U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Solar Photovoltaic Economic Development:

Building and Growing a Local PV Industry

August 2011

SOLAR AMERICA COMMUNITIES

Solar Photovoltaic Economic Development

Building and Growing a Local PV Industry

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Abbreviations and Acronyms

>	greater than
<	less than
$/W	dollars per watt
AC	alternating current
ARRA	American Recovery and Reinvestment Act
BETC	Business Energy Tax Credit
BOS	balance of system
CAPEX	capital expenditures
CEMF	Clean Energy Manufacturing Fund
CdTe	cadmium telluride
CIGS	copper indium gallium diselenide
CIS	copper indium diselenide
c-Si	crystalline silicon
CPV	concentrating photovoltaic
CSLP	
DC	direct current
DOE	U.S. Department of Energy
EPC	engineering, procurement, and construction
F&E	franchise and excise (tax)
FIT	feed-in tariff
FTE	full-time equivalent
GRU	Gainsville Regional Utilities
GW	gigawatt
IREC	Interstate Renewable Energy Council
JEDI	Jobs and Economic Development Impact
JTIP	Job Training Incentive Program
KEPCO	Korea Electric Power Corpoation
kg	kilogram(s)
kW	kilowatt(s)
kWh	kilowatt-hour(s)
kWh/kW	kilowatt-hour(s) per kilowatt
MW	megawatt(s)
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority

OPEX	operating expenditures
OEWD	Office of Economic and Workforce Development
PACE	Property Assessed Clean Energy
PBI	production-based incentive
PPA	power purchase agreement
PV	photovoltaic(s)
R&D	research and development
REC	renewable energy certificate
RETA	Renewable Energy Transmission Authority
RFP	request for proposals
RPS	renewable portfolio standard
SETP	Solar Energies Technologies Program
SIC	Standard Industrial Classification
W	watt(s)
W_p	(peak) watt(s)

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About This Document

Purpose

This report is intended to be an introductory guide for local economic development offices to set informed recruitment targets for renewable energy. It was developed to help communities evaluate opportunities in the photovoltaic (PV) industry and develop a strategic approach appropriate to a specific community. The document provides the information for communities to:

1. Build an understanding of the various sectors of the PV industry, metrics, differentiation, and trends in each segment
2. Build an understanding of site selection processes and criteria for each industry segment, and the potential economic benefits of each segment
3. Begin to evaluate the city's strengths, weaknesses, and potential to change within the context of the industry segments
4. Understand tools and programs used to encourage investment and economic development. Use these tools to reinforce strengths, improve weaknesses, and market to the PV industry over the long term.

This report summarizes the PV industry, but further information and reading may be important to city-specific efforts. Appendix A describes additional resources.

Organization

The PV industry is an umbrella category that represents many diverse business models. In order to discuss and review the whole industry effectively, this report groups the industry into two major sectors: Section 1 discusses the PV products and energy generation sectors, with a particular focus on details relevant to economic development entities. This grouping splits the industry according to basic business models and allows some comparisons between similar business activities. Section 2 describes the employment opportunities available through the PV products and energy generation sectors, and describes economic development strategies targeted at attracting these employers. Section 3 provides case studies of economic development programs and strategies successfully employed by states and local jurisdictions in the United States. Appendix A provides a list of recommended resources, while Appendices B and C provide additional details on the value chain and business structures employed in both sectors.

Methodology

Financial analyses were completed by a financial expert at CH2M HILL with 28 years of professional experience, including the creation of financial models for PV manufacturers, solar farms, and financial institutions working with the PV industry.

Primary-source research comes from communication with researchers at the U.S. Department of Energy (DOE) and market research firms. Case studies were created through communication with local economic development experts and other sources, as cited.

Secondary-source research comes from studies conducted by the DOE, local and national economic development agencies, and market research firms, as cited.

Executive Summary

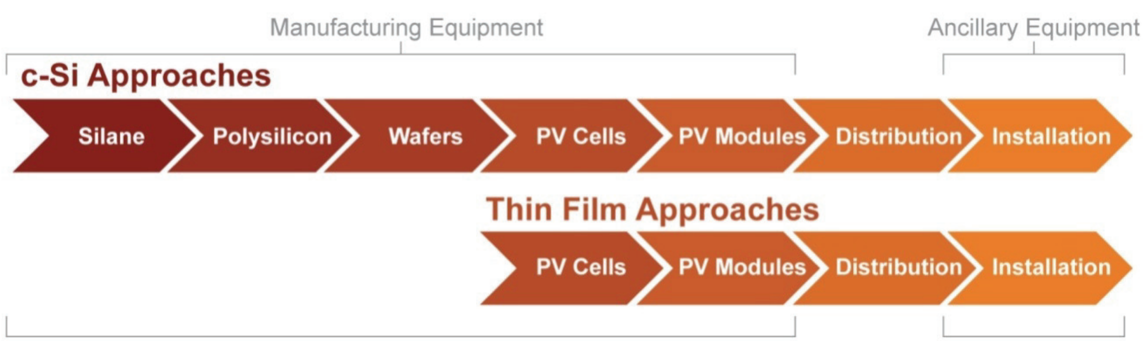
The U.S. photovoltaic (PV) industry is forecast to grow in both the short term and the long term. It represents a significant opportunity for economic development and job creation in communities throughout the United States.

For the purposes of designing economic development efforts, the PV industry is best regarded as two major sectors: PV products (a sector of businesses that manufacture raw materials, PV modules, and other components) and PV energy generation (a sector of services centered on the purchase of components and the installation of PV systems).

The differences between these two sectors are important because they each have unique economic development strategies.

The PV Products Sector

Within the PV products sector, there are two segments. The dominant segment is based on crystalline silicon (c-Si) modules. There is also a growing segment based on thin-film technology modules. Figure 1 shows the value chain elements for these two segments.



Source: O'Rourke et al. 2009

Figure 1. PV products sector value chain.

Metrics, Markets, and Trends

Companies in the PV products sector generally share the following major metrics:

- Product performance (power output in watts)
- Efficiency (percentage of sunlight or energy that is converted into usable electricity)
- Product cost (dollars per watt)
- Reliability (product life and performance covered by warranties).

Typically[1], markets for these PV products are differentiated by their scale, as follows:

- Residential—less than (<) 10 kilowatts (kW)

[1] Scale-based definitions of these market segments vary throughout the solar industry. These system size ranges are defined strictly for the purposes of this report.

- Commercial—10 kW to 1 megawatt (MW)
- Utility—greater than (>) 1 MW.

The PV products sector is also characterized by several general trends:

- A shake-out of manufacturing companies driven by the economic downturn
- Integration of companies up and down the supply chain to deal with the boom-and-bust cycles in raw materials and with the competition from international markets
- Diversification of products driven by the expansion of PV applications.

PV Products Sector Site Selection Criteria

Understanding how companies in the PV products sector evaluate a location is critical to understanding an area's competitive position and developing strategies to improve that position. For the purposes of this report, the products sector has been divided into four industry groups:

- Raw materials (such as polysilicon, glass, metal products, and gases) used in the production of panels
- Manufacture of wafers and cells that are integrated into panels
- Assembly of components into panels
- Products (such as inverters, racking, and wiring) that are integrated into and support panels.

Table 1 presents a summary matrix of the PV products sector requirements by industry segment and their relative importance. Section 1.1 and Appendix B discuss these requirements.

Table 1. Matrix of PV Products Sector Site Selection Criteria

	PV Products			
Industry Criteria	Raw Materials	Wafer/Cell	Assembly	Other Supply Chain
Land and Buildings	2	2	2	2
Utilities	1	1	3	3
Operating Cost Environment	1	1	2	2
Schedule Considerations	1	1	2	3
Transportation	2	2	1	2
Proximity to End Market	2	2	1	2
Technology Support, Higher Education and Research	2	1	3	3
Workforce and Training	1	1	2	2
Public/Private Support and Policies	2	1	1	2
Incentives	1	1	2	2

Legend Critical (1) Somewhat Important (2) Less Important (3)

The PV Energy Generation Sector

Figure 2 shows the various segments within the PV energy generation sector. Many companies span multiple segments, and third-party companies (such as financial institutions) may operate across various segments as well.

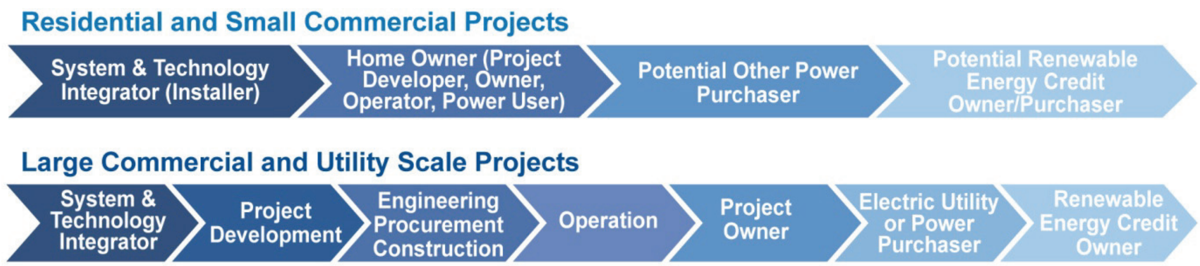


Figure 2. PV energy generation sector value chain.

Markets and Trends

PV energy generation markets are typically characterized in terms of residential, commercial, and utility scale. PV energy generation services can also be analyzed in terms of the following:

- **Project scope**. From locally labor-intensive segments, like system integration and installation, to low-labor-intensity segments like project development
- **Project integration**. Energy generation services that are often bundled together
- **Project risk**. From existing and proven models of ownership to new legal or financial structures.

The PV energy generation sector can be characterized by several general trends:

- An increasing separation between owners and hosts, exemplified by the third-party power purchase agreement project structure
- An increase in the participation of electric utilities
- Increased integration of services into single contracts
- Diversification and specialization of services within the PV energy generation sector as increasingly complex project opportunities emerge.

PV Energy Generation Sector Site Selection Criteria

The location factors and criteria considered by PV energy generation companies are relatively concise and straightforward (compared with PV products companies). They are driven primarily by market proximity, as well as by the criteria presented in Table 2.

Table 2. Matrix of PV Energy Generation Market Criteria

	Energy Generation	
Industry Criteria	Residential / Commercial	Utility Scale
Solar Resource	2	1
Cost of Electricity, Utility Structure and Attitudes	1	1
Public / Private Support and Policies	1	1
Workforce and Training	3	3

Legend Critical (1) Somewhat Important (2) Less Important (3)

Employment Opportunities and Economic Development Strategies

While PV products sector jobs vary by market segment, they are generally stable, highly skilled, and long term. Because of the large investments required, and the high level of competition for these facilities, recruiting or growing a large PV products sector company is complex and can require significant investment, planning, and long-term commitment. Not all communities have the same opportunities, but those that have been successful have capitalized on economic assets while providing incentives to compensate for shortcomings.

PV energy generation jobs tend to be more variable. Installation labor often represents the largest opportunity for economic development and job creation. PV energy generation jobs are dependent on project durations and are often short term. They can, however, be more permanent if the community commits to the long-term development of energy generation projects. Because of local conditions like solar resources and local utility structures, building an attractive market for PV energy generation companies usually requires strong public policy support and investment incentives.

Conclusion

Many U.S. communities have some opportunity to develop a segment of the solar PV industry. While not every community can recruit a large factory or install megawatts per year of distributed PV on local homes, many have high potential in some segments and can invest in and recruit a part of the PV industry—thereby creating jobs and bolstering the local economy.

Precursors to successful PV industry recruitment include the following:

- Understand the segments of the industry and what is required to operate successfully in an area
- Make a realistic evaluation of how well a community meets the requirements of various segments
- Target a market segment(s) that best meets community economic development goals and whose siting requirements are satisfied by the community's economic capabilities
- Develop strategies to strengthen advantages and overcome disadvantages
- Market opportunities to target segments.

1 Photovoltaic Industry Basics

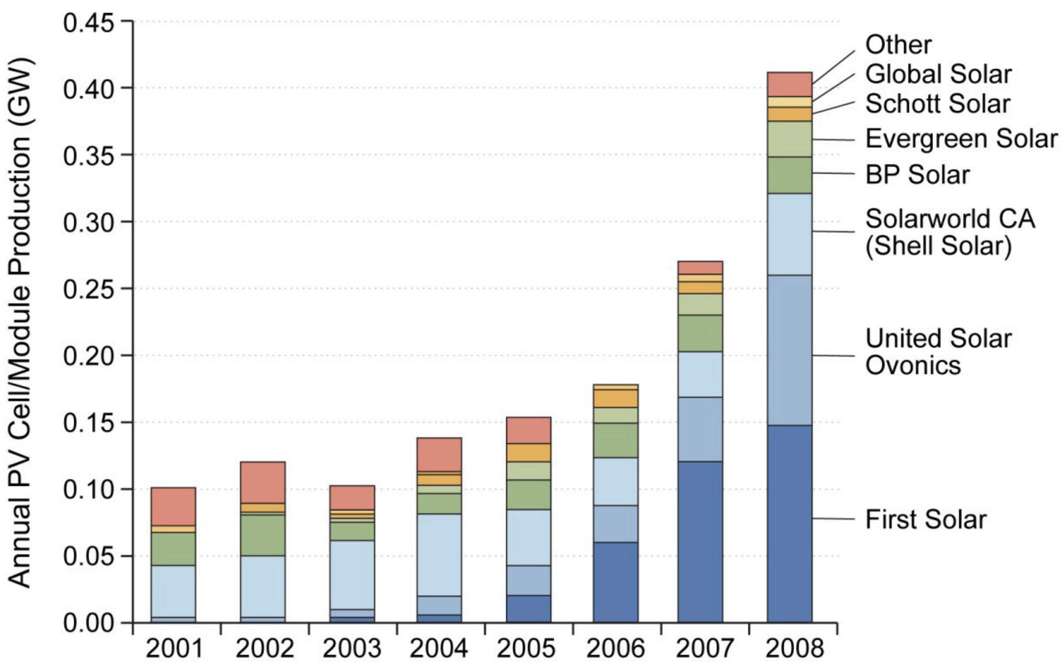
While most industry analysts agree that the future outlook and forecasted economic impact of photovoltaics (PV) at the national scale is very positive, it is important to distinguish the various sectors of the U.S. PV industry, each of which has different needs, drivers, and success metrics. This report focuses on two major PV sectors: PV products and PV energy generation.

These two PV industry sectors are fundamentally different economic development targets. Appendices B and C describe the business and manufacturing processes utilized in each of these sectors in more depth, highlighting those details relevant for economic developers.

1.1 Photovoltaic Products

For the purposes of this report, the PV products sector is defined as businesses that design, manufacture, or distribute PV equipment, including PV panel subcomponents and consumables, PV panels, inverters, racking, and other components (called the balance of systems or BOS). At its core, it is a sector defined by manufacturing.

Growth in manufacturing of PV products is illustrated in Figure 3, which shows the manufacturing capacity of U.S. PV product companies measured in megawatts (MW) of PV cells.



Source: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy 2010

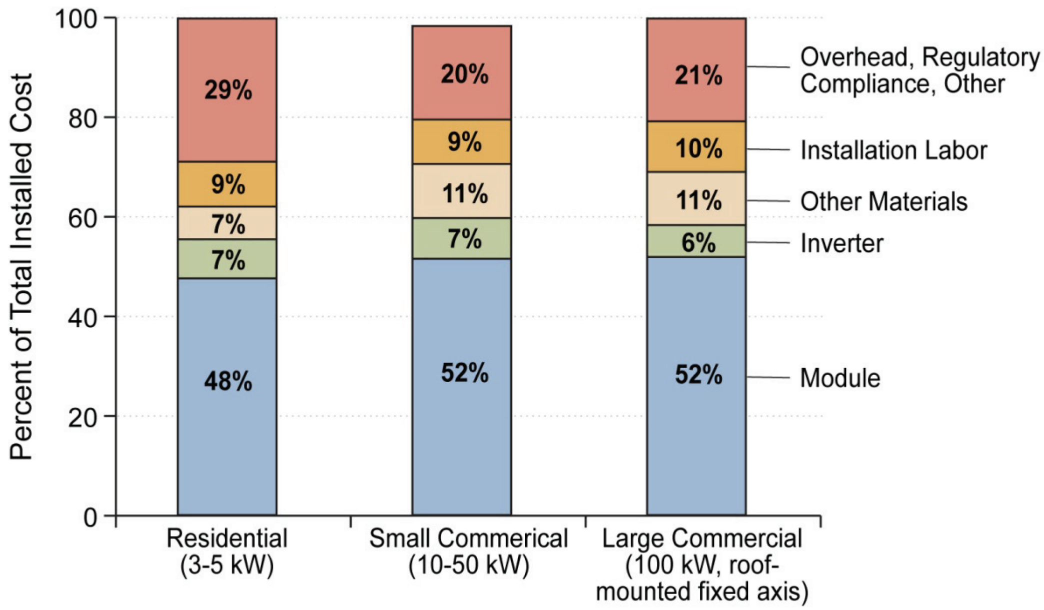
Figure 3. U.S. annual PV cell/module production by U.S. manufacturers.

The major businesses in the PV products sector manufacture or fabricate the following products:

- Polysilicon
- Solar glass
- Bulk chemicals and gases
- Manufacturing equipment and parts
- Junction boxes and connectors
- Other cell and module materials (such as films, string, and silver paste)
- Module frames
- Silicon wafers
- PV cells
- PV modules
- Inverters
- Wiring, conduit, and connectors
- Transformers and switchgear
- Racking
- Trackers
- Sensors, controls, and actuators
- Anchors and ballasts
- Optical components.

