CASE: P84
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BRIGHTSOURCE: CHALLENGES AND PROSPECTS FOR A CONCENTRATED SOLAR POWER PLANT

INTRODUCTION

In January 2013, BrightSource CEO John Woolard was looking forward to the completion of the company's first commercial-scale solar thermal power plant. The $2.2 billion, 392 megawatt (MW) plant, called Ivanpah, was located in California's Mojave Desert, and would be completed by mid-year. At that point, it would start providing electricity for 140,000 homes during peak hours. It was the first truly commercial-scale power tower project in the world. Utility giants PG&E and Southern California Edison had signed long-term contracts with BrightSource for the plant's electricity. Ivanpah had strong backing from investors and the U.S. Department of Energy (DOE). The company had won a $1.6 billion loan guarantee from the DOE to help reduce the financing costs of its solar power projects.

When Woolard became CEO in 2006, one of his first tasks had been to find a site for the power plant. He began searching for what he called a "boring piece of land."[1] It needed to be previously disturbed,[2] flat and located somewhere near transmission lines and natural gas. Because solar

[1] Interview with John Woolard, December 7, 2012. Subsequent quotations are from the author's interviews unless otherwise noted.

[2] Land that was previously used for agricultural purposes but had been abandoned.

Debra Schifrin and Professor Donald Kennedy prepared this case as the basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation.

power is intermittent, solar power plants usually were required by the utilities to add baseload standby power from other sources (e.g. natural gas) to be available when clouds or twilight hours intervened. Woolard also needed to find an area where a solar plant would cause minimal environmental impact. Because the land being considered would be publicly owned, there could be serious public environmental concerns and pushback if vulnerable ecosystems, threatened species, or other natural land values were adversely affected.

These criteria led him to 3,600 acres of federal land in the Mojave Desert managed by the Bureau of Land Management (BLM). Following a multi-year application and the process of obtaining a permit from the California Energy Commission, BrightSource began construction of Ivanpah in 2010, made up of three separate facilities of 133 MW, 133 MW and 126 MW.

The road to building Ivanpah had not been an easy one, especially because of legal and other challenges by environmental groups over the ecological impact of constructing and operating a large solar power plant in the area. The issue at the forefront was that the federal land set aside for Ivanpah was also a habitat for the desert tortoise, listed by the U.S. government as a threatened species under the Endangered Species Act (ESA).

Kim Delfino, California program director for Defenders of Wildlife (which did not take any legal action against BrightSource), said the number of tortoises at Ivanpah was far higher than original BrightSource estimates. During the negotiations, the U.S. Fish and Wildlife Service (FWS is the agency responsible for ESA evaluations) had to evaluate the project's construction and operations and set the number of "takings" of tortoises that would be acceptable under the Endangered Species Act. The ESA's definition of "taking" includes harming, killing or collecting the species.[3] (See Footnote 3 for full definition.) During the project, FWS increased the number of acceptable "takings" from 38 to 1,200, including just 9 deaths. Delfino argued that BrightSource's attempts to move the tortoises to nurseries to save them would not be effective: "BrightSource has to put them into the wild at some point, and that usually does not go well. A tortoise that has been pulled up and put in a pen and released into the wild is pretty much a dead tortoise. When the army did this for the expansion of Fort Irwin also in the Mojave Desert, the survival rate was shockingly low."[4] Delfino pointed out that mortality events during the project were not the only criterion for judging the risks. BrightSource said that the total number of tortoises found and moved off the site by early 2013 was 172, including 107 juveniles that were relocated into the BrightSource nursery (called by their staff the "Head Start" project). In the fall of 2011, 53 juveniles were hatched in the nursery.

Other challenges came from groups who wanted to preserve the visual attractiveness of the area or were opposed to federal land being used for any commercial purposes. These and other environmental challenges continued into 2013.

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[3]From Section 3(18) of the Federal Endangered Species Act: "The term 'take' means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."

[4]For details on Fort Irwin desert tortoise relocation efforts, refer to the following article:
Louis Sahagun, "Army Grants a Stay to Desert Tortoises," *The Los Angeles Times*, October 11, 2008, http://articles.latimes.com/2008/oct/11/local/me-tortoise11 (accessed February 22, 2013).

Adding to concerns was the large amount of land needed for Ivanpah. BrightSource was in the concentrated solar power (CSP) sector, which commonly involved a substantial land commitment. The other solar power sector utilized photovoltaic (PV) power, employing semiconductor materials to receive solar radiation directly and converting it into current. Such PV facilities were often distributed, in that they could be installed on rooftops or other temporary locations. But they could also be assembled into large capacity “solar farms,” also involving large spatial requirements. (See later in this case for more on the distinction between the technology of concentrated and distributed solar systems.)

With his background in environmental planning and twenty years of experience in clean energy technology, Woolard understood the balancing act that building such a plant required, and BrightSource had taken some measures to protect the desert tortoise. These included thoughtful siting, the hiring of 150 biologists, and spending $56 million on the tortoises’ care, including on land acquisition for their relocation. Woolard did not take the situation lightly. He was personally and seriously concerned about climate change, often commenting that the general population did not understand the enormity of the danger, and that few people were doing anything to mitigate the harmful potential effects. He pointed out that a daunting number of new carbon-free power plants would need to be built quickly in order to maintain the already serious state of climate change:

> The challenge we all face is immense. Just to stabilize CO_2 in the atmosphere, we need to build 300 new carbon-free power plants every year, each the size of a nuclear power plant. Last year we only built one-tenth of what we needed to stay on pace, and we are on a trajectory to do even less this year. If a renewable energy project like Ivanpah has so much trouble crossing the finish line because of so many legal challenges, how are we going to build the equivalent of an Ivanpah plant every two or three days?

Woolard’s conclusion suggested that a primary consideration was the need for major renewable facilities to deal with the coming climate change problem. BrightSource had other solar facilities in the planning, permitting or construction phases. Given what he had learned in carrying out the Ivanpah project, Woolard had to determine the best way to move forward on the others.

CLIMATE CHANGE

By 2012, climate change had become a serious problem. The Earth’s average temperature had increased by more than 1.4 degrees Fahrenheit between 1900 and 2012, and the first ten years of the twenty-first century were the warmest on record. According to the Intergovernmental Panel on Climate Change (IPCC), natural factors alone could not explain the Earth’s warming over the previous half-century. Instead, IPCC warned that the warming to date had been caused in large part by post-industrial human activities such as burning fossil fuels, which increased greenhouse gas emissions. Greenhouse gases (GHG), of which carbon dioxide (CO_2) is the most harmful, trapped heat from the sun in the atmosphere causing global warming, which resulted in melting ice caps, rising sea levels, more intense rain, more frequent and severe heat waves, and warming oceans.

