Overview of the Solar Energy Industry and Supply Chain

Prepared for the BlueGreen Alliance
By Stone & Associates
January, 2011

http://www.bluegreenalliance.org/cemc

Introduction

This Overview of the Solar Energy Industry and Supply Chain was prepared for the BlueGreen Alliance Foundation's Clean Energy Manufacturing Center (CEMC) as the first step in identifying opportunities to increase the base of domestic suppliers in the U.S. solar energy industry. The overview includes general information about the solar energy market as well as current installed capacity and expected growth, but its primary focus is the solar energy supply chain. Building the domestic supply chain for the solar energy industry has the potential to create jobs while accelerating the transition to a clean energy economy.

The BlueGreen Alliance Foundation (BGAF) is a non-profit, 501 (c) (3) organization. BGAF conducts research and educates the public and media about solutions to environmental challenges that create economic opportunities for the American people. The CEMC seeks to identify job creation opportunities in the U.S. wind and solar energy sectors and works with manufacturers, public officials, and others to grow the domestic base of suppliers in the clean energy manufacturing economy.

This document is based solely on secondary research to develop a set of industry information that can be used to help U.S. manufacturers participate in solar industry growth. The document is a starting point to assist in determining where and how to focus resources to maximize employment growth in the solar industry. The assessment of job creation opportunities in section one is preliminary, and requires additional primary research to validate and elaborate.

Section Topics

1. **Summary Assessment of Job Creation Opportunities in Solar**
   Includes PV manufacturing opportunities by supply chain component
2. **Solar Technologies – Installed Capacity and Growth**
   Overview of PV, CSP, and SHC
3. **Photovoltaic (PV) Global Supply Chain and Production**
4. **Trends in PV Production, Supply and Demand**
   National incentives for U.S. production facilities and competitive advantage in a global market
5. **Concentrated Solar Power (CSP)**
   Includes list of manufacturers by supply chain component
6. **Solar Heating and Cooling (SHC)**
   Includes list of U.S. Manufacturers
7. **Solar Industry Employment**

1. Summary Assessment of Job Creation Opportunities in Solar

Topics Covered In This Section

- Summary of Job Creation Opportunities by Solar Segment
- Assessment of Job Creation Opportunities within PV by Supply Chain Component

This section shares a set of preliminary hypotheses, to be confirmed with additional primary research.

Summary of Job Creation Opportunities by Solar Segment

	Photovoltaic	Solar Thermal
Distributed	**Photovoltaic** Current US Employment (2010): ~55 K Projected US Employment (2016): 197 K Largest employment potential	**Solar Heating and Cooling** Current US Employment (2010): few thousand Projected US Employment (2016): 13K Limited employment potential (unless demand increases)
Central / Utility		**Concentrated Solar Power** Current US Employment (2010): few thousand Projected US Employment (2016): 20K Strong competitive position, but limited employment potential

Employment Projections depend Heavily on Demand Assumptions/Projections

Note: Employment estimates are based on sources cited in employment section. Numbers above include only direct and indirect employment. Projections are probably overstated (Navigant Consulting) because they do not take into account foreign competition for manufacturing value added.

Summary of Job Creation Opportunities by Solar Segment *(continued)*

	Photovoltaic	Solar Thermal
Distributed	**PV – Distributed** • Low penetration – significant opportunity (only 29K residential installations in 2009) • Incentives now beginning to spark growth • High jobs per MW, driven by substitution of labor and equipment for fuel, and installation work on site • Opportunities for job growth: – Installation/construction as US demand grows – Some in manufacturing, particularly in modules, though low cost countries are increasing share of manufacturing – US producers may need to focus on niche technologies, such as thin film where they have been strong	**Solar Heating and Cooling** • Low penetration – significant opportunity • 90% of current installed base is pool heating • Market recently revived by local and federal incentives • Employment numbers, current and projected, are very low • Opportunities for job growth: – Installation as US demand is spurred by government incentives
Central / Utility	**PV – Utility** • Rapid growth • High jobs per MW, driven by substitution of labor and equipment for fuel (but lower than distributed) • Opportunities for job growth: – Installation/construction as US demand grows (but considerably less than distributed) – Some in manufacturing, particularly in modules, though low cost countries are increasing share of manufacturing – US producers may need to focus on niche technologies, such as thin film where they have been strong	**CSP** • 95% of global capacity is in the US • Growth slowed after installations in 1980s • Major resurgence underway: – Projects under development represent over 20X current capacity • US has unique strength in this technology due to sunlight in Southwest • Job potential per MW is considerably lower than PV

Assessment of Job Creation Opportunities Within PV By Supply Chain Component

Supply Chain	Jobs Per MW (Residential)	Trends	Opportunities
Operations & Maintenance	0.3 (FTEs)	Small employment	Limited opportunity
System Integration, Installation, Construction	16.8	Tied to end-market – will grow as demand increases, driven by policy	Policies to stimulate demand should create jobs in this segment
Modules & Cells	11.0	Growing in response to global demand, but increasingly growth captured by low cost countries	Uphill battle. US producers may need to focus on niche technologies, such as thin film or ribbon. Module plants are more likely than cell plants to be located near the customer in North America
Wafers		Has been area of US strength, but now shifting to vertically integrated players in low cost countries	Difficult to compete against China
Other Components (BoS)	3.0	Insufficient information	Insufficient Information

2. Solar Technologies – Installed Capacity & Growth

Topics Covered In This Section

- Overview of Solar Technologies
- Installed Capacity by Technology and Application
- Annual Installations and Growth
- Cost Comparisons with Other Energy Sources

Overview – The Solar Industry Can Be Segmented By Technology & Application

Application	Photovoltaic (PV) •Generates electricity from the sun through semi-conductors	Solar Thermal (ST) •Uses the sun to heat a working fluid
Distributed • Located at the user • Residential, commercial/ industrial • Can be tied to the grid or not connected to the grid	PV – on the roof 🗲 • Photons in sunlight are absorbed by semiconductors, causing electrons to move. This current is electricity. • Electricity is converted from DC to AC and is either used immediately, stored in a battery or sent back to the utility grid	Solar Heating & Cooling (SHC) • These low and medium temperature collectors do not generate electricity • Heats liquid which is used to heat or cool a home or building (e.g.; solar water heaters, solar pool heaters, and solar cooling*) • Note: often the term "solar thermal" only includes these non-electricity generating technologies (i.e. does NOT include CSP) *Solar cooling uses heat to create air-conditioning
Central/Utility	PV- Utility 🗲	Concentrating Solar Power (CSP) 🗲 • Concentrated sunlight heats a fluid which drives a turbine to generate electricity

🗲 Generates Electricity

Photovoltaic – Utility Scale

Nellis AFB Solar Project (courtesy SunPower Corp.)

Source: The Sun Rises on Nevada Report

Distributed Solar Capacity is Predominantly Photovoltaic & Some Solar Heating/Cooling, while Utility Capacity is CSP & PV

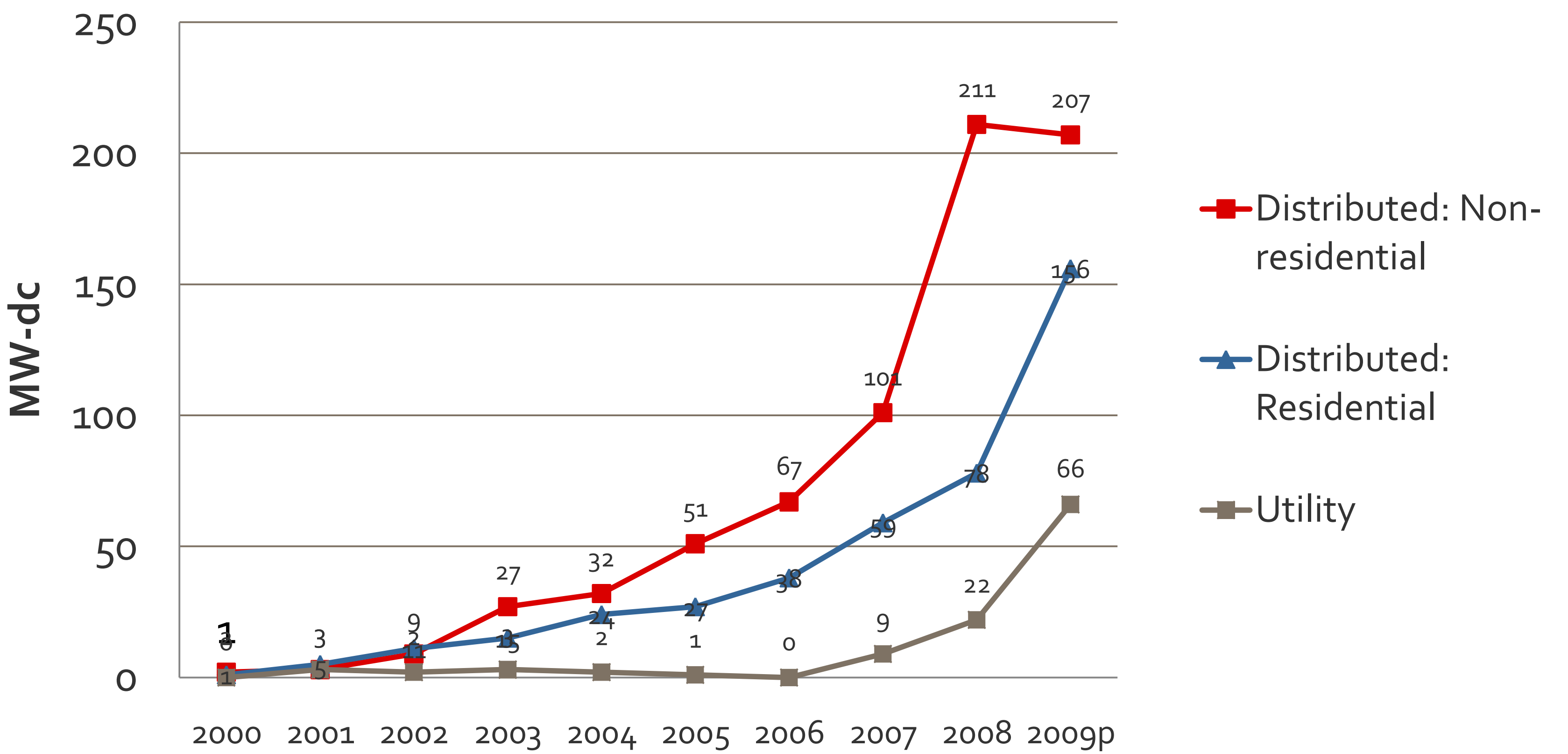
US Installed Solar Capacity – 2009

Technology	Central/ Utility	Distributed Non-Residential	Distributed Residential	Total	Comment /Source
PV (MW-dc)	109	932	571	1,612	SEIA '09; Off -grid est. =NREL
CSP (MW-ac)*	431	--	--	431	SEIA '09
SHC (MW-th)**	--	***	***	~25,000	SEIA '09

* Roughly 15% loss in converting DC to AC
**MW-thermal is a measure of thermal power NOT electrical power; it is roughly 3x MW-e
*** The SHC split between Non-Residential and Residential is not given

While the Growth of PV Installations Is Accelerating…

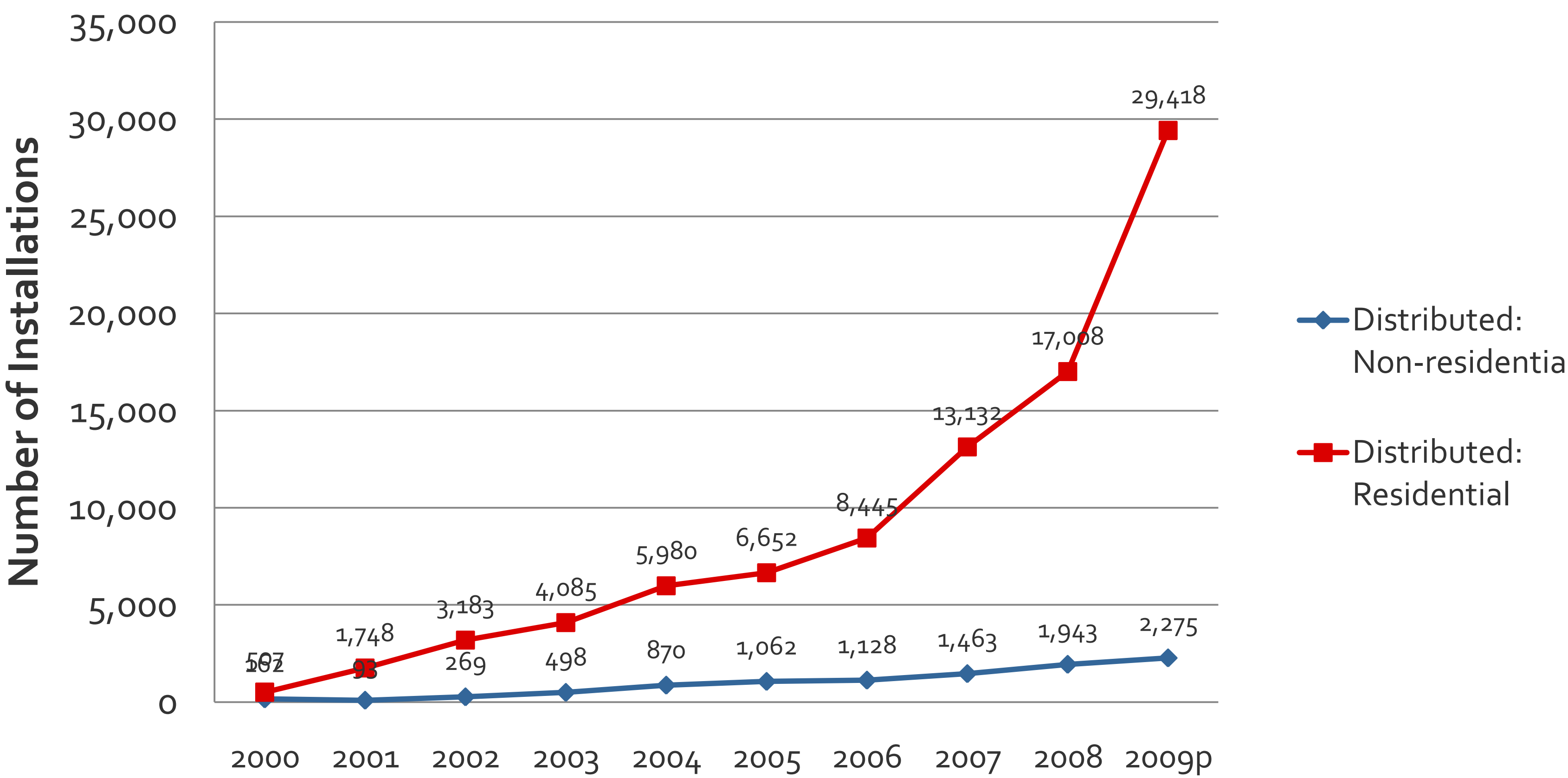
Annual US PV Installations (Grid-Tied)