These products are commodity-like in nature. For example, while brand, country of origin, or other factors can influence buying decisions, these influences are generally minor—and shrinking. Exceptions to this trend are "Buy American" or local content provisions in incentives, and specific rules for certain potentially hazardous materials (such as lead or cadmium) in Japan and the European Union.

The focal point of the PV products sector is the functional unit of a PV system, the PV module. Typical system components and their estimated contribution to the installed cost of a typical PV system, differentiated by market segment, are illustrated in Figure 4.



Sample Size: Six installers provided survey responses for residential and large commercial systems and five installers provided survey responses for small commercial systems.

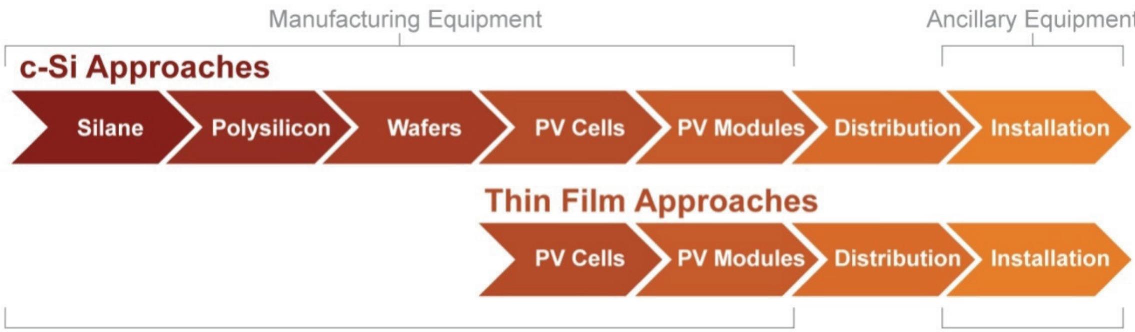
Source: Wiser et al. 2009

Figure 4. PV system component contribution to total system costs.

The products listed in Figure 4 are produced by the supply chain shown in Figure 5. The depicted supply chain divides the PV products industry into two fundamental manufacturing strategies that use different materials and different technologies to make PV modules:

- **Crystalline silicon (c-Si)**. This dominant technology based on bulk silicon, uses proven manufacturing technology and well-understood materials, has a history of improvement, and has a strong road map for modest future improvements.
- **Thin film**. This newer technology is based on very thin layers of other semiconductor materials, deposited on glass or another substrate. It uses a variety of manufacturing technologies and core materials, each with its own challenges. The history of thin film is shorter than c-Si, and its manufacturing process development is of somewhat higher risk. However, thin film has more room than c-Si for cost and performance improvements before approaching theoretical maximums.

Further discussion of the PV products supply chain is included in Appendix B.



Source: O'Rourke et al. 2009

Figure 5. PV products sector supply chain.

1.1.1 Sector Metrics

PV product performance is typically measured by peak watts (W_p), the peak power a PV product is capable of generating or handling under ideal installation conditions, by percent efficiency and reliability:

- Peak watts is a measurement of power, and is the metric by which PV products are sold, often dollars per watt ($/W). This is often confused with kilowatt-hours (kWh), a measurement of the energy generated that depends on a variety of system and geographic factors.
- Efficiency is the percentage of solar energy falling on the PV device that is converted to usable electricity. Efficiencies are quoted for many individual PV products, with system efficiency always lower than the efficiency of any one component. Typical commercially available panel efficiencies (not including concentrating photovoltaic, or CPV, systems) range from 6% to 25%, and system efficiencies range from 5% to 20%. System efficiencies are often guaranteed by the manufacturer.
- Reliability is typically defined as the usable lifetime of the product under forecast conditions, and its ability to perform predictably. Typical commercially available ranges are 10 to 30 years, with some minor per-year performance degradation typical of most PV systems. These lifetimes are often guaranteed by the manufacturer.

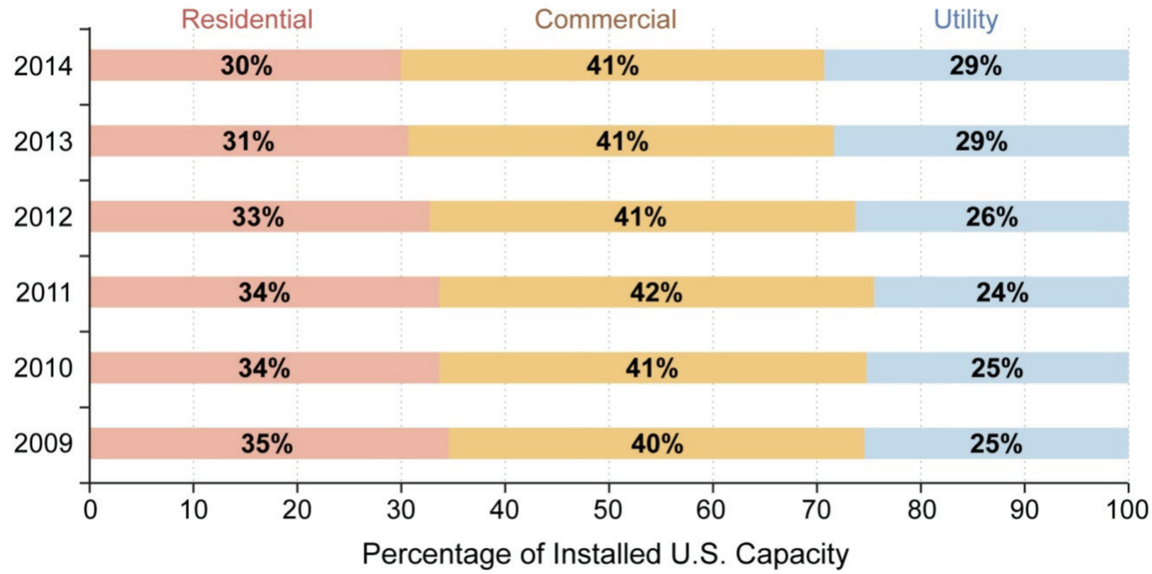
The PV products sector's warranties on their products (and their ability to make good on those warranties) is a variable that many energy generation sector businesses watch closely.

1.1.2 Sector Differentiation

PV products are differentiated according to market scale and cost-per-performance, as described below.

1.1.2.1 Market-Scale Differentiation

PV products are typically intended for one of three markets, defined by their scale: residential, commercial, and utility. Although there is some crossover, these markets are becoming increasingly differentiated. The most significant difference exists between residential-/commercial-scale and utility-scale projects (Figure 6).



Source: Schreiber 2010

Figure 6. U.S. market segmentation 2009–2014.

1.1.2.2 Cost-per-Performance Differentiation

The c-Si strategy targets high performance (lowering cost per watt by increasing efficiency and W_p). The thin-film strategy targets lower costs (including focusing on reducing material usage and manufacturing complexity).

These two product differentiation themes are interrelated; the general trend shows that the smaller the market scale for which the product is intended, the greater the focus on high performance.

1.1.3 Supply Chain—Raw Materials to Finished Products

The PV products sector supply chain involves many discrete manufacturing businesses. These major activities include the manufacture of key raw materials, PV modules, and other supply chain components. While raw materials manufacturing has a high barrier to entry based on technology and economies of scale, downstream manufacturing operations have decreasing barriers and significantly more competition.

Many of the following supply chain steps are often geographically distant, but some can also be integrated at a single site. Locations ideal for such integrated facilities meet the combined site selection criteria listed at the end of this section.

1.1.4 Trends

The PV products sector is growing and changing. The following paragraphs describe some ongoing trends affecting companies throughout the supply chain.

1.1.4.1 Influence of the Economic Downturn

From 2005 through 2008, a lot of investment and energy went into PV manufacturing research and development (R&D). Manufacturing capacity was being built and expanded as fast as construction schedules would allow. Manufacturers expected endless demand. In the last part of

2008, 2009, and into 2010, however, the general economic downturn cut PV demand, and growing inventories led to falling average selling prices. While the long-term outlook is strong, the industry will face many challenges; therefore, investments must have strong economic justifcation.

1.1.4.2 Continued Vertical Integration

While no supply-chain bottlenecks are currently driving vertical integration in the PV products sector, a history of boom-and-bust cycles continues to drive PV products sector companies to seek partners and acquisitions. By integrating vertically and buying or developing upstream and downstream capabilities, companies hope to increase their internal coordination and cost and margin control and reduce their exposure to supply-chain imbalances. If companies cannot buy or develop these vertically integrated capabilities, they are trying to sign long-term contracts and form strong ties within the supply chain.

As a result of the economic downturn, many of the weakest companies simply have failed. These companies' intellectual property, industry scientists and experts, and valuable tools, equipment, facilities, and staff are being acquired by the stronger companies.

1.1.4.3 Differentiation and Diversification

Market maturity is slowly defining various market niches by scale, location, and needs for intelligence, and shaping products that best fit them. Building-integrated photovoltaics is a great example of this trend, as PV products increasingly are being integrated into standard building materials, as well as into other devices, appliances, consumer products, and road signage and lighting.

At the same time, other functions and intelligence are being integrated into PV products, such as modules that optimize output under shading conditions through integrated electronics.

While these innovative market niches are exciting, they are not forecast to be a meaningful portion of the overall PV product market. The market will continue to be driven by on-grid residential, commercial, and utility installations.

1.1.5 Site Selection Criteria

When companies in the PV products sector choose a new place to manufacture products, they evaluate areas based on the following key criteria:

- Land and buildings
- Utility service for electricity, water and wastewater treatment, and natural gas
- Operating cost environment
- Ability to meet production schedules and deadlines
- Transportation
- Proximity to PV end market
- Technology support, higher education, and research
- Workforce and training

- Public and private support and policies
- Incentives.

Informing city-level economic development strategies, communities need to consider how they measure up against these metrics, and what they can do to improve their scores. Table 3 illustrates the relative importance of these site selection criteria to companies in various parts of the PV products sector. Communities can use these criteria to quickly evaluate themselves relative to the needs of the industry segment they are considering targeting. In so doing, communities can identify potential strengths, challenges, and criteria on which they must improve to be successful. Note: the rankings in Table 3 are solely the opinion of the authors. These rankings are a first-order attempt at characterizing the siting criteria utilized in the PV products sector, included here solely for the purposes of informing economic development planning.

Table 3. Matrix of PV Product Sector Site Selection Criteria

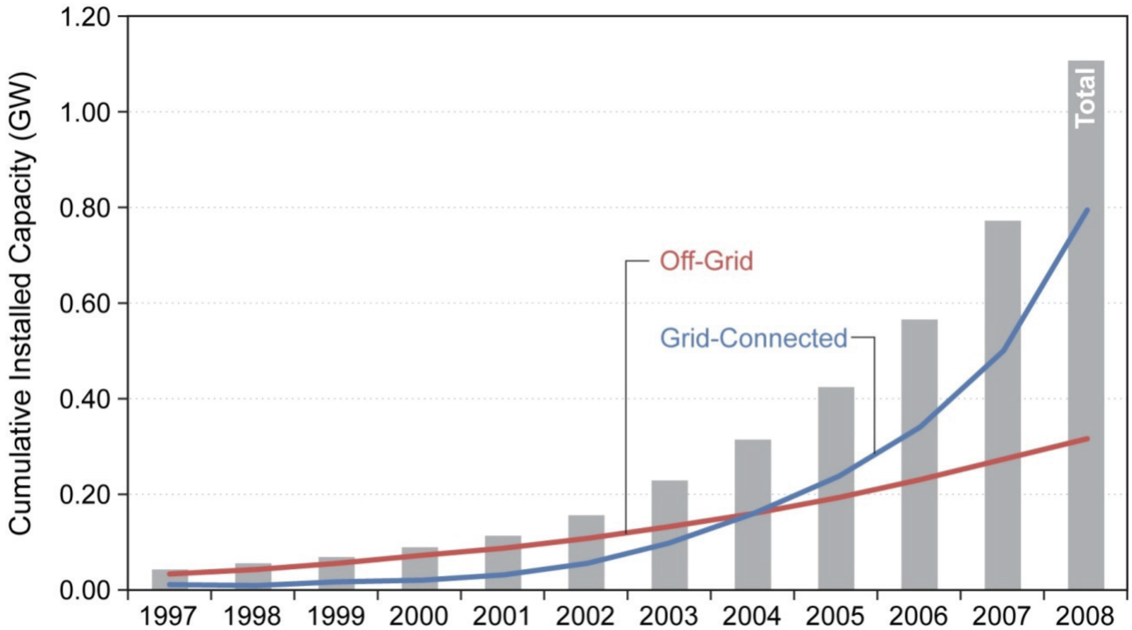
	PV Products			
Industry Criteria	Raw Materials	Wafer/Cell	Assembly	Other Supply Chain
Land and Buildings	2	2	2	2
Utilities	1	1	3	3
Operating Cost Environment	1	1	2	2
Schedule Considerations	1	1	2	3
Transportation	2	2	1	2
Proximity to End Market	2	2	1	2
Technology Support, Higher Education and Research	2	1	3	3
Workforce and Training	1	1	2	2
Public/Private Support and Policies	2	1	1	2
Incentives	1	1	2	2

Legend Critical (1) Somewhat Important (2) Less Important (3)

1.2 Photovoltaic Energy Generation

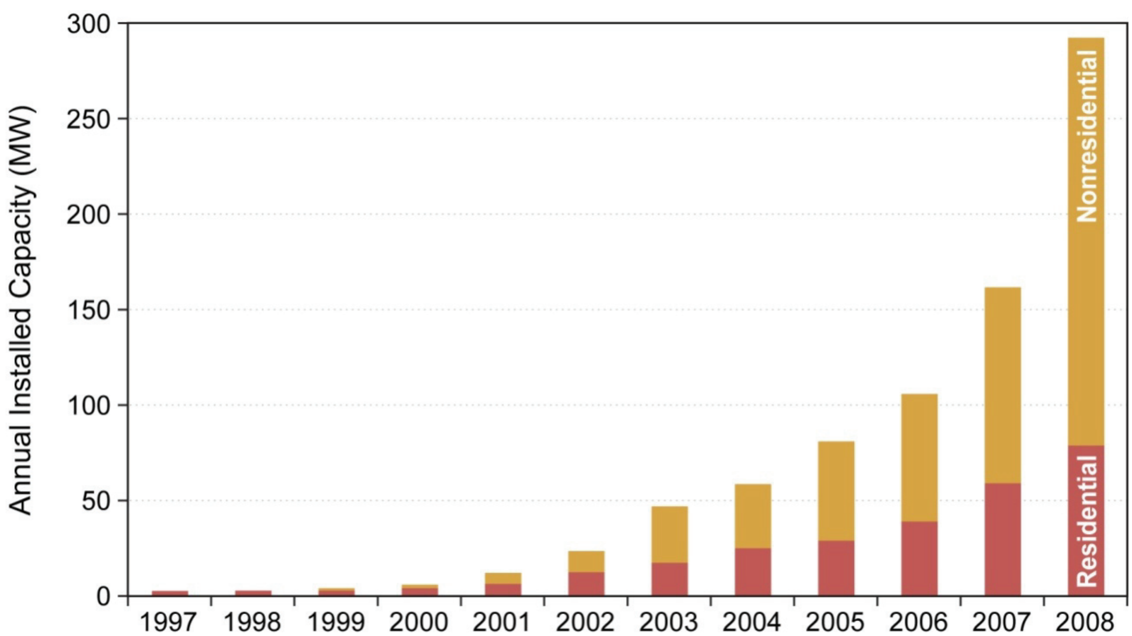
For the purposes of this report, the PV energy generation sector is defined as businesses that (a) model, design, or install PV systems, or (b) generate, distribute, sell, and/or provide any guarantees on system performance. At its core, it is a sector defined by technical and construction services, most important of which is the installation of PV systems.

Growth in PV energy generation is illustrated in Figures 7 and 8, which highlight the increasing growth of grid-connected PV, as well as the importance of commercial- and utility-scale installations compared with residential installations. Grid-connected PV is the market for PV installations interconnected to the general electrical transmission and distribution system. This is in contrast with off-grid PV markets, which are systems often paired with battery backup systems for rural or remote power. Residential-, commercial-, and utility-scale PV refer to different general markets in PV energy generation defined by their scale.



Source: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy 2010

Figure 7. U.S. cumulative installed PV capacity by interconnection status.



Source: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy 2010

Figure 8. U.S. annual grid-connected PV capacity by sector.

The PV energy generation sector is a services sector. Major services and businesses in the PV energy generation sector include:

- Array and system design
- Electrical and mechanical contractors
- Power producers
- Engineering, procurement, and construction
- Financial and legal consulting
- Industry organizations and lobbyists
- Logistics and transportation
- Operations and maintenance
- Owner's engineer
- Performance modeling
- Performance monitoring
- Site and civil work
- Site selection
- System finance (including lease and third party)
- Tax investor
- Training organizations
- Transmission and interconnection studies.

The focus of PV energy generation activities is the delivery of a kilowatt-hour from a PV system to a customer; however, the range of services in this category is very broad. In general, PV energy generation activities strive to purchase and install PV products, operate them, and make their output available to energy users.

