight	US	Nano-Si	Plastic (flexible)	Ink printing, roll-to-roll
Octillion	Canada	Nano-Si	Glass	Electrochemical (and ultrasound)
Nanogram	US	Nano-Si		
Soltaix	US	Nano-Si		
Nanosys	US	Nanostructure		
Stion	US	Nanostructure		
Solasta	US	Nanostructure		
Solexant	US	Nanostructure		Printing, roll-to-roll
NewCyte	US	Nano-CdTe	Silicon	CVD
Bloo Solar	US	Nano-CdTe	Glass	Growing nano-structured bristles cells
Solaronix	Switzerland	DSC	Metal (flexible)	
Solaris Nanoscience	US	DSC	Plastic (flexible)	Roll-to-roll
SCHOTT Solar	Germany	DSC		
AISIN Seiki	Japan	DSC	Plastic (flexible)	
Fujikara	Japan	DSC		
3G Solar (Orion Solar)	Israel	DSC		
Peccell Technologies	Japan	DSC	Plastic (flexible)	Printing, high-speed, roll-to-roll

Source: Greentech Media & Prometheus Institute

PV Technology Companies in Ohio

- **High-growth thin-film PV module developers/manufacturers:**
 - First Solar
 - Xunlight
 - Calyxo (Q-Cells & Solar Fields)
 - Innovative Thin Films
 - NewCyte
- **Developers/suppliers of materials for modules:**
 - Pilkington
 - Owens Corning
 - Ferro
 - GrafTech
 - MetaMateria Partners
 - Akron Polymer Systems
 - Replex Plastics
 - Five Star Technologies
 - GlassTech



WRIGHT CENTER *for* PHOTOVOLTAICS INNOVATION AND COMMERCIALIZATION

- **Focus areas:**

- Building science/technology foundation through basic and applied research in PV
- Developing related device and system components
- Building a full system-integration infrastructure for residential and commercial
- Developing a skilled PV workforce, informed consumers, rational public policy

- **Statewide collaboration:**

- **Academia:**

- University of Toledo (host)
- Ohio State University
- Bowling Green State University



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BGSU

- **13 companies, including:**

- DuPont
- Owens Corning
- Pilkington



PILKINGTON

- **Not-for-profit organizations:**

- Battelle
- Edison Materials Technology Center (EMTEC)
- Green Energy Ohio (GEO)

- **\$18.6 million from Ohio, \$30 million from federal agencies and partners**

CLEVELAND
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Summary

- **PV market is already large (globally if not locally), and growing rapidly – with immense future potential as economics improve**
- **Technology advancements underway (thin-film) to improve PV economics, through increased efficiencies and lower costs**
- **Ohio has substantial thin-film PV technology capabilities to capture a good share of the future market opportunity**

Contact Information

Richard T. Stuebi

**BP Fellow for Economic and Environmental
Advancement**

The Cleveland Foundation

1422 Euclid Avenue, Suite 1300

Cleveland, OH 44115-2001

Phone: 216.685.2011

Fax: 216.861.1729

rstuebi@clevelandfn.org