Large contributors to GHG emissions were the releases of CO_2, methane, and nitrous oxide into the atmosphere. Although these events sometimes occurred naturally, an increasingly large fraction of the emissions came from human activities, which released over 30 billion tons of CO_2 annually. This was a 40 percent increase over pre-industrial times when CO_2 was at 280 ppmv (parts per million by volume). By 2013 the CO_2 concentration had reached nearly 400 ppmv. Indeed, between 1992 and 2012, the atmospheric CO_2 load had grown by 50 percent, reaching its highest concentration over the past 800,000 years. (See Environmental Protection Agency Website "Causes of Climate Change."[5])

Methane, the major component of natural gas being mined extensively in the U.S. and elsewhere, is also a powerful greenhouse gas. Resident in the atmosphere for approximately a decade, it is ten times more powerful than CO_2 on a molecular basis while there. Black carbon (soot) and certain fluorocarbon compounds are also strong GHGs that are temporary in the atmosphere. Some observers advocated making a strong start on the issue of controlling climate change by eliminating methane and other temporary GHGs entirely.[6] But this partial solution would not slow the long-range growth of CO_2.

Indeed, many scientists argued that if significant measures were not taken to reduce climate change effects by 2020, the results would be essentially irreversible on human timescales. To stabilize the climate, the world would have to be completely decarbonized within the twenty-first century. This would require near-zero emissions of carbon dioxide and other long-lived greenhouse gas emissions.[7,8]

By 2012 most countries agreed that the average surface temperature of the Earth should not be allowed to increase more than 2 degrees Celsius above pre-industrial levels, which would mean returning to a value of 350 ppmv of CO_2 in the atmosphere, which is some 45 ppmv below 2012 levels. Scientists vigorously debated these targets, with many arguing that holding the 2 degree target would be entirely inadequate to avoid serious interference with the climate system. The only global meeting to discuss that goal was the 2009 Copenhagen Accord, with the target agreed to by over 140 countries. However, that agreement was not legally binding, nor did it establish a common understanding of the risks of failing to meet it.

Woolard put the climate change situation in these terms:

> We are floundering so much from a policy perspective and doing absolutely nothing to put a dent in the carbon issue. There is an enormous gap between what needs to get done and what is actually happening on the ground. I don't think

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[5] United States Environmental Protection Agency "Causes of Climate Change," http://www.epa.gov/climatechange/science/causes.html (accessed February 22, 2013).

[6] David G. Victor, et al., "The Climate Threat We Can Beat," *Foreign Affairs*, May/June 2012, http://www.foreignaffairs.com/articles/137523/david-g-victor-charles-f-kennel-veerabhadran-ramanathan/the-climate-threat-we-can-beat (accessed February 22, 2013).

[7] Richard C.J. Somerville, "Climate Change, Irreversibility, and Urgency," *Bulletin of Atomic Scientists*, August 13, 2012, http://thebulletin.org/web-edition/features/climate-change-irreversibility-and-urgency (accessed February 22, 2013).

[8] Ken Caldeira, "The Great Climate Experiment," *Scientific American*, September 2012, pp. 78-83, http://dge.stanford.edu/labs/caldeiralab/Caldeira_research/Caldeira_Climate_Experiment.html (accessed February 22, 2013).

> people really have digested how far behind we are from a policy perspective and how bad the consequences are. On a global basis we have got to put one gigawatt of zero carbon power online every single day between now and 2040 just to stabilize CO_2 emissions. Given the size of our carbon footprint relative to that of the rest of the world, the U.S. would have to add one gigawatt of zero carbon power each week.

Solar energy Overview

Globally, 25 percent of power generating capacity came from renewable sources of energy in 2011 (7.3 percent excluding hydroelectric power). Solar power's share of global renewable power was low at 6.5 percent, trailing hydroelectricity, wind, biomass, and geothermal. Wind made up 2 percent of total electricity production, and capacity was doubling every year. At that rate, wind was set to surpass nuclear power capacity by 2022. However, in 2011, solar power accounted for 20 percent of the growth in renewables.

At the end of 2012 global solar capacity was about 102.55 gigawatts (GW), with the vast majority of that coming from photovoltaics (100 GW) and less from concentrated solar power (2.55 GW). (See **Exhibit 1** for solar power capacity growth.) It is important to note that in 2006, when Woolard began looking for a site for Ivanpah, PV capacity was only 7 GW – which means there was a more than 14-fold increase in PV capacity in six years. In 2006, CSP capacity was 367 MW, which translates to 7-fold increase in six years.

Europe was the most advanced market for solar energy, with Germany, Spain, and Italy leading in installed solar capacity. Capacity growth in Italy and Germany accounted for 57 percent of 2011 growth. The next largest market was Asia, with Japan leading. Although China was behind Japan in installed energy capacity, it was the world's largest PV cell manufacturer, and was beginning to develop its domestic solar market, adding 2.2 GW in 2011, for a total of 3.3 GW of capacity going toward domestic power generation.[9]

By the third quarter of 2012, the United States had 6.4 GW of solar electric capacity, 5.9 GW of which was from photovoltaics, with 0.5 GW from concentrated solar power facilities. Solar accounted for less than one percent of domestic energy consumption; it could power about one million average homes or 0.75 percent of total U.S. homes.[10,11] (See **Exhibit 2** for breakdown of U.S. primary electricity by source and renewable energy consumption by source.) By comparison, fossil fuels made up 80 percent of U.S. energy consumption.

The best region for large solar facilities in the United States was the southwest, led by California, Nevada, Arizona, Colorado, and New Mexico. These regions had the most conducive climate for solar facilities. Elsewhere in the country, there was a concentration of large solar facilities in

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[9] International Energy Agency Co-operative Programme on Photovoltaic Power Systems, China National Photovoltaics Status Report 2012.

[10] Solar Energy Industries Association, http://www.seia.org/news/new-report-3rd-quarter-us-solar-energy-growth-highlighted-pv-record-residential-installs (accessed February 22, 2013).

[11] U.S. Census Bureau based on 2011 housing units, http://quickfacts.census.gov/qfd/states/00000.html (accessed February 22, 2013).

New York and Texas. The U.S. solar power generation industry comprised about 230 companies operating over 270,000 installations.[12]

Although some utilities had their own solar plants, the majority bought solar energy from Independent Power Producers (IPP). However, utilities were increasing their investment in solar energy production, and utility ownership in this sector grew 300 percent in 2011.[13]

Centralized versus Distributed Solar Power

Electricity from solar energy came to end-use customers in two ways: through centralized or through distributed systems. Centralized systems were those in which electricity was generated by mid-sized or large solar facilities and then sold in large amounts to utilities, which then delivered it to end customers. Distributed systems involved the installation of solar panels on customers' roofs to generate power, using a variety of pricing models. Using net metering, utilities could charge customers for the power they used, and refund them for what they returned. That excess power would be credited back to the customer at the price a newly constructed power source would have to charge. Distributed installations made up the vast majority of U.S. solar electricity generation, and 4.3 GW of new PV installations were forecast for the U.S. in 2013. But new centralized solar facilities were coming online as well, with a forecast of 946 MW for the year.[14]

Technology: Photovoltaics (PV) versus Concentrated Solar Power (CSP)

Distributed solar power systems used photovoltaics (PV), converting sunlight directly to electricity using solar cells made from semiconductor materials, predominantly silicon. In contrast, concentrated solar power (CSP) facilities created electricity indirectly by collecting the sun's rays through thousands of reflective mirrors, and focusing them on a fluid to heat it and produce steam. The steam then powered mechanical turbines to generate electricity. The turbines required cooling and adequate water supplies, a potential problem in dry (desert) environments.