In forming local economic development strategies for this sector, it is important to think in terms of building an attractive market for PV projects (installations), not recruiting other PV energy generation services companies that provide relatively few direct and indirect local jobs, or that can operate distant from project sites. The majority of jobs from the PV energy generation sector are in project installation labor.

Figure 9 illustrates the value chain for the PV energy generation sector. The value chain is divided between residential and small commercial projects, and large-scale commercial or utility projects. Larger scale, more complex projects benefit from increased specialization and more complex agreements, often involving third parties, such as financial institutions. The business processes and market actors observed in the PV energy generation sector are discussed in further detail in Appendix C.

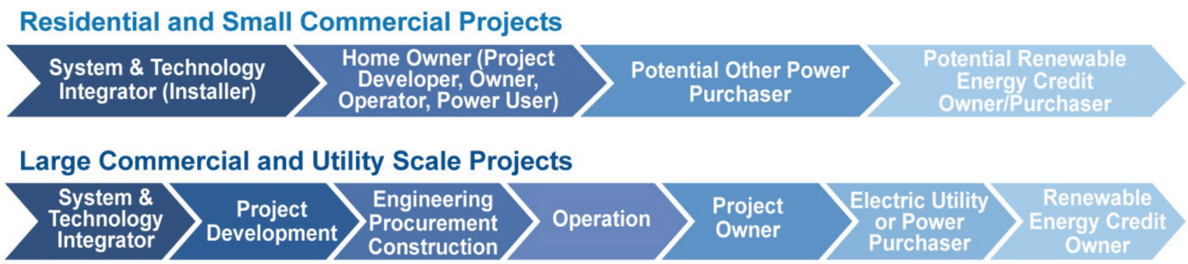


Figure 9. PV energy generation sector value chain.

1.2.1 Project and Service Distinctions

PV energy generation sector services are differentiated most by their scope, scale, the degree to which their services are integrated or bundled together, and the degree of project risk and complexity:

- **Scope**. PV energy generation sector services range from performance modeling, to tax credit investing, to construction management. Although this wide range of services is necessary to execute large projects, many services can be geographically distant from project installation sites.
- **Scale differentiation**. PV energy generation companies typically focus their business models on supporting either residential-scale (typically less than [<] 10 kW), commercial-scale (10 kW–1 MW), or utility-scale (greater than [>]1 MW) projects, with some crossover. Scale differentiation is clearest at the utility scale, where the project size drives a significantly more complex process and more specialized services.
- **Level of integration**. PV energy generation companies often integrate the many required steps of executing a PV project into a turn-key package, taking ownership of a project from start to finish with a single contract. The individual tasks required can all be done in-house, or be distributed in subcontracts. This integration is most common in physical design and construction, especially at large scales, but can include other financial or legal activities.
- **Risk**. Projects on challenging sites, or with complicated use requirements or uncommon ownership arrangements, have increased project risk and typically are handled by companies with relevant specific expertise. Examples of specific expertise include projects on brownfield sites, on tribal lands, or in extremely remote or hazardous conditions.

1.2.2 Costs

Like most service costs, PV energy generation services costs in the United States vary by geography, project scope and scale, the level of expertise or specialization required, and the level of competition. The costs of services are usually built up from hourly rates, and calculated for comparison purposes in dollars per watt at the project level.

PV energy generation sector costs are not driven down directly with economies of scale, but design, permitting, finance, and legal services' share of project costs generally do go down as project size increases.

1.2.3 Trends

1.2.3.1 Increased Third-Party Ownership Accompanying Power Purchase Agreements

Companies with experience in finance (e.g., banks and insurance companies) are increasingly bearing the up-front costs of a PV project in return for the secure future cash flows and tax benefits that can be created through a power purchase agreement (PPA) with the local electric utility or the host of the PV system.

By separating ownership and hosting of the PV system, this PV project structure creates benefits for multiple parties. Third-party financiers take on some project risk, but they monetize the financial incentives being offered, along with the long-term cash generated according to the terms of the PPA. Third-party financiers typically also have more ready access to cheaper sources of capital as well as the ability to monetize tax credits (“tax appetite”) than other potential project developers or project owners.

1.2.3.2 Increased Participation of Utilities

The economics of PV in the United States to date have not driven utility ownership and operation of PV energy generation projects. Utilities are currently required to “normalize” the accounting for tax benefits (such as the solar investment tax credit or accelerated depreciation). This means that the value of the tax benefits passed through to utility customers is spread over the life of the system, rather than the time the tax benefits are incurred, making the levelized cost of energy from the system appear higher for utilities than for third-party PPA providers who are not required to normalize the accounting for tax benefits.

PV is also inherently difficult for utilities to operate and absorb because of its inconsistent power generation. For these reasons, many utilities, even those facing renewable portfolio standard (RPS) requirements, are electing to purchase renewable energy certificates (RECs) from project developers or project owners rather than own large PV generation projects themselves. However, as the industry continues to mature and PV product costs and perceived risks continue to decrease, utility PV project ownership, and utility PPA agreements will increase.

1.2.3.3 Continued Integration

The PV energy generation sector is becoming increasingly integrated, with many of the largest system integrators, project developers, and engineering, procurement, and construction (EPC) firms expanding their scopes and roles on large projects. This integration is also crossing over into the PV products sector.

At smaller scales, many energy generation companies are finding integration advantages across geographies. By replicating a successful business model like third-party ownership, many system integrators are working with local contractors to build regional teams to take advantage of local market conditions.

1.2.3.4 Differentiation and Diversification

The PV energy generation sector is maturing. It is slowly defining various market niches based on local economic conditions and solar resources, and shaping services that best fit them. PV energy generation sector companies are increasingly finding advantages in developing local expertise and relationships. The most important local drivers of PV energy generation sector attractiveness are discussed below.

1.2.4 Site Selection Criteria

When PV energy generation sector companies choose a new market to enter, they evaluate areas based on the key criteria listed below. In forming city-level economic development strategies, communities need to consider how they measure up against these metrics, and what they can do to improve their overall score:

- Solar resource
- Local cost of electricity and utility structures and attitudes
- Public/private support and policies (rebates and incentives)
- Workforce and training.

Table 4 illustrates the relative importance of these site selection criteria to companies in various parts of the PV energy generation sector. In forming city-level economic development strategies, communities can use these criteria to quickly evaluate themselves relative to the needs of the industry segment they are considering targeting. In so doing, they can identify potential strengths, challenges, and criteria on which they must improve to be successful. Note: the rankings in Table 4 are solely the opinion of the authors. These rankings are a first-order attempt at characterizing the siting criteria utilized in the PV energy generation sector and are included here solely for the purposes of economic development planning.

Table 4. Matrix of PV Energy Generation Site-Selection Market Criteria

	Energy Generation	
Industry Criteria	Residential / Commercial	Utility Scale
Solar Resource	2	1
Cost of Electricity, Utility Structure and Attitudes	1	1
Public / Private Support and Policies	1	1
Workforce and Training	3	3

Legend Critical (1) Somewhat Important (2) Less Important (3)

2 Employment Opportunities and Economic Development Strategies

2.1 Employment Opportunities

2.1.1 PV Products Sector

As the PV market grows, most analysts expect the solar supply chain to produce many more jobs than are available today. Optimistic analysts estimate that solar PV installed capacity will increase dramatically in the next 20 years, bringing potentially a tenfold or greater increase in solar-related employment opportunities (Worldwatch Institute 2008, Global Insight, Inc. 2008, and Friedman 2009). However, PV products sector jobs will not scale directly with installed capacity. Imports of PV products will continue, and as the solar PV industry matures, the United States will see increases in manufacturing efficiencies, resulting in fewer jobs per watt (Friedman 2009). See Figure 10. Although the figure does not break out PV products sector jobs specifically, a 2005 report from the Renewable Energy Policy Project suggests that as much as 80% of all PV jobs involve manufacturing and assembly, with the remaining 20% involving construction and installation (Sterzinger and Svrcek 2005).

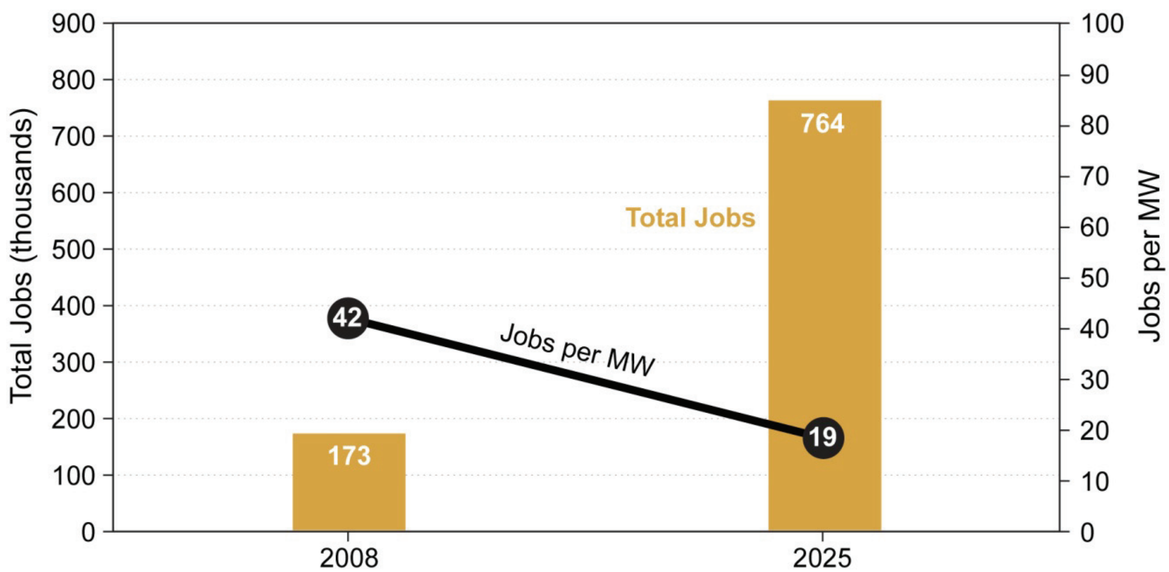
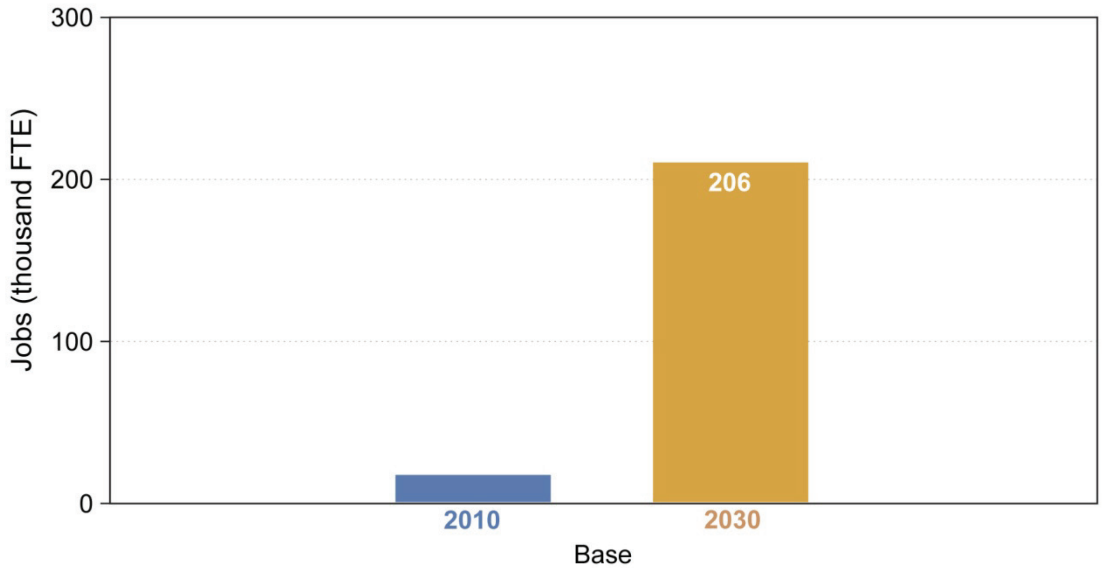


Figure 10. Decrease in jobs per megawatt with increase in total jobs.

Figure 11 illustrates baseline forecasts (given little to no added support for the industry) of the number of jobs that could be created if efforts were undertaken to support the PV industry. Because of the different metrics used in the projections, and the different analysis dates, the numbers themselves cannot be compared directly. However, the trend clearly predicts a significant increase in jobs available in the PV industry over the next 20 years.



Source: American Solar Energy Society and Management Information Services, Inc. 2008

Figure 11. High and low forecasts for jobs in the PV industry in the United States.

Tables 5 through 7 estimate the types and number of jobs available in a typical ingot preparation and cell manufacturing facility, module assembly facility, and thin-film production facility. Estimated staffing levels for each type of facility assume production capacity sufficient to generate 65 MW of PV capacity annually.

The PV products sector also creates indirect jobs, such as sales, planning, financing, consulting, and investing. Short-term construction jobs are created for the building of manufacturing facilities. These indirect and short-term jobs are not included in this analysis.

The bulk of PV products sector jobs are in manufacturing operations, specifically in ingot preparation and wafer slicing, and PV cell manufacturing, or in thin-film panel production. These operations require a skilled and trained workforce that includes a large percentage of production operators and assembly workers.

The typical PV products workforce consists predominantly of production line operators, but it also includes line supervisors; industrial, mechanical, and chemical engineers; quality managers; procurement, logistics, and material managers; and other management and administrative positions.

Table 5. 65-MW Manufacturing Facility Staff Mix

Staff Mix	FTE Staff
Production Operators and Maintenance Technicians	120 - 220
Engineers	5 - 10
Management / Administration	5 - 10
Total Workforce	130 - 240

* Labor workforce size and mix is heavily dependent on specific technology and number of process steps. Above figures are general averages only. It should be noted that published sources vary widely between companies and technology.

PV module assembly is much less costly and complex than ingot preparation and slicing or cell manufacturing. A module assembly workforce requires general manufacturing skills, with some special skills dependent on the technology and processes.

Table 6. 65-MW Facility Module Assembly Staff Mix

Staff Mix	FTE Staff
Assemblers	80
Engineers	10
Management / Administration	10
Total Workforce	100

Thin-film PV manufacturing steps cannot be broken into separate factories like ingot preparation and slicing, cell manufacturing, and module assembly, as they represent the equivalent of all of these steps. Thin-film staff counts, while potentially lower per megawatt output, generally have a higher average skill level and wage than c-Si-based processes.

Table 7. 65-MW Facility Sample Thin-Film Staff Mix

Staff Mix	FTE Staff
Production Operators and Maintenance Technicians	80 - 120
Engineers	10 - 15
Management / Administration	5 - 10
Total Workforce	95 - 145

* Labor workforce size and mix is heavily dependent on specific technology and number of process steps. Above figures are general averages only. It should be noted that published sources vary widely between companies and technology.

2.1.2 PV Energy Generation Sector

As mentioned earlier, as few as 20% of all jobs in the PV industry come from the energy generation sector, the majority of which are in installation. This disparity in job opportunities by sector is largely due to the duration of each type of job. The manufacturing and assembly jobs involve long-term operation of facilities, while installation of solar energy systems provides short-term employment for installers. Unless there is a steady stream of new projects, installation does not provide long-term employment. Utility-scale solar power plants employ relatively few long-term workers.

The PV energy generation industry also creates indirect jobs, such as sales, planning, financing, consulting, and investing. Indirect PV generation jobs were not included in this analysis because they are difficult to quantify, largely because the definitions of direct, indirect, and induced jobs vary between studies (Wei, Patadia, and Kammen 2010).

Installation jobs primarily require skills as an electrician, construction laborer, site and civil earthwork laborer, or roofer with some specialized training and certification. Workers currently in the construction industry can supplement existing skills with solar or renewable energy classes or apprenticeships with experienced solar installers (Environmental Defense Fund and Ella Baker Center for Human Rights 2008). Community colleges can support their local workforce by developing programs in solar and renewable energy. Organizations such as the Interstate Renewable Energy Council (IREC) audit and certify these programs, many of which work in conjunction with apprenticeship programs designed specifically for green jobs (State of New Jersey, Department of Labor and Workforce Development 2010, State of California, Department of Industrial Relations 2010, Interstate Renewable Energy Council, 2010).

The location of residential and commercial PV installation jobs is driven by local incentives, solar resources, and the competing price of electricity. Utility-scale installations may be designed by non-local companies, but local installers and construction personnel will more than likely do the physical work. Areas wishing to increase installation job opportunities should focus on improving the local market for the systems by gearing incentive programs to the consumer.

Table 8 provides estimates of full-time equivalent (FTE) staff for installation of a single, 50-MW, utility-scale PV system.

Table 8. Sample 50-MW Utility-Scale Installation Staff Mix

Staff Mix	FTE Staff
Craft Labor	175 - 200
Professional Labor	75 - 100
Total Workforce	250 - 300

2.2 Economic Development Strategies

2.2.1 PV Products Sector

Not all cities are good locations for all segments of the PV products sector. Local economic development groups must consider and analyze local assets and challenges, and target PV industry segments that are attainable. Appendix B lists the typical criteria that PV products manufacturers consider when selecting a manufacturing site.

2.2.1.1 Designing a Successful Economic Development Strategy

Successful economic development programs have been both comprehensive and strategically focused on those segments of the products sector for which the community's assets and infrastructure are a good match. In many cases, successful economic developers were also able to identify their disadvantages and invested to overcome them.

