Journal of Energy Challenges and Mechanics
http://www.nscj.co.uk/JECM/
ISSN 2056-9386
Volume 1 (2014) issue 3, article 8

Policy impact on concentrated solar power technology deployment: experience of global environment facility

集中式太阳能技术普及：全球环境基金的经验

Ming Yang（杨明）[1*], Hang Yin（尹航）[2]

[1]*Senior Climate Change Specialist, Global Environment Facility, Washington DC, USA*
[2]*Intern, Global Environment Facility, Washington DC, USA*

myang@thegef.org

Accepted for publication on 27th November 2014

Abstract - **Concentrated solar power (CSP) is a renewable energy technology that is advancing from the technology demonstration stage to the technology deployment and commercialization stage. With the current available CSP technologies and economy scale, the cost of CSP power production is in the range of US$0.18 to US$0.35/kWh. This cost is projected to drop to US$0.12-0.15/kWh in 2020 with appropriate energy policy initiatives and further technology advancement. This paper introduces the current CSP technologies and renewable energy policies for CSP technology development in the US, China, the EU, the Middle East and North Africa region, and South Africa. It also presents case studies on CSP finance in South Africa, Morocco, and Egypt. These case studies show that international funding sources are important to reduce risks for the private sector in CSP technology investments. National government policies are also necessary to develop new financial models and mechanisms that would attract private investments in CSP. The objective of this paper is to share Global Environment Facility (GEF)'s experience in policy development for CSP investments. This paper concludes that with appropriate national energy policies and with large-scale investments in CSP technologies, the production cost of CSP will be competitive to conventional fossil-fired power by 2020.**

Keywords – **New Renewable Energy Policy, Finance and Investments, Technology Development.**

摘要 – 集中式太阳能（CSP）是一种正从技术示范阶段向普及阶段发展的新能源技术。根据现有的技术和经济规模，生产集中式太阳能的成本在每千瓦时 0.18 到 0.35 美金之间。若有适当的政策推动和技术发展，这个成本预计在 2020 年降至 0.12 到 0.15 美金之间。这篇论文介绍了现有的集中式太阳能技术以及在美国、中国、欧盟、中东和北非地区以及南非等国家的技术发展状况。文章还通过南非、摩洛哥和埃及的集中式太阳能融资案例分析发现，来自国际范围的资金对于降低私营部门在集中式太阳能技术投资领域的风险起着重要的作用。本国政府政策对于发展新的融资模式和机制用以吸引私人投资也是非常必要的。这篇文章是为了分享全球环境基金（GEF）在针对集中式太阳能的政策推广的经验。这篇文章的结论是，若有合适的国内能源政策以及大规模的集中式太阳能技术投资，能源的生产成本将可以在 2020 前和传统的化石能源相竞争。

关键词 – 新能源政策，融资与投资，技术普及。

I. INTRODUCTION

Concentrated solar power (CSP) technologies use mirrors and lenses to concentrate solar thermal power to heat fluid, generate steam, and eventually power. CSP technologies depend on direct-beam irradiation, and their maximum benefits for power generation are restricted to arid and semi-arid areas with clear skies. The most promising areas for the use of CSP technologies are locate in the Middle East and North Africa (MENA), Australia, South Africa, the United States, Chile, Spain, India, and the Gobi Desert in China.

CSP technologies stand out owing to their energy storage ability. Thermal storage is relatively easy to be integrate into CSP projects, and allows CSP plants to generate electricity at peak time for the grid. On top of conventional power generation, CSP can be applied to industrial processes to desalinize water, produce hydrogen, and generate heat.

Commercial CSP technologies have been developed over the past four decades. The first commercial CSP plant with 10 MW capacity started operating in 1982 in the US. Afterwards, a wave of CSP construction followed in the US, Spain, MENA, South Africa, India, and China. However, CSP capacity has not increased as fast as expected, because of the economic and financial crises in the 1990s and 2000s, and the rapid cost reduction of solar photovoltaic (PV) technologies. By the end of 2012, global CSP capacity reached 2.8 GW, and major CSP plants were installed in Spain, the US, the MENA region, and South Africa (IRENA, 2013a).

Spain has been leading the world in CSP since 2010. By the end of 2012 Spain had installed over 2 GW of CSP, which accounts for more than three-fourths of the world's CSP capacity (REN21, 2013). Most of the CSP capacity came forth with the tailoring of the feed-in tariff in 2004 and the key decree signed in 2007—Royal Decree 611 (ESMAP, 2011). So far there are 50 CSP plants in Spain (NREL, 2014). Spain has made concrete plans to deploy a total of 2.5 GW CSP by 2015 (CSP World, 2013).