For PV systems, each half-inch to four-inch cell generated between one and two watts of power. These cells were combined into weatherproof modules, of which thousands could be put together to form a solar panel array. Smaller-scale installations could be used in "distributed generation" and placed on roofs of homes or businesses. Although PV systems converted sunlight into direct current (DC) electricity, an inverter was needed to convert that into the alternating current (AC) used by utility grids—a conversion involving the loss of some energy.

The efficiency of PV cells in most commercial models could reach 16 percent, with some reaching up to 21 percent. In 2009 the National Research Energy Laboratory (NREL) produced a

[12] Solar Energy Industries Association, http://www.seia.org/news/new-report-3rd-quarter-us-solar-energy-growth-highlighted-pv-record-residential-installs (accessed February 22, 2013).

[13] Solar Electric Power Association.

[14] "U.S. Solar Market Grows 76%; Now an Increasingly-Competitive Energy Resource for Millions of Americans Today," Solar Energy Industry Association, March 14, 2013, http://www.seia.org/news/us-solar-market-grows-76-2012-now-increasingly-competitive-energy-source-millions-americans.

PV cell that reached an efficiency of over 40 percent, but in 2013 it was still prohibitively expensive to use.

Distributed PV systems had quicker installation times than CSP facilities and when on rooftops meant lower levels of environmental impact. However, PV systems—on roofs or in large farms—were more susceptible to weather changes like passing clouds and fog, which could affect energy output.

An advantage of CSP systems was that while they were also affected by weather changes, they could add an accessory natural gas system to help firm up the power, providing a source as dispatchable as a plant fired by fossil fuel. Because a CSP plant already had invested in a conventional power block system and turbine, it required only limited additional capital to add an auxiliary boiler to burn a small amount of natural gas. A similarly sized PV plant would require the construction of an entirely new natural gas plant to produce backup power to fill in the solar gap. In fact Ivanpah had a small accessory boiler powered by natural gas, called a “peaker” that could by itself supply enough electricity to meet 20 percent of Ivanpah’s capacity at a given time, but was limited to a much lower figure. Under California’s Renewable Portfolio Standards that favor the use of renewable fuels, BrightSource could only use that backup source less than 5 percent of the time. In practice, that system was used only 2 percent of the time, mostly in the early morning before the sun rose, just to “warm the system up.” Woolard said that percentage was reflected in contracts with the utilities.

According to Woolard: “Solar power or wind goes up and down, on and off, when the sun is not shining or there are clouds, or you have wind blowing or not. I have to then back that up with other resources, generally fossil fuel, so that I can keep supplying the utility with what it needs to keep the lights on. So there is this hidden environmental cost.”

A CSP thermal power plant, if it were coupled with some storage capacity, could provide even more consistent output. Several technologies had been developed to allow CSP systems to provide electricity for many hours after sunset. CSP fluids such as molten salt held their heat for an extended period of time, allowing them to produce steam and generate electricity even after dark or during cloudy or foggy periods. The molten salt essentially created a thermal storage system for CSP. However, no storage capacity was planned for Ivanpah because investors and utilities were reluctant and concerned about the cost and risk of adding it.

Government Incentives

Governments around the world provided financial incentives to encourage conversion from fossil fuels to solar power. The United States had 30 percent Investment Tax Credits (ITC) for solar power, which would be in effect until 2016. At that point, ITCs were expected to drop to 10 percent. Also, most states had Renewable Portfolio Standards (RPS) regulations, which required energy providers to generate some portion of their electricity from renewable energy sources. California led the way in requiring the state’s utilities to have a third of its electricity come from renewable energy sources by 2020. Solar providers also enjoyed some residential and commercial tax breaks, and there were monetary incentives for consumers who installed solar panels on their homes or businesses.

Since 2009, the U.S. government had provided solar power projects with $117 million in funding and over $13.5 billion in loan guarantees and conditional commitments.[15] In Europe, the solar industry was supported by Feed-in-Tariffs (FiTs), which required utilities to purchase long-term electricity contracts from renewables at above-market rates.

Purchase Power Agreements

U.S. solar power producers operated under purchase power agreements (PPA), which required them to fund and maintain facilities and then to sell electricity to utilities under long-term contracts (typically 20-25 years) at a fixed price. The advantage of PPAs—used for utility-scale projects—was that they allowed for pricing certainty for new technologies to leverage when financing projects. Because utility-scale installations required large up-front capital investment, the revenue certainty provided by the PPAs allowed for banks or other larger project investors to make these long-term investments. In the absence of PPAs, developers would be building on speculation alone and would have far greater risk to project investors.

Solar panels installed on individual houses used different forms of financing incentives. In California, there was a tiered rebate system that paid for the amount of KW installed. In other policy environments, feed-in tariffs were used to provide an above market rate for power produced. Both policy approaches were meant to incentivize solar rooftop installations by reducing the system's payback time.

Costs

BrightSource indicated that a 100 MW CSP plant generally cost around $500 million—a number that included such upfront costs as construction, labor, marketing, and negotiation with other interests. The energy itself was free, but solar energy costs for the provider could be measured in a several ways: levelized costs of energy (LCOE), cost per watt, life-cycle direct costs, or Net System Costs.

Levelized costs of energy (LCOE), a metric used to compare costs of different sources of energy, showed the cost of constructing and operating a plant over an assumed financial life and duty cycle. LCOE metrics include overnight capital costs, fuel costs, operation and maintenance costs, financing costs, and an assumed utilization rate. According to the Department of Energy's predictions, U.S. averaged levelized costs for plants entering service in 2018 would be $261.5 per megawatt-hour for solar thermal and $144.3 per megawatt-hour for solar PV.[16] These figures did not factor in government financial incentives. By comparison, levelized cost for conventional coal was $100.1, and for natural gas was $67.1.[17] (See **Exhibit 3** for LCOE chart.)

