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# Photovoltaic Technology Incubator Selections

## Technology Development

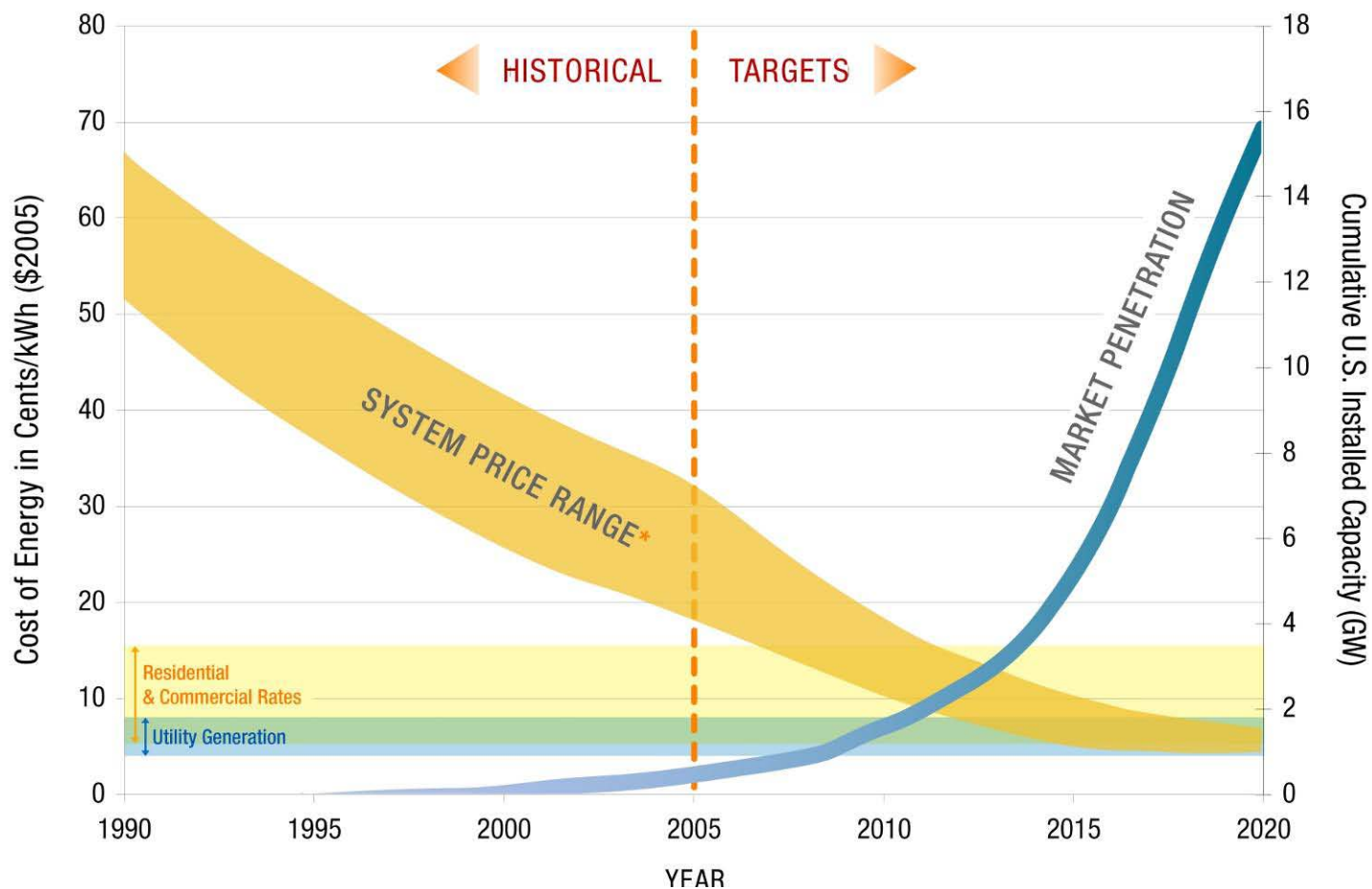


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DOE Solar Energy Technologies Program  
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# Making Solar Cost-Competitive Nationwide by 2015



Market Sector	Current U.S. Market Price Range (¢/kWh)	Cost (¢/kWh) Benchmark 2005	Cost (¢/kWh) Target 2010	Cost (¢/kWh) Target 2015
Residential	5.8-16.7	23-32	13-18	8-10
Commercial	5.4-15.0	16-22	9-12	6-8
Utility	4.0-7.6	13-22	10-15	5-7

# Photovoltaic Technology Incubator Objectives



## Explore the commercial potential of new manufacturing processes and products

- Promote the development of a diverse set of PV technologies which cover a variety of target markets including residential, commercial, and utility power generation.
- Investigate the scale-up potential of a promising technology which has already been proven on a small laboratory scale.

