國立政治大學亞太研究英語碩士學位學程
International Master's Program in Asia-Pacific Studies
College of Social Sciences
National Chengchi University

碩士論文
Master's Thesis

太陽能源應用之美國市場研究
The Study of Photovoltaic (PV) Solar Energy in the United States

Student: Timothy Beal
Advisor: Dr. Jen-Te Hwang

中華民國 102 年 7 月
July, 2013

太陽能源應用之美國市場研究
The Study of Photovoltaic (PV) Solar Energy in the United States

研究生： 貝提畝 Student: Timothy Beal
指導教授： 黃仁德 教授 Advisor: Dr. Jen-Te Hwang

國立政治大學

亞太研究英語碩士學位學程

碩士論文

A Thesis

Submitted to International Master’s Program in Asia-Pacific Studies

National Chengchi University

In partial fulfillment of the Requirement

For the degree of Master in China Studies

中華民國 102 年 7 月
July, 2013

Abstract

Solar PV energy is one of the fastest growing forms of renewable energy in the world. Since the last decade, the PV market has been expanding rapidly in the United States as a result of government policies, financial incentives, and declines in costs for installed PV systems. PV manufacturers have grown in number in order to meet increasing demand, but global oversupply has made profitability for most PV suppliers in the U.S. challenging. Despite the impressive rate of market growth, electricity produced by PV is still not cost-competitive with traditional forms of electricity generation without government support. An abundant supply of natural gas in the U.S. and its growing role as a source of electricity also presents a unique challenge to the development of renewable energies such as solar PV. Nevertheless, the PV market continues to expand and is predicted to maintain strong growth over the next several years in the U.S., even though much uncertainty remains on its long-term prospects.

Acknowledgements

There are many people I feel a sense of gratitude towards after completing this study. I would like to thank Professor Jen-Te Hwang for his patience and guidance while advising me for my thesis. Thanks to the other committee members, Professor An-Pang Kao and Professor Huey-Lin Lee, for the time they took for my presentations and the advise the offered me. My special friend Enid Wu did much too help me with some of the technical aspects of my thesis format. I would like to thank all of the staff and administrators in the International Master's Program in Asia Pacific Studies and the Office for International Cooperation at National Chengchi University for all of the assistance they have provided me. I am grateful to Emily Shen of the Taipei Economic and Cultural Office in Los Angeles for all that she did to help me with the requirements needed to come to Taiwan for graduate study. I would like thank Taiwan's Ministry of Education for offering me the generous Taiwan Scholarship. And finally, I would like to give a special thanks to all the people of Taiwan for the pleasant experience I have had living and studying in this wonderful country.

TABLE OF CONTENTS

LIST OF TABLES

Chapter 1 Introduction

There are several different types of solar energy technologies. These include: both passive and active solar energy systems, thermal and photovoltaic (PV), and concentrating and non-concentrating energy designs. Passive solar energy makes use of heat and light energy from the sun without converting it into other forms of energy. Active solar energy designs include photovoltaic and solar thermal power. Photovoltaic technology is able to use sun light to stimulate electrons from semiconductor materials to produce electrical current. Heat produced by solar thermal technology can be used for heating applications or to produce electricity using other mechanisms. In my thesis I will focus my study on solar photovoltaic (PV) technology.

The last 10 years has seen high growth in solar energy utilization in several countries in the world. PV solar energy is becoming an emerging new source of energy in these countries for a variety of reasons: the desire to reduce greenhouse gases that cause global warming, to offset the negative health effects of air pollution, to develop a more sustainable source of power, to provide increased energy security and limit dependence on foreign suppliers for energy imports, and in the case of Germany, to provide a safe alternative to nuclear energy, for example. Although Europe has been the leading the world in PV power installations for several years, solar power in the United States has risen sharply over the last few years as well.

Lower PV system prices over time, combined with government incentives, has encouraged continued growth in the solar PV market in the United States. Although electricity produced by solar PV is not yet competitive with traditional forms of utility electricity generation without government aid, the outlook for solar PV market growth remains positive despite a reduction in government incentives in some cases. Many factors will influence the economic viability of solar PV electricity generation in the coming years.

1.1 Motivation and Methodology

My motivation for this study is a personal interest in the energy dynamics in the United States and how they affect the economy and the way people interact with their environment. I am interested in the factors that influence the growth of solar PV use in the U.S. and its development as a fast growing sector of the renewable energy market. The purpose of this study is to gain a greater understanding of the PV solar energy market in the United States and its likely developments.

I expect the results of my study will demonstrate that the use of solar energy in the United States is likely to increase and become a more important portion of the U.S. energy mix in the future. However, there are still many challenges to PV energy becoming a more mainstream source of electricity, and there are many variables that could affect the PV market either positively or adversely in the future. The methods of my research will consist of evaluating primary data sources and qualitatively analyzing secondary academic sources. I will also use industry reports to supplement my ideas and conclusions, as well as to touch on current developments in the PV industry. All of the dollar amounts given in my thesis will be given in USD.

1.2 Framework

In chapter 2 I will give an overview of energy production and consumption in the United States. I will discuss the main types of power sources used in the U.S. historically, recently, and what is projected for future use. Fossil fuels have been the primary energy source in the U.S., and coal has been the major source of electricity. Despite the prevalence of fossil fuels as a source of energy (electricity in particular), nuclear and renewable energy use has increased over time. Natural gas has also gained in importance as a source of electricity generation. Hydroelectric power has traditionally been the most important source of renewable electricity generation, but wind and solar energy have recently been increasing at a much faster rate.

In chapter 3 I will give a brief history of the early developments of the PV solar energy market around the world and how it progressed into a more viable energy source in different regions. Photovoltaic solar cells using silicon were first developed in the United States in the 1950s. PV cells have been an expensive source of electricity since their inception and were not widely used. In the 1960s, Japan started producing the first practical solar modules for some applications, namely for powering lighthouses in remote coastal areas. In the 1970s, solar energy gained new interest during the global energy crisis; this led to more development within the PV industry. The global PV industry slowly progressed in the 1980s but was still mostly a niche market for off-grid applications. By the year 1999, worldwide production reached 1gigawatt (GW).

In the early 2000s, the U.S. was the dominate producer of solar electricity. After 2004, solar electricity in Japan and Germany began to increase substantially, with Germany becoming the world leader in 2006. By the year 2009, Germany was producing more than twice as much electricity from PV cells than any other country. However, due to cuts in government incentives, Germany is projected to command a decreasing share in global PV installations, with China, Japan, and the U.S. increasing their global share of installations.

In chapter 4 I will discuss the governmental policies in the United States that encourage the proliferation of PV solar energy. On a federal level, the major PV initiatives I will discuss are the Million Solar Roofs Initiative (MSR), the Solar America Initiative (SAI), and the SunShot Initiative. These federally supported programs have been important for encouraging and supporting growth and development in the PV industry. Federal tax credits and cash grants have been vital in supporting the demand side of PV energy. After several years of government programs and financial incentives, the United States is developing into one of the larger world markets for PV energy. At the state level, the California Solar Initiative (CSI) has had a major effect on PV installations. The financial incentives it offers have done much to make California by far the largest PV market in the nation.

In chapter 5 I will discuss the factors of the supply of PV solar energy in the United States. In the late 1990s, PV shipments by U.S. suppliers started to rise. In 2003, the rate increased and again rose sharply in 2005. The total shipments of both solar cells and modules continued to rise even faster in subsequent years. However, in 2007 imports began to exceed exports and outpaced exports greatly in 2009. The price of both solar cells and modules started to fall substantially due to oversupply in the market. The manufacturing capacity of solar cell and module producers continues to exceed global demand. This has resulted in low spot prices for cells and modules, with prices lower than most suppliers can produce them. The problem of oversupply and excess production capacity will likely continue to plague suppliers for the next couple of years or even longer.

In chapter 6 I will discuss factors of the demand for PV solar energy in the United States. Solar energy consumption in the U.S. remained fairly constant from 1991 to 2006. It began to rise noticeably in 2007 and increased more each year, more than doubling from 2007 to 2011. Federal and state incentives have proven effective in launching solar energy as a high growth market. In the year 2006, California had the third largest solar energy capacity in the world, behind Japan and Germany. Although California is by far the nation's leading state in solar power installations, several other states have begun to provide their own incentives to encourage growth in solar power use.

Solar leasing contracts are becoming popular, and its market is expanding quickly. Solar leasing companies provide another option for customers to purchase solar electricity without having to purchase the solar power system themselves. This has helped to create new demand for residential solar installations. Historically volatile energy prices and predictions of higher energy prices in the future make PV systems an appealing investment. Falling PV module prices, combined with greater cell conversion efficiency, has made the price of solar electricity per watt more affordable than ever before.

In chapter 7 I will give my conclusion and suggestion for the solar PV market in the United States. When the cost of producing electricity with PV systems becomes comparable to utility retail electricity prices, solar power is poised become a more mainstream source of power for consumers. For the meantime, government policies will still be important for ensuring the demand for PV energy systems. Because solar modules are designed to retain most of their productivity for 25 or 30 years, solar energy is also an attractive option for hedging against not only rising energy prices, but against future inflation of the U.S. dollar as well. PV component manufactures will remain challenged to make profits for the time being, and additional bankruptcies and plant closers are likely. Nevertheless, those that are able to survive the solar shakeout will likely emerge as profitable and competitive enterprises and will be in good position to prosper in a future PV market with higher demand.

CHAPTER 2 Energy Use in the United States

This chapter will give a general overview of the types of energy used in the United States. Fossil fuels, nuclear power, and renewable energy are the three main types of energy. Fossil fuels and renewable energy include several different types of energy sources, while nuclear power only consists of nuclear power plants.

2.1 Fossil Fuels

Fossil fuels have long been the primary source of energy in the United States. Of these types of fuels, the main fossil fuels are petroleum-based products, coal, and natural gas. Petroleum is most important for the transportation sector. Coal is primarily used for electricity generation. Natural gas is often used for heating homes, but more recently it has become more important for electricity generation.

2.1.1 Petroleum

Petroleum products have been the most important source of energy in the United States. Since 1960, petroleum has accounted for close to 40% of the total energy consumption. Annual petroleum consumption nearly doubled from 1960 to 2000, from nearly 20,000 trillion British thermal units (Btus) to over 38,000 trillion Btus. As a power source it has increased consistently during this time. Between the years 2004 and 2007, it rose to about 40,000 trillion Btus before dipping to about 37,000 trillion at the end of the decade (U.S. Energy Information Administration (EIA), 2012a). In 2006, petroleum comprised 40 percent of all energy sources consumed (EIA, 2007). In 2010, this number dropped to 37 percent (EIA, 2012b).

Petroleum is a major energy source for transportation, accounting for 93% of the energy consumed by that sector (EIA, 2012c). Petroleum as a fuel source for electricity as varied since 1960 but has never been a major source of electricity. It peaked at more than 3,000 trillion Btus in 1975, but never reached close to 2,000 trillion units after the early 1980s. It last reached above 1,000 trillion units in the year 2005 (EIA, 2012a). In the year 2011, it only accounted less than 1 percent of all the energy used to produce electricity in the U.S. (EIA, 2012c).

Domestic crude oil production had been decreasing since the mid-1980s but has been increasing over the last several years. In 2008, the U.S. was producing 5 million barrels of crude oil a day. In 2010, this number rose to 6.5 million barrels a day. Advances in technology combined with tight formations and increased natural gas production have made oil extraction more economically viable. Domestic oil production is expected to continue its strong growth the remainder of this decade before declining gradually after 2020 in anticipation of increased fuel efficiency (EIA, 2013a).

In correspondence with decreased domestic oil production in the mid-1980s, net imports of petroleum products increased steadily from that point until the mid-2000s. Since 2005, net imports of petroleum have decreased every year. The downward trend of petroleum imports is expected to continue over the next 6 years, but will still account for about a third of the total supply of petroleum products in the U.S. (EIA, 2013a).

2.1.2 Coal

Coal has been the largest source of electricity generation in the United States. Coal rose steadily as a fuel source for electricity in the 1960s, 70s and 80s. In 1960, it accounted for over 4,000 trillion Btus of electrical power and reached over 16,000 trillion units by the year 1990. From the mid to late-1990s, its growth as a source of electricity leveled off and had maintained at around 19,000 to 20,000 trillion Btus to 2010 (EIA, 2012a). Ninety-one percent of the coal consumed in the year 2011 was used to generate electricity (EIA, 2012c). Due to tougher environmental regulations on greenhouse gas emissions, the percentage of electricity generated by coal in the U.S. is predicted to decline. Some projections predict natural gas could surpass coal as a source of electricity (EIA, 2013a).

2.1.3 Natural Gas[1]

The second largest source of energy in the United States has been natural gas. It increased rapidly as an energy source in the 1960s, rising in use by 75 percent, from over 12,000 trillion Btus in 1960 to over 21,000 trillion by 1970. From 1970 to 1990 it fluctuated between over 16,000 trillion Btus to over 22,000 trillion annually. Since 1990,

[1] Information in this section sourced from EIA (2013a).

its rate of consumption has remained stable, never dipping below 20,000 trillion Btus. It peaked in the year 2010 at over 24,000 trillion Btus.

Natural gas has also been the second leading source of electricity as a fossil fuel and the third largest source of electricity overall. It grew steadily in use for electricity production 1960-2010. In 1960, it accounted for 1,785 trillion Btus of electric power and reached over 5,000 trillion by the year 2000. It has shown considerable growth, increasing from 6,000 trillion units in 2005 to over 7,000 in 2007. In the year 2006, it surpassed nuclear power to become the second leading source of electricity generation in the U.S.

Natural gas production is expected to increase by an average of 1.3 percent a year through 2040. Production supply is poised to exceed domestic demand by the year 2019, which could result in the U.S. becoming a net exporter of natural gas. This could also result in natural gas replacing coal as the primary fuel used for electricity generation. Since natural gas is a cleaner burning fossil fuel, increasing concerns about greenhouse gas emissions could lead to policies that encourage natural gas to further replace coal as a source of electricity generation.

2.2 Renewable Energy

Renewable energy has had modest beginnings but has increased in its share of the amount of energy produced in the United States. There are many different types of renewable energies used in the U.S. Most notably, these include; hydroelectric power, biomass, geothermal, solar, and wind power. Some types of renewable energy have been growing quickly the last several years. In 2011, renewable energy accounted for almost 13 percent of the total electricity generation capacity and over 12 percent of the total electricity generated. In the year 2011, total installed renewable electricity in the U.S. reached over 146 gigawatts (GW).[2] In the same year, renewable energy accounted for over a third of all newly installed electricity generation capacity (Office of Energy Efficiency and Renewable Energy (EERE), 2013a).

Hydroelectric and biomass combined have accounted for the bulk of renewable energy consumption in the last 50 years. Each accounted for over 1,000 trillion Btus of

[2] This is a substantial increase from 2010, which had 59 GW worth of installed capacity (EERE, 2011).

all types of energy consumption in 1960, and both totaled about 2,500 trillion Btus in 2010. Hydroelectric power reached over 3,000 trillion Btus in 1974 and has fluctuated between over 2,000 to over 3,000 trillion since then. Biomass has also fluctuated, reaching over 3,000 trillion Btus in 1989 and 1996. However, it has only contributed over 300 to less than 500 trillion Btus to the electric power sector 1990-2010. In the years 1960-1990, it consisted of a much slighter proportion (EIA, 2012b). Since the year 2006, corn ethanol has also been an important source of renewable energy for the transportation sector. The amount of ethanol used in gasoline has tripled from the year 2005 to 2011. The amount of ethanol produced in 2011 was 8 times greater than the amount produced in the year 2000 (EERE, 2013a).

Geothermal energy had started by 1960 and has slowly grown in use, although its contribution to total energy consumption has been minimal. In reached over 100 trillion Btus in 1986 and 200 trillion in 2009. As a source of electricity to the power sector, it provided nearly 100 trillion Btus in 1985 and has provided at or near 150 trillion units of electrical power since 1990 (EIA, 2012a).

Nuclear electric power is in a class of its own. It does not use fossil fuels and has been coined as a clean source of energy. But the uranium that it is fueled by is not considered a renewable fuel source, since it is a natural element found in the earth that is limited in quantity. Nevertheless, it has developed into a significant source of power in the United States and has been the second leading source of electricity generation. It had very meager beginnings in 1960, producing only 6 trillion Btus. However, by the mid-1970s it reached over 1,000 trillion Btus and increased to over 6,000 trillion by 1990. In comparison to natural gas as source of electricity production, it lagged far behind in the 1960s and 70s before surpassing natural gas in the mid-1980s. Its use as a power supply continued to increase in the 1990s and remained near or above 8,000 trillion Btus throughout the last decade (EIA, 2012a). Although it has recently been surpassed by natural gas as a source of electricity, it still remains an important source of electricity for the U.S. and accounts for close to 20 percent of electricity generation.

Wind power and solar PV are two of the fastest growing sources of new electricity generating installations in the nation. “In 2011, cumulative installed wind capacity increased by nearly 17% and cumulative installed solar photovoltaic capacity grew more than 86% from the previous year" (EERE, 2013a). Wind power started to mark its place as an electrical energy source in the early 1980s and grew more substantially in the late 1980s. It grew from 22 trillion Btus in 1989 to over 900 trillion units in 2010. Solar energy also began to make headway in the early 1980s and grew to nearly 60 trillion Btus by 1990. It reached 70 trillion units in 1996 and 1997, but after that it accounted for less than 70 trillion Btus until 2007. It stood at 63 trillion Btus in 2005, however, that figure doubled by 2010 to 126 trillion Btus. As a source of electricity to electric utilities, it consisted of a modest amount. It hovered between 5 and 6 trillion Btus from the mid-1990s to the mid-2000s, but has increased quickly since then, doubling by 2010 (EIA, 2012a).

In 2009, the U.S. led the world in installed wind capacity at over 35 GW. In that year it had increased in capacity by 40 percent from 2008 and increased in electricity generation by more than 33 percent. At that time it accounted for just under 2 percent of all power generation in the U.S. (Walsh, 2012; EERE, 2013a). Since then wind power has continued to grow substantially. The amount of wind power capacity in the year 2011 was 18 times greater than the amount in the year 2000. In the last for 4 years of the last decade, wind accounted for more than third of all forms of new electricity generation capacity in the United States. "Wind energy accounted for about 75% of newly installed U.S. renewable electricity capacity in 2011." New wind power capacity installations in the year 2011 totaled almost 7 GW, led by California with over 921 MW (EERE, 2013a).

Of all the renewable energy sources, wind and solar power increased the most. The use of solar power doubled to 2 percent of all renewable energy, and wind nearly tripled from 4 to 11 percent. Hydroelectric and geothermal declined as a percentage while biomass increased somewhat. The increased use in biomass can be attributed to the increased use of corn ethanol mixed with petroleum. As a result, the transportation sector consumed 13 percent of all renewable energy produced in 2010. In 2006, the transportation sector only consumed 7 percent (EIA, 2007; EIA, 2012b).

The growth in use of renewable energy in the U.S. could vary greatly depending on changes in technology, the use of natural gas, and policies aimed at reducing greenhouse gas emissions. Conservative predictions cite an increase in renewable energy for electricity production from 13 percent in 2011 to 16 percent in 2040. If natural gas prices become lower than predicted, combined with a lack of policy incentives catering to investments in renewable energy, it is expected that the impetus towards renewable energy propagation would be adversely affected. However, technology improvements could make renewable energy more affordable than predicted. Wind and solar power are expected to experience declines in costs, and of the two sources, solar PV is thought to have more potential for future cost declines than wind energy. This, combined with the potential for more stringent emission policies, could raise the percentage of renewable energy for electricity generation to as high as 31 percent by 2040 (EIA, 2013a).

2.4 Energy Overview

The total amount of energy used by all sectors in the United States amounted to nearly 100 quadrillion Btus in the year 2011.[3] Fossil fuels (petroleum, coal, and natural gas) together account for the majority of energy used in the U.S., totaling about 81 percent of all energy consumed in 2011. Thirty-six percent of the energy came from petroleum, 25 percent came from natural gas, 20 percent came from coal, 8 percent came from nuclear power, and 9 percent came from all forms of renewable energy combined (EIA, 2012c). Renewable energy as a whole accounted for over 8 percent of all the electricity consumed in 2010, and fossil fuels accounted for 83 percent of all electricity consumed in the same year (Walsh, 2012).

As a comparison to overall energy consumption in the U.S. in the years 1960-2010, energy consumption more than doubled, from more than 45,000 trillion Btus in 1960 to over 97,000 trillion in 2010. Energy consumption rose sharply in the 1960s and early 1970s, reaching over 72,000 trillion Btus in 1972. Energy consumption increased steadily from that point to the year 2000, reaching nearly 99,000 trillion Btus. Energy consumption rose above 100,000 trillion Btus in 2004, 2005, and 2007 but dropped below 98,000 trillion in 2010. Electrical power consumption by the electric power sector also rose sharply in the 1960s and early 1970s. The rate of electricity consumption grew even faster than overall energy consumption, slowing in growth in the mid-1990s. In the last decade, the electric power sector consumption leveled off, ranging from over 38,000 to over 40,000 trillion Btus (EIA, 2012a).

[3] One quadrillion Btus is roughly equal to the energy stored by 172 million barrels of oil, 50 million tons of coal, or 1 trillion cubic feet of natural gas (EIA, 2012c).

Between the year 1960 and 1995 consumption of electricity quadrupled. Data for retail electricity sales show electricity use rising from over 2,300 trillion Btus to nearly 13,000 trillion in 2010. In the 2000s, electricity sales leveled off from over 11,000 to over 12,000 trillion Btus. In 2010, there was about 5.5 times the electricity sales as in 1960, and more than double than in 1975. Interestingly, the amount of power lost by the power sector while generating, transmitting, and distributing, as well as unaccounted for loses, is much greater than the about of electricity consumed by the customers. In 1960, the amount of power lost by utilities was about 2.5 times the amount sold to costumers. Efficiency slowly improved in the following decades, but only slightly. In 2010, the amount of power lost by the power sector was still more than double the amount used by consumers (EIA, 2012a).