Successful economic development programs targeting the PV products sector industry have several common elements, including:

- Investing in understanding the requirements for the various segments of the industry and the relevant local assets and challenges. Matching an area's attributes to the needs of targeted businesses creates more achievable goals.
- Determining those disadvantages that can be overcome and those that cannot
- Developing incentives specifically to overcome area disadvantages, or to provide a competitive advantage
- Providing non-financial assistance that can improve the business environment
- Taking a long-term approach. Although there is usually pressure to achieve short-term results, successful economic development programs must think long term
- Working with higher education and research to support and complement the targeted industry segment. These efforts should allow for collaboration with industry and be open to partnerships and intellectual property development.
- Marketing efforts to targeted segments only after careful analysis.

2.2.1.2 Economic Development Tools and Programs

States, regions, and cities have developed a wide range of tools, both financial and non-financial, to support and grow the solar PV products sector in their areas.

Financial Tools

A successful, comprehensive economic development program for the PV products sector that typically includes financial incentives.[2]

Grants

Grants are powerful incentives that can be used to assist directly with the development or expansion of a new facility, to fund research projects into new technologies, or to conduct other activities that directly benefit a targeted segment. Grants for new facilities are most often provided on a case-by-case basis, with the amount of the grant based on job generation, investment, and meeting and expanding the economic goals of the area. The granting entity and business typically enter into an agreement that describes terms of the grant and penalties for not meeting the terms.

Grants are often viewed by the PV industry as an effective way to reduce investment requirements. However, grants programs offer little opportunity to sustainably operate long term, as they typically have no pay-back requirements.

[2] For more information about financial tools, see Kubert and Sinclair 2009, Mehta 2009, and North Carolina State University 2010.

Loan Programs

With direct loan programs, money is lent directly from the lending entity to the project owner. Direct loans allow money to be lent at low interest rates to projects that might not receive funding through traditional financing. They can be easier on the lending agency than rebates and grants because payments and interest can be invested back into the fund. Direct loans require higher capital, more risk, and greater administrative costs by the agency than other types of loans.

Matching loans provide a share of a loan, often at low or no interest, to borrowers who are able to find traditional financing from a commercial lender. These loans reduce the risk and expense to the granting agency, but rely on private lenders' willingness to match the loan.

Interest rate buy-down programs and linked deposits both subsidize rates offered by commercial lenders, resulting in a lower interest rate to the project owner. Interest rate buy-down reduces costs for project owners while alleviating the risk of loan defaults for the lending agency, but—like rebates and grants—the lending agency does not receive any repayment. These programs also hinge on the owner's ability to secure financing through a commercial lender.

Loan guarantee programs have received a great deal of attention lately in conjunction with the American Recovery and Reinvestment Act (ARRA). Several large manufacturing projects have received loan guarantees through the U.S. Department of Energy that have allowed them to secure investment funding. Guarantees will continue to be important because they protect lenders against a specified amount of capital losses if a borrower defaults on a loan. Loan guarantees can allow projects that normally would not qualify for financing to receive loans. This is especially useful to manufacturing companies scaling up production to bring new technologies to market.

Many states and cities offer direct loans, reduced-interest loans, and matching loans specifically targeted for manufacturing projects. These loans may also contain clauses that allow them to be forgiven if certain conditions are met. These conditions usually include job creation and investment within an agreed-upon timeframe. These loans often include a cap that requires that additional equity or debt financing must be secured, and can be used for construction financing. These loans can be strong incentives for companies to locate manufacturing facilities in particular areas.

Tax Incentives

PV products sector tax incentives are granted by states and local governments to companies that move to, or expand in, a certain area. These usually take the form of reduction or exemption of sales tax, employment tax, corporate income tax, or property tax. Many times these are granted outright, but they can also be provided as tax credits to reduce tax liability in the short or long term. Additional credits are offered in some areas for R&D expenditures, employment of certain workers, and investment tax credits.

Tax credits that can be monetized or sold to others enable more businesses to take advantage of the credits. This is a particular advantage to companies that may not have a tax liability in a location for several years and cannot effectively use the credit. The ability to sell the credit can provide up-front investment capital, which is especially valuable to startup companies.

Other Financial Incentives
Most states and cities offer customized incentive packages, on a case-by-case basis, that have the potential to provide a significant number of jobs or otherwise contribute strongly to the local economy. Examples of incentives include the following:

- Discounted or free land, infrastructure upgrades, and waived or reduced development fees
- Research funding or collaboration opportunities with research universities or institutes, and workforce training targeted to the specific needs of the company
- Reduced electric or other utility prices or long-term price contracts
- Off-take agreements to guarantee markets and lower risk (an off-take commitment is a commitment by a public or private entity to purchase a portion of the new facility's production over a set period of time)
- Company-specific incentives can have high up-front costs, but economic development groups typically can analyze the payback and the competition by other regions before making a commitment. Specialized incentive packages are generally expected by large PV products sector companies and can be the deciding factor in site selection.

Non-Financial Tools and Programs
Successful economic development programs have incorporated non-financial incentives and programs, such as:

- Improvements to permit processes, reasonable permitting fees and licensing costs, and a supportive regulatory environment
- Overall tax policies supportive of the PV products sector
- Involvement and commitment of public and private sector leaders, including active, visible champions, elected officials, utility and business leaders, public servants, and business and neighborhood organizations
- Public outreach and education on the broad benefits of the PV solar industry
- Targeted marketing to appropriate industry segments.

Technology Development Assistance Programs
PV product companies are driven to constantly improve their product performance and reduce costs through R&D and collaboration.

Areas with technical resources, local research laboratories, research universities, and specialized institutes have used these assets as an incentive to attract and grow PV product companies. Access to existing local expertise is especially important to companies in the early stages of growth. Frequently, the benefits of technology development programs are not one sided, and local institutions greatly appreciate industry connections.

2.2.2 PV Energy Generation Sector
Similar to the PV products sector, not all areas are prime locations for segments of the PV energy generation sector. Local economic development efforts must consider and analyze local assets

and challenges, and target PV industry segments that are attainable. Appendix C lists the typical criteria that businesses in the PV energy generation sector consider.

2.2.2.1 Designing a Successful Economic Development Strategy

Areas that have had success in growing jobs in the PV energy generation sector have created comprehensive programs that have a strategic focus based on sound understanding of industry requirements and local conditions. In many cases, these areas have assumed disadvantages where there are none. One clear example of this lack of industry understanding is the common assumption that PV is not well suited to northern latitudes and cold climates.

Programs that have had success in attracting or growing segments of the PV energy generation sector have several common elements, which often include the following:

- Investing in understanding the requirements of various PV energy generation markets and the relevant local assets and challenges. Matching an area's attributes to the needs of targeted businesses allows increased focus on the most realistic opportunities.
- Determining what disadvantages, such as restrictive PPA or net metering rules, can be overcome through public policy change to create an attractive market. Many states do not currently allow PPAs, which is a significant barrier to the development of PV in the United States.
- Developing financial incentives that can be used to overcome area disadvantages like less-than-ideal solar resources, and that provide a competitive advantage
- Providing non-financial assistance that can improve the business environment and make investment and development easier
- Focusing on a specific PV segment(s) as a strategic target for economic development and creating a supportive public policy environment
- Taking a long-term approach. Although there is usually pressure to achieve short-term results, successful areas have leveraged early actions into long-term results.
- Making investments as needed in workforce training, education, and research that support and complement energy generation sector needs. These efforts should allow for collaboration with industry and be open to partnerships.
- Marketing efforts to targeted segments based on careful analysis.

2.2.2.2 Economic Development Tools and Programs

States, regions, and cities have developed a wide range of financial and non-financial tools to support and grow the PV energy generation sector in their areas. To simplify the discussion of these tools and programs, they are divided below into financial and non-financial tools.

Financial Tools

A successful comprehensive program needs to include tools and financial incentives that provide direct assistance. The following are the most commonly used tools.[3]

Rebates

Rebates are payments made to a PV energy generation project owner, after the project is complete, to cover part of the capital costs. Most often, rebates have specific criteria for size and performance of systems, requirements for certified installers, and sometimes requirements for local content, other energy-efficiency measures, or other restrictions. The amount of the rebate is usually based on system size, but it can also be a fixed dollar amount or percentage of total dollar amount per system. Rebates can be structured to draw from a limited funding amount, or confined to a period of time, and then renewed or adjusted based on changes in the market, new policies, or program goals.

If not well structured, rebates can create market dependency that leads to a dramatic drop in demand when rebate programs end or rebate amounts are reduced. They also are not revolving or self sustaining, and once rebates are awarded to the customer, there is typically no return back into the fund.

Production-Based Incentives

Production-based incentives (PBI) are tied to actual or forecasted energy generation in kilowatt-hours for a fixed period of time. They can take the form of rebates or installment payments over a year or more. PBIs may be based on the actual performance as measured by a monitoring system, or on estimated output based on size, efficiency rating, and site as determined by a credible system performance model. Unlike rebates, PBIs grant the greatest incentives to the systems that perform the best (not simply to the largest nameplate sizes), encouraging careful planning and quality installations. While PBIs may make more sense for the funding agency, they can be less valuable to project owners at small scales. Although they do accelerate return on investment, they do not help with up-front project costs. They also require ongoing tracking and payment, which increase the administrative costs of the program.

Incentive or tariff rates can be set based on type of technology, project size, location, type of ownership, or any other variable that the agency is promoting.

These types of incentives require close coordination with utilities, as prices are determined and the programs are fine tuned and adjusted over time to match the market. Because it is difficult to predict the response to new PBI or feed-in tariff programs, determining the best rate can be challenging. Too high a rate could lead to rate increases if the number of generation projects surged, but a rate that is too low could fail to yield enough new projects. Feed-in tariffs also require that net metering and interconnection policies be in place and well structured.

Grants

Grants for energy generation sector markets usually target installation projects at a residential or commercial/utility scale, within a specific boundary, or on a property with a specific prior or

[3] For more information about financial tools, see also Kubert and Sinclair 2009; Mehta 2009; and North Carolina State University 2010.

ongoing use. Large grants are usually awarded to qualified projects on a competitive or request for proposals (RFP) basis. Grants are an effective way to reduce investment requirements. However, they offer little opportunity to operate sustainably long term, as they typically have no pay-back requirements.

Loan Programs

There are also a wide variety of loan programs: direct loans, matching loans, interest rate buy-downs, linked deposits, or clean energy assessment districts.

With direct loan programs, money is lent directly from the lending entity to the project owner. Direct loans allow money to be lent at low interest rates to projects that might not receive funding through traditional financing. They can be easier on the lending agency than rebates and grants because payments and interest can be invested back into the fund. Direct loans require higher capital, more risk, and greater administrative costs by the agency than other types of loans.

Matching loans provide a share of a loan, often at low or no interest, to borrowers who are able to find traditional financing from a commercial lender. These loans reduce the risk and expense to the granting agency, but they rely on private lenders' willingness to match the loan.

Interest rate buy-down programs, loan loss reserves created with public funds and linked deposits can result in subsidized rates offered by commercial lenders, resulting in a lower interest rate to the project owner. Interest rate buy-down reduces costs for project owners while alleviating the risk of loan defaults for the lending agency, but—like rebates and grants—the lending agency does not receive any repayment. These programs also depend on the owner's ability to secure financing through a commercial lender.

Clean energy assessment districts and property tax financing, also called Property-Assessed Clean Energy (PACE) models, all eliminate the up-front cost of installing a system by creating an installment payment plan tied to utility payments or property taxes. These programs also reduce the risk to owners by tying the payments to the property. For example, when the property is sold, the new owner takes over the payments along with the utilities and property taxes. These programs can be administratively complex. As of August 2010, the residential PACE model has been put on hold, as rulings from federal financial regulators have specifically opposed any programs where special property tax assessments are in a senior lien position. While the PACE model is very promising, the future of PACE models as a financial tool is unsure.

Tax Incentives

Energy generation incentives are often in the form of tax credits, where a certain percentage of installed cost or dollar amount can be regained as a state or federal tax credit or deduction. States with sales tax often offer sales tax exemptions on the purchase of PV systems, effectively giving the consumer a discount on the system price. Some tax incentives also extend to property tax exemptions for residential and commercial owners. Tax credits and sales tax exemptions can apply to small or large systems, while property tax exemptions generally do not apply to utility-scale projects.

Tax credits that can be monetized or sold to others enable more businesses to take advantage of the credits. This is a particular advantage at the utility scale and for projects with specific tax investors or developers that do not have a tax liability in a location for several years.

Non-Financial Tools and Programs
Although specific financial incentives are very important tools, they are not the only options available. Successful areas have integrated economic development tools and incentives into a comprehensive program of support. Program elements that successful areas have used include the following:

- Policies and a regulatory environment that support market transformation that can include easy and understandable permit processes, expedited processes for interconnections and incentive applications, and reasonable permit fees
- Overall tax policies that support PV installation
- Involvement and commitment of public and private sector leaders in the promotion and support of energy generation projects. These include elected officials, utility and business leaders, public servants, and business and neighborhood organizations
- Public outreach and education on the broad benefits of local PV energy generation can be one of the most important factors in gaining public support for efforts and incentives
- Targeted marketing to appropriate installation types and applications.

Available economic development tools that are specific to the PV energy generation sector include RPSs, and allowances or requirements for net metering, PPAs, and third-party leases.

Renewable Portfolio Standards, Renewable Energy Certificates, and Solar Set-Asides
RPSs are requirements by the state or local jurisdiction that local utilities supply a certain percentage of their energy from renewable resources. These programs may treat all renewable energy sources as equal, or provide different levels of support for different energy sources, called "set-asides." Set-asides (also known as carve-outs) require that a portion of the RPS must use specific technologies or project types. Utilities may comply with the RPS by direct investment in renewable generation projects such as solar PV, by purchasing solar RECs, or by making compliance payments to the requiring agency.

RPS solar set-asides are one of the most powerful and influential drivers for utilities to increase use of PV power. These set-asides are also often drivers of other supportive solar policies discussed in this section.

Net Metering and Interconnection Standards
Policies such as interconnection standards and net metering rules allow system owners to connect to the grid. They govern how owners will be compensated for energy sent to the grid over and above what they have consumed.

Net metering and interconnection rules are often driven by state governments, which generally authorize their state public utilities commissions to develop net metering rules. At the city level, city governments can influence municipal utilities over net metering rules in their territories.

Net metering is one of the most important policy drivers for PV markets. This is because it enables system owners to reduce energy costs, and it is an enabler for other financial incentives (such as feed-in tariffs).

Third-Party Lease Agreements and Residential Power Purchase Agreements

Third-party leases and residential PPAs typically are provided by private sector companies. However, support for these companies can be a positive influence for residential PV market transformation by allowing residential and commercial property owners to have systems installed with reduced up-front cost and maintenance requirements. The simplest arrangement is typically structured in the following way:

- **PPAs**
    - The building owner agrees to host the system on its roof and purchase the electricity generated by the system over an extended period of time.
    - The system owner agrees to lease the roof space and to install, operate, and maintain the system.
    - The solar developer/PPA provider is usually partnered with a financial investor who takes the tax benefits associated with the PV installation.
- **Solar Leases**
    - Under a solar lease, the building owner leases the system from the solar developer. The monthly lease payments that the building owner makes are offset by the utility bill savings.
    - At the end of the lease, the building owner often has an option to purchase the system, extend the lease, or have the system removed.
    - The solar leasing company is usually partnered with a financial investor who takes the tax benefits associated with the PV installation.

One potential complication in these types of arrangements is that the system is generally attached to the property, but the lease or PPA is attached to the owner. This puts the burden on the property owner to transfer the lease if the property is sold, which may be difficult.

Community PV

Community-based PV programs organize and enlist participation from residential and small commercial owners to collectively install a large PV system in coordination with a local utility, or to install distributed smaller systems under a single contract.

In the case of a centralized system, participants buy into the program and benefit from the system-generated energy in proportion to the amount of their buy-in. In the distributed model, each participant purchases an independent system as part of a group buy. The key advantage to these models is that they can reduce system costs through larger scale purchases and allow non-homeowners to contribute to and benefit from a PV system.

These programs typically are initiated, organized, and managed by community groups, local utilities, or local businesses. If not organized by the utilities themselves, centralized community solar projects require close collaboration with utilities and with administrators of net metering policies, as well as careful legal crafting to avoid the formation of investments that might trigger state or federal securities law. Public support for these projects is important because it can increase the number of installations and related job growth.

3 Case Studies and Examples

Many communities have been successful in developing various segments of the PV industry. The following are examples of incentive programs and public policy commitments by different jurisdictions, and their results.

3.1 PV Products Sector

When economic developers target the PV products sector, what they are typically targeting is a large factory and the factory's centralized, stable, direct, and indirect jobs. Because these opportunities are generally large, it is often beyond the resources of cities to offer substantial enough incentives that are competitive. As a result, city economic developers lean heavily on state governments for large opportunities. The following examples contain mostly state incentive and program details; however, city-level efforts are noted whenever applicable.