The US was the first country in researching, developing, and deploying CSP technologies. By the end of 2013, the total installed CSP capacity had reached 918 MW in the US (SEIA, 2014). In 2013, the US Treasury Department 1603 Renewable Energy Grant authorized the payment to developers of qualified renewable energy facilities of grants equal to 10% or 30% of their capital expenditure, depending on the project technology. With strong financial support from the US government, it is expected that that additional 20 GW of CSP will be installed in the US by 2020.

India has recently made progress to research and develop CSP technologies. In 2010, the Ministry of New and Renewable Energy (MNRE) of India announced Phase I of the National Solar Mission (NSM). The NSM has proven to be very effective in creating a strong national solar PV industry, but it has been not so successful in CSP. By the end of 2013, there was only a 3 MW pilot CSP project by the Indian Institute of Technology, which has been in operation since 2011. In early 2014, the MNRE announced Phase II of the NSM, including two CSP pilot projects, 50 MW each. It also announced to establish a CSP research and development center opening in 2015 (Beatriz, 2014).

China started developing CSP technology in the 2010s. The first tower-type CSP pant with 50 MW power generation capacity was connected to the grid in July 2013 in the Qaidam Basin of Qinghai. Between 2010 and 2011, five CSP plants with total installed capacity of 343 MW were approved by different national administrations. In April 2014, Rayspower, a CSP mirror manufacturer, announced that it could offer lower costs for CSP mirrors, with similar performance (Solar Thermal Energy News, 2014).

Australia is home to about 56 MW of three CSP plants in total nowadays. A 44 MW plant is under construction to feed steam to an existing coal facility. Kogan Creek Solar Boost project is set to become the largest solar-coal hybrid power plant in the world. Moreover, Novatec, the Australian solar energy technology developer and manufacturer, has a 9 MW solar boiler, which acts as a fuel-saver by feeding steam into the existing coal fired power plant (NREL Website, 2014).

The MENA region has a fast-growing demand of energy consumption with 7% of growth rate each year (World Bank, 2012a). The region also has abundant solar resources available. In 2013, the region pledged an ambitious program to create a 1 GW CSP network in five countries: Egypt, Morocco, Algeria, Tunisia, and Jordan (CIF, 2013). As one of the five participating countries, Egypt now has 20 MW of CSP capacity integrated in a 120 MW combined cycle power plant in Kuraimat, which became operational in June 2011. Meanwhile, the Egyptian government approved the Egyptian Solar Plan in July 2012, which set a target for 2.8 GW of CSP by 2027 (REN21, 2013).

Morocco has 184 MW of CSP capacity by the end of 2013 (NREL, 2014). A consortium of power companies including ACWA Power, Acciona, Sener and TSK, developed a 160 MW parabolic trough CSP plant in Ouarzazate, Morocco, which was the largest CSP plant in the world as in July 2014. The plant was in part of the Moroccan government's Solar Plan, launched in November 2009, which aimed to produce 2 GW of solar electricity by 2020 (EPIA, 2012). Along with its great success, Morocco also established the Moroccan Agency of Solar Energy (MASEN), which is notable in offering a successful institutional model for all other CSP projects in the MENA region.

Algeria has a CSP plant with 25 MW capacity using Integrated Solar Combined-Cycle (ISCC) technology in Hassi R'mel, Algeria (NREL, 2014). The energy generated by solar power would in part replace fossil fuel consumed in the power plant. The whole facility was composed by a 150 MW gas and steam combined cycle power plant and a 25 MW solar thermal plant. Besides, Algeria has set a target of 325 MW of CSP capacity to be achieved by 2015, and 7.2 GW by 2030.

South Africa started its CSP technology development at the end of last century. The first CSP feasibility study project was financed by the Global Environment Facility (GEF) between 1999 and 2001. In the early 2010s, Eskom, the national state-owned utility of the country, started construction of two CSP plants with a total capacity of 150 MW. In addition, the government of South Africa has introduced a Renewable Energy Independent Power Producers' Procurement Program, which allows private developers to bid for CSP investments. Under the program, two CSP developers—Abengoa and Bokpport CSP—won a bid for three projects with a total capacity of 200 MW (SASTELA, 2012). Looking forward, South Africa aims to build 3.3 GW of CSP by 2030 (CPI, 2014).

Since 1990, the GEF has financed five CSP projects in South Africa, Egypt, Mexico, Morocco, and Namibia with governments, multilateral development banks and agencies, and private investors. One of the major achievements of GEF funding in these projects is the development and implementation of government policies to foster CSP investments. The objective of this paper is to share GEF's experiences in policy development for catalyzing CSP technology investments in developing countries. This article concludes that the government should develop and implement policies that will incentivize private investments. These may include (1) policies to establish national risk guarantee funds to reduce risk for private investments, and (2) policies to reform power tariffs for countries, and (3) policies in concessional use of government owned land for the private sector investments in CSP technologies.

II. Methodology and Data

An empirical methodology is used in this study. The methodology includes data collection and documentation, cost-benefit analysis, project case studies, in-depth interviews, experts' opinion, and walk-through surveys.