In July 2012 the weighted average cost per installed watt of solar photovoltaics in the U.S. (including costs of electrical grid connection and other installation equipment) was $4.44—a

[15] The U.S. Department of Energy, http://www1.eere.energy.gov/recovery/index.html.
[16] 2010 dollars.
[17] Convention Combined Cycle Natural Gas technology.
EIA, Annual Energy Outlook 2013, http://www.eia.gov/forecasts/aeo/er/electricity_generation.cfm (accessed February 22, 2013).

decrease of 17.4 percent from 2011. In 2009 the cost was over $7.50 per installed watt. Much of this cost decline was attributed to the decrease in module prices, helped by a 50 percent decline in the cost of individual silicon wafer panels in 2011 (from $1.85 per watt to $0.97 per watt).[18] Other forces driving down module prices included vertical integrations, economies of scale, and overproduction of polysilicon. Costs per installed watt for CSP were $5.79 per installed watt. (See **Exhibit 4** for costs and capacities of the two types of solar energy production.) However, it is important to note that when broken down by type, the average cost per watt for a distributed PV system was much higher than a utility scale PV solar array or CSP system. In California in February 2013, for example, the average cost per watt for distributed PV system with less than 10kW was $6.54, and $5.98 for a system with more than 10kW.[19]

Costs could also be measured in total life-cycle direct costs for electricity, which put solar costs, excluding government incentives, at the highest level among the primary energy sources at 7.7 cents per kilowatt-hour.[20] This compared with 5.3 cents for natural gas, 4.1 cents per coal and 3.3 cents for hydro.[21] (See **Exhibit 5** for direct costs of primary energy sources.)

However, the CSP sector argued that LCOE, the most used measurement, failed to capture all the costs for a given resource. BrightSource said that LCOE was an inadequate measure considering how power systems operate. The company added that LCOE largely ignored the integration costs and the benefits of a resource. Net System Cost, sometimes referred to as Net Cost, Net Value, or Green Premium, looked at the cost required to produce and integrate a resource into the grid, and subtracted the benefits supplied by the regulatory capacity of the mix of energy sources. BrightSource indicated that by using this methodology, utilities and regulators had a more comprehensive view of the costs and benefits of keeping the power grid stable and the lights on. An NREL report by Paul Denholm quantified the benefits of a future CSP plant with storage versus an intermittent resource like photovoltaics. Using Net System Cost, this report estimated that CSP with storage would be $16-$40 per MWh more valuable than PV solar arrays.[22] But Ivanpah and BrightSource's next big project, Palen, did not have storage capacity.

Thus BrightSource's CSP technology on a LCOE basis was not competitive with utility-scale PV. Using the Net System Cost methodology, however, the added benefits of CSP to hybridize or add storage could make the technology the lower future cost alternative in the U.S. BrightSource claimed that the key to a project like Ivanpah was its status as the first critical step in the company's technology roadmap; indeed BrightSource said that Ivanpah would be the most expensive plant the company would ever build. As the company looked to its next generation of plants that had storage, it forecast cost reductions of 40 percent or greater. These cost reductions

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[18] Center for Climate and Energy Solutions, Solar Power factsheet, http://www.c2es.org/technology/factsheet/solar (accessed February 22, 2013).

[19] Go Solar California, http://www.californiasolarstatistics.ca.gov/# (accessed February 22, 2013).

[20] 2011 dollars. Costs include construction, operation and maintenance, fuel and decommission over 60 years normalized to 0.5 trillion kWh.

[21] James Conca, "The Naked Cost of Energy – Stripping away Financing and Subsidies," *Forbes,* June 15, 2012, http://www.forbes.com/sites/jamesconca/2012/06/15/the-naked-cost-of-energy-stripping-away-financing-and-subsidies (accessed February 22, 2013).

[22] Paul Denholm, (solar thermal forecasting & modeling analyst at NREL) "Tradeoffs and Synergies between CSP and PV at High Grid Penetration." PowerPoint presentation on July 5, 2011.

would come from efficiency improvements by moving from the 133 MW plant facilities at Ivanpah to larger facilities for future projects, and to increasing the capacity factor (how much power a plant can produce annually) by hybridizing or adding storage.

Growth Issues

In the first three quarters of 2012, solar power grew more than in the entire year of 2011,[23] and the history of growth in both distributed and concentrated solar systems suggested that this pattern would continue. However, the challenges included the uncertain future of government incentives and subsidies, as well as the growth of issues concerning the allocaton of lands for development. The BrightSource project, like other large-scale facilities for renewable power, raised new problems for energy companies and for organizations concerned with environmental quality and land values. Large amounts of land—most of it publicly owned, especially in the western United States—were inviting candidates for the development of large solar or wind projects. Not only would these require concentrated primary facilities, they might need transmission lines to connect them to the power grid. Those uses might rouse objections from groups with special fondness for the visual beauty of an area, the biological diversity of its ecosystem, or the endangered species it may contain. Environmental organizations might insist on a comparison of the benefits of the new renewable power against the costs they perceive in the quality of the land. For all these reasons, some investors felt that higher risks might be associated with such projects.

In addition, a critical element in the economics of renewable energy sources was the need for entrants to secure Purchase Power Agreements (PPAs). By 2012, most utilities had executed sufficient renewable PPAs to meet their Renewable Portfolio Standards (RPS) requirements. Competition for what few PPAs were left was fierce. Solar thermal had to compete against other resources like solar PV and wind for these PPA, as RPSs did not specify allocations among the various sources, meaning utilities could choose whichever renewable was cheaper. Note that in some states, like Arizona and Colorado, the utilities were also buying and owning renewable projects to meet RPS. Either way, most utilities had filled their RPS-created buckets. In addition, most of the utilities subject to RPS laws had been signing PPAs for years, since the mid- to late-2000s.

BrightSource Financing

In April 2011, BrightSource won a $1.6 billion loan guarantee from the Department of Energy to help reduce the financing costs of its solar power projects. According to Woolard, at the beginning of 2013, the Ivanpah project was on budget, on schedule, and would be fully operational by mid-year as planned. He said BrightSource would be able to pay back taxpayers with interest. BrightSource also had private investment of over $615 million, including from Alstrom, Google, NRG Solar, Chevron and BP.[24] Woolard said the logical commercial size for Ivanpah was 200 megawatts or greater for each facility; but he also pointed out that owing to the

[23] "Banner Year Expected for U.S. Solar, Supplies 1 Million Homes," SustainableBusiness.com, December 12, 2012, http://www.sustainablebusiness.com/index.cfm/go/news.display/id/24361 (accessed February 22, 2013).
[24] "BrightSource Raises More than $80 Million of Additional Equity Financing," BrightSource Press Release, October 24, 2012, http://www.brightsourceenergy.com/brightsource-energy-raises-more-than-80-million-of-additional-equity-financing (accessed February 22, 2013).

realities of project financing and the risk profile of the debt and equity markets, "your first plant is easier to build smaller. So in 2006, the Ivanpah plan for configuration was: 100 megawatts, 100 megawatts and 200 megawatts, as you went from the front to the back of the site. We had PPAs and contracts that mirrored that plan."

IVANPAH

As noted in the Introduction, BrightSource began construction of Ivanpah, located in California's Mojave Desert, in 2010 and had a completion date of 2013. It was the company's first commercial scale solar power plant, with 392 MW of electricity, making it the largest solar thermal power plant in the world. It would reach 140,000 homes during peak hours, and BrightSource had signed contracts with utilities PG&E and Southern California Edison for the plant's electricity. Ivanpah was located on 3,600 acres of federal land, granted by the U.S. Bureau of Land Management. Google, NRG Solar and BrightSource were equity investors.