3.1.1 New York

3.1.1.1 Program Features

- **The Solar Energy Consortium** is a non-profit public/private partnership focused on attracting and growing solar companies, and increasing PV efficiency through collaborative industry/university R&D initiatives.
- **New York State Energy Research and Development Authority (NYSERDA)** provides funding to New York-based renewable energy manufacturing companies. The Clean Energy Business Acceleration program provides:
    - Incentives to help fund new production facilities for clean energy technologies and commitments of $35 million to support business expansion, including marketing, business development, capital raising, and building business infrastructure
    - Investment of $9 million in the creation of six incubators throughout the state providing mentoring, technical and business assistance, networking, training, access to capital, and other resources to entrepreneurs and start-up clean energy companies
    - Entrepreneurial training for university researchers, mid-career executives, graduate students, and veteran entrepreneurs.

Empire State Development Corporation
Website: http://www.empire.state.ny.us/

The Solar Energy Consortium
Website: http://thesolarec.org

New York State Energy Research and Development Authority
Website: www.nyserda.org

- **Empire State Development Corporation** provides loans, grants, and tax credits to companies that will locate operations in-state. Incentives are based on private investments, business viability, and job creation potential.
- Supportive public policies include an RPS of 30% by 2015, net metering, and commitments to invest $2.99 billion into renewables projects through 2025.
- Focus on education and training for the solar industry is provided through a consortium of New York community colleges and the New York Department of Labor.
- The state is focused on developing an integrated in-state PV manufacturing supply chain.

3.1.1.2 Successes

New York's comprehensive economic development approach has resulted in nearly 1,000 direct new manufacturing jobs and dozens of companies in the state solar supply chain.

- **Globe Specialty Metals** is converting an idle factory in Niagara Falls into a solar-grade silicon manufacturing facility, creating up to 500 new jobs. The New York Power Authority has provided low-cost hydropower to the company in return for the right of first refusal to 20% of the silicon manufacturer's annual production, which can be offered at a reduced cost to downstream PV companies located in-state. This is the first silicon supply incentive offered by a U.S. jurisdiction.

- **Solar Tech Renewables** plans to build a PV module assembly facility that will create 300 jobs. It will purchase solar cells produced by New York-based SpectraWatt for use in their modules.
- **Prism Solar Technologies** has repurposed a former plasma display factory for the manufacture of unique solar concentrator films and modules. The company expects to employ up to 250 people in the next 5 years and has hired many of the laid-off workers from the plasma display facility.

3.1.2 Colorado and the City and County of Denver

3.1.2.1 Program Features

- Incentives and assistance programs offered to manufacturing companies including tax credits, grants, and loans from a strategic fund, and job training and investment tax credits available to small innovative companies
- State and local focus and public policy support for solar and renewable energy projects, increasing the local market for PV products; these include a RPS that was recently expanded to 30% by 2020, net metering policies, and financial assistance for installations
- Proximity to R&D and higher education from the National Renewable Energy Laboratory (NREL) and numerous Colorado Universities that have formed the Colorado Renewable Energy Collaboratory to support and promote renewable energy research
- Existing technology companies in Colorado have provided a base of skilled workers and a technology-oriented manufacturing environment
- Technical job training programs
- The **Metro Denver Economic Development Corporation (Metro Denver EDC)** works with the state and its local partners to help PV products sector companies select sites, expedite permitting, and negotiate state, city, and county incentives and job training assistance programs.

3.1.2.2 Successes

- **PrimeStar Solar**, a manufacturer of thin-film PV modules for large-scale commercial applications, has expanded to a 106,000-square-foot facility to increase production. The Metro Denver EDC assisted with site selection, while the City of Arvada and Jefferson County provided incentives in the form of business personal property tax rebates.
- **SMA Solar**, a large manufacturer of inverters for solar power systems, has developed a manufacturing facility in Denver that will initially employ 300, with potential to grow to 700. The state offered incentives in the form of tax credits, job training assistance, performance incentives, and enterprise-zone tax credits. The City of Denver has also offered job training, relocation expenses, and site selection services.
- **Abound Solar**, a manufacturer of cadmium telluride (CdTe) thin-film PV modules, received a $400 million loan guarantee from the DOE in 2010 to expand its manufacturing facilities in the Denver metro area.

Colorado Office of Economic Development and International Trade

Phone: (303) 892-3840
Website: http://www.colorado.gov/cs/Satellite/OEDIT/OEDIT/1162927366289

Governor's Energy Office

Phone: (800) 632-6662
Email: geo@state.co.us
Website: http://www.colorado.gov/energy

Metro Denver Economic Development Corporation

Contact: **Laura Brandt**
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Email: laura.brandt@metrodenver.org
Website: http://www.metrodenver.org

- **Ascent Solar**, a manufacturer of thin-film PV modules, opened its new world headquarters in March 2009 in Denver. Ascent will employ 300 people at the 145,000-square-foot plant, with plans to add an additional 200 employees in 2 years.
- The **Solar Technology Accelerator Center** is a facility based in suburban Aurora, Colorado, for the testing of solar products and new innovations. The city of Aurora assisted with the acquisition of land and infrastructure for the center.

3.1.3 New Mexico

3.1.3.1 Program Features

- Green job training programs at state community colleges and incentivized job training programs customized for qualifying companies
- Creation of a governor-backed Green Jobs Cabinet, tasked with developing a statewide strategic plan for clean technology economic development
- The state's **Job Training Incentive Program** reimburses qualified companies for on-the-job and classroom training for creating qualifying jobs. The reimbursements range from 30% to 75% of the employee's wage for up to 1,040 hours. Additionally, specialized classroom training at post-secondary educational institutions is eligible for $1,000 in reimbursement per employee hired through the program
- Numerous highly leveraged tax credits intended to stimulate both the PV products and PV energy generation sectors, such as the **High Wage Jobs Tax Credit**, the **Alternative Energy Product Manufacturers Tax Credit**, and the **Advanced Energy Tax Credits**, the **Renewable Energy Production Tax Credit**, as well as **Industrial Revenue Bonds** to finance new machinery and equipment
- **R&D centers and educational research programs** at Sandia National Laboratories and research universities, such as University of New Mexico, New Mexico Tech, and New Mexico State University all have expertise in technologies at the core of PV products. Close proximity to these permits PV products sector companies to capitalize on breakthrough research while allowing researchers to benefit from industry collaboration
- The **New Mexico Renewable Energy Transmission Authority** is authorized to develop new transmission lines to serve the renewable energy installations in New Mexico, increasing the potential for siting of large-scale solar generating facilities.

New Mexico Energy, Minerals, and Natural Resources Department
Contact: **Craig O'Hare**
Phone: (505) 476-3207
Email: craig.ohare@state.nm.us
Website: http://www.emnrd.state.nm.us/ecmd

New Mexico Economic Development Department
Contact: **Jon Barela, Cabinet Secretary**
Phone: (505) 827-0300
Website: http://www.goNM.biz

Albuquerque Economic Development
Contact: **Debra Inman**
Phone: (505) 246-6200
Email: dinman@abq.org
Website: http://www.abq.org

3.1.3.2 Successes

- **SCHOTTSolar** has completed a manufacturing facility in Albuquerque to produce PV modules and receivers for concentrating PV solar power plants. The 200,000-square-foot facility employs 325 workers.
- In a joint venture between Germany-based Fraunhofer, Canada-based CSA Group, and Germany's VDE Testing and Certification Institute, the **CFV Solar Test Laboratory** will provide testing services for the certification of solar products in North America and internationally.
- Established New Mexico solar companies, including **Emcore**, **UniRac**, **Array Technologies**, **Qnuru**, and **Zomeworks**, continue to expand in-state operations.

3.1.4 Michigan

3.1.4.1 Program Features

- Highly leveraged pre-existing economic assests, such as a skilled manufacturing workforce and existing supply chain and manufacturing infrastructure from the automotive industry
- Investment and commitment to R&D through university and research centers, with a focus on renewables and solar technologies, building on Michigan's significant R&D capacity
- Focus on education and training for the solar industry through the development of the University Research Corridor and investment in job training and retraining programs
- Targeted state and local financial incentives for renewables and solar manufacturing, including:
    - The **NextEnergy** program that provides tax credits and general property tax exemptions for renewables research and manufacturing activities
    - The $109 million **21st Century Investment Fund**, created to leverage private sector investments in new and emerging technology companies
    - Creation of a **Venture Capital and Angels Fund** and **Angel Investment Incentive** tax deduction to help stimulate more early stage investment in technology-based companies
    - State tax credits for "anchor" technology companies that assist in attracting a supply chain facility within 10 miles of the "anchor" facility
    - The designation of **Renewable Energy Renaissance Zones**. Businesses located within these zones receive exemptions from the state business tax, education tax, personal and real property taxes, and local income tax, where applicable. Tax abatements are available for up to 15 years, with a 25% incremental phase-out over the last 3 years.
    - A solar PV-specific tax credit for manufacturing activities or development of PV energy, systems, or technology. The credit is equal to 25% of capital investments in a new facility in a given year, up to $15 million.

3.1.4.2 Successes

- **GlobalWatt.** The state of Michigan approved a performance-based tax credit valued at $14 million over 7 years to encourage GlobalWatt to expand in Michigan. GlobalWatt plans to invest $177 million for c-Si module assembly in Saginaw, creating up to 500 jobs.
- **Hemlock Semiconductor Corporation** plans to invest $1 billion in a new polysilicon manufacturing facility, creating 190 direct jobs. The project is eligible for the Anchor District incentive, $180 million in local incentives, a federal tax credit valued at $141 million, a Community Development Block Grant valued at $6.9 million, and job-training grants valued at $390,000.

Michigan Economic Development Corporation

Email: MEDCservices@michigan.org
Website: http://www.michiganadvantage.org/

- **Clairvoyant Energy Solar Panel Manufacturing, Inc**. plans to invest $856 million at the former Ford Wixom Assembly Plant to manufacture thin-film PV modules. The project is expected to create over 750 direct jobs over the next 5 years and 4,600 indirect jobs.
- **United Solar Ovonic (UNI-SOLAR)** thin-film PV manufacturer has developed four manufacturing facilities in Michigan and is considering a fifth.
- **Suniva** has received a U.S. Department of Energy loan guarantee to construct a solar cell plant, in addition to approval for a PV Michigan Business Tax Credit of $25 million. Suniva's capacity expansion will create up to 500 direct jobs over the next 5 years.

3.1.5 Oregon

3.1.5.1 Program Features

> **Business Oregon**
>
> ***Website***: http://www.oregon4biz.com
>
> **Oregon Department of Energy**
>
> ***Email***: Matt.Hale@state.or.us
> ***Websites***: http://www.oregon.gov/ENERGY
> http://www.oregon.gov/DOR/

- Advantageous pre-existing economic assets, including low electricity rates, an attractive corporate tax structure, and proximity to a semiconductor industry providing a trained workforce, a valuable supply chain, and existing manufacturing infrastructure
- A supportive policy environment, including an RPS of 25% by 2025, as well as local programs, such as feed-in tariffs and community solar programs, that incentivize the installation of solar PV systems
- A generous **Business Energy Tax Credit (BETC)** equal to 50% of the incurred capital investment costs for eligible renewable energy manufacturing activities, up to $40 million for each phase of development. The credit features a transfer provision, allowing financing partners to monetize the credit to produce upfront investment capital. Projects are subject to a $300 million cap.
- A package-based economic development approach that pairs the BETC, property tax abatements, certified "shovel-ready" sites, and other financial incentives to drive rapid project development.

3.1.5.2 Successes

- **SANYO Solar** opened an $80 million, 130,000-square-foot silicon ingot manufacturing facility in Salem, Oregon. The facility created an estimated 150 new jobs, with an average salary and benefit package of $50,000 per employee and an estimated annual payroll of $8.6 million. The new manufacturing facility is located within the Salem Renewable Energy and Technology Park, an economic development zone designated by the city of Salem for renewable energy companies. Thanks to state pre-certification, SANYO was able to bypass any permitting and regulatory siting requirements, and also received tax abatements on construction and equipment.
- **Solar World**, a German manufacturer of solar wafers, cells, and PV modules, acquired a former semiconductor manufacturing facility in Hillsboro in 2009, where it employs 500 workers, with an estimated workforce of 1,000 employees and a 500-MW production capacity by 2011.
- **Solaicx**, a manufacturer of monocrystalline silicon ingots and wafers in Portland, Oregon, employs 80 workers.
- **Solexant**, a thin-film PV manufacturer, has announced plans to construct a new facility in Gresham, Oregon, employing 170 workers and eventually growing to 1,000.
- **PV Powered**, a manufacturer of inverters, employs nearly 100 workers.

3.1.6 Tennessee

3.1.6.1 Program Features

- A comprehensive **Volunteer State Solar Initiative**, funded in part through $62.5 million in ARRA funding, to increase the number of in-state PV installations and to bolster PV research and development efforts
- The **Tennessee Solar Institute**, created under the Volunteer State Solar Initiative, leverages the resources of the University of Tennessee and Oak Ridge National Laboratory to coordinate solar PV research and development and to administer two grant programs through its Solar Opportunity Fund
- Relatively low-cost electricity, economic development resources, and incentive programs available through the Tennessee Valley Authority (TVA)
  - The TVA's **Generation Partners Program** creates a 10-year production-based incentive for residential and commercial installations of qualified renewable generation systems less than 200 kW. Its **Midsized Renewable Standard Offer** program provides standard offtake rates for systems between 200 kW and 20 MW.

State of Tennessee Energy Policy Office

Phone: (800) 342-1340 or (615) 741-2994

Tennessee Valley Authority Economic Development

Phone: (615) 232-6225
Email: econdev@tva.com

Tennessee Department of Economic & Community Development Energy Division

Phone: (615) 741-2994
Fax: (615) 741-5070

Tennessee Valley Authority

Phone: (865) 632-2101
Email: tvainfo@tva.com
Website: http://www.energyright.com/

Tennessee Solar Institute

Phone: (866) SOL-AR90
Email: solar@tennessee.edu
Website: http://solar.tennessee.edu

- An aggressive financial incentives strategy that includes:
  - A **Jobs Tax Super Credit** that offsets 100% of franchise and excise (F&E) tax liability for up to 20 years for capital-intensive projects investing over $100 million and creating at least 100 jobs
  - An **Integrated Supplier and Customer Tax Credit** that provides Super Credit tax status to suppliers and customers that locate near a large "anchor" project
  - A **Green Energy Tax Credit** for certified green energy supply chain manufacturers, which provides a F&E tax credit for the differential cost to purchase green energy
  - A **Carbon Charge Tax Credit** allows for a refundable credit for any future carbon charge, whether federal or state, imposed on a certified company
  - An **Emerging Industry Tax Credit** and a reduced electricity tax rate of 1.5%.

3.1.6.2 Successes

- **Hemlock Semiconductor Corporation** is constructing a large polysilicon manufacturing facility that will create up to 500 new jobs.

- **Wacker Chemie,** a global German manufacturer of polysilicon, has announced the development of a $1 billion polysilicon plant that will create 500 jobs.
- **Confluence Solar** has announced plans to build a $200 million single crystal ingot manufacturing facility for solar cells that will create up to 250 jobs.
- **Sharp Solar Energy Solutions** has continued to expand its PV manufacturing facility and currently employs over 500.

3.2 PV Energy Generation Sector

When economic developers target the PV energy generation sector, what they are typically targeting are installations and the associated energy, RECs, and, most importantly, direct construction jobs required to install PV systems. The larger and more significant programs often require the financial and public policy support of county and state governments. Following are both city- and state-level economic development program examples from throughout the United States.

3.2.1 New Jersey

New Jersey is second only to California in installed capacity in the United States. With a lower than average amount of solar radiation, New Jersey used policy to encourage installation and drive job growth in the PV energy generation sector.

3.2.1.1 Program Features

- New Jersey's Clean Energy Program, administered through the Office of Clean Energy, is a legislatively mandated initiative of the New Jersey Board of Public Utilities, which provides education, information, and financial incentives for renewable energy systems and energy efficiency measures.
- New Jersey's RPS requires that every utility that provides electricity to residents of New Jersey provide 22.5% of total electricity from renewable sources by 2021.
- The Edison Innovation Clean Energy Manufacturing Fund (CEMF) provides assistance to for-profit entities that manufacture energy efficient and renewable energy products by providing grants and loans. CEMF helps companies become competitive with traditional sources of electric generation.
- Interconnection and net metering standards make it easier for systems to connect to the distribution system and to be compensated for their contribution.
- Solar Loan Program allows residents to take a loan from the utility providers for up to 40% to 60% of capital cost of the PV system. Customers may then repay the loan using solar RECs produced by their system.

Public Information - Renewable Energy Program, New Jersey Board of Public Utilities, Office of Clean Energy

Phone: (866) 657-6278

Website: http://www.njcleanenergy.com/renewable-energy/home/home

Edison Innovation Clean Energy Manufacturing Fund
New Jersey Economic Development Authority

Phone: (866) 534-7789

Email: EdisonCEMF@njeda.com

Website: http://www.njeda.com/

3.2.1.2 Solar Renewable Energy Certificates

The solar REC program is a solar credit trading system and allows electric suppliers to buy certificates in order to meet its solar RPS requirements. The SREC price averages approximately $100 lower per megawatt-hour than the Solar Alternative Compliance Payment during a given year; however, actual prices vary with market demand.

3.2.1.3 Renewable Energy Manufacturing Incentive

The Renewable Energy Manufacturing Incentive program provides rebates for homeowners and businesses who install solar PV system components such as modules, inverters, and racking systems manufactured in New Jersey from certified local manufacturers. Equipment must be made by program-certified manufacturers, which demonstrate at least 50% of the product cost is associated with facilities located in New Jersey.