## Foster innovation and growth in the domestic PV industry

- Provide U.S. small businesses with a chance to expand quickly in a rapidly maturing industry. Aggressive production ramps will establish significant domestic PV module manufacturing and help make solar energy cost competitive with conventional forms of electricity by 2015.

## Establish an efficient and cyclic funding opportunity

- Funding is structured so that companies receive funding from the Department only upon successful performance of pre-specified new hardware.
- Provide funding opportunities for new applicants annually.
- Perform a stage-gate review of each project's progress 9 months after project start.

# Project Development Focused on Improvements at the Module Level



TECHNICAL IMPROVEMENT OPPORTUNITIES		METRICS			
TEIR 1 TIOs	TEIR 2 TIOs	Performance	Cost	O&M	Reliability
<b>Modules</b>	<b>Module</b>	High-Impact	High-Impact		Moderate-Impact
	Absorber	High-Impact	High-Impact		
	Cells and Contacts	High-Impact	High-Impact		Moderate-Impact
	Interconnects				Moderate-Impact
	Packaging		Moderate-Impact		High-Impact
	Manufacturing	Moderate-Impact	High-Impact		Moderate-Impact

■ = High-Impact Opportunities    ■ = Moderate-Impact Opportunities

- Project development is focused on a limited number of high impact technical improvement opportunities at the module level that lie on the critical path to scaling-up their technology to full manufacture.
- Full system cost reductions including installation, inverters, and balance of system components is currently the focus the DOE's [Technology Pathway Partnership \(TPP\) projects.](#)

# Photovoltaic Technology Incubator

## Details of Selected Projects



### **Incubator projects will significantly expand and diversify domestic “market ready” PV technologies:**

- Establish up to 1 GW of annual manufacturing capacity, of technology which is not commercially produced today, by 2010.
- Successful projects will competitively position incubator companies among the world’s top PV manufacturers in the 2010-2012 timeframe.

### **Projects include a diverse set of technological approaches:**

- Novel wafered silicon processing and thin-film crystalline silicon growth
- Innovative multi-junction cell production
- Low and high concentration
- Low-cost, thin-film manufacturing