Ivanpah would employ 170,000 low impact heliostats—software-controlled mirrors that tilted with the sun's rays and reflected the sunlight to a boiler atop a tower. (See **Exhibit 6** for a picture of Ivanpah and the heliostats.) When the concentrated sunlight hit the boiler's pipes, it would heat the water to create superheated steam. That steam would be piped from the boiler to a conventional steam turbine to produce electricity.

BrightSource also used the new technology of "dry-cooling," which allowed a thermal solar plant to reduce water usage by more than 90 percent. Other solar thermal technologies used a "wet-cooling system." Dry-cooling addressed a major concern of environmental groups that solar plants diverted large amounts of water away from the ecosystem. If cooling could be achieved without that water level demand, it could serve to simplify the permitting process for a new power plant. However, dry-cooling systems required higher capital costs and could lower plant efficiency.

According to BrightSource, operating Ivanpah would mean that more than 400,000 tons of carbon dioxide equivalence in emissions would be avoided per year—the equivalent of taking 70,000 cars off the road each year. The company also said Ivanpah would cut major air pollutants by 85 percent compared to a new natural gas fired power plant.

Choosing the Site

In looking for a "boring site" for the new power plant, BrightSource found Ivanpah, which Woolard said met most of the criteria BrightSource was looking for: "It was flat, it was near transmission lines, it was near Highway 15—right out the back of a casino and next to a 36-hole golf course—and had enough contiguous land to make it commercially feasible to build a power plant there. It was also had very little wildlife, which was important for local environmental issues." BrightSource then began a dialogue with the utilities, primarily PG&E, which had also been looking at Ivanpah as a potential site.

The Process

Woolard said the next step was submitting an application to acquire the right to use federal land for the project. Following that was site selection, which, once finished, led the way to the start of negotiations with the Bureau of Land Management, the U.S. Fish and Wildlife Service (FWS), and the California Energy Commission (CEC), as well as subsequent conversations with possible utility customers. The process next required a hearing before the California Energy Commission to get the necessary permits for the project. Public inputs came from interested parties, including representatives of environmental and other organizations. (See **Exhibit 7** for list of intervenors in the certification process.) Woolard said: "One of the interesting things about Ivanpah was that it was what some people call 'first out of the foxhole.' It was the first large scale permitting effort on public land."

Environmental Issues

Once BrightSource had the permits, it began collecting data on the site's culture, biology and anthropology, and developing studies to determine the best way to build the plant. BrightSource knew the area was a habitat for the desert tortoise, a threatened species under the Endangered Species Act (ESA). According to Woolard, the site selected was not a very good tortoise habitat, but many environmental groups disagreed, and tried to persuade the Bureau of Land Management and the California Energy Commission to stop BrightSource from building Ivanpah on that land. Both the Sierra Club and Defenders of Wildlife had additional meetings directly with BrightSource.

As was noted in the introduction, the FWS was required to decide what number of tortoise "takings," including risks related to translocation occurring during construction, would violate the terms of the Endangered Species Act. To protect the tortoises, BrightSource made several concessions to environmental groups and government agencies early on in the process, including shrinking the size of the plants by 2 percent (without significantly reducing the project's output.[25]) Woolard explained that the original footprint or configuration had been two 100 megawatt facilities and one 200 MW facility toward the back of the site to the north. But the tortoise population was more concentrated toward the back, so BrightSource began discussions with environmental groups about changing the footprint of the back of the site and moving it to the front. It also involved taking tortoises that were on the far end of the site to make accommodations for rare plants in the area. Woolard said ultimately the three facilities ended up being 126 MW, 133 MW, and 133 MW as a result of discussions between BrightSource and the Bureau of Land Management.

In describing the negotiations involving all the environmental groups, Woolard said: "Eighty percent of the groups were constructive and thoughtful and reasonable and you'd say, 'Okay, look, let's work with something, we hear you, let's sit down, let's talk.' They were very pragmatic through the process. But other groups were not open to discussions and in 2013 were still intervening with lawsuits."

[25] Julie Cart, "Saving Desert Tortoise is a Costly Hurdle for Solar Projects," *Los Angeles Times,* March 4, 2012, http://www.latimes.com/news/local/la-me-solar-tortoise-20120304,0,6145488.story (accessed July 20, 2013).

Defenders of Wildlife's Delfino said that Ivanpah, especially unit three at the back, was just not a good site. "We offered up alternatives for BrightSource, but the company was not interested in moving or making any changes. We think that if they brought the site closer to the highway it would be much better for the tortoises, but they felt no pressure to do so from the Bureau of Land Management. It was a project that was very political." BrightSource spokespersons asserted that their consulting biologists had disagreed with Defenders of Wildlife's claim that moving toward the highway would benefit the tortoise population.

Delfino said her organization was trying to find a balance between mitigating climate change and protecting animals and plants. "We are spending huge amounts of time to keep the renewable industry moving forward while not completely tanking the wildlife population in the process. We need to have this type of development, and we need to figure out a way to site it in the most strategic way possible. We have to figure out a more proactive approach of directed development."

Mike Brune, the executive director of the Sierra Club agreed, and said that with respect to the more general issue of land values versus renewable energy projects: "We should literally start to mark areas on the map so that these projects are what we call 'smart from the start' and are being located in ways that minimize the disruption to wildlife or aesthetic values or recreational opportunities—and are still viable economically in terms of producing significant amounts of clean energy."

Overall, Brune described the solution as "less than ideal," but reported that neither his organization nor Defenders of Wildlife would block the project through litigation. He said that the Sierra Club did not come to that decision easily, as there were differences of opinions between Sierra Club chapters in different locations.

Based on biological estimates, the U.S. Fish and Wildlife Service issued BrightSource a permit to move only 38 adult tortoises, with an acceptable level of accidental deaths of tortoises of three a year during construction.[26] If either of these numbers were exceeded, Ivanpah could be shut down.

As construction moved forward, the number of tortoises discovered kept rising. BrightSource responded by placing as many as 150 biologists on the site to care for the tortoises and move them to nearby nurseries, with the plan to return them to their natural habitat yet far enough from the plant to keep them out of danger. BrightSource spent about $22 million on these projects during that time. BrightSource also agreed to install fencing to prevent relocated tortoises from returning to the plant site and entering a potentially dangerous situation. The 50 miles of fencing cost $2.5 million.

