
T2+2™ Market Overview

# Concentrating Solar Power Technology

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While market sizes are hard to estimate, the following describes how we arrived at an estimate for the total addressable market for concentrating solar power (CSP). We estimate the market size to be approximately:

| *Market Niche Size* | | | |
|---|---|---|---|
| ***Market Size in Dollars*** | ***Growth Rate*** | ***Base Year*** | ***Detailed Basis for Estimate*** |
| $1.16 billion | n/a | 2007 | The average reported capital cost of CSP facilities is $2.77 per watt,[1]and CSP in the United States accounted for just 419 MW of power in 2007.[2] Combining these two figures, we get a total estimated capital cost of $1.16 billion spent on CSP facilities. Although we could not accurately determine a suitable growth rate, overall growth is expected to be robust, with some conservative estimates forecasting global CSP output to reach 4,000 MW by 2012.[3] |

There are two main types of CSP systems in use today: concentrating solar thermal (CST) and concentrating photovoltaic (CPV) technologies. CST systems concentrate sunlight onto a thermal conductor and use the heat produced to move an engine or turbine. These include parabolic trough, solar power towers, parabolic sterling dishes and linear fresnel systems.[4] Alternatively, CPVs concentrate solar energy onto high efficiency photovoltaic panels to directly create electricity. These systems can utilize both mirrors and lenses implemented in a broad range of sizes from small modular systems to larger commercial units.[5]

Today, CSP systems can range in size from 10 kilowatts to grid-connected applications of up to 100 megawatts. CSP technology is quite versatile, as some systems use thermal storage when it is cloudy or at night, while other systems are combined with natural gas, providing high-value, dispatchable power. These benefits, coupled with high solar conversion efficiencies, have made concentrating solar power an attractive renewable energy solution in the Southwest and in other sun-belt regions worldwide.[6]

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[1] "Energy: Renewable and Sustainable Solar." Railroad Commission of Texas web site. http://www.rrc.state.tx.us/commissioners/williams/energy/solar.php (accessed May 26, 2009).
[2] Gereffi, Gary and Kristen Dubay. "Concentrating Solar Power: Clean Energy for the Electric Grid." Center for Globalization Governance & Competitiveness, 2008. http://www.cggc.duke.edu/environment/climatesolutions/greeneconomy_Ch4_ConcentratingSolarPower.pdf (accessed on May 26, 2009).
[3] Ummel, Kevin and David Wheeler. "Desert Power: The Economics of Solar Thermal Electricity for Europe, North Africa, and the Middle East." Center for Global Development, 2008. http://solarthermalworld.org/files/Desert%20Power.pdf?download (accessed May 26, 2009).
[4] "Concentrating Solar Power: Technology, Costs, and Markets." Greentech Media 2008 industry report. Greentech Media web site. http://www.greentechmedia.com/assets/images/Concentrating-Solar-Power-Final-Executive-Summary.pdf (accessed May 26, 2009).
[5] Ibid.
[6] Ummel, Kevin and David Wheeler. "Desert Power: The Economics of Solar Thermal Electricity for Europe, North Africa, and the Middle East." Center for Global Development, 2008. http://solarthermalworld.org/files/Desert%20Power.pdf?download (accessed May 26, 2009).

The market size and growth rate is a function of the number of people in the market and the anticipated rate of buying. As markets transition between emerging, growth, shakeout, mature, and declining, the basis for competition and the number of competitors usually changes, along with the factors influencing adoption of innovation. The number of and growth rate for customers suggests how many units might be sold.[7]

| *Our Current View on the Phase of the Market* | |
|---|---|
| ***Today*** | ***Trend*** |
| Growth | Growth |

The market appears to be in a growth phase as CSP technology is well understood and is mature enough to grow exponentially to meet the rising renewable demand expected from numerous projects currently under construction in the US and Europe.[8] Furthermore, the U.S. Department of Energy estimates that robust growth is likely in CSP technology as up to 20 gigawatts of concentrating solar power capacity will be installed worldwide by 2020.[9]

Markets can also be described in terms of the basis for competition (best technological performance, best value or the price/performance tradeoff that best matches the end-users' preferences, lowest cost, or best availability or the ability to get the product quickly). This dimension helps to define the context in which a commercialization strategy must be developed.