### **Selected PV Technology Incubator Projects:**

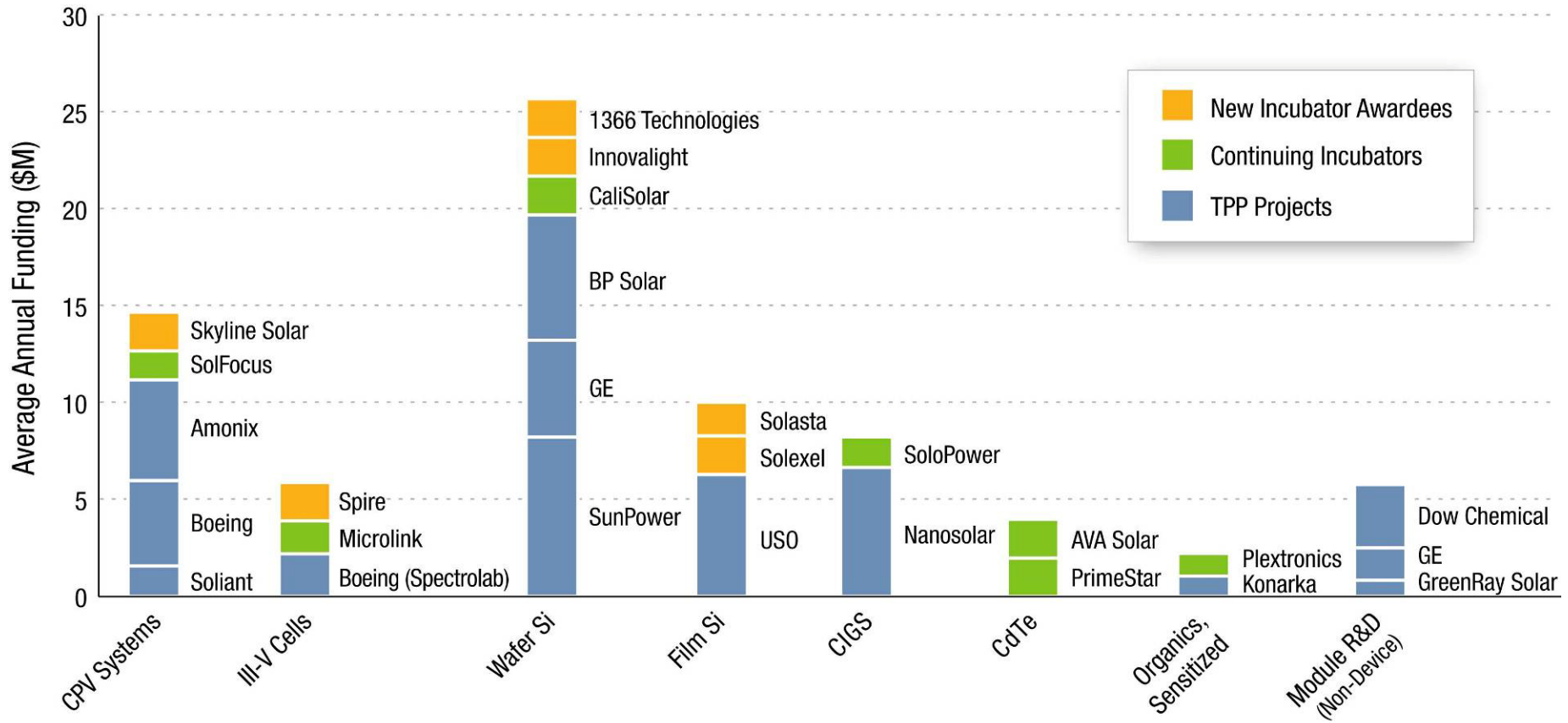
#### Newly Selected Projects

- 1366 Technologies
- Innovalight
- Skyline Solar
- Solexel
- Solasta
- Spire Semiconductor