By February 2011, it became clear that the tortoise numbers were much higher than allowed by the permit, and in April construction on parts of units two and three of Ivanpah was suspended by federal and state agencies pending a new biological assessment. The construction suspension lasted only three months but during the deliberation period, the Fish and Wildlife Service

[26] Julie Cart, "Saving Desert Tortoise is a Costly Hurdle for Solar Projects," *Los Angeles Times*, March 4, 2012, http://www.latimes.com/news/local/la-me-solar-tortoise-20120304,0,6145488.story (accessed July 20, 2013).

increased the permitted "taking" of tortoises to 1,200. (As mentioned earlier, BrightSource said the number of tortoises found and relocated or moved into BrightSource nurseries by early 2013 was 172.) Woolard said BrightSource had taken other steps to mitigate environmental concerns through its low impact design and minimal use of water. "That is something where we set the tone for the whole industry. We were the first to really dive deep into dry-cooling and using very little water."

But Woolard said the environmental groups were not the only stakeholders in the debate. He stated:

> We had to then go back to PG&E and others and say, "Look, we had 100 megawatt contract and a 200 megawatt contract and now we are talking about changing the contract size. This is really complicated stuff. You have got commercial negotiations interfacing with environmental negotiations, if you will, and you can't just do something without involving all the other decisions that are affected: transmission sizing, the size of the contract itself. So ultimately the three facilities ended up being 126 MW, 133 MW, and 133 MW."

Distributed versus Centralized Debate

The Sierra Club's Brune said there was a need to provide as much renewable energy as possible and as quickly as possible. His preference for getting there was: first, through energy efficiency; second, through distributed solar; and third, through large concentrated facilities like Ivanpah:

> Approving one project of 392 megawatts that takes a couple years to build is an effective way to bring on a lot of clean energy pretty fast if you compare that to thousands and thousands of homes doing distributed energy. I think a decent argument could be made that we do need some of these big facilities. What we are trying to do is get to a point where it is not an either or, but that we are putting more muscle into the distributed part. So that is where we are putting our focus, but we do think that we need both.

But Woolard said: "At BrightSource we have done some analysis on how much solar rooftop can do, and we think that if you put solar on every single south-facing rooftop in the entire country you could handle 10 percent of the climate problem."

BRIGHTSOURCE'S NEW TECHNOLOGY

Since a solar power plant's energy generation is intermittent, there had to be another source to supply power when utilities needed more. These backup sources were usually from fossil fuel. In the Ivanpah case, the backup was a natural gas plant that was expensive and required to sit idle much of the time because of PPA limitations. But for future projects, BrightSource would use an economically viable and technologically feasible thermal storage system for energy created by the sun's rays during the day. Woolard said, "I think it is one of the real key long-term positive design attributes of solar thermal technology." This was especially useful because the peak hours of the air conditioning load had been advanced from 4 to 6 p.m. to 5 to 7 p.m. because the new inputs of PV solar to the grid had delayed the period of maximum demand and price. Woolard explained that if BrightSource needed to generate more heat, say 20 percent more, to meet that peak hour demand, it needed to build a boiler that was 20 percent larger. Eighty percent of that went as steam on the direct path through the turbine, as with previous technology, but the extra 20 percent of Btu generation from the boiler would go through a heat exchanger where on the ground there was a big tank of molten salt. The salt was heated up to 550 degrees centigrade, which gave it heat retention properties, allowing BrightSource to dispatch that heat and turn it back into steam whenever it was the most advantageous. (See **Exhibit 8** for diagram of CSP plant with thermal storage.)

Thermal storage technology also made the plant vastly more efficient. The equipment that made electricity from steam was the most expensive part, but it could run almost twice as many hours as plants without storage technology. Using storage technology would allow BrightSource to fetch higher prices because it could charge utilities more for electricity dispatched during peak hours.

Thermal storage technology was also more economical. Woolard said it was about one-fifth the cost of electrical storage: "You will hear a lot of people talk about electrical storage as really, really important to enable renewables. It is. It is just really expensive. Thermal storage is about a fifth the cost because you are essentially heating up an insulated thermos versus a thermochemical battery. The thermos costs pennies versus expensive electrochemical storage."

Woolard said BrightSource chose not to use its new thermal storage system at Ivanpah because "it is harder and riskier from a project financing perspective. So you have got to overlay what is financeable with your new design technologies. So we chose not to use storage at Ivanpah, but we are starting to integrate thermal storage with molten salts in many of our future plants."

Other BrightSource Solar Projects

Before Ivanpah, BrightSource built two projects featuring its solar thermal technology. Its first project was the 6 MWth (megawatt-thermal) Solar Energy Development Center (SEDC) in the Negev desert in Israel. Operational since 2008, the demonstration facility produced the world's highest temperature and pressure solar steam. The second project was the 29 MWth Chevron/BrightSource Solar-to-Steam Demonstration Facility in Fresno County, California. Operational since 2011, it was the world's largest solar thermal enhanced oil recovery demonstration facility. It was built for Chevron to demonstrate solar thermal technology's ability to cost-effectively support enhanced oil recovery efforts in California and around the world. Two other projects (Rio Mesa, located on private land and scheduled to supply Los Angeles, and Hidden Hills, a solar power plant in Inyo County) were slated for review by the California Energy Commission, but BrightSource suspended the permit applications for both.

Another project moving forward was the $2.6 billion 500 MW plant at Palen in Riverside County, California. Woolard explained that BrightSource bought Palen in July of 2012 from Solar Trust of America when the latter went bankrupt: "It was a solar thermal project and then it was acquired by a PV firm, after which both companies went bankrupt. So we acquired it ─ a history of that tells much about the challenges facing solar thermal and the photovoltaic industry over the last few years. But at 500 MW, it starts to be at a size and scale that can make a difference in climate change." The plan for Palen was to construct a solar tower plant that could accomplish that. So BrightSource partnered with Abengoa, a Spanish multinational company, to jointly develop, build and operate the 500 MW Palen Solar Electric Generating System. As partners, the two companies would work together to permit and finance Palen. Abengoa would build the plants as the Engineering, Procurement and Construction contractor, and would lead the operation and maintenance (O&M) of the plants once online. BrightSource would provide the solar field technology and plant design. Like Ivanpah, the Palen CSP facility would not have a molten salt storage capacity.

Looking Abroad

BrightSource was looking abroad as well. Its first commercial scale international effort would be Ashalim, a 121 MW plant in southwestern Israel, scheduled to start construction in 2014. It was also making advances in China carrying out negotiations with several leading Chinese power producers for several gigawatts of power. Woolard pointed out that one big difference between the U.S. and China was that the U.S. was very balkanized in the way it handled transmissions, but China could build new lines very quickly: "Once China actually decided to build them they could execute fairly quickly. It takes a year or two to build a new transmission line in China. It takes about that to build one in Texas, twice that to build one anywhere else in the U.S. outside of California, and it takes about 10 to 15 years to build one in California."

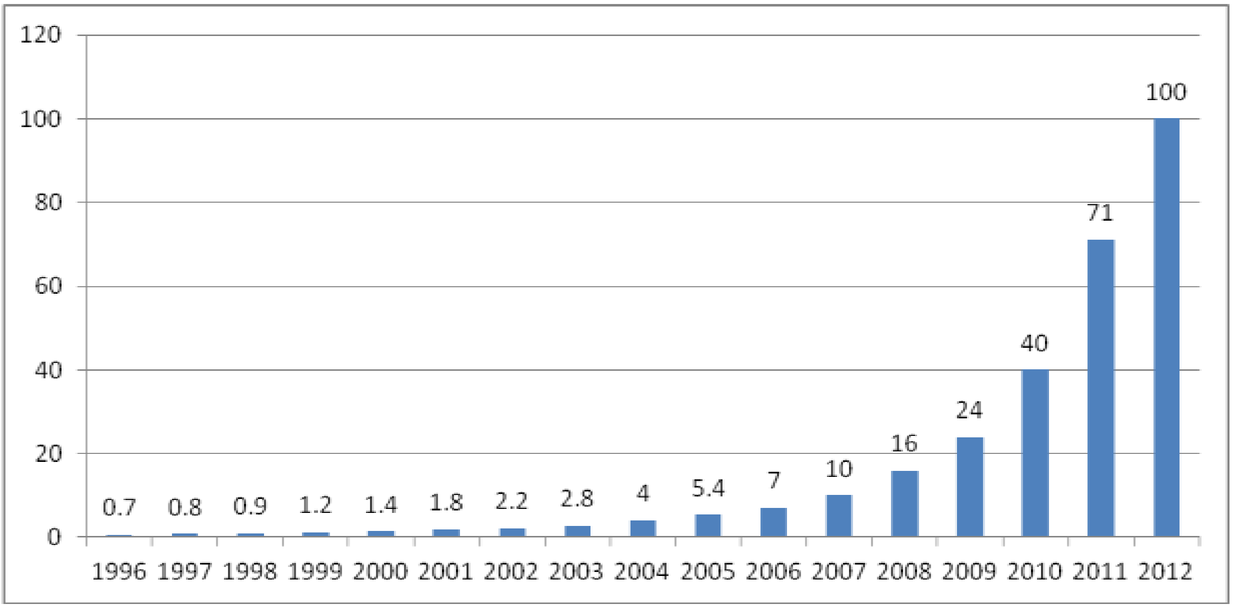
CONCLUSION

In January 2013 BrightSource celebrated a milestone. The company had just installed the 100,000th heliostat at Ivanpah.

Some environmental groups had presented challenges to the project, but the two most active ones had decided against litigation. Woolard had expended time and financial resources to deal with the objections, and left the effort behind without regrets but with some long-range policy concerns. Here is how he expressed some views about future projects, considering the challenges involved in his Ivanpah effort to produce renewable energy in the interest of climate stability:

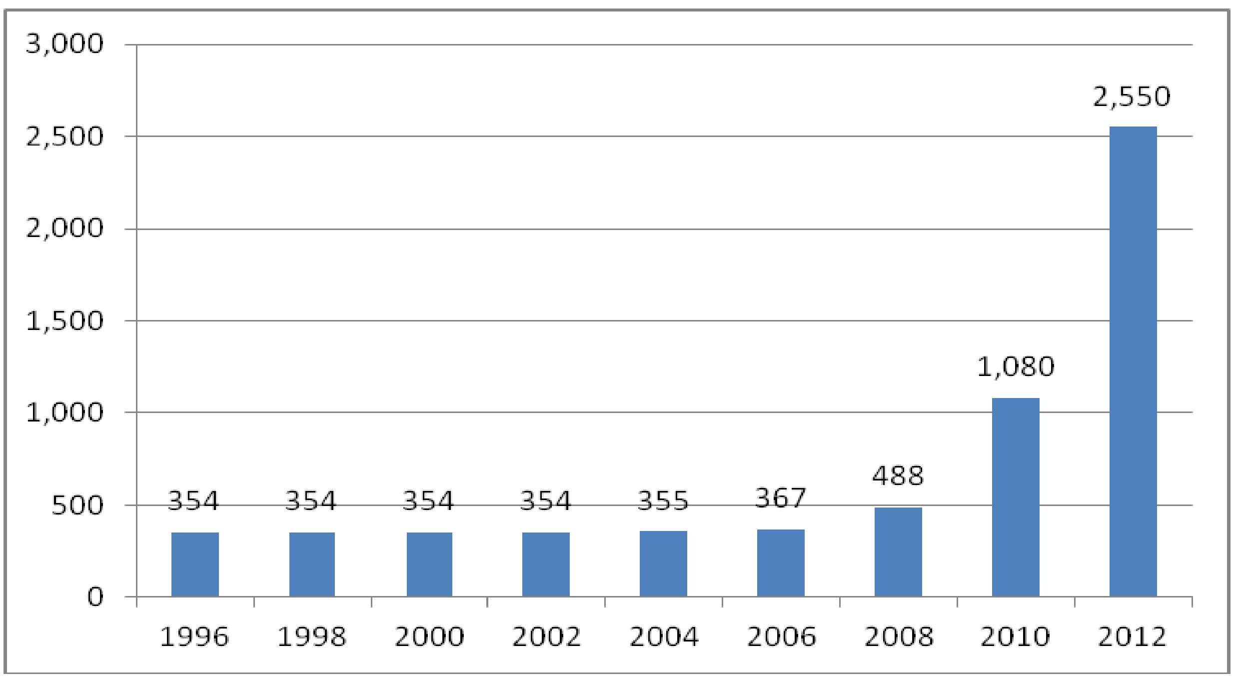
> How can you get through this gauntlet of the permitting process and still emerge with a project that can work? If Ivanpah was hard to do then we are in trouble because Ivanpah was not very good quality land from a habitat perspective. If we turn the southwestern U.S. into a dust bowl through climate change what have we won? How do you reconcile that tension with the habitat on site? How do you resolve that debate? To me that is a very interesting discussion that needs to happen.

Exhibit 1
Solar Photovoltaics (PV) World Capacity 1996-2012
In Gigawatts



Source: REN21, "Renewables 2012: Global Status Report," http://ren21.net.

Concentrated Solar Thermal Power (CSP) Total World Capacity 1996-2012
In Megawatts



Source: REN21, "Renewables 2012: Global Status Report," http://ren21.net.

Exhibit 2
U.S. Sources of Electricity Generation by Source 2005-2014

	Share of Total Generation						
	Coal	Natural Gas	Petroleum	Nuclear	Hydro Power	Renewable Energy	Other
2005	49.6%	18.8%	3.0%	19.3%	6.5%	2.2%	0.6%
2006	49.0%	20.1%	1.6%	19.4%	7.0%	2.4%	0.7%
2007	48.5%	21.6%	1.6%	19.4%	5.8%	2.5%	0.6%
2008	48.2%	21.4%	1.1%	19.6%	6.0%	3.1%	0.6%
2009	44.4%	23.3%	1.0%	20.2%	6.8%	3.7%	0.6%
2010	44.8%	23.9%	0.9%	19.6%	6.2%	4.1%	0.6%
2011	42.3%	24.7%	0.7%	19.3%	7.6%	4.7%	0.6%
2012	**37.6%**	**30.3%**	**0.6%**	**18.9%**	**6.7%**	**5.4%**	**0.6%**
2013(e)	39.0%	27.9%	0.6%	19.2%	6.8%	6.0%	0.6%
2014(e)	39.6%	27.5%	0.6%	19.3%	6.5%	6.0%	0.6%

Source: EIA, http://www.eia.gov/forecasts/steo/report/renew_co2.cfm.