Table 2-1: Energy Consumption in the United States一1960-2010

Unit: Trillion Btu

Year	Coal	Petroleum	Natural Gas	Nuclear Power	Renewable Energy	Total Energy
1960	9,831	19,919	12,385	6	2,928	45,079
1965	11,582	23,246	15,779	43	3,396	54,028
1970	12,269	29,522	21,693	239	4,070	67,742
1975	12,656	32,732	19,977	1,900	4,687	71,987
1980	15,461	34,205	20,227	2,739	5,425	78,093
1985	17,540	30,925	17,714	4,076	6,084	76,464
1990	19,168	33,552	19,628	6,104	6,043	84,507
1995	20,099	34,441	22,721	7,075	6,560	91,092
2000	22,576	38,265	22,295	7,862	6,106	98,806
2005	22,795	40,397	22,567	8,161	6,229	100,277
2010	20,869	36,020	24,249	8,434	8,056	97,711

Source: EIA (2012a).

From 2010 to 2011, although the total amount of electricity consumed in the U.S. decreased by -.6 percent, electricity generated by solar energy sources increased by 50 percent. Wind accounted for the second largest increase in energy use, rising by 27 percent. In third place was conventional hydroelectricity at 22 percent. Natural gas was the only fossil fuel that increased that year with a modest 2.6 percent gain. Coal consumption decreased by over 6 percent and petroleum liquids decreased 31 percent. This demonstrates significant growth in renewable energies despite a decrease in overall electricity demand. It also reveals a notable decrease in coal consumption and a significant decline in petroleum as a fuel used to produce electricity. Nuclear power also decreased by over 2 percent (EIA, 2013b). Although it is just a one year comparison, it is difficult to explain such large increases in renewable electricity generation during a time of reduced electricity consumption without concluding there was a shift in investment towards renewable energy sources and changes taking place in America's total electricity generation composition.

Table 2-2: The Distribution of U.S. Electricity Generation by Source－2000-2011

Unit: %

Year	Coal	Petroleum Liquids	Petroleum Coke	Natural Gas	Other Gases	Nuclear Power	Renewable Energy	Other	Total
2000	51.6	2.7	0.2	15.8	0.4	19.8	9.4	0.1	100
2001	50.8	3.1	0.3	17.1	0.2	20.5	7.7	0.3	100
2002	50.0	2.0	0.4	17.9	0.3	20.2	8.9	0.4	100
2003	50.7	2.6	0.4	16.7	0.4	19.6	9.1	0.4	100
2004	49.7	2.5	0.5	17.8	0.4	19.8	8.8	0.4	100
2005	49.5	2.5	0.6	18.7	0.3	19.2	8.8	0.3	100
2006	48.9	1.1	0.5	20.1	0.3	19.3	9.5	0.3	100
2007	48.4	1.2	0.4	21.5	0.3	19.4	8.5	0.3	100
2008	48.1	0.8	0.3	21.4	0.3	19.5	9.3	0.3	100
2009	44.4	0.7	0.3	23.3	0.3	20.2	10.6	0.3	100
2010	44.7	0.6	0.3	23.9	0.3	19.5	10.4	0.3	100
2011	42.1	0.4	0.3	24.7	0.3	19.2	12.8	0.3	100

Source: EERE (2013a).

Table 2-3: The Distribution of U.S. Renewable Electricity Generation — 2000-2011

Unit: %

Year	Hydro	Solar	Wind	Geothermal	Biomass	All Renewables
2000	7.2	0.0	0.1	0.4	1.6	9.4
2001	5.8	0.0	0.2	0.4	1.3	7.7
2002	6.8	0.0	0.3	0.4	1.4	8.9
2003	7.1	0.0	0.3	0.4	1.4	9.1
2004	6.7	0.0	0.4	0.4	1.3	8.8
2005	6.7	0.0	0.4	0.4	1.3	8.8
2006	7.1	0.0	0.7	0.4	1.3	9.5
2007	5.9	0.0	0.8	0.4	1.3	8.5
2008	6.2	0.1	1.3	0.4	1.3	9.3
2009	6.9	0.1	1.9	0.4	1.4	10.6
2010	6.3	0.1	2.3	0.4	1.4	10.4
2011	7.9	0.2	2.9	0.4	1.4	12.8

Source: Same as Table 2-2.

2.5 Summary

In summary, there has been a lot of growth in energy use in the United States from the 1960s through the 1990s. This is to be expected with economic and population expansion. In the last decade energy use has leveled off, and has even reduced by a modest amount at the end of the 2000s.[4] Fossil fuels, such as petroleum, coal, and natural gas are the primary fuel sources for transportation and electricity in the U.S. Petroleum will continue to be an important fuel for transportation in the foreseeable future. Increased domestic production of oil and increased fuel efficiency of automobiles should help limit U.S. dependence on foreign oil suppliers in the future.

Coal has been the primary fuel used to generate electricity. Increased emission standards on coal plants will make coal less economically viable as a source of electricity as it is currently. Coal will likely account for a smaller percentage of electricity generation in the future, but will still be one of the leading sources of electricity. Natural gas is already the second leading source of electricity and is projected to increase its share of the total electricity generated. Due to its abundant supply in the U.S. and advances in technology to produce it, natural gas is becoming an increasingly important

[4] This can be expected considering the economic recession in the U.S. starting in the year 2008.

energy source. In the next decade the United States could become an important regional exporter of natural gas.

Nuclear power accounts for a significant share of the electricity produced, but its share has leveled off and will not continue to grow in importance as a source of electricity. Renewable energy sources do not have a large share of the total electricity produced in the United States, although not insignificant. Government policies and concerns about greenhouse gas emissions will lead to renewable energy increasing its share of the total U.S. energy composition. Solar and wind power installations have been growing at a tremendous rate the last several years. This is likely to continue considering the current political climate for clean energy.

Chapter 3 The Development of Solar Energy around the World

In this chapter I will discuss about the global development of solar PV energy. Silicon-based solar PV technology has existed for nearly 60 years. For the first few decades of its existence it had served mostly small niche markets, such as powering space equipment and remote off-grid locations. In the 1990s, the technology and costs to install PV systems improved, and grid-connected PV systems began to gain traction. In the 2000s, the solar PV market grew rapidly in a number of countries as a result of government incentives and continued reductions in the cost of PV components. Solar PV continues to grow globally, although recently there have been some regional changes in market growth.

3.1 Early Developments of Solar PV

Solar photovoltaic cells were first developed in the year 1954 by the Bell Laboratories in the United States. In the 1950s and 60s, the United States and the former Soviet Union used PV technology primarily for space craft applications. “The first generation of photovoltaic manufacturing firms included such names as Hoffman Electronics, Heliotek, RCA, International Rectifier, and Texas Instruments.” The Japanese company Sharp was the first to pioneer PV applications for other uses. In the 1960s Japan started producing the first practical solar modules, mostly for powering lighthouses in remote coastal areas. The second generation of PV producers were spurred by the oil crisis of the 1970s and a renewed interest in alternative energy sources. Major oil companies also invested in solar PV development at the time (Platzer, 2012; Timilsina et al., 2011).[5]

In the year 1980, one of the PV manufacturing companies started by a major oil company, Arco Solar, was the first company in the world to produce over a megawatt (MW) of PV modules in a single year. In the year 1983, 21.3 MW were produced worldwide at a value of $250 million. By 1999 worldwide production reached 1 gigawatt

[5] The Energy Policy Act (ETA) of 1978 created residential solar credits of up to $2,000 for devices installed on homes, which in turn spurred investment for the industry.

(GW) (EERE, 2004). In the following decade the solar energy market began to change rapidly.

The cost of solar modules has decreased substantially in the last 3 decades. In the year 1982 the installed cost of solar was about $27,000 per kilowatt (kW). In the year 1992 the cost had gone down to $16,000 per installed kW. By the year 2008 the cost dropped to $6000 per kW. The total installed capacity of all global PV stood at 1.4 GW in the year 2000. This would increase to 40 GW in 2010 with an annual increase in growth of about 50 percent per year. In the year 2010, 85 percent of PV installations were connected to utility grids and 15 percent were independent of any grid (Timilsina et al., 2011).

3.2 Types of Solar PV Technology

The two main types of PV cell technologies used today can be classified as either crystalline silicon PV cells or thin-film PV cells. Crystalline cells is the dominate PV technology used for PV systems across the globe. Thin-film cells are constructed with a variety of materials; including, amorphous silicon (a-Si), copper indium diselenide (CIS), copper indium gallium diselenide (CIGS), and cadmium telluride (CdTe). Thin-film PV is cheaper and less complicated to produce, but also less efficient than crystalline cells in producing electricity. "On average, thin-film cells convert 5%-13% of incoming sunlight into electricity, compared to 11%-20% for crystalline silicon cells" (Platzer, 2012).

In the year 2003, only 5 percent of PV systems were built with thin-film modules compared to 95 percent from crystalline technology. Thin-film PV modules have since then gained in market share, although the PV market is still dominated by crystalline modules. Higher efficiency concentrating photovoltaics (CPV) PV modules have also increased in popularity and recently entered larger-scale production.[6] "By the end of 2010, thin-film technology accounted for 13% of global PV shipments (3% a-Si, 8% CdTe, and 2% CIGS). The United States was responsible for 18% of global CdTe and 20% of global a-Si shipments in 2010." (U.S. Department of Energy (DOE), 2012a).

[6] Concentrating photovoltaic (CPV) systems consist of crystalline PV modules arranged to receive a greater concentration of sunlight, which in turn increases the conversion efficiency of the modules.

3.3 Solar Energy Development in Germany[7]

Germany is the global leader in installing solar PV systems. Due to generous FiTs (feed-in tariffs),[8] the growth of solar PV installations in Germany has been very impressive, starting in the mid-part of the last decade and picking up impressive momentum in the latter part of the decade. In the year 2004, solar PV installations totaled 660 MW, more than 4 times the amount installed in the year 2003. In the year 2005, the amount of PV installed increased to over 900 MW before dropping down to 850 MW in the year 2006. In the year 2007, installed PV reached over 1.2 GW and jumped to nearly 2 GW in the year 2008. The amount of solar PV installed in Germany rose impressively after that. In the year 2009, 3.8 GW of PV was installed. In the year 2010 and 2011, 7.4 and 7.5 GW of PV was installed respectively for total of nearly 25 GW installed in the country.

As a result of the increase in PV installations, the amount of PV power produced in Germany increased as well. From the year 2004 to the year 2011, electricity produced by solar PV increased at a rapid pace, from 556 million kilowatt hours (kWh) in the year 2004 to 18 and a half billion kWh in the year 2011. In the year 2011 alone, there was about a 60 percent increase in electricity produced by solar PV than in the year 2010. The system cost to install solar PV also has steadily declined in Germany. This, in combination with policy incentives, helped to make solar PV systems a more attractive investment. In Q2 of 2006, the average price per kW for installed PV was 5,000 Euros. This price fell nearly every quarter and reached 1,776 Euros per kW during Q2 of the year 2012. The total drop in the price to have PV installed in Germany from Q2 of the year 2006 to Q2 of the year 2012 was about 65 percent.

3.4 Solar Energy Development in Japan[9]

In the 1960s and 70s, Japan's early production and use of solar PV was mostly restricted to special commercial applications; including space vessels, communications, and lighthouses. In the early 1990s, the Japanese government introduced policies to encourage PV installations, such as net metering and subsidies. These policies laid the

---

7 Information in this section sourced from the German Solar Industry Association (GSIA) (2012).
8 Solar feed-in tariffs (FiT) refers to long-term contracts that guarantee payments for the amount of kWh of electricity produced by a qualifying PV system.
9 Information in this section sourced from Kimura and Suzuki (2006).

foundation for the growth of the solar PV market in Japan in the second half of the 1990s into the 2000s. Several major Japanese appliance companies were able to use government subsidies for solar PV R&D and manufacturing development. Also, "the strong commitment by the government to introduce PV very much stimulated private investments, which rose well over governmental subsidies."

Consistent, predictable, and adequate support by Japan's government for PV R&D in the 1980s and 90s was important for long-term PV technological development by Japanese companies. Stable funding and support for PV initiatives also provided a secure investment environment for private firms and investors. Subsidizing customers also provided a 'demand-pull' effect by encouraging Japanese PV producers to develop production abilities to meet the induced demand. Using especially designed taxes to raise funds solely for the support of the solar industry also provided secure and lasting funding, which also helped the subsidy program to last more than 10 years. This in turn effectively created a niche market for solar PV systems in Japan.

The 700 Roofs Program introduced subsidies at the end of the year 1993, and Japanese PV producers increased production capacity to meet demand for residential PV systems. The program lasted from the year 1994 to 2005 and offered regressive subsidies over time. "The subsidy rate for individual installation was gradually decreased from 50% of the investment cost in 1994 to only 20,000 JPY per kW or 3% of the investment cost in 2005." While subsidies decreased over time, so did the costs of PV systems, offsetting the effects of lower subsidy rates somewhat. Nevertheless, despite the subsidies offered by the government, the cost of electricity generated from PV systems during that time still cost more than utility-provided retail electricity rates. But demand for solar PV existed from people who earned a higher than average income, were concerned for the environment, and indifferent towards the higher rates for electricity from PV systems.

3.5 Global Growth in Solar Energy

Global solar PV capacity fluctuated between 22 percent and 38 percent annual increases between the year 2000 and 2006. The year 2007 marked an unusual year for that decade with only a 5 percent growth from the year 2006. Nevertheless, PV capacity grew rapidly after that year to 71 percent growth in the year 2008. The year 2009 still showed strong growth with a 62 percent increase in capacity from 2008. The year 2010 had remarkable growth, nearly doubling from the year 2009 with a 90 percent increase. The year 2011 also showed strong growth with nearly an 80 percent increase over 2010 (EERE, 2013a).

After the steady gains in global solar PV capacity in the first half of the 2000s, the overall percentage of solar PV electricity as a percentage of the total global electricity capacity increased from 0.1 percent between the years 2000 to 2005 to 0.2 percent in the years 2006 and 2007. The percentage began to increase faster after the year 2007. In the year 2008 solar PV accounted for 0.3 percent of the global electrical capacity, and in the year 2009 it rose to 0.4 percent. That amount doubled in the year 2010 to 0.8 percent of the global share. In the year 2011, it rose even more to 1.4 percent. When calculating solar PV as an electrical power source tied to power grids, the annual global growth of solar PV capacity averaged 43 percent a year between the year 2000 and 2011 (EERE, 2013a).

As a source of global electricity generation, solar PV accounted for less than 0.0 percent of all global electricity generation until the year 2006. In that year it finally broke the 0.1 percent milestone. Solar PV retained its 0.1 percent global share until the year 2010, when it accounted for 0.3 percent of global electricity. In the year 2011 it increased further to a half percent of global electricity generation (EERE, 2013a).

In the 1970s off-grid PV applications were the norm. Grid-connected systems have led the recent boom in solar PV growth, but in places like India and China off-grid installations have still been popular. “This trend could be a reflection of their large rural populations, with developing countries adopting an approach to solar PV that emphasizes PV to fulfill basic demands for electricity that are unmet by the conventional grid.” Off-grid solar PV installations nearly doubled grid-connected solar panel in the early 1990s. However, grid-connected PV systems surpassed off-grid systems in the second half of the 1990s and have continued to quickly outpace off-grid solar installations since then. In the years 2006 and 2007 grid-connected solar grew 50 percent annually and in 2008 grew 70 percent (Timilsina et al., 2011).

In 2011, the top 5 countries with the most cumulative solar PV installed included Germany, Italy, Japan, Spain, and the United States, in that order. Germany had over 24 and a half GW installed, nearly twice as much as the second leading country in the world, Italy. Italy had over 12.7 GW installed, well over twice the amount as third place Spain, which had over 5.3 GW. Japan had nearly 5 GW, and the United States had over 4 and a half GW. Rounding off the top ten countries with installed PV in 2011 include China, France, the Czech Republic, Belgium, and Austria. China had nearly 3 GW of installed PV. France had about 2.7 GW installed, and the Czech Republic had nearly 2 GW. Belgium had 1.6 GW, and Austria had about 1.3 GW of installed capacity (EERE, 2013a).

Table 3-1: Global PV Capacity by Country－2010

Unit: %

Country	Global Share
Germany	44
Spain	10
Italy	9
Japan	9
United States	6
Czech Republic	5
China	2
Rest of EU	7
Rest of World	8
Total	100

Source: Timilsina et al. (2011).

3.6 Feed-in Tariffs[10]

Feed-in tariffs (FiTs) have also been very important for the development of solar PV demand in other countries. As of the year 2012, 61 countries and 26 regional jurisdictions had FiT laws in place. The majority of the growth in PV solar installations has taken place in these countries. Between the years 2005 and 2010, all of the growth in solar PV capacity in Europe took place in countries with FiT policies. They give investors incentive to invest in PV systems because of the guaranteed rate of return from fixed prices. The certainty also reduces investment costs.

[10] Unless otherwise noted, information in this section sourced from Prest (2012).

Table 3-2: Global Solar PV Growth Rate

Unit: %

Year	PV Growth Rate
2000	22
2001	29
2002	33
2003	25
2004	33
2005	38
2006	32
2007	5
2008	71
2009	62
2010	90
2011	79

Source: EERE (2013a).

Table 3-3: Global Solar PV Share of Total Electricity Distribution

Unit: %

Year	PV Electricity Capacity	PV Electricity Generation
2000	0.0	0.0
2001	0.1	0.0
2002	0.1	0.0
2003	0.1	0.0
2004	0.1	0.0
2005	0.1	0.0
2006	0.2	0.1
2007	0.2	0.1
2008	0.3	0.1
2009	0.4	0.1
2010	0.8	0.3
2011	1.4	0.5

Source: Same as Table 3-2.

Feed-in tariffs have "… been implemented in more than 75 jurisdictions around the world as of early 2010, including in Australia, EU countries, Brazil, Canada, China, Iran, Israel, the Republic of Korea, Singapore, South Africa, Switzerland, the Canadian Province of Ontario and some states in the United States" (Timilsina et al., 2011). They are important for the development of PV markets in that they provide a return on investment for investors in PV power generation. They have been monumental for creating huge new solar PV markets in countries leading the world in PV installations, especially Germany and Italy. Most importantly, feed-in tariffs have been the single most effective policy in promoting the rapid growth in global solar PV installations.

The downside to feed-in-tariffs is that the cost of solar electricity generation is shared by all consumers of electricity, including those who do not benefit from owning a solar PV system and receiving the FiT. This causes increases in the overall cost of electricity. FiTs also change over time as a result of changes to system costs and technology, and sometimes because of political atmosphere or concerns over high electricity rates. This causes future uncertainty and can negatively affect the investment climate for PV systems.

The explosive growth in solar PV in some European markets also created pressure to place caps on FiT rates quicker than anticipated, due to unsustainable support costs. Germany has imposed substantial reductions in FiT guarantees, and France and Spain have placed drastic sudden limits on installed capacity. Places such as Spain and New South Wales in Australia have even stopped all FiTs for new installations.

By the year 2011, solar PV had become the world's fastest growing form of power generation. Pressure to amend FiT laws has come from the need to reduce the impact of residential electricity rates, and in some cases, the need reduce the impact on a country's budget. Reports had been made in New South Wales, Australia about the effects FiT had caused on increases in electricity rates. However, data later revealed that utility infrastructure upgrades were more responsible for higher energy prices than their FiT. The Australian Energy Market Commission "predicted that NSW retail electricity prices will rise by a cumulative total of 39.3 % between 2009–2010 and 2012–2013. Of this increase, 59.12 % will be due to distribution costs, only 6.17 % due to the NSW FIT, and 6.47 % due to the federal small-scale renewable energy scheme."

In Australia, the Czech Republic, the United Kingdom, France and Spain, FiTs have been capped on the basis of installation limits with little notice, causing investment uncertainty and instability in their solar PV markets. When Spain capped its FiTs in the year 2008, it was followed by a loss of 30,000 jobs in the renewable energy sector between the year 2009 and 2010. Spain went from having robust solar PV growth under the FiT laws to having a stagnant PV market after the FiT was capped. A similar effect could be witnessed in the Czech Republic. In the year 2011, only 10 MW of solar PV was installed following major cuts to the FiT scheme there compared to 1.5 GW of installed PV in the year 2010.

3.7 Global Solar PV Manufacturing

Although the market for solar PV has expanded rapidly in the United States over the last several years, its percentage share of the global market declined over the last decade. In the year 2000, the United States accounted for 30 percent of the global PV shipments, but soon began to lose its position as the dominant supplier of solar PV modules. Manufacturing by Japanese and German producers increased accordingly to meet local demand. The U.S. market share first shifted to Japan, which held the top position for a short while. Germany emerged as the largest supplier of solar PV, surpassing Japan, but then gave up the top spot to China in the later part of the decade. "During 2006–2010, China and Taiwan invested heavily in PV manufacturing and demonstrated an ability to scale-up production rapidly while reducing manufacturing cost substantially." In the year 2010, China and Taiwan together accounted for more than half of all global PV shipments (DOE, 2012a).[11]

Between the year 2000 and 2010, the global shipments of PV modules around the world averaged an annual growth of 53 percent and reached a total of 17 GW in 2010. This brought the total amount of PV shipments to a total of about 40 GW. "In 2010, the United States accounted for 8% or about 1,400 megawatts (MW) of PV market demand and 6% or about 1,000 MW of supply" (DOE, 2012a).

The total amount of global solar PV module production in 2011 totaled nearly 35 GW. China was by large the biggest global supplier of solar PV modules. China produced 61 percent of the global share for a total of over 21 GW worth of modules. The rest of Asia combined (excluding Japan) was the second leading producer of solar modules with

[11] Production was primarily driven by the high-demand markets in Europe at the time.