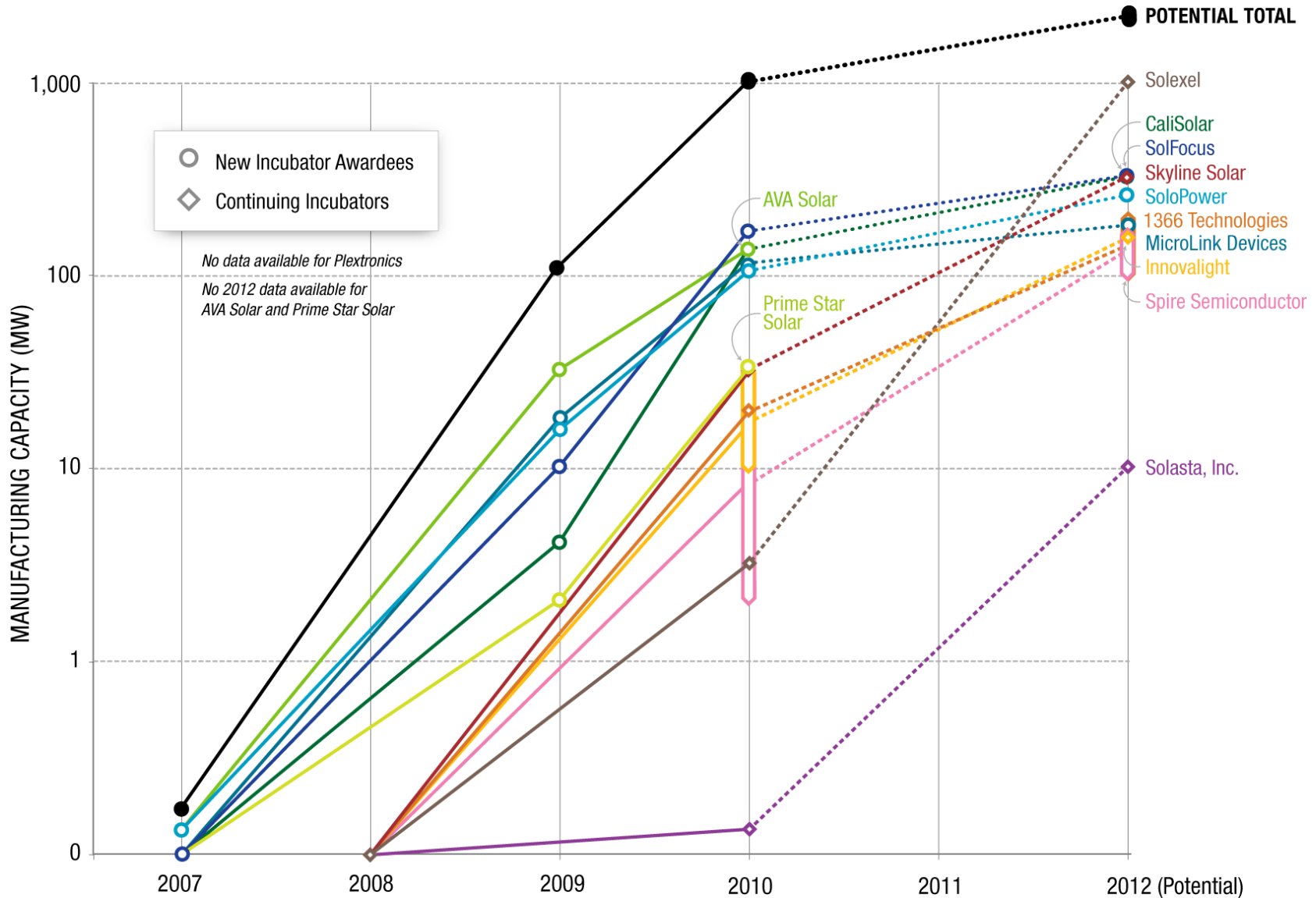
#### Second Phase Projects

- AVA Solar
- CaliSolar
- MicroLink Devices
- Plextronics
- PrimeStar Solar
- SolFocus
- SoloPower

# DOE's Portfolio Balances Technology, Maturity & Risk



# Incubator Projects Quickly Ramp Production Capacity to Pilot and Commercial Levels



# DOE's Photovoltaic Technology Incubator



The following six companies have been selected to begin their first 9-month phase of their PV Incubator Project:



*Proposals from these companies were selected for their superior technical plan and capabilities, verified baseline performance, and robust hardware delivery schedule.*

# 1366 Technologies: Scaling Up Manufacture of a Cost Effective Cell Architecture for Multi-Crystalline Silicon PV



## Technologies Addressed

**Wafer Silicon**

## Target Market

**Residential and Commercial**

## Description

**1366 Technologies, Inc.** (Lexington, MA) is developing a new cell architecture and related processes for low-cost multi-crystalline silicon cells. Cell performance will be enhanced by light-trapping texturing and grooves for self-aligned metallization fingers. By the end of the project, 1366 Technologies plans to deliver a 19% efficient, 15.6x15.6 cm<sup>2</sup>, multi-crystalline silicon cell with a technology that is applicable across the crystalline silicon cell industry.



## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$3,750,000</b>	<b>\$3,000,000</b>	<b>\$750,000</b>

## Annual Production (MW)

Baseline Production (2008)	<b>0</b>
18 Month	<b>3 - 30</b>
2012 Potential	<b>100 - 300</b>

# Innovalight: High-Efficiency, Low-Cost Solar Cells Manufactured Using “Silicon Ink” On Thin-Crystalline Silicon



## Technologies Addressed

**Silicon Ink on Silicon**

## Target Market

**Residential and Commercial**

## Description

**Innovalight** (Sunnyvale, CA) is developing very high-efficiency, low-cost solar cells and modules by ink-jet printing their proprietary “silicon ink” onto thin-crystalline silicon wafers. The company’s contactless printing process significantly reduces both the manufacturing costs and the complexity required to make today’s very high-efficiency cells and modules.



## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$8,209,956</b>	<b>\$3,000,000</b>	<b>\$5,209,956</b>

## Annual Production (MW)

Baseline Production (2008)	<b>0</b>
18 Month	<b>10 - 50</b>
2012 Potential	<b>200</b>

# Skyline Solar: Medium-Concentration PV with Low Cost and Explosive Scalability



## Technologies Addressed

**Mid-Concentration PV**

## Target Market

**Utility, Industrial, and Commercial**

## Description

**Skyline Solar (Mountain View, CA)** has developed an integrated lightweight, single-axis tracked system that reflects and concentrates sunlight over 10X onto silicon cells. The design leverages the mainstream PV industrial base and amplifies its capacity through significant concentration to enable rapid scaling. It will dramatically lower the cost to manufacture modules and install complete systems to achieve LCOE below grid parity. By the end of this project, Skyline will deliver modules that exceed 12m<sup>2</sup> area and 15% aperture-area efficiency.



## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$5,399,143</b>	<b>\$2,999,999</b>	<b>\$2,399,144</b>

## Annual Production (MW)

Baseline Production (2008)	<b>0</b>
18 Month	<b>50</b>
2012 Potential	<b>500</b>

# Solasta: Amorphous-Silicon Nanocoax Solar Cells



## Technologies Addressed

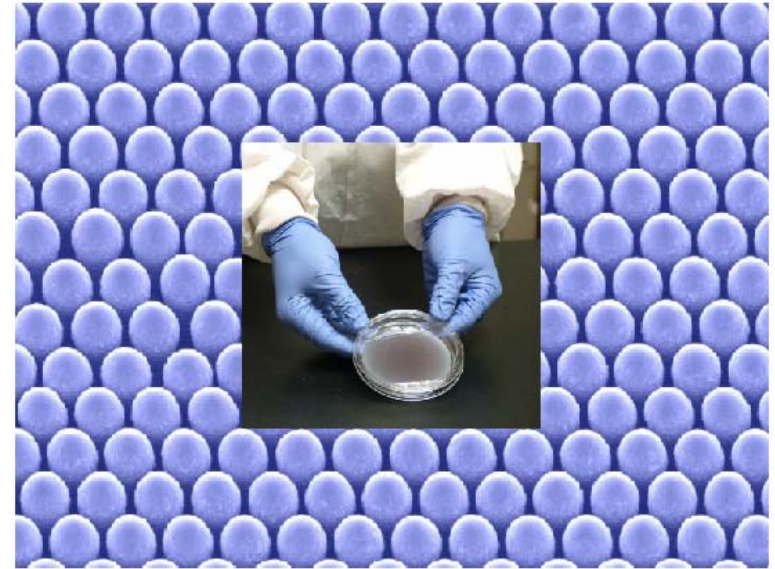
**Amorphous-Silicon Nanocoax**

## Target Market

**Residential and Commercial**

## Description

**Solasta** (Newton, MA) is using a novel cell design based on an amorphous-silicon “nanocoax” structure, which increases current and lowers materials cost by collecting light normal to the substrate (thick section) and transferring collected carriers laterally (thin section). This approach effectively decouples the optical and electronic pathways. If successful, Solasta will deliver 15% efficient, 100-cm<sup>2</sup> pre-production cells at the end of the project.



## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$3,250,000</b>	<b>\$2,600,000</b>	<b>\$650,000</b>

## Annual Production (MW)

Baseline Production (2008)	<b>0</b>
18 Month	<b>0.1</b>
2012 Potential	<b>10</b>

# Solexel: High-Efficiency Solar Cells and Modules Based on a Disruptive Low-Cost, Mono-Crystalline Technology



## Technologies Addressed

**Crystalline Silicon**

## Target Market

**Residential and Commercial**

## Description

**Solexel** (Milpitas, CA) plans on commercializing a disruptive, 3D, high efficiency mono-crystalline silicon cell technology, while dramatically reducing manufacturing cost per watt. At the end of this project, Solexel plans to deliver a 17-19% efficient, 156x156 mm<sup>2</sup>, single-crystal cell that consumes substantially lower silicon per watt than conventionally sliced wafers. Solexel aspires to be a GW scale PV producer within five years.



## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$11,053,791</b>	<b>\$3,000,000</b>	<b>\$8,053,791</b>

## Annual Production (MW)

Baseline Production (2008)	<b>0</b>
18 Month	<b>5</b>
2012 Potential	<b>1000</b>

# Spire Semiconductor: Manufacturing of high-efficiency bi-facial tandem concentrator solar cells



## Technologies Addressed

High-Concentration PV (III-IV MJ Cell)

## Target Market

Utility and Commercial

## Description

**Spire Semiconductor** (Hudson, NH) plans on opening up the design space for three-junction tandem solar cells by growing differentiated bi-facial cells on a Gallium Arsenide substrate. Spire Semiconductor is targeting cell efficiencies over 42% using a low-cost manufacturing method.



## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$3,713,525</b>	<b>\$2,970,820</b>	<b>\$742,705</b>

## Annual Production (MW)

Baseline Production (2008)	<b>0</b>
18 Month	<b>3 - 50</b>
2012 Potential	<b>100 - 250</b>

The following companies have successfully passed into the second 9-month phase of their PV Incubator Contract:



**AVA**SOLAR



 **MicroLink  
Devices, Inc.**

**PLEX**TRONICS  
Light. Power. Circuitry.™

 PrimeStar Solar  
Making It Happen

**SolFocus**

**SOLO** POWER

*These companies have demonstrated the timely completion of their scheduled deliverables, relevance to the current industry developments, and a likelihood of future success.*

# AVA Solar: Low-Cost, High-Throughput, Automated Fabrication of Thin-Film Cells and Modules



## Technologies Addressed

**CdTe Thin Film**

## Target Market

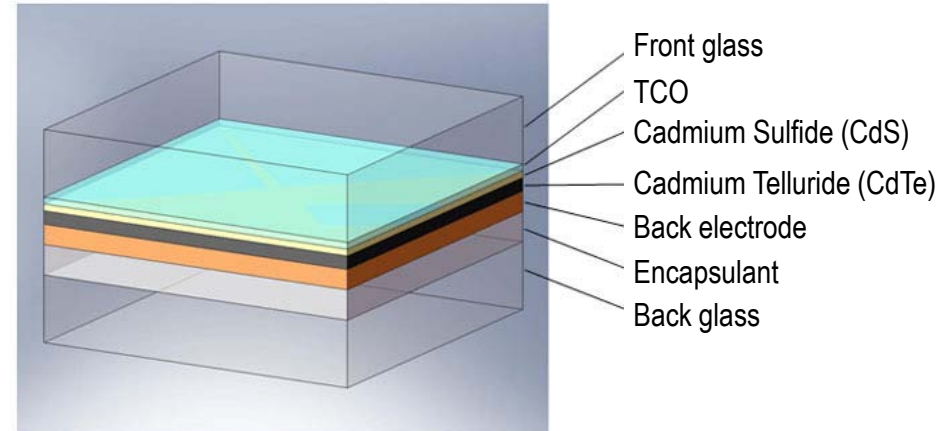
**Commercial**

## Description

**AVA Solar** (Fort Collins, CO) has developed a robust, industrial scale, continuous process for producing solar PV modules at a cost below \$1/watt, significantly reducing the cost of generating solar electricity. With this manufacturing line, extremely low capital expenditure cost below \$1.50/Watt will be demonstrated.

## Phase I Achievements

- A production process capable of fabricating devices with average efficiencies > 11%
- Modules passed 1000 hrs at 85 C / 85% RH test
- Excellent materials utilization above 90%



## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$13,744,186</b>	<b>\$2,730,000</b>	<b>\$11,014,186</b>

## Annual Production (MW)

Baseline Production (2007)	<b>0.1</b>
18 Month	<b>50</b>
2010 Potential	<b>200</b>
2012 Potential	<b>200+</b>

# CaliSolar: Manufacturing High-Efficiency Cells Using Upgraded Metallurgical-Grade Silicon



## Technologies Addressed

**Crystalline Silicon**

## Target Market

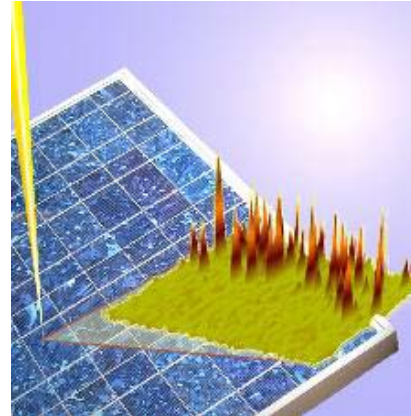
**Residential and Commercial**

## Description

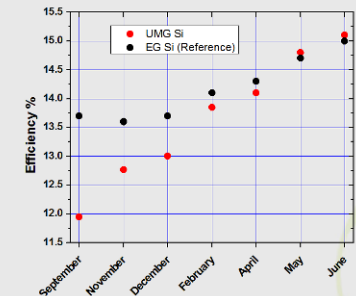
**CaliSolar** (Sunnyvale, CA) is producing cost-effective solar cells from low-cost, abundant, but impurity-rich Si feedstock materials. This project focuses on metallization, hydrogenation, and cell processing that are specifically suitable for the use of metallurgical Si to manufacture solar cells with over 17% efficiency at a cost of \$1.2/Watt.