Source: SEIA 2009 Supplemental Charts

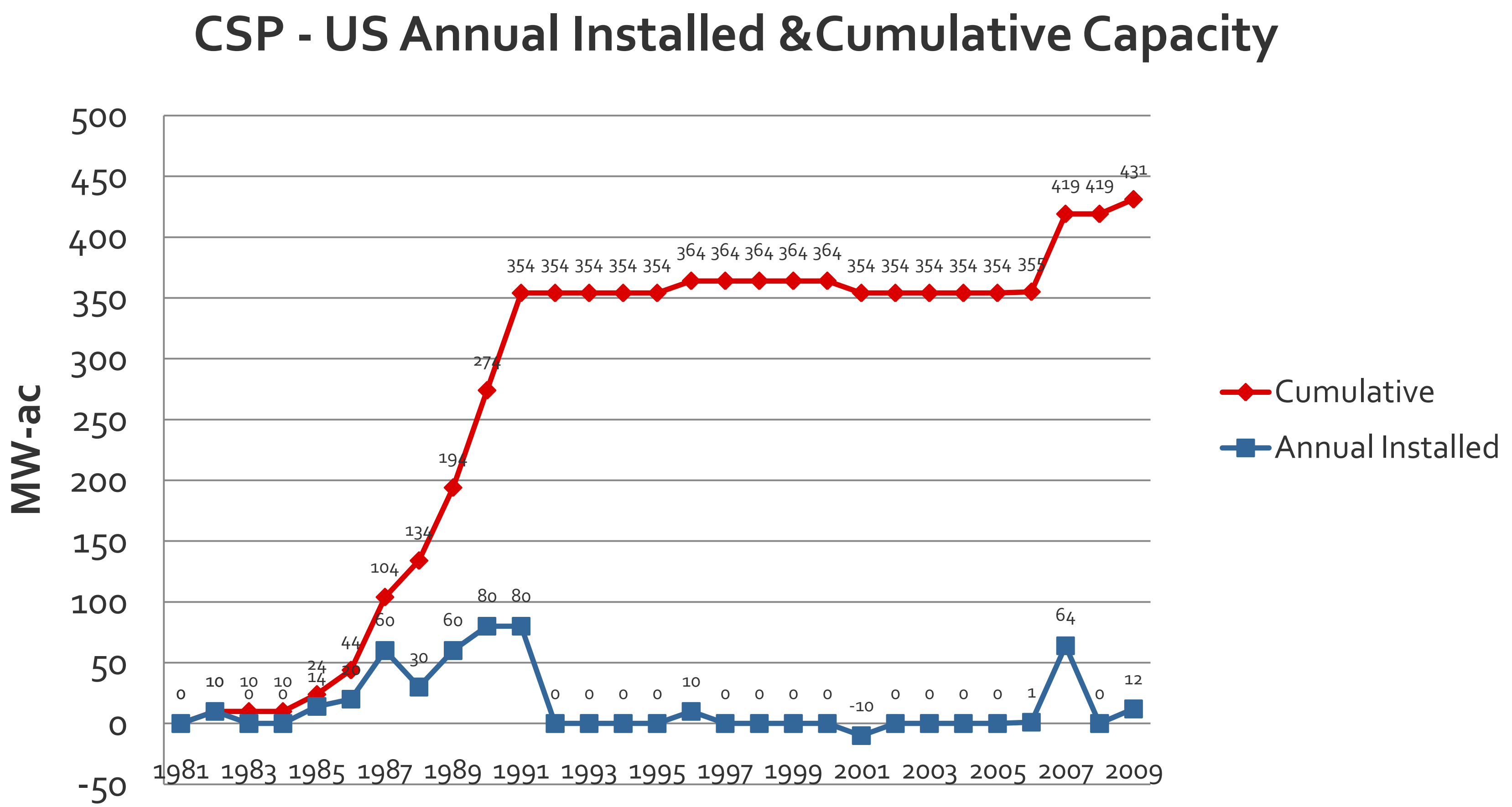
...Only 29K Homes Installed PV Systems In 2009

Annual US PV Installations (Grid-Tied)



Source: SEIA 2009 Supplemental Charts

The US Increased Its CSP Capacity From 1985-1991, But Since Then Little New CSP Has Come Online



Source: SEIA 2009 Supplemental Charts

However a Large Amount of Solar Capacity Is Under Development For Utility Scale Projects – Employing Both PV & CSP Technologies

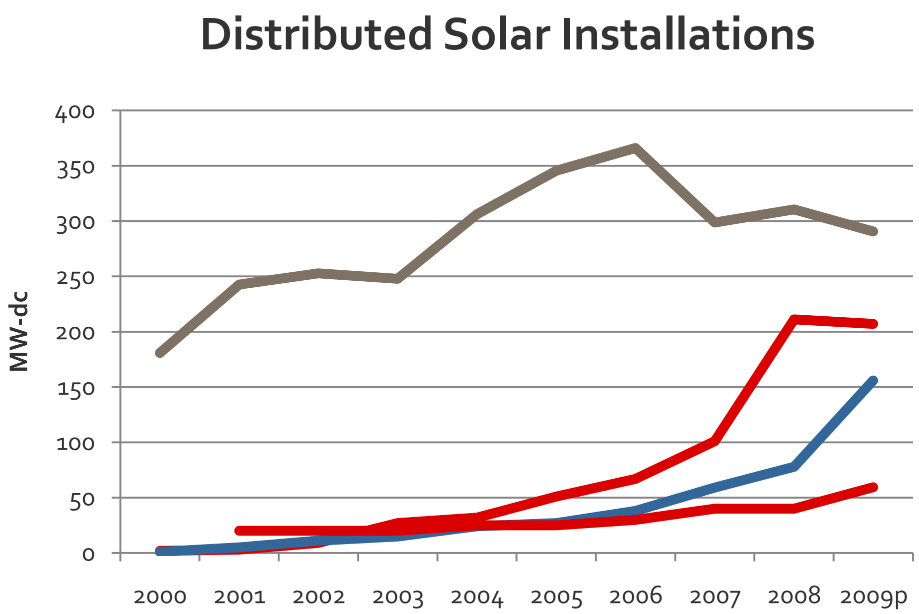
Central/Utility Growth - US by Technology

Utility Scale Solar Projects in the US as of June 25, 2010

	CSP		PV-SI		PV-Thin Film	
	# Plants	MW	# Plants	MW	# Plants	MW
IN OPERATION pre-2004	9	354	1	3	0	0
IN OPERATION post-2005	6	79	12	84	5	51
Total Current Capacity	15	433	13	87	5	51
UNDER CONSTRUCTION	1	75	9	89	1	40
UNDER DEVELOPMENT	35	9,929	77	11,414	8	1,207
TOTAL current & pipeline	51	10,437	99	11,590	14	1,298

Source: SEIA "UTILITY SCALE SOLAR PROJECTS IN THE US", 6/25/2010

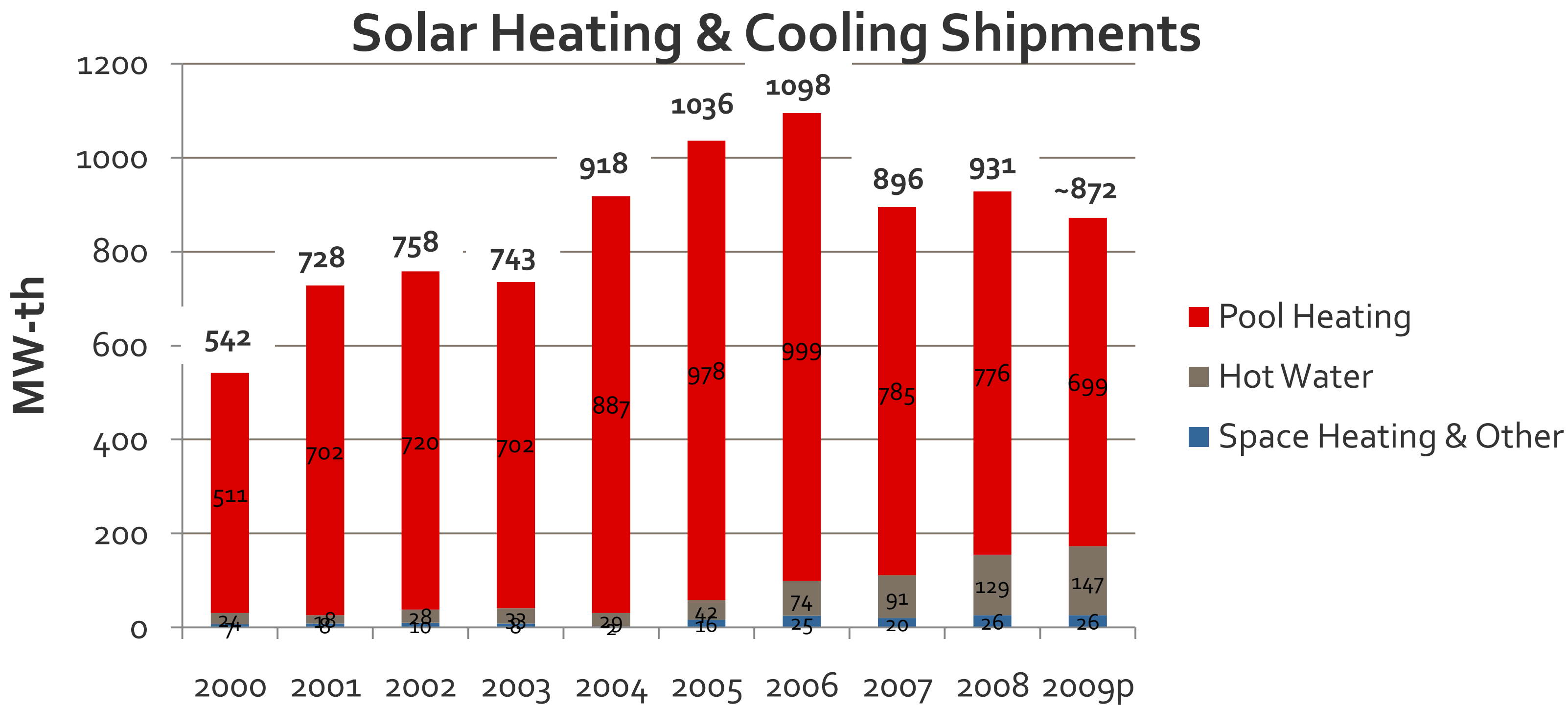
The Growth of Distributed PV Solar Capacity Has Accelerated, However SHC (mainly pool heating) Has Leveled Off



- **In MW – Annual installed capacity for distributed (located at user site) solar energy (Note: SHC adjusted from MW-thermal to MW-electrical)**
- **SHC – Pool heating is 80-95% of this total; hot water makes up most of the remainder**

Source: SEIA 2009

Annual US Shipments of Solar Heating & Cooling are Dominated By Pool Heating Applications

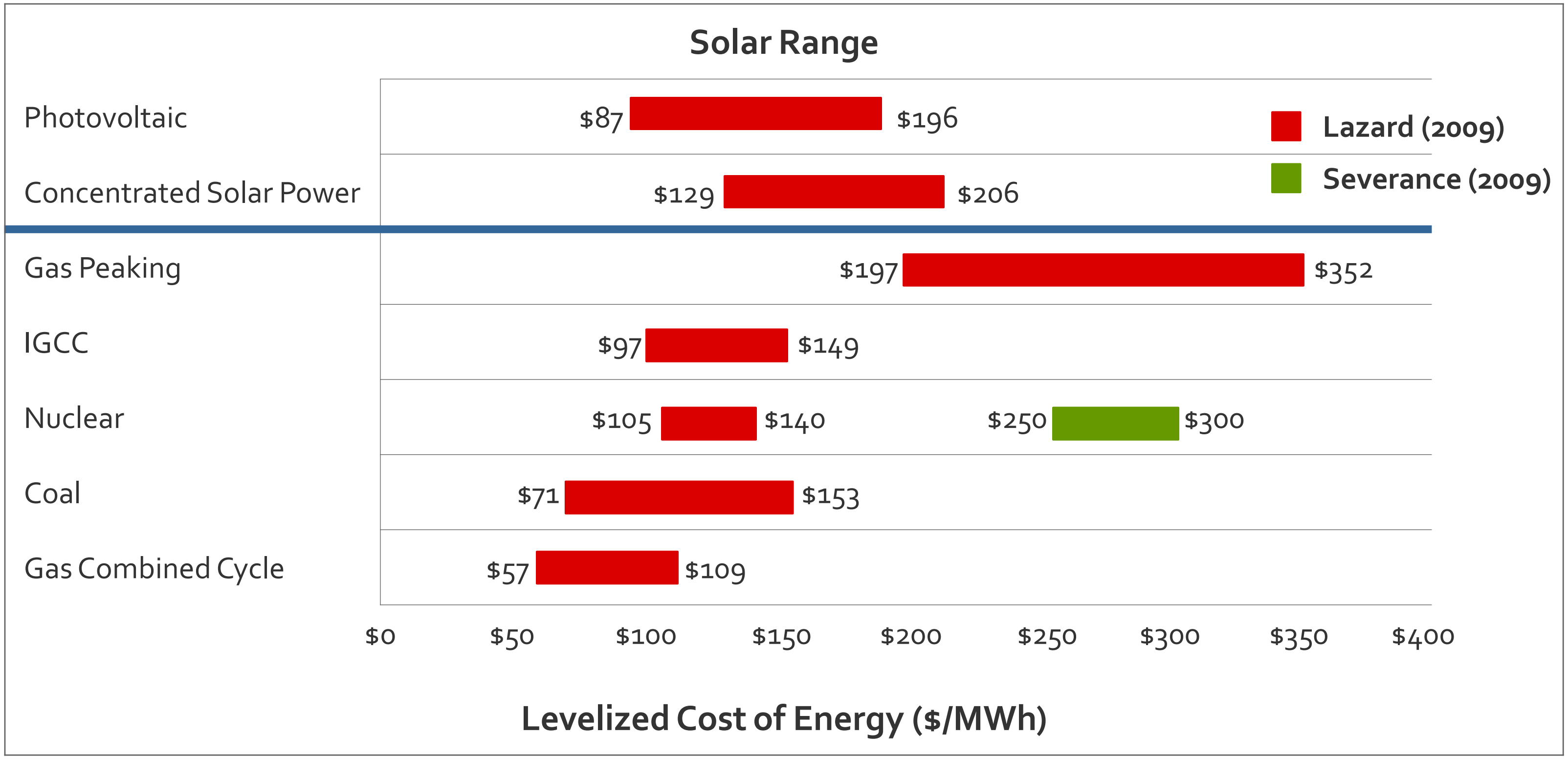


- **Cumulative Solar Water Heating and Pool Heating growth from 2000 to 2009:**
  - SWH increased from 1500 to roughly 2200 MW-th (CAGR=4%)
  - Pool Heating increased from roughly 14,500 to 22,500 MW-th (CAGR=5%)

Source: Based on a chart in the SEIA 2009 Supplemental Charts

Cost Comparison of Energy Sources: Solar is Becoming Increasingly Competitive With Other Sources

- **Solar is increasingly competitive with traditional generation technologies**
- **Almost always less expensive than new peaking plants**
- **Increasingly less expensive than new baseload**



Source: SEIA 2009 Supplemental Charts

Achieving Cost Parity With Grid Supplied Electricity

- **Module prices will resume their rapid decline in 2011, following steady to slightly upward price movements in the first half of 2010. In 2011, difficult demand conditions will force module prices down by a further 19 percent, reaching below $1.40/W on average.**

- **However, ASPs declines will begin to moderate in 2012 and 2013 as stronger demand growth returns to the global market, supported by a class of secondary markets.**

- **Italy and Japan will be the first major PV markets to reach unsubsidized grid parity, thanks to high retail electricity prices and established PV demand centers.**
  - Projects in both countries will begin to achieve this milestone within the next three years, with global grid parity following thereafter.