Data collection and documentation: Documents were gathered to enable understanding of the historical processes and developments in CSP related issues and technologies. The documents included the design and constructions papers of CSP, annual reports, mid-term review reports, and project terminal evaluation reports of selected GEF CSP projects. Government policy papers and reports on CSP technology related feed-in tariffs, technology development and project financing were also collected. This approach of data collection was used for triangulating data and helping to counteract the biases of other approaches such as in-depth interviews and experts' opinions and supplementary sources of information.

Cost-benefit analysis: Cost-benefit analyses were conducted to identify financial viability of new CSP projects. The analyses involved detailed economic and technology data collection that are specifically related to individual CSP projects. Financial criteria such as annualized net present value and internal rate of return of the project investment were calculated for overall CSP technologies as shown in the section of cost-effectiveness of CSP technologies.

Case studies: While carrying out these case studies, the GEF project implementing and executing agencies conducted more than 20 in-depth interviews with multiple stakeholders of CSP technology owners and government officers in different countries. These case studies, employing in-depth-structured interviews at CSP plant sites, tend to provide a qualitative, multi-aspect and in-depth study of selected cases. The multi-source data of case studies accurately captured real-life CSP related technologies, policy issues, and barriers. The case studies built a complex and holistic picture, and detailed views of the CSP stakeholders on technology development, investment, and deployment.

Experts' opinions: In this study, experts' opinion was a structured process of collecting and distilling knowledge from a group of experts through email communications, questionnaires, meetings and conference calls. Some data, energy efficiency outputs of the CSP plants for example, were not certain or accurate for some projects. To finalize those data, workshops and seminars were held to get opinions from a group of CSP stakeholders and experts. These brainstorm meetings were to gather ideas and wisdom from a group of experts and to improve data quality.

Walk-through surveys: The authors and their colleagues conducted walk-through surveys with a few CSP plants. These included inspections on the CSP plant premises to assess the solar energy resources, solar energy storage, electricity generation, and power transmission lines and grids.

The following sections briefly present the technology data, economic/financial data, policy achievements, and other results from the analyses mentioned above.

III. CSP TECHNOLOGIES

A CSP technology generally consists of three parts. The first part includes collectors and convertors of solar energy to thermal energy, such as parabolic troughs and the receiver. The second part refers to thermal energy storages including storage tanks. The third part converts thermal energy to electricity, consisting of thermal turbines, power generators, steam condensers, and power transmission grids.

While four technologies exist, two dominate the market: parabolic trough and solar tower. Other technologies such as dish sterling systems or Fresnel collector systems are less mature. With parabolic trough technology, which is the most mature today (Figure 1), solar energy is concentrated by parabolically curved, trough-shaped reflectors onto a receiver pipe running along the inside of the curved surface. Within the pipe, solar energy heats transfer medium (e.g. oil or molten salt) to approximately 400°C. The average operating efficiency of parabolic trough plants ranges from 9% to 14% (Viebahn et al, 2008).

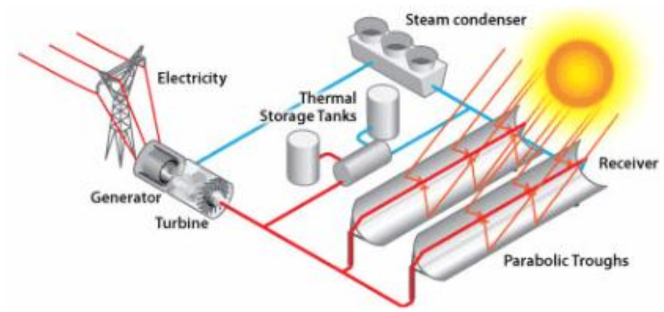

Figure 1 Diagram of a Parabolic Trough Technology. Source: (Hamilton, 2013)

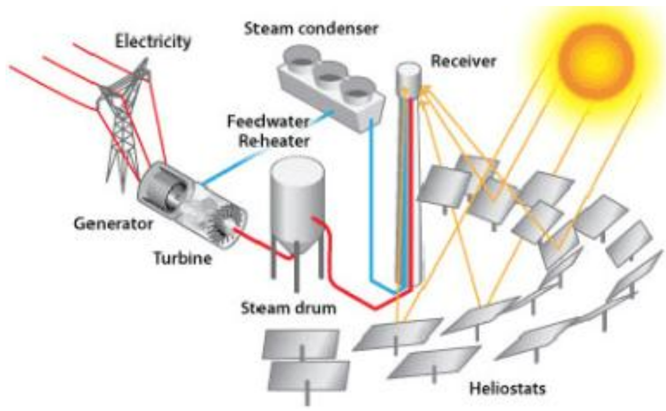

Figure 2 Diagram of a Solar Tower Technology. Source: IEA (2011)

The second widely used CSP technology is solar tower that utilizes numerous large sun-tracking mirrors (heliostats) to focus sun light on a receiver at the top of a tower (Figure 2). A heat transfer fluid heated in the receiver up to temperatures of 500–1000°C, is used for steam generation. The steam is then stored and fed to a conventional turbine generator to produce electricity. Steam, molten salt or air is used as heat transfer media. Since heat transfer is limited to one point of the process, solar tower systems have higher efficiency in harnessing solar energy with overall efficiency ranges from 13% to18% (Viebahn et al., 2008).

IV. Cost-effectiveness of CSP Technologies

CSP technologies are currently not as cost-effective as some other new renewable energy technologies. Today the costs of CSP technologies are three or four fold as high as those of other renewable technologies such as wind and biomass power technologies (IRENA, 2013b). High capital investment costs result in high production costs. Table 1 compares the levelized cost of energy (LCOE) calculation results and capital costs of biomass, wind power, solar photovoltaic (PV), and two representative CSP technologies. While on-shore wind power and biomass power technologies can provide electricity at a LCOE of US$0.05/kWh that is competitive to electricity generated from fossil fuels, CSP technologies provide electricity at a LCOE of US$0.18/kWh. As for the capital costs, CSP technologies could reach as high as US$10,000/kW, which exceeds the capital cost range of other renewable energy technologies on a large extent, as shown in Table 1.

Due to these higher production costs of CSP, developers and investors have been reluctant to finance CSP technologies. This has hindered expansion to economies of scale, limited the cost reductions of the technologies in the market, and increased complexity and risks related to securing finance.

TABLE 1, Cost comparisons between renewable technologies

Technology	LCOE range USD/kWh	Capital Costs range USD/kW
Wind onshore	0.05 – 0.15	1000 – 2500
Wind offshore	0.15 – 0.25	4000 – 4500
Solar PV	0.15 – 0.35	2000 – 5000
CSP Parabolic Trough	0.18 – 0.38	3500 – 10000
CSP Power Tower	0.18 – 0.28	7000 – 10500

These high LCOE costs of CSP technologies have also been acknowledged by the International Energy Agency (IEA). Figure 2 shows that the CSP technologies have not matured in the energy market, falling into the stage of technology deployment where there is a high cost gap between CSP and more mature technologies. To succeed, CSP technologies need reliable support from the public sector and multilateral financing institutions such as the GEF to fill the high cost gap and to attract investments from the private sector.

V. CSP Projects Financed by the Global Environment Facility

The GEF unites 183 countries in partnership with international institutions, civil society organizations, and the private sector to address global environmental issues including climate change. Since 1991, the GEF has performed a catalytic, innovative, and cost-effective role; led in financing new and emerging low-carbon technologies; and pioneered market-based approaches and innovative instruments. The GEF has provided over US$4 billion in more than 600 climate change projects and programs in 157 countries, leveraged more than US$27 billion in co-financing, avoided 2.6 billion tonnes of CO_2 eq through project development and finance, and catalyzed the reduction of 6.8 billion tonnes of CO_2 eq through market transformation.

The GEF’s support for climate change projects includes financing for CSP technologies. In partnership with the World Bank, the GEF completed a feasibility study in South Africa, and developed a portfolio of four CSP demonstration plants in Mexico, Morocco, Egypt, and Namibia. These projects laid out a road map for CSP development in participating countries, and built approximately 70 MW of solar power in the fields as part of hybrid gas-turbine plants. Table 2 highlights these projects. In the following sections with case studies, this paper compares and analyzes policy components in three GEF financed projects and derives the most effective government policy that facilitates investments in CSP technologies.

VI. Case Study: GEF Morocco CSP Project

Rationale and Objectives of the GEF Project

With a growing population and economic development, Morocco's electricity demand has been increasing rapidly. Between 1983 and 2003, electricity consumption grew at an average rate of 6% per year and was satisfied by domestic production and imports from Spain and Algeria. The need for additional power capacity and public spending control led the Moroccan government to tap private investments for support.

Morocco took initiatives and managed to gradually meet some of the important milestones that were previously set up in its national plan to develop renewable energy. To achieve these goals, the government created the Centre de Développement des Energies Renouvelables (CDER), to hold responsibility for new renewable energy development and investments. Besides, CDER played an important role in the implementation of promoting reduction of greenhouse gas emissions. The GEF financed CSP project was in the national least-cost power expansion plan of the Office National de l’Electricité (National Electricity Utility, or ONE). The project also fitted well with the energy sector development plans by the government of Morocco (GOM). Morocco had a great potential to achieve the diversification of energy type, therefore the GEF project contributed to the national plan by increasing the share of renewable energy.

GEF's strategy in Morocco was to support policies and investments that encouraged public and private capital investments in environmentally-friendly technologies and projects. The GOM took important steps to improve the performance of the power sector through restructuring and private sector participation and to develop the use of renewable energy. The GEF project addressed key issues in the government strategy such as increasing institutional capacity and reliance on renewable energy, while meeting growing demand for electricity.

Table 2 Highlights of GEF financed CSP projects

	Period	Partners	GEF Grant	Co-financing	Project outputs	Major policy components	Environment impacts
South Africa	1999-2001	World Bank, Eskom, and NREL, USA	US$230,000 (56%)	US$180,000 (44%)	Feasibility study, technology identification, and leveraging public and private investments in CSP	Feed-in tariffs, and tax incentives	Leading to large scale investments in CSP technologies in the country
Morocco	2007-2012	The World Bank and Office National De L'electricite	US$43.9 million (8%)	US$524 million (92%)	Build 225 kV power lines, a 225 kV substation, and an access road	Power sector privatization; Electricity tariff reforms	Install 20 MW of solar power; generate 37.5 GWh per year; and reduce 450,000 tonnes of CO_2 eq in 20 years
Egypt	2007-2011	The World Bank and Egyptian Electricity Holding Company	US$49.8 million (15%)	US$278 million (85%)	Integrated solar combined-cycle with a capacity of 150 MW including 20 MW from solar	Feed-in tariffs; Tax incentives on CSP; Land use policy.	Generate 852 GWh per year including 33.4 GWh per year from solar energy; and reduce 20,000 tonnes of CO_2 eq annually
Mexico	2008-2011	The Federal Commission of Electricity of Mexico and the World Bank	US$49.4 million (14%)	US$299 million (86%)	Integrated solar combined-cycle with a capacity of 271 MW including 29 MW from solar	Reform tariffs, subsidies, and cost-recovery goals	Generate 80 GWh per year; and reduce 149,975 tonnes of CO_2 eq in 25 years
Namibia	2013-2014	The UNDP, Ministry of Mines and Energy (MME) of Namibia, Renewable Energy and Energy Efficiency Institute (REEEI)	US$1.72 million (66%)	US$0.87 million (34%)	Construction and commissioning of a 50 MW commercial CSP	Form policy issuance of CSP concessions to IPPs	Generate 175.2 GWh annually, and reduce 4.8 million tonnes of CO_2 eq (with energy storage) or 2.4 million tonnes of CO_2 eq (without energy storage) over 10 years

Source: GEF PMIS (2014)

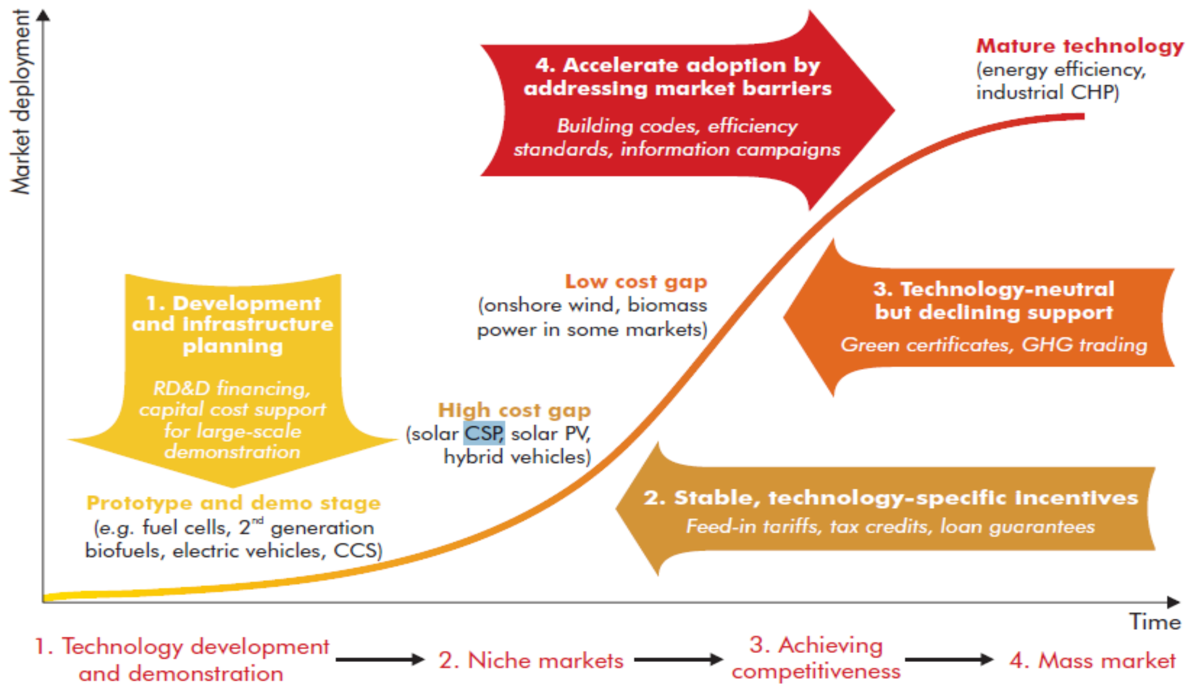

Figure 3. CSP in Clean Energy Technologies Value Proposition. Source: IEA, 2010

The goal of this GEF project was to reduce greenhouse gas emissions from anthropogenic sources by increasing the market share of low greenhouse gas emitting technologies. The project was also designed to contribute to the global learning of the CSP technology to drive down its costs to commercially competitive levels through economies of scale and innovation. A US$43.2 million GEF grant was allocated to cover the costs of policy development, private sector engagement, and the incremental cost of the plant arising from the addition of the solar field.

GEF's support for the proposed project was critical for the following reasons: (a) it helped mitigate the high financial and technical/operational risks of grid based solar technology that were usually high in developed countries as well as relatively advanced middle-income countries such as Morocco; (b) the success of the proposed pilot project was a critical step in the gradual but global approach for adapting and developing grid based solar technologies on a large scale, and GEF involvement would leverage technical knowledge and international best practice to ensure the success of the project; (c) it helped confirm that Morocco and the Mediterranean region in general had a large potential market for dissemination of the technology; (d) the potential for cost reduction was high because of the significant size of the market for this type of technology, not only in the region but also worldwide; and (e) the GEF support accelerated the dissemination of grid based solar energy in the power market of Morocco, and ultimately achieved a very large quantity of reduction in greenhouse gas emissions.

Major Project Components

There were three major project components: (1) policy improvement for Morocco to facilitate private investments in renewable energy technologies; (2) the integration of a solar trough collector field (of about 151,000 m^2) producing a minimum energy output with a traditional natural gas-based power generating unit, namely a hybrid power plant; and (3) economic and financial analysis for the project.

Project Achievements

Three achievements were expected from the project. First, the project was expected to facilitate the development of competitive bidding procedure for CSP power investments from both public power utilities and independent power producers (IPPs) with government policy support. The competitive bidding received a limited number of responses from the IPPs. The Morocco's public power utility decided to finance the CSP plant itself. The ONE thus became the owner of the plant. Second, a solar trough collector field (of about 151,000 m^2) was completed to produce energy. The solar energy production system was integrated with a traditional natural gas based power generating unit to make the whole power plant a hybrid one. The CSP station had a capacity of 20 MW and could produce 37.5 GWh of solar energy per year. The total hybrid power plant installed capacity was 472 MW. Third, an economic and financial analysis of the project was performed. The net present value and internal rate of return of the project were US$305 million and 16.6%.

Policy Discussions

The government of Morocco embarked on a program to reform the energy sector and to promote private investments in infrastructure. The energy policy of the government was to continue the privatization process. Open competitive bidding was carried out among reputable IPPs and the bidder offered lowest price among the responsive proposals was selected in order that net economic and financial benefits could be maximized. In the power sub-sector, the government took important steps to secure private investors to operate the sector's generating and distribution facilities, including (1) the September 1997 financial closure for the Build, Transfer, and Operation (BTO) of the Jorf Lasfar power plant (4x330 MW); (2) rationalization of electricity tariff structures combined with increases in tariff levels; (3) concession for the operation of the power and water distribution systems of the cities of Casablanca; and (4) creation of the CDER which is responsible for undertaking studies and research addressed to promote and develop the utilization of mini-hydro, solar, and wind technologies. When the GEF project was under preparation and implementation, the main issues confronting the power sector included lack of regular adjustment of electricity tariffs, the magnitude of the arrears owed by some of the Régies (the municipal utilities) to ONE, the high level of taxes imposed on the fuels used for power generation, the lack of proper regulation and a regulating agency.

The GEF project in Morocco focused on one important policy issue: increasing private investments in renewable energy. The project supported private participation in the power sector, especially on the generation side. It also promoted the development of environmentally sustainable energy production. The proposed GEF grant supported the government policy to further develop renewable energy and to promote private participation in the energy sector as well as actions underwaywhich complemented private participation, such as the reform of the sector's regulatory framework and practices. The project contributed further to increasing institutional capacity and reliance on renewable energy, widening private sector participation, and meeting growing demand for electricity (World Bank, 2006).

The approach to promoting private investments in CSP was open bidding for the CSP project. Bidding the project with single contract for the construction, operation and maintenance of the plant achieved smooth operation of the plant. The GEF Morocco project involved the financing of only one contract, jointly financed by the ONE, the World Bank and African Development Bank. The project went through international competitive bidding and had its procurement actions advanced and completed before the World Bank's Board approval of the grant. The ONE, with the support of its technical advisor Fichtner Solar, dealt with only one contractor, Abengoa, which introduced simplicity to an already complex project. However, the bidding did not effectively involve the private sector. The reason was that the electricity market condition in Morocco was not attractive to private investors at that time. Feed-in tariff policy and company corporate tax exemption policy were not available in the market. The private sector did not have guaranteed return.

VII. Case Study: GEF South Africa CSP Project

Rationale and Objective of the GEF Project

Solar thermal electricity was considered as an attractive energy supply option for South Africa, since this country has abundant solar resources, available land and a technical infrastructure that could support extensive deployment of CSP technologies. However, many barriers such as high up-front capital investment costs and insufficient incentives for private investments, were preventing CSP technologies from deploying and developing. Given this background, from 2000 to 2001, the GEF, the World Bank, and the National Renewable Energy Laboratory (NREL) of the United States jointly financed the first CSP study project in South Africa: Concentrating Solar Power for South Africa Study.

The goal of the project was to support South Africa in developing renewable energy technologies and mitigating greenhouse gas emissions. The objectives of the project were to (1) evaluate the leading solar thermal electric technology options with regards to their current and future potentials for South Africa; (2) conduct a broad site assessment to identify the most attractive areas for potential plants; (3) identify preferred system(s) that could be economically feasible for Eskom to implement in the coming decade; and (4) identify specific policy and other constraints that need to be addressed to attain a sustainable deployment of solar thermal electric systems in South Africa.

Major Project Components

The major project components included (1) evaluation of CSP technology options according to certain criteria; (2) identification of a reference site to provide information for technology assessment; (3) conceptual designs for promising technologies; (4) performance figures for simulated plant operation; (5) estimation of capital cost, operation and maintenance (O&M) figures and life-cycle costs; (6) evaluation of environmental and social impacts; and (7) evaluation of the viability of CSP implementation under the new national policy.

Project Achievements

The major project achievements included: (1) two CSP technology options were identified and evaluated according to the international CSP technology criteria for the government and power utility of South Africa; (2) a reference site at Upington in South Africa was identified for CSP technology assessment; (3) based on the current state-of-the-art CSP technologies, a concept was designed to meet the region's power dispatch requirements; (4) an operation of 140 plant designs were simulated and evaluated by using international standard modelling and assessment software packages; (5) capital cost, O&M costs, and life-cycle costs of a future CSP plant were estimated; (6) the environmental and social impacts on the region, due to the implementation of CSP technologies were assessed; and (7) through consultation with manufacturers and suppliers, and national policy makers, a policy reform to facilitate CSP investment was proposed.

Policy Discussions

This project was successful in two policy areas. First, the project produced a policy for development of CSP generation in South Africa. In early 2000s, the commercial exploitation of South Africa's renewable energy sources, including CSP, was very limited, but it was clear that the cost of renewable energy would continue to decline as technologies mature. Government policy supports to CSP technology development and investment should include government capital support and other financial incentives to the development of new renewable technologies. These policies may cover (1) feed-in tariff mechanisms for renewable energy generation; (2) portfolio quotas with or without tradable certificates; (3) tax incentives; and (4) green pricing. Eskom has confirmed their interest in proceeding project development with the government CSP policies. As a measure of their interest and commitment, they have decided to proceed with the next phase (detailed design) without accessing further GEF support.

In addition, the GEF first CSP project in South Africa transferred knowledge and built up initial CSP development capacity to the country. In 2005 after the GEF project was completed, the government of South Africa established Renewable Energy Finance and Subsidy Office. The office's mandate included the management of renewable energy subsidies and provision of advice to developers and other stakeholders on renewable energy finance and subsidies, including size of awards, eligibility, and procedural requirements.

With the new CSP investment policy and locally-developed capacity in CSP development through the GEF project, in the 2010s, South Africa built two CSP power plants: (1) Khi Solar One with a capacity of 50 MW in the Northern Cape Region, using solar tower technology; and (2) KaXu Solar CSP 100 MW in Pofadder Sudáfrica, using parabolic trough technology. These two CSP plants will mitigate 498,000 tonnes of CO_2 eq each year when in full operation.

VIII. Case Study: GEF Egypt CSP Project

Rationale and Objective of the GEF Project:

The electricity demand was increasing rapidly in Egypt with an average rate of 7% in the late 1990s and 2000s. The strategy of the government of Egypt was to continue implementing gas-fired power plants, with a long-term strategy to increase the share of renewable energy power in the generation mix. The government was targeting 3% of its electricity to be generated from renewable energy sources by 2010; and 20% by 2020. Egypt is endowed with abundant solar resources and favorable geological locations. To achieve the ambitious goal, successful demonstration of the operational viability of hybrid solar thermal power generation with CSP technologies would be the key to achieve the learning effect and economies of scale, as the use of the technology expands.

The objective of the GEF project was to increase the share of solar-based electricity in the Egyptian energy generation mix, and also to contribute to the government's objective of increasing the share of renewable energy. Besides, this project ran parallel with the objectives of GEF's programming of reducing, over the long-term, the costs of energy technologies with low greenhouse gas emissions.