| *Basis for Competition in the Arena* | |
|---|---|
| ***Today*** | ***Trend*** |
| Best Value | Best Value |

The concentrating solar power market appears to have value-based competition, as a fundamental driver of CSP research and development (R&D) is to reduce cost, increase efficiency, and demonstrate improved reliability.[10] Concentrating solar power can also utilize similar equipment and technologies found in conventional power stations, thereby making CSP a more cost-effective solar solution for large-scale energy generation.[11] This

[7] For a detailed discussion of the "innovativeness dimension," see Everett M. Rogers, *Diffusion of Innovations*, 4th ed. (New York: Free Press, 1995). For further readings related to market phases and innovation, see also James Utterback, *Mastering the Dynamics of Innovation* (Boston: Harvard Business School Press, 1996) and Vijay K. Jolly, *Commercializing New Technologies: Getting from Mind to Market* (Boston: Harvard Business School Press, 1997).

[8] "Concentrating Solar Power: Global Outlook 09." 2009 Greenpeace web site. http://www.greenpeace.org/raw/content/international/press/reports/concentrating-solar-power-2009.pdf (accessed May 26, 2009).

[9] "Concentrating Solar Power." U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. http://apps1.eere.energy.gov/states/alternatives/csp.cfm (accessed May 26, 2009).

[10] "National Solar Technology Road Map: Concentrator PV." U.S. Department of Energy: Solar Energy Technologies Program. http://www1.eere.energy.gov/solar/solar_america/pdfs/41735.pdf (accessed May 26, 2009).

[11] "Concentrating Solar Power." Concentrating Solar Power web site. http://www.concentratingsolarpower.com/ (accessed May 26, 2009).

is indicative of a best value market, as cost-effective solutions lie at the intersection of price and performance.

In each market there may be stakeholders and companies with significant market share that will influence the introduction of your technology. Some organizations or companies that will likely influence the introduction of this technology are the following:

| *Examples of Major Competitors in the Arena* | | |
|---|---|---|
| ***Competitor*** | ***Relevance*** | ***Web site*** |
| Amonix | Amonix develops and manufactures concentrated solar photovoltaic systems that utilize multi-junction solar cells and are able to track to the sun for improved solar energy conversion.[12] | http://www.amonix.com |
| Concentrix solar | Concentrix Solar is a Germany-based company that has developed concentrator PV technologies for commercial and industrial applications.[13] | http://www.concentrix-solar.de/technology/?L=1 |
| SolFocus | SolFocus develops and manufactures concentrator photovoltaic (CPV) technology that when integrated, can greatly improve the efficiency of solar cell energy conversion.[14] | http://www.solfocus.com/ |
| Acciona | Acciona is a Spain-based renewable energy company that built the largest CSP plant in 18 years in Nevada called Solar One.[15] | http://www.acciona-energia.com/default.asp?x=00020204 |
| Isofoton | Isofoton is Spain-based solar energy company that utilizes photovoltaic and solar thermal technology.[16] | http://www.isofoton.com/energy-solutions/developments/concentration-systems/ |

| *Examples of Key Stakeholders or Networking Channels with Contact Information* | | |
|---|---|---|
| ***Stakeholder*** | ***Relevance*** | ***Contact Information*** |
| Solar Energy Industries Association (SEIA) | SEIA is a national trade organization focusing on promoting the advancement of solar energy through outreach and education. The SEIA web site provides detailed industry information through relevant news and research coverage, solar jobs and federal and state issues | 805 15th Street, NW Suite 510<br>Washington, DC 20005<br>Tel: 202 682-0556<br><br>http://www.seia.org |

[12] "About Amonix." Amonix web site. http://www.amonix.com/about_amonix.html (accessed May 26, 2009).
[13] "Technology Page." Concentrix Solar web site. http://www.concentrix-solar.de/technology/?L=1 (accessed May 26, 2009).
[14] "About Us." SolFocus web site. http://www.solfocus.com/ (accessed May 26, 2009).
[15] "Solar Energy Page." Acciona web site. http://www.acciona-energia.com/default.asp?x=00020204 (accessed May 26, 2009).
[16] "Our History." Isofoton web site. http://www.isofoton.com/solar-energy/get-to-know-us/our-history/ (accessed May 26, 2009).