3. Photovoltaic (PV) Global Supply Chain & Production

Topics Covered In This Section

- **Photovoltaic Supply Chain Overview**
- **Manufacturing of Supply Chain Components**
  - Polysilicon ingot and wafer
  - Cell
  - Module
  - System integration, assembly and installation

Photovoltaic Supply Chain (most common)

Raw Material

- Crystalline/multicrystalline (80-90% of market) (silicon is purified but lower grade than for computers)
- Thin-film (uses less than 1% of light absorbing material compared to traditional method; cheaper, but less efficient; 0-20% of market and growing)

↓

Ingot

- Ingot casting

↓

Wafer mfg

- Silicon wafers make up 40-50% of crystalline module cost
- Doping: Create n-type and p-type wafers

↓

Solar Cell (semiconductor cells)

- Screen printing
- Encapsulant
- Top surface (usually glass) and bottom surface (weatherproof sheet)
- Aluminum frame and junction frame

↓

Solar Module

- String cells together into module

↓

Solar Panel

- Add Balance of System to modules (BoS manages power) – 20% of total cost
  - Inverter (converts power from DC to AC) – 10% of total cost
  - Blocking diode, charge controller, circuit breaker, switch gear, wiring
  - Battery (optional)

↓

Installation

- Construction and/or installation (20%)

Photovoltaic Supply Chain Illustration

Source: Hemlock Semiconductor

The Supply of Polysilicon Wafers is a Critical Driver of Cost & Quality in the Photovoltaic Industry

- **Polysilicon wafers are a major PV cost component**
  - 40-50% of the finished module, (module is 50-60% of installed cost)
  - Producing solar-grade polysilicon is complex and capital intensive
    - Minimum purity: 6N or 99.999999%
  - Maintaining polysilicon quality is critical
    - Even small decreases in PV efficiency resulting from using lower quality polysilicon can offset the cost savings gained from using the lower quality polysilicon

- **The 2005 polysilicon shortage was due to lack of capacity for purifying silicon to 6N**
  - Initially, the PV industry relied on leftover polysilicon from the electronics industry
  - However, PV demand surpassed electronics in 2007 and is now the primary driver of growth in polysilicon production
  - Shortage in 2005 (created by PV demand) drove up prices and resulted in significant investment in polysilicon production facilities
  - Cell and module manufacturers who could not secure long term contracts paid substantially higher prices

- **But now, because of over-investment, polysilicon prices have been driven down**
  - 2010: 72 million metric tons (MT) of demand vs. 122 million MT of supply
  - From roughly $2/watt in 2008 to less than 50 cents/watt in 2010

Sources: Solarbuzz.com, NREL 2008 report (published 2010) and Motech/AE Polysilicon

Polysilicon Ingot & Wafer *Production is Generally Located Near Cell Plants To Ensure Uninterrupted Supply*

- **Crystal growing and casting plants are best sited where there is an abundant source of reliable, cheap energy to power the high temperature operations [1]**
- **They do not need to be sited close to solar cell plants because wafer transportation is cheap, but most are because the investment has been by PV manufacturers to secure wafer supply to their cell plants [2]**
- **In 2008, the US was the largest producer of polysilicon (43%) [3]**
- **But the market is changing quickly now: [4]**
  - Established producers expanded capacities
  - Newcomers , especially from China, have moved into this market (primarily to vertically integrate their PV cell mfg)

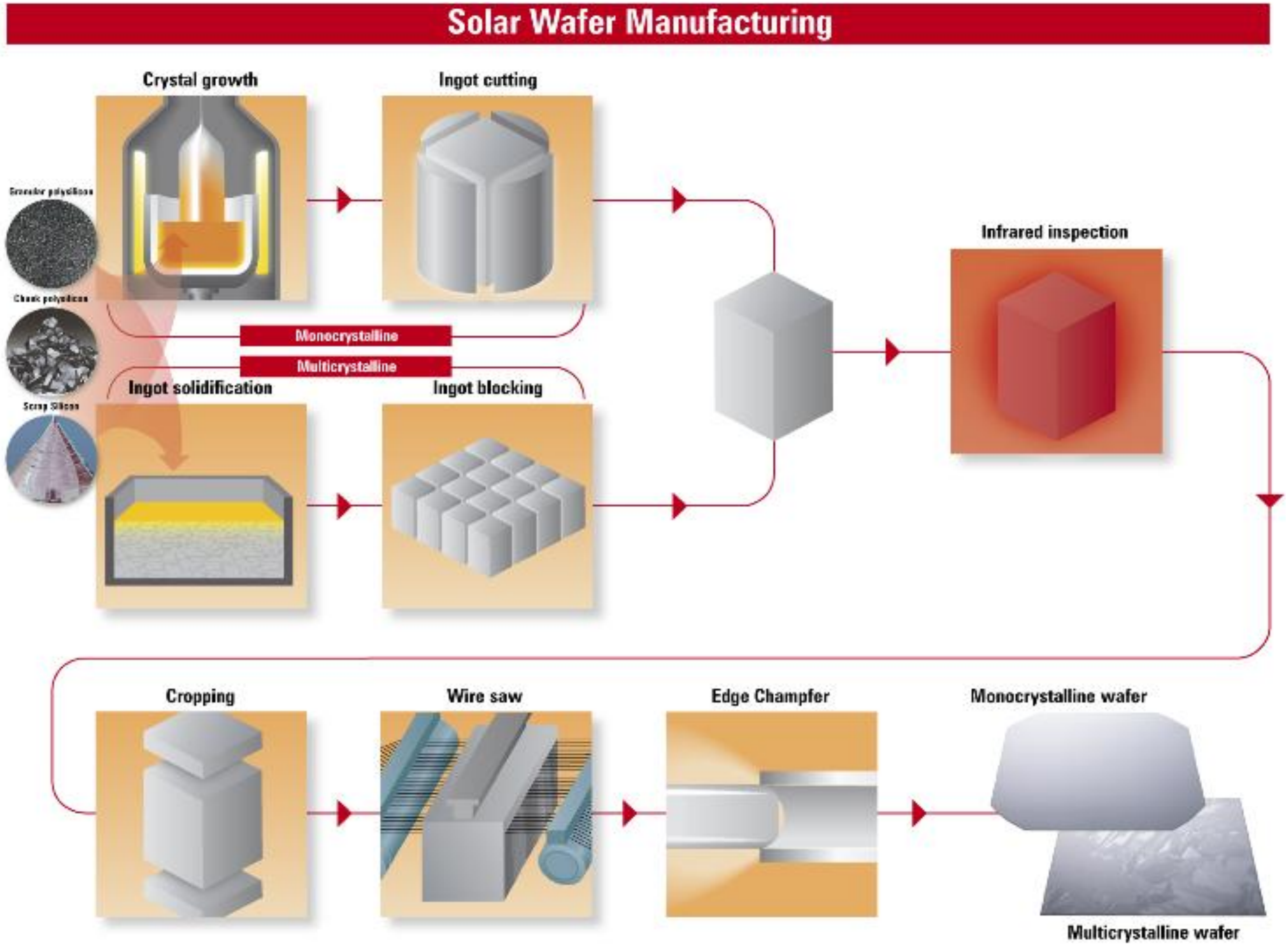
[1] Solarbuzz.com
[2] Solarbuzz.com
[3] NREL 2008 Solar Technologies Market Report (released 1/2010)
[4] NREL 2008 Solar Technologies Market Report (released 1/2010)

*Polysilicon **Wafer** Manufacturers – Market Leaders*[1]

Company	Capacity Data Points	Location
Hemlock Semiconductor	36kt (2010)	US (all?)
Wacker Chemie	*25kt (2010)* "2nd largest hyperpure polycrystalline silicon manufacturer"	German company (+ US location)
GCL-Poly	18kt (2010) New leader	Hong Kong Company (manufacturers in China)
OCI	17kt as of 6/2010; expected to be 27k as of 12/2010 and 32k as of 10/2011 . New leader	South Korea
Renewable Energy Corp ASA (REC)	17kt (2010)	Norway
MEMC Electronic Materials	8kt (2010)	US Company (mfg in Korea, Taiwan, Malaysia, Italy, Japan, Texas [2], Missouri)
Tokuyama	8kt (2010)	Japan

[1] NREL 2008 Solar Technologies Market Report (released 1/2010)
Sources: SEIA, NREL, solar.calfinder.com, wikipedia

Solar PV **Casting & Wafering** *Process*

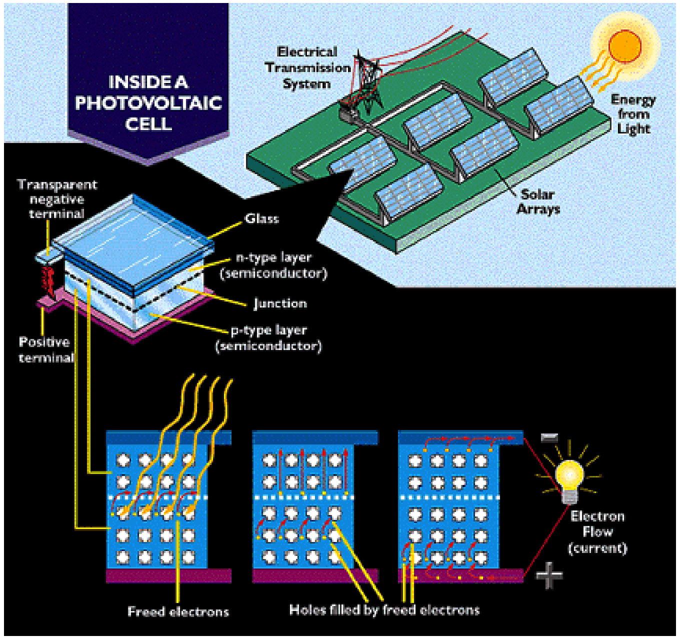


Source: MEME.com

Solar Cell Manufacturing Process

Process Steps:

- Wafers are doped (create n-type and p-type wafers)
- Sandwich each type together
- Apply contacts on both sides (screen printed, or other methods)
- Add an external pathway connecting both sides so the electrons can flow
- Apply an anti-reflective coating



Source: www.azsolarcenter.org

Solar Cell Manufacturing Plants are Capital Intensive, thus Companies Generally Supply Global Markets From One Location

- **Solar cell plants are complex and large**
  - Typically 10-50MW capacity and over 50,000 sq ft of plant area
  - A rule of thumb guide to the capital investment in building a solar cell plant is US$1M/MW for crystalline silicon and US$2M/MW or more for thin films.

- **Because this is a highly capital intensive part of the manufacturing chain, most manufacturers seek to centralize this activity at few locations.**
  - Thus solar cell production will typically <u>service international markets from a single facility.</u>
  - Crystalline-Si cell plants, based on well-proven technology, can be operational within 1 1/2 to 2 years of project approval and could be running at full capacity after another year.
  - At a fully operational 50 MW Plant, around 300 jobs might be created, including operational, warehousing, fabrication and overhead administration.
    - The actual number will be dependent on the chosen technology and degree of automation.

