



Concentrating Solar Power (CSP):

Into the Mainstream Towards a Sustainable Energy Future

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What is Concentrating Solar Power?

Concentrating solar power (CSP) technologies use mirrors to reflect and concentrate sunlight onto receivers that can achieve high temperatures. This thermal energy may then be used to produce energy by way of a steam turbine or heat engine that drives a generator. It is also feasible to store the heat in insulated containers and to use it to generate electricity at a later date – hours or even days later. CSP with thermal storage is one of the few renewable energy supply options that provides both base load power (i.e. the amount of energy needed to meet minimum customer demand) and is dispatchable (i.e. the power can be turned on or off to meet changing demand).¹

SECTION 1 Overview / Concentrating Solar Power



Solar thermal energy provides a range of benefits when considered as part of a country's or region's energy generation mix. Solar energy is the planet's most abundant sustainable energy resource. Considering the favourable geography for solar thermal energy of many of the world's developing countries, its importance as an energy resource is even more significant. Solar thermal, using a hot fluid, can be readily integrated with conventional thermodynamic cycles and power generation equipment, and with advanced emerging technology. The collection technology is largely constructed of conventional materials such as glass, steel or concrete, and as a result, no major scientific breakthroughs are necessary to continue lower-

ing the cost of solar thermal development.² An additional advantage is that, at a time when reductions to greenhouse gas emissions are being sought, (i.e. Copenhagen Accord), solar thermal may be installed in large scale installations made up of easily available, modular components.

SECTION 2 An Historical Perspective / CSP Market Developments

During the 1980's, solar electricity generation systems (SEGS) were built in California and successfully generated electricity from that time up until the present. The Federal Energy Regulatory Commission (FERC) provided fiscal incentives in the form of production tax credits and attractive time-of-day tariffs to defray the high up-front costs of these demonstration facilities. Construction time for the plants was reasonable. During the subsequent three decades, improvements were made to different aspects of the technology and many of these improvements were field tested. Operational and maintenance costs in solar thermal plants also dropped as a result of improved components and practices. The nine SEGS plants in California were constructed with private capital at a cost of \$1.2 billion. By 2005, more than 13 terawatt hours (TWh) of solar electricity had been generated on a cumulative basis from these plants with the value of those electricity sales exceeding \$2 billion.

In the early 1990's, most OECD countries, including the U.S., ceased creating conditions favourable to solar electricity generation. Deregulation in the power industry occurred on a global scale. Increased competition and a still developing green power market meant that utilities were unwilling to support projects with long term strategic value but uncompetitive short term returns.

By the mid 1990's, the industry continued to face considerable challenges but, as a result of past experiences, an improved understanding of project financing in a competitive environment was developing. In addition, other project related factors were becoming better understood, including, for instance, project permitting, regulatory regime and tender requirements. Interest in solar thermal power and CSP projects was generated in Spain and Arizona. Further, several projects supported by the Global Environment Facility (GEF) served to nurture the industry and technology in a challenging environment.

2.1 Assessing the World Bank/GEF Strategy for the Market Development of Solar Thermal Power

The GEF's engagement with CSP technology was intended to assist in the advancement of this technology under its Operational Program 7, Reducing the Long-term Costs of Low-GHG Emitting Energy Technologies. The GEF financial support would provide a boost to the deployment of this technology in developing countries during a time when both U.S. and European markets were stagnant.

In 1996 the GEF recommended high temperature solar thermal power technology as one of the renewable energy technologies that had major cost reduction potential and potentially a high demand from countries in the world's solar belt. Four solar thermal projects managed by the World Bank entered the GEF CSP portfolio with a grant volume of \$194.2 million in total:

- » Egypt Solar Thermal Hybrid Project in Kuraymat, Egypt;
- » India Solar Thermal Project in Mathania, India;
- » Mexico Hybrid Solar Thermal Project in Agua Prieta, Mexico; and
- » Morocco Integrated Solar Combined Cycle Power Project in Ain Matar, Morocco.