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| | pertaining to the development of solar technology in the United States.[17] | |
| American Solar Energy Society (ASES) | ASES is a non-profit organization created to advancing solar energy use, education and technological development.[18] | 2400 Central Ave, Suite A<br>Boulder, Colorado 80301<br>Tel: 303-443-3130<br>E-mail: ases@ases.org<br><br>http://www.ases.org/ |
| Solar Electric Power Association (SEPA) | SEPA is a trade organization that has a member base of over 560 utility and solar industry members. The association fosters business development and provides useful news and information regarding policies and technological developments in the solar industry.[19] | 1220 19th Street NW, Suite 401<br>Washington, DC 20036<br>Tel: 202-857-0898<br>E-mail: info@solarelectricpower.org<br><br>http://www.solarelectricpower.org |
| CPV Consortium | Formed in late 2008, the CPV Consortium is a global solar industry association established to support the development and success of the concentrator photovoltaics industry.[20] | P.O. Box 60265<br>Sunnyvale, CA 94088-0265<br>Tel: 650-623-7302<br>E-mail: info@cpvconsortium.org<br><br>http://www.cpvconsortium.org/ |
| International Solar Energy Society (ISES) | ISES is Germany-based a non-governmental organization, present in over 50 countries. The Society seeks to advance renewable energy technology through worldwide education and implementation. Members include government, researchers, industry and private individuals. It is based in Germany.[21] | Villa Tannheim<br>Wiesentalstr. 50<br>79115 Freiburg<br>Germany<br>Tel: +49-761-5906-0<br><br>http://www.ises.org/ |

Users' abilities to buy the technologies they want are constrained by relevant government regulations and by relevant industrial standards and certification requirements. These requirements indicate test and evaluation procedures that can speed market acceptance if incorporated into concurrent engineering.

| *Examples of Regulations, Standards, and Certifications* | | |
|---|---|---|
| ***Identifier and Promulgator*** | ***Description*** | ***Comments*** |

[17] "About SEIA." Solar Energy Industries Association web site. http://www.seia.org/cs/about_SEIA (accessed May 26, 2009).
[18] "About the American Solar Energy Society." American Solar Energy Society web site. http://www.ases.org (accessed May 26, 2009).
[19] "About SEPA." Solar Electric Power Association web site. http://www.solarelectricpower.org (accessed May 26, 2009).
[20] "Home Page." CPV web site. http://www.cpvconsortium.org/ (accessed May 26, 2009).
[21] "About Us." International Solar Energy Society web site. http://www.ises.org/ (accessed May 27, 2009).

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| IEC 62108 Ed. 1.0 b:2007<br>International Electrotechnical Commission | Concentrator photovoltaic (CPV) modules and assemblies - Design qualification and type approval | IEC 62108 Ed. 1.0 b:2007 specifies the minimum design requirements of CPV modules and assemblies applicable to long-term, outdoor implementation.[22] |
| BSR/IEEE 1611-200x Institute of Electrical and Electronics Engineers | Recommended Practice for Characterizing Solar Tracker Controllers Used for Solar Electric Systems (DRAFT STANDARD) | This draft standard seeks to develop recommended specifiers for the functional characterization of all solar tracking controls including those used in CSP systems.[23] |
| ASTM E744-07<br>ASTM International | Standard Practice for Evaluating Solar Absorptive Materials for Thermal Applications | ASTM E744-07 details the testing methodology for the evaluation of absorptive materials found in flat plate or concentrating solar collectors.[24] |

Entry barriers are obstacles that remove customer segments from the market for some period of time. They limit the size of the addressable market in general or the market share that can be captured. These barriers must be overcome or avoided to have a successful market entry. Our work to date suggests the following entry barriers may prevent customer segments from buying this type of technology for some period of time.