Source: Solarbuzz.com

Global Solar Cell Production by Region

Global Cell Production by Region, 2009 (MW-dc)			
Region	2007	2008	2009
North America	269	401	595
Europe	1,067	1,985	1,930
China/Taiwan	1,251	2,785	5,191
Japan	938	1,268	1,503
ROW	223	610	1,436
Total	**3,746**	**7,049**	**10,655**

Source: GreenTechMedia Research 2009 Global PV Cell and Module Production Analysis, May 2010

*Top 10 Global Solar **Cell** Producers*

Rank	Company	2009 Cell Production (MW-dc)
1	First Solar	1011
2	Suntech Power	704
3	Sharp	595
4	Q-Cells	537
5	Yingli Green Energy	525
6	JA Solar	509
7	Kyocera	400
8	Trina Solar	399
9	Sunpower	398
10	Gintech	368
11	Motech	360
12	Canadian Solar	326
13	Ningbo Solar Electric	260
14	Sanyo	260
15	E-Ton Solar	225

Table 10: Top 15 Cell Producers, 2009 (MW-dc)

Source: GreenTechMedia Research 2009 Global PV Cell and Module Production Analysis, May 2010

Solar Cell Producers by Region

Table 5: North American Cell Production, 2009 (MW-dc)

Company	2007	2008	2009	08 to 09 Growth	Capacity YE09	Capacity YE10
First Solar	120.0	147.0	147.0	0.0%	160.0	214.0
United Solar	47.0	112.0	120.0	7.1%	150.0	150.0
Solarworld USA	35.0	33.0	71.8	117.4%	250.0	375.0
Evergreen Solar	16.4	26.5	104.6	294.7%	160.0	160.0
Solyndra	0.0	1.6	30.0	1775.0%	70.0	110.0
Other	50.7	81.0	121.6	50.2%	542.5	879.0
Total	**269.1**	**401.1**	**595.0**	**48.3%**	**1,332.5**	**1,888.0**
w/o First Solar	149.1	254.1	448.0	76.3%	1,172.5	1,674.0

*Table 6: Japanese Cell Production, 2009 (MW-dc)**

Company	2007	2008	2009	08 to 09 Growth	Capacity YE09	Capacity YE10
Sharp	363.0	473.0	595.0	25.8%	710.0	870.0
Kyocera	207.0	290.0	400.0	37.9%	400.0	700.0
Sanyo	165.0	215.0	260.0	20.9%	345.0	570.0
Mitsubishi Electric	121.0	148.0	120.0	-18.9%	220.0	400.0
Kaneka	42.5	52.0	40.0	-23.1%	70.0	150.0
Mitsubishi HEL	16.0	40.0	30.0	-25.0%	68.0	120.0
Other	23.0	50.0	58.0	16.0%	147.5	187.5
Total	**937.5**	**1,268.0**	**1,503.0**	**18.5%**	**1,960.5**	**2,997.5**

** Most data for Japanese producers was generously provided courtesy of RTS Corporation in Japan.*

Table 7: European Cell Production, 2009 (MW-dc)

Company	2007	2008	2009	08 to 09 Growth	Capacity YE09	Capacity YE10
Q-Cells (DE)	389.2	570.4	462.0	-19.0%	500.0	500.0
First Solar (DE)	87.0	196.0	196.0	0.0%	214.0	214.0
Solarworld (DE)	95.0	160.0	122.2	-23.6%	200.0	250.0
Bosch Solar/Ersol (DE)	53.0	143.0	200.0	39.9%	380.0	470.0
Schott Solar (DE)	67.0	119.0	102.0	-14.3%	170.0	170.0
REC Scancell (NW)	46.0	132.0	134.0	1.5%	180.0	180.0
Isofoton (ES)	85.0	130.0	70.0	-46.2%	140.0	140.0
Sovello (DE)	49.8	94.1	66.6	-29.2%	180.0	180.0
Solland (NE)	37.0	52.0	80.0	53.8%	170.0	170.0
Sunways (DE)	36.0	33.0	64.8	96.4%	116.0	116.0
Photovoltech (BE)	29.1	48.4	54.0	11.6%	80.0	155.0
Other	92.4	306.9	378.3	23.3%	1,214.0	1,468.0
Total	**1,066.5**	**1,984.8**	**1,930.0**	**-2.8%**	**3,544.0**	**4,013.0**

Source: GreenTechMedia Research 2009 Global PV Cell and Module Production Analysis, May 2010

Solar Cell Producers by Region (continued)

Table 8: China/Taiwan Cell Production, 2009 (MW-dc)

Company	2007	2008	2009	08 to 09 Growth	Capacity YE09	Capacity YE10
Suntech (CH)	327.0	497.5	704.0	41.5%	1,000.0	1,400.0
Motech (TW)	176.0	275.0	360.0	30.9%	600.0	800.0
Yingli Green Energy (CH)	142.5	281.5	525.0	86.5%	600.0	1,000.0
JA Solar (CH)	113.2	277.0	509.0	83.8%	875.0	1,100.0
Trina Solar (CH)	37.0	210.0	399.0	90.0%	600.0	900.0
Gintech (TW)	55.0	180.0	368.0	104.4%	640.0	750.0
Solarfun (CH)	88.0	172.8	220.0	27.3%	360.0	480.0
Canadian Solar (CH)	7.5	71.6	326.0	355.3%	420.0	700.0
China Sunergy (CH)	80.3	111.0	160.1	44.2%	320.0	352.0
Neo Solar (TW)	36.0	102.0	200.0	96.1%	240.0	600.0
E-TON (TW)	60.0	95.0	225.0	136.8%	320.0	500.0
DelSolar (TW)	45.0	83.0	88.8	7.0%	180.0	360.0
Ningbo (CH)	7.5	80.0	260.0	225.0%	350.0	500.0
Other	75.5	348.9	846.1	142.5%	2,262.0	3,597.5
Total	**1,250.5**	**2,785.3**	**5,191.0**	**86.4%**	**8,767.0**	**13,039.5**

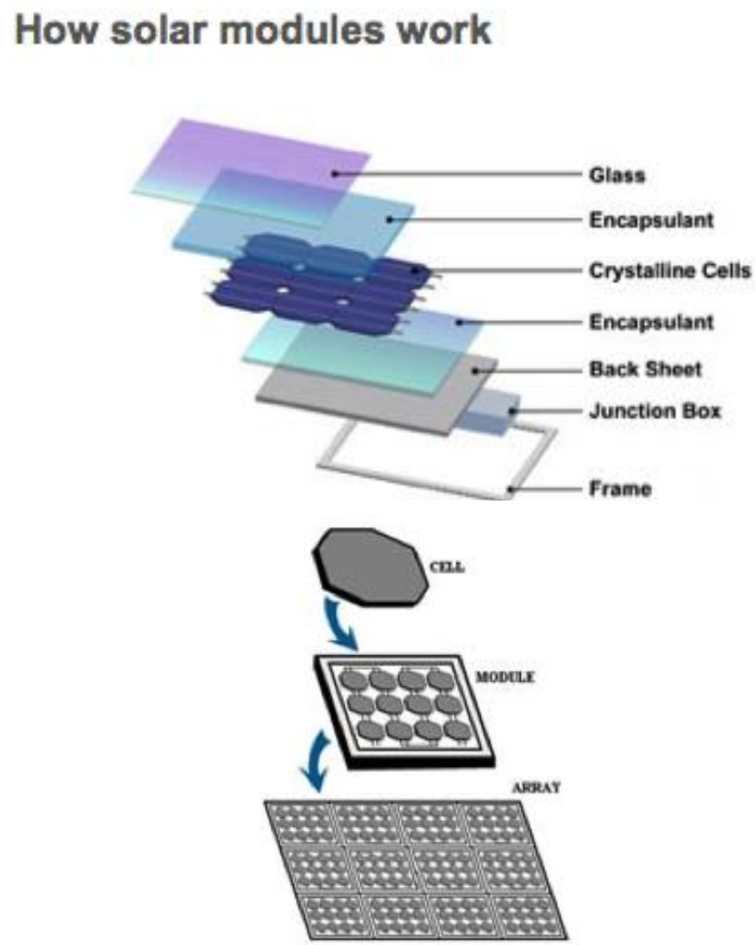
Table 9: Rest of World Cell Production (MW-dc)

Company	2007	2008	2009	08 to 09 Growth	Capacity YE09	Capacity YE10
First Solar (ML)	0.0	161.0	668.0	314.9%	854.0	854.0
SunPower (PH)	100.1	236.9	398.0	68.0%	574.0	654.0
Q-Cells (ML)	0.0	0.0	75.0	NA	300.0	600.0
Other	122.6	212.4	294.7	38.8%	944.0	1,515.5
Total	**222.7**	**610.3**	**1,435.7**	**135.3%**	**2,672.0**	**3,623.5**

Source: GreenTechMedia Research 2009 Global PV Cell and Module Production Analysis, May 2010

*Solar PV **Module** Manufacturing Process*

- **Solar cells are interconnected in a matrix to form a module**
- **Solar module assembly involves:**
  - Soldering cells together to produce a 36 cell string (or longer)
  - Laminating it between toughened glass on the top and a polymeric backing sheet on the rear.
  - Frames are usually applied to allow for mounting in the field, or the laminates may be separately integrated into a mounting system for a specific application such as building integration.



Sources: Solarbuzz.com, Dowcorning.com

*Solar PV **Module** Manufacturing*

- **The assembly of crystalline Si solar modules is most commonly carried out in the cell plant, but can be done in smaller plants closer to the end market.**
  - This can be preferable because while solar cells are relatively inexpensive to transport, modules with a glass front sheet and an aluminum frame are heavy and bulky.
- **The capital cost of translating the solar cell into a laminated solar module is low, so the economics of smaller capacity plants can be justified.**
  - Economies of scale can be captured with an annual capacity of 5 MW or greater
  - Capital cost for equipment will be around US$0.5M for this scale of plant, but the all up cost will be up to $5M.
- **Number of jobs created is dependent on the level of automation utilized, but typically would be in the 30-100 range.**
  - From the point that the site location has been acquired, module assembly plants can be operational in 6-9 months.
  - If a new building is required: 12-18 months.
- **Module production is labor intensive, benefitting low-cost labor countries.**

Source: Solarbuzz.com

*Solar PV **Module** Production by Region*

Global Module Production by Region, 2009 (MW-dc)			
Region	**2007**	**2008**	**2009**
North America	327	540	777
Europe	1,022	1,808	1,892
China/Taiwan	1,019	2,165	3,580
Japan	674	929	934
ROW	291	901	1,758
Total	**3,334**	**6,344**	**8,941**

Source: GreenTechMedia Research 2009 Global PV Cell and Module Production Analysis, May 2010

*Solar PV **Modules** – Top 15 Producers*

Table 11: Top 15 Module Producers, 2009 (MW-dc)		
Rank	**Company**	**2009 Module Production (MW-dc)**
1	First Solar	1011
2	Suntech Power	704
3	Sharp	595
4	Yingli Green Energy	525
5	Kyocera	400
6	Trina Solar	399
7	Sunpower	398
8	Canadian Solar	326
9	Solarfun	313
10	SolarWorld	288
11	Sanyo	260
12	Ningbo Solar Electric	201
13	Schott Solar	167
14	Changzhou Eging	150
15	Aleo Solar	139

Source: GreenTechMedia Research 2009 Global PV Cell and Module Production Analysis, May 2010

PV System Integration, Assembly & Installation

- **The final part of the overall manufacturing process is the solar system assembly and installation – this has two aspects:**
  - Mechanical integration of the solar module into its chosen array structure
    - Array structure will depend on the final location
  - Electrical integration of the solar module with rest of system
    - Includes inverters, batteries, wiring, disconnects, and regulators (charge controllers).
    - Requires matching equipment to the electrical load required by the customer
- **This part of the manufacturing process is the least capital intensive and can be located on small premises, or even be undertaken at the customers site:**
  - Sales companies ("Integrators", "Dealers" or "Installers") perform this task
  - Relatively labor intensive and is an important component of job creation within the industry

Source: Solarbuzz.com

4. Trends in PV Production, Supply & Demand

Topics Covered in This Section

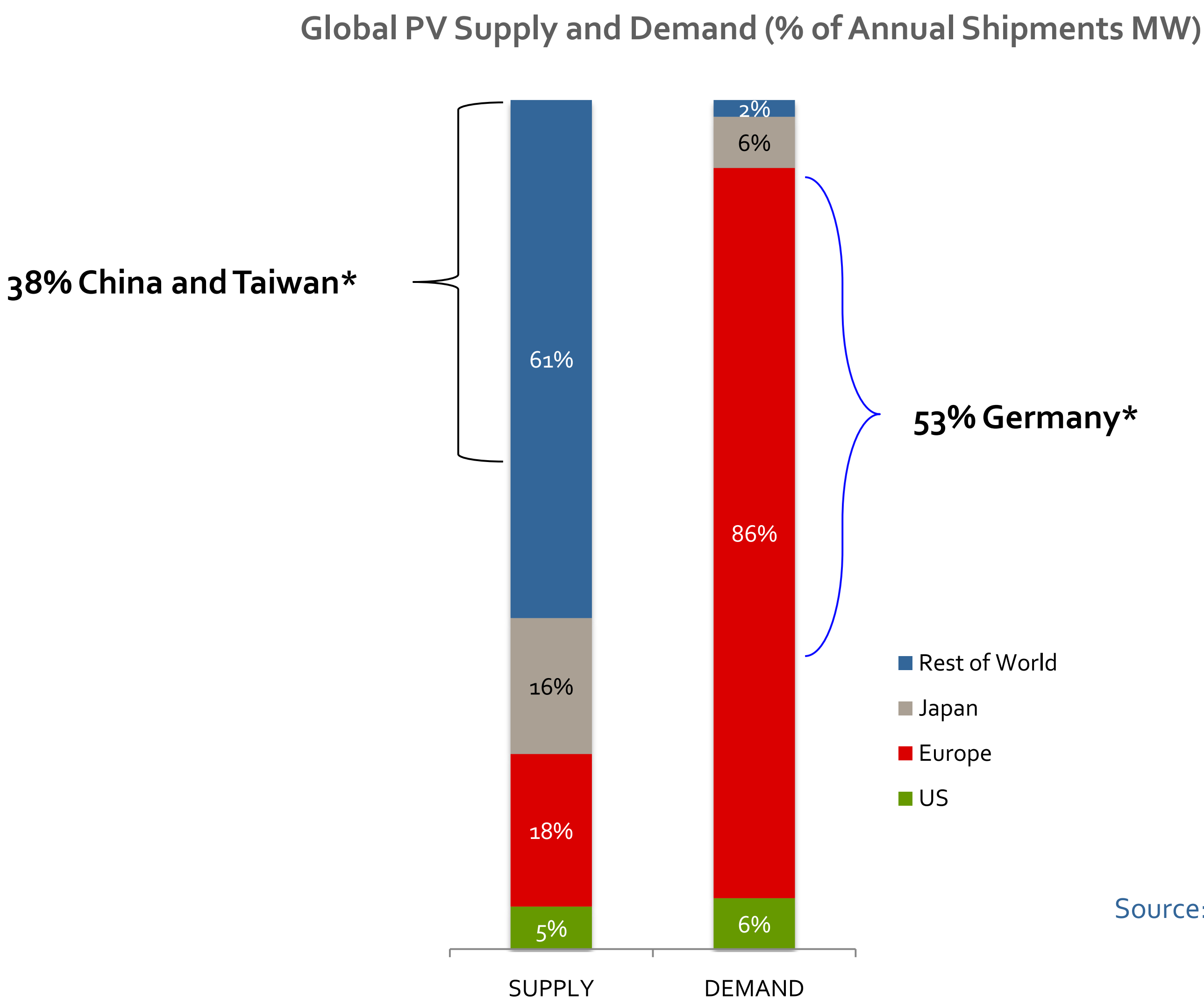
- Historical Background
- Global Supply and Demand
- US Production Facilities
- US Incentives and Market Potential
- The Emergence of China
- US Strength in Thin Film
- Trade Patterns

Trends in Global PV Production – Historical Overview: The US Lost Market Leadership in PV after 1999

- **US led in PV shipments before 1999, but lost market leadership over the subsequent decade – first to Japan and then to Europe (primarily Germany), and finally to China/Taiwan which shipped 46% of total product in 2009:**
  - Japan – market surge resulted largely from the Japanese residential subsidy program
  - Europe – demand resulted largely from the German feed-in tariff and similar policies adopted by other European countries
  - China and Taiwan – in 2009 they surged to dominance primarily due to price leadership
  - All the above had strong production growth rates in the past decade, but market share for Japan, Europe and US dropped due to the emergence of China and Taiwan

Source: Solar Vision Study Draft (May 2010)

Global PV Supply & Demand (Cell & Module Shipments): 86% of Demand is in Europe, Much of it Supplied From Asia



Source: Solar Vision Study Draft (May 2010)
*SEIA 2009

Demand Globally is Driven By Subsidies & Feed-In-Tariff

- "Germany has the same solar insolation as the US state of Alaska. Yet Germany is the global leader in solar installations. Why is that? Three words – policy, policy, policy."[1]
- "Over the first half of 2010, most module shipments will be sent to Germany, which will run at full capacity." In the second half, German demand will fall due to feed-in tariff cuts in the second half of the year.
- "Italian demand will spike to 1,487 MW in 2010, maintaining its position as the second- largest national market. Italian demand will be spurred by forthcoming feed-in-tariff reductions in 2011."
- "2010 will mark the beginning of a global diffusion of demand: Whereas the past few years have been characterized by a single "savior" country essentially keeping the global market afloat, 2010 will mark the beginning of a global diffusion of demand across a class of growing markets."
- "Although Germany will retain its position atop national markets, its fall from grace beginning in the second half of 2010 will leave suppliers seeking the next "gold rush." But no other market has all the necessary characteristics to ramp up in volume and with sufficient pace to serve as a singular replacement for German demand. Instead, demand will become increasingly spread out amongst markets and the boom/bust cycle will begin to dissipate."