16 percent of the global share for a total of about 5.4 GW. Europe as a whole was the third largest supplier with 14 percent of the global share for a total of about 4.8 GW. Japan came in at fourth place, producing over one and a half GW accounting for 5 percent of the global supply. The United States was the fifth largest producer of solar PV modules, producing over 1.3 GW for 4 percent of the global supply. All other countries combined only produced less than 0.4 GW, or 1 percent of the global supply (EERE, 2013a).

The major solar PV module manufactures have been China, Germany, Japan, Taiwan, and the United States. Between the year 2008 and 2010, China emerged as the major center for solar PV cell and module production. A huge increase in global PV installed capacity took place during this time, nearly doubling in the year 2010, with about 40 GW of capacity from less than 23 GW in 2009. Leaders in crystalline module production included Suntech, Yingli, Trina Solar, and Sharp, all of whom produced over 1 GW of solar modules in the year 2010. Suntech led all producers that year with over 1.5 GW. The major global thin-film module producer is First Solar, which produced over 1.4 GW of modules in 2010. China produced 45 percent of the global crystalline modules and 12 percent of the global thin-film modules in 2010 (Globaldata, 2011).

In the year 2010, Germany accounted for over 14 percent of the global crystalline module production and over 19 percent of the global thin-film module production. Japanese production provided over 12 percent of the global supply of crystalline modules and 12 percent of the global thin-film modules in 2010. Taiwan accounted for 6 and a half percent of global crystalline module production and nearly 10 percent of thin-film modules in 2010. The United States produced 5 percent of the global crystalline modules and 16 percent of the global thin-film modules, due mostly to thin-film module producer First Solar, which accounted for 97 percent of the thin-film modules produced in the United States (Globaldata, 2011).

The top three companies for global crystalline modules in the year 2010 were all Chinese. Chinese companies Suntech, Yingli, and Trina Solar were the top producers with a global share of 17.6 percent, 11.9 percent, and 11.7 percent respectively. While global crystalline modules accounted for 17.5 GW of total production, thin-film modules only accounted for 3.6 GW of solar PV in the year 2010. United States company First

Solar produced over 60 percent of the total global supply, followed by Japanese company Sharp with 8.5 percent in the year 2010. From the beginning of the year 2010 until the end of 2011, the price for crystalline modules fell from $2.52 per watt to $1.71 per watt. In the same time the price for thin-film modules fell from $2.07 per watt to $1.36 per watt (Globaldata, 2011).

In the past two decades, every time a given volume of PV modules sold had doubled the price for PV modules decreased by over 20 percent, and the cost of modules per watt has decreased by 22 percent every time the global utilization capacity doubles (Prest, 2012). Technology improvements, increased PV efficiencies, more efficient manufacturing techniques, reductions in material costs, and increases in economies of scale have led to the price reductions. The drastic price declines in the year 2011 and 2012 were also a result of over capacity.[12] The price reductions have fueled further increases in the global demand for solar PV systems. However, financial problems in Europe also led to many cuts to financial inventive for PV installations in European countries.

Table 3-4: Top Global PV Cell Manufacturers一2010

Global Ranking	Manufacturer	Headquarters	Share of Global Production (%)	Founded
1	Suntech	China	6.6	2001
2	JA Solar	China	6.1	2005
3	First Solar	United States	5.9	1990
4	Yingli	China	4.7	1998
5	Trina Solar	China	4.7	1997
6	Q-Cells	Germany	3.9	1999
7	Gintech	Taiwan	3.3	2005
8	Sharp	Japan	3.1	1959
9	Motech	Taiwan	3	1981
10	Kyocera	Japan	2.7	1996
11	Hanwha Solar	South Korea	2.2	2004

Source: Platzer (2011).

[12] PV module prices fell by nearly 50 percent in 2011, 75 percent lower than in mid-2008 (Prest, 2012).

The top ten PV solar module suppliers in the year 2012 included (Lian, 2013):

1. Yingli Green Energy (up one spot from the year 2011);
2. First Solar (up 2 spots from 2011);
3. Suntech (dropping 2 places from number 1 in 2011);
4. Tina Solar (dropping from number 3 in 2011);
5. Canadian Solar (keeping the same spot from 2011);
6. Sharp Solar (also keeping the same spot from 2011);
7. Jinko Solar (up 2 spots from 2011);
8. JA Solar (up 7 spots from number 15 in 2011);
9. SunPower (down 1 spot from 2011); and
10. Hanhwa Solar (down 3 spots from 2011).

Of the top ten solar PV producers in 2012, seven of these companies were based in China, two were based in the United States, and one was based in Japan. The top global producer, Yingli, supplied more than 2.2 GW of solar PV modules in the year 2012. The top ten global PV suppliers still accounted for less than 50 percent of the global demand (Lian, 2013).[13]

By the end of 2012, there was over 100 GW of cumulatively installed PV capacity worldwide. In the year 2012, years of excessive global production of PV supplies continued the problem of chronic oversupply, which brought PV module prices well below $1.00 U.S. per watt (Colville, 2013a). The oversupply led to negative margins for PV producers and caused many bankruptcies, especially for European and American suppliers. The oversupply and low margins also resulted in PV producers lobbying their governments for protection from foreign suppliers, particularly those from China.

3.8 Future Outlook for Global Solar PV

The cost of electricity produced by solar PV systems has continued to fall by impressive amounts; however, it is still a rather expensive source of electricity in many areas in the world compared to traditional utility electricity generation. "In the year 2011, the average minimal cost for solar PV electricity was $192 per MW hour, making it four

[13] Many Tier 1 Chinese producers have accumulated vast amounts of debt. Recently, Suntech's manufacturing subsidiary, Suntech Wuxi, entered bankruptcy proceedings, despite being one of China's largest PV module suppliers.

times more expensive than coal without carbon reduction technology or carbon tax" (Timilsina et al., 2011). Other types of alternative energy have been more cost competitive for electricity generation, including hydropower, wind energy, and nuclear energy.

Demand for solar PV in the Asia Pacific region is forecast to have strong growth in the year 2013 and increase by 50 percent. The four largest PV markets in the Asia Pacific, China, Japan, India, and Australia, should account for 90 percent of the demand for new solar PV installations in the region. However, incentive reductions in Australia will slow PV growth there in 2013, and PV policies there remain uncertain (NPD Solarbuzz, 2013).

Solar incentives in China and India have made them fast growing PV markets. "By the end of 2011, cumulative installed and connected capacity in China had risen substantially to 2.9 GW." India's National Solar Mission is also likely to bring substantial growth to its PV demand. Its policy targets 20 GW of its electricity generation to come from solar energy by the year 2020 (Platzer, 2012). India could see solar PV installations grow by over 5 GW to 9 GW of total installed capacity this year, and off-grid and rooftop installations will be major drivers of PV growth. Risk factors to solar PV growth in China and India include financing and grid access (NPD Solarbuzz, 2013).

The solar shakeout that has been taking place is likely to continue in the year 2013, and perhaps even longer. However, the five-year forecast for the demand for solar PV products remains positive. According to an NPD Group report, it is likely that 230 GW of solar PV capacity will be added globally between the year 2013 and 2017. Almost half of the new global capacity will come from utility-scale installations. China will surpass Germany as the world's largest solar PV market in the year 2013. China will then have a global lead in both the supply and demand segments of the PV industry. While the share of global demand for new PV capacity will decline in Europe, many new emerging PV markets will support solid overall PV growth the next several years. Latin America, the Middle-East, Africa, and SE Asia only accounted for 2 percent of global PV demand in the year 2012 but will experience 50 percent annual growth from 2013 to 2017, which will amount to 10 percent of the global cumulative PV capacity (Colville, 2013a).

Residential PV systems are forecast to decline in the share of the global PV demand during this time, and both utility-scale and non-residential PV markets are set to increase in market share. As grid parity is realized in several PV markets by the year 2017, commercial businesses will be help drive PV demand as they seek to secure energy cost (Colville, 2013a).

There is a recent trend in the global PV market that involves distinct local markets with their own policies, product specification requirements, and consumer preferences, as opposed to the single market approach to solar development previously capitalized on by global PV suppliers. Customized supply channels have forced global companies to make adjustments to the products they offer, whereas before the same product would be suitable for different markets. Trade wars and import restrictions is creating application-specific markets that vary between countries (NPD Solarbuzz, 2013).

3.9 Summary

In Summary, solar PV energy technology had modest beginnings and was not a widely-used technology. However, over the last decade it has experienced impressive global growth, especially in key European countries and Japan, as well as the United States. Government policies have been paramount in stimulating high market growth for solar PV energy. In particular, Germany's government policies for solar PV have transformed it into the world's premier PV market.

Although Germany and other European countries have been the center stage for much of the rapid increase in PV installations over the last several years, the percentage of Europe's global share of newly installed PV systems is showing signs of waning. Nevertheless, global growth in PV installations is set to continue its increase with emerging markets in the Asia Pacific and North America increasing in share.

Over the next several years there will be many different barriers and challenges to entering PV markets that have their own particular set of qualities and requirements. Individual PV markets may contain a preference for domestic products and require specific local technical requirements. Also, the recent wave of protectionism being sought by regional suppliers seeking shelter from China's huge production capacity has brought new challenges to China’s traditional markets. Solar PV suppliers will need to focus on particular target markets in order to achieve adequate market share.

CHAPTER 4 Policies Affecting Solar Energy in the United States

Government policies in the United States that have provided financial incentives for investment in PV systems have been successful in stimulating domestic PV market growth. A combination of policy incentives, including federal tax credits, subsidies and rebates, net metering, and renewable energy certificates have largely contributed to the fast growth rate of solar PV. Policies offered by the federal government have been important for the PV market in the United States; however, each state has their own policies that influence their particular PV market, and within states some municipalities and regions have differentiated policies that create sub-markets.

4.1 Federal Initiatives Supporting Solar PV

There are several reasons why the U.S. federal government would impose policies to encourage the propagation of renewable energies such as solar PV. Conventional forms of electricity generation using fossil fuels contributes to air and water pollution, greenhouse gas emissions linked to climate change, the need for mining and wells to secure fuel sources, as well as hazardous waste byproducts. In the cause of nuclear power, expensive large-term storage of dangerous radioactive waste is needed and carries the potential risks of more substantial threats to environment and human health in the event of structural failure. There have been several federally sponsored programs and initiatives aimed at supporting both the supply and demand side of solar PV energy in the United States. The three most important federal programs that were designed for solar PV include the Million Solar Roofs Initiative (MSR), the Solar America Initiative (SAI), and the SunShot Initiative.

The first significant government policy that supported the solar PV market in the United States was enacted in the year 1978. The Public Utility Regulatory Policies Act (PURPA) of 1978, enacted by the federal government, required investor-owned utilities to sign long-term electricity purchase agreements with renewable energy providers. This helped cause the PV solar market in the United States grow significantly and played a large role in the PV market multiplying in total capacity many times from the mid-1970s to mid-1980s. However, PURPA contracts were allowed to expire as the cost for fossil fuels subsided (Heiman and Solomon, 2004)

A major government policy that supported the PV market worth noting was enacted in the year 1997. The federal Million Solar Roofs Initiative (MSR) was enacted in the year 1997 and expired in the year 2005. Between those years it formed official partnerships with 94 coalitions and 971 private firms, electric utilities, building contractors, property developers, as well as both nonprofit and governmental organizations. The primary focuses of the Million Solar Roofs Initiative included: best practices for market transformation and distributed technology diffusion, addressing barriers to technology acceptance, market expansion efforts, partnerships, and best programmatic practices (Strahs and Tombari, 2006). The areas related to stimulating the use of solar PV that the MSR made the most significant contributions to were reducing barriers to technology acceptance, expanding the solar market, and developing the best practices for transforming the solar market.

The focus on transformation and technology by the MSR addressed key issues such as net metering rules and standards, incentive funding for solar installations, the need for stability of solar programs, and regulation requirements. In addressing barriers to technology acceptance efforts were made to resolve the high cost of solar PV, increase customer awareness and knowledge of PV systems, pass new net metering laws, and support training for PV installers, inspectors, and manufacturers. Efforts were also made to educate property developers on solar-friendly building practices and integrating solar PV systems in building designs.

In an effort to expand the solar market, the Million Solar Roofs Initiative encouraged building codes for solar installations and called on property developers to voluntarily incorporate solar power into their productions. The MSR also worked towards greater use of solar power for public buildings. Solar PV systems were also installed at high profile public areas to garner higher awareness and interest in solar power by the community. The MSR had six regional offices that were used to enroll partnerships, issue competitive grants, and address the needs of partners for technical and analytical support. “Over the years, grants totaling $9.2 million were awarded to partnerships, accounting for an estimated 68% of MSR funds disbursed.” The “MSR’s program design provided opportunity for feedback from the real world of solar technology users, marketers and installers back to laboratory scientists and program professionals at the Department of Energy (DOE)" (Strahs and Tombari, 2006).

The Million Solar Roofs Initiative was remarkable in how much it was able to assist in developing the solar market in the United States despite having a total budget of just $16 million for the duration of the program.

The participants of MSR partnerships included (Strahs and Tombari, 2006):

- Electric and gas utilities;
- Architects;
- Builders;
- Developers;
- Solar equipment manufacturers (including inverters);
- Aggregators, retailers, and distributors;
- Banks and financiers;
- A labor union;
- Municipalities and their associations, as well as mayors' offices; government agencies such as housing authorities and planning departments;
- State energy offices, environmental regulators and economic development agencies;
- Federal government agencies;
- Non-governmental organizations; and
- Agricultural agencies and associations.

In the year 2006, the U.S. federal government launched a major policy to further advance the PV market in the United States, the Solar America Initiative (SAI). This initiative served as a continuation of the Million Solar Roofs Initiative that expired at the end of 2005. In line with the U.S. Department of Energy's (DOE) Solar Energy Technology Program (SETP) under the Million Solar Roofs Initiative, its objectives also included the directives "to make photovoltaic technologies (solar electricity) cost-competitive with conventional forms of electricity from the utility grid by 2015." Like the MSR, the SAI approached its goals for the solar PV market by working with key partnerships with governmental and nongovernmental organizations, national laboratories, universities, and different groups within the industry. The U.S. Department of Energy has taken credit for much of the technology advancements in PV modules that led to a tenfold drop in PV electricity cost from the year 1976 to 2008 (EERE, 2008).

In February of 2011, the U.S. Department of Energy (DOE) launched the SunShot Initiative, which was another important program designed to support the growth of the solar energy market. Also similar to the Million Solar Roofs Initiative, the Sunshot Initiative is focused on supporting research that leads to progress and solutions for manufacturing and PV system costs improvements in order to make PV solar more accessible and cost-effective for a greater number of people. It has been responsible for funding over 150 projects related to solar PV and concentrated solar power, reducing balance of systems costs, and systems integration (EERE, 2013b).

Some of the strategies of the SunShot Initiative to make solar power more affordable include: reducing the time gap between when a new technology is first developed and when it is incorporated in commercial production, increasing the efficiency and costs of production, creating new markets for solar energy, gaining greater cooperation with utilities for higher market penetration, achieving improved supply chains and superior technology for use in solar manufacturing, increasing the size of a well-trained solar power workforce, investigating approaches to further remove barriers to the growth of the solar market, and investment in policy analysis (EERE, 2013c). Competitive grants are also awarded to companies and researchers in order to support creative solutions toward achieving these goals and making solar PV a bigger part of meeting the United State's energy needs.

4.2 Federal Financial Incentives for Solar PV

The U.S. federal government has offered various financial incentives in the last several years that have supported the solar PV market. In the year 2005, the Energy Policy Act introduced by the U.S. federal government created Clean Energy Renewable Bonds in order to finance public renewable energy development. $800 million worth of tax credit bonds were issued for the years 2006 and 2007, and $800 million more was supplied as an extension of the program in the year 2008. In the year 2009, the American Recovery and Reinvestment Act (ARRA) provided an additional $1.6 billion for the same purpose. Later in 2009, the U.S. Department of the Treasury allocated an additional $2.2

billion for new clean energy bonds. “Moreover, the U.S. Department of Agriculture established the Rural Energy for America Program (REAP), which provides grants and loan guarantees for investments in renewable energy systems, energy efficiency improvements and renewable energy feasibility studies.” Under this program, $255 million was provided between the year 2009 and 2012 (Timilsina et al., 2011).

The Business Energy Investment Tax Credit (ITC) has been a major federal government incentive that supports investment in solar PV systems. The ITC was first introduced in 1978 as part of the Energy Tax Act at that time. Since then it has expired and been reinstated at different times. The latest version was enacted as part of the American Recovery and Reinvestment Act. It expanded the Business Energy Investment Tax Credit, which had already been extended by the Tax Relief and Health Care Act of 2006 and the Energy Improvement and Extension Act of 2008 (Database of State Incentives for Renewables & Efficiency (DSIRE), 2013a).

The ITC offered a one-time tax credit worth 30 percent of the total project investment. If the 30 percent credit were larger than the current tax liability of the investor, the surplus amount could be carried over to the next tax year for up to 20 years. It could also be carried back one year to be applied towards current tax obligations (Walsh, 2012). The ITC is available for approved renewable projects placed in service before the year 2017. The Business Energy Investment Tax Credit is a corporate tax credit designed for renewable energy projects that serve commercial, industrial, utility, or agricultural applications. Currently, the ITC is scheduled to revert to a 10 percent tax credit in the year 2017 (DSIRE, 2013a).

Also, as part of the American Recovery and Investment Act of 2009, the federal 1603 Treasury Cash Grant was enacted. Like the ITC, It was introduced to encourage commercial-scale renewable energy development, such as solar PV plants. It provided a 30 percent cash grant for approved renewable energy projects. It was designed as a grant that can be converted from the ITC award as a cash fund. It was extended the following year as part of the Tax Relief, Unemployment Reauthorization, and Job Creation Act in the year 2010 and expired at the end of 2011 (Walsh, 2012). In order to qualify for the grant, applicants had to begin construction on their plants by December 31, 2011 and be scheduled to conclude construction by the end of 2016 (Solar Energy Industries

Association (SEIA), 2013a). Recently, a temporary 8.7 percent reward reduction has been put in place effective in March 2013 through September 2013. This has caused some uncertainty among developers regarding the reliability of expected returns on investment from renewable energy projects based on current government policies (SEIA, 2013b).

The importance of the 1603 Cash Grant was that it provided funding for 30 percent of a PV project irrespective of tax liability. "By the end of March 2012, the 1603 Treasury Program awarded grants to more than 33,000 solar projects totaling $2.1 billion." Because the 1603 Cash Grant has expired, investors that do not have the funds or necessary tax liabilities to fully utilize the ITC will have to rely on third-party investors to fully take advantage of the incentive. "One outgrowth of this situation is a developing business in third-party ownership of residential and commercial PV systems, with the outside owner installing and maintaining the systems to take advantage of the tax credit; funding comes from investors in securities backed by system leases or from agreements to purchase the power" (Platzer, 2012).

Also introduced by the Energy Policy Act of 2005 was the federal Residential Renewable Energy Tax Credit. This tax credit is similar to the Business Energy Investment Tax Credit, except that it is designed for residential rather than commercial renewable energy systems. In the Energy Improvement and Extension Act of 2008 the program was extended through the year 2016 and had the $2,000 credit limit changed to an unlimited 30 percent tax credit starting in the year 2009. "The credit was further enhanced in February 2009 by The American Recovery and Reinvestment Act of 2009, which removed the maximum credit amount for all eligible technologies (except fuel cells) placed in service after 2008." Excess tax credit from the renewable energy system can be carried forward each tax year up until at least 2016 (DSIRE, 2013b).

4.3 Solar PV on Public Lands

In the year 2009, the U.S. federal government started approving of utility-scale solar electricity generation plants on public lands after satisfying environmental impact reviews. By July of 2012, the U.S. Department of the Interior (DOI), in cooperation with the U.S. Department of Energy, has approved 17 large projects, which is enough to provide nearly 6 GW of power after their completion. This would be enough electricity for about 1.8 million households. The recent Final Programmatic Environmental Impact Statement (PEIS) released in October of 2012 outlines 17 "Solar Energy Zones" comprising of 285,000 acres of land that is set aside as primary areas for utility-scale solar power plants. The report also includes 19 million acres beyond the Solar Energy Zones as variance areas suitable for future solar development. The 17 priority zones for development identified in the PEIS, together with the variance zones, are estimated to eventually lead to the development of nearly 24 GW worth of projects, enough electricity to power 7 million homes (DOI, 2012).

An example of the effort to develop solar PV energy projects on public lands is the 750 MW McCoy Solar Energy Project and the 150 MW Desert Harvest Solar Farm recently approved by the U.S. Department of the Interior. The McCoy Solar Energy Project will be one of the largest PV projects on public land and will be developed on 1,780 hectares, which will be managed by the Bureau of Land Management (BLM). The project is worth $100 million dollars and will be able to supply 200,000 households with electricity (Chan, 2013a).

4.4 California State Government Policies for Solar PV

As a result of effective government incentives, California has become a model state in the U.S. for its success in supporting a strong PV market. California is the national leader for PV installations. Although it is difficult to predict how its PV market would look today in the absence of state and local policies that support PV installations, California provides an example of how important financial incentives are to PV markets in the United States.

4.4.1 Early Policies That Supported Solar PV in California[14]

The first significant policies in California to encourage PV system installations mirrored closely with the federal tax credits of 1978. "From 1980 to 1983, for example, California homeowners could claim a state tax credit worth up to $3,000 for any solar energy system installed on their homes." This policy was not continued, however, and the solar PV market in California stalled, falling from a nearly half a billion dollar industry to

[14] Information in this section sourced from Chiaro and Gibson (2006).

only 20 million dollars within 2 years in the latter part of the 1980s. It was not until the next decade that further legislation was enacted to support the PV industry in the state. "In 1995, California passed its first net metering law, Senate Bill 656, establishing a key financial driver for homeowners to invest in small solar power systems (under 10 kilowatts) cost-effectively."

The benefit of net metering is that it enables the owner of the solar PV system to receive credit for unused electricity that is produced and supplied to the grid. This also encourages energy conservation, because the more energy the PV owner can supply to the grid the greater the credit they can receive. This results in lower electricity bills in the future when PV power generation is reduced due to weather. In the year 2002, net metering policies in California were continued, but a cap was put in place amounting to a half percent of the total peak demand of a utility company. The cap was already reached for the San Diego Gas & Electric company in 2005, but was subsequently raised.

In the year 1996, a rebate for solar power systems less than 30 kW was created in California with a total worth of $180 million. In the year 2002, the rebate was extended to 2007 with an additional $118 million provided. By the year 2006, $371 million had been spent on the special rebates and resulted in a total of 60 MW worth of solar PV on more than 15,000 buildings. In the year 2000, the Self-Generation Incentive Program (SGIP) was created for larger-scale PV systems (over 30 kW up to 1 MW). This program provided $138 million for rebates. In the year 2003 it was extended to the year 2007 with an additional half a billion dollars provided. Other policy incentives in California included a 15 percent income credit between the year 2001 and 2003 and a 7.5 percent credit for the year 2004 and 2005.

Because of the energy crisis in California in the year 2000 and 2001 that caused blackouts and increased awareness of issues surrounding global warming, the number of applications for subsidies for solar PV increased by 2,800 percent between the year 2000 and 2004. In August 2002, the governor of California signed into law a renewable portfolio standard that required the state's investor-owned utilities to supply 20 percent of their energy from renewable energy sources. A few years later the date was moved forward to the year 2010. This caused utility scale renewable energy projects to increase.

By the year 2006, 10 percent of the state's energy came from renewable energy sources.[15] At that time, it was estimated that the percentage could increase to 30 percent by the year 2020. However, at the time solar PV only accounted for less than one half of one percent of the state's total electricity supply, despite having been the third largest market in the world for solar power, behind Japan and Germany.

4.4.2 California Solar Initiative

In January of 2006, the California Public Utilities Commission (CPUC) adopted the California Solar Initiative.[16] The landmark initiative was designed to lead to solar PV installations on one million roofs in ten years time, or 3 GW of solar PV capacity. It was also designed to result in an affordable and self-sufficient solar market in the ten year time frame. The California Solar Initiative was the culmination of 3 consecutive years of previously proposed legislation aimed at supporting the solar power market in California that failed to get passed into law, the Million Solar Roofs Bill.

California's Million Solar Roofs Bill was largely modeled after the success of Japan's solar rebate program.[17] The CSI also hoped to emulate the demand-pull effect Japan's solar policies had on Japan's PV manufacturers. The rebate level of $2.80 U.S. per watt offered beginning in the year 2006 was designed to decrease by 10 percent a year in line with the expected decrease in solar PV system costs. For every 100 MW of solar power installed, ratepayers were to save the cost of a new natural gas power station as well as the higher cost of peak energy prices (Chiaro and Gibson, 2006). An added benefit to the CSI was it would keep more money used for energy costs in the state of California, rather than use the money to pay for out-of-state energy suppliers.

The CSI was designed to offer rebates that depended on the actual amount of electricity produced by the PV system over time rather than based solely on system capacity at the time of installation. This was in order to encourage the purchase of higher efficiency PV systems. The CSI also took measures to protect lower-income households from having to pay the utility surcharges required to finance the initiative. Those whose

---

[15] At the time 90 percent of California's electricity came from fossil fuels, and over 40 percent came from natural gas power plants (Chiaro and Gibson, 2006).

[16] The California Solar Initiative is the largest solar program in the United States (Loewen, et al, 2012).

[17] Japan led the world in both PV capacity and electricity generated by PV systems at the time the CSI was enacted (Chiaro and Gibson, 2006).

incomes were up to 200 Percent of the poverty level were exempt from any surcharges (Chiaro and Gibson, 2006).

The California Solar Initiative offers rebates for customers of the investor-owned utilities Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and San Diego Gas and Electric (SDG&E). Utility customers in these districts together account for more than two thirds of all utility customers in the state of California. "The CSI program has a total budget of $2.167 billion between 2007 and 2016 and a goal to install approximately 1,940 MW of new solar generation capacity." It also has $250 million allocated for the solar thermal goal of 200,000 new solar water heater systems. "The CSI program is funded by electric ratepayers and the CSI-Thermal portion of the program is funded by gas ratepayers" (Go Solar California, 2013a).

At the time the California Solar Initiative was passed, a 2.5 kW PV system could supply half the electricity needs for an average household at the initial investment of $20,000. A buy-down grant offered by the CSI amounted to $2,000 per installed kW. For a 2.5 kW system, this would amount to $7,000, or more than a third of the cost. An additional $2,000 could be deducted by the federal Residential Renewable Energy Tax Credit at the time,[18] bringing the total cost to the customer down to $11,000, or nearly half of the initial cost for the system. At the time this meant that savings through electricity supplied by the PV system would bring a payback on total investment cost in 10 or 12 years (Chiaro and Gibson, 2006). Since PV systems are designed to operate for 25 or even 30 years, the CSI made solar PV systems a viable investment.[19]

The California Solar Initiative Rebates are paid upfront in one lump sum or by monthly payments over a period of 5 years. The Expected Performance-Based Buydown (EPBB) is the upfront payment only available for smaller PV systems. The payment is based on estimates on system performance derived from the tilt, azimuth, location, PV module type, and the mounting type of the PV installation (Go Solar California, 2013b).

[18] At the time the CSI was enacted, the federal Residential Renewable Energy Tax Credit had a $2,000 limit. The limit was removed effective in 2009 (DSIRE, 2013b).

[19] This does not take into account the need to replace inverters. Inverters convert the direct electricity current (DC) to alternating current (AC). Most inverters have a service life of about 10 years, and they are expected to need replacement at least once in the lifetime of a PV system. Inverters at the time cost about $2,000.

The Performance Based Incentive (PBI) is paid based on actual performance over the course of five years. The PBI is paid on a fixed dollar per kilowatt-hour ($/kWh) of generation basis and is the required incentive type for systems greater than 30 kW in size, although smaller systems may opt to be paid based on the PBI. In the beginning of the CSI Program, all systems 100kW and greater were required to take the PBI incentive, and in January 2008, all systems 50kW and greater were required to take the incentive. As of January 2010, all systems 30kW and greater are required to take the PBI incentive (Go Solar California, 2013b). The EPBB and PBI incentive types are explained in the table below:

Table 4-1: CSI Incentive Types

Expected Performance-Based Buydown (EPBB)	Performance-Based Incentive (PBI)
Ideal for residential and small business projects	Ideal for larger commercial, government & non-profit projects
Systems less than 30 kW	Mandatory for all systems 30 kW and greater Systems less than 30kW can opt-in to PBI
Incentive paid per Watt based on your system's expected performance (factors include CEC-AC rating, location, orientation and shading)	Incentive paid based on the actual energy produced by the solar system, measured in kilowatt-hours
One-time, lump-sum upfront payment	60 monthly payments over five years

Source: Go Solar California (2013b).

The California Solar Initiative (CSI) was designed as a 10 year program to achieve 3 GW of new PV installations, but more importantly, to help solar PV to be a self-sustaining market in the absence of government incentives. The levels of incentives were based on market demand and total PV installations. These incentives were organized in ten different phases, with each phase automatically adjusting to greater market demand conditions with fewer incentives. For example, in the year 2007, the CSI provided a rebate for about 25 percent of the cost of the average PV system. In the year

2012, the rebate was only valued at 6 percent of the installed cost (Movellan, 2012). The transparency of the program has provided predictability and stability for PV developers operating in the state.

4.5 Summary

As this chapter has revealed, there are many approaches government can take to encourage and support growth in domestic PV supply and demand. Early attempts by the United States government to support the utilization of renewable energy sources such as solar PV made noticeable changes in the developments of the PV industry, but low energy prices and a lack of political will to sustain those policies resulted in modest, short-lived advancements. On the other hand, the small amounts of growth in the industry helped lead to larger steps later on.

The federally implemented Million Solar Roofs (MSR) that started in the late-1990s, and the other federal programs designed to support the solar PV industry that came afterwards, seemed to be an important step in laying the foundation for further PV development in the United States. Federal solar programs have helped make the necessary first steps by pulling together information and cooperation among the various entities necessary for a growing solar energy industry. As a simile, one can compare the federal government's efforts as an organizer between different communities in order to build a common road, and by building that road the goal of building more cars becomes more viable.

As important as government policies are for the PV market in the United States, perhaps none are as important for substantive results as financial incentives. Because the cost to install PV systems is costly, much of the rapid growth of solar PV in the United States can be attributed to the increase in affordability it has been able to obtain after factoring in government financial incentives. California is a good example of this reality. As a U.S. state, it is by far the largest PV market in the nation. Much of this rapid growth followed the enactment of the CSI, which, combined with federal financial incentives, provided attractive financial benefits to investing in solar PV systems.

Chapter 5 The Supply of Solar PV in the United States

The United States at one time was a major global supplier of solar PV components. Thirty years ago the United States manufactured nearly half of the world's PV panels. However, this number shrunk to 27 percent of the global supply in the year 2000. Since then the United States' share of the global production has continued to decline. By the year 2010, the U.S. was only producing about 7 percent of the PV panels in the world. The global overcapacity caused mostly by Chinese producers has caused havoc and financial ruin for many domestic PV suppliers in the U.S. Although the year 2013 has shown some signs of respite, the problem of oversupply and net operating losses continues to challenge the long-term solvency of many U.S. PV manufacturers.

5.1 The Supply of Solar PV in the 2000s

The United States has only a small percent share of the global PV panel and cell supply in spite of the fact that both venture capital and private equity investments in U.S. solar production companies increased greatly from the year 2000 to 2011, from $50 million to more than $1.7 billion respectively. This has made the solar PV market by far the greatest recipient of investment for renewable energy technologies in the United States (EERE, 2013a). Although the United State's global share of PV models and cells has declined, it has grown in the number of companies that produce these products. It has also increased in the production of PV modules and cells.

In the year 2000, there were 21 companies in the United States that produced PV cells and modules. They accounted for over 68 MW of exports and nearly 20 MW of domestic shipments for a total of over 88 MW. In the year 2001, there were 19 U.S. companies that accounted for over 61 MW of exports and over 36 MW of domestic shipments for a total of nearly 98 MW. In the year 2002, there were also 19 U.S. companies that accounted for nearly 67 MW of exports and over 45 MW of domestic shipments for a total of over 112 MW (EIA, 2010).

In the year 2003, there were 20 U.S. companies that accounted for nearly 61 MW of exports and nearly 49 MW of domestic shipments for a total of over 109 MW. In the year 2004, there were 19 U.S. companies that accounted for nearly 103 MW of exports and over 78 MW of domestic shipments for a total of over 181 MW. In the year 2005, there were 29 U.S. companies that accounted for over 92 MW of exports and over 134 MW of domestic shipments for a total of nearly 227 MW. In the year 2006, there were 41 U.S. companies that accounted for nearly 131 MW of exports and nearly 207 MW of domestic shipments for a total of over 337 MW (EIA, 2010).

In the year 2007, there were 46 U.S. companies that accounted for over 237 MW of exports and over 280 MW of domestic shipments for a total of nearly 518 MW. In the year 2008, there were 66 U.S. companies that accounted for over 462 MW of exports and over 524 MW of domestic shipments for a total of nearly 987 MW. In the year 2009, there were 101 U.S. companies that accounted for over 681 MW of exports and over 601 MW of domestic shipments for a total of nearly 1,283 MW. From these numbers we can see a significant surge in PV production in the U.S. after the year 2003 (EIA, 2010).

Table 5-1: U.S. PV Cell and Module Shipments－2000-2009

Unit: Kilowatts (kW)

Year	Number of Companies	Exports	Domestic Shipments	Total
2000	21	68,382	19,838	88,221
2001	19	61,356	36,310	97,666
2002	19	66,778	45,313	112.09
2003	20	60,693	48,664	109,357
2004	19	102,770	78,346	181,116
2005	29	92,451	134,465	226,916
2006	41	130,757	206,511	337,268
2007	46	237,209	280,475	517,684
2008	66	462,252	524,252	986,504
2009	101	681,427	601,133	1,282,560

Source: EIA (2010).

Up until the year 2006, the United States was a net exporter of PV cells and modules, and exported a significant amount more than it imported from before the 2000s through the year 2004. However, by the year 2008 the U.S. had increasingly become a net importer of PV cells and modules. This discrepancy accelerated greatly by the year 2010 when it imported nearly twice the amount of cells and modules as it exported. In the year 2004, the U.S. exported more than twice the amount of PV modules and cells as it imported, with nearly 103 MW of exports and less than 48 MW on imports. In the year 2006, the U.S. imported nearly 174 MW and exported less than 131 MW. In the year 2007 imports and exports were nearly on par. But in the year 2008, imports jumped to nearly 587 MW while exports amounted to about 462 MW. Although the rate of exports was increasing, the rate of imports was increasing more quickly. In the year 2009, imports accounted for over 743 MW and exports totaled over 681 MW (EIA, 2012d).

5.2 The Supply of Solar PV in 2010

In the year 2010, there were 121 U.S. companies that accounted for the production of over 2,644 MW of PV cells and modules, nearly 977 MW of which were exported. In 2010, imports expanded significantly to 1,734 MW compared to about 978 MW of total exports (EIA, 2012d). SolarWorld (based in Germany), First Solar, and Suniva supplied almost 60 percent of the U.S. domestic production of PV cells. U.S. producers accounted for 1.1 GW worth of PV modules. The combined value of both PV cells and modules produced by the U.S. totaled $6.4 billion that year (Platzer, 2012).

The value of the global PV market across the supply chain, including materials, modules, and installations, was valued at $2.5 billion in the year 2000. In the year 2010, the value of the solar chain increased to $71.2 billion, with the U.S. accounting for about 7 percent of the global share (Platzer, 2012). In 2010, U.S. crystalline PV module producers accounted for 5 percent of the global market with a total of 796 MW of modules. SolarWorld AG dominated the U.S. suppliers of crystalline modules with 27.5 percent of the 796 MW produced in the country. BP Solar International Inc. was the second leading U.S. supplier with 9.3 percent of the production. Solar Infar Inc. was third with 4.6 percent. SCHOTT Solar AG was the fourth largest supplier accounting for 3.4 percent of the market. Unicor Federal Prison Industries was fifth with 2.5 percent of the production share (Globaldata, 2011). These 5 producers accounted for over 47 percent of all crystalline solar modules produced in the U.S. in 2010, but the relatively low percentages of some of the top 5 producers implies several producers in the U.S. producing relatively small amounts of crystalline PV modules at the time.

The United States was a much larger supplier of thin-film PV modules in the year 2010, accounting for 16 percent of the global supply for a total of 575 MW. Thin-film PV module production has been dominated by First Solar, the world's leading thin-film PV module producer. First Solar produced more than 40 percent of the thin-film module supply in the U.S. in 2010, followed by United Solar Ovonic LLC with 27 percent. Solyndra Inc produced over 11 percent of the market share. The forth leading producer, Abound Solar Inc., produced over 5 percent. Global Solar Energy Inc supplied nearly 5 percent of the thin-film modules in the U.S. in 2010. The eight top thin-film module producers in the U.S. accounted for more than 97 percent of the total supply (Globaldata, 2011).

For the year 2010, it was estimated that the domestic value of PV systems installed with crystalline modules that were made in the U.S. was at 20 percent. For PV systems installed using thin-film modules, the percentage is much higher, at over 70 percent. These percentages were both somewhat lower than the estimates for the year 2009, which had crystalline PV systems at 24 percent domestic value and thin-film systems at 77 percent. U.S. produced components in other balance of system inputs have increased, however. Domestic value of inverters and mounting structures rose from 26 percent to 45 percent and from 84 percent to 94 percent respectively from the year 2009 to 2010 (Platzer, 2012).

5.3 The Supply of Solar PV in 2011[20]

As of July of 2011, there were a total 59 PV production facilities in the United States that produced PV cell, module, wafer, or polysilicon, and were spread out among 22 states. These facilities either produced crystalline-silicon PV products, including polysilicon and wafers used for crystalline-silicon cells, concentrating photovoltaics (CPV), or thin-film cells and modules, including –Si, CdTe, CIGS, and organic photovoltaics (OPV) (DOE, 2012a). In 2011, there were 300 companies producing solar PV modules and more than 100 companies producing PV cells in the U.S. There were 120 companies involved in the shipment of PV components on some level, up from 112 in 2010. Of these companies: "63 companies were involved in module and/or cell

[20] Information in this section sourced from EIA (2012e) and Platzer (2012).

manufacturing, 57 designed modules or systems, 35 developed prototype modules, 22 developed prototype systems, 65 were involved in wholesale distribution, 29 were involved in retail distribution, and 32 installed PV systems" (EIA, 2012e). Ninety-seven of these companies gained at least 90 percent of their revenue from the PV market, and fourteen gained less than 10 percent of their revenues from PV. Six companies had 50 to 89 percent of their revenue source gained by the PV market, and three had 10 to 49 percent.

Table 5-2: U.S. PV Cell and Module Production — 2010

Unit: Megawatts (MW)

Company	**Headquarters**	**PV Cells**	**PV Modules**	**Share of U.S. Cell Production (%)**
SolarWorld	Germany	251	219	22.9
First Solar	United States	222	222	20.2
Suniva	United States	170	15	15.5
Evergreen Solar	United States	158	158	14.4
United Solar	United States	120	120	10.9
Solyndra	United States	67	67	6.1
Solar Power Industries	United States	35	31	3.2
Abound Solar	United States	31	31	2.8
Miasole	United States	20	20	1.8
Global Solar	United States	17	0	1.5
All Others		7	382	0.6
Total		**1,098**	**1.265**	**100**

Source: Platzer (2012).

In the year 2011, the value of PV module shipments in the United States totaled almost $6 billion, and the value of PV cell shipments totaled over $1.7 billion. The dollar value of shipments is actually misleading in regards to the increase in PV shipments as measured in kilowatt hours; because the price declines in PV cells and modules are translated through the value of shipments. “For photovoltaic cells, the average price decreased more than 18 percent, from $1.13 in 2010 to $0.92 in 2011, and the average price of photovoltaic modules fell nearly 19 percent, from $1.96 in 2010 to $1.59 in 2011” (EIA, 2012e).

In 2011, the amount of PV modules that were produced in the United States increased by 9 percent from the previous year, totaling more than 1,160 MW. Three quarters of these modules were manufactured in California, Ohio, Oregon, and Tennessee. Nearly a third of the PV modules produced in the U.S. were thin-film and close to two thirds were crystalline modules. Imports of PV modules that year amounted to over 3.3 GW. Over 80 percent of the imported modules were made from crystalline cells, and 50 percent of all module imports came from China. Together with the Philippines and Malaysia, these three countries combined accounted for nearly 90 percent of all PV module imports in the U.S. in 2011. The value of imports of PV cells and modules in the United States reached nearly $5 billion, up from $227 million in the year 2005.

U.S. exports of PV cells and modules to the rest of the world increased leading up to 2011 albeit slower than global growth in demand, with $442 million shipped in the year 2006 and more than $1 billion in the year 2011. The amount of exports of PV modules from the U.S. totaled nearly 800 MV in the year 2011 and amounted to less than a quarter of the imports. Crystalline modules accounted for just over two thirds of the modules exported. Of these, Germany, Canada, and Italy were the main export markets, together totaling nearly 60 percent of all exports. Total U.S. PV module shipments totaled just under 3 GW in the year 2011 including shipments to all 50 U.S. states. About two thirds of all the shipments went to five states; California, New Jersey, Arizona, Colorado, and Texas. California led the nation with 36 percent of all module shipments in the U.S. This is not surprising considering California’s high growth of PV installations.

In the year 2011, nearly half of the U.S. PV module shipments went to the commercial sector, totaling about 1.4 GW. The domestic shipments were predominantly crystalline modules, over 95 percent, while thin-film modules accounted for most of the rest. The electric power sector accounted for over 760 MW of domestic shipments. It was the second largest domestic market with just over a quarter of the market shipments. Eighty-three percent of the modules received were crystalline, 11 percent were thin-film, and 6 percent were concentrator PV modules. Module shipments for the residential sector nearly equaled the power sector with 754 MW. About 95 percent were crystalline modules and the rest were thin-film. The industrial sector was the smallest market for domestic shipments, only accounting for 0.4 percent, for a total of less than 13 MV. It had the largest portion of concentrator modules at nearly 15 percent. Crystalline modules accounted for about 85 percent, and thin-film accounted for a small fraction.

Total U.S. PV module shipments in 2011 were predominantly shipped to grid-connected distributed PV systems. These shipments totaled more than 2.1 GW, or nearly three quarters of all shipments. Crystalline modules accounted for 96 percent of the shipments, thin-film accounted for nearly 4 percent, and concentrator modules accounted for less than 0.2 percent. Grid-connected centralized PV systems accounted for more than a quarter of the shipments at about 760 MV. 83 percent of the modules received were crystalline, 11 percent were thin-film, and 6 percent were concentrator PV modules.

Off-grid residential PV systems only accounted for less than 0.3 percent of total U.S. module shipments, totaling about 7.6 MV. More than 95 percent of these shipments were crystalline modules, about 1 percent thin-film, and nearly 4 percent were concentrator modules. Specialized off-grid applications for equipment accounted for about 5.3 MV, with about two thirds of the modules being crystalline and about a third being thin-film. The total inventory of PV modules at the end of 2011 totaled about 1,164 MV. The inventory for 2011 was over 200 percent higher than at the end of 2010. "Compared with industrial output, this was 2,259 peak kilowatts more than the 1,161,589 peak kilowatts of PV modules manufactured in the United States during the year" (EIA, 2012e).

In 2011, SolarWorld had the largest PV cell and module factory in the United States in the state of Oregon, with a total capacity of 500 MW. There were also foreign firms that had PV component factories in the U.S. to better access the local markets.

These included companies such as Schott Solar, Sanyo, Kyocera, Siemens, and Suntech.[21] States with larger concentrations of PV plants include California, Oregon, Arizona, Ohio, Texas, and Colorado. More than 20 companies in the United States produced PV grade polysilicon materials for the PV market, such as wafers and ingots. About 50 companies produced PV cells, PV modules, or both. Around 30 other companies produced solar PV inverters.

Although 2011 was a year of much activity by PV manufactures in the U.S., it was also a year of financial collapse for some of them. "Industry data indicate that at least eight U.S. solar manufacturing facilities were closed in 2011. Of these, five had operated for less than five years" (Platzer, 2012). The most notable PV producing companies that closed operations in the United States in the year 2011 include: Evergreen Solar, MEMC Southwest, SolarWorld Americas, Solon America Corp., Solar Power Industries, Solyndra, SpectraWatt, and Energy Conversion Devices. In the year 2012, notable closers included BP solar and Sanyo (closed one factory). Of the ten companies mentioned, seven of them had produced PV cells, modules, or both.

Even though many companies in the U.S. have fallen victim and continue to fall victim to the "solar shakeout" that hit the global solar market in the year 2011 due to oversupply, other U.S. producers have made plans to begin or expand operations for manufacturing PV components and materials. "GE Energy is building a $600 million 400 MW state-of-the-art thin-film CdTe manufacturing plant in Colorado" (Platzer, 2012), and several companies will open new PV material facilities. Notable PV producers that had plans to commence operations in the year 2012 or later include: 1366 Technologies, Abound Solar, Calisolar, Fronius USA, GE Energy, Hemlock Semiconductor Corp., SoloPower, and Waker Polysilicon.

Between the year 2005 and 2011, the total value of imports of PV cells and modules increased by over 2000 percent and nearly 90 percent from 2010 to 2011. PV imports from Malaysia have seen the steepest increase 2005-2011, increasing by nearly 317,000 percent. In second place were imports from the Philippines, increasing by over 37,000 percent over the same time period. PV imports from China grew by over 12,500

[21] Suntech closed down its PV panel manufacturing facility in Arizona this year, its only U.S. based factory (Yantis, 2013).

percent. PV imports from Mexico increased by over 900 percent, and imports from Japan increased 221 percent between 2005 and 2011. The largest percent increase of imports from 2010 to 2011 came from Mexico at 767 percent. Malaysia had the second largest percent increase during that time at over 300 percent growth, and China was third with a 135 percent increase. Imports from Mexico and Japan dropped to an increase of 7 and 30 percent respectively.

Reasons for the increases in imports of PV supplies are attributed to the increase of crystalline PV production capacities in China, Malaysia, and the Philippines, the increase in demand in the U.S. for PV systems, and increased outsourcing for PV cells used for module assembly in facilities in the United States. First Solar and AUO SunPower are American companies that account for much of the imports from Malaysia into the United States, since both companies operate production facilities there.

Japan had been the top exporter of PV cells and modules to the U.S. up until 2008. In 2011, Japan had dropped to the fourth largest exporter to the U.S. with a total value of under $400 million. Exports from South Korea have been modest, but that could change as South Korea pushes to gain a greater share of the world PV market. The imports from Mexico are valued at over $500 million, but much of the market growth can be attributed to foreign countries setting up operations there, such as Japanese companies Kyocera and Sanyo that export PV modules assembled in Mexico to the U.S.

The incentives put in place in the mid-2000s in several countries led to a surge in companies producing PV products. By the year 2011, there were more than 1,000 companies worldwide producing PV materials, components, and equipment. But lower prices for polysilicon, cells, and modules have made it impossible for many PV manufactures to operate without sizable loses. "Meanwhile, some manufacturers in China and Taiwan continue to expand rapidly to obtain economies of scale and reduce unit costs" (Platzer, 2012).

5.4 The China Factor

U.S manufacturers have a relatively small share of the global PV market compared with China, which accounts for more than three quarters of all PV cell manufacturing. China's total domestic PV installed capacity was less than 1 GW in the year 2010, and in 2011 China exported roughly 95 percent of the PV modules it produced.

The enormous production capacity for PV cells and modules that has developed in China has put pressure on U.S. producers. As a result, the Coalition for American Solar Manufacturing (CASM) petitioned the U.S. Department of Commerce (DOC) and the International Trade Commission (ITC) over allegations that Chinese producers were dumping crystalline PV products in the United States at below market value. “In a second preliminary decision in May 2012, the department announced … duties on imports of Chinese crystalline silicon solar cells and panels ranging from 31% to 250%, with the majority subject to the 31% duties. Final determinations are scheduled to come later in 2012” (Platzer, 2012).[22]

Meanwhile, the Coalition for Affordable Solar Energy (CASE) opposed such tariffs on Chinese made PV products on grounds that it would impede positive momentum for PV system market growth and reduce the overall number of Americans employed in the PV industry supply chain. As a result of the tariffs, Chinese suppliers may set up productions in other countries or outsource part of their supply chain in order to circumvent the U.S. tariffs. “Some Chinese producers may seek to avoid the duties by opening up production in the United States” (Platzer, 2012). Since the tariffs only target PV cells manufactured within China, this will provide new opportunities for PV cell producers such as Taiwan.[23]

Although the International Trade Commission (ITC) issued hefty tariffs on PV cells produced in China, it did not materialize into higher PV module prices in the U.S. It is estimated that if Chinese module producers outsource their PV cells to Taiwan for their modules they will incur an increase in module pricing by less than $0.10 U.S. per watt. This amount is not thought to be enough to price Chinese modules above average prices for PV modules produced in the United States. Nevertheless, the overall percentage of Chinese made PV modules has declined in the U.S. since the tariffs were enacted (SEIA, 2013d).

Even though Chinese module shipments to the U.S. decreased in 2012 due to new tariffs enacted against Chinese suppliers, PV prices in the U.S. continued to fall. The global overcapacity problems caused by overinvestment in solar PV production at the end

[22] On November 7, 2012, the ITC announced duties on PV cells produced in China ranging from 22.5 to 255.4 percent (SEIA, 2013c).
[23] Taiwan is the world’s second largest supplier of PV cells.

of last decade and the year 2011 continued to suppress margins for PV manufacturers in the United States. Many manufacturers worldwide have faced the need for consolidation for survival or have discontinued production all together.

While labor accounts for about 10 percent of the cost to manufacture PV equipment, most production stages are primarily operated by automatic assembly by machines. PV module assembly requires the most manual labor, but even that is becoming more automated as the industry matures. A report conducted by the U.S. International Trade Commission (ITC) found that manufacturers in China and the United States are now using similar levels of automation to produce PV modules. The cost for China to ship their PV products internationally ranges between 1 to 3 percent of the total value of goods. Taking this into consideration, it would appear that production and transportation costs are not major factors in determining the best locations for manufacturing PV products. “For example, according to a National Renewable Energy Laboratory presentation, Chinese producers have an inherent cost advantage of no greater than 1% compared with U.S. producers; in the U.S. market, China suffers a 5% cost disadvantage when shipping costs are included” (Platzer, 2012).

Interestingly, despite the complaints by U.S. PV manufacturers that cheap PV modules and cells from China has brought them to a competitive disadvantage, the United States exported a greater value of clean energy supplies to China than vise versa. The U.S. had a net-export advantage of $1.63 billion over China in green energy technology. Ninety-five percent of the solar products shipped to the U.S. from China were solar PV modules, worth a total of $2.65 billion. China also exported PV cells to the U.S. worth a total of $151 million. “By contrast, US firms exported only US$12 million worth of modules to China.” The U.S. shipments of PV products to China were mostly comprised of polysilicon, wafers, and equipment used for PV productions. U.S. companies Hemlock Semiconductor Group, MEMC Electronic Materials, and the U.S. division of REC Group were major global suppliers of polysilicon products, all belonging to the list of the top ten polysilicon companies in the world in the year 2011. “MEMC Electronic Materials exported $289 million worth of polysilicon and wafers to China in 2011” (Carus, 2013a).

5.5 Polysilicon

In 2010, the global production of polysilicon was nearly 150,000 metric tons; more than 80 percent of this was attributed to supplying solar PV cells. This represented more than a 60 percent increase from the previous year. Large-scale production of polysilicon for the global PV industry has continued. Investment in the United States for capital and technology in producing polysilicon has made it an important supplier of this material for the global PV materials supply chain (DOE, 2012a).

Between the year 2008 and 2012, the price for solar grade polysilicon has fallen substantially, by a rate of 38 percent a year. In the year 2012, polysilicon prices fell below $20 per kilogram, a more than 50 percent decrease in price from the year 2011. Capacity for production has been much higher than the demand for several years. To make matters worse, several new large polysilicon plants are scheduled to commence operations over the next several years. This will lead polysilicon capacity to more than double the supply demanded by the PV industry for years to come even though current polysilicon producers are reducing utilization rates in order to help minimize losses due to prices falling below the cost of production (Annis, 2013).

Some of the new polysilicon plants are a result of PV manufacturers seeking to expand their company's vertical supply chain to better control the quantity and quality of the main material used for wafer production. But another problem comes from the years it can take to build a polysilicon plant and begin large-scale operations. "… once land is purchased, site construction commenced, and equipment ordered and delivered, it may be both politically and financially difficult to abandon a project" (Annis, 2013). Due to the current climate for the polysilicon market it is likely only Tier 1 producers will have the financial ability to continue production until the market becomes profitable, which will likely take years to improve significantly.

5.6 Government Policies for PV Supply

Government policies in the United States have played an important role in supporting domestic manufacturers of PV supplies. The Energy Tax Act (ETA) introduced by the federal government in 1978 helped to improve the market climate for U.S. PV manufacturers. The Public Utility Regulatory Policies Act in the same year also required public utilities to purchase renewable energy from approved sources. PV production remained modest, however, and in the mid-1980s the solar PV market was not profitable for manufacturers. "President Reagan's Tax Reform Act of 1986 reduced the Investment Tax Credit (ITC) to 10% in 1988, where it remained until 2005." However, this was still not enough to significantly entice the solar market and expand PV manufacturing very much. When the Energy Policy Act of 2005 expanded the ITC to 30 percent, solar manufacturing increased more substantially in order to accommodate higher domestic PV demand (Platzer, 2012).

Some of the federal policies that directly support PV manufacturing and other renewable energy investments in the United States include the Advanced Energy Manufacturing Tax Credit (MTC) enacted in 2009 and the Section 1703 Loan Guarantee Program enacted in 2005. The MTC reached its funding cap in the year 2010, but the second phase of this program started in 2013. The Loan Guarantee Program was revised in 2009 as the Section 1705 loan program and was retired in 2011, but loans from this program can still be awarded under the previous Section 1703 scheme (DSIRE, 2012; DSIRE, 2013b).

The MTC was part of the American Recovery and Reinvestment Act of 2009 and provides a 30 percent tax credit for approved operations that can be valued up to $30 million U.S. (DSIRE, 2013b). This bill supported PV manufacturing with $2.3 billion in tax expenditures. One hundred and eighty-three manufacturing projects in 21 different states were accepted under the program (SEIA, 2013e). "Solar PV manufacturers benefiting from the credit including Miasole, Calisolar, First Solar, Suniva, Yingli, SunPower, Suntech, and Sharp." The Section 1703 and 1705 Loan Guarantee Program was primarily designed to assist projects costing more than $25 million. Some loans awarded from the program have been massive, including a $1.2 billion loan to NRG Energy and a partial guarantee of $1.4 billion to Prologis for PV generation projects. Eighty-two percent of the Section 1705 loan program, amounting to $13.27 billion, had been awarded to support solar manufacturing and PV power generation projects before it expired in 2011 (Platzer, 2012).[24]

[24] The most famous beneficiary of the loan program was the U.S. company Solyndra, which made national headlines after defaulting on over $500 million worth of federally awarded loans when it filed for bankruptcy in the year 2011.

The SunShot Initiative enacted by the U.S. Department of Energy in the year 2007 has put in place directives and goals intended to foster PV manufacturing in the U.S., including the PV Incubator Program, the Photovoltaic Supply Chain and Cross-Cutting Technology projects, and the Scaling Up Nascent PV at Home (SUNPATH) program. Separate from the SunShot Initiative, the U.S. Department of Energy also has the Advanced Research Project Agency-Energy program (ARPA-E), which has awarded funds to a silicon PV company to support research.

5.7 Outlook for U.S. PV Suppliers

The incentives put in place in the mid-2000s in several countries led to a surge in companies producing PV products. By the year 2011, there were more than 1,000 companies worldwide producing PV materials, components, and equipment. The lower prices for polysilicon and PV cells and modules have made it impossible for many PV manufactures to operate without sizable loses. The prices of polysilicon and PV cells and modules continued to fall in the year 2012 due to the continued problem of oversupply that hit the PV market strongly in the year 2011. "Blended module ASPs for Q4 2012 were down to $0.68/W, a staggering 41% lower than Q4 2011 levels of $1.15/W" (SEIA, 2013f).[25] Making matters worse, some producers are trying to expand production capacity in order to reach greater economies of scale and further cut costs in order to survive the environment of low prices. In this sense, low prices have helped create a vicious cycle of increased capacity and unhealthy margins.

The two main markets for U.S. exports are Canada and Germany, and Europe as a whole accounts for about one third of the total. Due to the Information Technology Agreement (ITA), U.S. producers of PV cells and modules do not face tariffs on their exports, and tariffs for poliysilicon are mostly either very low or non-existent in destinations that are PV cell and module producing countries. Other barriers do exist for U.S. PV exports though, such as local content requirements and related policies that exist in countries such as Canada, Italy, and India. Regular customs taxes and specific product standards also make it harder for foreign companies to ship their products, as well as subsidies that support local producers (Platzer, 2012). In order to support U.S. PV

[25] ASPs represents average selling prices.

producers in their effort to expand exports, government programs and banking funds have given direct loans as guarantees for exporting solar modules in some cases.

Although oversupply has made it difficult for many PV producers in the United States to achieve healthy margins, there may still be hope for U.S. companies able to weather the current storm. Demand for solar PV systems remains healthy and will likely continue to grow. However, demand for PV systems in the U.S. will not necessarily be enough to ensure survival for some of the companies that are struggling to remain solvent. "… even if the popularity of solar systems grows, falling equipment prices are likely to further challenge the profitability of manufacturers and interfere with efforts to sustain a solar manufacturing base in the United States" (Platzer, 2012).

The solar shakeout is continuing with financial woes by many PV manufacturers being complicated by slowing growth of PV demand in Europe. Increases in domestic PV demand in the U.S. won't necessarily result in a healthier environment for U.S. PV component manufactures. Between the year 2008 and 2010, Germany more than quadrupled its solar PV capacity. During the same time, installed PV systems in Germany that used PV modules manufactured in Germany declined from 77 percent to just 27 percent (Borenstein, 2012).

Current technology limitations to PV system enhancements could require significant research and investment procurements in order to achieve drastic industry changes. If new machinery for large-scale production capacity is needed to implement new production technologies, vast amounts of financing will need to be made available for PV component suppliers. Capital upgrading will likely be difficult or impossible for PV manufacturers considering the current market environment of low or negative margins and high debt.

Vertical integration along the PV products supply chain is becoming an increasingly popular strategy among the tier 1 PV producers; however, the global PV market in general is still reliant on a large network of component suppliers. The advantage of vertical integration of PV components and materials for PV manufacturers is better control over the entire manufacturing process. Producing their own materials to supply production for finished products also reduces the problem of timing deliveries and potential supply constraints caused by production and supply problems from other companies (Platzer, 2012).

Historically, there have not been great technological differences between most PV products and systems regardless of origin. Most manufacturers have had little opportunity for product differentiation and customization in order to achieve a competitive advantage over other producers. What has been more important is the net result, that is, the amount of electricity produced by the product for a given price (Platzer, 2012). However, this trend seems to be showing signs of changing. As mentioned in chapter 3 of this thesis, product differentiation and localized PV product specification requirements will likely play a more important role in a company's ability to secure market share. The current market environment for solar PV demand suggest a shift from standard mass produced products shipped to various markets to one of unique micro supply and demand segments. "These segments can be differentiated by the type of PV suppliers preferred, the technologies of the modules required, the supply channels in play and the returns that can be expected" (Colville, 2013b). This will create new challenges and opportunities for existing manufactures over the next several years and may significantly affect the viability of many U.S. suppliers in the future.

Large Chinese PV producers will have a strong advantage with Chinese domestic demand for PV systems increasing sharply but will no longer necessarily be able to use their economies of scale alone to penetrate the U.S. PV market. This is partly due to the trade wars and domestic protectionism within the global PV market, but it is also a result of market segmentation. Companies that are not leaders in their own domestic market will likely have difficulty allocating the resources needed for specialized outside markets with unique requirements. This will apply to U.S. suppliers as well (Colville, 2013b).

5.8 Summary

The United States was once a global leader in manufacturing PV components. The global share of PV supply was first ceded to countries like Japan and Germany as manufacturers there increased production to meet increasing local demand. In the second half of the 2000s, as European PV growth surged, countries such as China and Taiwan ramped up PV production capacity in order to capitalize on the emerging global PV market. By the end of the decade, PV production capacity was outpacing global demand, which lead to the solar shakeout that began in 2011. The solar shakeout has continued, and many U.S. PV cell and module producers have had difficulty competing with the huge economies of scale that exist in Asia.

Falling PV component prices as a result of global overcapacity has placed pressure on U.S. manufactures, and many producers have become insolvent over the last couple of years. PV module and cell prices have shown some signs of stability in the year 2013, but the challenges of low margins continue. Polysilicon oversupply has caused prices to dip below the cost to produce it. The end to the polysilicon overcapacity is nowhere in sight. This will be a concern to polysilicon producing companies in the U.S. considering it is a major global supplier of the material.

As the global PV market matures, domestic content preferences and local technical requirements will create new challenges for U.S. and global PV suppliers alike. Even if the global oversupply of PV supplies subsides, U.S. PV manufactures will need to be able to produce low-cost components in an increasingly competitive market. PV customers are increasingly concerned with efficiency and reliability. These companies will need to find the funds needed for necessary capital upgrades in order to produce the PV products customers require in the future. PV manufacturers in the U.S. that fail to thrive in the domestic market will not likely fair well on the global stage.

CHAPTER 6 The Demand for Solar PV Energy in the United States

The demand for solar PV energy in the United States has grown impressively over the last 10 years. California's PV market has overshadowed the rest of the nation, but recently several other states have made impressive strides to develop their own PV markets. Government incentives are still an important catalyst for PV market growth, and the states with the more favorable incentives also lead the nation for PV installations. As the main federal incentives are set to expire or drastically reduce in the end of 2016, there is much unknown about what will replace those incentives as the impetus towards continued PV market growth in the U.S.

6.1 The Decline in Price for Solar PV[26]

Overall, declines in PV module prices have occurred at a faster pace than declines in the installed prices, and even more so the last several years. Several years ago, PV module prices accounted for 50 to 60 percent of the total installed price of PV systems. In the year 2011, the average global price of PV modules as a percentage of the total installed cost for a PV system smaller than 10 kW was just 21 percent. Non-module costs are a much larger percentage of the installation cost for PV systems than in recent past.

The bottom-up price for the average residential PV system fell by 26 percent from the fourth quarter of 2010 ($5.90/W) to the fourth quarter of 2011 ($4.39).[27] The bottom-up prices for the average commercial rooftop PV system fell by 28 percent from the fourth quarter of 2010 ($4.74) to the fourth quarter of 2011 ($3.43). The bottom-up price for the average fixed-tilt utility-scale PV systems fell by 29 percent from the fourth quarter of 2010 ($3.93) to the fourth quarter of 2011 ($2.79). During the same time, the average price for utility-scale PV systems with one-axis tracking systems fell 26 percent, from $4.54/W to $3.37/W. Most of the price declines in PV systems quoted at the end of 2011 were due to decreases in PV module prices. The amount of the price decline

[26] Information in this section is sourced from Feldman et al. (2012) and SEIA (2013f).
[27] The term "bottom-up" refers to price quotes by developers in the fourth quarter of particular year for a PV system to be installed the following year.

attributed to cheaper PV modules was 66 percent for residential, 73 percent for commercial rooftop, and 80 percent for utility-scale PV systems. Decreases in balance of system (BOS) costs also were reflected in the price declines, such as increased module efficiency, improved labor efficiency, and improvements in supply chain management.[28]

For PV systems installed in the year 2011, the average price for residential and small commercial systems in the United States of 10 kW or less averaged $6.13/W for the total installed price. Commercial PV systems that were larger than 100 kW averaged $4.87/W to install in the same year. The average price to install utility-scale PV systems averaged $3.42/W. The total number of all PV systems installed in the U.S. in 2011 was more than 150,000.

Depending on the size of the PV system, the average price for installed residential and commercial PV systems in the U.S. declined 5 to 7 percent each year from the year 1998 to 2011. The average price dropped from 11 to 14 percent from the year 2010 to 2011. Bottom-up figures place 2012 average installed prices at $4.39/W for average-sized residential systems (5.1 kW), $3.43/W for average-sized commercial rooftop systems (221 kW), and $2.79/W for average-sized fixed-tilt utility-scale systems (191.5 MW). Overall, these average price estimates show a 25 to 29 percent decrease in installation prices from the fourth quarter price quotes from 2010.

The average price declines of PV systems from the year 1998 to 2011 did not always occur as consistent yearly declines. Between the year 1998 and 2005, the price for PV installations declined substantially. In the years between 2005 and 2009, the rate of PV system price declines lost momentum as the PV supply chain was faced with tremendous global demand. Since the year 2009 the cost to install PV systems has dropped markedly as the supply chain expanded and economies of scale have grown for both PV equipment and installations.

The price for utility-scale installations declined from an average of $6.21/W for projects installed between the year 2004 and 2008 to less than $4.00 for those installed in 2009 and 2010. The average price for utility PV projects in the year 2011 was $3.42/W. Large differences in prices of particular utility-scale PV installations were also apparent

[28] Balance of system costs refers to costs associated with installing PV systems other than the main PV components, such as PV modules and inverters.

in the U.S. in the year 2011. Prices per installed watt ranged from $2.45 to $6.26. For utility-scale installations that were larger than 10 MV, prices ranged from $2.80/W to $3.50/W. “The projects smaller than 10 MW span a broader range, with most projects priced between $3.50/W and $5.00/W” (Feldman et al., 2012).

In the year 2011, the average installed price for PV systems 2 kW or less was $7.69/W. In the same year, PV systems larger than 1 MW averaged $4.48/W to install. The most substantial differences in price per installed watt in terms of economies of scale can be seen from PV systems 2 kW or less to those 5 to 10 kW in size. But even PV systems 5 to 10 kW in size can vary greatly in installed price per watt. “Among 5–10 kW systems, for example, the 20th and 80th percentile values span $4.98/W to $6.89/W” (Feldman et al., 2012).

In the year 2012, the average price per installed watt for residential PV systems stood at $5.04. Non-residential PV systems averaged $4.27/W and utility PV plants averaged $2.27/W to install in 2012. “Of the 3,313 MW installed in 2012, 1,300 MW (39.2%) came online in the fourth quarter, making the quarter by far the largest in the history of the U.S. solar market” (SEIA, 2013f). It was also the single biggest quarterly expansion for both the residential and utility PV markets, almost double the second largest quarterly expansion, which happened in the second quarter of 2012. From the first quarter of 2012 to the first quarter of 2013, the average cost to install a PV system dropped by 24 percent to $3.37/W. Solar panels have now declined by 60 percent since the beginning of 2011.

The average price for all types of PV installations combined decreased by over 26 percent in the year 2012 from the year 2011. However, the price per watt of residential PV installations fell by 18 percent in 2012 from 2011, and non-residential prices fell by only more than 13 percent. The large overall decrease in installation prices was mostly attributed to the largest share of PV installations in the U.S. coming from the utility sector, and the fact that the utility sector also showed the largest decline in installed prices per watt than any other PV sector.

Table 6-1: PV System Installation Prices Per Watt一2010-2012

Unit: USD

PV System Type	2010	2011	2012	Average Price Decline 2010-2012 (%)
Residential	6.42	6.18	5.04	21.5
Non-Residential	5.71	4.92	4.27	25.2
Utility	4.05	3.20	2.27	44
All PV Combined	5.13	4.08	3.01	41.3

Source: SEIA (2011, 2012, and 2013f).

Residential PV prices in the major states for residential PV declined the most, including states such as California, Arizona, New Jersey, and Massachusetts. The price per watt for residential PV systems fell below $4.00 in a number of states. In the fourth quarter of 2012, residential PV averaged $5.04 nationwide, down from $6.16/W in the fourth quarter of 2011. The average price to install non-residential PV fell from $4.65/W to $4.27/W. "SREC states, such as New Jersey and Massachusetts, saw the most significant price declines" (SEIA, 2013f).[29]

Despite the declines in the average prices for installed PV systems in the United States, PV systems can vary greatly in price depending on the state as well as the individual project. In the year 2012, residential PV systems cost less than $4.00/W to install in many places, but could reach as high $7.00/W or more. Non-residential PV systems varied even more in price, from as low as $2.25/W to as much as $8.00/W. Utility PV plants also vary in price, but this is not surprising considering the vast differences in size and design between what are considered utility-scale PV plants. Large PV plants (50 or more MW) with simple designs are cheaper to install per watt than a much smaller plant that includes dual-axis tracking for its PV panels.

Some examples of the regional differences in price for PV systems in the year 2011 include an average price of $4.90/W for systems 10 kW or smaller in the state of Texas compared to $7.60/W in Washington, D.C. The average installed price for PV

[29] SREC stands for Solar Renewable Energy Certificate. SREC markets involve a trading scheme linked to electricity generated by PV systems that is designed to better ensure compliance with renewable energy portfolio standards (RPS). Nine U.S. States and Washington, D.C. are using SRECs (Bird et al., 2011).

systems 10 to 100 kW in size was about $5.00/W in both Florida and Nevada, but $7.2/W in Texas. Larger and more mature PV markets would be expected to have lower prices for system installation. However, California is by far the largest PV market in the U.S., but the cost to install PV systems in that state is relatively high. Higher electricity prices and better government incentives for solar PV also tend to translate into higher system cost. The higher calculated value of the PV system results in higher prices commanded by the installers. The level of competition between installers also affects the prices they are able to seek to for their services.

Besides economies of scale affecting the price of the PV systems, other factors such as site-specific differences and the differences in experience and level of integration by the installers can also be determining factors. Several other factors can affect the system prices for utility-scale PV projects. These include: differences in compliance costs for regulations on public and private land, whether land for the project is leased or owned, and climate considerations affecting project design.

For PV systems as a whole, there can be differences in permitting and administrative costs, as well as the cost to interconnect with the utility grid. Regional differences in labor cost also affect installations prices. Different states also have different conditions within their PV markets that can affect the value and pricing of PV systems, such as average levels of radiant energy from the sun and the typical characteristics of their systems such as size, mounting structures, and the use of tracking equipment. Different installers may also require different fees for similar PV projects. Differences in sales tax rates also affect PV prices and can lead to regional differences as high as $0.40/W.

In comparison to a mature solar PV market such as Germany, the price for PV system installations in the United States is substantially higher. Given that PV component prices between the two countries are similar, much of the differences in prices can be attributed other inputs that affect system costs. In the year 2011, the average price for a PV system ranging in size of equal to or less than 10 kW was $6.13/W in the U.S., but the price quoted for the same size PV systems in Germany was only $3.40. For PV systems in the U.S. ranging from 10 to 100 kW the price was $5.62/W vs. only $3.10/W in Germany. PV systems greater than 100 kW averaged $4.87/W in the U.S., while similar systems in Germany averaged $2.60/W.

6.2 The Increase in Demand for Solar PV

Solar PV power systems are the fastest growing renewable electricity technologies in the world. Between the year 2000 and 2011 solar PV grew by a factor of more than 51 globally. In the United States electricity generated by solar power has increased by a factor of more than 9 during the same time (EERE, 2013a). Before the 1990s, U.S. demand for PV technology was dominated by off-grid applications. Most of these PV systems were small and measured in the hundreds of watts. In the 1990s, grid-connected installations began to arrive in greater magnitude around selective parts of the globe. System costs for PV systems began to decline as technology improved and economies of scale increased in magnitude. PV system capacities increased from the hundreds of watts to kilowatts then to megawatts (DOE, 2012a). The following decade the United States followed this global trend, and grid-connected PV systems began to dominate the solar PV market in the U.S.

In the past 5 years the solar energy market in the United States has been experiencing explosive growth, with an annual compound growth rate of about 77 percent. This culminated to what became nearly 4 GW of total solar power capacity by the end of the year 2011. From the middle of the year 2010 to the middle of 2011, the total employment in the United States increased by less than 1 percent. During the same time period, employment growth in the solar industry grew by nearly 7 percent for a total of more than 100,000 solar related jobs (Solar Foundation and SolarTech, 2012).

The 17 GW growth of solar PV shipments in the year 2010 brought the total world supply of PV modules to about 40 GW. In that year, the United States accounted for about 8 percent of the global growth in demand at 1.4 GW and about 6 percent of the global growth in supply at roughly 1 GW (DOE, 2012a). Solar PV installations grew by over 75 percent in the year 2012 from the year 2011, totaling more than 3.3 GW of new PV installations for a total value of $11.5 billion. This accounted for 11 percent of the PV systems installed globally in 2012 and was the highest U.S. percentage of new global installations in the last 15 years. Residential, commercial, and utility markets for solar PV all expanded in the year 2012. The number of PV systems installed in the U.S. reached over 300,000 total systems, and over 80,000 new systems were installed on homes in 2012 alone. Eleven U.S. states installed at least 50 MW of new PV, and the U.S. reached a total installed PV capacity of 7,221 MW nationwide (SEIA, 2013f).

The fast growth in the solar PV market in the United States is a result of several factors. These include "… an eagerness on the part of U.S. citizens to have access to clean renewable power generation sources, manufacturing cost reductions, technological advancements, a surge in private investment, and a number of federal, state, and local policies that support the development of solar markets." The nearly 4 GW of installed PV capacity by the end of 2011 provided enough electricity generation capability to supply power for almost 700,000 houses. As the solar market continues to expand in the U.S. so will the job opportunities and economic benefits associated with installing PV systems. It is estimated that as many as 300,000 people could be employed in the solar industry by the year 2016. These workers include all aspects of solar PV systems, including developers, engineers, installers, electricians, financiers, and electricians (Solar Foundation and SolarTech, 2012).

In the year 2001, 29 MW of new solar PV capacity was installed, marking over a 62 percent increase from the previous year. In the year 2002, 52 MW of new solar PV capacity was installed, marking nearly a 77 percent increase from the previous year. In the year 2003, 97 MW of new solar PV capacity was installed, marking over an 87 percent increase from the previous year. In the year 2004, 155 MW of new solar PV capacity was installed, marking over a 59 percent increase from the previous year. In the year 2005, 234 MW of new solar PV capacity was installed, marking a 51 percent increase from the previous year (EERE, 2013a).

In the year 2006, 339 MW of new solar PV capacity was installed, marking nearly a 45 percent increase from the previous year. In the year 2007, 508 MW of new solar PV capacity was installed, marking nearly a 50 percent increase from the previous year. In the year 2008, 819 MW of new solar PV capacity was installed, marking over a 61 percent increase from the previous year. In the year 2009, 1,257 MW of new solar PV capacity was installed, marking nearly a 54 percent increase from the previous year. In the year 2010, 2,153 MW of new solar PV capacity was installed, marking over a 71 percent increase from the previous year. In the year 2011, 4,011 MW of new solar PV capacity was installed, marking over an 86 percent increase from the previous year (EERE, 2013a).

These totals of the solar PV installations in the United States amounted to an annual compound growth rate of over 63 percent per year between the year 2000 and 2011. The growth in solar installations towards the end of the last decade raised the total PV electricity generation capacity as a share of all sources of electricity capacity in the United States from 0.1 percent in the year 2008 to 0.4 percent in the year 2011. As a total of all electricity generated in the United States, the percentage of electricity generated by solar PV systems rose from 0.1 percent in the year 2008 to 0.2 percent in the year 2011 (EERE, 2013a). The year 2012 was a year when many of large utility-scale solar PV systems came on-line. Eight of the ten largest PV power plants in the U.S. were completed in 2012. Currently, more than 4 GW of utility-scale PV plants are being constructed, with more than 8 GW worth of projects scheduled to begin development (SEIA, 2013f).

In the year 2013, the United States is expected to set another record for the most solar PV capacity installed in a single year. In the first quarter of 2013, there has already been 723 MW of installed PV, which is a 33 percent increase over levels in the first quarter of 2012. At the end of the first quarter of the year 2013, the United States had a cumulative PV capacity of 8.5 GW. This amounts to enough PV electricity to supply more than 1.3 million households. Total PV capacity in the United States in the year 2013 is predicted to reach close to 4.4 GW (SEIA, 2013d).

The first quarter in 2013 showed record levels of installations for both residential and utility-scale PV systems. Residential systems accounted for 164 MW, and utility-scale systems amounted to 318 MW. The number of utility-scale PV systems installed in Q1 of 2013 was more than double from what was installed in the first quarter of 2012. In Q1 of 2013, residential PV systems grew by over 50 percent from Q1 of 2012 (SEIA, 2013d).

Table 6-2: U.S. PV Annual Increase一2001-2011

Unit: Megawatts (MW)

Year	PV Capacity	Annual Increase (%)
2001	29	62.4
2002	52	76.9
2003	97	87.3
2004	155	59.2
2005	234	51
2006	339	44.7
2007	508	49.8
2008	819	61.2
2009	1,257	53.5
2010	2,153	71.3
2011	4,011	86.3

Source: EERE (2013a).

Table 6-3: U.S. PV Installations一2000-2012

Unit: Megawatts (MW)

Year	Residential	Non-Residential	Utility	Total
2000	1	2	0	4
2001	5	3	3	11
2002	11	9	2	23
2003	15	27	3	45
2004	24	32	2	58
2005	27	51	1	79
2006	38	67	0	105
2007	58	93	9	160
2008	82	200	16	298
2009	164	213	58	435
2010	246	336	267	848
2011	302	826	760	1,887
2012	488	1,043	1,781	3,313

Source: SEIA (2013f).

6.3 The Leading U.S. States for Solar PV

Similar to countries that are global leaders in solar PV utilization, the U.S. states that have the largest cumulative and annual increases in solar PV installations are those with the most extensive solar incentive policies. At the end of the year 2011, the top ten U.S. states for installed solar electricity capacity accounted for 87 percent of the total capacity for the entire nation (Solar Foundation and SolarTech, 2012).

In the year 2011, California led all states in new PV solar power capacity with nearly 538 MW worth of installations. Its total installed capacity for solar PV totaled more than 1.5 GW in the year 2011, making it the national leader in solar PV capacity. New Jersey came in second with nearly 1 GW less capacity as California, for a totaled installed PV capacity of about 566 MW. It was also the second leading state in new PV installations in 2011 with over 300 MW of new PV capacity. Arizona was third in the nation with nearly 400 MW of total capacity and was also third in new PV in 2011 with about 288 MW. Colorado came in fourth place with about half the total PV capacity as Arizona, less than 200 MW, but was only sixth in the nation in new PV installations with 75.5 MW (EERE, 2013a).

New Mexico had the fifth largest total PV capacity in 2011 with 165 MW and was fourth in new PV with just over 122 MW. Pennsylvania was sixth in the nation with a total PV capacity of 133 MW and fifth in new PV capacity in 2011 with over 78 MW. Nevada held the seventh largest PV capacity with 124 MW but failed to reach the top 10 in PV installations in 2011. New York was eighth in the nation with almost 124 MW and seventh in new PV installations for 2011. Florida came in ninth with a total PV capacity of 95 MW but did not make the top 10 for new PV capacity in 2011. Texas came in tenth place with total PV at more than 85 MW and was number 8 in new 2011 installations at more than 51 MW. Hawaii was tenth in the nation in 2011 for new PV installations with more than 40 MW (EERE, 2013a). From these numbers we can see that several states had begun to dramatically increase their growth in PV installations in the year 2011.

When comparing data on PV systems funded by the California Solar Initiative (CSI) for the year 2011 and the first half of 2012, price declines in 2012 seemed to be on pace with the price declines in 2011. "The median installed price of CSI systems installed in H1 2012 fell by roughly $0.43/W (7%) for systems of 10 kW or smaller, and by roughly $0.35/W (6%) for systems of 10–100 kW, relative to the median price of systems installed in 2011.” PV systems in the range of 100 to 500 kW showed a price drop of only $0.18/W, or 3 percent. The modest drop is partly due to a greater number of smaller-sized PV systems in the sample for systems installed in California in the first half of 2012 compared to 2011 (Feldman et al., 2012).

The growth in solar PV installations in California in the year 2012 was impressive. It upheld its dominant position in the nation as the top solar PV market with a record breaking 1,033 MV of new PV, the first time a U.S. state achieved over 1 GW of new installations in a single year. It was also an impressive 455 MW increase from the previous year. California led all states with residential and non-residential PV installations in 2012 and was second in the nation for utility installations. Arizona was the second leading state for new PV in 2012 with 710 MW, well over twice the amount it had installed in 2011. It led the nation in utility PV growth and had the second largest residential PV market. Arizona had the fourth largest market for non-residential installations in the year 2012 (GTM Research, 2013).

New Jersey was the third biggest PV market in 2012 with 415 MW. It had the second largest non-residential, fourth largest residential, and fifth largest utility PV markets in the nation. Nevada was the fourth biggest market with nearly 200 MW of new PV. It had the third largest utility PV market but did not reach the top 5 for residential and non-residential PV systems. North Carolina had the nation’s fifth largest amount of installations at 132 MW and the fourth largest utility PV market. Massachusetts came in sixth with 129 MW and had the third largest non-residential market. At seventh place was Hawaii with 109 MW. Hawaii had the third largest residential and fourth largest non-residential markets in 2012. Maryland held the eighth spot with 74 MW of PV. Texas was ninth with 64 MW, and New York rounded off the tenth spot with 60 MW of new installations. Colorado had the fifth largest amount of installed residential PV in 2012, but failed to reach the list for the top ten U.S. states for overall PV installations (GTM Research, 2013).

The residential PV market in the United States in the year 2012 amounted to 488 MW of newly installed PV systems, a 62 percent growth over the year 2011. California, Hawaii, Arizona, and Massachusetts all showed substantial growth in the residential PV sector. “The only major state residential market to shrink year-over-year was Pennsylvania, which fell from 17 MW in 2011 to 7 MW in 2012.” The non-residential market grew 26 percent in the year 2012 from 2011 and amounted to over 1 GW of new PV installations (SEIA, 2013f).

California and New Jersey started 2012 with robust growth in non-residential PV, with Hawaii, Maryland, and New York showing notable increases. Massachusetts’ non-residential PV market grew by over 400 percent in 2012 compared to 2011. One hundred and fifty-two Utility-scale PV projects accounted for 1,782 MW of new PV installations in the year 2012, a 134 percent increase over 2011. Purchase power agreements that currently stand as projects set for development amount to 10.5 GW. Nearly a third of these projects are now in the construction phase (SEIA, 2013f).

The U.S. state with the top cumulative solar PV capacity in the year 2012 was California with over 2.9 GW. The second leading state was Arizona with just under 1.1 GW. New Jersey was in third place with 971 MW. Nevada was fourth with over 400 MW. Colorado was fifth with 270 MW. North Carolina was sixth in the country with 229 MW. Massachusetts was in seventh place with nearly 200 MW. Pennsylvania held eighth place with 196 MW. Hawaii had the ninth largest capacity at 191 MW, and New Mexico held on to the tenth spot with 190 MW (SEIA, 2013f).

If states are ranked by the amount of solar PV they have installed per capita, Arizona leads the country with 167 W per person. Nevada is second with 146 W. Hawaii is third in the country with 137 W per person. New Jersey is in fourth place with 110 W. New Mexico has the fifth spot with 91 W. California comes in sixth with 76 W. Colorado is seventh with 52 W. Delaware is in eighth place with 48 W per capita. Vermont is ninth with 34 W, and Massachusetts is in tenth place with 30 W of PV installed per capita (SEIA, 2013f).

6.4 The Outlook and Potential for Future Solar PV Demand

From a geographic perspective, the United States’ geography gives it tremendous potential as a country for substantial amounts of electricity produced by solar PV systems. The United States is a country with a large land mass with good solar radiation. If just 0.6% of the total land area in the U.S. was used for PV installations with today’s technologies it could generate enough electricity to supply all of the country’s end-use electricity needs. Despite Germany being the world's top country for solar PV installations, its radiant sun energy resources are comparable to the United States' low-end solar resource states (Alaska, Washington State). "The U.S. solar resource is much higher than Germany's, and the southwestern United States has a better resource than southern Spain" (DOE, 2012a).

Table 6-4: Top U.S. State PV Installations

Unit: Megawatts (MW)

State	2010	2011	2012
California	216	577	1,033
Arizona	63	273	710
New Jersey	132	313	415
Nevada	61	44	198
North Carolina	31	55	132
Massachusetts	22	31	129
Hawaii	16	40	109
Maryland	8	22	74
Texas	23	44	64
New York	23	60	60

Source: Same as Table 6-2.

There is also much more potential for installing PV systems on underutilized land areas, such as parking lots, some agricultural settings, public spaces, and building rooftops. When considering rooftops alone, even after accounting for shading and other constraints, there is the potential for more than 600 GW of installations nationwide based on current PV performance (DOE, 2012a). Based on an evaluation by the National Renewable Energy Laboratory (NREL), taking into consideration land-use constraints, it is estimated that the United States has the potential to install 1,200 GW of urban utility-scale PV plants, 153,000 GW of rural utility-scale PV plants, and 664 GW of rooftop PV systems (Lopez et al., 2012).

Greentech Media predicted that PV installations in the U.S. will increase by 29 percent in 2013 from 2012, for a total of 4.3 GW in new PV capacity. The growth rate for

PV installations is expected to have an annual growth rate of 28 percent between the year 2013 and 2016. This marks strong, consistent growth, but is more moderate than the 82 percent annual average growth between 2009 and 2012. Utility-scale installations have been a major catalyst for PV capacity growth in the U.S. the last few years, but residential and more distributed PV installations are likely to command a greater share of the PV market over the next several years. "Whereas utility installations increased by 134% in 2012, we expect only 31% growth in 2013" (SEIA, 2013f).

6.4.1 Future Decline in Price for Solar PV[30]

Demand for solar PV systems is likely to increase as installations prices continue to decline. "Since the beginning of 2010, average residential system prices have decreased an average of 3% each quarter" (Solar Foundation and SunTech, 2012). Assuming a similar rate of price reduction will continue in the near future, the average price for residential PV systems is projected to drop to $4.50 per installed watt by the year 2015. Some analysts predict the United States could be once again become the global leader in PV installations in the next few years and reach about 14 percent of the global market share by the year 2016.

The National Renewable Energy Laboratory (NREL) estimates that PV system costs will level out by the year 2015 after continued drops in system prices. In the same year it is predicted that the cost for solar PV systems will reach a break-even point for 75 percent of the United States ($4.00/W), that is, the net cost of solar PV systems will be equal to or less than the net financial benefits of the systems. If or when this takes place it is expected to lead to accelerated solar PV growth in the United States far beyond what has been induced primarily by government incentives. However, some projections for the price declines in leading PV cell technologies fail to place utility-scale PV systems as a competitive form of electricity generation in the year 2016 in the absence of government incentives.