## Phase I Achievements

- Routine production of >14.5% efficient cells made from upgraded metallurgical grade Silicon
- Currently running at 1.5 MW capacity



Cell Process Improvements On Poly Si as Benchmark



- Continuous cell efficiency improvement on Electronic Grade Silicon
- No cell degradation vs. Poly

## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$9,661,762</b>	<b>\$3,000,000</b>	<b>\$6,661,762</b>

## Annual Production (MW)

Baseline Production (2007)	<b>0</b>
18 Month	<b>6</b>
2010 Potential	<b>200</b>
2012 Potential	<b>500</b>

# MicroLink Devices: Development of Lower Cost, High-Efficiency, Solar Cells For Concentrating Applications



## Technologies Addressed

**High-Concentration PV (III-IV MJ Cell)**

## Target Market

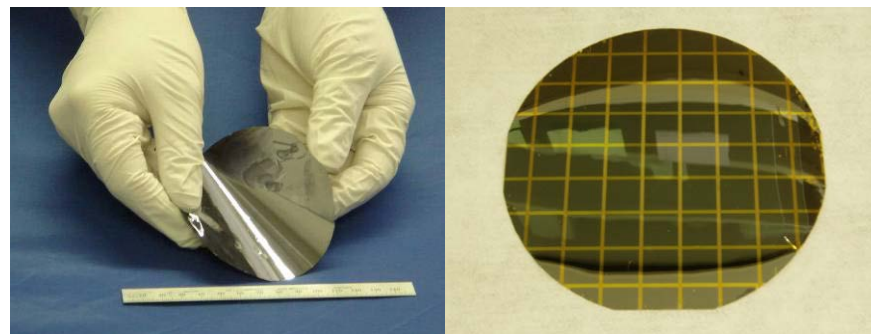
**Utility/Commercial Concentrating Systems**

## Description

**MicroLink Devices** (Niles, IL) is developing a low-cost, high-efficiency, inverted dual-junction solar cell using epitaxial liftoff technology for concentrator systems. By the end of the project MicroLink Devices plans on delivering 27% efficient cells and demonstrating performance stability and a cost reduction of 35% for lifted off cells grown on reused GaAs substrates.

## Phase I Achievements

- 26.1% (1-sun AM1.5) efficient NREL-certified inverted dual-junction cells (area: 1cm<sup>2</sup>)
- GaAs substrates were recycled once and used for solar cell fabrication with no degradation



**Cells are flexible with a thickness <50 μm**

## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$3,200,000</b>	<b>\$2,550,000</b>	<b>\$650,000</b>

## Annual Production (MW)

Baseline Production (2007)	<b>1</b>
18 Month	<b>25</b>
2010 Potential	<b>150</b>
2012 Potential	<b>250</b>

# Plextronics: Economic On-Grid Solar Energy via Organic Thin-Film Technology



## Technologies Addressed

**Next-Generation Organic Photovoltaic**

## Target Market

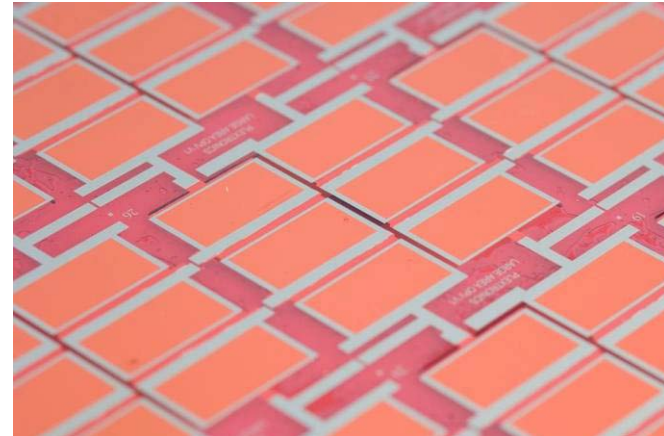
**Industrial and Commercial**

## Description

**Plextronics, Inc.'s** (Pittsburgh, PA) overall vision is to enable the low cost, high volume manufacture of organic photovoltaic (OPV) devices for use as alternative energy sources. The target of this project is to develop cells and modules with efficiencies greater than 5.8% and 3.5%, respectively, and lifetimes over 5000 hours.

## Phase I Achievements

- 3.4% active-area efficiency (1.6% total-area efficiency) in NREL-certified module (area: 232cm<sup>2</sup>, FF: 59.7%) – OPV world record
- 5.98% efficient NREL-certified cell (aperture area: 0.043cm<sup>2</sup>, FF: 71.7%) – OPV world record



## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$3,240,000</b>	<b>\$2,490,000</b>	<b>\$750,000</b>

## Annual Production (MW)

Baseline Production (2007)	<b>0</b>
18 Month	-
2010 Potential	-
2012 Potential	-

# PrimeStar Solar: Production Scale-Up of World Record CdTe/CdS Cell



## Technologies Addressed

**CdTe Thin Film**

## Target Market

**Utility and Commercial**

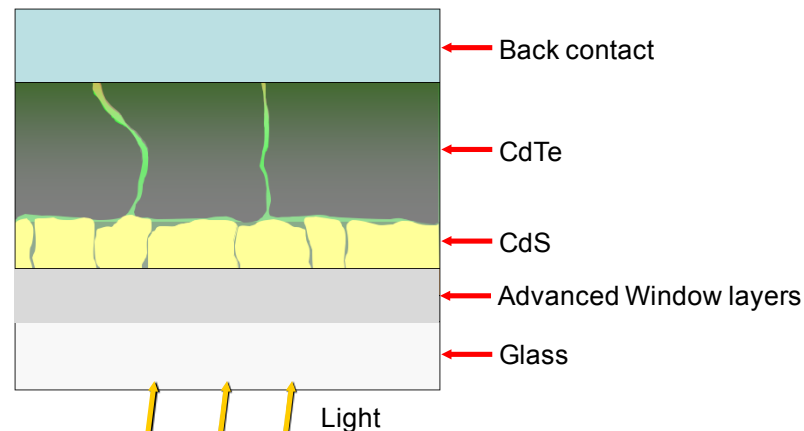
## Description

**PrimeStar Solar** (Golden, CO) is developing commercial CdTe modules based on the NREL 16.5% world record CdTe laboratory cell. By the end of the project, PrimeStar Solar will have a pilot line producing 60x120 cm<sup>2</sup> modules with competitive efficiencies.

## Phase I Achievements

- Produced NREL certified high-efficiency cells on mini-module substrate (6x6 in<sup>2</sup>)
- Produced NREL certified high efficiency mini-modules (6x6 in<sup>2</sup>)
- Designed pilot line for producing production scale modules, 60x120 cm<sup>2</sup>

Thin Film **CdTe** Solar Cell



## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$11,603,400</b>	<b>\$2,978,400</b>	<b>\$8,625,000</b>

## Annual Production (MW)

Baseline Production (2007)	<b>0</b>
18 Month	<b>3</b>
2010 Potential	<b>50</b>
2012 Potential	<b>-</b>

# SolFocus: Reflective Concentrating PV Panels Enabling Large-Scale, Reliable Energy Generation



## Technologies Addressed

**High Concentrating PV**

## Target Market

**Industrial, Commercial, and Utility**

## Description

**SolFocus** (Mountain View, CA) has developed a 500x concentrating PV module with a folded reflective design in a compact frame. The design can be manufactured in volume and is scalable to GW capacity. By the end of the project, SolFocus will have a 25%+ efficient pilot-run production module and be on path to achieve > 3MW annual capacity.

## Phase I Achievements

- Power unit efficiency of 25.5% using Spectrolab cells
- Module efficiency > 20% (verified by NREL)



## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$4,075,877</b>	<b>\$2,241,732</b>	<b>\$1,834,145</b>

## Annual Production (MW)

Baseline Production (2007)	<b>0</b>
18 Month	<b>10</b>
2010 Potential	<b>200</b>
2012 Potential	<b>500</b>

# SoloPower: CIGS Technology Based on Electroplating



## Technologies Addressed

**Flexible CIGS Thin Film**

## Target Market

**Commercial**

## Description

**SoloPower** (San Jose, CA) is developing an electroplating-based, high-efficiency, low-cost CIGS cell and module manufacturing technology. By the end of the project, SoloPower will have demonstrated large-area solar cells with efficiencies of 12% and a 10% aperture-area efficient 1-m<sup>2</sup> module, both fabricated with their roll-to-roll reaction process.

## Phase I Achievements

- 8.96% ,1-m<sup>2</sup> NREL-certified module
- 10.3-11.1% cell efficiencies (cell area: 100cm<sup>2</sup>)



*1.05 m<sup>2</sup> module*

## Resources (\$)

Total Project	DOE Funds	Cost Share
<b>\$29,277,529</b>	<b>\$2,370,315</b>	<b>\$26,907,214</b>

## Annual Production (MW)

Baseline Production (2007)	<b>0.1</b>
18 Month	<b>20</b>
2010 Potential	<b>120</b>
2012 Potential	<b>220</b>