3.2.2 Ontario, Canada

Ontario, Canada, passed its Green Energy Act in May 2009 with the intent to encourage new investment in renewable energy creating green jobs and economic growth. Goals included creating 50,000 new manufacturing jobs in the first 3 years of the program. The success of this program in creating manufacturing jobs is great evidence of a strong link between incentives on PV energy generation and installations with local content provisions, and PV products manufacturing growth.

3.2.2.1 Program Features

- One of the most aggressive feed-in-tariffs (FIT) in North America
- A domestic content requirement that is tied directly to the FIT which requires projects 10-kW and larger to have 50% domestic product content and projects under 10 kW to have 40%. Both will increase to 60% in 2011
- Renewable Energy Facilitation Office helps companies, developers, communities, and municipalities navigate through the regulatory approvals necessary for starting and completing projects.

Ministry of Energy and Infrastructure

Email: write2us@energy.gov.on.ca

Website: http://www.mei.gov.on.ca/en/energy/renewable/?page=osthi

FIT Program/microFIT Program, Ontario Power Authority

Email: FIT@powerauthority.on.ca

Website: http://fit.powerauthority.on.ca/

Ontario Ministry of Economic Development and Trade

Email: info@edt.gov.on.ca

Website: http://www.ontariocanada.com/ontcan/1medt/en/home_en.jsp

3.2.2.2 Successful Project

Samsung C&T Corporation and Korea Electric Power Corporation agreed to develop and operate solar and wind power projects throughout the province. The plan includes up to 2,000 MW of wind and 500 MW of solar generation capacity. The government attracted the agreement by providing incentives for green energy production. Samsung has agreed to build four local manufacturing plants to meet the requirement for locally-made equipment. The agreement is expected to create 16,000 jobs (direct and indirect) from 2010 to 2015.

3.2.2.3 Status Update

- Due to the very large demand for ground-mounted systems less than 10 kW, the FIT was reduced to $.588 per kilowatt-hour in August 2010. The FIT for roof-mounted systems remains at $.80 per kilowatt-hour.
- Existing Ontario manufacturing companies have expressed concern that use of more expensive green power will increase electricity prices and put the company at a competitive disadvantage, restricting its ability to grow and create jobs in Ontario.
- With the rapid growth in small-scale installations, there is a shortage of trained installers. Training institutions are struggling to grow fast enough to meet demand.

3.2.3 Portland, Oregon

Portland has capitalized on strong state-level incentives by providing local education programs, supporting community-led volume purchasing campaigns, and lowering municipal regulatory barriers to solar installations.

3.2.3.1 Program Features

- Incentives and tax credits from the State of Oregon and Energy Trust of Oregon, which dramatically reduce up-front costs
- Extensive training and educational opportunities, including workshops, tours, and a solar expo
- Strong community-based social marketing effort through Solarize Portland, supported by the local government
- Streamlined electronic permit submittal process.

3.2.3.2 Solarize Portland

Solarize Portland is a community-based, volunteer-run effort, made possible with support from the City of Portland's Bureau of Planning and Sustainability and the Energy Trust of Oregon. The program connects neighbors who want to invest in solar energy systems, provides workshops, and arranges for an approved contractor. Neighbors work together to understand options, and receive volume pricing on the panels and installation.

City of Portland, Bureau of Planning and Sustainability

Phone: (503) 823-7700

Website: http://www.portlandonline.com/bps/index.cfm?c=28534

Solarize Portland

Website: http://www.solarizeportland.org

3.2.3.3 Oregon Pilot Solar Volumetric Incentive Rates & Payments Program

Oregon's Volumetric Incentive program pays system owners for the kilowatt-hours generated over 15 years, at a rate set at the time of enrollment. The pilot program has a cap of 25 MW, spread over 4 years. The first two rounds of enrollment were fully subscribed within minutes of opening.

3.2.4 San Francisco, California

San Francisco's Office of Economic and Workforce Development (OEWD) emphasizes vocational skills training with the city's Green Skills Academy, which targets individual low-income neighborhoods.

San Francisco Office of Economic and Workforce Development

Website: http://www.oewd.org/

TrainGreenSF

Phone: (415) 575- 4556

Email: traingreensf@sfgoodwill.org

3.2.4.1 Program Features

- The training program recruits participants from four of the city's highest-poverty areas.
- The program promotes attainment of job skills to help participants find employment in green industry.
- Participants in San Francisco's GoSolarSF incentive program for installing a PV system must use contractors who employ staff who have completed OEWD training programs.

3.2.4.2 Group Purchase Programs

San Francisco has also had success with group purchase programs. The city's Department of Environment has worked with several local communities to facilitate group purchases. The city has also worked with One Block Off the Grid to organize residential group purchases.

3.2.5 Gainesville, Florida

Gainesville Regional Utilities' (GRU) feed-in tariff program is modeled after Germany's FIT. Space in the program was initially acquired by businesses with plans for large systems, but the program has since been modified to dedicate more kilowatts to smaller residential systems.

3.2.5.1 Program Features

- Residential and commercial systems are eligible for FIT.
- The FIT tariff rate is designed to allow an investor to earn roughly a 5% internal rate of return after taxes and realizing all federal tax benefits.
- GRU purchases power from PV system owners at a set rate over a 20-year contract.
- GRU owns any renewable energy certificates from the energy produced.
- Program limit of 4 MW per calendar year is broken into three classes depending on system size and mounting (roof or ground). For small residential systems, 200 kilowatts are reserved, and 1 MW is reserved for ground-mounted systems.

> **Gainesville Regional Utilities**
>
> ***Website:***
>
> https://www.gru.com/OurCommunity/Environment/GreenEnergy

3.2.5.2 Other Incentives

GRU also offers net metering for PV systems and PV system rebates up to $7,500 based on system size and available sunlight, as well as a solar water heating rebate. Systems that have received these other incentives are not elegible for the FIT.

3.2.6 Salt Lake City, Utah

In 2009 and 2010, Utah went from double “Fs” to double “As” for Intereconnection and Net Metering in the annual *Freeing the Grid* report (Network for New Energy Choices, Vote Solar Initiative, and Interstate Renewable Energy Council 2010). As a direct result of the involvement and educational efforts of the Solar Salt Lake Partnership, Utah was one of only two states to earn two As. Solar Salt Lake partners (in collaboration with NREL and IREC) engaged and educated key decision-makers about best practices for net metering and interconnection and the value of removing barriers to solar energy. In 2008, the state’s legislature revised its net metering policy and in 2009 the Utah Public Service Commission adopted favorable rules for net metering customers. The commission finalized updated Interconnection Standards in 2010, following a 2.5-year docket proceeding.

Utah Clean Energy

Website: http://utahcleanenergy.org/

Rocky Mountain Power Net Metering

***Website*:**
http://www.rockymountainpower.net/env/nmcg.html

Solar Salt Lake Project

Website:
http://utahcleanenergy.org/our_work/solar_salt_lake_project

***SLC Solar Map*:**
http://www.slcgovsolar.com/

In 2010, Utah adopted a bill to enable third-party financing for certain eligible entities. As a result of these successes, Salt Lake County is slated to install one of the largest roof-top solar projects in the nation, taking advantage of third-party financing and improved net metering.

3.2.6.1 Program Features

- Net metering is available to residential systems up to 25 kW and nonresidential systems up to 2 MW.
- Residential and small commercial net metering customers receive kilowatt-hour-for-kilowatt-hour credits for excess generation; the credits roll over month-to-month during the annualized billing period. Large commercial customers are given an option for the value of their excess generation, to better account for demand charges.
- PV system owners retain the renewable energy certificates associated with the power they produce.
- Removal of barriers to third-party financing created opportunity for a 2.6-MW solar PV system on Salt Lake County’s Salt Palace Convention Center.
- An implementation plan for Salt Lake City and Salt Lake County establishes a long-term commitment to solar deployment and facilitates solar adoption in all sectors.
- Education and training is provided for building community, utilities, code officials, real estate and appraisal community, city zoning, historic district commissions, and the general public, other local governments, non-profits, churches, schools, and businesses.

3.2.6.2 Solar Salt Lake Project

The Solar Salt Lake Project, managed by Utah Clean Energy in collaboration with Salt Lake City and Salt Lake County, and funded by DOE’s Solar America Communities, plans to facilitate at least 10 MW or 10,000 new PV systems by 2015. The Solar Salt Lake implementation plan outlines core strategies to achieve this goal.

Bibliography

American Solar Energy Society and Management Information Services, Inc. (2008). *Defining, Estimating, and Forecasting the Renewable Energy and Energy Efficiency Industries in the U.S. and in Colorado*. December. http://www.ases.org/images/stories/ASES/pdfs/CO_Jobs_Final_Report_December2008.pdf. Accessed on September 27, 2010.

Bartlett, J.E.; Margolis, R.M.; and Jennings, C.E. (2009). *The Effects of the Financial Crisis on Photovoltaics: An Analysis of Changes in Market Forecasts from 2008 to 2009*. National Renewable Energy Laboratory Technical Report, NREL/TP-6A2-46713. http://www.nrel.gov/docs/fy10osti/46713.pdf. Accessed on September 28, 2010.

Clean Energy Group and Smart Power. (2009). *Smart Solar Marketing Strategies: Clean Energy State Program Guide*. August. http://www.cleanegroup.org/Reports/CEG_Solar_Marketing_Report_August2009.pdf. Accessed on October 14, 2010.

Environmental Defense Fund and Ella Baker Center for Human Rights. (2008). *Green Jobs Guidebook: Employment Opportunities in the New Clean Economy.* http://www.edf.org/cagreenjobs. Accessed on September 28, 2010.

Friedman, B. (2009). *NREL PV Jobs/Labor Intensity Project: New Ideas in Educating a Workforce in Renewable Energy and Energy Efficiency*. November 19. http://irecusa.org/wp-content/uploads/2009/11/Friedman.pdf. Accessed on September 27, 2010.

Friedman, B./ (2010a). National Renewable Energy Laboratory Senior Energy Analyst. Personal communication with Amy Maule/CH2M HILL. July 14.

Friedman, B./ (2010b). Personal communication with Amy Maule/CH2M HILL. August 16.

Glass Association of North America, Flat Glass Manufacturing Division. (date?). *Float Glass Manufacturing Process Video*. http://www.glasswebsite.com/video/fgmd.asp. Accessed on October 27, 2010.

Global Insight, Inc. (2008). *U.S. Metro Economies, Current and Potential Green Jobs in the U.S. Economy*. October. http://www.usmayors.org/pressreleases/uploads/greenjobsreport.pdf. Accessed on September 27, 2010.

Goldberg, M.; Cliburn, J.K. (2011). *Economic Impacts from the Boulder County, Colorado ClimateSmart Loan Program using Property Assessed Clean Energy Financing.* MGA & Associates. January. Soon to be available on the NREL publications database.

Greenpeace and European Photovoltaic Industry Association. (2007). *Solar Generation IV – 2007: Solar electricity for over one billion people and two million jobs by 2020*. http://www.greenpeace.org/international/en/publications/reports/solar-generation-iv/. Accessed on September 28, 2010.

Interstate Renewable Energy Council. (2010). *Education Information*. http://irecusa.org/irec-programs/workforce-development/education-information/. Accessed on November 30, 2010.

Jordan, P./Green LMI. (2010). Personal Communication with Amy Maule/CH2M HILL. August 19.

Kubert, C.; Sinclair, M. (2009). *Distributed Renewable Energy Finance and Policy Toolkit.* Clean Energy States Alliance. December. http://www.cleanenergystates.org/Publications/cesa-financial_Toolkit_Dec2009.pdf. Accessed on September 28, 2010.

Lantz, E.; Tegen, S. (2009). *NREL Response to the Report Study of the Effects on Employment of Public Aid to Renewable Energy Sources from King Juan Carlos University (Spain).* White Paper, NREL/TP-6A2-46261. http://www.nrel.gov/docs/fy09osti/46261.pdf. Accessed on September 27, 2010.

Mehta, S. (2009). *PV Manufacturing in the United States: Market Outlook, Incentives and Supply Chain Opportunities*. Executive Summary. GTM Research. September.

Network for New Energy Choices, Vote Solar Initiative, and Interstate Renewable Energy Council. (2010). *Freeing the Grid: Best Practices in State Net Metering Policies and Interconnection Procedures*. http://www.newenergychoices.org/uploads/FreeingTheGrid2010.pdf. Accessed on December 9, 2010.

North Carolina State University. (2010). *Database of State Incentives for Renewables & Efficiency: Summary Maps*. http://www.dsireusa.org/summarymaps/index.cfm?ee=1&RE=1. Accessed on September 28, 2010.

O'Rourke, S.; Kim, P.; Polavarapu, H. (2009). *Solar Photovoltaic Industry: Looking Through the Storm*. Deutsche Bank Securities Inc. January 21.

Roberts, B. (2008a). *Photovoltaic Solar Resource of the United States*. National Renewable Energy Laboratory. http://www.nrel.gov/gis/images/map_pv_national_lo-res.jpg. Accessed on January 31, 2011.

Roberts, B. (2008b). *Wind Resource (50m) of the United States*. National Renewable Energy Laboratory. http://www.nrel.gov/gis/images/map_wind_national_lo-res.jpg. Accessed on January 31, 2011.

Schreiber, D. (2010). *Hot PV Markets in the U.S*. Presented at Intersolar West, San Francisco. July 14.

Sherwood, L. (2009). *U.S. Solar Market Trends 2008*. Interstate Renewable Energy Council. July. http://irecusa.org/fileadmin/user_upload/NationalOutreachDocs/SolarTrendsReports/IREC_Solar_Market_Trends_Report_2008.pdf. Accessed on November 30, 2010.

Solar Energy Industry Association. (2004). *Our Solar Power Future. The US PV Industry Roadmap through 2030 and beyond.*

State of California, Department of Industrial Relations. (2010). *Division of Apprenticeship Standards - California Needs Apprentices in Green & Growing Fields*. http://www.dir.ca.gov/das/DAS_ApprenticesGreenGrowingFields/DAS_ApprenticesGreenGrowingFields.htm. Accessed on September 28, 2010.

State of New Jersey, Department of Labor and Workforce Development. (2010). *Incentives & Training Programs: Apprenticeship Training—Office of Grants Operations*. http://lwd.dol.state.nj.us/labor/employer/training/Apprenticeship.html. Accessed on September 28, 2010.

Sterzinger, G.; Svrcek, M. (2005). *Solar PV Development: Location of Economic Activity*. Renewable Energy Policy Project, Technical Report. January. http://www.repp.org/Solar_PV_Dev.htm. Accessed on September 28, 2010.

U.S. Department of Energy, Energy Efficiency and Renewable Energy. (2010). *2008 Solar Technologies Market Report.* DOE/GO-102010-2867. January. http://www1.eere.energy.gov/solar/pdfs/46025.pdf. Accessed on October 28, 2010.

U.S. Department of Energy, Energy Efficiency and Renewable Energy and Solar America Cities. (2009). *Solar Powering Your Community: A Guide for Local Governments*. July. http://www.solaramericacities.energy.gov/resources/guide_for_local_governments/. Accessed on October 14, 2010.

U.S. Department of Energy, National Renewable Energy Laboratory. (2005). *Best Research-Cell Efficiencies*. http://www.nrel.gov/pv/thin_film/docs/kaz_best_research_cells.ppt. Accessed on September 28, 2010.

U.S. Department of Energy, National Renewable Energy Laboratory. (2009). *The Effects of the Financial Crisis on Photovoltaics: An Analysis of Changes in Market Forecasts from 2008-2009*. http://www.nrel.gov/docs/fy10osti/46713.pdf. Accessed on September 28, 2010.

U.S. Department of Energy, National Renewable Energy Laboratory. (2010). *Dynamic Maps, GIS Data, & Analysis Tools: Solar Maps*. http://www.nrel.gov/gis/solar.html. Accessed on November 30, 2010.

U.S. Department of Energy, National Renewable Energy Laboratory. (2010a). *JEDI: Jobs and Economic Development Impact Models*. http://www.nrel.gov/analysis/jedi/. Accessed on September 28, 2010.

U.S. Department of Energy, National Renewable Energy Laboratory. (2010b). Photographic Information eXchange. http://www.nrel.gov/data/pix/. Accessed on October 19, 2010.

U.S. Energy Information Administration. (2010). *Energy Outlook 2010, High and Low Economic Growth Tables*. Report #: DOE/EIA-0383(2010). http://www.eia.gov/oiaf/ieo/index.html. Accessed on September 28, 2010.

Wei, M.; Patadia, S.; Kammen, D.M. (2010). "Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the U.S.?" *Energy Policy*, 38 (2010) 991-931. http://rael.berkeley.edu/node/585. Accessed on December 2, 2010.

Wiser, R.; Barbose, G.;Peterman, C. (2009). *Tracking the Sun, The Installed Cost of Photovoltaics in the U.S. from 1998-2007*. LBNL-1516E. February 27. http://eetd.lbl.gov/ea/ems/reports/lbnl-1516e.pdf. Accessed on September 28, 2010.

Worldwatch Institute. (2008). *Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World*. September. http://www.unep.org/labour_environment/features/greenjobs.asp. Accessed on September 27, 2010.

Appendix A: Recommended Resources

The following references and resources provide further information on topics addressed in this report that may be relevant to communities' economic development efforts.