U.S. Renewable Power Consumption (all uses) 2012

Hydroelectric Power	33%
Wood Biomass	24%
Wind	17%
Ethanol	13%
Waste Biomass	5.7%
Geothermal	2.8%
Solar	2.6%
Biodiesel	1%

Source: EIA, http://www.eia.gov/forecasts/steo/report/renew_co2.cfm.

Exhibit 3
U.S. Average Levelized Costs (2010 $/megawatthour) for Plants Entering Service in 2018

Plant type	Capacity factor (%)	Levelized capital cost	Fixed O&M	Variable O&M (including fuel)	Transmission investment	Total system levelized cost
Dispatchable Technologies						
Conventional Coal	85	65.7	4.1	29.2	1.2	100.1
Advanced Coal	85	84.4	6.8	30.7	1.2	123.0
Advanced Coal with CCS	85	88.4	8.8	37.2	1.2	135.5
Natural Gas-fired						
Conventional Combined Cycle	87	15.8	1.7	48.4	1.2	67.1
Advanced Combined Cycle	87	17.4	2.0	45.0	1.2	65.6
Advanced CC with CCS	87	34.0	4.1	54.1	1.2	93.4
Conventional Combustion Turbine	30	44.2	2.7	80.0	3.4	130.3
Advanced Combustion Turbine	30	30.4	2.6	68.2	3.4	104.6
Advanced Nuclear	90	83.4	11.6	12.3	1.1	108.4
Geothermal	92	76.2	12.0	0.0	1.4	89.6
Biomass	83	53.2	14.3	42.3	1.2	111.0
Non-Dispatchable Technologies						
Wind	34	70.3	13.1	0.0	3.2	86.6
Wind - Offshore	37	193.4	22.4	0.0	5.7	221.5
Solar PV[1]	25	130.4	9.9	0.0	4.0	144.3
Solar Thermal	20	214.2	41.4	0.0	5.9	261.5
Hydro[2]	52	78.1	4.1	6.1	2.0	90.3

1 Costs are expressed in terms of net AC power available to the grid for the installed capacity.
2 As modeled, hydro is assumed to have seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.
Note: These results do not include targeted tax credits such as the production or investment tax credit available for some technologies, which could significantly affect the levelized cost estimate. For example, new solar thermal and PV plants are eligible to receive a 30-percent investment tax credit on capital expenditures if placed in service before the end of 2016, and 10 percent thereafter. New wind, geothermal, biomass, hydroelectric, and landfill gas plants are eligible to receive either: (1) a $22 per MWh ($11 per MWh for technologies other than wind, geothermal and closed-loop biomass) inflation-adjusted production tax credit over the plant's first ten years of service or (2) a 30-percent investment tax credit, if placed in service before the end of 2013 (or 2012, for wind only).
Source: U.S. Energy Information Administration, Annual Energy Outlook 2013,December 2012, DOE/EIA-0383(2012)

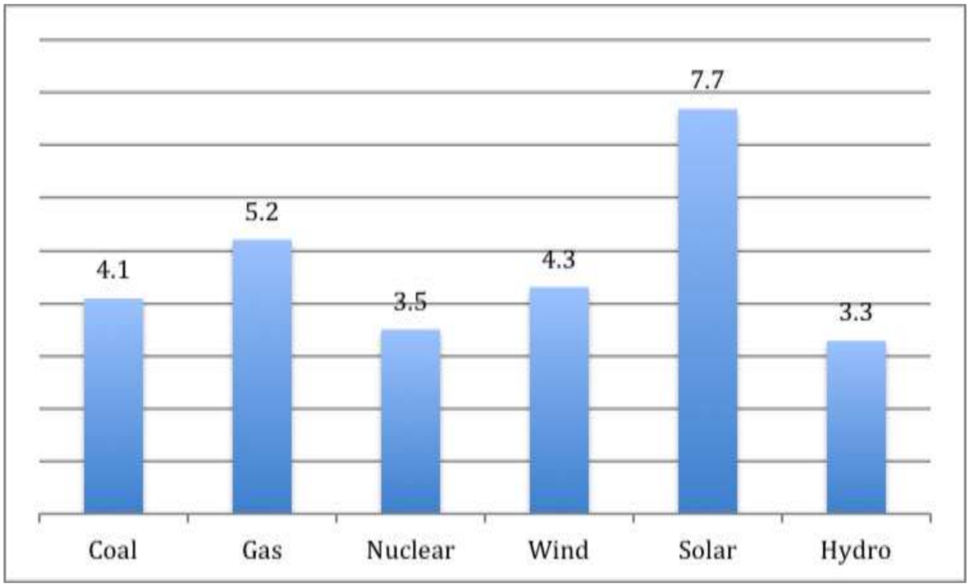
Source: EIA, Annual Energy Outlook 2013, http://www.eia.gov/forecasts/aeo/er/electricity_generation.cfm.

Exhibit 4
Solar Cost per Installed Watt
July 2012

DESCRIPTION	STATUS
Solar PV Price	$4.44/installed watt
U.S. Solar PV installed capacity	4.4 GW
Global Solar PV installed capacity	69 GW
CSP (parabolic trough) price	$5.79/installed watt
U.S. CSP installed capacity	0.507 GW[39]
Global CSP installed capacity	1.76 GW[40]

Source: Center for Climate and Energy Solutions.

Exhibit 5
Lifecycle Direct costs
Cents per kilowatt hour (kWh) (2011 $)



Note: Energy sources over 60 years normalized to 0.5 trillion kWh.
Costs include construction, operation and maintenance, fuel and decommissioning.
Source: Forbes.[27]

[27] James Conca, "The Naked Cost of Energy – Stripping away Financing and Subsidies," *Forbes*, June 15, 2012, http://www.forbes.com/sites/jamesconca/2012/06/15/the-naked-cost-of-energy-stripping-away-financing-and-subsidies (February 22, 2013).

Exhibit 6
Ivanpah Solar Thermal Plant

Source: BrightSource website.

Exhibit 7
Intervenors in the Application for Certification Process for the Ivanpah Project

1. California Unions for Reliable Energy ("CURE")
2. Western Watersheds Project
3. Sierra Club
4. Defenders of Wildlife
5. Basin and Range Watch
6. Center for Biological Diversity
7. California Native Plant Society
8. County of San Bernardino

Source: Energy Resources Conservation and Development Commission of the State of California.

Exhibit 8
CSP Plant with Storage Diagram

Source: BrightSource, http://www.brightsourceenergy.com/technology (February 22, 2013).