[1] GreenTechMedia, 7/26/2010: Update! 14 PowerPoint Slides That Shook the Earth

Source: GreenTechMedia Research, Global PV Demand Analysis and Forecast: Executive Summary, May 2010

US PV Supply Chain: In 2009 There Were 49 PV Facilities in 22 States in Operation or Under Construction in the US

- **Federal and state incentives have been encouraging manufacturers to expand PV production in the US**
- **US facilities produce crystalline silicon, CPV*, and thin film** technologies as well as polysilicon material (for use in crystalline silicon PV)**
- **In 2008:**
  - Cell production was about 400 MW (6% of global production)
  - Module production was about 500 MW (9% of global production)
  - Polysilicon production was about 26,000 MT (41% of global production)
- **The US was a leader in polysilicon production in 2008, but this is probably no longer the case:**
  - Chinese PV cell and module manufacturers have invested in polysilicon facilities to lock up supply
- **In 2009 and 2010 module production has begun to move offshore to low labor cost countries**

* Concentrator PV uses reflectors to focus light on small, high-efficient PV cells; high production cost and higher efficiency rates. New and growing technology, ed by Spain. Utility scale CPV would compete with CSP. (source: 2009 Tapsolar-Technology Action Plan- Solar Energy)

** a-Si (amorphous silicon), CdTe (cadmium telluride), CIGS (copper indium gallium diselenide), and OPV (organic PV)

Sources: Solar Vision Study Draft (05/28/2010)- DOE/SEIA/SEPA, citing Mehta 2009, Bartlett et al. 2009

Incentives Exist To Stimulate PV Demand

- **There are Federal incentives for PV on the roof (without which PV is not economical)**

- **In some places there are local incentives as well:**
  - The President of SEIA stated that he received $17K from the state of Maryland, plus a $2K tax credit
  - The price of the PV system was $35K, with a net addition to his mortgage of $60-70/month
  - But electricity savings were $100 per month, therefore PV is a net savings to him from day one

- **At least one utility company is putting PV on customer roofs, where they own the equipment and the electricity goes back to the grid:**
  - The customer pays their normal electric bill, the company pays you a fee for “leasing” roof space (Duke Electric)

PV – US Market Potential

- **Despite a long history of public and private investments in PV technology, the US continues to be a relatively immature PV market**
- **In 2008, the US accounted for:**
  - 8% or about 440 megawatts (MW) of PV global market demand
  - 7% or about 385 MW of global market supply
- **The *technical* potential of the US PV market is substantial:**
  - The land area required to supply all end-use electricity in the US using PV is only about 0.6% of the country's total land area or about 22% of the "urban area" footprint

Source: Solar Vision Study Draft (May 2010)

China's PV Industry Has Predominantly Supplied Export Markets, but the Government is Now Stimulating Domestic Demand

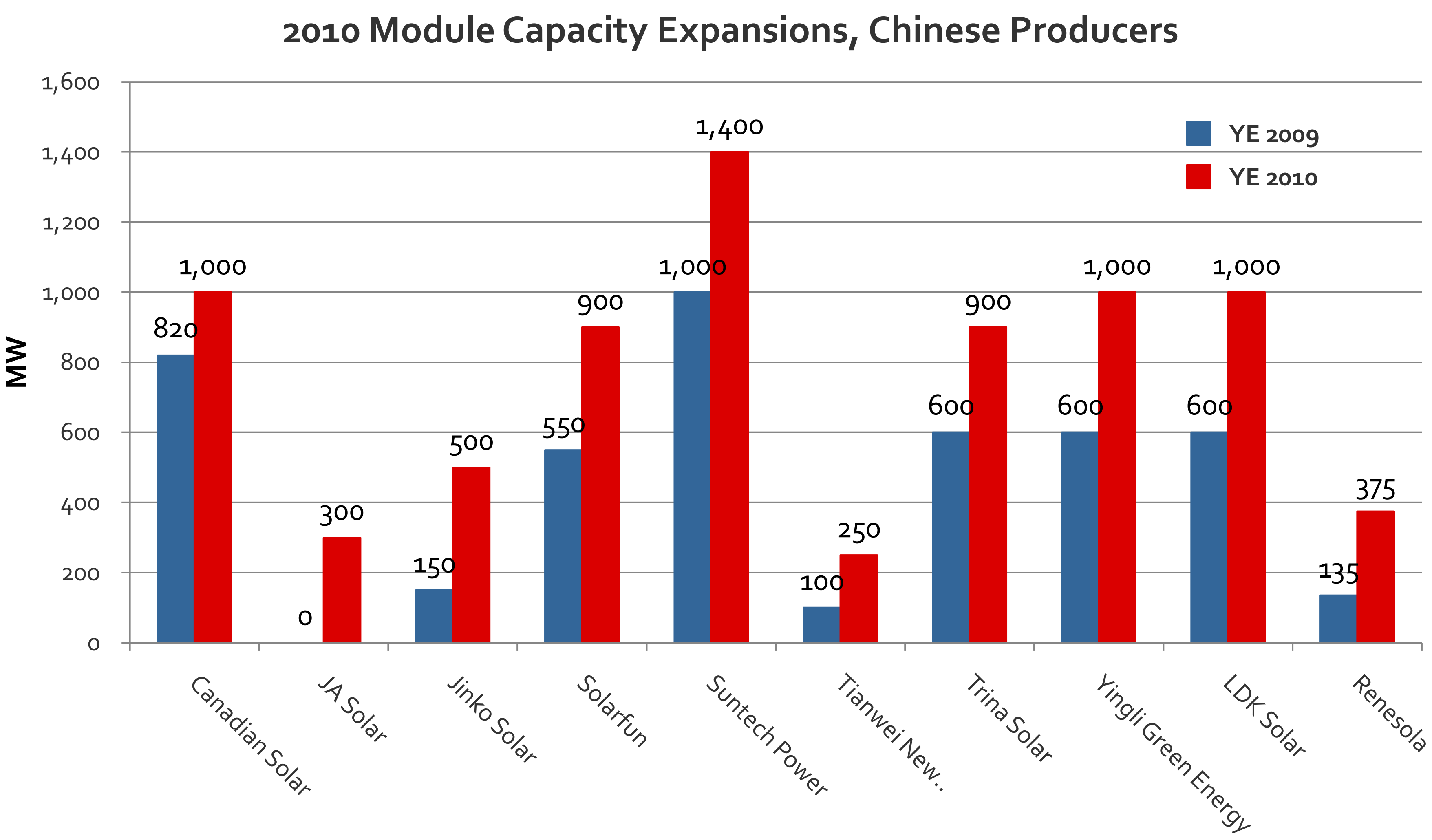
- "One constant in what many have called "the miracle" of China's enormous economic growth over the past 30 years has been a reliance on export economies. The development of the PV industry has been no exception."

- "Since the industry's modest beginnings in 2002, domestic cell and module manufacturers have exported more than 95 percent of their products to overseas markets – relying on the favorable energy policies of European governments to drive demand for Chinese production. As China has rapidly vaulted to the top of global solar cell manufacturing capacity, it has done so largely due to unprecedented demand from countries like Germany, Spain, Italy, and the United States, among others."

- "As 2008 drew to a close and the realities of one of worst global economic crises since the Great Depression began to crystallize, domestic Chinese manufacturers in many industries scaled back production, laid off workers, and some even stopped operations completely. It was in this context that the Chinese government, recognizing the need to support this critical growth industry with domestic demand, began to seriously consider national solar incentives. With many other markets stalling due to a lack of financing and uncertain policy regimes, China will likely be one of the key growth markets for the solar sector in both the near- and long-term."

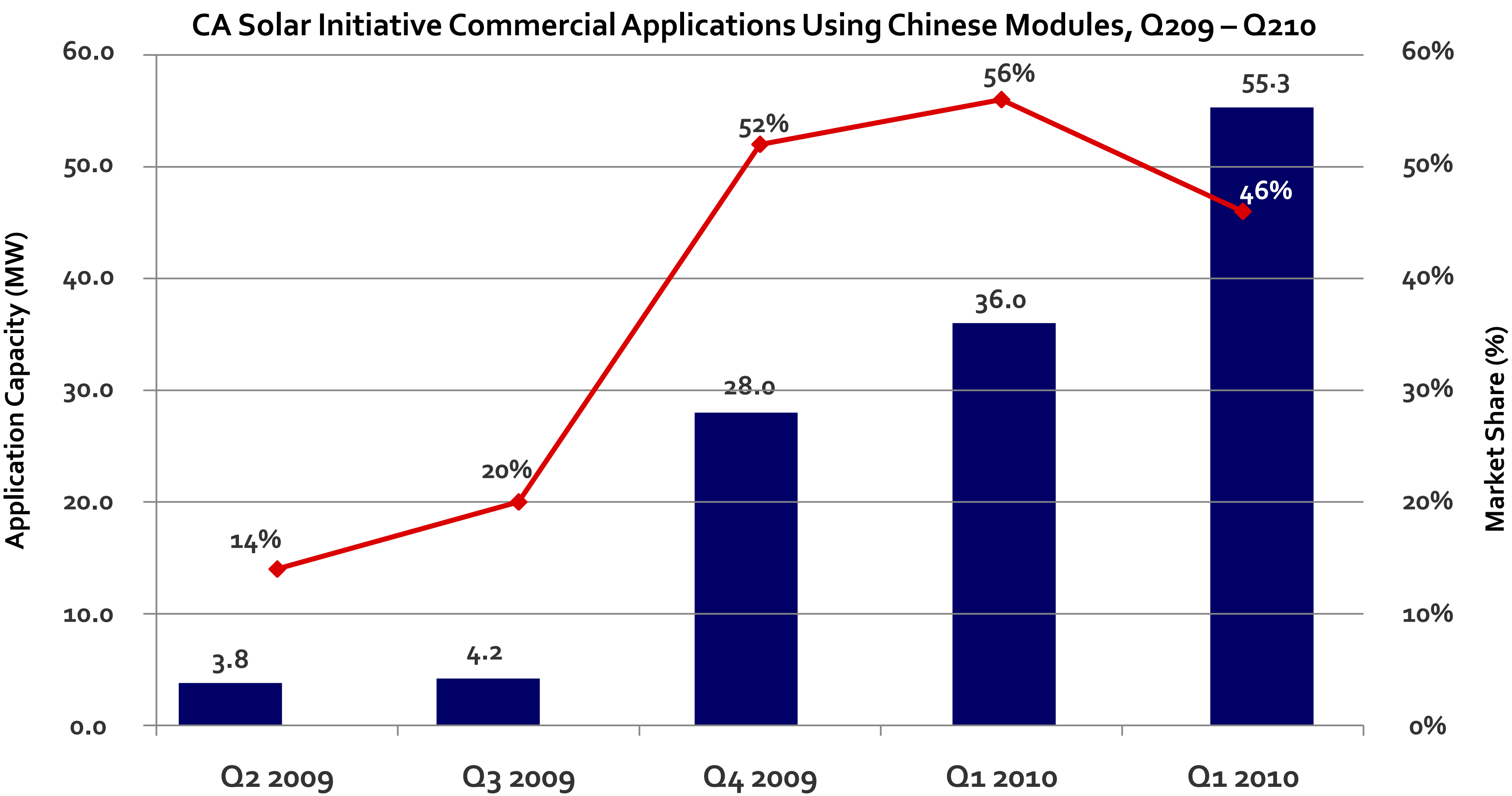
Source: CHINA PV MARKET DEVELOPMENT, Executive Report, Green Tech Media, Sept 2009

China is Rapidly Expanding its Module Production Capacity



Source: GreenTech Media: 2011 Shakeout (July 28, 2010)

China is Gaining Market Share in PV Modules, as Illustrated By Data from the California Solar Initiative



Source: GreenTech Media: 2011 Shakeout (July 28, 2010)

The US Has Dominated Global Thin Film Production, While Other Producers Focus on Crystalline…

- The US was responsible for 19% of global thin film shipments in 2009 [1]

Top Global PV OEMs – 2008					
Name	**Country**	**Production (GW)**	**%**	**Production Location**	**Technology**
Q-Cells	German	.57	8%	Germany (plans to expand)	Crystalline + thin film
First Solar	US	.50	7%	US (0.15), Germany (0.20), Malaysia (0.16)	Thin film
Suntech Power	China	.50	7%	China	Crystalline silicon
Sharp	Japan	.47	6%		Most- Crystalline silicon
Motech	Taiwan	.38	5%	Taiwan (plans to expand to China & US)	Crystalline silicon
Kyocera	Japan	.29	4%		
Yingli	China	.28	4%	2010- now has 1/3 of California PV market	Crystalline silicon
JA Solar	China	.28	4%		Crystalline silicon
SunPower	China	.24	3%		
Sanyo	Japan	.21	3%		