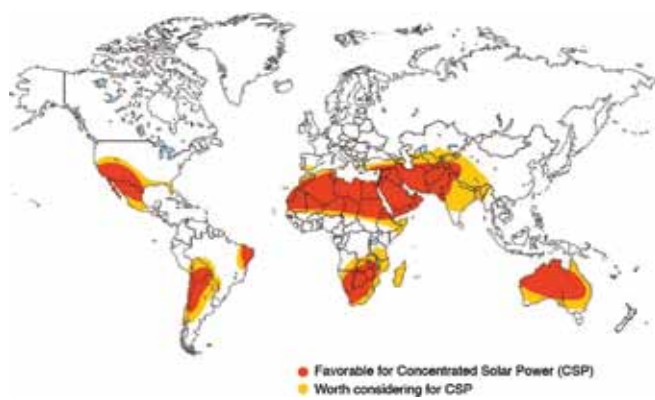
Given the limited attention that had been paid to the technology in recent years, the four GEF supported CSP projects encountered significant delays. An early assessment report of the portfolio (*Mariyappan and Andersen, 2001*) highlighted common implementation issues as the reason for delays including, for instance, power sector restructuring or difficulties in IPP projects in emerging markets.³ In its assessment report of the World Bank/GEF CSP portfolio, (*Assessment of the World Bank/GEF Strategy for the Market Development of Concentrating Solar Thermal Power, 2006*) project status by country was presented (Chapter 4.2). In each instance, the key project difficulties encountered were primarily non-technical in nature, demonstrating the critical importance of having a supportive enabling environment for investments in these new technologies. In addition, this experience demonstrated the importance of and necessity for international collaboration, donor assistance and further, domestic policy support. At the same time, project experience gained from these four initiatives continued to point to the significant potential benefits of the technology, ranging from energy security to local job creation (Approximately one half of the solar island components were manufactured by Egyptian firms for the Kuraymat project).

Notwithstanding all of these challenges and delays, the GEF and the World Bank's commitment to the CSP projects remained firm, even when the stakeholders decided that the design of the India project was too flawed to allow it to successfully move ahead.

SECTION 3 Expanding the Use of Concentrated Solar Power in Areas Suitable for CSP

The International Energy Agency has identified concentrating solar power (CSP) as being central to, “... the energy revolution because [CSP] can make the largest contribution to reducing greenhouse gas emissions.” Recent policy decisions in Europe (e.g. European Renewable Energy Directive (2009/28/EC)) and the U.S. (e.g. U.S. Department of Energy⁴) are contributing to an increase in CSP development with generating capacity expected to expand significantly over the next five years.⁵

MAP Areas physically suitable for CSP

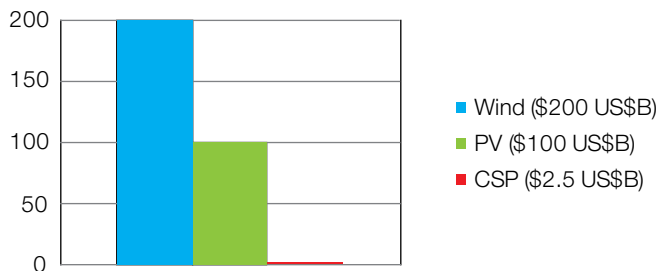


SOURCE: DLR data for EU-project REACCESS

The economic potential for CSP in desert regions is larger than the current global power demand—CSP has the potential to replace a large proportion of the current thermal power generation from fossil fuels.⁶

If the Clean Technology Fund (see Section 4.1) CSP program announced in December 2009 is successful and replicated, the global benefits will be far larger. At the end of 2008, an estimated 482 MWs were being generated in operational commercial plants and announced projects by 2008 year end were in the order of 6–7 gigawatts. Despite this growth, at the global level, Figure 1 shows that the cumulative financial investment in CSP is modest when compared to investment in other renewable energy technologies.

FIGURE 1 Cumulative Global Investment in Renewable Energy Technologies (US\$ billions)



Source: MENA CTF Investment Plan, Page 4. http://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/mna_csp_ctf_investment_plan_kd_120809.pdf

As a result of this limited investment to date, the global installed capacity of CSP remains low compared to Wind and PV (two other important new, renewable energy resources) and the costs of CSP have yet to fall to competitive levels. In other words, the cost-reduction benefits of investment in CSP have yet to be realized. The November 2009 CTF announced investment in CSP in the MENA region will nearly triple global investment in the technology with anticipated decreases in investment costs. Table 1 presents total installed capacity and cost per MWh of wind, photovoltaic and CSP.

Renewed interest in solar thermal energy projects is evident in the United States and Europe.

- » Florida’s state power and utility company (FPL) announced in 2008 new solar energy projects that include the world’s largest photovoltaic solar plant and first “hybrid” energy center, coupling solar thermal technology with an existing combined-cycle generation unit. The facility’s 190,000 solar panels will concentrate the sun’s ray into a vacuum-sealed tube that contains synthetic oil which will heat up to 748°F. The oil is then used to produce steam that is fed into an existing turbine to produce energy. The FPL plant will generate approximately 110 MWs of solar power making the state the second

largest U.S. domestic generator of solar energy⁷ and the plant the world's second largest solar facility.⁸ The plant is scheduled for completion by the end of 2010.

» In February 2010, two California-based concentrating solar power (CSP) companies signed agreements with major European power-plant developers underscoring the financial practicality of large-scale solar for baseload electricity production and the value solar technology in export markets:

i) The French nuclear engineering firm Areva, after forecasting CSP growth of 20 percent per year to 20 gigawatts by 2020, announced the purchase of Ausra. In 2007, Ausra built a 5 MW demonstration plant near Bakersfield, California. The project uses fresnel mirrors to focus sunlight on pipes to generate turbine steam directly, without an oil-based thermal transfer fluid.

ii) The company eSolar of Pasadena, California signed an agreement to construct CSP plants around the world in partnership with the German engineering firm Ferrostaal AG. eSolar is to provide the mirror field and power tower technology, and Ferrostaal, jointly owned by Abu Dhabi's International Petroleum Investment Co. and MAN SE (Munich), will make the power turbines and manage both contracting and financing. In 2009, eSolar built a 5 megawatt (MW) pilot plant in Lancaster, California, and in January 2010 signed an agreement to build a 2,000 MW project in China.⁹

» In compliance with the Spanish Royal Decree of 2007 which called for the installation of 500 MW of installed solar CSP capacity by the end of 2010, the Spanish solar industry may bring on line 22 CSP projects totaling 1037 MW of installed capacity by the deadline. The most recent plant to come on line is the 50 MW CSP-fired Solnova 1 Plant, commissioned near the Solucar Platform in Seville on 6 May, 2010 by Agengoa Solar. The rapid growth of the Spanish industry draws heavily upon the generous feed-in tariff (FiT) for solar electricity currently established at Euros 0.27 per KWh as well as the Spanish Government's early commitment to Research and Development in this sector which has resulted in a large, well-educated work force. If there are no changes to the FiT and current plans remain unchanged, Spain is scheduled to bring on-line more than 2,400 MW of CSP capacity by the end of 2013, making it the world leader in this technology.

TABLE 1 Total Installed Capacity and Cost per MWh of Wind, Photovoltaic (PV), and CSP

Renewable Energy Source	Total installed Capacity (MW) ¹	Levelized Cost per MWh (US\$/MWh) ²
Wind (on-shore)	159,000	81.9–115.0
PV (on-grid)	21,000	158.7–323.9
CSP	662	120.0–180.0

¹ Total Installed capacity figures are for December 2009, taken from REN21, 2010. *Renewables: Global Status Report 2010 Update*. Paris: REN21.

² Levelized cost per MWh for wind and PV is taken from the regional low and upper bounds for costs of capacity that could be brought on line by 2016 measured in 2009 US dollars, taken from US Energy Information Agency, *Annual Energy Outlook, 2011*. December 2010. DOE/EIA 0383. Levelized cost of CSP is an industry estimate taken for plants being commissioned in 2009, taken from C. Bishopric at the *Global Climate and Alternative Energy Conference*, San Francisco, 2009.

SECTION 4. Concentrating Solar Thermal Power / Responding to Current Challenges in the Energy Sector

Access to modern energy sources and adequate supplies of energy is central to successful outcomes in development and poverty reduction strategies. An estimated 1.5 billion of the global population do not have access to electricity. In Sub-Saharan Africa, on average, 80 per cent (640 million) of the population do not have access to electricity. To provide electricity to those without it, it will be necessary for enormous investments in increasing electricity generation using all available sources. In such a context, CSP holds great potential to generate large volumes of electricity using a freely available natural resource: sunlight.

Investments in this technology will be critical to helping meet developing country electricity needs over the coming century.

In 2009 the United Nations Framework Convention on Climate Change (UNFCCC) underscored the urgent need for additional financing for climate change adaptation and mitigation projects and initiatives in developing countries. Climate change is expected to disproportionately affect the urban and rural poor of developing countries, thus making it central to poverty reduction, economic growth and development initiatives. In this context, solar power—which emits no GHGs—will become increasingly attractive as the pressure to respond to the climate change challenge intensifies.

4.1 The Climate Investment Fund and Concentrating Solar Power in the Middle East and North Africa

The Clean Investment Fund (CIF) is comprised of two trust funds each with specific scope, objectives and governance structures

- i) *The Clean Technology Fund (CTF)*: promotes investment initiatives to initiate a shift towards clean technologies. Through the CTF, countries, the MDBs, and other partners agree upon country investment plans for programs that contribute to the demonstration, deployment and transfer of low-carbon technologies with significant potential for greenhouse gas emissions savings.
- ii) *The Strategic Climate Fund (SCF)*: serves as an overarching fund to support targeted programs with dedicated funding to pilot approaches with potential for scaled-up transformational change.

Source: *Climate Investment Fund, History*,
<http://www.climateinvestmentfunds.org/cif/designprocess>

The Climate Investment Funds (CIFs), approved by the World Bank Board of Directors (July 2008) represent collaborative efforts among Multilateral Development Banks (MDBs) and countries to bridge the financing and learning gap between now and a post-2012 climate change agreement. Donor pledges have been made for over US\$ 6.1 billion.

In December 2009, the Clean Technology Fund (CTF) approved financing of \$750 million (USD) as part of an investment plan intended to mobilize an additional \$4.85 billion (USD) from other sources, to accelerate the global deployment of Concentrated Solar Power. The CTF will invest

in CSP programs in five countries in the Middle East and North Africa: (MENA) Algeria, Egypt, Jordan, Morocco, and Tunisia.¹⁰

4.2 Benefits to MENA from Concentrating Solar Power Projects

The total \$5.6 billion project investment will enable the MENA region to contribute the benefit of its unique geography to global climate change mitigation, while helping to achieve transformational development in achieving development goals of energy security, industrial growth and diversification, as well as regional integration.

No other region has such a favourable combination of physical and market advantages for CSP. The investment will support:

- » the deployment of about 1 gigawatt (GW) of CSP generation capacity, amounting to a threefold increase of worldwide CSP capacity;
- » associated transmission infrastructure in the Maghreb and Mashreq for domestic supply and exports, as part of Mediterranean grid enhancement. This will enable the scale up of CSP through market integration in the region; and
- » leveraging of public and private investments for CSP power plants, which will almost triple current global investments in CSP.

TABLE 2 List of CSP Projects in MENA

Country	No. of Projects	Location	Capacity (MW)	Est. Cost (\$USD millions)	CTF Contribution (\$USD million)
Algeria	3	- Megahir	80	322	58
		- Naama	70	285	51
		- Hassi R'el II	70	285	51
Egypt	2	- Kom Ombo	70	370	51
		- Marsa Alam (1)	30	270	44
Jordan	2	- Maan Prov.	100	418	72
		- Aqaba-Qatrania transmission	—	410	40
Morocco	3	- Tan Tan (2)	50	240	35
		- Ain Beni Mathar	125	525	90
		- Ouarzazate	100	440	72
Tunisia	3	- IPP-CSP Project	100	450	73
		- ELMED-CSP	100+	450	73
		- Tunisia-Italy transmission	—	1140	40
Total	13		900	5,604	750

(1) A project with 8 hour storage. The solar field will be equivalent to a 60MW project.

(2) This is a CSP desalination project.

Source: Clean Investment Fund, Clean Technology Fund: Concept Note for CSP Scale-Up Program, MENA, page 9, April 2009. <http://siteresources.worldbank.org/INTCC/Resources/CSPConceptNoteApril27.pdf>

The gigawatt-scale deployment of CSP through 11 commercial-scale power plants over a 3-5 year period is expected to provide the critical mass of investments required to attract essential private sector interest, benefit from economies of scale to reduce costs, result in learning in diverse operating conditions, and manage risk.¹¹

SECTION 5 Path Forward

From the solar energy generation systems (SEGS) in California in the 1980's, to the GEF funded portfolio of CSP projects in the mid-1990's (e.g. Mexico's Hybrid Solar Thermal Project), and the 2010 CTF supported initiatives in the MENA region, coupled with recent concentrated solar power developments in both Europe (e.g. Spain; Mediterranean Solar Plan) and the U.S. (e.g. Florida's FPL new solar facility and requirements of 29 state utilities to increase the amount of power from renewable energy—including solar), the role of CSP in the energy sector is gaining momentum.

Expected Project Benefits of CSP Investment in MENA

- GHG reductions of at least 1.7 million tons of CO₂-equivalent per year.
- Approximately 900 MWs of installed CSP capacity by 2020.
- \$4.85 billion of co-financing mobilized, including sufficient concessional financing to ensure viability of plants.
- Cost of a typical solar field (in US\$ per m²) is expected to decline over the life of the program.

This growth is expected to continue. The potential environmental, economic, development and social benefits of a successful industry are significant. The major outstanding obstacle is cost reduction. Progress is being made and there does not appear to be major impediments to CSP technology following a similar cost

The Potential of Solar Energy

- A solar source: The Sahara is a massive natural storehouse of solar energy—some areas of the 8.6 million-square-kilometre desert reach 45C on many afternoons.
- 1,000: Average constant amount of solar energy reaching the earth in watts per square mile (Source: University of Oregon Solar Monitoring Lab.).
- 0.3: Percentage of light falling on the Sahara and Middle East deserts that could provide all of Europe's power needs (Source: German Aerospace Center). Cost of a typical solar field (in US\$ per m²) is expected to decline over the life of the program.

Source: *The Globe and Mail*, May 10, 2010

reduction curve to that experienced with wind energy to becoming cost-competitive.¹²

The GEF and the World Bank demonstrated foresight in choosing to invest in this promising technology and by steadfastly maintaining their commitment to this technology through the times when the interests of much of the developed and developing world in the technology waned. The vision and commitment shown by this commitment will be essential if the world hopes to address the challenges posed to it by climate change.

MAP Area of CSP desert coverage required to power the Middle East and North Africa, the EU, the World



The 'WORLD' square is representative of an area of 114,090 km² of desert (about 338 km × 338 km) that, if covered with CSP plants, would provide as much electricity as the world is now using. The 'EU' square (19,200 km² or about 139 × 139 km) shows a corresponding area required to provide the electricity needs of the 25 EU countries, and the 'MENA' square (3,600 km² or 60 km × 60 km) for that of the countries of the Middle East and North Africa.

Source: www.desertec.org

ENDNOTES

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- ⁶ *Ibid*
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