| *Market Entry Barriers* | |
|---|---|
| ***Name of Barrier*** | ***Description/Why*** |
| ***Capital Intensive Development Requirements*** | Although cheaper in the long run, concentrating solar power facilities face higher upfront capital costs than fossil-fueled power plants; Over a decade, an overall large scale project cost is estimated to be approximately $12 to $28 billion.[25] These high capital costs will likely pose a significant barrier to new market entry, particularly for firms who lack adequate funding or access to government subsidies or support. |
| ***Geographical Constraints*** | To be most effective, CSP facilities must be placed in areas with high solar densities and low cloud coverage. This greatly increases the complexity and cost of a facility, and for this reason the Southwest of the United States is the only viable domestic region for CSP systems.[26] This geographical constraint could pose a real problem for firms looking to enter the market who may not be located or have access to suitable site for developing or implementing CSP facilities. |

[22] "Detail Results." NSSN Search Engine for Standards web site, http://www.nssn.org/search/DetailResults.aspx?docid=572384&selnode= (accessed May 26, 2009).
[23] "Detail Results." NSSN Search Engine for Standards web site, http://www.nssn.org/search/DetailResults.aspx?docid=41966&selnode= (accessed May 26, 2009).
[24] "Detail Results." NSSN Search Engine for Standards web site, http://www.nssn.org/search/DetailResults.aspx?docid=562037&selnode= (accessed May 27, 2009).
[25] Ummel, Kevin and David Wheeler. "Desert Power: The Economics of Solar Thermal Electricity for Europe, North Africa, and the Middle East." Center for Global Development, 2008. http://solarthermalworld.org/files/Desert%20Power.pdf?download (accessed May 26, 2009).
[26] "North American Non Residential Solar Power Markets." December 2007. Frost & Sullivan web site (subscription required). http://www.frost.com/ (accessed May 26, 2009).

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| ***Lack of Electrical Transmission Line Infrastructure*** | The lack of adequate electrical transmission lines is one of the biggest roadblocks facing further implementation of CSP facilities.[27] Development of new lines can also be highly problematic, as they may run through state parks or other environmentally sensitive lands and face staunch opposition.[28] The problem of transporting power generated proposed CSP facilities will likely be a major hurdle that new firms and CSP projects will ultimately have to successfully deal with in order to install new facilities. |

The development of concentrating solar power facilities can be severely constrained by geography, as they can only be implemented in locations without significant cloud cover.[29] Furthermore, the nature of solar energy is periodic and not totally reliable, thus making its use in conjunction with modern grids problematic.[30]

Market drivers are forces that strengthen or weaken the importance of end-user needs over time. Practice level drivers are micro-economic; they affect the end-user directly. They influence the selection of substitutable goods and thus affect market share. Arena level drivers affect the organizations and industrial sectors in which the end-users work. They influence the overall demand for goods like this technology and its substitutes. They affect when and how much of the total addressable market is actually going to be in the market and buying.

| *Market Drivers* | |
|---|---|
| ***Name of Driver*** | ***Why Significant*** |
| ***Growing Environmental Concerns*** | Growing public awareness of air pollution and greenhouse gas emission has greatly increased the deployment of renewable energy technologies. These increased environmental concerns have become an important factor in further investment and deployment of solar power technologies. This is particularly true for CSP systems as one square meter of concentrator surface can avoid annual emissions of 200 to 300 kg of carbon dioxide.[31] |
| ***Beneficial Similarities to Traditional Fossil Fuel Power Plants*** | Concentrating solar power systems' resemblance to traditional fossil fuel based power plants is a major competitive advantage for the CSP industry. CSP systems share similar equipment and processes with conventional fossil fuel combustion technology. This enables easier implementation and improves cost-effectiveness. [32] These similarities will likely drive growth of the market as the efficacy of many of these systems and processes are well-tested and mature. |