[1] Solar Vision Study Draft (May 2010)
Source for table: 2008 NREL (2010) p 17-183

…Many of the Top US Producers Make Thin Film…

Largest US OEMs (based on US Production) in 2008				
Name	**US Production (MW)**	**%**	**HQ**	**Comments**
First Solar	147	36%	US	Thin film (CdTe)
Uni-Solar	113	27%	US	Aka United Solar Ovonics a-SI thin-film
Solarworld (Shell Solar)	61	15%	Germany	Largest production site for solar modules in US (source: solarworld-usa.com)
BP Solar	28	7%	US	closed US production 3/2010 to move to Asia
Evergreen Solar	27	6%	US	String-ribbon technology
Schott Solar	11	3%	Germany	70MW produced in Germany
Global Solar	7	2%	US	flexible, thin-film, CIGS-based cells
Other	16	4%		

•Production source: 2008 NREL (2010) p. 19

…Unfortunately, the US's Dominance in the Thin Film Segment May Not Be Sustainable

- **Some believe the Major US thin film player – First Solar – is rumored to be in trouble**
- **While thin film pioneers like Applied Materials and Signet have already "expired on the battlefield"**
- **Japanese solar giant Sharp, Enel, the largest power company in Italy, and STMicroelectronics, the leading European semiconductor supplier have declared their entry into the market**

Source: GreenTechMedia

US PV Trade Patterns: The US Had a Positive Trade Balance in PV Up Until 2005, When the Spike in US Demand Forced Greater Imports

- **In 2005, imports caught up to imports, and since 2006 imports exceed exports**
- **Exports of thin-film doubled each year from 2005-07 (dominating 2007 PV exports)**
- **Exports of Crystalline PV stayed flat**
- **But the spike in US PV demand forced greater imports:**
  - Demand was in to response to federal investment tax credit for PV systems, including the Energy Policy Act of 2005.
- **US production and exports nearly doubled – but imports more than doubled**

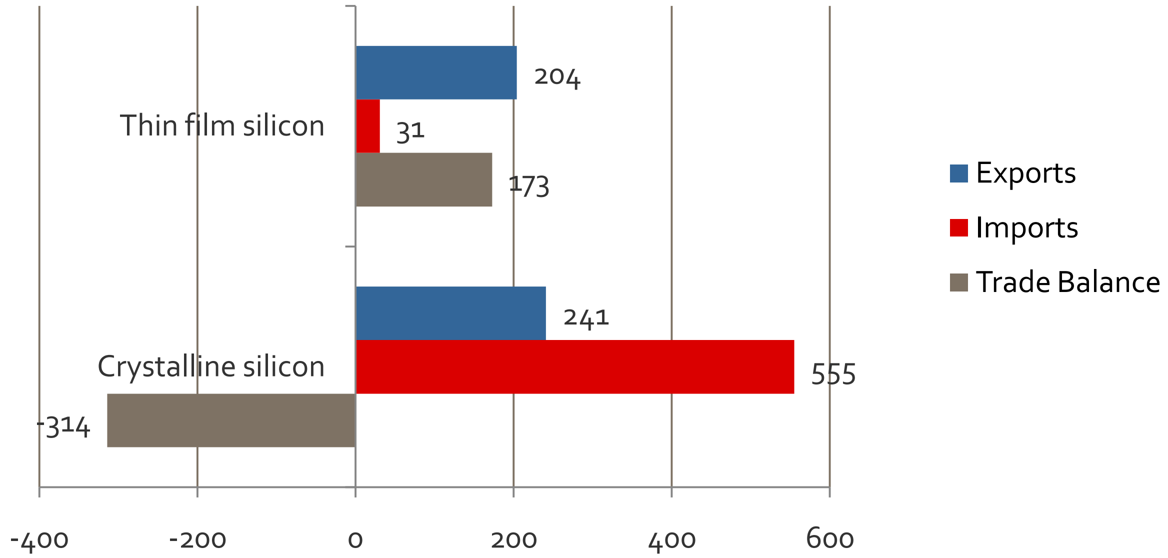
Peak kW(000)	Calculation	2007	2008	% Increase
US Shipments	a	518	987	191%
-Exports	b	237	462	195%
-Domestic Shipments	c= a-b	280	524	187%
Imports	d	238	587	246%
US Consumption	c+d	518	1111	214%

Source (bullets) 2008 NREL (2010), p27
Source (table) US Energy Information Administration

US Import & Export Data Detail Confirms the US Traditional Strength in Thin Film & Trade Deficit in Crystalline Silicon

- **The US is a net exporter of thin film modules…**
- **…and is a net importer of crystalline silicon modules and cells**
  - Importing predominantly modules, rather than cells

US Export-Import Data 2008
(Shipments of Peak kW (000)



Source: US Energy Information Administration

US Import & Export Supporting Detail

IMPORT				
Shipments Peak kW (000)		2007	2008	% incr
Cells				
	Crystalline Silicon	64.76	136.74	111%
	Thin film Silicon	-	0.01	
	Concentrator Silicon	0.10	-	
	Other	-	-	
	Total	64.85	136.75	111%
Modules				
	Crystalline Silicon	149.70	418.25	179%
	Thin film Silicon	23.47	30.66	31%
	Concentrator Silicon	-	0.90	
	Other	-	-	
	Total	173.17	449.81	160%
Total				
	Crystalline Silicon	214.46	554.99	159%
	Thin film Silicon	23.47	30.67	31%
	Concentrator Silicon	0.10	0.90	847%
	Other	-	-	
	Total	238.02	586.56	146%

EXPORT				
Shipments Peak kW (000)		2007	2008	% incr
Cells				
	Crystalline Silicon	16.59	36.42	119%
	Thin film Silicon	1.50	0.61	
	Concentrator Silicon	3.75	15.97	
	Other	-	-	
	Total	21.85	52.99	143%
Modules				
	Crystalline Silicon	66.79	204.47	206%
	Thin film Silicon	148.48	203.39	37%
	Concentrator Silicon	0.10	1.40	
	Other	-	-	
	Total	215.36	409.26	90%
Total				
	Crystalline Silicon	83.38	240.89	189%
	Thin film Silicon	149.98	204.00	36%
	Concentrator Silicon	3.85	17.37	351%
	Other	-	-	
	Total	237.21	462.25	95%

Source: US Energy Information Administration

US PV Imports Have Dramatically Increased From Low Cost Countries: Philippines, China & Taiwan

US PV Imports (peak kW 000)			
Country	2007	2008	% Increase
Philippines	0	150	41134%
Japan	103	146	42%
China	59	133	124%
Germany	41	59	42%
Taiwan	1	45	7600%
Mexico	24	43	81%
Hong Kong	3	6	81%
Spain	-	4	
India	5	1	-78%
Canada	1	-	
UK	0	-	
TOTAL	**238**	**587**	**146%**

- **Surprisingly, in 2008, Philippines topped the list:**
  - Almost equal to Japan
- **China believed to have taken lead in 2009**

Source: US Energy Information Administration

US PV Exports Primarily Supply Demand in Europe

US PV Exports 2007-2008				
Shipments peak kW	**2007**	**2008**	**% increase**	**2008 % total**
Germany	152,654	198,230	30%	42.88
Spain	31,384	105,555	236%	22.84
Italy	10,364	49,830	381%	10.78
France	10,228	31,196	205%	6.75

- **These 4 countries account for more than 80% of export shipments**

Source: US Energy Information Administration

5. Concentrated Solar Power (CSP)

Topics Covered in This Section

- ❑ **Overview**
- ❑ **Supply Chain and Manufacturers**
- ❑ **Market Potential**

CSP Example

Parabolic trough concentrators. Source: NREL

CSP US Overview: CSP Capacity is Considerably Smaller Than PV, but 95% of CSP Global Capacity is in the US

- **CSP plants have been in continuous operation in the US since 1982**
- **As shown on page 14, the US increased its CSP Capacity from 1985-1991, but since little new CSP has come online**
- **However, a large amount of capacity is now under development (page 15)**
- **As of 2009, 433 MW CSP capacity (cumulative):**
  - Vs. 1248 MW of PV (grid-tied)
- **95% of global CSP capacity was in the US in 2008:**
  - US share declined to roughly 72% in 2009
  - But the US has over 10,600 MW of capacity in the pipeline
- **Several types of CSP technology:**
  - Parabolic trough currently makes up 96% of US capacity
    - But represents 56% of capacity in the pipeline
      - Tower is 21%
      - Dish-Engine is 21%

Source: SEIA 2009 Supplemental Charts

CSP US Manufacturing

- **Altogether, there were 18 CSP manufacturing facilities in 14 states in operation or under construction during 2009.**
- **CSP components—many of which cut across technologies—include mirrors, reflectors, collector structures, heat-transfer fluids and salts, turbines, and controls.**
- **However, the expectation of strong CSP installation growth has resulted in CSP component production facilities being established by specialized manufacturers and large industrial conglomerates**

Manufacturing Companies – CSP Components			
Company	**State**	**Component**	**CSP Technology***
Stirling Energy Systems	AZ	Dishes	Dish
Infinia Corp	WA	Dishes	Dish
Austra	NV	Reflectors and Receivers	Linear Fresnel
Sopogy	HI	Reflectors and Receivers	Micro CSP
Rocketdyne	CA	Heliostats and Salt Systems	Tower
Dow Chemical	MI	Heat Transfer Fluid	Trough
Solutia	MO	Heat Transfer Fluid	Trough
Schott Solar	NM	Receiver Tubes	Trough
SkyFuel/ReflecTec	CO	Reflectors and Tracking Controls	Trough
Schuff Steel	AZ	Collector Structures	
Gossamer Space Frames	CA	Collector Structures	
Helec	WA	Drives	
SQM N.Am	GA	Heat Transfer Salt	
Coastal Chemial	TX	Heat Transfer Salt	
Flabeg Solar	CT	Reflectors	
3M	MN	Reflectors	
Flabeg Solar	PA	Reflectors	
PPG Industries	PA	Reflectors	
*If blank- component cuts across technologies			

Source: Solar Vision Study Draft (5/28/2010)-DOE/SEIA/SEPA

CSP Manufacturers By Component

REFLECTORS	RECEIVERS	TURBINES
Market Leader: •FLABEG Increased Durability: •PPG •RIOGLASS Low Cost: •3M •ALANOD •REFLECTECH	Market Leader: •SOLEL Others: •SCHOTT SOLAR SYSTEMS	Market Leaders: •ABB •GE-THERMODYN •SIEMENS Others: •ALSTOM •MAN TURBO •ORMAT

Source: 2008 NREL (2010)

CSP Has Considerable Technical Potential For the US, Since the Southwest Has Some of the Best Locations For CSP Capacity

- **According to the Solar Vision Study Draft, the technical potential of the US CSP market is about 7,500 GW of potential generating capacity:**
  - Which exceeds the total US electric grid capacity (about 1,100 GW) by a factor of more than six
  - And exceeds US electricity demand (about 224 million GWh) by a factor of more than four (EIA 2009; EIA 2010c)
- **This potential resides in 7 Southwestern states because CSP can exploit only direct normal insolation, i.e.; light that can be focused effectively by mirrors or lenses:**
  - Globally, the most suitable sites for CSP plants are arid lands within 35° north and south of the equator
  - The US has some of the best solar resources in the world in the following states
    - Arizona, California, Colorado, Nevada, New Mexico, Texas, and Utah

Source: Solar Vision Study Draft (May 2010)

6. Solar Heating & Cooling (SHC)

Topics Covered in This Section

- **Overview**
- **Global Capacity**
- **Market Potential**
- **Demand Incentives**
- **Manufacturing**

US Solar Heating & Cooling (SHC) Overview: 90% of US Installed Capacity is Pool Heating

- **Of the 147 GW-thermal of installed global SHC capacity (in 2007), US accounted for 8 GW-th or 5%**
- **Solar pool heating accounts for more than 90% of capacity**
- **Solar Water Heating (SWH) market is less than 10%**
- **Other SHC technologies – such as solar space heating and cooling and industrial process heat – are still relatively uncommon in the US**
- **SHC systems are concentrated in certain a few states:**
  - Hawaii is the leading SWH market
  - Florida and California are the leading solar pool heating markets.