Economic Development Tools

- The U.S. Department of Energy's *Solar Powering Your Community: A Guide for Local Governments* (2009) is a great resource, covering best practices and lessons learned from the original 25 Solar America Communities. These examples are available as an easy-to-use online resource titled Solar Powering Your Community: A Guide for Local Governments. The guide describes many of the country's most innovative solar programs and policies. It also provides implementation tips and example case studies that are focused mostly on growing PV markets.
- GTM Research published a report titled *PV Manufacturing in the United States: Market Outlook, Incentives and Supply Chain Opportunities* (Mehta 2009). The report offers an overview and forecast of the PV manufacturing industry, as well as in-depth analysis of the location of PV manufacturing facilities and the types, availability, and success of manufacturing incentives.
- Clean Energy Group has published two guides to assist with local renewable energy efforts. Both are aimed at states rather than cities, but the material described will be helpful to cities as well. Both focus more heavily on the PV energy generation sector, but they will be useful in regard to both sectors.
    - *Smart Solar Marketing Strategies: Clean Energy State Program Guide* (Clean Energy Group and Smart Power 2009) provides information about marketing clean energy programs. The guide begins with a general introduction to marketing principles. Six marketing strategies are then described, with examples of successful implementation and action plans for each strategy. The report concludes with advice on how to begin developing a customized marketing plan.
    - The *Distributed Renewable Energy Finance and Policy Toolkit* (Kubert and Sinclair 2009) provides detailed descriptions of types of financial support that public benefit funds can provide to encourage the adoption of renewable energy technologies. The report describes each financing tool, outlines important strengths and weaknesses of the tool, lists best practices for successful implementation, and gives one or more examples of where the tool has been used.
- *Database of State Incentives for Renewables & Efficiency* (DSIRE) (North Carolina State University 2010) is a website funded by the U.S. Department of Energy and maintained by the North Carolina Solar Center and the Interstate Renewable Energy Council. DSIRE includes a complete listing of all renewable energy and efficiency incentives by state (including state-, local-, and utility-funded incentive programs), maps, tables, and a publications library. DSIRE is an excellent resource for in-depth research into the incentive programs in other states.

Employment Forecasts

Researchers at DOE, national and international agencies, and universities are studying the potential jobs associated with renewable energy in general and the PV products sector specifically. The following are a few especially relevant resources that will provide greater insight into the potential for solar PV job creation in the years to come.

- NREL's Jobs and Economic Development Impact (JEDI) model allows users to analyze the job and economic impact of power generation products, including biofuels, coal, concentrating solar power, natural gas, and wind. The user inputs such variables as location, year, type, size, and installed cost. The output is a summary of jobs resulting from both construction of the facility and long-term operation. Earnings and economic impact are included in the summary (http://www.nrel.gov/analysis/jedi/).
- NREL is also working on a forthcoming labor market analysis to support DOE's SunShot Initiative and to improve the JEDI model with respect to PV. The study includes primary-source research targeting installers and construction firms to identify workforce skills seen as lacking in the current labor pools (Friedman 2010a).
- The Solar Foundation's "National Solar Jobs Census 2010" targeted the remaining portions of the PV value chain. The study measured solar jobs in R&D, professional services, manufacturing, and wholesale trade, and provides insight into types of jobs, location, and growth potential. Secondary data for this study were derived from economic models based on Standard Industrial Classification (SIC) codes, while primary research was conducted through interviews of human resources personnel at various firms (Jordan/Green LMI 2010).

Appendix B: Understanding the Photovoltaic Products Sector

Polysilicon

Polysilicon manufacturing is a large, heavy-industrial chemical operation activity that is not suitable for most U.S. locations. It is a highly capital- and engineering-intensive activity, and it requires the investment of hundreds of millions of U.S. dollars. A nominal 5,000-ton annual capacity (roughly equivalent to 500 MW of c-Si panels per year) would require a construction period of 2 years, a long ramp-up period, hundreds of acres, and electrical connections in the tens of megawatts. Polysilicon manufacturing also benefits from "over-the-fence" access and proximity to other chemical plants for chlorine or caustic soda. Because they are so energy intensive, polysilicon plants often choose regions with exceptionally cheap power prices and low power price escalation assurances. Figure 12 is a photograph of solar-grade polysilicon feedstock.

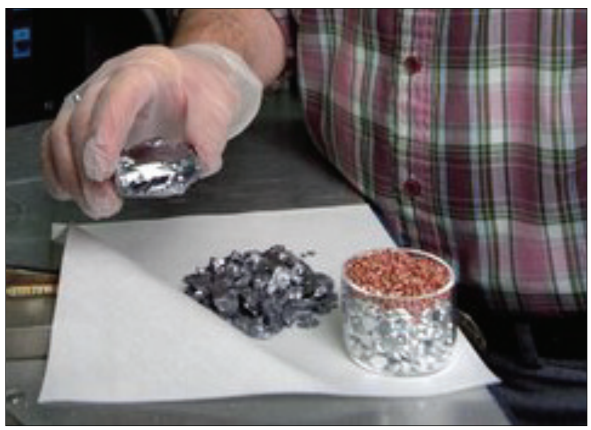

Photo by Warren Gretz, NREL/PIX 08791

Figure 12. Solar-grade polysilicon feedstock.

A handful of major manufacturers produce almost all of the U.S.-made polysilicon. The leading producers are:

- Hemlock Semiconductor (United States)
- MEMC (United States)
- Mitsubishi (Japan and the United States)
- Renewable Energy Corporation (REC) (Norway)
- Tokuyama Corporation (Japan)
- Wacker-Chemie AG (Germany).

Solar Glass

Solar glass manufacturing is a heavy-industrial operation. Solar glass manufacturing plants are typically capable of 200–600 tons of production per day, depending on process type and application—roughly equivalent to 700–1,200 MW of solar panels per year. Glass plants typically require 5–30 acres, and can require up to a few hundred million U.S. dollars in investment capital. Glass plants are also very energy intensive, burning natural gas to provide heat for production operations. Energy and raw materials make up more than 70% of the glass manufacturing cost of goods sold.

Because they are energy intensive and have large volume and weight of incoming materials and outgoing glass, glass plants often choose regions that have cheap energy prices and are closely connected to customers by rail.

Many container-glass and architectural-glass companies also produce solar glass, but they typically do so on different process equipment.

Bulk Chemicals and Gases

High-purity bulk gases like nitrogen, oxygen, helium, hydrogen, and argon are raw materials consumed later in the PV manufacturing process, often in large enough volumes to require on-site generation. Although these gases are not particularly hazardous or toxic, on-site generation equipment of these bulk gases can require significant site area and electric power. Gas plant equipment is often one of the tallest structures in a PV product manufacturing facility.

Bulk chemicals like hydrochloric, hydrofluoric, or nitric acid, as well as cleaning agents like potassium or sodium hydroxide, and surfactants also are often required in manufacturing PV products. A number of chemical companies supply these high-purity industrial chemicals.

Polysilicon, solar glass, and chemical and gas manufacturing have high barriers to entry due to high capital investment, large economies of scale, and mature technology and process expertise. These factors have kept the number of competitors for these markets in the United States low. A few major players in each major segment are competing in the U.S. market, and opportunities are somewhat limited to well-funded players with new differentiating technologies, or to expansions of existing players.

The Heart of the PV Products Sector: Ingot Preparation and Wafering, Cell Manufacturing, and Module Assembly

Most PV module production is based on c-Si materials and technology. The major manufacturing operations discussed here are for the c-Si strategy. Because of the growth in thin-film panels, however, information about thin film has been added where the panels are notably different.

c-Si Ingot Preparation and Wafer Slicing

In this process, a silicon ingot is grown from polysilicon and sliced into wafers. Ingot preparation and wafer slicing are typically done in separate buildings on the same site.

A nominal plant processes about 1 million kilograms (kg) of polysilicon per year (roughly 100 MW of annual capacity) and has typical investment requirements of about $50 million, although this can vary considerably depending on individual company strategies. Sites for ingot preparation and wafer slicing are typically greater than 5 acres and can be tens of acres. Ingot and wafer operations can require more than a 10-MW electrical connection, as well as large water and wastewater connections. Air emissions can include significant amounts of nitrogen oxide and particulates.

Ingot preparation and wafer slicing are not a distinct business for thin-film PV panels.

Cell Manufacturing

The second major step in the production of a PV panel is the transformation of a silicon wafer into a PV device or cell. This process typically takes place in a single building. Cell manufacturing processes have many variations that are tightly guarded by individual manufacturing companies as they define the performance of the PV product. For this reason, PV cell manufacturing companies hold a significant portion of the PV industry's intellectual property.

A nominal cell manufacturing plant processes 120 MW of cells per year, requires tens of acres, and has a typical investment requirement of $40 million, although this can vary considerably depending on individual company strategies. Figure 13 shows a typical c-Si PV cell and part of an automated cell manufacturing line.

Cell manufacturing is usually not a distinct business for thin-film PV panels.

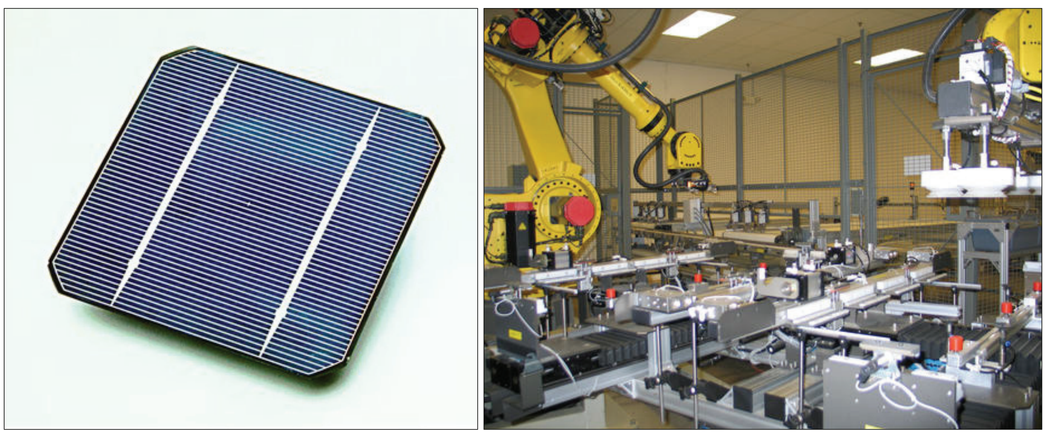

Photo by Rick Mitchell/PIX 04065 Photo by Shell Solar/PIX 13380

Figure 13. Shell Solar Industries' crystalline silicon solar cell (left) and manufacturing robots (right).

Module Assembly

The final step in manufacturing a PV panel is module assembly, the process of connecting PV cells electrically and mechanically and then packaging them into usable PV panels (Figure 14). Typical packaging includes lamination and framing using glass and aluminum as support structures. Module assembly typically takes place in a single building and has relatively low infrastructure requirements.

A nominal module assembly manufacturing operation plant that processes 120 MW of cells per year would require tens of acres of site area and have an investment requirement of about $40 million, although this can vary considerably depending on individual company strategies.

In the United States, module assembly operations frequently are based on turn-key equipment provided by one of a few equipment companies. This equipment is generally highly automated—a different business model than is frequently used in Asia, where many operations are done by hand.

Module assembly is not a distinct step in the process of manufacturing thin-film PV panels.

Photo by BP Solar/PIX 13459

Figure 14. BP Solar's crystalline silicon modules for residential and commercial buildings

Thin Film and Other PV Panel Manufacturing Approaches

Crystalline silicon PV, which accounted for approximately 85% of PV module production in 2009, is not the only available manufacturing technology.

Thin-film PV typically uses thin layers of semiconductor materials like amorphous silicon, copper indium diselenide (CIS), copper indium gallium diselenide (CIGS), or cadmium telluride (CdTe). These PV module materials and manufacturing technologies produce PV modules that generally have lower efficiencies, but also lower cost per watt, than c-Si PV modules. Thin-film processes typically are more engineering-intensive and complex than c-Si processes. This is because there are fewer turn-key providers of manufacturing equipment, there is less industry experience, and the existing experience is split among the three major materials.

Thin-film manufacturing processes, unlike c-Si, are not easily split into multiple factories, producing cells in one location and modules in another. Because thin-film manufacturing operations generally span multiple materials and processes, they can also span a wide range of site selection or economic development criteria. In general, however, thin-film manufacturing is more equipment- and automation-intensive than are c-Si processes, and more focused than c-Si on intellectual property and research and development (R&D). Figure 15 shows a flexible thin-film product, as well as roll-to-roll deposition equipment. Flexible thin film is not the dominant thin-film PV product (most thin-film PV modules look very similar to c-Si modules).

Photo by UNI-SOLAR/PIX 15779 Photo by Global Solar Energy/PIX 13415

Figure 15. Thin-film laminate at UNI-SOLAR (left) and roll-to-roll deposition equipment at Global Solar Energy (right).

Inverters

Inverters are electrical products that convert the direct current (DC) electric output of solar modules into alternating current (AC) electricity. Grid-tied inverters, the market share leader, also integrate (characteristics such as frequency and phase) the energy into the existing electrical grid. PV inverters are typically divided into stand-alone, grid-tied, or battery-backup types, with some crossover. In the United States, however, grid-tied systems are the dominant type. Grid-tied inverters typically are designed specifically for residential, commercial, or utility applications.

U.S. inverter manufacturing businesses typically have a wide range of business models, manufacturing various components locally or outsourcing a range of components. U.S. inverter assembly facilities do not have especially high needs for any specific utility, specialized workforce, or other economic development requirement. They can also scale up and down relatively easily.

There are dozens of U.S. inverter companies, many specializing in specific technologies, at specific scales, or in serving local markets.

Photo by U.S. Postal Service/PIX 11016

Figure 16. Commercial-scale PV system inverter.

Racking

Racking product companies typically produce support structures for fixed-tilt or tracking PV installations. Racking systems can also be specialized according to their intended use in ground or roof attachment.

Racking structures are primarily metal, based on standard angles, pipe, and flat steel and aluminum bar products, and assembled through standard metalworking processes like cutting, drilling, grinding, welding, and fastening. Racking also serves to route wiring and provide some grounding connections. The tracking system can include electromechanical assembly components.

Racking product manufacturing facilities vary widely, but generally they do not require large infrastructure connections. They are similar in appearance to warehouse or industrial space.

Figure 17 shows the physical structure of a two-axis PV tracking system holding eight PV modules. This tracker includes sensors and electromechanical assemblies, and it is one of the most complex examples of PV racking products.

Photo by SunPower/PIX 14598

Figure 17. PV panels on a single-axis tracking array.

Site Selection Criteria

Land and Buildings

Land and building requirements for manufacturing facilities vary greatly depending on product type and technology. Generally, land needs to be:

- Able to meet the development schedule, with required permits, approvals, title transfers, environmental studies, and utilities/infrastructure in place, and low development fees
- Appropriately zoned for proposed operating uses, with no code restrictions or easements that would affect operations; near compatible surrounding uses
- Flat in a square or rectangular configuration (ideally)
- Close to good transportation, including highways (and, in some cases, rail) for the shipping and receiving of large products.

Different manufacturing processes require different types of buildings. Sometimes companies can take advantage of existing buildings to reduce schedule and startup costs. In most cases, it is the costs associated with infrastructure and permits (not the structure) that create advantages to building reuse.

Typical building requirements where building reuse is possible include the following:

- Building size requirements vary greatly by segment and can range from tens of thousands of square feet to several hundred thousand square feet in a single building.
- Buildings generally should be single story; if multiple story, they should have good connectivity between floors. Clear interior heights are driven by equipment requirements, but they can be above 20 feet. Floors must be able to support heavy industrial loads, without column spacing less than 30 feet.
- Existing infrastructure should be capable of meeting electrical, water and wastewater, and communication requirements, as well as occupancy codes and permits.
- Buildings should have no unmitigated hazardous material use or history.
- Buildings should have good truck access and adequate truck loading and parking spaces.

Utilities

Utility requirements of the PV products sector vary by product and technology. Typical utility requirements include:

- **Electricity.** Requirements range from conventional light industry loads to tens of megawatts for integrated panel manufacturing, glass, or polysilicon production.
- **Water and wastewater.** Polysilicon, silicon ingot preparation and wafer slicing, and cell manufacturing can require more than 1 million gallons of water per day. Many manufacturing processes use process chemicals and gases that may not meet discharge standards for existing wastewater treatment facilities.
- **Natural gas.** Standard industrial gas connection sizes, with the exception of solar glass manufacturing.
- **Communications.** Standard commercial voice and data based on office staff counts.

Available utilities should satisfy these criteria:

- **Competitive cost.** The cost of electricity is critical for large users such as polysilicon, solar glass, ingot preparation and wafer slicing, and cell manufacturing. Electrical costs at or below $.06 to $.08 per kWh (and, in extreme cases, as low as $.03 to $.04 per kWh) are ideal, and can include long-term contracts at fixed prices. Other segments of the PV industry have much lower electrical requirements and can tolerate higher electricity costs.
- **Sufficient supply.** Overall capacity and connections to the site without significant cost to the user, and ability to negotiate cost-sharing arrangements quickly.
- **Availability within the project schedule.** If system improvements are required, the area must be able to meet milestones and deadlines in the facility startup schedule.
- **Reliable and knowledgeable providers.** Local utilities should be familiar with the particular business and have experience in dealing with large or unique users.

Operating Cost Environment

PV products companies must reduce costs continually to remain competitive. The primary components of operating costs for PV products business vary. Generic c-Si and thin-film module manufacturing operating costs are shown in Tables 9 and 10, respectively. In the tables below, the sales price for thin film is set at 90% of the sales price of c-Si. While this is not universally true, it is a reasonable assumption that allows a comparison of the major cost categories of each manufacturing process.

Table 9. Crystalline Silicon PV Generic Costs

Crystalline Silicon PV Manufacturing - 100 MW	Total CAPEX ($)	Total Annual OPEX ($)	$/Watt	% of Cost/Watt
Ingot Preparation and Wafering:				
Factory Capital Investment (Deprec. Over 7 yrs)	$ 60,000,000	$ 8,900,00	$ 0.09	4%
Polysilicon		46,200,000	0.46	23%
Wire Saw Materials		9,800,00	0.10	5%
Ingot Casting Materials		7,300,000	0.07	4%
Labor		6,100,000	0.06	3%
Other Materials and Overhead Costs		8,800,000	0.09	4%
Ingot Preparation and Wafering Costs		87,100,00	0.87	44%
Cell Manufacturing:				
Factory Capital Investment (Deprec. Over 7 yrs)	40,000,000	5,600,000	0.06	3%
Labor		7,200,000	0.07	4%
Utilities		5,000,000	0.05	2%
Overhead Costs		10,808,000	0.10	5%
Materials (Spray on Etches, Screen Printing Inks, etc.)		12,000,000	0.12	6%
Cell Costs		39,880,000	0.40	20%
Module Assembly:				
Factory Capital Investment (Deprec. Over 7 yrs)	23,000,000	3,220,000	0.03	2%
Labor		4,000,000	0.04	2%
Overhead Costs		4,000,000	0.04	2%
Materials (Glass, EVA, Tedlar, Junction Box, Frame)		40,000,000	0.40	20%
Module Costs		51,220,000	0.51	26%
Total Annual Manufacturing Costs		178,200,000	1.78	0.89010989%
Gross Margin			0.22	11%
Total Panel Sales Price			**2.00**	**100%**

CAPEX = Capital expenditures
OPEX = Operating expenditures

Table 10. Thin-Film PV Generic Costs

Thin Film (a-Si base) PV Manufacturing - 65 MW	Total CAPEX ($)	Total Annual OPEX ($)	$/Watt	% of Cost/Watt
Building (Depreciation over 15 years)	$ 50,000,000	$ 3,333,333	$ 0.05	3%
Tools (Depreciation over 7 years)	140,000,000	20,000,000	0.31	15%
Glass (Front and Back)		21,962,000	0.34	17%
Gasses and Chemicals		13,206,000	0.20	10%
Maintenance		9,391,000	0.14	7%
Utilities		9,000,000	0.14	7%
Framing Materials		8,000,000	0.12	6%
Labor		6,000,000	0.09	5%
Other Overhead		12,000,000	0.18	9%
Total Annual Manufacturing Costs		102,892,333	1.58	79%
Gross Margin			0.22	12%
Total Panel Sales Price			**1.80**	**100%**

CAPEX = Capital expenditures
OPEX = Operating expenditures

Of the generic costs in Tables 9 and 10, the line items that vary the most by location are land and building costs, utilities, labor costs, and other overhead.

Tax structures and incentives vary greatly by location and can affect land and building costs and other overhead. Most state and local tax systems include a combination of income, sales, and property taxes that can affect each industry segment differently. There is no perfect tax system for all businesses, so most locations provide credits and other incentives to help overcome negative impacts to targeted companies. Major considerations can be how sales are apportioned for income tax purposes, whether there is a personal property tax, and how tax credits, abatements, and other incentives are applied.

Utilities vary significantly across the country according to power generation sources, utility structure, and taxes.

Schedule Considerations

Delivery contracts, incentives, and other deadlines make manufacturing project schedules important. Many PV product manufacturing facilities are large and require equipment that can have long lead times or build out periods. To meet these schedules, PV products sector companies look for the following:

- Land and buildings that are "shovel ready" (with clear ownership, immediate availability at a listed price, and a transferable title) and that meet infrastructure requirements
- Multiple appropriate sites and alternatives if the preferred site or facility falls through
- Zoning, permits, and other regulatory and environmental approvals that are complete or in progress, funded, and approved in writing

- Required infrastructure that is ready or in progress, funded, and approved in writing (infrastructure primarily includes electricity, water and wastewater, and transportation)
- Staff members who are experienced in meeting schedules for similar projects, as well as experienced with governmental processes for occupancy codes, hazardous gases and chemicals, air emissions, and special building requirements
- Staff members who are experienced in writing a memorandum of understanding that defines a clear process for receiving incentives and development assistance
- A facility engineering, procurement, and construction company that has a successful local history and on-schedule, within-budget experience with similar facilities.

Transportation and Proximity to End Markets

PV products sector companies often are very shipping-intensive. Easy transportation access is important, especially for segments with large economies of scale.

Proximity to end-user markets in the PV products sector has not been a critical factor to date, but it is becoming more important as transportation costs increase. The products segment most influenced by proximity to end markets is module assembly.

Technology Support, Higher Education, and Research

Proximity to existing technology companies, higher education programs, and related research is a site selection criterion for PV products sector businesses whose advantage is in the intellectual property and not only the low manufacturing cost. Companies in the early stages of development will benefit the most from access to these resources. For these companies, the following are attractive area assets:

- **An existing cluster of similar businesses.** Clusters provide companies with an environment that includes existing technology R&D, technology workers, and focused education and training.
- **A business culture of innovation.** Product companies like to have access to other researchers and institutions to drive product development.
- **Access to local universities.** Universities provide science and engineering expertise that is important to manufacturing companies. They also supply employees, continuing education, and faculty members who may collaborate on research.

In addition to providing a supportive and attractive environment for growing or recruiting existing companies, these area characteristics create an environment for the spinoff and creation of new PV product companies.

Workforce and Training

Workforce requirements vary by segment. For most PV products sector businesses, only a small number of staff members are engineering or management professionals. Most workers are skilled or semi-skilled operators with experience in manufacturing, such as the following:

- Equipment operators
- Process technicians

- Maintenance technicians
- Line supervisors.

In addition to an available, trained workforce, PV products sector companies often look for a training system. The majority of PV products sector workers can receive training from community colleges and local technical schools.

Public and Private Support and Policies

Areas that have been successful in attracting PV products sector businesses have created an overall environment that is supportive of the PV industry in general. Although financial incentives are important public commitments, successful economic development strategies have also adopted a more comprehensive approach, including investment in the following:

- A regulatory environment that is supportive, easy to understand, and easy to navigate. This can include:
    - Public offices that understand PV products sector metrics and vocabulary
    - Regulatory processes that are understandable and reasonable
    - The support and encouragement of a local solar market.
- Long-term, visible, and proactive support for the PV products sector and a pro-business climate
- The involvement and support of local electric utilities; utility support and involvement in the form of special rates can be as important as public policy for some segments.
- Special districts and incentives to targeted PV products sector businesses.

Incentives

Successful local incentives target specific segments based on local goals. While federal incentives are critically important, they are available throughout the United States and are not viable regional or local economic development tools.

The most effective local incentives are financial. While incentives are one of the most powerful tools available to economic development groups, incentives alone normally are not enough for a company to make an investment decision. A few of the most common incentives are as follows:

- Cash grants or low-cost financing
- Tax credits, particularly those that can be monetized or passed through
- Tax holidays and abatements
- Free or low-cost land; waiver of development and other fees, and worker training costs; or reduced utility hookup costs
- Funding to participate in R&D partnerships
- Expedited permits and other regulatory processes
- Reduced utility costs

- Off-take agreements (agreements by a public or private entity to purchase a set amount of a PV products sector company's production over a certain period). Often, such an agreement provides the company with an order commitment that can be used to help secure project financing.

Key Lessons about the PV Products Sector

The PV products supply chain includes a variety of different manufacturing processes, each with very distinct requirements from land and energy-intensive chemicals production, from specialized cell manufacturing to less specialized assembly operations and production of inverters and racking. Companies may specialize in one small portion of the supply chain, or combine production steps in a single location.

Communities should understand each product in the supply chain and the requirements of each manufacturing process. It is important to be able to realistically evaluate the resources available in the community against the needs of the manufacturers when deciding what types of PV business to target in an economic development campaign.

Local incentives and improvements should be tailored to the needs of the targeted sectors to emphasize strengths and mitigate weaknesses. Communities should also be aware of other locations that could potentially compete for the same businesses, and monitor incentives and improvements undertaken by these competing areas.

Appendix C: Understanding the Photovoltaic Energy Generation Sector

Value Chain—from Components to Kilowatt-Hours

The following PV energy generation segments typically are increasingly distinguished at larger scales, specifically at the commercial and utility scales, where larger project budgets and complexity require specialized expertise. At residential scales, there are generally only a few project participants, most commonly the land or building owner and the installer/system integrator or system integrator in partnership with a third-party financier/owner, as illustrated in Figure 9.

As economic developers focus on developing attractive local PV installation markets to create local jobs, it is important to note in the following supply chain that the two major segments with the largest jobs impacts are the segments most directly involved in PV system installation:

- System or technology integration
- Engineering, procurement, and construction.

System or Technology Integrators

System integration is the process of intelligently matching and combining system components into an installation that is physically, aesthetically, and electrically designed to perform well at a given site.

System integrators must know the range of products, the performance specifications, and the requirements of the project site. Their services attempt to minimize the project's cost, maximize its energy production, and satisfy its technical requirements.

System integrators' facility needs are neither utility-intensive nor complex, and they typically use existing buildings. Some system integrators may require space for testing and simulation, training, or warehousing. System integration companies can be small and local, or large and national. At residential and small commercial scales, system integrators often do installation themselves. At larger commercial and utility scales, system integrators typically are not involved in installation labor.

Project Developers

For large commercial- and utility-scale projects, project developers find and create PV project opportunities. They then bring together the required partners to perform the work, often providing initial and high-risk capital. PV project developers typically hire service providers to propose and evaluate sites; model system performance; conduct environmental, land use, and interconnection studies and apply for permits; negotiate power purchase agreements (PPAs) with the utility; negotiate incentives with economic development groups; lobby local residents; and hire construction and operation providers.

Most important, a project developer's primary expertise is in the legal and financial structure of a PV project. This includes the energy, debt and equity, and energy credit transactions among all of the project stakeholders and regulatory agencies.

Developers may also provide a source of capital to fund projects, take initial risks such as paying for feasibility studies, and take on other, ongoing project risk.

Engineering, Procurement, and Construction Firms

At commercial and utility scales, engineering, procurement, and construction companies bundle together many of the technical services hired by the project developer into a single contract. They often begin with PV system performance modeling, conduct environmental and interconnections studies, and end with system commissioning. Their fundamental role in most PV projects is the design and construction; however, they may also provide schedule, cost, and performance guarantees. Some specialty firms will also take on project risk or participate in the project beyond its traditional role as a technical and construction services provider.

Engineering, procurement, and construction firms typically have direct design and project management staff, but use local subcontractors for construction and installation services. As a result, the facility needs usually are limited to office space and limited construction management space on project sites.

Engineering, procurement, and construction firms typically are hired through a request for proposals process on a project-by-project basis.

Operation and Maintenance Contractors

Commercial and utility PV projects have ongoing monitoring and maintenance requirements that typically are contracted to firms with expertise in performance monitoring and maintenance (such as panel washing and PV component replacement). These ongoing services are important and local, but they create very few ongoing jobs.

At residential and small commercial scales in the right climate, these activities are often the responsibility of the building or property owner. However, third-party ownership paired with subcontracts for performance monitoring and maintenance is also common.

Project Owner

Project owners can be land or building owners, or, as is common with third-party models, own only the solar equipment and lease the roof or land. Often, when the tax credits or depreciation and tax benefits have run their course, project ownership will change.

Electrical Utility or Power Purchaser

Increasingly, electric utilities are playing a role in PV energy generation, either as power purchasers (forming agreements with PV energy generation project owners or developers to buy electricity through PPAs) or as PV project owners and developers themselves. Utility structure and attitudes can play a large part in the overall PV energy generation climate. Supportive electric utilities often see PV energy generation sector growth as a way to satisfy renewable portfolio standards (RPS) goals, delay or eliminate pending investment in electrical infrastructure, or reduce peak loads. Utilities with this perspective may create PV energy generation incentives, and be economic development partners. Unsupportive electric utilities are important challenges that local economic developers need to recognize and work to overcome.

Renewable Energy Certificate Owner

RPSs are important drivers of the PV energy generation sector. RPS goals are typically state goals, met through the purchase or creation of renewable energy certificates (usually measured by the kilowatt-hour or megawatt-hour). In many cases, RECs are granted to project owners; however, RECs typically are sold through long-term agreements with electric utilities or power purchasers.

Site Selection Criteria

Table 11 highlights the major financial categories involved in building and operating a utility-scale PV energy generation project. The cost of utility-scale PV materials within the United States generally is not subject to much regional variation. Installation labor, however, can vary according to the degree of experience and competition available at a given site, and the degree of complexity driven by project conditions.

Table 11. Sample Utility-Scale PV Energy Generation Project Costs

Solar PV Farm - System Size = 50 MW	Total CAPEX ($)	Total Annual OPEX ($)	$/Watt	% of CAPEX Invt.
Modules CAPEX	$ 100,000,000		$ 2.00	65%
Rack (Fixed)	12,970,000		0.26	8%
Inverter	12,410,00		0.25	8%
Other BOS Materials	9,220,000		0.18	6%
Labor - Installation - Craft ($40/hr)	7,520,000		0.15	5%
Labor - CM & Engineering-Professional ($80/hr)	7,520,000		0.15	5%
EPC Expense	1,600,000		0.03	1%
Site Work Expense	1,600,000		0.03	1%
Other Indirect	940,000		0.02	1%
Land	940,000		0.02	1%
Total Balance of Plant	**54,720,000**		1.09	**35%**
Total Installed System CAPEX	**154,720,000**		3.09	**100%**
Total Annual Operating Costs (Labor & Expense)		**$ 800,000**	**0.02**	**1%**

CAPEX = Capital Expenditures
OPEX = Operating Expenditures
BOS = Balance of System
BOP = Balance of Plant
EPC = Engineering, Procurement, and Construction
CM = Construction Management

Solar Resources

Solar resources are not something that can be changed. Every city's solar resource potential is fixed, and this resource is an important criterion in defining the potential PV energy generation sector's evaluation of a city. Solar resources are typically measured in kilowatt-hours per square meter (m^2)/year or kilowatt-hours/m^2/day, and combined with other location-specific variables and into kilowatt-hour/kilowatt factors.

Experienced energy generation sector companies will know what a city's solar resource is, and know what this means for the local market. The general public, however, may not accurately understand the solar resource. In many cases, a cold or harsh climate is mistaken for a poor solar resource, and this is not an accurate assumption. The best and most widely used solar resource data comes from the National Renewable Energy Laboratory.

While solar resources are fixed, city economic developers should understand these resources to comprehend their competitive position and the gaps that must be bridged through incentives. Good solar resource understanding can also be the basis of marketing to combat public misperceptions about the viability of solar energy.

Local Cost of Electricity and Utility Attitudes and Structures

PV energy generation sector projects ultimately compete with the local price of a kilowatt-hour delivered by the local electric utility. When a PV energy generation sector company selects project sites, it looks for the following:

- **A high competing cost of electricity.** The higher the competitive price, the easier it is to make a PV energy generation project viable or to realize a greater financial return.
- **An energy demand profile that aligns with PV energy generation.** If loads are driven by space cooling from solar heat gain (e.g., air conditioning) or other demands that align with peak solar generation, PV energy would be well suited to offset this energy requirement.
- **A PV-friendly utility.** Utility structure and attitude have a large influence on the attractiveness of a city for PV energy generation project development. Investor-owned utilities operate differently than cooperative utilities, and differently than municipal utilities. While one structure is not inherently more PV-friendly than another, cooperative utilities and municipal utilities have more history of PV energy generation project involvement. Investor-owned utilities need to balance the needs of their shareholdes with the desires of their customers, which may make it more difficult to support PV energy generation projects.

Public and Private Support

In many locations, PV energy generation sector projects require the financial and non-financial support of local governments to become viable in the short term. Such support can often overcome challenges identified in local solar resources or competing cost of electricity. Overall community support can significantly affect PV market transformation. The leadership of public officials and local institutions can be influential.

Workforce and Training

While the range of PV energy generation sector services is broad, local economic developers are best served by recruiting PV energy generation projects, as project location (installation location) is the largest driver of local jobs.

The largest workforce requirement of PV energy generation projects is installation, construction, or trade labor. Training this workforce is an important step to building a market; however, many areas have existing and often available construction laborers who can easily be retrained.

Key Lessons about the PV Generation Sector

While there are a variety of pieces to the PV generation value chain, encouraging installation of generation projects is the primary focus of successful economic development efforts in this sector.

The solar resources of an area are somewhat important to the potential success in developing the PV generation sector (more so for encouraging utility-scale installations), but communities should not assume that cold weather makes an area unsuitable for PV generation. As discussed above and illustrated in the case studies in Section 3, many states in the northern United States and Canada have had great success in encouraging installation of PV systems and increasing the size of the PV generation workforce and the economic development opportunities from PV generation businesses.

The cost of conventional energy and attitudes of local utilities toward solar and other alternative energy sources are of paramount importance to the success of the PV generation industry. Public and private support in the form of policy, financial, and non-financial support can encourage the market and often compensate for factors such as low competing energy costs and less-than-ideal solar resources.

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