[27] Moran, Susan; J. McKinnon,. "Hot times for solar energy: utility-scale solar thermal power may be poised for the big time.(concentrating solar power)." 2008. *World Watch*. HighBeam web site (subscription required). http://www.highbeam.com (accessed May 26, 2009).
[28] "All About: Concentrated Solar Power (CSP)." November, 2007. CNN web site. http://www.cnn.com/2007/WORLD/asiapcf/11/12/eco.about.csp/#cnnSTCText (accessed May 27, 2009).
[29] "Research and Markets Adds Report: 'Concentrated Solar Power Market Potential'." 2008 *Wireless News*. HighBeam web site (subscription required). http://www.highbeam.com (accessed May 26, 2009).
[30] "Concentrating Solar Power: Technology, Costs, and Markets." Greentech Media 2008 industry report. Greentech web site. http://www.greentechmedia.com/assets/images/Concentrating-Solar-Power-Final-Executive-Summary.pdf (accessed May 26, 2009).
[31] "North American Non Residential Solar Power Markets." December 2007. Frost & Sullivan web site (subscription required). http://www.frost.com/ (accessed May 26, 2009).
[32] "Concentrating Solar Power." Concentrating Solar Power web site. http://www.concentratingsolarpower.com/ (accessed May 26, 2009).

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| ***Widely Available Sunlight*** | Solar radiation is highly abundant and the total available resources are thousands of times greater than the electric capacity consumed globally each year.[33] According to some estimates, a 92 square mile CSP farm in the desert could potentially meet the entire electrical demand of the United States.[34] |
| ***Alternative Benefits from Heat Production*** | Aside from clean energy production, waste heat from CSP facilities can be utilized to desalinate seawater or used for thermal cooling (air conditioning). The treatment of water can save communities billions of dollars a year, and limit the need for developing new large desalination plants.[35] These added benefits will likely further drive demand for CSP technologies, as they can potentially help to mitigate the growing problem of water scarcity. |

Overall, global investment in concentrating solar power is increasing, technology costs are decreasing, and governments such as the U.S. and others are requiring more clean energy generation.[36] When combined, these factors will likely play a significant role in furthering the demand for CSP systems and the growth of the CSP market in the long term.

Here is some additional data and sources that can help you better understand the market.

| *Name* | *Description* |
|---|---|
| National Solar Technology Roadmap: Concentrator PV | The National Solar Roadmap provides a background on concentrator PV systems, and the industry and governmental goals for furthering concentrator PV technology.<br><br>For more information please see the below URL:<br>http://www1.eere.energy.gov/solar/solar_america/pdfs/41735.pdf |
| US Department of Energy Solar Energy Technologies Program: Concentrating Solar Power | The DOE's Solar Energy Technologies Program provides basic CSP information and data and is a useful resource students, educators and trainers interested in the CSP industry.<br><br>For more information please see the below URL:<br>http://www1.eere.energy.gov/solar/csp_program.html |
| IEEE Power & Energy Society | The Power & Energy Society is a specialist group of the global IEEE organization that provides reports and industry news on the electric power generation industry, which includes solar power.[37]<br><br>For more information please see the below URL:<br>http://www.ieee.org/portal/site/pes/index.jsp?pageID=pes_home |
| National Renewable Energy Laboratory (NREL) | NREL seeks to develop and advance the use of concentrating solar power technology as a viable power source in the US through partnerships with |

[33] "Concentrating Solar Power: Technology, Costs, and Markets." Greentech Media 2008 industry report. Greentech web site. http://www.greentechmedia.com/assets/images/Concentrating-Solar-Power-Final-Executive-Summary.pdf (accessed May 26, 2009).
[34] "All About: Concentrated Solar Power (CSP)." November, 2007. CNN web site. http://www.cnn.com/2007/WORLD/asiapcf/11/12/eco.about.csp/#cnnSTCText (accessed May 27, 2009).
[35] Ibid.
[36] Lacey, Stephen. "Tracking the Sun: Concentrating Solar Power Faces Bright Future." March, 2007. Renewable Energy World web site. http://www.renewableenergyworld.com/rea/news/article/2007/03/tracking-the-sun-concentrating-solar-power-faces-bright-future-47803 (accessed May 26, 2009).
[37] "About Us." IEEE Standards Association web site. http://standards.ieee.org/announcements/PRNESR.html (accessed May 26, 2009).

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| | industry, academia and research laboratories. It is a useful resource that provides a technology overview, news, and data resources regarding the concentrating solar industry.<br><br>For more information please see the below URL:<br>http://www.nrel.gov/csp/ |