Source: Solar Vision Study Draft (5/2010)-DOE/SEIA/SEPA

Solar Heating & Cooling – Global Capacity: Globally, Installed Capacity is Primarily For Water Heating

- **By the end of 2007, global cumulative installed SHC capacity was about 147 GW-thermal in 49 surveyed countries:**
  - Representing an estimated 60% of the world population and 85%–90% of the world SHC market
- **The 147 GW-th is comprised of:**
  - 46 GW – glazed flat-plate collectors (primarily for water heating)
  - 74 GW – evacuated tube collectors (primarily for water heating)
  - 25 GW – unglazed collectors (unglazed plastic collectors typically for pool heating)
  - 1.2 7GW – glazed and unglazed air collectors
- **China is the leader in total installed SHC capacity:**
  - The US is a distant second because of the large domestic capacity in solar pool heaters
  - The EU leads in space heating and process heating applications

Source: Solar Vision Study Draft (May 2010)

Solar Heating & Cooling Has Considerable Potential For Growth

- **The International Energy Agency (IEA) recently referred to renewable energy heating and cooling (including solar thermal, biomass, and geothermal) for use in domestic hot water, space heating and cooling, and process heating and cooling as the 'sleeping giant' of renewable energy potential**
- **On-site energy use for industrial purposes represents 31% of US energy use[1], and 86% of this energy is thermal**
- **One study found that SHC could:**
  - Reduce US electricity use by 1.2% (with higher potential in specific regions, such as up to 4% in Florida)
  - Reduce natural gas use by 2.1% (with higher potential in specific regions, such as up to 4.7%, in California)
  - SHC systems use both direct and indirect (diffuse) solar resources, therefore, can be sited almost anywhere in the US

[1]Source- EIA, cited by the Solar Vision Study Draft
Source: Solar Vision Study Draft (May 2010)

Solar Heating & Cooling Has Considerable Potential For Growth
(continued)

- **Solar Water Heating:**
  - Roughly 110 million residential housing units have water heaters (EIA 2005)
  - 15% of energy consumed by residential and commercial buildings is for water heating
- **Solar Pool Heating:**
  - Nearly 300,000 non-residential pools at hotels, schools, gyms, and physical therapy centers need year-round heating
  - Current law prohibits these facilities from taking advantage of the federal ITC
- **Space Heating and Cooling:**
  - "While solar cooling technologies have yet to take off in the US, the potential is enormous." 45% of energy consumed by residential and commercial buildings is for space heating and cooling, a huge opportunity for solar energy over the next few years." -SEIA 2009

Sources: Solar Vision Study Draft (5/2010)- DOE/SEIA/SEPA, SEIA 2009

Solar Heating & Cooling – Demand Incentives

- **A significant US market for residential Solar Water Heating (SWH) existed in the '70-'80s in response to the energy crises and a 40% federal tax credit:**
  - This market disappeared with the end of federal incentives in the mid '80s
- **The market was revived with federal solar incentives (tax credits) enacted in 2006–2009:**
  - This revival has created interest for other thermal applications as well
- **And the federal tax credits have also increased interest in SHC at the state level:**
  - Some states have created SHC incentives, primarily for SWH but also for space heating, process heating, and (in a very small number of states) space cooling
- **Solar pool heating has declined in the past few years because of declining real estate markets:**
  - Few government incentives apply to solar pool heating
  - However, because it is relatively cost effective compared with fossil fuels, pool heating does not appear to be affected significantly by the absence of incentives

Source: Solar Vision Study Draft (May 2010)

US SHC Manufacturing

- In 2009, there were 9 glazed flat plate collector and absorber facilities in 7 states in operation
- Production in 2008 exceeded 150,000 m2 and accounted for 75% of the total quantity of flat plate and evacuated tube collectors installed in the US

Manufacturers of SHC Products			
Company	State	Products	m^2 (2008)
Sunearth	CA	flat plate collectors, OEM products & absorbers	66,000
AET	FL	flat plate collectors, OEM products & absorbers	53,450
Solar Skies	MN	flat plate collectors, OEM products & absorbers	6,800
Solarroofs	CA	flat plate collectors, OEM products	2,400
Dawn Solar	NH	own brand flat plate collectors & absorbers	N/A
Sunsiaray	MI	own brand flat plate collectors & absorbers	N/A
Heliodyne	CA	own brand flat plate collectors & absorbers	20,000
Power Partners	GA	own-brand flat plate collectors	N/A
Bubbling Springs	WI	own-brand flat plate collectors	959

Source: Solar Vision Study Draft (May 2010)

7. Solar Industry Employment

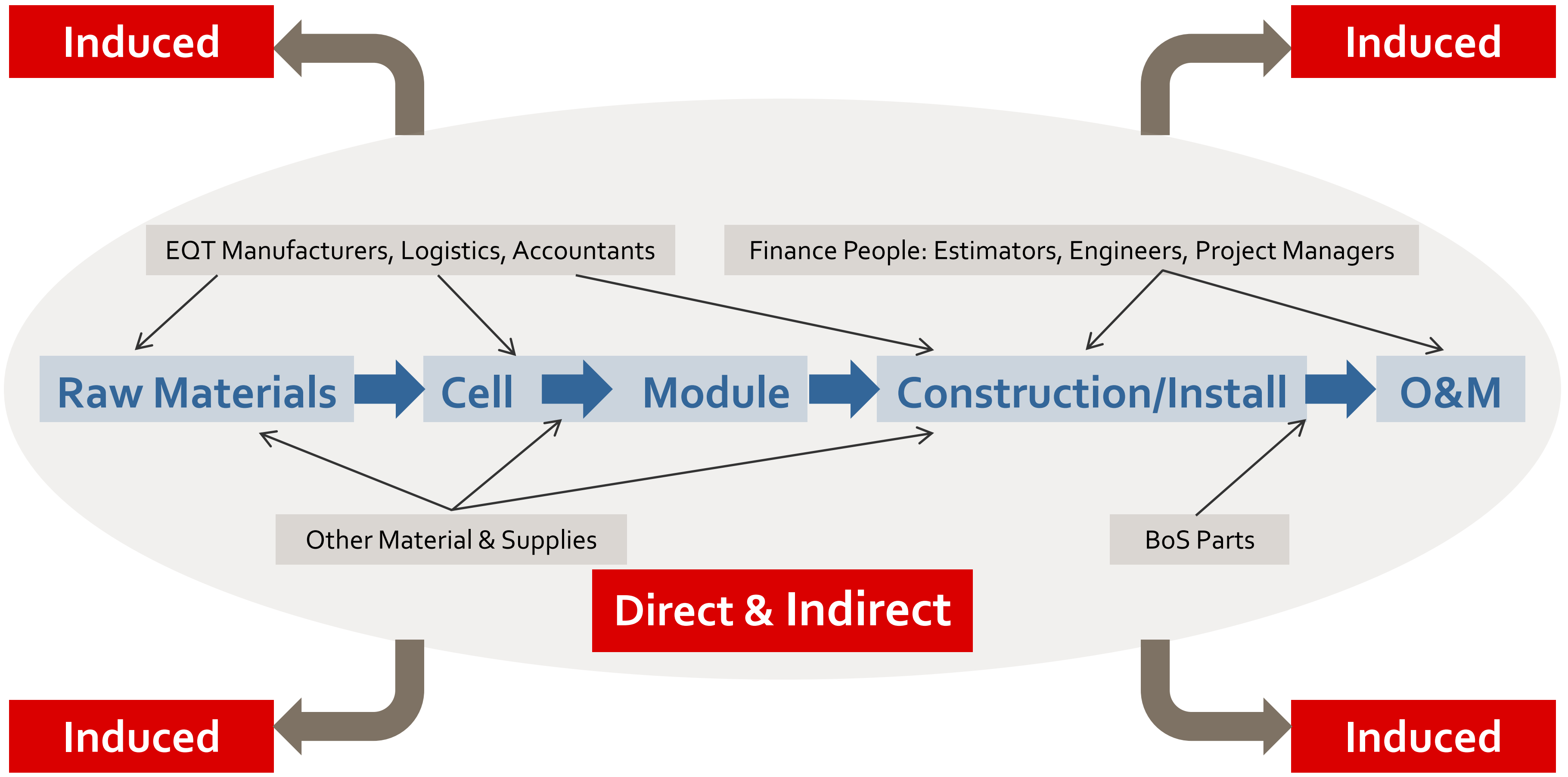
Topics Covered in This Section

- ❑ Employment Job Categories and Definitions
- ❑ Current US Employment
- ❑ Forecast US Employment
- ❑ Current Global Employment
- ❑ Jobs Per MW by Energy Source, Solar Technology and Application
- ❑ Photovoltaic Labor Intensity

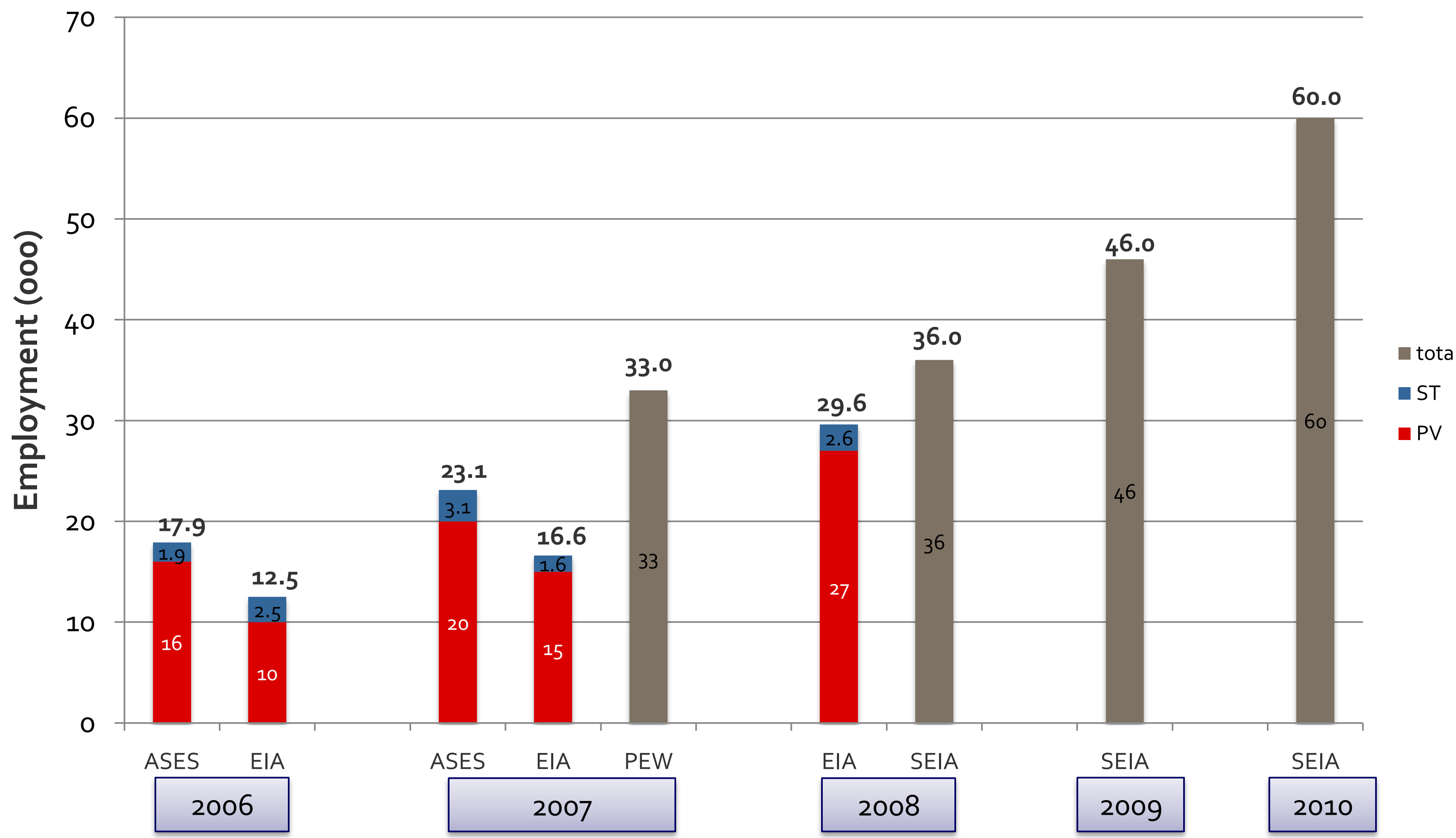
Employment Estimates Include Three Job Categories: Direct, Indirect & Induced

- **Definitions differ among reporting organizations**
- **DIRECT and INDIRECT are jobs in the solar supply chain, including raw material suppliers, cell and module manufacturing, installation and operations and maintenance:**
  - The line between DIRECT (solar companies) and INDIRECT (solar suppliers) is not universally agreed upon
  - But, both represent the jobs that make up the solar supply chain
- **INDUCED is the economic activity that is not part of the solar supply chain, but is driven by the money spent by solar industry employees:**
  - Induced as percent of direct and indirect
    - 72%: SEIA
    - 33-100%: Center or American Progress; Political Economy Research Institute
    - 87%: Navigant Consulting

Employment Estimates Include Three Job Categories: Direct, Indirect & Induced *(continued)*



US Solar Employment Summary: Direct & Indirect Employment is Approximately 60K



ST = Solar Thermal (CSP + SHC)

Navigant Consulting Forecasts 240K Direct & Indirect US Solar Jobs in 2016 & 440K When Induced is Included

Type	Solar Employment
Direct	110K
Indirect	130K
Induced	200K
Total	440K

Technology	Solar Direct+ Indirect Employment	Total Employment
PV	197K	377K
CSP	20K	38K
Solar Water Heating	13K	24K
Total	230K	440K

- However, Navigant's thorough methodology calculates the TOTAL labor required for a given production level; it does not appear to adjust for FOREIGN-made content.

Source: Navigant Consulting (Economic Impacts of the Tax Credit Expiration; Prepared for the AWEA and SEREF; 2/13/2008, cited by NREL)

Assumed: nearly 6.5 GW of installed in 2008 and 28 GW of cumulative solar installations through 2016 in the extended ITC scenario

Forecast US Solar Employment – Additional Data Points are Provided By Different Sources

Year	Total	Photovoltaic	Solar Thermal (CSP+SHC)	CSP	SHC
2015		62K (CIM[1] ; REPP)			
2016	440K (NCI[2]) (direct + indirect + induced)	377K (NCI)	62K (NCI)	38K (NCI)	24K (NCI)
2030	~150K (Greenpeace[3]) (Direct)	~120K (Greenpeace)	~30K (Greenpeace)		

[1]REPP (Construction, Installation, Manufacturing only; based on 9600 MW total capacity)

[2]Navigant Consulting (Based on 28 GW installed capacity; includes CIM and O&M)

[3]Rutovitz, J., Atherton, A. 2009, Energy sector jobs to 2030: a global analysis. Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney (Direct only; in this most aggressive scenario, 51% of energy comes from RE). Assumes that all manufacturing occurs within North America, and that the region exports just under 10% of globally traded [solar] components (p45). 5% of jobs are export jobs.

Current *Global Solar Employment: A Variety of Sources Estimate Global PV as Approaching 200K*

Direct & Indirect Employment

Year	Total	Photovoltaic	Solar Thermal (CSP+SHC)	CSP	SHC
2007		170K (UNEP)[1]			
2008		169K (NEF)[2]		4k (NEF)	
2009		200K (CleanEdge)[3]			
2010		190K (Greenpeace[4], direct only)			

[1]United Nations Environment Programme, 2008-PV jobs in 5 leading countries

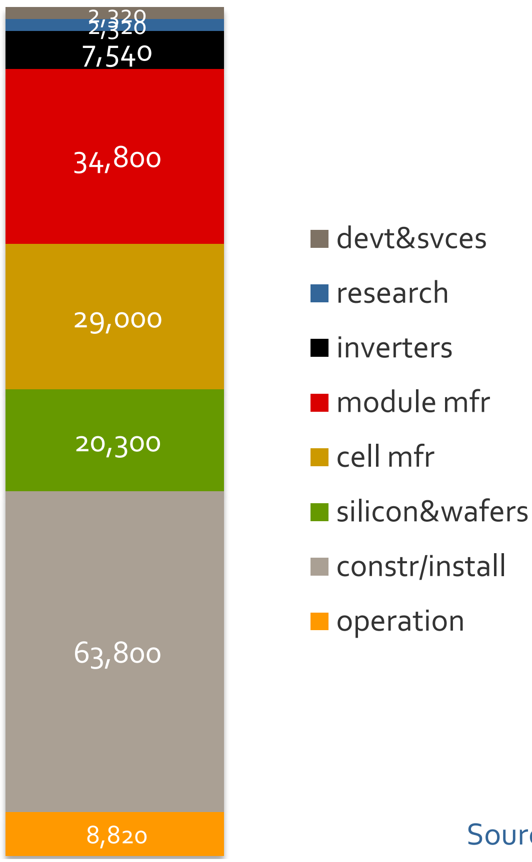
[2]New Energy Finance, 2009, electricity-generating solar (PV and CSP)

[3]Clean Edge Research (Clean Tech Job Trends 2009)

[4]Rutovitz, J., Atherton, A. 2009, Energy sector jobs to 2030: a global analysis. Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney.

