

**How the Sun Drives Us:
Photovoltaics in the US and Germany**

by

Alison Hyde

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ABSTRACT

With the realization that traditional means of providing useful energy have formidable environmental and economical repercussions, many countries have begun to explore more benign and sustainable energy sources—renewables. Photovoltaics (PV), a sub-group of renewable energy technologies, convert incident solar radiation into electrical power. Germany, the US and Japan are racing to attain and maintain global PV prowess. Global leadership guarantees the leading nation the economical benefits of a booming technological industry, a secure, reliable energy source, and a limitless, environmentally responsible energy.

As Germany and the United States are two very politically and economically influential nations with sophisticated industrial sectors and substantial populations to power, it is only fitting that these countries be in the forefront of a PV revolution. This thesis compares the federal efforts made by the German and the American governments to support the technological development, market integration and implementation of PV technology. It examines the resulting state of each nation's industry and considers why, despite having nearly twice the solar resource of Germany and 28 times more land on which it falls, the US is trailing behind Germany.

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Thesis of Alison C. Hyde

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Approved:

Dr. William Hetherington, Thesis Advisor Department of Physics

Kate Lajtha, Chair of Environmental Sciences Department

Mark Lusk, Director of International Degree Program

I understand that my thesis will become part of a collection at Oregon State University. My signature below authorizes release of my thesis to any reader upon request. I also affirm that the work represented in this thesis is my own work.

Alison C. Hyde, Author

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INTRODUCTION

Of the electricity generated globally each year, 66% is fossil fuel based, contributing 3.2 billion metric tons of CO₂ to the atmosphere annually and incurring widespread environmental damage [1] [2]. The finite quantity and patchy distribution of fossil fuel sources has made them a global commodity—frequently resulting in international tension. Yet, as electricity is a vital component of modern societies and its production is a huge economy in itself, fossil fuels will continue to be an influential component of international affairs and a major cause of environmental degradation until viable alternative energy technologies are developed and implemented. One such technology is photovoltaics (PV). PV is a clean, renewable energy technology referred to as solar energy, and more specifically it is a solar electric technology.

For any work to be done, energy is required. Energy is commonly measured in Joules, but electrical energy is quantified in kilowatt-hours (kWh) where 1 kWh=3.6 MJ. Power is the amount of energy delivered over a given time period and is measured in Watts (W).

The sun has provided the earth with its primary source of energy for 4.5 billion years and will continue to do so for another 6 billion. Solar rays strike the earth's surface with a maximum intensity of 1000 kilowatt-hours per square meter (kWh/m²)[3]. This intensity is known as solar insolation. Over the surface of the earth, solar insolation delivers 1.6×10^{17} watts (W) of power or 1.4×10^{18} (kilowatt-hours) kWh of energy each year [4]. This is 100,000 times more energy than the global electric consumption of 1.36×10^{12} kWh in 2003 [1]. In fact, no country consumes as much

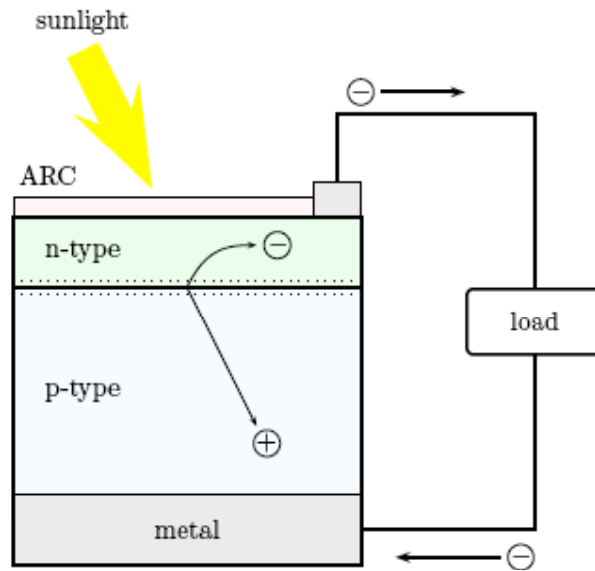
energy as strikes the surfaces of its buildings in the form of solar radiation and roughly as much energy as was globally consumed by the burning of fossil fuels as fell on the surface of US roads in 2004 [5].

The Photovoltaic Concept

Solar derived energy powers the earth's biosphere, driving the hydrological cycle, weather patterns and vegetative growth. The photoelectric or photovoltaic effect is the same mechanism that plants have used to convert sunlight into usable energy for millions of years through the process of photosynthesis and it is used today to create electrical energy.

Light energy transferred from the sun is a form of electromagnetic radiation, quantized in units of energy called photons—ergo photovoltaic and photoelectric. The photovoltaic conversion of photons to electrical energy takes place within a solar cell (Figure 1). Cells are devised of 2 layers of semiconductor wafers commonly made of silicon. In each semiconductor crystal, electrons are separated, in an energetic sense, into a valence band with a lower energy level and a conduction band with a higher energy level. If a photon with enough energy strikes the crystal, its energy is transferred to an electron in the valence band allowing this electron to “jump up” energetically to the conduction band. In order to give the movement of the electrons directionality, two semiconducting materials of differing charges are laid side-by-side. The n-layer semiconductor has a lower energy level and an abundance of negatively charged electrons while the p-layer has electron “holes” or positively charged spaces in the crystalline structure, which electrons are attracted to. When two such semiconductors come in contact with each other an electric field within the cell is created at this p/n

junction. By attaching wires to the cell, electrons begin to flow in response to absorbed photons and an electrical current ensues. Current, coupled with the voltage at which it is delivered, leads to electrical power that can then be tapped to perform work.



source: Hetherington 2002

Figure 1. Photovoltaic Cell. ARC is an anti-reflection coating

Even as the basic concept remains the same, not all PV cells employ the same technology. PV cells were originally made from silicon, but today a number of different semiconductor materials are used in thin-film, copper indium diselenide (CIS), and cadmium telluride solar cells.

PV cells are aggregated into modules and several modules to make up an array. When arrays are coupled with a power inverter, which converts DC generated power into usable AC power, and a battery or other energy storage technology, a complete PV system is formed. This system can provide useful electrical power for any application where ever the sun shines.

PV Technology

Although the active development of PV is a fairly recent phenomenon of the last half-century, the concepts behind photovoltaic technology were discovered over 150 years ago [6]. The French physicist Becquerel first cited the photoelectric effect in 1839, yet PV technology progressed slowly until the United States began developing PV for use in satellites in the 1950's [6].

Electrical energy provided by PV technology displaces fossil fuel-based generation and negates the associated environmental costs and political factors. PV does not contribute to pollution or global warming. Emissions such as cadmium, that do arise during manufacturing, are produced in quantities orders of magnitude smaller than those from a traditional coal-fired power plant [7]. Some PV manufacturers have "closed loop" factories, using energy converted by PV arrays to manufacture more PV modules.

One characteristic of PV that is of great political interest is that a nation deriving energy through PV is tapping a limitless, domestic fuel source and is therefore that much less reliant on imported fuel sources. Traditional fuel sources are not only expensive to explore, extract, transport and market, but also expensive to secure. The US for example, finances a permanent fleet of ships continuously policing oil lanes in the Persian Gulf [5]. Conventional fuels are also subject to greater market volatility and international affairs. They are more prone to supply/delivery disruptions and many of these technologies convert expensive and limited fuel sources very inefficiently. The combustion of fossil fuels is also the number one cause of air pollution and contributes heavily to water quality issues [2].

PV however, is not a perfect power source. Like all other forms of electricity, PV generated power still requires transmission from its source to its end use. Although this is not the case for site-mounted systems, large PV power stations or PV parks in the American South West, could not feasibly produce energy for the entire nation due to transmission and energy storage factors. PV is also strictly limited by the amount of sunlight, i.e. solar resource available. Although PV arrays still produce power on overcast days, an alternate source is needed for supplemental power when solar insolation is insufficient or at night. Batteries are currently used for energy storage on small-scale PV systems, being charged when an excess of solar resource is available and then tapped when the arrays are not producing. The charge/discharge efficiency of these batteries is only about 60% however, and decreases over time. Batteries also contain hazardous acids requiring special disposal. Clean and efficient energy storage technologies that can be used on a wide scale are being developed and will be critical in the widespread feasibility of PV.

PV arrays are currently used to provide back up for conventional electrical generation systems and in remote grid-independent application, but their increased use would do more to enhance energy infrastructure security, as well as diversify a nation's fuel supply and bypass severe environmental degradation by displacing power produced through the combustion of fossil fuels [8]. Distributed energy sources also mitigate power quality and reliability problems, which cost the nearly US 119 billion USD a year [8]. Since PV is non-centralized, thousands of independent solar systems coupled with reliable storage devices will not leave thousands of people without power, as an equipment failure in a single power plant or a downed power line would.

When discussing the price and performance of PV modules it is important to distinguish between module capacity and module performance. Peak-watt (Wp) describes the capacity or the maximum power output of a module under lab conditions (1,000W/m² of solar insolation within the at 25°C) [9]. Knowing the capacity of a module helps to compare different PV technologies and is used in calculating capacity-based incentives. Module performance is measured in Whs or kWhs, reflecting the amount of energy actually produced. Costs expressed per Wp are installed costs. They are an aggregate of the raw technology, or manufacturing costs, based on a module's capacity and module installment. Costs per kWh account for solar conditions by balancing the installed cost and maintenance costs with the amount of the electricity produced. Although modules have high up-front costs, the price of generated electricity does on fluctuate. This is because the ¢/kWh price of a module is a reflection of only the installed costs and performance, and not the fuel source—the fuel source is free. In essence, a PV purchaser is all buying all the electricity provided by the system over its lifetime, up to 30 years, at once. This stands in stark contrast to incremental purchases of traditional fuel sources that are highly subject to international energy politics and market variability.

PV has no fuel costs, significantly lower operating costs, and the external costs to human health and safety and the environment are practically non-existent [10]. In addition to these direct economic considerations, as a budding industry, PV stimulates industrial innovation and development, promoting economic growth and creating thousands of higher income jobs in every region it is deployed.

BACKGROUND

National Electricity Profiles

Germany consumed 505 billion kWh of electricity in 2004 or 7,396 kWh per capita, and the US consumed 3,584 billion kWh or 11,998 kWh per capita [11][12]. For comparison, a standard 100W light bulb will use only 2.4 kWh of electricity in a day or 0.1 kWh in an hour.

Because the US has a substantial domestic energy resource base, only 33% of the US energy mix is imported [13]. Germany, on the other hand, has very limited domestic energy resources and a dwindling hydrocarbon supply so Germany imports over 63% of its energy supply [14]. Despite the deregulation of utilities in accordance with directives from the European Union (EU), Germany still has some of the highest electricity prices in Europe nearing 22 EUR ¢/kWh (26 US¢/kWh) [13]. Compare this to the average retail price for American electricity of only 7.4 ¢/kWh [15]. The higher price of electricity and utility taxes promulgated by the Bundesregierung has lead Germany to consume electricity more efficiently on a lower overall and per capita basis.

2004	Germany	United States
total electric consumption (kWh)	505 X 10 ⁹	3,548 X 10 ⁹
% fossil fuels	60%	71%
% energy sources imported	63%	33%
Price of electricity (in US ¢)	26¢/kWh	7.4 ¢/kWh
per capita electric use (kWh)	7,369	11,998

Table 1. National electricity statistics for the US and Germany in 2004

In 2000, Germany enacted a plan to phase out all nuclear power by 2021 [14]. Insufficient, diminishing domestic resources coupled with the phase out of nuclear energy production will leave renewables with a large gap to fill if Germany's modern day energy demands are to be met without increasing energy imports and thereby driving the price of electricity even higher.

The US managed to lead the industry for 40 years, before the upper hand was relinquished to Japan in 1998 [16]. Currently, the United States is the world's third largest PV producer, manufacturing 12% of the global PV supply [17]. This is less than half of the 25% that Germany ships as the second largest PV producer [17].

On average, the US receives 1,800 kWh/m² of solar radiation annually and Germany receives around 1,000 kWh/m² annually [18] [19]. America's electricity consumption spikes in the summer as energy intensive air conditioning systems are switched on, concurrent with a seasonal increase in incoming solar radiation. Germany's most energy intensive time of the year, however is the winter, anti-parallel with available sunlight and solar intensity [20]. Yet, despite this large discrepancy in raw solar resource, its lack of coincidence with energy demand and despite having considerably less land area on which to capture that resource (US land area = 9,826,675 sq km, Germany land area = 357,021 sq km), Germany far out competed the US in 2004 with 794,000 kW of installed PV capacity; more than twice the US installed capacity of 365,200 kW [21]. How is it then that a nation, which alone consumes more than 25% of the world's total energy, is well endowed with solar resource, and that prides itself as being one of the most technologically sophisticated societies on the globe is lagging behind in energy technology [14]?

Perhaps Germany's greater interest in seeking out alternative energy sources is due in part to the higher price of electricity and limited domestic sources of traditional energy sources and a greater environmental consciousness.

A Budding Market

PV has a long list of benefits, hardly defrayed by its few drawbacks. PV is a reliable means of generating clean, sustainable energy in a well-distributed fashion. It has a predictable cost curve and is secure from foreign influences or national crises. Yet the high up-front cost of PV technology makes it appear inaccessible and as a non-lucrative investment.

As it stands, the high-cost drawback of PV is the result of an immature, developing technology. The PV industry must first overcome a standard "learning curve", often demand driven, to become successful and self sufficient (Figure 2). Progression along this curve reflects the establishment of the market made possible by sufficiently refined technology leading to lower prices.

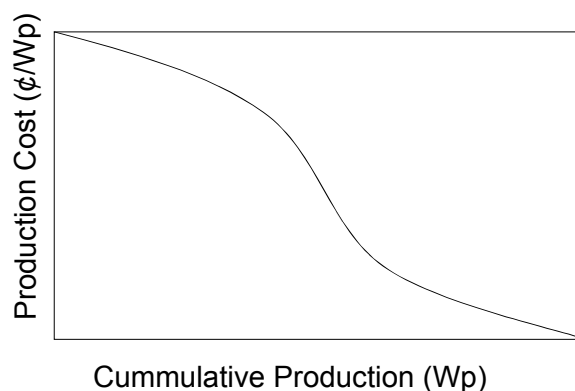
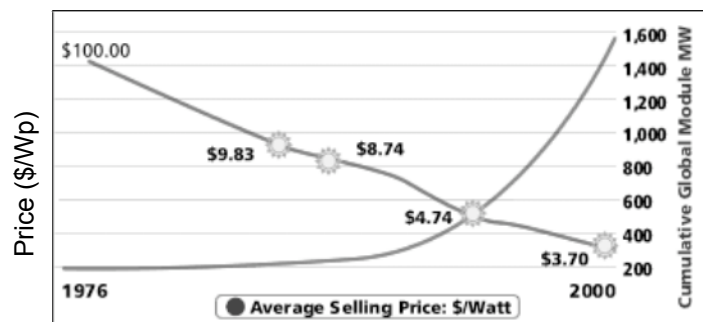


Figure 2. S-shaped learning curve of a new technology. High cost of technology production is lowered as demand driven production increases.

In 1974, the price of a PV module in the US was over 50 USD/Wp, but in 2003 the price had already fallen to 3 USD /Wp [22] [23]. Despite this precipitous price drop, PV technology is still expensive. Although the cost of PV generated electricity is already competitive in areas with high energy prices during peak demand hours, in order to compete with conventional energy technologies that produce electricity for 10 ¢/kWh in the United States, electric production costs must drop below the current cost of 21 ¢/kWh [24]. Price is directly influenced by economies of scale meaning that the cost of PV will remain high until the demand for PV increases; yet public demand will stay low until prices drop (Figure 3).



Source: <http://www.seia.org/>

Figure 3. Average module price/Wp as a function of global cumulative installed capacity

It should be noted however, that the price of conventional electricity is highly subsidized and does not reflect the true costs of generation. Long-term contracts for the purchase of fossil fuels lock the price of the raw fuel supply at a constant rate for 7 to 30 years. Generation costs are often then levelized or lowered by 5 to 10%. So while the true cost of power from what is considered the least costly fossil fuel technology, a natural gas-fired combined-cycle plant, is 7 ¢/kWh, the levelized cost is only 3 ¢

US/kWh [25]. The volatile price fluctuation of fossil fuels also has a large negative impact on the gross domestic product and correlates strongly with economic recessions [25].

Since the private sector has been unsuccessful in soliciting enough demand, proper economies of scale can only be created with the help of government procurement and incentive programs. Through federal support, the costs of cells, modules and all system components including the inverter, mounting and installation equipment can be lowered, system efficiency increased, and systems life spans prolonged. All of these improvements will make PV technology a more viable option for the greater public.

METHODS

This project was primarily a web-based literature review. Electronic and web resources were used extensively as they provided the most up-to-date information. Many reports, book chapters, conference reports and other documents were acquired in PDF format from government and institutional websites. HTML format newspaper articles and press releases from reliable, credible and non-biased sources were also examined.

For each topic examined in one country, the same topic was addressed for the other. Information was taken from independent international agencies, US or German governmental sources or neutral parties whose purpose was to provide accurate, non-biased information.

In an attempt to get first-hand information and the opinions of professionals in the field, questionnaires were sent out to German and American institutions and private

firms that develop, manufacture and/or distribute PV technologies. Individuals were asked questions about how they viewed the current state of their respective industry, how they thought the government was handling PV issues and what their opinion of the PV industry in the other country was. Refer to Appendix I for survey information. Questionnaires were in compliance with the guidelines set forth by the Oregon State University Institutional Review Board. Very little response was received however, as only 3 out of 14 questionnaires were returned.

ANALYSIS

Federal PV Efforts

Both the US and Germany claim to pursue PV as a means to reduce CO₂ and other green house gas emissions in the face of global climate change, yet while many Americans are still highly skeptical that climate change is a response to anthropogenic activity, Germans have taken it to heart and have gotten serious about cutting emissions.

In 1991, the German government was already serious about PV, other renewable energy technologies and energy efficiency. This dedication was exemplified through the creation of Berlin's Solare Regierungsviertel (Solar Government District). Aging federal buildings were renovated and new buildings were erected using green design principles. A total of 10,000m² of PV cells were installed on the roofs of the Presidential Bureau, Department of Trade and Industry, Parliament and the Department for Education and Research buildings [26].

US President Jimmy Carter installed a solar energy system on the roof of the Whitehouse in 1977, but the system was later removed when Reagan came into office

[27]. In 2003, solar energy returned to the White House upon the installation of a 9-kWp PV system [27]. This is a very clear example of the blatant contrast between each government's dedication to PV.

The Kyoto Protocol in 1997 and its ratification in 2000, were the first international steps taken to reduce CO₂ emissions. The pivotal role that renewable energy sources will play in combating global warming was recognized and a predominant strategy for reducing CO₂ emissions is the increased generation of electricity through non-green house gas emitting technologies or renewables.

Although the US chose not to ratify the protocol, several states have adopted their own policies to meet and exceed protocol recommendations. Germany, on the other hand, has made it national business to not only comply with the conditions specified for renewable energies under the protocol, but instigate their own more stringent standards. As it stands Germany, is one of the few nations on track to meeting Kyoto protocol directives [19].

Within the German federal government or Bundesregierung, the Federal Ministry of Environment (BMU) is the primary ministry responsible for administering federal renewable energy efforts (Figure 4). The 4th program on Energy Research and Technology oversees federal research and development through contracts with the Jülich Research Institute and specifically their Institute of Photovoltaics. Other federal ministries play a part including the Federal Ministry of Education and Research and the Federal Ministry of Economics and Technology, which provides grants for schools through the Federal Office of Economics and Export Control.

The United States Department of Energy's (DOE) administers the research, development, demonstration and deployment of renewable energies through their office of Energy Efficiency and Renewable Energy (EERE). The EERE operates 11 renewable energy programs, whose primary purpose is to create connections between the private sector and other government agencies. The DOE's Solar Energy Technologies Program, for example, works with national laboratories, universities, industry, professional associations and other programs within the DOE and with local, state and federal agencies across the US to create cost-effective solar technologies through research, development, and deployment.

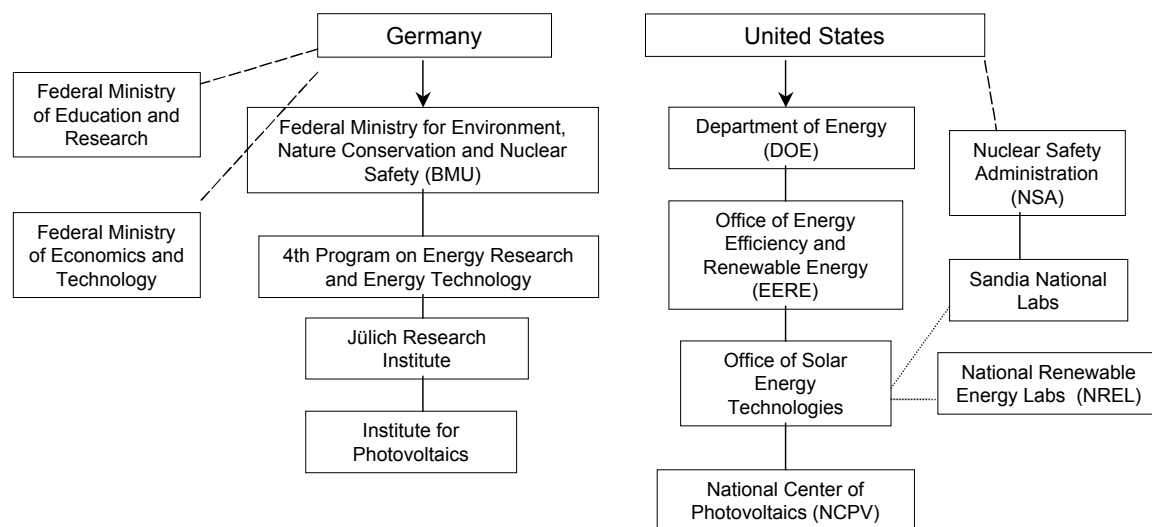


Figure 4. Delegation of responsibility for federal-level photovoltaic research, development, demonstration.

Goal Setting

Both the US and Germany recognize the importance of reducing module and system costs per Wp if installation and production goals are to be met. As cost reduction strongly depends on the price of semiconductor materials, conversion

efficiency and system lifetime, each of these parameters come under key consideration. However, while the German Bundesregierung dictates specific goals they would like to see meet by the industry. The US federal government only reiterates projections cited by national labs if industry recommendations are granted. More over as the US seeks mainly to raise the nation's bulk cumulative capacity, Germany has since progressed to focus on precisely where new capacity will be installed.

Germany's national PV goals are directly influenced by the conditions of the Kyoto Protocol, directives from the European Union, the national Renewable Energy Law the Erneuerbare Energien Gesetz (EEG) and Germany's push for a complete phase-out of nuclear energy by 2021. The EEG—first instigated in 2000 and since modified in 2004--vowed to increase the percentage of Germany's total electric production derived from renewable sources to 12.5% in 2010 and 20% in 2020 and 45% in 2050 [19]. Although these are the percentage goals specified on paper, German officials are shooting even higher, predicting that renewable energy production will reach 65% by 2050 [28]. PV generated electricity is projected to comprise 3.4% of all renewable energy produced by 2010 and 11% by 2050 [28]. Professionals in the German industry are excited about the EEG and the part that PV will play in meeting these goals [29][30].

In 2001, the European Union upped the ante by releasing a directive requiring all member states to derive 22% of their energy mix from renewable sources by 2010 [31]. Germany is currently on track to meet both goals. In fact, the Enquete Commission that was established to provide a scientific basis for energy policy decisions in the Bundestag, reported in 2002 that all of the nation's energy needs could be meet with solar/renewable energy sources. German policy has progressed accordingly [18].

Germany intends to suppress system prices by 5% per year [32]. The German government also seeks to increase system efficiency and lifetime to operate at 95% of its peak output for over 25 years, further build on their current technological leadership and create recycling concepts for aging systems [33]. Jürgen Trittin, Germany's Environmental Minister until 2005, stressed the importance of encouraging arrays on buildings preferentially over free-standing arrays and emphasized that attention should be paid to developing smaller arrays, which have greater installation potential on smaller and crowded roof spaces. Trittin also pushed for the construction of more cost-effective freestanding arrays with peak capacities of greater than 100kWp in suitable locales [34].

By backing the industry-led Crystalline Silicon Initiative, US President Bush aims to increase PV performance by 50% by 2015 and help to reduce PV generated power costs to 6 US¢/kWh and the current 6.10 USD/Wp system cost to consumers by 40% to about 3.68 USD/Wp [16]. Industry leaders believe this initiative should pave the way for their goal of producing half of all new US electric generation with solar technologies in 2025 [18]. National goals also aim to reduce the direct manufacturing costs of PV to 1.75 USD/Wp in 2006, develop technologies with the potential for further cost reduction, and expand current system lifetimes from 25 years to more than 30 years in 2010 [23][18]. The federal government sides with the industry's goal for cumulative PV sales or installation and has chosen to act as a facilitator to help the industry reach its 1GW of cumulative US sales goal by 2006 [35]. In a 2005 report, the National Center for Photovoltaics (NCPV) set its sights on extending the current national PV capacity of 365 MWp to 30,000 MW by 2020 [8].

Germany		United States
•EEG - National electricity production		•1/2 of all new electrical generation in 2025 through solar electric
all renewables	PV	
12.5% in 2010 20% in 2020 45% in 2050	3.4% in 2010 11% in 2050	
* goal of Bundesregierung		* goal of national lab

Table 2. National goals for PV in electric generation

Budgeting

Public monies budgeted for PV activities in the US and Germany includes allocations by federal, state and local governments, partnerships and industry cost sharing. In 2004, the US government appropriated 72.5 million USD for PV research and development [36]. The aggregated public budget was 277 million USD [36]. In Germany, 30 million USD was allocated for research and development, yet the aggregated public budget soared to 339 million USD [21]. This was mainly due to the 308 million USD spent on market stimulation—more than twice the US expenditure of 180 million USD. The value of market stimulation in the US however, is primarily attributable to expenditures in California [21]. Germany has focused more than 200% more funding on market stimulation and deployment incentives than research and development [37]. To get an idea of PV's among renewable, of the entire requested budget for renewable energy by the EERE, only 6% was set-aside solely for PV whereas in Germany, nearly 32% of the federal renewable energy budget is reserved for PV [38][39].

In 2005, of the 85 million USD was federally allocated for solar technologies

through the EERE, 75 million USD was specified solely for PV research and development [38]. Bush also called for the set aside of 4.5 million USD for a Crystalline Silicon Initiative to reestablish global market leadership and PV technology ownership [16]. This was a small amount compared to the much larger budget requests made for weatherization and vehicle technologies; upwards of 200 million USD and small compared to investment of 75 million EUR or 90 million USD for research and development in Germany that same year [34][38].

* in millions of USD	Germany	United States
<i>2004</i>		
R & D	30	72.3
Market Conditioning	308	180
D & D	0	10.5
Aggregated Public*	339	277
% of R.E. budget specifically for PV	30%	6%
<i>2005</i>		
R & D	90	79.5

* includes funding from state and local governments, partnerships and cost sharing with the industry

Table 3. 2004 and 2005 Public budgets for PV in millions of USD

German research and development institutions for renewable energies receive funding not only from the Federal Government, but the Federal States also undertake their own projects. In fact, Germany's PV industry has become so successful that a large proportion of PV research and development activity has been privatized. In 2004, the PV industry alone spent 283 million EURO (340 million USD) on installation [39]. It should be noted however, that the private sector does receive some funding from the federal government. About 45% of a private institution's total income is federal money [40]. From government funding perspective, the US lags behind Germany in its support

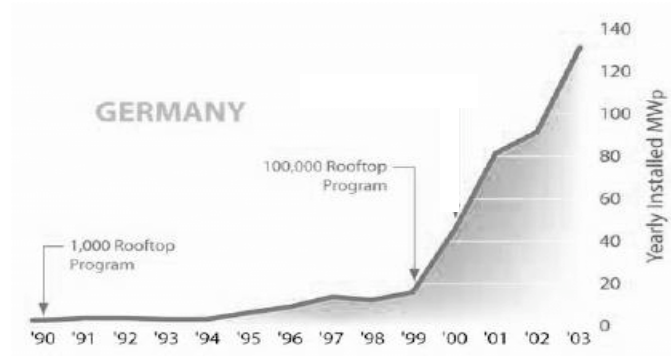
of PV on an absolute basis and even more so on a per capita basis. Refer to table 3 for summary values.

Federal Demonstration Programs

Germany has chosen to actively pursue PV not only earlier than the United States, but has also done so with greater success by simplifying and consolidating efforts on a much more intense level. The major influences on Germany's success are due to key national measures including clear policy framework, sufficient and PV-specific financial programs, and the support of goal-oriented research and development programs [41].

In 1990, the German government deployed the 1,000 Solar Rooftops Program to develop a market for PV and stimulate the industry. The program was oversubscribed and resulted in the installation of 2,000 domestic PV arrays from 1991 to 1996 [42].

Due to the success of the 1,000 Solar Rooftops Program, the 100,000 Solar Rooftops Program of 1999 was launched to further encourage the PV market and push for more building-integrated PV. Low-interest loan rates of 0%, and an additional guarantee of 51 EUR¢/kWh (61 US¢) paid from utility company profits, resulted in the installation of 100,000 grid connected PV systems totaling 300 MWp in 6 years [43][19]. An innovative component of the program that has since become a trademark in German incentive strategies is the long-term distribution of incentive payments.



Source: NCPV U.S. September 2004

Figure 5. Effect of German national PV demonstration and deployment programs on yearly installation

In 1997, the US followed Germany's example with the Million Solar Roofs Initiative aiming to install solar technologies, including PV arrays on a million domestic and commercial roofs by 2010. The American program differed significantly from its German counterpart, as it offered no federal funding until 2001. Instead the 1,000,000 Solar Roofs Program used its federally backed prestige to foster the creation of partnerships between states and local communities. As of 2003 40MWp of PV had been installed [44]. The program has since trickled down to the states. Many states including California and North Carolina have instigated their own Solar Roofs Programs made possible by federal funding.

Germany		United States	
1990	1,000 Rooftops Program •2,000 domestic arrays	1997	1,000,000 Solar Roofs •40 MWp as of 2003
1999	100,000 Rooftops Program •400 MWp of solar		

Table 4. Federally funded PV demonstration and deployment programs in Germany and the US

Both nations have programs like the US DOE Brightfields Initiative that transforms contaminated industrial sites into fields of large-scale freestanding PV arrays. In Germany, however such projects, although made possible by federal incentives, are run by private corporations, utilities and local municipalities.

Federal Financing and Incentive Measures

Market conditioning in the US and Germany uses similar incentive strategies to encourage PV demand such as offering low interest loans and grants. Yet, where the US favors state and regional level incentives primarily determined by the size or capacity of a system, Germany employs nation-wide incentives based on the amount of electricity a system actually produces.

Tax incentives, usually in the form tax credits, are applied annually towards income taxes. Credits can be performance-based, proportional to the electricity systems produces, but more often than not tax credits are capacity-based, applicable simply upon purchase and installation, based on the Wp capacity of a system. Tax credits do not benefit everyone however. Government agencies, non-profit organizations, schools and other entities with no tax liability or a limited tax burden fail to effectively capture tax credit benefits.

Rebates on PV generated electricity from utility companies or the federal government and funding received for PV projects and purchases are tax-exempt. Renewable Electricity Standards (RES) or Renewable Portfolio Standards (RPS) require utilities to gradually increase the proportion of renewable energy bought and sold by utility companies. Net-metering, as it is referred to in the US, or feed-in tariffs as

they are called in Germany, can function along side a RES or independently. By law, producers of renewable energy are entitled to receive a fixed rate for surplus energy fed back into the grid.

Germany implemented its first feed-in tariff, the “Electricity Feed-in Law” in 1991, the *Stromeinspeisungsgesetz*, and the success of the 1,000 Solar Rooftops Program was primarily due to this law. The tariff rate for all grid-connected arrays was set at 90% of the average utility electricity rate [45]. A similar strategy wasn’t deployed in the US until 2002 when the Senate passed an Energy Bill allowing, but not requiring, states to set RESs or RPSs [46].

Germany’s 1999 Eco-Tax raised the price of oil, gas and electricity by an average of 11 EUR ¢/kWh (13 US¢) to encourage overall energy efficiency [47]. The Eco-Tax has since increased on an annual basis. However, electricity produced by renewable sources and fed into independent networks or used directly on site are exempt from taxation [47].

The *Erneuerbare Energien Gesetz* (EEG), implemented in 2000, is the predominant driver of Germany’s success with the implementation of renewable energy technologies and the biggest influence on PV deployment. The EEG regulates all electricity fed into the grid that is generated by renewable sources through a national feed-in tariff. Under the EEG, utility companies are required to use annual profits to pay PV operators for surplus electricity feed back into the grid. Current feed-in tariff rates are show in Table 5.

The Bundesregierung employs a dynamic approach in supporting the PV market through a range of tariff rates and decreasing tariffs for newly installed arrays by 5% per

year. By offering varying rates for PV in different applications, the Bundesregierung is able to steer the direction of the market, and can encourage, for example, building integrated PV above all other applications. This approach also stimulates the purchases of PV arrays early on, when tariffs are most favorable, so that an ample PV infrastructure will be in place as the market is weaned off of government support and purchasers will have been able to receive a return on their investment.

To illustrate this, in 2000 freestanding, grid-integrated systems earned a base feed-in tariff of 50.6 EUR¢/kWh (60.7 US¢) [48]. This tariff was the lowest offered to PV in any application, but still more than sufficient to encourage the construction of large MWp scale PV parks. By 2003 the feed-in tariff rate for freestanding systems had been reduced to 45.7 EUR¢/kWh (¢56 US) and is currently 40.6 EUR ¢/kWh (49 US¢/kWh) [49].

PV Application		Tariff (US¢/kWh)
Arrays on buildings and fences	< 30kWp	62.5
	30 - 100 kWp	59.4
	> 100 kWp	58.8
Building Integrated		6 ¢ bonus
Free standing arrays and all others		48.9

Table 5. 2006 tariff rates for Germany's Erneuerbare Energien Gesetz (EEG)

Tariff rates are guaranteed for 20 years after the module comes into service. Although the cost of connecting the system to the grid is the responsibility of the system owner, the grid operator is required under the EEG, to give preference to generators of renewable energy and must expand or renovate grids to incorporate new arrays. The

original installation capacity limit for tariff-eligible systems of 350 MWp was raised to 1,000 MWp in 2002, and later completely removed. This move essentially provided for almost limitless expansion of German PV [43][19].

Currently, Germany's PV incentives are enticing enough to not only drive the demand for PV within its own borders, but overwhelmed domestic suppliers and producers have begun pulling in resources from foreign PV markets to meet domestic demand [50].

Program Title	Incentive Type	Effective Dates	Specifications
Stromeinspeisungs-gesetz	feed-in tariff	1991-1999	PV rate equaled to 90% of electricity rate
Öko-Steuer (Eco-Tax)	utility tax	1999-present	renewably produced electricity independent of conventional electric grid is tax exempt
Erneuerbare Energien Gesetz (EEG)	feed-in tariff	2000-present	current PV rates between 48.9-67.3EUR ¢/kWh

*incentives available to all producers of PV-generated electricity

Table 6. German federal incentive policies applicable towards PV technologies

As part of his Climate Change Initiative in 2002, President Bush proposed the first residential solar energy tax credit that would allow for a 15% tax credit for PV property expenditures up to a maximum of 2,000 USD [51]. The tax credit, known as the Residential Solar and Fuel Cell Tax Credit, finally came into effect under the Energy Policy Act of 2005. The final terms reward residential owners of PV systems installed before 2006 with a personal tax credit of 10% of the purchase and installation costs. The credit increases to cover up to 30% of systems installed after 2006 [52]. Tax credits will last until 2008. Tax credits fail to benefit everyone however, as government

agencies, non-profit organizations, schools and other entities with no tax liability or a limited tax burden fail to capture tax credit benefits.

Before 2006, the American federal government offered only corporate tax and production incentives for PV power produced by commercial and industrial sources. In 1986, the Modified Accelerated Cost-Recovery System (MACRS) allowed businesses to recover investment costs for PV equipment through depreciation deductions. The Renewable Energy Production Incentive (REPI) effective as of 1992 is the only national feed-in tariff offered. State, local and tribal governments and small-scale utilities are awarded 1.9 US¢(indexed for inflation) for every kWh produced [53]. Since the tariff is paid out of federal appropriations it is subject to budget cuts.

Program Title	Incentive Type	Date Enacted	Specifications
Modified Accelerated Cost-Recovery System (MACRS)	corporate depreciation	1986	five year depreciation terms for PV in commercial and industrial use only
Renewable Energy Production Incentive	feed-in tariff	1992	1.9 ¢/kWh for PV in state, local, and tribal government use only
Business Energy Tax Credit	corporate tax credit	1999	credit equals 10-30% of purchase and installation costs for PV in commercial/industrial use only.
Residential Conservation Subsidy Exclusion	tax exemption	u.k.	100% of subsidy value is not calculated into tax liability. For residential and commercial PV
Residential Solar and Fuel Cell Tax Credit	tax credit	2005	personal tax credit of 10-30% of purchase and installation costs

Table 7. Selected US incentive policies applicable towards PV technologies.
See appendix II for a more complete listing.

The 1.9 ¢/kWh US feed-in tariff is significantly smaller than the Stromeinspeisungsgesetz tariff of 8.5 EUR¢/kWh (10 US¢) that was offered in 1999

and smaller yet in comparison to the base feed-in allowances presently offered under the EEG. The US tariff is limited only to government and tribal entities when appropriations are available, while German feed-in tariffs are guaranteed for all array operators.

Germany	United States
Stromeinspeisungsgesetz : 1991-1999	Renewable Energy Production Incentive : 1992-present
eligibility: all array owners	eligibility: state, local and tribal government entities
US ¢/kWh: 90% of average utility rate	US ¢/kWh 1.9
Erneuerbare Energien Gesetz: 2000-present	guaranteed for 10 years
eligibility all array owners	
US ¢/kWh 48.9 - 67.3	
guaranteed for 20 years	

Table 8. Comparison of US and German feed-in tariffs for PV technologies

German businesses, industries, organizations and homeowners have access to national and EU PV support programs. EU programs such as, Intelligent Energy for Europe, offer coverage for specific costs associated with the implementation of community PV systems. Nachhaltige Energiesysteme in Rahmen des 6. Forschungsrahmenprogramms subsidizes up to 50%, the total costs associated with large-scale PV research and deployment projects. These costs may include, but are not limited to associated educational, administrative, organizational, institutional, financial and social expenses. Financing of 70-100% of total cost is also available through the Europäische Investitionsbank [54].

On the national level, the Kreditanstalt für Wiederaufbau (KfW) is the central

administrator of funding for the majority of loans and grants applicable towards PV installation and deployment. KfW awarded grants for the 100,000 Solar Rooftops Program, and the Umweltprogramm finances community-centered and environmentally conscious programs. Two KfW programs, the CO₂-Gebäudersanierungsprogramm and Solarstrom Erzeugen, offer financing and support for PV to individuals and corporations under the premise of clean energy technologies and the reduction of green house gas emissions (See Appendix II). Twelve other KfW financing programs encompass PV in areas such as ecological construction and renovation as well as CO₂ reduction. KfW programs finance home or business owners as well as groups and individuals working in all branches of the PV industry including research, distribution, and installation. Much of the financing KfW offers comes in the form of low interest, long-term loans and grants [54].

The Umwelt und Energiesparprogramm of the national European Recovery Program sponsors measures aimed at improving the environment including the installation of renewable energy technologies. The Vor-Ort-Beratung Program from the Ministry for Economics and Technology offers financing for on-site consultations from energy efficiency professionals. PV in agricultural uses is eligible for grants through the Forschungs- und Entwicklungsvorhaben im Agrarbereich für Umweltschutz. Schools can get a fixed grant of € 3,000 (3,600 USD) for PV installation through the federally administered Sun at School Program.

Germany EU Europäische Investitionsbank <i>regional development programs with an environmental focus</i> ALTENER <i>research of renewable energies in communal applications</i>
Federal Kreditanstalt fuer Wiederaufbau -Solarstrom Erzeugen <i>installation, expansion or sharing of a PV array.</i> European Recovery Program -Umwelt und Energiesparprogramm <i>installation of renewable energy systems</i> Vor-Ort-Beratung <i>on-site assessment by an energy professional for residential use of alternative energy technologies</i>

Table 9. Selected examples of financing options for German PV in the form of low-interest loans or grants. See Appendix II for a more complete listing.

In the US, financing options for federal and private PV systems are available through a handful of federal agencies as loans and grants. Energy Efficient Mortgages (EEM) promote residential energy efficiency measures and are intended to be used in addition to standard, preexisting mortgages. PV directed loans and mortgages, are offered through Fannie Mae and the Federal Home Mortgage Loan Co. among others. The US Department of Agriculture includes PV in the Renewable Energy Systems and Energy Efficiency Improvement Program. PV for small rural businesses and agricultural uses may apply for grants up to 25% of projected costs and are eligible for loans up to 50% of projected costs. The US Department of Housing and Urban Development offers mortgage, grant and lending programs for PV installation. The Environmental Protection Agency's Energy Star Program provides mortgages for the purchase of

homes equipped with PV. The Tribal Energy Grant Program offers technical assistance and financing as cost sharing for renewable energy installations on tribal lands.

Veterans, surviving spouses and retired service personnel can use the Veterans Housing Guaranteed and Insured Loans Program from the Department of Veteran Affairs to receive up loans up to \$6,000 for the installation of PV on their residences.

United States

Federal

Energy Efficient Mortgages

to be used in addition of preexisting mortgages for improvements in energy efficiency in residences

Department of Agriculture

-Renewable Energy Systems and Energy Efficiency Improvement Program

grants and loans available to rural small businesses and agricultural producers

Department of Energy

-Tribal Energy Grant Program

cost sharing and technical assistance for the installation on tribal lands

Environmental Protection Agency

-Energy Star Mortgages

For the purchase of homes with energy efficiency improvements

Table 10. Selected examples of funding for PV in the United States through federal grants and low-interest loans or mortgages.

The German federal government has provided an all-encompassing blanket of direct and indirect financing opportunities for PV that are easily accessible to public, private, and non-profit entities of all scales. American PV financing has yet to offer the same degree of availability and is only just starting to be available to residential customers in the last few years. American programs are also not as heavily marketed as German programs and therefore are not as actively sought after.

State and Municipal Level Incentives

The US federal government has done comparatively little to instigate clear, unified incentives nation-wide. In fact, the 2005 Energy Bill, the House of Representatives delegated the responsibility for PV demonstration to the states [55]. To fill the void left by the federal government, many states and regional authorities have chosen to promulgate their own “micro level” measures. In turn, substantially more incentive options for PV are available on the state and municipal level than apply nation-wide. Yet, like federal incentives, many of these incentives are highly selective in the amount of funding available, or if funding will be available at all depending on the application (i.e. arrays for residential, commercial and federal use).

The database for State Incentives for Renewable Energy lists 21 types of state-level incentives that may be applied toward PV that are categorized as either financial incentives or as rules, policies and regulations [53]. For further simplification, Gouchoe et al. categorizes state financial incentives into tax credit programs, buy downs, and loans [56].

State-level tax credit incentives can be performance-based, but tax credits are overwhelmingly capacity-based. In 2003, over 200 million USD in state tax credits were awarded to PV systems [23]. In 2004, 57 MWp of PV were installed as a result of state incentives and 23 MWp were installed in California alone [36]. Credits have historically applied to a person’s income, but investment-tax credits (ITC) are also available. ITCs work by directly reducing the purchaser’s federal liability by a percentage of the cost of the system. Again, tax credits have a limited reach and cannot be effectively applied to everyone.

Buy downs, or direct subsidies in the form of rebates and cash incentives, are used to stimulate early sales of PV arrays by creating greater customer appeal through large, upfront sums that significantly lower initial cost to the purchaser. Rebates are typically calculated on a Wp basis. In New York for example, a state-run PV stimulation program funded private PV suppliers, allowing them to offer 3 USD/Wp rebates up to 50% of the installed cost for PV systems [56]. Rebates on PV generated electricity from utility companies and funding received for PV projects and purchases are tax-exempt. Although buy downs help stimulate demand while manufacturing prices are still high, it can be argued that buy downs encourage neither improvements in performance nor a lowering of prices. If a large portion of the cost of a system is paid for out of someone else's pocket, PV purchasers will be less likely to seek out the manufacturer who offers modules with lowest price or highest efficiency.

Renewable Electricity Standards (RES) or Renewable Portfolio Standards are in effect in 21 states and Washington DC and although the Senate approved a national RES in the 2002 Energy Bill, the RES did not make it past the House of Representatives [46] [57].

In 2004, over 300 utilities offered green pricing options [58]. Green pricing allows utility customers to pay a premium on their normal utility bill, guaranteeing that PV or other renewables produce part of their energy mix. Utility customers can also buy "shares" of PV capacity. Although green pricing is a step in the right direction, these pricings alone are insufficient to create broad market shares for PV, and multiple market-based incentives are needed [59].

Utilities in over 35 states currently offer feed-in tariffs, or net metering as they are

referred to in the US [57]. Net-metering rates for surplus renewable energy are commonly set at the retail rate for electricity and are often credited to the customer's next bill [60].

Market conditioning for PV is also being undertaken on the micro level. The Solar Pioneer Program, initiated in 1999 by the Sacramento municipal utility district in California, is a flagship program for municipal level PV activity. Now in its second stage of offering subsidized grid-connected PV systems, residential customers can get 3 USD/Wp up to 15,000 USD per installation paid to certified contractors and 2 USD/Wp for businesses [61]. Over 10 MWp of installed PV have resulted from this program [21].

United States	
State, Regional and Municipal	
<i>Capacity-Based</i>	<i>Production-Based</i>
–state tax credits	–state tax credits
–buy downs	–net metering/feed-in tariffs
–grants	–renewable energy/ portfolio standards (RES)
–low-interest loans	–green pricing

Table 11. Incentive strategies used in the United States by state, regional and municipal governments for PV market conditioning

Apart from the Federal Government, German citizens interested in PV can still access incentives offered on the state, multi-state and regional levels. One program, the Investitionszulagengesetz, promotes PV installation in the “new” German states, i.e. states in the former East Germany. Due to the great success enjoyed by nation-wide PV programs, incentive options offered by the 16 federal states have begun to dwindle. Many programs are allowed to expire while more recent programs are effective for only one to two years. Since the federal government already has a sufficient feed-in tariff in

place, much state-level financing comes in the form of long-term, low- interest loans and grants. These programs support PV through incentives aimed either explicitly at the installation of renewable energy technologies or more indirectly by sponsoring building renovations to enhance energy efficiency or projects focused on creating new jobs in the environmental arena.

Just as the KfW administers many nation-wide incentives, state run banks such as the Landeskreditbank in Baden-Württemberg, administer the majority of state-offered PV funding. As part of the Landeskreditbank's Umweltschutz und Energiesparprogramm, potential PV purchasers can apply for low interest loans lasting from 2 to 20 years with no upper limit on the face value of the loan [62]. This program and others like it in Baden-Württemberg are overwhelmingly geared towards small and mid-sized businesses. Residential PV use is promoted through renovation and restoration measures that are undertaken to decrease the energy consumption of apartment buildings and that raise the value of the building through increased energy efficiency like the Modernisierung/ Instandsetzung Programm of Brandenburg's Investitionsbank.

In Bavaria, regional development programs such as LEADER+, are an indirect source of PV funding. Creative pilot projects undertaken primarily to stimulate the local economy play a two-fold purpose in supporting PV as projects centered around environmental problem solving are eligible for grants of up to 50% of investment costs [63].

Schools have also been a focus of PV funding. Through Saarland's Zukunftsenergieprogramm Technik, schools with grid-integrated PV arrays are eligible

for grants of 2,600 € (3,150 USD) [64]. Similar to the US Departments of Agriculture's Rural Developments Program, the Agrärinvestitionsförderprogramme provides low interest loans and grants in several states for PV arrays in agriculture. Financing is from 50,000 € (60,590 USD) to 1.25 million € (1.5 million USD) [65].

Germany	
State, Regional and Municipal	
<i>Capacity-based</i>	<i>Production-based</i>
–low-interest loans –grants	–feed-in tariffs

Table 12. State, regional and municipal level strategies for PV market conditioning in Germany

Literally hundreds of German municipalities and parishes offer PV incentive programs [54]. It should also be mentioned that feed-in tariffs do exist below the federal level. All grid-connected arrays within the Schönaauer utility district in Baden-Württemberg receive an additional 6 EUR ¢/kWh on top of the EEG tariff [66].

DISCUSSION

State of the Industry

The PV industry raises a nation's technological bar, stimulates the economy, and fosters the creation of thousands of high-paying jobs. The influence of PV on the expansion of the labor market is especially important in Germany where the unemployment rate is 12.1% [67]. In Germany, about 25,000 laborers were employed in PV related activities—an estimated 32 per MWp in 2004 [68] [43]. PV related employment in the US lagged behind, estimating that 20,000 positions had been created in the US or about 8/MW [18].

Germany is also particularly keen on PV activity because it is a critical piece in retaining and improving the German prowess in the solar energy market. Although the US PV industry and many Americans institutions lay similar claims to the benefits of a thriving PV industry, the current administration chooses to place more emphasis on the research and development of fuel cells, clean coal technologies and the more efficient use of other fossil fuel resources rather than on developing the solar energy industry to its full potential [23]. In fact, the American PV industry admitted that they have fallen inexcusably far behind Germany [18].

PV constitutes 1.6% of the Germany's renewable energy production and nearly 0.16% of Germany's entire energy mix [39]. In the US, PV comprises about 0.06% of America's energy mix and 1% of the renewable energy production [69]. PV has a much further way to go before it can become a major producer of both German and American energy, but Germany has a hefty head start on the US.

The estimated value of the US PV market in 2004 was 1.2 billion USD [36]. At the current rate, it is expected to grow at a rate of 25% per year [36]. Germany's market was worth over 2 billion USD and its growth rate is twice as high at greater than 50% [43] [68]. In 2005, the estimated value of the industry was about 3.6 billion USD [68].

	Germany	United States
Employment	25,000 =	20,000
% of renewable energy generation	1.6%	1%
Value (billion USD)	>2	1.2
Annual growth rate of the industry	50%	25%

= 2005 data

Table 13. 2004 statistics for the number of persons employed in PV related fields, percentage of renewable energy production from PV, value of the industry in billions of USD and the annual growth rate of the PV industry in US and Germany

As of 2004, the US had an installed PV capacity of 365 MWp, or 1.23 kWp per capita, 52% of which is grid-connected [36]. At the same time, Germany boasted 794 MWp of PV capacity, bringing their per capita total to 9.62 kWp [21]. By mid 2005 they had a solid 1.4 GWp of installed PV capacity producing 1 TWh of electricity that year [68]. An overwhelming 97% is grid-connected, due to EEG feed-in tariffs. In 2004 alone, 366 MWp of PV were installed. In that same year, the US installed only 90 MWp of new PV capacity[36]. PV installations in Germany represented 39% of the global total in 2004 [70]. Compare that to the US's share of only 9% [70]. An installed PV system less than 10 kWp cost 6.50 USD/ Wp on average in Germany, where as it can

2004		Germany	United States
Installed capacity (MWp)	total	794	365.2
	kWp/capita	9.62	1.23
	on-grid	768	175.6
	off-grid	26	189.6
	% global	31	14

Table 14. Statistics for 2004 installed PV capacity in the US and Germany cost anywhere from 7 to 10 USD/Wp in the US [36].

In 2004, Germany produced 198 MWp of PV and the US turned out 138 MWp [36]. Of the PV cells and modules shipped in the US in 2004 shipments, 43% went to satisfy the domestic demand and 57% was exported. Of all US PV exports, 41% was shipped to feed the German market alone [71]. Germany exports 20% of their PV production, which is an increase from 11% in 2000 [72][73].

		Germany	United States
Production (MWp)	total	198	138
	% global	18%	12%

Table 15. 2004 statistics for the production of PV technologies in the US and Germany in 2004

CONCLUSIONS

Room for Improvement

In Germany, the EEG has caused such a high demand for PV that consumers can expect to for wait weeks or up to a year for modules [74]. In fact, the PV demand in Germany is so intense that modules are being pulled off the market in the US and shipped over seas [50]. US consumers are forced to wait for modules because the draw from Germany is so strong.

It is not to say though, that Germany doesn't have problems of its own. Rapid industrial grow may taper off under political pressure and technological limitations. The heavy push for renewable energies has not been well received by conventional fossil fuel-based utility companies. Major utilities complain about the discriminatory government favoritism given to renewable energy producers who would otherwise not be able to survive the energy market alone [37]. Forced RESs and high feed-in tariffs paid out of annual utility profits under the EEG have made many utility corporations resentful [37]. Strong opposition to the EEG has been put forth by the coal industry and other fossil fuel industries complain about cross subsidizing, where levies collected from energy taxes are fed back into renewable energy programs. In 2004, the German Union and FDP political parties attempted to force a slackening of stringent EEG measures claiming that they were unobtainable and economically infeasible [75].

Another challenge threatening the German PV industry is its own rate of technological advance. Market-focused policies for PV deployment can be a disadvantage, as funding for research and development is averted to stimulate consumption. And while the European Union undertakes efforts to lower the transfer costs of renewable energy—a definitive benefit for PV—EU-wide energy network integration may make cheap wind energy from Britain more affordable than domestic solar energies at the same time.

The limitations of the American PV industry are much more elementary. Due to the lack of decisive action from the federal government, the US has no national PV standards to streamline PV installation and operation, no uniform nation-wide policy or procedures to smooth the connection of arrays into utility grids, and no quality benchmarks. This has led to a hodge-podge of policies and procedures that vary from state to state and even city to city. Lack of cooperation from utility companies and difficulties in acquiring interconnection has been a major deterrent in the effectiveness of many PV programs [56].

Some critics attribute the US's lack of initiative in implementing more substantial incentives such as those in Germany and other European nations to the large and influential fossil fuel industry and utility companies who fear competition from renewable energy sources. Since the US government presently doesn't see renewable energies as of great a priority it has yet to step in on behalf of the American consumers [50]. In the US, state and regionally promulgated PV policy and incentives drive the American industry, while the tremendous success of the German industry stems from nation-wide action.

Apart from the level in which incentives are offered, incentive strategies vary as well. In Germany, long-term production-based incentives reward PV *operators* while in the US up-front capacity-based incentives reward PV *purchasers*. Although the capacity-based incentive approach may be initially more gratifying for the purchaser and easier to administrate, such incentive types neither effectively promote the reduction of module costs nor the increase in conversion efficiency within the industry. Income- and investment-based tax credits are limited in the number of people that can successfully utilize their benefits, by the size of the purchaser's tax liability. Buy downs that fund a large portion of the up-front system costs, give purchasers little incentive to seek out manufacturers who have cut their production costs to offer modules at the lowest price or refined their technology to offer the highest efficiency. With tax-oriented incentives, only purchasers with a high tax liability will receive enough benefit from tax incentives to make an investment in PV worthwhile and they will receive the same amount of incentive regardless of if an array is installed for optimum performance or facing the ground. In short states' capacity-based incentives have a great potential for bias and result in more expensive, inefficient arrays operating at less than peak performance.

Germany's nation-wide feed-in tariff, laid out in the EEG, offers substantial financing to all PV operators tied into the grid. Since rewards are proportional to module performance, operators will gravitate towards modules with not only the best price, but also the greatest conversion efficiency proving them with a faster return on their investment. Operators will also take special care to install PV equipment for peak performance. Performance-based incentives get at the very heart of PV, generating environmentally benign energy so that conventionally generated electricity is displaced.

Currently, 35 US states have net metering laws and only 21 impose renewable portfolio standards; neither of these strategies are used on the national-level [57]. Industry recommendations to enact a nation-wide tax credit for both residential and commercial systems were finally met in August of 2005 [76]. For the US industry to reach Germany's level of commercialization, more market driven incentives that attack the PV issue from every angle, directly and indirectly are needed. Federal procurement, tax incentives, utility deregulation, pollution prevention, and research and development programs all present logical pathways that lead to the increased mobilization and development of the PV technology [18]. Actions must be advanced nation-wide over long, multi-year terms to ensure sustained market growth and include special allocations exclusively for PV in order to secure a favorable position among other renewable technologies [5]. Initial incentives must be sufficiently high to attract investment interest from consumers, but like Germany, the US could to eventually transition to a subsidy-free market, through incremental decreases in incentives.

Aside from incentive levels, the US faces other market problems in terms of the current PV infrastructure. PV demand can be greater than the support available in some areas. Adequately trained technicians, qualified installers and building inspectors do not always coincide with demand, often deterring would be purchasers [56].

Up until recently, solar energy has been considered a niche industry in the US, pursued predominantly by techies and serious conservationists, and in need of government muscle to overcome elementary market barriers. By realizing the benefits of PV and its immense potential in the US, the government could dramatically sink costs, by sponsoring programs to incite public demand, speeding PV along its learning

curve. Considering US federal government's consumption of more than 54 billion kWh of electricity per year, an increase in federal procurement of solar power procurement is another strategy to boost the industry by providing much needed demand [18].

So while the German Bundesregierung has gone to great lengths to create effective incentives to accelerate the reduction of system costs and the enlargement of the scales of production and use, the US federal government has been less active, choosing to wait until the price of raw PV technology dips down gradually over time to a level that can be afforded by the greater populous and complacent to leave action up to inferior regulators [43].

To step up the US involvement in the global PV sector, industry leaders have laid out a number of recommendations for government action:

- State and local advances in PV should be encouraged by enacting policies that reinforce existing deployment programs.
- Uniform net metering and interconnection standards will need to be enacted.
- 250 USD million should be invested in research annually over the next five years
- Stronger connections must be made between industry, universities and national renewable energy laboratories.
- Greater focus is needed in the research and development of technologies that increase efficiency and lower costs.
- Investments should also be made into architecture-based PV and energy storage technology

If followed, a doubling of system efficiency and an increase by more than 6 fold in the number of PV shipments and installations would result. This in turn would secure a 35% growth rate for the industry and lower the system selling costs to 3.68 USD/Wp propelling the US towards market leadership [18].

Germany's position as the #2 producer and #1 installer of PV proves Germany's major market barriers have already been negated, and the highly privatized industry proves that government support measures have been effective in fostering greater self sufficiency. Yet the Bundesregierung, working closely with industry leaders, is no less adamant about maintaining the "overheated" state of their market and becoming #1 in global PV production [31]. Progress in conversion efficiency and module production can still be made, the transfer of technology from research institutions to rooftops can always be quickened, and the price of PV can be driven down even further [77]. And even as suitable installation sites at home are becoming scarce and Germany is increasingly turning towards foreign markets, their intent on plastering even the tiniest roofs and the facades of domestic buildings with PV is not slackening.

The increasing necessity for clean and sustainable energy technologies has only accelerated the pace of the global race for market PV domination and technological mastery. Despite a moderate domestic solar resource Germany has not failed to recognize that more than 80 times more solar energy falls on the surface its land than it consumes daily and has moved itself to the forefront of the PV industry in just 10 years [79] [19].

An objective comparison of the US and Germany in terms of PV may be difficult, as each nation receives substantially different levels of incident radiation and has

differing patterns of energy usage. Yet these considerations make Germany's lead over the US in terms of PV installation capacity and production even more compelling.

Considering how more favorable solar conditions are in the US, as the US receives nearly double the amount of solar radiation/m² over a vastly greater area of land, Germany's accomplishments in PV appear all the more impressive. Ken Zweibel, a project manager at the US National Renewable Energy lab expresses this difference very clearly: "Germany has too little sunlight . . . but much more political will. We have the sunlight, but no will [79]."

Appendix I

Returned Questionnaires from American and Germany PV Distributors and Research
Institutions

Name	Address sent to	Date Sent	Date Returned
German Research Institutions			
Fraunhofer Institut	Heidenhof Straße 2, 79110 Freiburg	4/1/05	never
Solar Fabrik	Munzinger Straße 10, 79111 Freiburg	4/1/05	never
Biohaus PV Handels GmbH	Otto-Stadler-Straße, 33100 Paderborn	4/1/05	never
RWE SCHOTT Solar GmbH	Carl-Zeiss Straße, 63755 Alzenau	4/5/05	4/5/05
German Distributors		4/6/05	never
IBC Solar AG	Am Hochgericht 10, 96231 Bad Staffelstein	4/1/05	4/17/05
SolarMarkt GmbH	Sasbacher Straße 9, 79111 Freiburg	4/1/05	never
Solar World AG	Kurt-Schumacher Straße 12-14 53113 Bonn	4/2/05	never
American Distributors			
First Solar Electric	4050 E. Cotton Center #6-68, Phoenix AZ 85040	4/4/05	never
Energy Smart Systems	P.O. Box 794 Hillsboro, OR 97123	4/5/05	never
Southwest PV Systems Inc.	212 East Main Tomball, TX 77375	4/4/05	never
American Research Institutions			
The Chicago Center for Green Technology	445 North Sacramento Blvd. Chicago, Illinois 60612	4/4/05	never
Sandia National Laboratories	Solar Programs P.O. Box 5800 Albuquerque NM, 80301	4/1/05	never
National Renewable Energy Laboratory	1617 Cole Blvd. Golden, CO 80401-3393	11/15/05	11/17/05

Questionnaire for IBC Solar AG

1. Who is your main clientele or from what sector of society does your highest demand come from?

farmers, private investors,
institutional investors

2. Why do you think your clients invest in PV?

a) because of environmental
awareness

b) because PV generates extra
income (see German Ren. En
law)

3. How do your clients compare to Germany as a whole in respect to environmental awareness?

they are the leading people
in respect to environm.
questions / problems

4. How would you describe that state of German PV?

fairly good

5. Do you think the EEG are fair/feasible?

yes

6. How great of an impact do you believe the widespread use of PV could have on global climate change?

tremendous ! But it needs
a lot of time
actually for 2005 we predict
1,2 GW global production; that
is still nothing compared with
other electricity
production

7. Additional comments:

What is the aim of
the study?

Best regards

Wolfgang

Questionnaire for Biohaus PV Handels GmbH

1. Do you think that the German government is doing too much or not enough to support PV? How should this be changed?

The actual government is supporting PV in a good way.

2. What do you think the overall opinion of the German people with respect to PV (or renewable energy) is?

PV is very well seen in the eyes of the majority.

3. Do you believe the EEG are fair/feasible? Why or why not?

the EEG conditions for PV are okay in general.
There could be an higher insfeed tariff in low radiation areas.

4. What is your opinion of the American PV industry/market compared to that of Germany?

the american market needs
general infeed tariffs like EEG

5. How could the U.S. and German PV sectors learn from one and other?

better exchange of informations

6. How great of an impact do you believe the widespread use of PV could have on global climate change?

A very important impact;
because of the mental influence
to people

Additional Comments:

Would you like to remain anonymous?

Yes

Questionnaire for the National Renewable Energy Laboratory

1. Where does the funding for your research come from and what is the predominant driving force behind the work being done at your institution?

DOE.

Development and commercial success of PV technologies to meet energy significance.

2. What do you think is impeding the spread or wide spread use of PV in the U.S.?

Disinterest in energy and climate change issues; ignorance of PV as an alternative.

3. What do you think needs to be done to change this and who should do it?

The elected officials should change their views on these subjects and be more proactive about them.

4. What is your opinion of U.S. PV and renewable energy policies?

US does not have a renewables strategy – it acts only reactively and in default modes. It does not know it needs renewables.

5. The German government passed a resolution stating that by 2020, 20% of its energy needs will be met by renewable sources and 50% by 2050. Do you think this could be feasible in the U.S.? How large of a roll could PV play in this scenario?

Yes, it's feasible with public will. Without storage, PV could be 20% of our electricity; with smarter storage and transportation infrastructure, PV could be 50% by 2050. But this latter is a much harder policy and technical problem.

6. What do you know about the German PV sector, and how does it compare to that of the U.S.?

A lot. Germany has much too little sunlight to be a PV leader; but much more political will. We have the sunlight, but no will.

7. How great of an impact do you believe the widespread use of PV could have on global climate change?

PV could be a small part (10%) or a large part (over 50%. Maybe 80%) of the solution, depending on how inexpensive it can be made; and on the infrastructure support for it – storage, transmission, transportation using fuels or electricity.

8. Additional comments:

All this is changing towards an avalanche of interest in PV and solar within the next 5 years.

Appendix II

Listing of Federal PV Financing and Incentive Measures

US

Program Name	Incentive Type	Application	Notes
Business Energy Tax Credit	Tax Credit	Commercial/ Industrial	10-30% of installation and purchase expenditures
Energy Efficient Mortgage	Federal Loan Program	Residential	government insured mortgage applied atop existing mortgage
Energy Star Financing and Mortgages	Federal Loan Program	Residential Commercial Schools Government Utility	to be used in addition to preexisting mortgages
Modified Accelerated Cost-Recovery System	Corporate Depreciation	Commercial/ Industrial	5 yrs
Renewable Energy Production Incentive (REPI)	Feed-in tariff	State/local government	1.9¢/kWh for 10 yrs as funding is available
Renewable Energy Systems and Tribal Energy Efficiency Improvements Program	Grants	Commercial Agricultural	grants for 25% project cost up to \$500,000
	Low-interest loans	Commercial Agricultural	Low-interest loans 50% project cost up to \$10 million
Residential Conservation Subsidy Exclusion (Personal)	Tax Exemption Utility Rebate	Residential	
Residential Conservation Subsidy Exclusion (Corporate)	Tax Exemption	Residential	100% of subsidy
Residential Solar and Fuel Cell Tax Credit	Tax Credit	Residential	30% up to \$2,000
Tribal Energy Program Grant	Grants	Tribal	varies
Veterans Housing Guaranteed and Insured Low-interest loans	Federal Loan Program	Residential	Guarantees 50% for loans up to \$45,000 or \$3,000-\$6,000

Germany
EU

ALTNER	Grants	many	for community-based renewable energy research and projects
Nachhaltige Energiesysteme im Rahmen des 6. Forschungsprogramms	Grants	Commercial/ Industrial	large-scale research and deployment
Europäisches Investitionsbank	Loans and Grants	Public/Private	research projects for mitigating air pollution
Erneuerbare Energien Gesetz	Feed-in Tariff	all grid connected arrays	40.6-56.8 €/kWh dependant on systems size and application. Guaranteed for 20 years
Kreditanstalt für Wiederaufbau (KfW)			
1) Solarstrom Erzeugen	Low-interest loans	Residential Commercial Business Agricultural	0% interest for first 2 years of 10 year term. After that 3.98% interest. Maximum amount of 50,000 €
2) CO2-Gebäudesanierungsprogramm	Low-interest loans	Residential	20 year term, no interest for the first 3. After that 1.6 % interest or 30 year term, no interest for the first 5 years and then 1.9% interest
3) Infrastrukturprogramme	Low-interest loans	Community projects	up to 50% of investment costs for a maximum of 30 years
Schönauer Sonnencent-Investstrom Bundesweit	Feed-in tariff	EWS electric customers	additional 6 €/kWh added to other tariffs
Energiesparberatung vor Ort	Grant	residential	pays for advising from an energy efficiency or renewable energy consultant

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