With PV systems installed at $1.00/W it would be cost-competitive with all other forms of electricity generation in almost every U.S. state. Analysis conducted by the National Renewable Energy Laboratory (NREL) predicts that if the $1.00/W goal is

[30] Information in this section sourced from Solar Foundation and SunTech (2012) and EERE (2010).

reached by the year 2020 then 100 GW of cumulative PV capacity could take place. Also, by the year 2030, 389 GW of new PV capacity could be reached, accounting for 14 percent of the total electricity generated in the U.S. Further analysis suggest that adjustments needed by utility systems to accommodate 14 percent of electricity generation from PV sources would not be drastic, but would include some degree of new transmission capacity and energy storage systems. The total amount of natural gas needed for peaking capacity would decline, but a higher degree of natural gas electricity generation capacity would be needed in place as a reserve source of electricity.

Cost reductions are expected for manufactures, and average selling prices may continue to fall in the United States and globally in 2013. However, the cost of installation accounts for more than half of the price of a PV system. Approaches to reducing this cost can include sophisticated machinery for precision placement of mounting used for large PV plants, built-in PV modules in roofing inputs that can be installed during a building's construction, and roofing mounts that can be used to easily attach PV modules to roofs at a later time.

If PV arrays could be implemented in construction materials for new buildings, then the cost for PV installations could be greatly reduced for residential and commercial applications. These applications could also be expanded to roof replacements for existing buildings using modules that could rapidly interconnect. Minimal added structural support would be needed, and the incremental cost to install built-in PV modules would be minimal as well. "Electrical component installation labor can account for as much 78% of the man hours required for a utility scale system" (EERE, 2010). Building integration PV systems could eliminate the need for expensive specialized labor needed for typical PV installations and could provide PV system savings of close to 20 percent.

6.4.2 Policy Effects on Future Solar PV Demand

If the federal Business Energy Investment Tax Credit (ITC) reverts to 10 percent at the end of 2016, and the federal Residential Renewable Energy Tax Credit does not get renewed and expires at the end of 2016, it is likely to result in significant new PV installations in 2016 as there will likely be a rush to finish projects in order to qualify for the benefits. It would be difficult to predict how it would affect the solar market in 2017, however, as there is currently uncertainty over how attractive PV systems would be to investors at that time in the absence of the tax credit. The cost of carbon finance mechanisms and tighter emission controls could also lead to a greater impetus for solar PV development and utilization. Since cost continues to be a significant barrier to PV market growth in most places, increasing the cost for fossil fuel consumption could help level the playing field.

The Solar Advisor Model (SAM) offered by the U.S. DOE placed the most effective residential PV programs in support of the PV industry within California, Hawaii, and Connecticut in the year 2010. Hawaii was considered the only state 2 years ago whose residential PV market was considered a positive investment environment in the absence of any state incentives. That is, the federal Investment Tax Credit and Residential Renewable Tax Credit alone were enough to make commercial and residential PV installations attractive investments. The SAM also revealed that the costs associated with installing PV systems were still an obstacle for strong solar PV growth in many states (Sarzynski, 2010).

The Obama Administration's Energy Policy hopes to set a course for an 80 percent reduction in greenhouse gas emissions by the year 2050. To help achieve this, the U.S. Department of Energy (DOE) hopes to reduce the installed cost for utility-scale PV systems to $1.00/w by the year 2017, which would make the electricity produced by PV systems about $0.05 to $0.06 per kWh over its estimated life of a PV system. Combined with cost-effective electricity storage systems in place, cheap PV electricity could become a major source of electricity for the United States as well as globally. This ambitious scenario has been investigated by the DOE, and relies on the assumption of high module efficiencies in the near future and drastic reductions in balance of system (BOS) costs (EERE, 2010).

Much could be done to improve the process needed to construct solar PV plants in the United States. "Even with the financial incentives, there are some barriers to entry that prevent developers from commencing a renewable energy project and investors from investing in such projects (for which the investment may be necessary for the project to commence)" (Walsh, 2012). Barriers include the process for meeting federal and state environmental compliances. The process can be time consuming and expensive, and can prevent renewable energy projects from being completed in time to qualify for financial incentives.

Utility-scale renewable energy project developers must provide environmental impact statements (EIS) according to the National Environmental Policy Act. The EIS can be costly and on average takes about three years to prepare. Another barrier to renewable energy plants such as PV is the standards in place for interconnecting the systems with the utility grid. Utility companies place restrictions on grid connections with generators that are owned and operated by non-utility sources that result in added costs for renewable energy providers. In some cases these restrictions cause renewable energy projects to become no longer economically viable. These factors combined can make renewable energy projects too unpredictable for some investors (Walsh, 2012).

Inconsistent and short-term incentives can also discourage institutional investors from entering what they view as a risky market. In order to overcome some of these barriers, policy and regulation constraints that make investments in solar energy projects unsuitable for pension and insurance funds should be removed in a way that will not undermine the security and solvency of such funds. To help investors raise funds for PV projects, regulators could switch to a corporate model rather than a finance model. In this way, stocks and bonds could be used to finance PV projects. Also, there is a need to "Develop better pooled investment vehicles that create liquidity, increase diversification, and reduce transaction costs while maintaining the link to underlying cash flows from renewable energy projects" (Willis, 2013).

Policies that promote PV systems to be incorporated in new building design and construction have been successful in Japan in helping to create a stronger PV market. This has led to an increase in the amount of installations while also lowering the cost. Encouraging property developers to incorporate PV systems in new buildings would not only reduce upfront costs and grid-connection issues, it would give builders leverage to negotiate better prices for solar components by buying in bulk on behalf of several properties (Chiaro and Gibson, 2006).

By the year 2012, PV component and supply costs for an average 4 kW residential PV had fallen to about $8,000. In Germany, these average PV systems cost about $10,000, not including any incentives, with about $2,000 attributed to the cost of installation. The return on investment for a PV system there is about 5 years. However, the price for a similar PV system in the United States was about twice that much. “Studies by the National Renewable Energy Laboratory and by the University of California, Berkeley both confirm that these higher prices are almost exclusively related to the paperwork it takes to ‘officially’ install a standard rooftop system in the U.S.” The paperwork involved with installing a PV system in the U.S. involves all levels of government; federal, state, and local. In comparison to the easy and efficient permitting system in place in Germany, the list of requirements for U.S. PV systems is extensive and burdensome to the industry, as well as costly to the consumers (Woody, 2012).

The amount of regulations and requirements from different agents makes the paperwork involved for PV installers in the United States complicated. It requires highly trained accountants to manage a complicated spreadsheet and specialized engineers to designs PV systems that meet the requirements for various codes. The advantage that Germany has includes: no requirement for permission to connect to the utility grid, no building permit is required, inspections are not required, and financing is automatic with the banking system. The application for PV systems in Germany is a simple, standardized two-page form. The difficulty in managing all of the government requirements is also likely to prevent many qualified electricians in the U.S. from entering the market for PV installations. This in turn reducers the number of installers and limits competition that otherwise might put more downward pressure on PV installation prices (Woody, 2012).

In an effort to address some of the problems with excessive regulation in the United States for PV systems, the U.S. Department of Energy (DOE) launched a program aimed at making inspections for residential PV systems more consistent and standardized across different jurisdictions. The department hopes it will lead to faster installation times and cost savings for customers. The DOE also launched the Photovoltaic Online Training (PVOT) program, which is designed to help train installers how to use installation techniques that will satisfy all the code requirements. In a different kind of effort to reduce the soft costs of PV systems in the U.S., the DOE announced the “SunShot Prize” worth $10 million in total prizes that will be awarded to the first 3 teams that can design a system in which residential PV systems can be installed for as low as $1.00/W. This figure is aimed at a reduction in soft costs, such as permitting, licensing, grid connection, and other costs by about two thirds (DOE, 2012b).

As of the year 2011, Renewable Portfolio Standards (RPS) existed in 31 U.S. states, and range from 10 to 40 percent. RPS can be useful in that they outline specific renewable energy targets that can lead to the policies needed to see the standards come to fruition. Of the states that have RPS, several have specific targets for solar PV. New Jersey required that .16 percent of its 6.8 percent RPS target in the year 2008 to be provided by solar PV. In the year 2010, New Jersey's RPS was increased to over 20 percent by the year 2021, including a provision requiring over 2.5 GW of electricity capacity coming from solar PV at that time and a further increase to 5.3 GW in the year 2026. Nevada's RPS stands at 20 percent by 2015, 5 percent of which must come from solar power including CSP (Timilsina et al., 2011). RPSs can play an important role in guiding the decision making process on how electricity utility companies plan to source future demand for electricity. There is research that show that states with RPS specific to solar installations have greater PV installations rates than what would otherwise be expected (Lopez et al., 2012).

6.4.3 Natural Gas as Potential Competition to Solar PV

Abundant and cheap natural gas could provide greater energy security and a cleaner source of electricity than coal.[31] It could also have an adverse affect on the development of the PV market. Cheap natural gas could keep electricity prices lower and increase the amount of time needed for PV technologies to become a competitive source of electricity without financial incentives. Also, if the power sector developed its infrastructure to accommodate natural gas generation to a great extent it could limit the accessibility of grid-connected renewable energy sources. This could also make the power sector vulnerable to large fluctuations in the price of natural gas.[32] For example, because of the low prices for natural gas due to oversupply, investment in natural gas production stalled

[31] The amount of greenhouse gas emissions from natural gas used for electricity generation is less than half of what is produced by using coal to generate electricity (Logan et al., 2012).

[32] Natural gas accounts for the greatest fluctuations in wholesale electricity prices. The price for natural gas can change quickly and is often used for peak electricity generation, which can be much more expensive than other generation sources (EIA, 2012f).

in 2012.[33] However, the price rose from $1.90 per 1 million Btu in the early part of 2012 to $3.60 in November of 2012 (Logan et al., 2012).

Natural gas was already the leading source of energy produced in the United States in the year 2011, totaling over twenty three and a half trillion Btu, or 1.3 trillion more Btu than the second leading source of energy, coal. Future projections list natural gas as building its lead as the United States' most important domestically produced source of energy. In the year 2020, natural gas is projected to increase, while coal production will decrease somewhat. Although coal production is predicted to recover modestly in 2030 and 2040, natural gas is projected to be produced in greater amounts and strengthen its position as the most produced form of energy in the U.S. This holds true even when the projections take into account variables of low and high economic growth scenarios. Long-term pricing trends for natural gas could prove to be a key factor for the solar energy market. In the DOE's reference case, natural gas prices are projected to nearly double from 2011 prices by the year 2040 (EIA, 2013a).

In the DOE's reference case for 2012, natural gas electricity generation is forecast to grow by 42 percent from the year 2010 to the year 2035 (EIA, 2012e) and is poised to double from the year 2010 to the year 2050 (Logan et al., 2012). Low natural gas prices, combined with lower capital costs for natural gas plants than coal plants, will make natural gas the primary new source of electricity generation capacity. "Natural-gas-fired plants account for 60 percent of capacity additions between 2011 and 2035 in the Reference case, compared with 29 percent for renewables, 7 percent for coal, and 4 percent for nuclear." Future limits imposed by environmental policies and unpredictable regulations on emissions in the future will also discourage some investment in coal plants and reduce their future cost-competiveness compared to natural gas (EIA, 2012f).

The increase in the ability to extract larger quantities of shale natural gas with fewer wells will make it unlikely that natural gas will reach very high prices for the foreseeable future, which in turn will likely make natural gas an increasingly attractive option for electricity generation. "While state-level renewable fuels standards, which require utilities to obtain a certain proportion of their electricity from renewable sources,

---

[33] In mid-2012, natural gas was in a state of oversupply in the United States, and natural gas storage facilities were at record high levels of reserves (Logan et al., 2012).

may provide continuing demand for utility-scale PV plants in some states, the lower cost of gas-fired generation may limit interest in large PV installations" (Platzer, 2012).

6.4.4 Smart Meters[34]

The importance that solar PV could have for supplying peak energy to the power grid brings to light the subject of "smart meters" and "smart grids."[35] "The term 'smart grid' refers to the modernization of the electricity delivery system so that it monitors, protects, and automatically optimizes the operation of its interconnected elements from the central and distributed generator through the high-voltage transmission network and the distribution system, to industrial users and building automation systems, to energy storage installations, and to end-use consumers, and their thermostats, electric vehicles, appliances, and other household devices." Smart grids will likely play a vital role in the expansion of the use of renewable sources of electricity, such as solar PV, and may be necessary for the support of expanded PV system utilization in the future.

The American Recovery and Reinvestment Act of 2009 provided $4.5 billion for the research and development of smart grid and smart meter technology. Many states have implemented new requirements for smart grid investments and pilot programs. Since federal funding for smart grid programs is set to decline, state programs and mandates will likely have the biggest effect on how the use of smart grids develops in the future. Utility providers tend to lack enough monitoring, communications, and control equipment to efficiently incorporate wholesale suppliers of electricity into their high voltage transmission network, which also limits the effective capacity that can be gained from grid-connected PV systems.

According to the Electric Power Research Institute (EPRI), it could cost as much as $64 billion to upgrade utility high voltage transmission with smart grid technology. But by doing so, utility companies could incorporate intermittent renewable electricity, such as wind and solar power, in ways that traditional utility grid technologies are unable. Because electricity from PV systems is produced according to solar exposure, its

[34] Information in this section sourced from Joskow (2012).
[35] The definition for smart meters given by the Edison Electronic Institute (EEI) is, "Smart Meters are electronic measurement devices used by utilities to communicate information for billing customers and operating their electric systems" (EEI, 2011).

electricity generation cannot be controlled based on supply and demand considerations the same way as conventional energy generation.

"To balance supply and demand continuously when there is significant intermittent generation on the high voltage network requires that system operators have the capability to respond very quickly to rapid changes in power flows at different locations on the network by holding more dispatchable generation in operating reserve status and having the capability to monitor and adjust the configuration of power flows on the transmission network to balance supply and demand continuously while minimizing costs." Smart grid technology will also be important for managing remote distribution systems on the grid as well. Automatic control mechanisms and monitoring will need to be in place at the local level to adjust to fluctuations in PV system generations efficiently and safely as the number of PV systems connected the utility grid increases in magnitude.

6.4.5 Other Factors Effecting Demand for Solar PV

Many factors might influence later developments in the PV industry in U.S. states. According to statistical analysis by the George Washington Institute of Public Policy, the expected developments in a state's PV market are influenced by the following variables (Lopez et al., 2012):

1. States with larger populations have more solar energy deployment;
2. States with higher average incomes have greater solar energy deployment;
3. States with higher electricity or natural gas prices have more solar energy deployment;
4. States with higher electricity or natural gas prices have more solar energy deployment;
5. States that need to import more energy have greater solar energy deployment;
6. States with better solar resources have more solar energy deployment; and
7. States with a more liberal citizenry have greater solar energy deployment.

A study on the plausibility of renewable energy sources becoming the predominate source of electricity in the United States finds that the power sector would need to make major adjustments. The required adjustments include: greater flexibility in the utilization of conventional energy sources, extensive electricity storage capacity, new transmission infrastructure, changes in power system responsiveness (smart grids), distributed and diverse sources of renewable power, dispatchable renewable generators, and development of demand-side technologies (Mai et al., 2012).

Limitations on the power generation capabilities of solar PV include: conversion efficiencies, performance limitations of inverters, battery storage technology limitations, and performance degradation due to time and weather (Timilsina et al., 2011). A Potential impediment to the rate of future growth in renewable energy includes the cost of infrastructure to connect remotely located renewable energy locations to the utility grid, in reference to utility-scale PV plants. There are also additional costs involved with the connections to the grid themselves (Heiman and Solomon, 2004).

The development of advanced battery technologies will be important for the future development of the solar PV market. Many countries are investing in the development of batteries to support utility-scale renewable energy projects. "(The) Most advanced economies in the region (Asia Pacific), including Japan, South Korea, and Australia, are moving toward smart grid and microgrid energy delivery models, which form natural tie-ins for energy storage, particularly batteries." Battery development is centered on lithium ion, sodium sulfur, and flow battery technologies. Stored energy such as pumped hydro, which is more widely used in China, can be another approach to utilizing electricity produced by PV systems to create a readily accessible source of power (Chan, 2013b). Perhaps the United States could learn from these developments and emulate some of the strategies used in the Asia Pacific if proven successful.

Financing has been a barrier to solar PV power installations in the United States. Solar PV has been growing quickly but is also considered a risky investment by some. Financing for solar energy projects can be burdened by higher financial charges "because solar energy projects have a shorter history, lengthy payback periods and small revenue stream" (Timilsina et al., 2011). Much more can be done to provide the financing needed to support more investment in PV systems.

Third-party-owned (TPO) and power purchase agreements (PPAs) continued to gain market share in the year 2012. TPOs accounted for 90 percent of Arizona's new residential PV installations, and have accounted for more than 50 percent of new installations in most major residential markets. This has attracted new investment for companies hoping to profit from such arrangements. “GTM (Greentech Media) Research forecasts that the third-party-owned residential solar market will maintain its momentum and become a $5.7 billion market by 2016” (SEIA, 2013f).

“Crowd funding,” a form of pooled funding investment, could develop into a more significant source of funding for PV systems in the future. The company Mosaic is a relatively new company using the crowd funding concept. It has raised over a $1.1 million U.S. from nearly 1,000 different investors solely for PV project investment. It recently partnered with a solar project developer to finance its first utility-scale PV plant totaling 6 MW (Carus, 2013b). Although crowd funding currently does not provide a large investment platform for the PV market in general, it is a relatively new approach to investing in PV, and its potential as a major investment vehicle has yet to be determined.

Another approach to diversifying the solar PV market comes in the form of “solar gardens.” An example of this is given by the company REC Solar, which develops community solar projects under Colorado’s Community Solar Gardens Act legislation that recently came into effect. The program caters to customers who are interested in PV electricity, but who are unable to get PV systems installed on their roofs. The program allows customers to purchase solar energy from the system operator through the utility and also receive benefits from the federal renewable tax credits. To qualify as a solar garden under the program there must be at least 10 subscribers within the same county, and the PV system can be no larger than 2 MV. Similar programs could be implemented in other U.S. states in the future. “California currently has two community solar bills proceeding through the legislature and the state’s investor owned utilities have put forward their own community solar plans to regulators” (Carus, 2013c).

There are many investment vehicles available globally that have not determined the solar PV market in the United States to be an appropriate form of investment for a variety of reasons. “According to research from the US-based Climate Policy Initiative think-tank, institutions such as pension funds and insurance firms worldwide manage around US$71 trillion of investors’ money, capital that could be used to meet a quarter to a half of the investment needs of renewable energy through to 2035” (Willis, 2013). However, this enormous amount of potential funding for renewable energy projects such as PV is not likely to be made accessible without changes in government policy and financial regulations. Because financial incentives for PV investment are largely based on income tax credits, tax exempt funds do not benefit from such investments.

There is currently an example of how successful incorporating PV systems into the construction of new buildings can be in supporting growth in the PV market in the United States. PV supplier and developer SunPower has partnered with property developer KB Home to construct new energy efficient homes that come complete with solar PV systems. In less than 2 years, their partnership had resulted in 1,000 new homes being constructed that include PV systems. The two companies plan on continuing their partnership with further construction projects (Alexopoulou, 2013).

There are some arguments that can be made in favor of residential PV systems over utility-scale PV arrays. As mentioned earlier, smaller PV systems cost more to install but benefit from reduced delivery cost of the electricity over the lifetime of the PV system. A large increase in residential solar PV systems could reduce the necessity for the installation and maintenance of transmission lines that carry electricity from large-scale or centralized generation of electricity. It is suggested that an increased use of residential PV systems would result in reduced costs for the distribution infrastructure for the utility grid (Borenstein, 2012).

One of the positive effects of smaller-scale PV installations, and one of the reasons they cost more per watt to install than large projects, is that they require more labor hours per watt to install and a greater number of projects to achieve similar capacity. This translates into more jobs related to the PV industry. "These jobs are more widely distributed in communities across the nation, including rural locations" (DOE, 2012a). If installed PV capacity shifted more to residential PV systems it would have a larger and more dispersed impact on the U.S. economy as a whole.

6.5 Summary

In summary, as the demand for solar PV in the United States has increased, so has the global PV production of PV components. Utilities of scale have increased from the PV supply-side vertically, from the basic materials needed to produce PV cells to the system installation process. This has lowered prices for PV systems, which in turn has stimulated further demand for solar energy. Prices for installed PV systems have plummeted the last few years. The demand for PV in the U.S. is growing robustly, and cumulative installed PV capacity has grown even faster than expected.

Despite the rapidly falling prices for PV systems, most of the price declines are a reflection of the reduction in PV component cost. BOS costs continue to create a barrier to solar PV-generated electricity becoming cost-competitive with traditional forms of electricity generation. Cuts to production costs and greater PV cell conversion efficiency in the future will help to make PV technology more economically viable, but even more needs to be accomplished in reducing the cost of installation.

Government policies and financial incentives have been vital for creating PV demand. Without such policies the demand for PV in the U.S. would likely not have grown nearly as much. Government policies are still important for the PV market. The recent price declines for PV systems are still not sufficient for achieving a self-sustaining market. There are several examples of recent attempts to diversify the PV market in the U.S. and stimulate further demand. These approaches seem mostly successful, but are also contingent on financial incentives for their models to work. More needs to be done to help enable the U.S. PV industry to access the vast amounts of investment capital available on the global financial stage.

CHAPTER 7 Conclusion and Suggestion

Many factors involving PV energy in the United States have been mentioned in the previous chapters. Although its total generation capacity is still small compared to most other forms of electricity in the U.S., PV is gaining in importance as a source of renewable energy. In this chapter I will list my conclusions about PV use in the U.S., as well as offer my suggestions.

7.1 Conclusion

In the last several years the United States has experienced impressive growth rates in solar PV installations. California has set the pace for solar PV in the U.S. and its PV market continues to expand; now several other states are quickly expanding their PV markets. Falling prices for PV components have had a positive effect on the demand for PV energy. As the demand has increased, more investment has been made in PV manufacturing, which in turn has created economies of scale and downward pressure on PV prices. So far this relationship has favored customers the most as the continual drops in system prices makes PV systems a more attractive investment. Based on my study, I have reached the following conclusions:

1. Government policies and financial incentives are important for PV demand

A recurrent theme in this thesis has been government policies and financial incentives. Government incentives are likely the single greatest factor in determining the success of a particular PV market. The countries with the best financial incentives for PV systems in relation to the cost of energy have the highest rates of market growth, and the U.S. states with the most extensive financial incentives for PV systems have the highest rates of PV market growth in the nation. Until the cost of electricity generation from PV becomes competitive with the cost for retail electricity sold by electricity utility companies, government policies and incentives will remain important for the continued expansion of PV system installations. The incentives needed for market growth will vary depending on the state and municipality because electricity prices and market conditions can differ greatly by region. There is also the political appeal of the subject of clean forms of renewable energy. Depending on political climate and particular elected and appointed government officials, political considerations could have a significant impact on policies affecting the PV market.

2. PV manufacturers in the United States will continue to suffer financial difficulty

For PV manufacturers, the solar shakeout that has existed the last couple of years is still in effect. Several U.S. PV suppliers have gone bankrupt or ceased production as a result of PV cells and modules getting priced below the cost it takes to produce them. The problem of oversupply in the PV supply chain will not disappear quickly. Many tier 2 and tier 3 PV manufactures in China continue to exist as potential PV supply capacity as they lie dormant when not fulfilling orders for tier 1 companies. Only the most cost-effective and efficient producers will emerge from the glut of the oversupply that is mostly blamed on Chinese manufacturers. In addition to the challenges created by oversupply, new challenges for global PV suppliers include meeting localized requirements and preferences for PV components in various regions. Large companies with manageable debt, a strong supply network, and a well-received name brand seem most likely to survive the current market climate. Because there are higher profits to be made from PV project development, PV suppliers that are successful as project developers are also more likely to prosper financially.

3. The market for solar PV will be affected by natural gas used for electricity

The capacity and utilization of natural gas used for electricity generation has grown over the last decade. It has recently become more cost competitive with the largest source of electricity produced in the United States, coal. Because of the vast amounts natural gas that exist in shale deposits in the U.S., combined with improved technology in horizontal drilling that can now better access it, the potential for large increases in the supply of natural gas give it potential as an increasingly important source of electricity generation. If the supply of natural gas is maintained as abundant and cheap, and because it is a cleaner source of electricity than coal, it could likely develop into the major source of new electricity generation in the U.S. for years to come. In such a scenario, interest by energy investors and energy policy makers alike for renewable energy projects such as solar PV could wane as natural gas is called upon to provide a source of electricity that is as cheap and abundant as coal but only produces half the air pollution.

7.2 Suggestion

The prices for particular energy markets can be difficult to predict, and much about the future developments of the PV market in the United States remains uncertain. We know that government policies, electricity prices, and the amount of electricity produced by natural gas will affect the future PV market. Based on my study of this topic, I would make the following suggestions:

1. Government policies that support PV energy should continue

It is important for financial incentives for PV to continue as necessary, but only in the amount necessary to elicit consist and moderate market growth. Any changes to incentive rates should be predictable and transparent in order to ensure confidence in investors. California has been successful at this approach with the California Solar Initiative (CSI). Incentive payouts have gone down steadily even though the rates of PV installations have gone up. The CSI has nearly achieved all of its objectives years ahead of schedule. Federal incentives have a history of being unpredictable and have changed often. The Business Energy Investment Tax Credit (ITC) and the Residential Renewable Energy Tax Credit have brought market incentive stability at the federal level since 2009 and is set to remain unchanged until the end of 2016. This has been very positive for encouraging investment in PV systems. However, there is much unknown about what the government will do to support the PV industry after 2016. The federal government should adjust its support for PV as market changes require and communicate its approach to providing the necessary financial incentives in a more transparent and predictable manner.

2. Priority should be given to residential PV systems over utility-scale PV

More effort should be made to focus on residential and decentralized PV sources rather than utility-scale PV systems. Much of the electricity utility infrastructure in the U.S. is old and will be costly to replace and maintain. Localized energy generation saves both cost and energy loss incurred from transmitting power over an extensive grid. In order to make the transition from traditional centralized power sources to several dispersed and localized electrical sources, smart meters and smart grids need to become mainstream resources. Energy storage technology will become pivotal in further reducing the need for a centralized grid. Small community grids centered on a localized electricity storage facility could serve surrounding buildings as a backup source of power that each PV system contributes electricity to. It could be partially backed by other microgrids, and buildings could possess energy storage of their own. A benefit of such an arrangement would be greater energy security, more efficient energy transmission, better protection from grid failures, as well as protection against future fluctuations in the price of electricity.

3. PV should be expanded in an effort to reduce greenhouse gas emissions

If climate scientists are correct and climate change is a human-made phenomenon it will become increasingly important to reduce the amount of fossil fuels used to provide energy needs. Currently, it is economically unrealistic to expect that most of the electricity in the United States will be met by renewable energy sources in the near future. Natural gas is the best compliment to renewable energies such as solar PV in providing enough electricity for U.S. consumption while reducing greenhouse gas emissions as much as possible. Efficient hybrid plants using both renewable energy and natural gas should be developed. As PV technology and costs improve it could replace some of the use of natural gas and account for a larger portion of U.S. electricity generation. Ideally, in the future natural gas would only be needed as a reserve source of power while renewable energies such as PV provide the bulk of the electricity demand. Even if one is skeptical about topic of climate change, emissions from fossil fuels used to generate electricity results in air and water pollution. By increasing the use of PV energy, this pollution can be reduced and alleviate some of the complications of air pollution that people suffer from, such as affected respiratory development and increased rates of asthma, for example.

4. Taiwan should focus on effective government policies to support its PV market

If reference to Taiwan, I think Taiwan can gain value from observing the success, and in some cases, failures, of the PV market in the United States. The United States and other countries with growing PV markets reveal the importance of effective government policies and incentives. The financial incentives need to be generous enough to spark the interests of investors, but they also need to be consistent, transparent, and reliable in order to make investors and financial backers comfortable investing in what is otherwise a relatively new energy market with unproven long-term results.

Although Taiwan only had less than 10 MV of PV before 2009, its PV market has grown to 222 MW since the Renewable Energy Development Act of 2009. Taiwan's Ministry for Economic Affairs and the Bureau of Energy recently announced a new strategy to prioritize the increase of residential and commercial rooftop PV installations to over 3 GW by 2030, and has targeted the renewable energy makeup of the country's total power generation to 18 percent by 2025. These would seem like steps in the right direction for developing Taiwan's PV market. Taiwan will be faced with familiar challenges as its PV market builds momentum, such as having qualified installers and the ability to effectively connect the PV systems within a larger grid. Consistent and manageable growth over the long term is more favorable than creating an unsustainable bubble that ends up crashing the market, such as what happened in Spain and the Czech Republic when the governments could no longer support their policy schemes.

References

Alexopoulou, M. (2013), "KB Home and SunPower Hit 1,000 Solar Home Milestone," PV-Tech,http://www.pv-tech.org/news/kb_home_and_sunpower_hit_1000_solar_home_milestone.

Annis, C. (2013), "More Polysilicon Plants Still Under Construction Despite Enormous PVOvercapacity－Why?" NPD Solarbuzz, http://www.solarbuzz.com/resources/blog/2013/03/more-polysilicon-plants-still-under-construction-despite-enormous-pv-overcapacity-why.

Bird, L., J. Heeter and C. Kreycik (2011), "Solar Renewable Energy Certificate (SREC) Markets: Status and Trends," technical report, National Renewable Energy Laboratory, http://apps3.eere.energy.gov/greenpower/pdfs/52868.pdf.

Borenstein, S. (2012), "The Private and Public Economies of Renewable Electricity Generation," *Journal of Economic Perspectives*, 26(1): 67-92.

Carus, F. (2013a), "US solar exports to China delivered US$913 million surplus in 2011," PV-Tech, http://www.pv-tech.org/news/exports_of_us_solar_products_to_china_reach_913m_surplus_in_2011.

Carus, F. (2013b), "Pristine Sun and Mosaic Agree First Utility-scale Crowd Funding Deal," PV-Tech, http://www.pv-tech.org/news/pristine_sun_and_mosaic_agree_first_first_utility_scale_crowdfunding_deal.

Carus, F. (2013c), "REC Solar Completes First Community Solar Project in Colorado," PV-Tech, http://www.pv-tech.org/news/rec_solar_completes_first_community_solar_project_in_colorado.

Chan, J. (2013a), "Secretary Salazar approves 900MW of Californian PV projects," PV-Tech, http://www.pv-tech.org/news/secretary_salazar_approves_900mw_of_californian_pv_projects.

Chan, J. (2013b), "Advanced Batteries for Utility-Scale Applications in Asia Pacific to Exceed 25GW by 2022," PV-Tech, http://www.pv-tech.org/news/advanced_batteries_for_utility_scale_applications_in_asia_pacific_to_exceed.

Chiaro, B. D., and R. Gibson (2006), "Government's Role in Creating a Vibrant Solar Power Market in California," *Golden Gate University Law Review*, 36(3): 347-91.

Colville, F. (2013a), "Discovering 230 GW of PV Demand in the Next 5 years," NPD Solarbuzz, http://www.solarbuzz.com/resources/articles-and-presentations/pv-demand-in-the-Next-5-years.

Colville, F. (2013b), "PV World Cup Restricted to Domestic League Winners," PV-Tech, http://www.pv-tech.org/guest_blog/pv_world_cup_restricted_to_domestic_league_winners.

Database of State Incentives for Renewables & Efficiency (DSIRE) (2013a), "BusinessEnergy Investment Tax Credit (ITC)," http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F.

Database of State Incentives for Renewables & Efficiency (DSIRE) (2013b), "Qualifying Advanced Energy Manufacturing Investment Tax Credit," http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US52F.

Database of State Incentives for Renewables & Efficiency (DSIRE) (2013c), "Residential Renewable Energy Tax Credit," http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US37F&re=1&ee=1.

Database of State Incentives for Renewables & Efficiency (DSIRE) (2012), "U.S. Department of Energy - Loan Guarantee Program," http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US48F.

Edison Electronic Institute (EEI) (2011), "Smart Meters and Smart Meter Systems: A Metering Industry Perspective," http://www.eei.org/issuesandpolicy/grid-enhancements/Documents/smartmeters.pdf.

Feldman, D., G. Barbose, R. Margolis, R. Wiser, N. Darghouth, and A. Goodrich (2012), "Photovoltaic (PV) Pricing Trends: Historical, Recent, and Near-Term Projections," technical report, U.S. Department of Energy, http://www.nrel.gov/docs/fy13osti/56776.pdf.

German Solar Industry Association (GSIA) (2012), "Statistic Data on the German Solar Power (Photovoltaic) Industry," http://www.solarwirtschaft.de/fileadmin/media/pdf/BSW_facts_solarpower_en.pdf.

GlobalData (2011), "Global Solar PV Module Market Share Analysis－Chinese OEMs Continue to Dominate," http://www.highbeam.com/doc/1G1-285485891.html.

Go Solar California (2013a), "About the California Solar Initiative (CSI)," http://www.gosolarcalifornia.ca.gov/about/csi.php.

Go Solar California (2013b), "California Solar Initiative Rebates," http://www.gosolarcalifornia.ca.gov/csi/rebates.php.

GTM Research (2013), "U.S. Solar Market Insight Report," http://www.greentechmedia.com/research/ussmi.

Heiman, M. K. and B. D. Solomon (2004), "Power to the People: Electric Utility Restructuring and the Commitment to Renewable Energy," *Annals of the Association of American Geographers*, 94(1): 94-116.

Joskow, P. L. (2012), "Creating a Smarter U.S. Electricity Grid," *Journal of Economic Perspectives*, 26(1): 29-48.

Kimura, O. and T. Suzuki (2006), "30 Years of Solar Energy Development in Japan: Co-Evolution Process of Technology, Policies, and the Market," 2006 Berlin Conference on the Human Dimensions of Global Environmental Change, http://userpage.fu-berlin.de/ffu/akumwelt/bc2006/papers/Kimura_Suzuki.pdf.

Lian, R. (2013), "Top 10 PV module suppliers in 2012," PV-Tech, http://www.pv-tech.org/guest_blog/top_10_pv_module_suppliers_in_2012.

Loewen, J., H. Miranda, A. Reardon, N. Reardon, E. Seyburt, and M. Charles (2012), "California Solar Initiative: Annual Program Assessment," California Public Utilities Commission, http://www.cpuc.ca.gov/NR/rdonlyres/0C43123F-5924-4DBE-9AD2-8F07710E3850/0/CASolarInitiativeCSIAnnualProgAssessmtJune2012FINAL.pdf.

Logan, J., G. Heath, J. Macknick, E. Paranhos, W. Boyd, and K. Carlson (2012), "Natural Gas and the Transformation of the U.S. Energy Sector: Electricity," technical report, Joint Institute for Strategic Energy Analysis, http://www.nrel.gov/docs/fy13osti/55538.pdf.

Lopez, A., B. Roberts, D. Heimiller, N. Blair, and G. Porro (2012), "U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis," technical report, National Renewable Energy Laboratory, http://www.nrel.gov/docs/fy12osti/51946.pdf.

Mai, T., D. Sandor, R. Wiser, and T. Schneider (2012), "Renewable Electricity Futures Study,"executive summary, National Renewable Energy Laboratory, http://www.nrel.gov/docs/fy13osti/52409-ES.pdf.

Movellan, J. (2012), "California Forecast to Lead US to Self-sustaining PV as Dependency onIncentives Diminishes," PV-Tech, http://www.pv-tech.org/guest_blog/california_forecast_to_lead_us_to_self_sustaining_pv_as_dependency_on_incen.

NPD Solarbuzz (2013), "PV Demand in the Asia Pacific Region to Reach 13.5 GW in 2013,Reports NPD Solarbuzz," http://www.solarbuzz.com/news/recent-findings/pv-demand-asia-pacific-region-reach-135-gw-2013-reports-npd-solarbuzz.

Office of Energy Efficiency and Renewable Energy (EERE) (2013a), "2011 Renewable Energy Data Book," http://www.nrel.gov/docs/fy13osti/54909.pdf.

Office of Energy Efficiency and Renewable Energy (EERE) (2013b), "SunShot Initiative: About the Solar Office," http://www1.eere.energy.gov/solar/sunshot/about.html.

Office of Energy Efficiency and Renewable Energy (EERE) (2013c), "SunShot Initiative: Key Activities," http://www1.eere.energy.gov/solar/sunshot/key_activities.html.

Office of Energy Efficiency and Renewable Energy (EERE) (2013d), "SunShot Initiative: President's 2014 Budget Proposes Critical Investments in Clean Energy," http://www1.eere.energy.gov/solar/sunshot/news_detail.html?news_id=19184.

Office of Energy Efficiency and Renewable Energy (EERE) (2011), "2010 Renewable Energy Data Book," http://www.nrel.gov/analysis/pdfs/51680.pdf.

Office of Energy Efficiency and Renewable Energy (EERE) (2010), "$1/W Photovoltaic Systems: White Paper to Explore a Grand Challenge for Electricity from Solar," http://www1.eere.energy.gov/solar/sunshot/pdfs/dpw_white_paper.pdf.

Office of Energy Efficiency and Renewable Energy (EERE) (2008), "About the Solar America Initiative," http://www.houstontx.gov/mayor/press/Solar%20America%20Initiative%20Fact%20Sheet%202008.pdf.

Office of Energy Efficiency and Renewable Energy (EERE) (2004), "The History of Solar," http://www1.eere.energy.gov/solar/pdfs/solar_timeline.pdf.

Platzer, M. D. (2012), “U.S. Solar Photovoltaic Manufacturing: Industry Trends, Global Competition, Federal Support,” Congressional Research Service, http://www.fas.org/sgp/crs/misc/R42509.pdf.

Prest, J. (2012), “The Future of Feed-in Tariffs: Capacity Caps, Scheme Closures and Looming Grid Parity,” *Renewable Energy Law and Policy*, 1: 25-41.

Sarzynski, A. (2010), “The Impact of Solar Incentive Programs in Ten States,” George Washington Institute of Public Policy, http://solar.gwu.edu/Research/10StateReport_GWSolar.pdf.

Solar Energy Industries Association (SEIA) (2013a), “1603 Treasury Program,” http://www.seia.org/policy/finance-tax/1603-treasury-program.

Solar Energy Industries Association (SEIA) (2013b), “Budget Sequestration and Impact on 1603 Treasury Program,” http://www.seia.org/research-resources/budget-sequestration-impact-1603-treasury-program.

Solar Energy Industries Association (SEIA) (2013c), “Issues & Policies: International Trade,” http://www.seia.org/policy/manufacturing-trade/international-trade.

Solar Energy Industries Association (SEIA) (2013d), “Solar Industry Data,” http://www.seia.org/research-resources/solar-industry-data.

Solar Energy Industries Association (SEIA) (2013e), “Solar Manufacturing Incentives,” http://www.seia.org/policy/manufacturing-trade/solar-manufacturing-incentives.

Solar Energy Industries Association (SEIA) (2013f), “U.S. Solar Market Insight 2012 Year in Review,” http://www.seia.org/research-resources/us-solar-market-insight-2012-year-review.

Solar Energy Industries Association (SEIA) (2012), “U.S. Solar Market Insight Report 2011 Year-in-Review,” http://www.seia.org/research-resources/us-solar-market-insight-report-2011-year-review.

Solar Energy Industries Association (SEIA) (2011), “U.S. Solar Market Insight: 2010 Year in Review,” http://www.seia.org/sites/default/files/us-solar-market-insight-report-q1-2011-120627093305-phpapp01.pdf.

Solar Foundation and SolarTech (2012), “Financing the Next Generation of Solar Workers: An Exploration of Workforce Training Program Sustainability in the Context of Reduced Public Funding,” http://thesolarfoundation.org/sites/thesolarfoundation.org/files/SWIC%20Final.pdf.

Strahs, G. and C. Tombari (2006), “Laying the Foundation for a Solar America: The Million Solar Roofs Initiative Final Report,” Office of Energy Efficiency and Renewable Energy (EERE), http://www.nrel.gov/docs/fy07osti/40483.pdf.

Timilsina, G., L. Kurdgelashvili, and P. A. Narbel (2011), “A Review of Solar Energy: Markets, Economics and Policies,” Development Research Group: Environment and Energy Team: World Bank, http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2011/10/17/000158349_20111017113749/Rendered/PDF/WPS5845.pdf.

U.S. Department of Energy (DOE) (2012a), “Sunshot Vision Study,” http://www1.eere.energy.gov/solar/pdfs/47927.pdf.

U.S. Department of Energy (DOE) (2012b), “Making Strides to Boost the Use of Solar Energy,” http://energy.gov/energysaver/articles/making-strides-boost-use-solar-energy.

U.S. Department of the Interior (DOI) (2012), “Obama Administration Releases Roadmap for Solar Energy Development on Public Lands,” http://www.doi.gov/news/pressreleases/Obama-Administration-Releases-Roadmap-for-Solar-Energy-Development-on-Public-Lands.cfm.

U.S. Energy Information Administration (EIA) (2013a), “Annual Energy Outlook 2013: With Projections to 2040,” http://www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf.

U.S. Energy Information Administration (EIA) (2013b), “Total Electric Power Industry Summary Statistics, 2011 and 2010,” http://www.eia.gov/electricity/annual/html/epa_01_01.html.

U.S. Energy Information Administration (EIA) (2013c), “Electric Power Monthly: With Data for April 2013,” http://www.eia.gov/electricity/monthly/pdf/epm.pdf.

U.S. Energy Information Administration (EIA) (2012a), “State Energy Consumption Estimates: 1960 Through 2010,” http://www.eia.gov/state/seds/sep_use/notes/use_print.pdf.

U.S. Energy Information Administration (EIA) (2012b), “Trends in Renewable Energy Consumption and Electricity,” http://www.eia.gov/renewable/annual/trends/.

U.S. Energy Information Administration (EIA) (2012c), “What are the Major Sources and Users of Energy in the United States?” http://www.eia.gov/energy_in_brief/article/major_energy_sources_and_users.cfm.

U.S. Energy Information Administration (EIA) (2012d), “Annual Energy Review,” http://www.eia.gov/cneaf/solar.renewables/page/solarphotv/solarpv.html.

U.S. Energy Information Administration (EIA) (2012e), “Solar Photovoltaic Cell/Module Shipments Report 2011,” http://www.politicaljunkiehandbook.com/uploads/-e.solarvoltaic_report2012.pdf.

U.S. Energy Information Administration (EIA) (2012f), “Annual Energy Outlook 2012: With Projections to 2035,” http://www.eia.gov/forecasts/aeo/pdf/0383%282012%29.pdf.

U.S. Energy Information Administration (EIA) (2010), “Solar Photovoltaic Cell/Module Manufacturing Activities,” http://www.eia.gov/cneaf/solar.renewables/page/solarphotv/solarpv.html.

U.S. Energy Information Administration (EIA) (2007), “Renewable Energy Consumption and Electricity Preliminary 2006 Statistics,” http://www.eia.gov/cneaf/solar.renewables/page/prelim_trends/rea_prereport.html.

Walsh, K. M. (2012), “Renewable Energy Financial Incentives: Focusing on Federal Tax Credits and the § 1603 Cash Grant: Barriers to Development,” Selected Works, http://works.bepress.com/kevin_walsh/1.

Willis, B. (2013), “Report: Policy Obstructing Institutional Investment in Renewables,” PV-Tech, http://www.pv-tech.org/news/report_policy_obstructing_instutional_investment_in_renewables.

Woody, T. (2012), “Cut the Price of Solar in Half by Cutting Red Tape,” Forbes, http://www.forbes.com/sites/toddwoody/2012/07/05/cut-the-price-of-solar-in-half-by-cutting-red-tape/.

Yantis, J. (2013), “Suntech to Close Goodyear Plant, Its only U.S. Factory,” Azcentral.com: Arizona’s Home Page, http://www.azcentral.com/community/swvalley/articles/20130312suntech-close-goodyear-plant.html?nclick_check=1.