Most of Global PV Employment is in Construction/Installation & Cell/Module Manufacturing

GLOBAL PV 2008
Direct & Indirect Employment



Total Jobs = 168,900

- **39% is local employment (site construction & roof installation plus development & services)**
- **Manufacturing of wafers, cells, and modules represents nearly 50% %**
- **Operations is only 5% of the total, but this will increase as installed capacity increases**

Source: New Energy Finance study (McCrone et al 2009), cited in NREL study

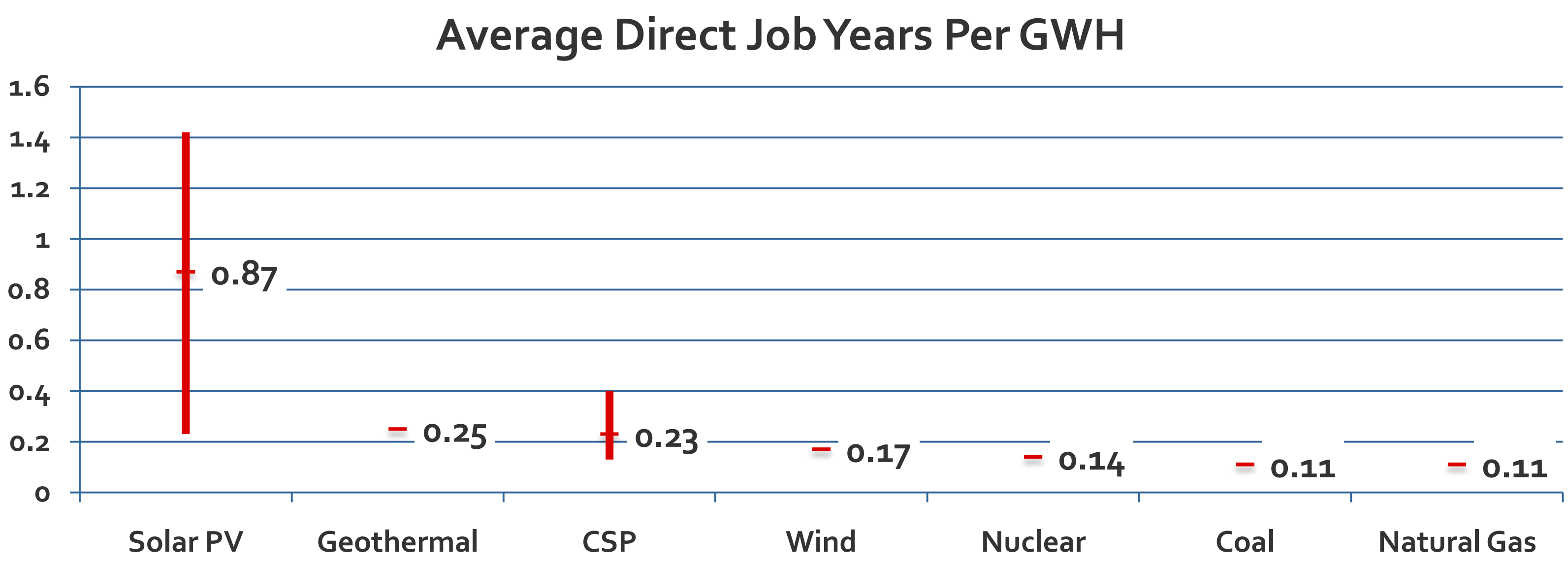
Jobs Per Megawatt is Often Used as a Basis for Employment Estimates in the Energy Sector

- **But jobs/MW rates generally calculate *all* labor required for an installation:**
  - Therefore, labor is erroneously assumed to be entirely domestic

- **Varying definitions and assumptions result in a wide range of Jobs/MW rates:**
  - Are "jobs" defined as FTE–years (i.e. normalized for duration) or are all jobs lumped together regardless of duration?
  - Was the MW capacity used in the calculation "peak" or "average" (adjusted for efficiency or utilization)?
  - Construction and Operations are typically included, but what about Manufacturing (particularly for CSP)?

- **Be wary of combined construction/installation/manufacturing (CIM) and operations and maintenance (O&M) job rates per MW:**
  - Often are (incorrectly) added together, but a clearer picture emerges if the rates are separate
  - CIM jobs are one-time jobs, i.e. jobs associated with installation of capacity (before the plant is on-line), often given as total FTEs for the duration of construction
    - CIM Jobs are estimated by multiplying FTEs/MW by new installations for a given year (even though CIM takes place over multiple years)
  - O&M jobs are on-going jobs that exist every year of operation from the date that the plant goes on line , described often as "permanent" jobs
    - O&M Jobs are estimated by multiplying FTEs/MW by new total existing capacity
  - CIM and O&M can only be added if they are on the same basis

Jobs Per MW: Solar PV is Universally Recognized as Creating More Jobs Per Unit of Energy Produced Than Any Other Energy Source



- **There are many comparisons of jobs per unit of energy – this one was chosen because it appeared to be the most robust:**
  - Only PV and CSP shows a range of average jobs years/GWh: For PV, this reflects a different mix of distributed versus utility scale applications (according to the authors)
  - It includes **direct** CIM and O&M jobs averaged over the life of the equipment (plant)
  - And for Coal and Natural Gas, it includes Fuel Extraction and Processing per GWh
  - The unit of energy produced is measured in GW-hour, adjusted for capacity utilization (i.e. does not use peak output)
  - The authors aggregated a number of studies for each energy type

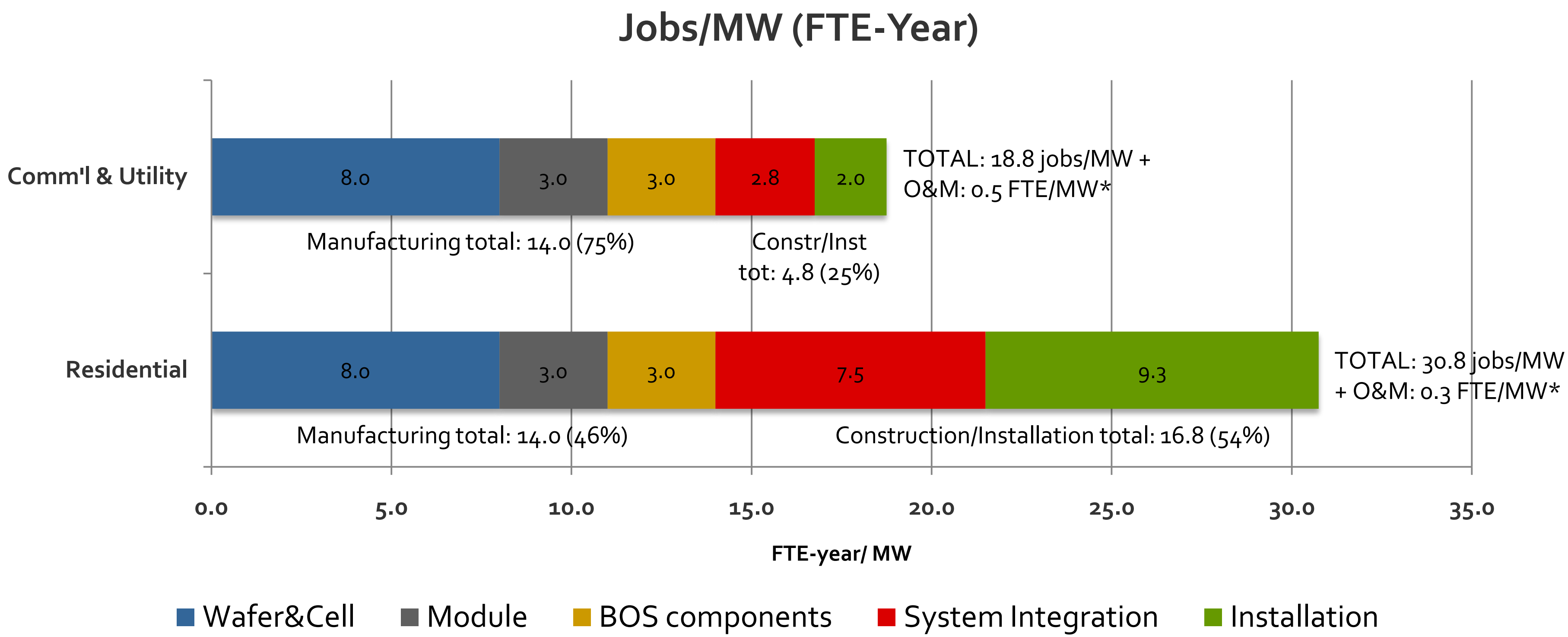
Source: Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the US?" 2010 (Berkeley)

PV Creates More Jobs Per Unit of Energy Produced Because it is a Distributed Energy Source

- **PV is deployed in much smaller capacity installations than other technologies, including other renewables**
- **"The main reason renewable energy sources generate more jobs than investments in fossil fuels is that they essentially substitute labor for fuel"**
- **The multiplicity of small and mid-sized solar energy systems yields more installation and operations jobs compared to common central station energy technologies, per energy unit produced (MWh):**
  - These jobs are more widely distributed in communities across the nation, including rural locations.
  - This enables communities to "in-source" energy production, expanding local economies and providing jobs that are impervious to off-shoring

Sources: Solar Power Partners, and "Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the US?" (Berkeley)

Photovoltaic Jobs Per MW By Value Chain Component: Residential PV Creates Higher Jobs Per MW Due To Construction/Installation



- Manufacturing job-years/MW is the same for residential, commercial, and utility (14 FTE-year/MW)
- But system integration/install per MW is much greater for residential PV because residential systems are much smaller

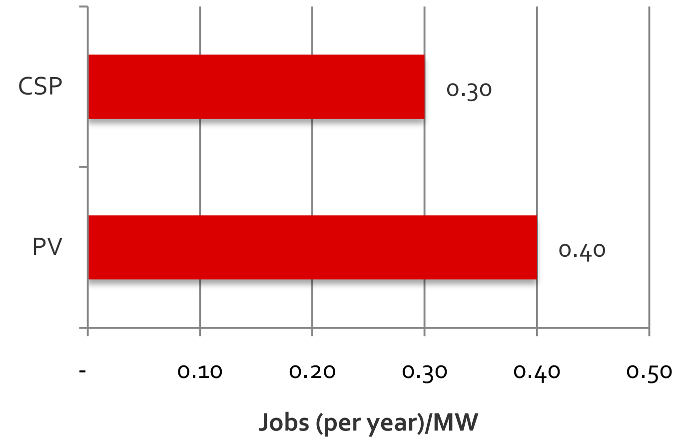
Source: Navigant Consulting; 2010 scenario

* FTE/MW are ongoing positions; FTE/MW X lifetime years of the plant = FTE-yr/MW

Photovoltaic Generates Many More Jobs Per MW Than CSP: Examples Comparison from One Data Source

Construction/Install/Manufacturing

Operations &Maintenance



- **Using one source reduces definitional or methodological differences**
- **Direct jobs only:**
  - Note: Source does not indicate, for PV, what mix of distributed vs. utility scale is being assumed. Based on Navigant Consulting information, nearly 40 jobs/MW reflects residential (roof-top) installations.

Source: Rutovitz, J., Atherton, A. 2009, Energy sector jobs to 2030: a global analysis. Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney;p10

Jobs Per MW: Photovoltaic vs. CSP – Estimates & Assumptions Can Vary Widely

- **Photovoltaic:**
  - Job-years per MW estimates vary widely, with a range of 25 to more than 50 (direct and indirect jobs)
  - A significant driver of variation for PV is the residential versus commercial vs. utility-scale mix
  - "A highly referenced rate for the US PV industry is 35.5 jobs/MW installed, based on a study by REPP in 2001":
    - Study focused on a 2-kW residential PV system (which is much more labor intensive than commercial and utility systems which benefit from scale)
    - Included mostly direct jobs and some indirect jobs
    - The study is now dated (and therefore does not incorporate 10 years of improved labor efficiency)

- **CSP:**
  - Most studies are based on trough technology plants (because the majority of installed CSPs are trough); rates for other technologies can be very different
  - Some studies do not mention "manufacturing" in relation to CSP job rates
  - Direct job rates are fairly consistent:
    - Range of direct-construction job-years per MW found is 8-9; one study gave CIM as 10
    - Range of direct-O&M jobs per MW found is 0.3 to 0.45
  - Indirect is harder to capture; some studies combine direct and indirect, others combine indirect and induced

Source: NREL 2008 Solar Technologies Market Report; released 2010)

Photovoltaic Labor Intensity is Decreasing Over Time

- **Navigant job-years per MW analysis**
- **Every component decreases from 2005 to 2010**

*Annual O&M x 25 year life
Source: Navigant Consulting (Economic Impacts of the Tax Credit Expiration; Prepared for the AWEA and SEREF; 2/13/2008)

Labor Intensity is Continuing To Decrease Over Time

- **NREL discussions with several US PV installation companies in 2008 confirmed a pattern of decreasing labor intensity:**
  - Solar labor intensity could decrease over time resulting from increased automation, economies of scale, and greater efficiencies in the use of labor throughout the supply chain.
- **28 jobs/MW worldwide labor-intensity for PV for 2008 is projected to decrease to about 13 jobs/MW in 2025 (NREL citing McCrone et al. 2009):**
  - Wafer, cell, and module manufacturing, system integration, and residential installations are projected to have the most dramatic drops in labor intensity
  - Whereas commercial and utility installations will see only a slight decrease
  - One cause being that many of the efficiencies in these areas have already been realized
- **Cost of PV is expected to fall by 50% by 2020 and 70% by 2030:**
  - It is assumed that employment per MW will fall at the same rate as the cost per MW falls

Sources: NREL 2008 Solar Technologies Market Report, released 2010; NREL-citing Navigant Consulting; Rutovitz, J., Atherton, A. 2009, Energy sector jobs to 2030: a global analysis. Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney