

# Solar Power Prospects

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*The production of electricity from renewable energy technologies is growing much faster than the electric power supply as a whole, and solar power is among the fastest growing segments of the renewable energy market. Public policy concerns and economics are driving this growth. Some analysts and politicians believe that increasing solar power use will enhance U.S. national security by reducing dependence on imported energy — primarily oil from the Organization of Petroleum Exporting Countries (OPEC) and Russia.*



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## Executive Summary

The production of electricity from renewable energy technologies is growing much faster than the electric power supply as a whole. Solar power is among the fastest growing segments of the renewable energy market. Centralized solar power is produced on large farms and fed into an electrical grid — a network of wires and transformers that allows electricity produced by multiple sources to be transported to industrial, commercial and residential consumers. Globally, grid-connected solar capacity increased an average of 60 percent annually from 2004 to 2009, faster than any other energy source. Solar electricity production grew 15.5 percent in 2009 alone. Today, however, solar power still accounts for less than one-half of one percent of the world's electric power output.

Despite its impressive growth, and even with significant subsidies, solar power is substantially more expensive than conventional power sources in most locations. This is true of solar thermal systems that use lenses or mirrors and tracking systems to focus sunlight into a small beam to heat a fluid that turns steam-powered turbines. It is also true of solar photovoltaic power, in which panels or modules of cells fabricated from semiconducting materials generate electrical power by converting solar radiation into direct-current electricity. This study focuses on solar photovoltaic (“solar”), the more mature, more widespread and historically easier to build form of solar generation.

Analysts agree that if solar is to become a significant power source, it must compete with other energy sources — in markets without subsidies to any form of energy, barriers to the entry of new producers or discriminatory price regulations. When the price at which customers in a particular area can purchase electricity generated by solar power is about the same as the average price of electricity generated by conventional sources, it is said to have reached grid parity.

**U.S. Energy Subsidies Are Substantial.** In the United States, federal energy subsidies have amounted to hundreds of billions of dollars. Refined coal receives more subsidies than any other single energy source. According to a 2008 Energy Information Administration (EIA) report:

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- Federal subsidies to all energy sources topped \$16.6 billion in 2007 alone, more than double the \$8.2 billion spent in 1999.
- Nonrenewable energy sources, including fossil fuels and nuclear power, received the majority of subsidies — slightly more than \$6.7 billion.
- By comparison, renewable fuels including solar, hydroelectric, wind, biofuels and geothermal, received \$4.8 billion.

In addition, some states have subsidies and mandates for renewable energy. Currently, subsidized solar energy costs between \$0.22 per kilowatt-hour and \$0.30 per kilowatt-hour, according to independent analyses. By contrast, the average cost of electricity nationwide is expected to remain roughly \$0.11 per kilowatt-hour through 2015, according to an August 2010 White House report.

### Solar Power Has Reached Parity in Some Areas.

The price point for grid parity varies by location, due to such factors as the amount of sunlight an area receives, the orientation of the solar array, whether the solar arrays are fixed or track the sun, construction costs, rate structure and financing options. As a result, according to the National Renewable Energy Laboratory, breakeven costs vary by more than a factor of 10 in the United States. Thus:

- Solar power has already reached grid parity in Hawaii, where the average price for electricity was \$0.25 per kilowatt-hour in 2010 — with the average residential price topping \$0.28 per kilowatt-hour.
- In some parts of the country, solar may approach grid parity soon.
- In other locations, such as Arizona, that have abundant sunlight but limited transmission access and low electricity prices, solar is not competitive.

**Solar Power Must Be Profitable in Order to Compete.** Most analysts agree that solar will reach grid parity in a wide range of locations if the price for solar panels falls toward \$1 per watt. Indeed, at \$1.50 per watt, solar might be competitive with conventional generation sources in locations with a combination of high average electric costs and/or good average sunlight — producing power at \$0.10 to \$0.15 per kilowatt-hour.

An online calculator called PVWatts, developed by the National Renewable Energy Laboratory, can be used

to determine the dollar value of the energy that could be produced in a city, based on current average electric prices in that state. Other factors, such as the derate — the percentage of a cell's rated output capacity that it will actually produce — can also be input. The result is a measure of the revenue potential of the installation.

Using the PVWatts calculator, at what price might solar become profitable? For example, take a 1,000 kilowatt system, with construction and installation financed at a 6.25 percent interest rate. The cost of the project would depend on the price of solar panels. At an installed cost of \$3.90 per watt, the project would cost \$3.9 million. At \$2.50 per watt, the project would cost \$2.5 million. At \$1.50 per watt, the project would cost \$1.5 million. Using three different prices for the solar cell modules in a selection of 13 U.S. cities:

- At a cost of \$3.90 per watt, only Hawaii generates enough income to cover its annual loan payments.
- At \$2.50 per watt and the higher 0.825 derate factor, San Diego also barely covers its note.

By contrast, when solar panels reach \$1.50 per watt, seven of the cities examined generate enough income to cover their financing even at the lower derate factor; as the derate factor improves, eight cities can cover their loan payments.

These scenarios are consistent with projections of future energy costs by the International Energy Agency (IEA) in 2010. The IEA concluded that:

- Over the next decade, with continued government support, solar power prices will decline sufficiently to compete with conventional electric retail prices in a “few” countries by 2015 and “several” countries by 2020.
- The IEA projects that the cost of solar electricity in 2020 will range from \$0.13 to \$0.26 per kilowatt-hour for commercially produced solar power and \$0.16 to \$0.31 for electricity produced by residential systems.
- If the IEA's estimates are correct, the price of solar power will still be higher than the cost of conventionally produced electricity in 2020.

With major technological breakthroughs that significantly reduce the cost of solar power production and the imposition of new environmental mandates that raise the price of electricity generated by other sources, solar could reach grid parity in some areas of the United States by the end of the decade.

## Introduction

The production of electricity from renewable energy technologies is growing much faster than the electric power supply as a whole, and solar power is among the fastest growing segments of the renewable energy market. Public policy concerns and economics are driving this growth. Some analysts and politicians believe that increasing solar power use will enhance U.S. national security by reducing dependence on imported energy — primarily oil from the Organization of Petroleum Exporting Countries (OPEC) and Russia. Environmentalists argue that solar power will improve air quality by reducing the use of fossil fuels — primarily coal — for electric power production. They claim this would reduce emissions of a variety of air pollutants, including greenhouse gases.

These concerns have led to favorable tax treatment, price supports and direct subsidies for renewable energy by both federal and state governments. Some states have implemented mandates — called renewable portfolio standards — for production and/or use of electricity from renewables. Tens of billions of dollars in public spending and renewable energy mandates have encouraged private investment in solar power. Indeed, in the United States, solar electricity production grew 55 percent from 2004 to 2008, and 15.5 percent in 2009 alone.<sup>1</sup> Today, however, solar power still accounts for less than one-half of one percent of U.S. electric power output. Public and private investment has encouraged innovation and increased production

efficiency, reducing the cost of solar panels considerably.

However, in most locations solar is still substantially more expensive than conventional power sources. Analysts agree that if solar is to become a significant power source, it must compete with other energy sources — in markets without subsidies to any form of energy, barriers to the entry of new producers or discriminatory price regulations. When the price at which customers in a particular area can purchase electricity generated by solar power is about the same as the average price of electricity generated by conventional sources, it is said to have reached grid parity.

*“Solar power has grown rapidly, but still accounts for less than one-half of 1 percent of U.S. electricity output.”*

It is important to compare the projected cost of solar power from new installations with power generated from new conventional power plants rather than existing conventional plants. Power generators already in operation represent sunk costs, and the capital costs to build those plants have been partially or completely amortized. Since new solar power plants will compete with other renewable energy sources, new fossil fuel plants and new nuclear facilities, the costs of new power plants should be compared. In this

study, the price of electricity from newly constructed solar facilities will be compared with prices from other new generating sources.

This study will also consider: What would be necessary for solar power to compete as a significant energy source with other new sources of electric power? When is widespread parity likely? When will the annualized cost of solar power be competitive with other sources of electric power over the life of the generation facility?

In Hawaii, for example, due to favorable climatic conditions and high energy costs, solar power, with present subsidies, is already cost competitive with electricity from other sources. In other areas with a combination of consistently sunny days and high energy costs, solar power could become cost competitive as additional power to the grid by, say, late in this decade. However, analysis of the available evidence indicates that unless the substantial subsidies recently available in the United States and in Europe are continued, widespread grid parity for solar power is a decade or more away.

Note that regulations that affect the costs and viability of energy production are in constant flux. Some environmental regulations — such as increasingly stringent air pollution limits, for example — will raise the costs of fossil fuels, especially in comparison to solar and other energy sources. Other regulations might never be implemented. Thus, in this study, it is assumed that current laws and standards will continue. It is on that basis that the future price of electricity generated by fossil fuel

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and nuclear powered plants will be compared with solar power.

### Solar Power Output, Technology and Efficiency

Earth receives more energy from the sun in one hour than the amount of energy the world uses in one year. The amount of solar energy reaching the surface of the planet in one year is about twice as much as will ever be obtained from all of Earth's nonrenewable resources of coal, oil, natural gas and mined uranium combined.<sup>2</sup> Even under the best circumstances, only a small part of this energy would be available for solar power use, because much of it is naturally consumed by plant photosynthesis. But this small amount could, in theory, be transformed into a significant amount of electricity.

**Solar Power Output.** Solar power includes both centralized and decentralized solar power sources and different technologies for generating power (which includes electricity and heat). Centralized solar power is produced on large farms and fed into an electrical grid — a network of wires and transformers that allows electricity produced by multiple sources to be transported to industrial, commercial and residential consumers. Globally, solar-powered electricity production has grown in recent years:

- Solar power is a tiny fraction of the 4,800 gigawatt total global electricity generating capacity, but it is the fastest growing technology in the world.

- Between 2004 and 2009, grid-connected solar capacity increased an average of 60 percent annually, to some 21 gigawatts (21 billion watts — or units of electric power).<sup>3</sup>
- As of 2010, solar power generated electricity in more than 100 countries.

This paper focuses on centralized solar power production. Off-grid photovoltaic, such as rooftop panels that generate power for on-site consumption, accounts for an additional 3 to 4 gigawatts.

*“Earth receives more energy from the sun in one hour than the amount the world uses in one year.”*

**Thermal versus Photovoltaic Solar.** Two main types of solar power are used to produce electricity. Thermal solar power systems generally use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam to heat a fluid that turns steam-powered turbines.<sup>4</sup> The most familiar solar technology, however, is solar photovoltaic technology used to produce electricity in calculators, yard lights and rooftop panels. Solar panels consist of a number of cells fabricated from semiconducting materials that generate electrical power by converting solar radiation into direct-current electricity.<sup>5</sup>

Solar photovoltaic is a more mature technology, easier to build and in much wider use. Most recent solar power installations are solar photovoltaic. Thus, unless otherwise noted, in this study “solar” refers to solar photovoltaic.

**Solar Cell Technology.** There are two main types of solar photovoltaic technologies: silicon wafer and thin film. Silicon wafer technology is the one used in most solar power plants. Indeed, silicon wafer makes up 82 percent of the installed solar market.<sup>6</sup> Thin film is less expensive, and accounts for a growing share of the market. Sales of thin film are growing 50 percent per year, while silicon wafer solar is growing approximately 30 percent per year. This paper focuses on common silicon wafer panels or modules, rather than thin film technologies, because silicon wafers convert sunlight to electricity more efficiently and therefore will likely continue to dominate the market:

- Silicon wafer technologies convert 13 percent to 20 percent of the sunlight hitting them into electricity whereas thin film technologies often convert just 4 percent.<sup>7</sup>
- Under artificial laboratory conditions, research scientists have produced 41 percent conditions from certain types of layered solar cells, but such advances will not be available commercially for years.
- Absent a significant technological breakthrough, the inherent physical characteristics of crystal silicon mean that energy conversion will top out at 30 percent.<sup>8</sup>

Solar cells last 20 to 25 years; however, even if solar panels are cleaned periodically to maintain peak efficiency, output declines by approximately 0.5 percent per year. Thus, after 20 years they will only produce 80 percent of their rated capacity. Less efficient cells may cost less per module, but are not necessarily less expensive to use because more have to be installed to get the same amount of energy.

## Energy Subsidies

Fossil fuels, nuclear and renewable energy sources — including solar power — are subsidized worldwide. Government subsidies tend to encourage increased investment in production and/or reduce the cost of a good or service to consumers. The cost of subsidies are less visible than the lower prices paid by consumers. They include costs to taxpayers and market distortions, which tend to protect less efficient technologies and reduce or undermine innovation.

### Global Energy Subsidies.

Globally, fossil fuels are the most heavily subsidized energy source:

- Developing countries annually spend \$220 billion on subsidies for all forms of energy, of which more than \$170 billion is spent on fossil fuel subsidies, according to International Energy Administration (IEA) estimates.<sup>9</sup>
- Worldwide energy subsidies topped \$490 billion in 2007 — of which more than \$400 billion were fossil fuel subsidies in developing countries and mostly through

price ceilings on oil and gas consumed in countries like Bolivia, Venezuela and Iran — according to the Global Subsidies Initiative, a collaborative effort of the environmentalist Institute for Sustainable Development and the Earth Council.<sup>10</sup>

- Subsidies in developed countries have shifted from fossil fuels and nuclear power toward renewable energy sources in recent years — U.S. subsidies to renewables, for example, grew from 17 percent of total energy subsidies in 1999 to 29 percent in 2007.<sup>11</sup>
- More recently, from 2008 to 2009, renewable energy subsidies increased from approximately \$46 billion worldwide to more than \$57 billion.<sup>12</sup>

**U.S. Energy Subsidies.** In the United States, federal energy subsidies have amounted to hundreds of billions of dollars. According to a 2008 Energy Information Administration (EIA) report:<sup>13</sup>

- Federal subsidies to all energy sources topped \$16.6 billion in 2007 alone, more than double the \$8.2 billion spent in 1999.
- Nonrenewable energy sources, including fossil fuels and nuclear power, received the majority of subsidies — slightly more than \$6.7 billion.
- By comparison, renewable fuels including solar, hydroelectric, wind, biofuels and geothermal, received \$4.8 billion.

Most federal energy subsidies (\$10.4 billion) are tax expenditures (tax credits and other preferences) rather than direct expenditures.<sup>14</sup>

Refined coal receives more subsidies than any other single energy source — mostly tax credits for research and development of so-called clean coal, carbon-capture and storage technologies, and synthetic fuels from coal to improve air quality, lower carbon emissions or reduce energy dependence. Renewable energy is the second most subsidized energy type, and receives more subsidies than all the other (noncoal) fossil fuels and nuclear power combined.

The installed base of solar and other renewables is small compared to fossil fuels. As a result, measured by the energy delivered per dollar of subsidy, solar is among the most highly subsidized power sources. According to the EIA:

- Natural gas and petroleum subsidies amount to \$0.25 per megawatt-hour of electricity produced.
- Coal subsidies amount to \$0.44 per megawatt-hour.
- Biomass (including biofuels) subsidies amount to \$0.89 per megawatt-hour.<sup>15</sup>

*“Refined coal receives more federal subsidies than any other single energy source.”*

By contrast:

- Nuclear power subsidies amount to \$1.59 per megawatt-hour of electricity produced.

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- Wind subsidies amount to \$23.37 per megawatt-hour.
- Solar subsidies amount to \$24.34 per megawatt-hour.<sup>16</sup>

**State Subsidies and Indirect Subsidies.** A majority of states and many localities subsidize various forms of renewable energy production. These subsidies include state grants, tax incentives, electricity purchase provisions, and rebates or property tax deductions for home photovoltaic installations.

*State Renewable Portfolio Standards.* State renewable portfolio standards have proliferated since the 1990s and, along with federal subsidies, have become the key driver of U.S. renewable energy growth. By 2008, 25 states and the District of Columbia had mandatory renewable power standards for electricity providers, and four more states had nonbinding goals.<sup>17</sup> The standards vary, but generally require retail electric suppliers to provide a minimum quantity or percentage of electric power from renewable resources. In many states, requirements increase over time.

Renewable portfolio standards are, in one sense, more powerful than subsidies. Subsidies only encourage utilities, firms and individuals to adopt, develop or use renewable power, but portfolio standards require electric suppliers to purchase (and thus consumers to pay for) renewable, regardless of the cost. This strategy appears to be working:

- Over 50 percent of the nonhydro renewable capacity added in the United States from 1998 through 2007

was in states with mandatory renewable portfolio standards.

- Since 2002, 60 percent of the renewable additions have been in states with mandatory standards.
- In 2007 alone, approximately 76 percent of all nonhydro renewable capacity additions were in states with these programs.<sup>18</sup>

In order to diversify supplies, states are increasingly encouraging or requiring utilities to meet a portion of their portfolio standard through renewable technologies or applications that are often more costly. This support includes credit multipliers, which give favored renewables more credit toward the requirements than other technologies, and specific set-asides, in which some fraction of the portfolio must be met with favored technologies.

*“State portfolio standards and federal subsidies are key drivers of renewable energy growth.”*

Both centrally generated and distributed (residential) solar generation have especially benefited from such set-asides. Indeed, 12 of the 26 U.S. renewable portfolio standard programs have set-asides for solar power, and four of these states combine set-asides with some form of credit multipliers.

*Long-Distance Transmission Lines.* Locations for centralized photovoltaic solar farms are somewhat limited. They require much more land than conventional electric power plants to produce the same amount of electricity. The land must be relatively inexpensive since it is an additional cost. In addition, solar farms must be in sunny areas, and they receive more energy closer to the tropic zones. Though solar panels generate some power on overcast days, too much rain or too many cloudy days reduce the amount of power generated below the level needed to cover costs and increases the variability of the power supplied.<sup>19</sup> Thus, solar farms are usually located hundreds or even thousands of miles from the cities and suburbs where the power is consumed.

The cost of high-voltage power lines to carry power long distances tops \$1.5 million per mile, assuming flat, rural terrain.<sup>20</sup> Obtaining permits and rights of way increases the cost. In addition, if the terrain is hilly, mountainous or forested, the cost can rise to 1.2 to 1.5 times the average cost.<sup>21</sup> Power lines have to be built at least to the nearest main transmission line, which may have to be upgraded to handle the additional flow and to regulate the variability of solar power. For example, thousands of miles of new power line would have to be constructed at a cost of tens of billions of dollars to deliver power from Midwest solar farms to East and West coast cities.

Renewables benefit from subsidies for the construction of new transmission lines and associated infrastructure.

Traditionally, public or private utilities built the transmission lines serving a particular area and passed on the cost to customers. However, at the behest of the renewable power industry and with the support of the Obama administration, the Federal Energy Regulatory Commission (FERC) has drafted a rule that could basically nationalize transmission infrastructure development costs by requiring either taxpayers or electric power consumers to pay for new transmission lines to bring remote wind and solar power to the national grid.<sup>22</sup>

Governors throughout the country object to the plan. A joint letter from the governors of Arizona, Nevada, Washington, Oregon and California says that it would be “inappropriate to assess the cost of transmission build-out to customers that cannot make use of the facilities, or who elect not to because they can access more cost effective options that do not rely on large, new transmission investments to meet environmental goals.”<sup>23</sup>

*Stabilizing Power.* Renewables also benefit from the availability of on-demand stabilizing and fill-in power from other sources. Fossil fuel or nuclear-powered generating plants run as spinning reserve at less than peak efficiency in order to be brought on-line if the variable flow from a solar farm falls precipitously over a short period of time. Some portion of these plants’ cost should be counted against the solar facility since they make it possible.

However, at locations where solar is ideal or nearly ideal, the larger the array, the less problem there is with power spikes or significant,

extended losses of power. Passing clouds only affect a few panels or small portions of the full array at a time. Even on days with little wind, if clouds are sporadic, large solar arrays produce near rated capacity.<sup>24</sup>

*“The Obama administration predicts electricity from solar power will be price competitive by 2015.”*

## When Will Solar Power Reach Grid Parity?

A common theme in many of President Obama’s speeches is that government subsidies will make a variety of “clean” energy technologies cost competitive. An August 2010 White House report singled out solar power produced by rooftop residential installations. In 2009, electricity produced by such systems cost the equivalent of more than \$0.21 per kilowatt-hour (including installation but not maintenance costs), whereas the average retail price of electricity nationwide was \$0.11 per kilowatt-hour.<sup>25</sup> However, the report predicts the average cost of residential solar will fall to \$0.10 per kilowatt-hour by 2015, while the average cost of electricity nationwide will remain roughly \$0.11 per kilowatt-hour. This would be grid parity. Other administration studies make similar claims for commercially produced solar power. Similar predictions

have been made in the past. [See the sidebar, “Solar Power: Promises and Subsidies.”] When are these more recent predictions likely to come true?

Currently, subsidized solar energy costs between \$0.22 per kilowatt-hour and \$0.30 per kilowatt-hour, according to independent analyses.<sup>33</sup> Projections of future energy costs by the International Energy Agency (IEA) in 2010 indicate that:

- Over the next decade, with continued government support, solar power prices will decline sufficiently to compete with conventional electric retail prices in a “few” countries by 2015 and “several” countries by 2020.
- The IEA projects that the cost of solar electricity in 2020 will range from \$0.13 to \$0.26 per kilowatt-hour for commercially produced solar power and \$0.16 to \$0.31 for electricity produced by residential systems.
- If the IEA’s estimates are correct, the price of solar power will still be higher than the cost of conventionally produced electricity, and thus solar will not reach grid parity in much of the United States by 2020.

However, the price point for grid parity varies by location, due to such factors as the amount of sunlight an area receives, the orientation of the solar array, whether the solar arrays are fixed or track the sun, construction costs, rate structure and financing options. As a result, according to the National Renewable Energy

### Solar Power: Promises and Subsidies

Harnessing sunlight for heating and other power purposes is not new. Solar collection devices were developed in the 17th century to protect plants brought from the tropics to northern countries, and both the first solar water heater and the first solar oven were developed the 18th century. Indeed, the solar power revolution has been on the verge of taking off for centuries.<sup>26</sup>

In response to the Arab Oil Embargo, in part, the relatively new U.S. Department of Energy (along with other agencies) began a slew of programs to fund solar energy research, deployment and commercialization. Based strictly on performance, these programs have failed at the cost of billions of dollars of taxpayers' money.

No one has ever lost money betting against the predictions that widespread, cost-competitive solar power was just "a few years" away.<sup>27</sup> The hyping of solar power's near-term potential as a source of electricity increased exponentially with the advent of large government grants and subsidies for solar power research in the 1970s. In 1976, for example, noted environmental author Barry Commoner stated that mixed solar/conventional installations could become the most economical alternative in most parts of the United States within the next few years.<sup>28</sup> In 1987 the head of the Solar Energy Industries Association stated: "I think frankly, the...consensus as far as I can see is after the year 2000, somewhere between 10 and 20 percent of our energy could come from solar technologies, quite easily."<sup>29</sup>

Why haven't these and other similar predictions come true? The answer of many advocates has been simple: inadequate government support.

A 1983 study by the Booz Allen Hamilton consulting firm for the Solar Energy Industries Association, the American Wind Energy Association and the Renewable Energy Institute found that solar and wind technologies would become competitive and self-supporting by the end of the 1980s, if "assisted by tax credits and augmented by federally sponsored R&D [research and development]."<sup>30</sup> Just three years later, long-time green energy booster Amory Lovins, of the Rocky Mountain Institute, decried what became a temporary scaling back of tax breaks for renewable energy, since the competitive viability of wind and solar technologies was "one to three years away."<sup>31</sup> And in 1990, with sufficient government support, the Worldwatch Institute predicted an *almost complete displacement* of fossil fuels for the electric power generation market by approximately 2010.<sup>32</sup>

It seems hardly fair, however, to claim that solar power has failed to reach widespread commercialization in the marketplace due to lack of subsidies since, by some measures, solar power is one of the most highly subsidized power sources on Earth.

Laboratory, breakeven costs vary by more than a factor of 10 in the United States.<sup>34</sup> Thus:

- Solar power has already reached grid parity in Hawaii, where the average price for electricity was \$0.25 per kilowatt-hour in 2010 — with the average residential price topping \$0.28 per kilowatt-hour.
- In some parts of the country, solar may approach grid parity soon.

In other locations, such as Arizona, that have abundant sunlight but limited transmission access and low electricity prices, solar is not competitive.<sup>35</sup>

### What Is the Breakeven Cost of Solar Power?

In order to determine whether a solar power plant is competitive in a particular area, one must determine if the electricity it produces can be sold at a profit, given average electric power prices in the region, the amount of power the plant could produce and capital costs (including interest) of construction.

**The Photovoltaic Watts Calculator.** An online calculator called PVWatts, developed by the National Renewable Energy Laboratory, allows nonexperts to quickly obtain performance estimates for grid-connected photovoltaic systems. The PVWatts calculator shows the dollar value of the energy that could be produced in a city, based on current average electric prices in that state. This is a



**TABLE I**  
**Hypothetical Solar Power Plant Revenue for Select Cities**

<u>City</u>	<u>Average State Price per Kilowatt Hour</u>	<u>At 0.77 Derate*</u>	<u>At 0.825 Derate*</u>
El Paso, Texas	9.36 ¢	\$155,097	\$166,285
Austin, Texas	9.36 ¢	\$127,528	\$136,849
Bridgeport, Conn.	17.42 ¢	\$208,172	\$223,533
Columbus, Ohio	9.13 ¢	\$102,665	\$110,254
San Diego, Calif.	13.97 ¢	\$209,339	\$224,528
Miami, Fla.	10.61 ¢	\$142,098	\$152,549
Nashville, Tenn.	8.66 ¢	\$110,636	\$118,763
Phoenix, Ariz.	9.78 ¢	\$158,138	\$169,522
Anchorage, Alaska	14.86 ¢	\$117,998	\$126,953
Honolulu, Hawaii	25.03 ¢	\$365,423	\$392,157
New York, N.Y.	16.37 ¢	\$199,459	\$214,172
Charleston, W. Va.	7.42 ¢	\$ 83,975	\$ 90,185
Rapid City, S.D.	7.78 ¢	\$109,547	\$117,543

\* The percentage of rated capacity a solar power plant is expected to produce.

Source: National Renewable Energy Laboratory, “PVWatts Calculator,” available at <http://www.nrel.gov/rredc/pvwatts/>, and author’s calculations.

measure of the revenue potential of the installation.

The calculator automatically adjusts for a number of variables, including the type of solar power system (fixed axis versus tracking), the average amount of sunlight in a particular area and the angle of the sun. Note, however, that the PVWatts calculations do not include the operating and maintenance costs of the systems (see additional considerations below).

**Solar Competition under Two Scenarios.** Following are two exercises using the PVWatts calculator, for a 1,000 kilowatt (1 megawatt) system using a fixed array at various locations, with a wide range of energy costs, and different geographic and climatic

conditions. The average cost of electricity for each state is the most recent estimate from the U.S. Department of Energy.

It is necessary to consider two scenarios to account for the fact that a solar cell will deliver less power than its rated capacity, due to such factors as dust and dirt, shade and power losses in the wiring. This “derate factor” is a percentage of the cell’s rated capacity. The first scenario uses PVWatts’ default derate factor of 0.77. The PVWatts derate factor is still commonly used, but it has not been updated since 2007. Some solar cell manufacturers now claim a 0.90 derate factor. The second scenario adjusts the PVWatts derate to 0.825, splitting the difference between manufacturers’ claims and

the old PVWatts factor. This derate also accounts for the fact that some solar farm developers might use higher rated (but more expensive) equipment, while others use less expensive, less efficient solar arrays. As Table I shows, the dollar value of the electricity produced by solar power varies dramatically by region and, more importantly, by the average price of electric power in a state:

- Due to high energy prices and favorable climatic conditions, a 1,000 kilowatt solar array in Hawaii delivers the highest dollar value of electricity in a year, ranging from \$365,423 to \$392,157.
- Low electric power prices and less available sunlight on average means that a

**TABLE II**  
**Annual Revenue Net of Capital Costs for a**  
**Solar Power Plant in Various Cities**  
 (Installed Capital Cost of \$3.90 per Watt)

<u>City</u>	<u>Annual Financing Cost*</u>	<u>0.77 Derate</u>	<u>0.825 Derate</u>
El Paso, Texas	\$348,928.20	-\$193,831.20	-\$182,643.20
Austin, Texas	\$348,928.20	-\$221,400.20	-\$212,079.20
Bridgeport, Conn.	\$348,928.20	-\$140,756.20	-\$125,395.20
Columbus, Ohio	\$348,928.20	-\$246,263.20	-\$238,674.20
San Diego, Calif.	\$348,928.20	-\$139,589.20	-\$124,400.20
Miami, Fla.	\$348,928.20	-\$206,830.20	-\$196,379.20
Nashville, Tenn.	\$348,928.20	-\$238,292.20	-\$230,165.20
Phoenix, Ariz.	\$348,928.20	-\$190,790.20	-\$179,406.20
Anchorage, Alaska	\$348,928.20	-\$230,930.20	-\$221,975.20
Honolulu, Hawaii	\$348,928.20	\$ 16,494.80	\$ 43,228.80
New York, N.Y.	\$348,928.20	-\$149,469.20	-\$134,756.20
Charleston, W. Va.	\$348,928.20	-\$264,953.20	-\$258,743.20
Rapid City, S.D.	\$348,928.20	-\$239,381.20	-\$231,385.20

\*Note: \$3,900,000 loan at 6.5 percent interest.

Source: National Renewable Energy Laboratory, "PVWatts Calculator," available at <http://www.nrel.gov/rredc/pvwatts/>, and author's calculations.

1,000 kilowatt array in West Virginia generates less than \$100,000 a year.

**Installed Cost per Watt.** The cost of new solar power plants fell and rose in recent years along with incentives, subsidies, mandates and other policies that encourage solar power use:

- For commercial solar, the installed cost of solar with incentives fell from \$5.50 per watt to \$3.60 per watt in 2006.
- By 2008 the installed cost rose to \$4.80 per watt as cash incentives and government subsidies declined.<sup>36</sup>
- Net of incentives, installed costs ranged from \$7.30 per watt to \$9.90 per watt in 2008.

The 2008 decline in incentives was reversed, and their value rose in 2009 and 2010.

The lower the price for solar materials, assembly and construction, the greater the net revenue at any electric power price point. Solar panels can make up nearly half the cost of solar systems. Over the past 15 years, the cost of solar photovoltaic systems fell an average of 4 percent per year, whereas the price of electric power has generally risen. In 2009 alone, prices for solar panels dropped approximately 40 percent, notes Navigant Consulting.<sup>37</sup> The most recent steep decline is due largely to the tremendous growth in China's solar panel production, which resulted in a glut in the market. This

shift in production of solar panels to China caused the cost per kilowatt-hour for solar cells to fall:<sup>38</sup>

- In 2009, the average installed cost of solar cells fell to \$3.90 per watt and in some cases nearly fell to \$2.33 per watt.
- The cost of solar photovoltaic-generated electricity in sunny locations would have been approximately \$0.22 to \$0.25 per kilowatt-hour in 2009, absent subsidies and incentives — well above the average residential price of electric power in most locations.

However, in 2009, as wages in China rose, and higher priced panel makers in the United States and

**TABLE III**  
**Annual Revenue Net of Capital Costs for a**  
**Solar Power Plant in Various Cities**  
 (Installed Capital Cost of \$2.50 per Watt)

<u>City</u>	<u>Annual Financing Cost*</u>	<u>0.77 Derate</u>	<u>0.825 Derate</u>
El Paso, Texas	\$223,671.96	-\$ 68,574.96	-\$ 57,386.96
Austin, Texas	\$223,671.96	-\$ 96,143.96	-\$ 86,822.96
Bridgeport, Conn.	\$223,671.96	-\$ 15,499.96	-\$ 138.96
Columbus, Ohio	\$223,671.96	-\$121,006.96	-\$113,417.96
San Diego, Calif.	\$223,671.96	-\$ 14,332.96	\$ 856.04
Miami, Fla.	\$223,671.96	-\$ 81,573.96	-\$ 71,122.96
Nashville, Tenn.	\$223,671.96	-\$113,035.96	-\$104,908.96
Phoenix, Ariz.	\$223,671.96	-\$ 65,533.96	-\$ 54,149.96
Anchorage, Alaska	\$223,671.96	-\$105,673.96	-\$ 96,718.96
Honolulu, Hawaii	\$223,671.96	\$141,751.04	\$168,485.04
New York, N.Y.	\$223,671.96	-\$ 24,212.96	-\$ 9,499.96
Charleston, W. Va.	\$223,671.96	-\$139,696.96	-\$133,486.96
Rapid City, S.D.	\$223,671.96	-\$114,124.96	-\$106,128.96

\*Note: \$2,500,000 loan at 6.5 percent interest.

Source: National Renewable Energy Laboratory, "PVWatts Calculator," available at <http://www.nrel.gov/rredc/pvwatts/>, and author's calculations.

abroad closed, the flood of low-cost panels ebbed. Thus, prices are likely to rise.

Most analysts agree that solar will reach grid parity in a wide range of locations if the price for panels falls toward \$1 per watt. Indeed, at \$1.50 per watt, solar might be competitive with conventional generation sources in locations with high average electric costs and/or good average sunlight — producing power at \$0.10 to \$0.15 per kilowatt-hour.<sup>39</sup> This is in the range of Obama administration estimates.<sup>40</sup>

**Assumed Interest Rate on Financing.** The profit point is significantly affected by changes in interest rates. If a solar farm

developer obtains financing that carries an interest rate higher or lower than the 6.25 percent rate used below, the price per watt at which solar power becomes profitable also changes. As discussed below, the cost of borrowing to finance large solar farms can be considerably higher than for other electric power developments. In addition, there is the uncertainty of continuing subsidies in the current fiscal situation. Indeed, some utilities are cancelling their contracts with solar developers.<sup>41</sup>

**Profitability under Different Installed Cost and Derate Assumptions.** In the same cities examined using PVWatts, at what price might solar become profit-

able? Take a 1,000 kilowatt system, with construction and installation financed at a 6.25 percent interest rate using three different prices for installed solar cell modules: the 2009 estimated average price of \$3.90 per watt, \$2.50 per watt and \$1.50 per watt. The results are shown in Tables II, III and IV.

- At a cost of \$3.90 per watt, only Hawaii generates enough income to cover its annual loan payments. [Table II.]
- At \$2.50 per watt and the higher 0.825 derate factor, San Diego also barely covers its note. [Table III.]
- By contrast, when solar panels reach \$1.50 per watt, seven of the cities examined generate

**TABLE IV**  
**Annual Revenue Net of Capital Costs for a**  
**Solar Power Plant in Various Cities**  
 (Installed Capital Cost of \$1.50 per Watt)

<b>City</b>	<b>Annual Financing Cost*</b>	<b>0.77 Derate</b>	<b>0.825 Derate</b>
El Paso, Texas	\$134,203.20	\$ 20,893.80	\$ 32,081.80
Austin, Texas	\$134,203.20	-\$ 6,675.20	\$ 2,645.80
Bridgeport, Conn.	\$134,203.20	\$ 73,968.80	\$ 89,329.80
Columbus, Ohio	\$134,203.20	-\$ 31,538.20	-\$ 23,949.20
San Diego, Calif.	\$134,203.20	\$ 75,135.80	\$ 90,324.80
Miami, Fla.	\$134,203.20	\$ 7,894.80	\$ 18,345.80
Nashville, Tenn.	\$134,203.20	-\$ 23,567.20	-\$ 15,440.20
Phoenix, Ariz.	\$134,203.20	\$ 23,934.80	\$ 35,318.80
Anchorage, Alaska	\$134,203.20	-\$ 16,205.20	-\$ 7,250.20
Honolulu, Hawaii	\$134,203.20	\$231,219.80	\$257,953.80
New York, N.Y.	\$134,203.20	\$ 65,255.80	\$ 79,968.80
Charleston, W. Va.	\$134,203.20	-\$ 50,228.20	-\$ 44,018.20
Rapid City, S.D.	\$134,203.20	-\$ 24,656.20	-\$ 16,660.20

\*Note: \$1,500,000 loan at 6.5 percent interest.

Source: National Renewable Energy Laboratory, "PVWatts Calculator," available at <http://www.nrel.gov/rredc/pvwatts/>, and author's calculations.

enough income to cover their financing even at the lower derate factor; as the derate factor improves, eight cities can cover their loan payments. [Table IV.]

Only in Hawaii, however, do the solar arrays deliver more than \$100,000 in value above their annual loan payment.

The preceding examples used the 2010 average price of electricity for the state of each city examined. Electric power prices fell in most of those locations from 2009 to 2010. But in almost all instances, prices have risen over the past decade. If average electric power prices rise, solar power could generate enough income to cover

its capital costs at more locations and deliver greater income.

#### **Additional Considerations.**

There are a number of caveats to consider regarding the estimates above.

PVWatts calculations do not include operation and maintenance costs of the systems. One of the selling points of fixed solar systems (as opposed to tracking arrays) is that, at \$4.17 per megawatt-hour, its operating costs are lower than any competing energy source.<sup>42</sup> For instance, a solar farm, unlike a nuclear power plant or a coal-fired power plant, does not require up to hundreds of highly paid engineers for its daily operations. Combined cycle natural gas plants have even

lower operating costs than solar — until the cost of fuel is factored in. Still, though low, operations and maintenance do add to the cost and could push solar into the red in those locations where profits at \$1.50 per megawatt-hour are extremely modest.

The profit point is also significantly affected by even modest changes in the interest rate obtained by the solar farm developer. If it is higher or lower than the one chosen for testing, then the price per watt at which minimum profit is obtained changes. [See the sidebar, "Financing Electric Power Plants."]

Note that the calculations above do not include the substantial

cost involved in permitting, environmental assessments and land purchases or leases. They also do not include the cost of transmission lines or the rights of way, the share of the costs that should be apportioned to a particular solar development for redundant power or spinning reserves, or the costs involved with fighting potential lawsuits aimed at halting the construction of the solar farm. Land conversion is especially an issue where the use of public land is proposed for a solar farm.<sup>44</sup> [See Appendix A, “Environmental and National Security Considerations.”]

Some of these costs would exist for almost any proposed new power plant. For instance, both nuclear and coal-fired power plants have substantial permitting and environmental assessment costs, and each proposed plant has recently faced substantial legal challenges. In the case of nuclear power, some states have banned the construction of new facilities.

## Comparisons of Current and Projected Costs of Solar and Other Power Plants

The Obama administration and the most optimistic of solar power proponents argue that solar power will reach widespread grid parity in 2013 to 2015. However, recent studies projecting solar power costs compared to other types of generation indicate that widespread grid parity is much further in the future.

### A 2008 Projection of the Cost of Solar Power Systems

## Financing Electric Power Plants

Financing costs are important to the viability of solar photovoltaic power plants. These cost vary considerably, depending on which type of entity develops the plant.

**Publicly-Owned Utilities.** Publicly-owned utilities include nonprofit electric cooperatives, and utilities owned by municipalities, states and the federal government. They have guaranteed service territories and face limited competition, but unlike investor-owned utilities set their own rates and make their own decisions to build power plants. A public utility usually finances a project with 100 percent debt because it can obtain an interest rate below those charged to publicly traded corporations due to the very low risk of defaulting on debt payments, and because the interest it pays is exempt from federal or state income taxes.

**Investor-Owned Utilities.** State utility commissions set electric rates and conditions of service of investor-owned utilities. Investor-owned utilities have guaranteed service territories and face limited competition. Investor-owned utilities must obtain the approval of state utility commissions to build new power plants. Privately-owned power plants are financed with a mix of debt and equity. The cost of borrowing is higher because their debt is not tax exempt and they usually have lower credit ratings. The debt of the average electric utility is in the lower tier of investment grade (BBB) bonds.

**Independent Power Producers.** Most solar energy projects are developed by independent power producers, who sell wholesale power to utility and industrial buyers. They make their own decisions to build power plants and, within limits, can sell power at whatever price the market will bear. They do not have guaranteed service territories and can face intense competition for power sales. They face more financial risk than regulated utilities — but can also earn larger profits.

However, the debt of independent power producers often falls in the speculative category and carries a higher interest rate. As a result, even with federal grants covering 30 percent of the construction costs, it is difficult for solar companies whose projects have been approved to find additional financing.<sup>43</sup>

**and Other Generating Plants.** A 2008 Congressional Research Service (CRS) report compared the current dollar cost of building, operating and maintaining a variety of electric power facilities to the cost of a new combined

cycle natural gas power plant being brought on-line in 2015.<sup>45</sup>

The study examined the demand for and costs of new power plants under a variety of conditions, including higher and lower natural

**TABLE V**  
**Capital Cost per Kilowatt**

	<u>Advanced Coal*</u>	<u>IGCC Coal*</u>	<u>Natural Gas</u>	<u>Nuclear</u>	<u>Wind</u>	<u>Solar Photovoltaic</u>
National Base Project Cost	\$2,844	\$3,221	\$ 978	\$5,335	\$2,438	\$4,755
Anchorage, Alaska	\$3,890	\$4,252	\$1,306	\$6,208	\$3,055	\$5,702
Phoenix, Ariz.	\$2,689	\$3,074	\$1,005	\$5,214	\$2,382	\$4,461
Los Angeles, Calif.	\$3,488	\$3,858	\$1,264	\$5,845	\$2,744	\$5,213
Hartford, Conn.	\$3,688	\$4,057	\$1,254	\$6,124	\$2,602	\$5,094
Tampa, Fla.	\$2,696	\$3,078	\$ 922	\$5,226	\$2,387	\$4,539
Honolulu, Hawaii	\$ 0	\$ 0	\$1,472	\$ 0	\$3,108	\$6,526
New York, N.Y.	\$3,842	\$4,170	\$1,650	\$6,058	\$3,040	\$6,494
Cincinnati, Ohio	\$2,863	\$3,246	\$ 963	\$5,385	\$2,393	\$4,535
Rapid City, S.D.	\$2,519	\$2,912	\$ 902	\$5,103	\$2,457	\$4,363
Knoxville, Tenn.	\$2,574	\$2,965	\$ 896	\$5,140	\$2,329	\$4,272
Houston, Texas	\$2,555	\$2,946	\$ 893	\$5,130	\$2,322	\$4,274
Charleston, W. Va.	\$2,791	\$3,172	\$ 981	\$5,298	\$2,437	\$4,652

\* Note: Advanced Pulverized Coal (APC) project cost was estimated, since there were no operating APC plants. IGCC is Integrated Gasification Combined Cycle (IGCC) Coal.

Source: U.S. Energy Information Administration, "Updated Capital Cost Estimates for Electricity Generation Plants," November 2010. Available at [http://tonto.eia.doe.gov/oiaf/beck\\_plantcosts/index.html](http://tonto.eia.doe.gov/oiaf/beck_plantcosts/index.html).

gas prices, requirements for carbon capture, increases or decreases in capital costs relative to a combined cycle gas power plant (used as a "base case" for comparison), and changes in financing terms relative to natural gas prices. The results of the CRS comparison are expressed as annualized costs: the present value of the total cost of building, operating and maintaining an electricity generating facility over its financial life converted to equal annual payments, amortized over the expected annual power generation from an expected duty cycle. Among the results:

- In the base case, the total annualized cost per megawatt-

hour (\$255.41) for solar photovoltaic was two-and-a-half times more than its nearest competing technology (solar thermal).

- It was four times more expensive than a pulverized coal plant, and more than two-and-a-half times more expensive than either an integrated combined cycle coal plant, a nuclear power plant or a land-based wind power plant.
- It was more than four times as expensive as a combined cycle gas plant.

Even under conditions most favorable to solar (higher gas

prices, lower financing costs, lower capital costs and carbon capture and storage requirements), solar power plants had significantly higher annualized costs than competing electricity sources.

Natural gas power plants are inexpensive to build relative to other major sources for electricity but the variability of natural gas prices can make the plants a very expensive power source. However, the price of natural gas would have to rise to and remain at 635 percent of its 2008 level in order for solar to match the price of electricity produced by a natural gas plant.

The only change the CRS examined that raised the cost of

the other electric power sources within less than half of the annualized cost of a solar plant were carbon controls. Assuming the government set a requirement that fossil fuel power plants capture 90 percent of the carbon produced, the CRS estimates that solar would still be two-and-a-half times as expensive as its closest rival, integrated combined cycle coal. Under this scenario, if price were the only consideration, geothermal power would become the electric provider of choice.

### **A More Recent Projection of the Cost of Solar Power Farms and Other Generating Plants.**

The price of solar cells has fallen considerably since the CRS report. Moreover, the efficiency of solar cells has improved. Thus, recent reports indicate that the cost of centralized solar has fallen relative to other sources.

In November 2010, the EIA issued “Updated Capital Cost Estimates for Electricity Generation Plants.” While the costs for natural gas plants remained largely unchanged, the capital costs for new coal-fired, nuclear and even wind power plants increased considerably — on average, 25 percent higher for coal-fired and nuclear power plants, and 21 percent higher for wind farms. By contrast, solar fell 10 percent due to increasing economies of scale and falling component costs.<sup>46</sup>

The 2010 EIA report provides both a national base case, or average estimated cost, and location-specific estimated costs for varying electric generating technologies. The EIA’s calculations consider a variety of factors

including labor costs and inflation. Since many of the EIA’s locations were not an exact match to the cities simulated in the PVWatts calculations above, the in-state location closest to the comparable PVWatts location is used. As shown in Table V:

- The projected average capital cost for natural gas is \$978 per kilowatt-hour, and the location-specific estimated cost ranges from \$893 in Houston, Texas, to \$1,650 in New York City, New York.
- The average cost for wind power is \$2,438 and ranges from \$2,322 in Houston, Texas, to \$3,108 in Honolulu, Hawaii.
- The average for solar photovoltaic power is \$4,755 and ranges from \$4,272 in Knoxville, Tenn., to \$6,526 in Honolulu, Hawaii.

Table V shows that even with increased costs associated with coal, nuclear and wind power plants, and substantial declines in the cost of solar, there is no location where solar’s capital costs match or beat any competing electric generating technology, with the exception of nuclear power.

**Annualized Cost of a Solar Power System over Its Operating Life.** As the EIA notes, and as discussed above, capital costs are only one factor in determining the viability and attractiveness of competing generating technologies. Many might argue that the annualized cost of newly built electricity generating facilities is the most important measure of the viability of solar power.

Solar’s annualized cost is significantly higher than almost every other generating technology, due primarily to three factors: a low capacity factor (the relatively small amount of energy it can be expected to deliver daily), a higher than average transmission cost and a shorter useful life than comparable facilities. For instance, using EIA data, the Institute for Energy Research, a private group that analyzes the economics of energy, estimates:<sup>47</sup>

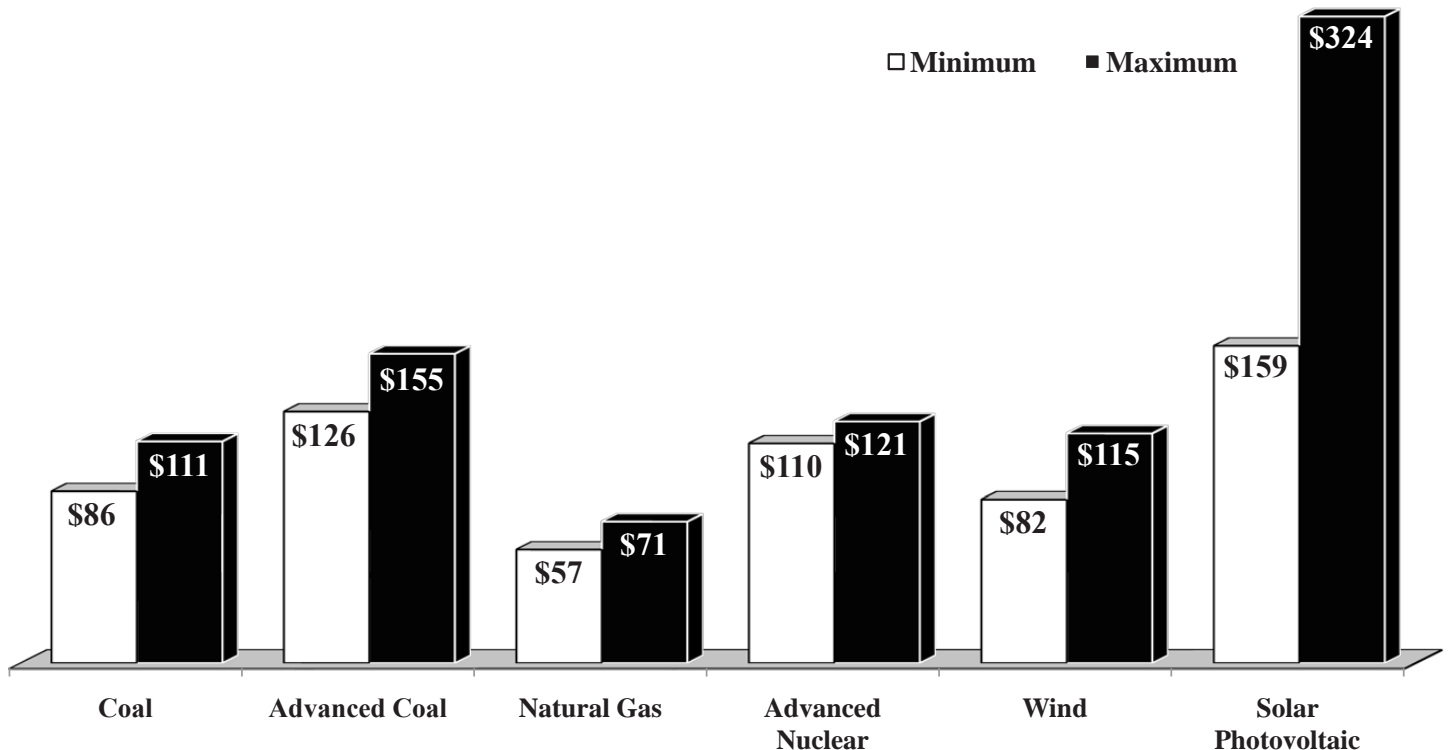
- The average annualized cost of an advanced combined cycle natural gas plant is \$63.10 per megawatt-hour.
- The average annualized cost of an advanced nuclear plant is \$113.90 per megawatt-hour.
- The average annualized cost of an advanced coal-fired power plant (with carbon capture technology) is \$136.20 per megawatt-hour.
- The average annualized cost of a solar photovoltaic plant is \$210.70 per megawatt-hour.

Thus, while the average annualized cost of solar power has declined markedly since 2008 from \$255.41 to \$210.70, it is still much more expensive than other electric power generating technologies.

Since costs vary considerably within regions, the EIA also provided a minimum and a maximum estimated cost for each of the generating technologies. As shown in Figure I:

- Total annualized costs for natural gas range from \$57 to \$71 per megawatt-hour.

**FIGURE I**  
**Range for Total System Annualized Cost (2009 \$/megawatt-hour)**



Source: U.S. Energy Information Administration, “Levelized Cost of New Electricity Generating Technologies,” Table 2, 2010. Available at [http://www.eia.doe.gov/oiaf/aeo/electricity\\_generation.html](http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html).

- Total costs range from \$86 to \$111 per megawatt-hour for coal-fired power plants.
- Annualized costs for advanced nuclear power plants range from \$110 to \$121 per megawatt-hour.
- And total annualized costs range from \$159 to \$324 per megawatt hour for solar power plants.

Even under the best conditions, solar’s minimum annualized cost (\$158.70 per megawatt-hour) is higher than the maximum cost for each of the technologies considered, though only slightly so in the case of advanced coal with carbon capture (\$154.50 per megawatt-hour).<sup>48</sup>

### Grid Parity: When?

Based on the EIA’s most recent assessment of annualized costs, solar is unlikely to be competitive with conventional generating technologies by 2015 — the Obama administration’s optimistic forecast. Indeed, to be competitive by 2015, solar’s annualized costs would have to decline approximately 10 percent each year. To reach widespread grid parity by 2013, it would have to fall nearly 20 percent each year. For solar to reach widespread grid parity in such a short time would require continued substantial government support and, as importantly, the expectation that such support will continue in order

to secure long-term financing and investment.<sup>49</sup> These subsidies are, in fact, driving the cost declines in solar materials. Artificial demand is stoking expanded production, which is in turn lowering the costs of delivered solar arrays.

Even with subsidies, a 20 percent average decline in price is unlikely. A 10 percent average decline might be possible, but subsidies would have to remain at or above where they are currently. [See Appendix B, “The End of Subsidies.”]

### Conclusion

Grid parity will be reached in some locations sooner than in others, but it is still at least a decade



away in most places. It will be reached sooner if electric power prices begin to rise again, rather than falling in conjunction with the price of natural gas as they have in the last two years. Widespread parity in either 2013 or 2015 is highly unlikely.

It is also important to note that if and when solar photovoltaic-generated electric power reaches widespread grid parity, it will still make up only a small part of the overall electric power mix. Thus, it will always be supplemental to generating technologies that can provide consistent baseload power or on-demand peaking power — neither of which solar photovoltaic can satisfy.

## Appendix A Environmental and National Security Considerations

Some advocate solar power for perceived environmental and energy security-related benefits rather than economic considerations. However, these advocates largely ignore the negative environmental impacts that solar power generation has on the environment. Like any power source, there are both benefits and costs associated with electric power generated from solar photovoltaic technology.

**Solar Sprawl.** The term solar sprawl has been used to refer to the large land and resource usage that accompanies expanding solar energy projects. Solar farms often require huge tracts of land in previously undeveloped areas in order to maximize energy output,

but this expansion comes at the expense of native plant and animal habitats. The Mojave Solar Park under construction in Southern California is one such example. It will require up to 6,000 acres for an expected 553 megawatts of solar power.<sup>50</sup> In contrast, a coal-fired plant can generate over 6,000 megawatts of power on less than 1,000 acres.<sup>51</sup>

In the rush to get large solar projects approved before a 30 percent federal grant program for construction costs expired at the end of 2010, a number of new and existing companies applied to build solar farms on public land in California.<sup>52</sup> There were nine projects approved in 2010, encompassing over 40,000 acres and able to produce roughly 4,500 megawatts.<sup>53</sup> Though approved initially, concern over the risk to various threatened and endangered species and historic cultural artifacts threaten to block the projects. Environmental groups fear the desert tortoise — listed as “vulnerable” by the International Union for Conservation of Nature — and other species, ranging from reptiles to sheep, are at risk.<sup>54, 55</sup> Some environmental groups have filed lawsuits against the federal government over its approval of the projects.

The proposed Ivanpah solar plant is at the center of a suit filed against the U.S. Department of the Interior, the Bureau of Land Management and the Fish and Wildlife Service. The plaintiffs argue that the 370 megawatt operation was approved without adequate attention to the effect on animals, as well as plants and groundwater.<sup>56, 57</sup> The suit claims construction could

significantly displace species by making the land permanently uninhabitable. Surveys have found 25 desert tortoises on the site.<sup>58</sup>

Attempting to assuage critics, Brightsource Energy, the project developer, has agreed to acquire thousands of acres of habitat to offset the damage. However, it is unclear that this will halt the lawsuit or, more importantly, protect the tortoise. Animal relocations are not always successful and it is uncertain whether the desert tortoises will thrive on the proposed set-aside land.

**Plants May Need to Be Bigger.** The large solar developments proposed on federal lands in California are solar thermal rather than solar photovoltaic. This is important because solar thermal plants require fewer acres to produce the same amount of electricity. If plans for the solar thermal plants are revised and solar photovoltaic is used instead, hundreds of acres more could be needed for each project.<sup>59</sup>

In addition, rated capacity is not the same as expected power output. For instance, the capacity factor for coal-fired plants is 85 percent, so a 1,200 megawatt plant would on average produce 1,020 megawatts of electricity.

By contrast, solar photovoltaic’s capacity factor is quite low. Areas of high sunlight might have a capacity factor of 23 percent, but in areas of only moderate sunlight the capacity factor falls to 11 percent.<sup>60</sup> Thus, to produce the same amount of energy on average as a typical nuclear or coal-fired power plant, a solar photovoltaic farm would have to be more than three times larger

### Federal and State Subsidies under Fire

The House of Representatives substantially reduced funding for various renewable technologies in its proposed budget for the remainder of fiscal year 2011. Though all these cuts might not be enacted, less support in this and coming years seems likely from a Congress interested in reducing the budget deficit and national debt.

Even solar firms that have already received substantial government support are experiencing difficulties in the current uncertain investment environment. For instance, Solyndra Inc., a solar panel manufacturer touted by President Obama as a model of a green energy future, received \$535 million in taxpayer loans to finance a new factory that would create 1,000 new jobs. Instead, it will close an existing factory and keep its workforce at present levels.<sup>64</sup> While its sales have grown in recent years, Solyndra has yet to make a profit. In July 2010 it withdrew plans for an initial public stock offering.<sup>65</sup>

In Massachusetts, despite receiving more than \$58 million in grants, loans and tax incentives in 2007 from the state (in addition to federal support), Evergreen Solar decided to close its doors and start a joint venture in China. Eight hundred workers are being laid-off. One of the largest incentive packages offered to a company in Massachusetts history was not enough to keep Evergreen, with its \$685 million in cumulative losses, in the state.<sup>66</sup>

in terms of rated capacity in sunny areas and seven to eight times larger in less sunny areas. This would increase the size of any solar farm's footprint considerably — adding up to tens of thousands of acres.

**National Security.** Though solar power is called a renewable energy source, the components required for installations can be difficult to obtain. For example, the rare element tellurium is a necessary component in photovoltaic cells used in solar panels, but there is currently only one tellurium mine on the entire planet — in the People's Republic of China. This means that U.S. production of solar cells relies

on China. The U.S. push for a larger "green" economy comes at a time when China is expanding its own position in the solar power market. In 2003 China produced around 1 percent of the world's solar panels, but by 2010 its market share had increased to 43 percent.<sup>61</sup>

Tellurium is also produced as a byproduct of copper purification. As such, a number of countries produce quantities of tellurium. However, domestically, the decline in lead mining and move to lower grades of copper ore — which require a different refining process — has reduced domestically recovered tellurium.

As a result, imports of tellurium have soared along with the price.

- From 2003 to 2007 China supplied 13 percent of the United States' imported tellurium.
- By September 2010, China's share of U.S. tellurium imports had grown to 43 percent, making China the single biggest source of imported tellurium.
- The U.S. Geological Survey notes that the price of tellurium increased 14-fold between 2002 and 2006, and seven-fold between 2004 and 2006.

Not only does China have the only mine devoted to tellurium production, a Chinese company is the largest single producer of the highly purified tellurium needed for thin-film solar cells. The top American producer of thin-film photovoltaic solar cells, First Solar, is already the Chinese company's largest tellurium customer. China's share of world tellurium production will likely grow since it has also become the world's largest producer and user of copper.

China has cut off supplies of critical minerals to countries with which they have geopolitical conflicts. For example, on September 7, 2010, a Chinese fishing boat collided with a Japanese coast guard vessel in a disputed portion of the East China Sea. When Japan refused to release the captain, China retaliated by withholding exports of rare earths used in electronics production.<sup>62</sup> This is consistent with China's overall strategy of restricting export of rare elements. Consider:

- China has eliminated export tax rebates for rare earth elements while increasing export taxes to rates as high as 25 percent.
- Further, China reduced its export quota 40 percent from 2009 to 2010.

This comes just as the U.S. government is pushing technologies that rely on these elements.<sup>63</sup>

## Appendix B The End of Energy Subsidies

Under the economic conditions facing governments around the world, the current level of support for solar developments is unlikely to continue. A program that provides federal grants for up to 30 percent of construction costs was continued for a year in the tax bill passed in December 2010. But even so, solar developers are finding it difficult to finance the other 70 percent of construction costs. In part, this is because there is uncertainty concerning whether the grant program and the other subsidies and mandates that have pushed solar growth in the past few years will be continued. At least at current levels, such support seems unlikely. [See sidebar, “Federal and State Subsidies.”]

**Fewer Economies of Scale Due to Slowing Global Solar Power Growth.** Events in Europe make it even less likely that solar’s recent rate of growth and cost decline will continue. The European Union has been the leader in installing solar. Indeed, from 2007 through

2010, EU countries accounted for more than 70 percent of solar energy demand. In 2009, Germany’s market alone accounted for 54 percent of the solar panels produced. These subsidies have been economically costly, due to higher energy prices and direct energy levies.

For example, Germany’s renewable energy act required utilities to pay generous prices — called feed in tariffs — for electricity produced by renewables. As a result, renewable power grew from 6 percent of generating capacity in 2000 to 16 percent in 2009.<sup>67</sup> Solar power is less than 2 percent of the total. The feed in tariff was €0.39 (about \$0.54) — eight times the price Germans pay for power generated by conventional fossil fuels. However, due to fiscal constraints as a result of the global economic recession, the German government has cut tariffs for large solar power facilities by 25 percent and for individual roof-top solar energy production by 15 percent. Further cuts are likely.<sup>68</sup>

Spain, the world’s largest solar power producer, has spent more than €23 billion (about \$32 billion) since 2002 supporting the industry.<sup>69</sup> However, the government is reducing support for existing plants by more than 30 percent and for new plants by 45 percent. As a result, Spain’s solar energy lobbying group predicts many solar companies will default on their debt.<sup>70</sup>

France has also indicated that it will implement a moratorium on new solar projects that are eligible for tariffs, and the United Kingdom and Canada might also reconsider their tariffs.

The reduced incentives in Europe and North America will likely lead to a worldwide fall in demand for solar panels. This will slow the decline of solar array prices that has resulted from economies of scale in production. As noted earlier, in the past, when subsidies for solar power were reduced, its use declined significantly and prices for both panels and the power ceased to decline, or declined at a much slower rate.

**Threats to U.S. Renewables Portfolios.** Even demand driven by renewable portfolio standards are under threat. In his State of the Union address, President Obama lumped natural gas, clean coal and nuclear power in with wind and solar as clean fuels of the future. Some state legislatures are considering transforming renewable portfolio standards into clean energy standards, which would allow natural gas, clean coal or nuclear generated electricity to count toward the overall energy goal. If this occurs, solar demand will further decline.

Thus, it seems unlikely that solar power costs will continue to decline at the historically high rates they have in the past couple of years. The decline in solar generated electricity prices will arguably return to its historic average of 4 percent per year, absent the tremendous government support that drove the recent phenomenal but aberrant decline. If it does, all else equal, it would not become cost competitive on an annualized basis with nuclear power until after 2020. In addition, it would take longer to match the price of electricity generated by coal-fired and natural gas power plants.

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### About the Author

**H. Sterling Burnett** is a senior fellow at the National Center for Policy Analysis. His work primarily focuses on the intersection between ethics, economics and politics in relation to environmental issues. He has numerous publications to his credit in academic journals, magazines and daily newspapers, including *Environmental Ethics*, *Ethics*, the *Texas Review of Law & Politics*, the *Washington Post*, *USA Today* and *Forbes*. He has provided invited testimony before the United States Congress and to various state legislatures. Burnett received his Ph.D. in Philosophy from Bowling Green State University in Ohio in 2001.

Burnett blogs about environmental issues and more at [www.environmentblog.ncpa.org](http://www.environmentblog.ncpa.org).

*The NCPA is a nonprofit, nonpartisan organization established in 1983. Its aim is to examine public policies in areas that have a significant impact on the lives of all Americans — retirement, health care, education, taxes, the economy, the environment — and to propose innovative, market-driven solutions. The NCPA seeks to unleash the power of ideas for positive change by identifying, encouraging and aggressively marketing the best scholarly research.*

### Health Care Policy.

The NCPA is probably best known for developing the concept of Health Savings Accounts (HSAs), previously known as Medical Savings Accounts (MSAs). NCPA President John C. Goodman is widely acknowledged (*Wall Street Journal*, WebMD and the *National Journal*) as the “Father of HSAs.” NCPA research, public education and briefings for members of Congress and the White House staff helped lead Congress to approve a pilot MSA program for small businesses and the self-employed in 1996 and to vote in 1997 to allow Medicare beneficiaries to have MSAs. In 2003, as part of Medicare reform, Congress and the President made HSAs available to all nonseniors, potentially revolutionizing the entire health care industry. HSAs now are potentially available to 250 million nonelderly Americans.

The NCPA outlined the concept of using federal tax credits to encourage private health insurance and helped formulate bipartisan proposals in both the Senate and the House. The NCPA and BlueCross BlueShield of Texas developed a plan to use money that federal, state and local governments now spend on indigent health care to help the poor purchase health insurance. The SPN Medicaid Exchange, an initiative of the NCPA for the State Policy Network, is identifying and sharing the best ideas for health care reform with researchers and policymakers in every state.

**NCPA President  
John C. Goodman is called  
the “Father of HSAs” by  
*The Wall Street Journal*, WebMD  
and the *National Journal*.**

### Taxes & Economic Growth.

The NCPA helped shape the pro-growth approach to tax policy during the 1990s. A package of tax cuts designed by the NCPA and the U.S. Chamber of Commerce in 1991 became the core of the Contract with America in 1994. Three of the five proposals (capital gains tax cut, Roth IRA and eliminating the Social Security earnings penalty) became law. A fourth proposal — rolling back the tax on Social Security benefits — passed the House of Representatives in summer 2002. The NCPA’s proposal for an across-the-board tax cut became the centerpiece of President Bush’s tax cut proposals.

NCPA research demonstrates the benefits of shifting the tax burden on work and productive investment to consumption. An NCPA study by Boston University economist Laurence Kotlikoff analyzed three versions of a consumption tax: a flat tax, a value-added tax and a national sales tax. Based on this work, Dr. Goodman wrote a full-page editorial for *Forbes* (“A Kinder, Gentler Flat Tax”) advocating a version of the flat tax that is both progressive and fair.

A major NCPA study, “Wealth, Inheritance and the Estate Tax,” completely undermines the claim by proponents of the estate tax that it prevents the concentration of wealth in the hands of financial dynasties. Actually, the contribution of inheritances to the distribution of wealth in the United States is surprisingly small. Senate Majority Leader Bill Frist (R-TN) and Senator Jon Kyl (R-AZ) distributed a letter to their colleagues about the study. In his letter, Sen. Frist said, “I hope this report will offer you a fresh perspective on the merits of this issue. Now is the time for us to do something about the death tax.”

### Retirement Reform.

With a grant from the NCPA, economists at Texas A&M University developed a model to evaluate the future of Social Security and Medicare, working under the direction of Thomas R. Saving, who for years was one of two private-sector trustees of Social Security and Medicare.

The NCPA study, “Ten Steps to Baby Boomer Retirement,” shows that as 77 million baby boomers begin to retire, the nation’s institutions are totally unprepared. Promises made under Social Security, Medicare and Medicaid are inadequately funded. State and local institutions are not doing better — millions of government workers are discovering that their pensions are under-funded and local governments are retrenching on post-retirement health care promises.

### Pension Reform.

Pension reforms signed into law include ideas to improve 401(k)s developed and proposed by the NCPA and the Brookings Institution. Among the NCPA/Brookings 401(k) reforms are automatic enrollment of employees into companies’ 401(k) plans, automatic contribution rate increases so that workers’ contributions grow with their wages, and better default investment options for workers who do not make an investment choice.

The NCPA's online Social Security calculator allows visitors to discover their expected taxes and benefits and how much they would have accumulated had their taxes been invested privately.

### Environment & Energy.

The NCPA's E-Team is one of the largest collections of energy and environmental policy experts and scientists who believe that sound science, economic prosperity and protecting the environment are compatible. The team seeks to correct misinformation and promote sensible solutions to energy and environment problems. A pathbreaking 2001 NCPA study showed that the costs of the Kyoto agreement to reduce carbon emissions in developed countries would far exceed any benefits.

### Educating the next generation.

The NCPA's Debate Central is the most comprehensive online site for free information for 400,000 U.S. high school debaters. In 2006, the site drew more than one million hits per month. Debate Central received the prestigious Templeton Freedom Prize for Student Outreach.

### Promoting Ideas.

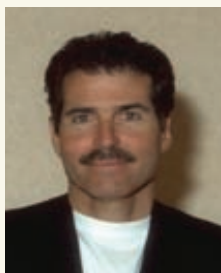
NCPA studies, ideas and experts are quoted frequently in news stories nationwide. Columns written by NCPA scholars appear regularly in national publications such as the *Wall Street Journal*, the *Washington Times*, *USA Today* and many other major-market daily newspapers, as well as on radio talk shows, on television public affairs programs, and in public policy newsletters. According to media figures from *BurrellesLuce*, more than 900,000 people daily read or hear about NCPA ideas and activities somewhere in the United States.

## What Others Say About the NCPA



*"The NCPA generates more analysis per dollar than any think tank in the country. It does an amazingly good job of going out and finding the right things and talking about them in intelligent ways."*

**Newt Gingrich**, former Speaker of the U.S. House of Representatives



*"We know what works. It's what the NCPA talks about: limited government, economic freedom; things like Health Savings Accounts. These things work, allowing people choices. We've seen how this created America."*

**John Stossel**,  
former co-anchor ABC-TV's *20/20*



*"I don't know of any organization in America that produces better ideas with less money than the NCPA."*

**Phil Gramm**,  
former U.S. Senator



*"Thank you . . . for advocating such radical causes as balanced budgets, limited government and tax reform, and to be able to try and bring power back to the people."*

**Tommy Thompson**,  
former Secretary of Health and Human Services