Many sites in Egypt comprised an uninhabited flat desert area with high intensity of direct solar radiation and were eligible to be selected to implement the projects. The Kureimat site was selected due to the minimal additional infrastructure required because of its proximity to water resources (the Nile River) and its proximity to the 750 MW El Kuriemat Power Plant Combined Cycle.

Major Project Components

The project was implemented through three components: (1) The design, construction and initial operation of the proposed ISCC Plant; (2) Capacity building to New and Renewable Energy Authority (NREA) through consulting services for management during the construction, testing and operation of the plant; (3) Environmental and Social Impact management component.

Project Achievements

The project achieved the objectives of increasing the share of solar-based electricity generation (20 MW) in Egypt and diversifying electric power generation. These included: (1) the construction of the integrated solar combined cycle power plant in Kureimat with total electricity of 35.1 GWh per year generated from solar sources, accounting for 4.1% of the total energy produced in the hybrid plant; (2) the demonstration of a new technology with prospects for scale up through learning and dissemination; and (3) greater awareness of this technology in Egypt, the region, and the world.

Policy Discussions

In line with the Egyptian structural adjustment policy, the power sector, operating under the direction of the Ministry of Electricity and Energy (MEE), was unbundled and reorganized in 2001. Power operations were organized under the Egyptian Electricity Holding Company (EEHC) that included five generation companies, seven regional distribution companies, a single transmission company, and IPPs. A regulatory board were established, chaired by the Minister of Electricity and supported by other ministries and consumers. With this policy adjusted structure, the government of Egypt intended to incentivize private investments in CSP technologies, but two government policies actually discouraged the private sector to invest in CSP technologies.

First, the government foreign currency repayment policy negatively affected CSP technology investments in Egypt. In the 2000s, Egypt had a rapidly expanding economy that was based on the availability of reliable and low cost electric power. The rate of growth of electricity demand in Egypt exceeded 6.5% per year and was expected to remain in the 6-7% range over the next 10 years. Three private sector generation projects were implemented in Egypt adding a capacity of 1,950 MW to the national grid. While the government strategy was very much to continue to award contracts to private investors in order to meet the need for additional capacity, the drop in the Egyptian pound to major foreign currencies resulted in a significant financial burden on the EEHC, since many of its loans were denominated in foreign currency. In Egypt where local currency was in high inflation (11.0% in 2007, 11.7% in 2008, 16.2% in 2009, and 11.7% in 2009), if a utility company borrowed US$1 from a foreign bank in any of the year between 2007 and 2011, the firm needed to pay more than US$1.1 back to the bank to clear the debt even without paying the interest. With fixed electricity sale prices, the power utility cannot make enough revenue to cover the costs. As a result, the government foreign currency policy for private investments caused private interest in power infrastructure in Egypt to evaporate.

The failure of the government foreign currency policy was confirmed by a survey that was conducted by an independent consulting firm with former investors who had previously expressed interest in developing the CSP project as IPPs. In this survey, 31 IPP investors were contacted. Only one company filled out the requested questionnaire; another 21 responded by stating that they were either not interested in general or not interested given the policy change. Three firms contacted were no longer in existence, and six responded that they would be interested in principle, but did not fill out the questionnaires and thus were not considered serious. The survey concluded that the change of government policy in foreign currency repayment for local firms greatly reduced the interest of private investments in CSP technologies in Egypt.

Electricity tariffs in Egypt did not favor CSP investments. Electricity tariffs in Egypt remain uniform across all distribution companies. The weighted average tariff was piaster 12.8/kWh (US$0.02/kWh) in the late 2000s. There were significant cross subsidies in the tariffs, and thus for most consumer groups the tariffs were substantially below marginal cost. For the two key consumer groups, households and the agriculture sector, tariffs were estimated to be half of the marginal cost. Until the GEF project was under implementation, subsidized tariffs remained an obstacle for large-scale private sector involvement, especially in the distribution business and also for the development of large-scale commercial renewable energy operations. However, the government announced its intention to gradually increase tariffs to allow for better cost recovery and reflection of true cost of electricity service delivery.

Having gained knowledge and experience from the GEF CSP project, the government has committed to sector reforms and has been facilitating renewable energy development through specific policy interventions. The Supreme Energy Council of South Africa announced in March 2010 the key policy steps of wind and CSP scale-up in the country that were proposed under the new electricity law. These policy steps included (World Bank, 2012b):

- acceptance of foreign currency denominated Power Purchase Agreements (PPAs) and confirmation of central bank guarantees for all Build Own Operate (BOO) projects;

- approval of the need to cover additional costs for renewable energy projects through tariffs;
- approval of zero customs duty on wind and CSP equipment;
- finalization of the land use policy for wind and CSP developers; and
- permitting support for developers with respect to environmental, social and defense permits.

These new policies will assist the private sector in (1) de-risking from foreign exchange; (2) allowing higher electricity tariffs for electricity produced from CSP technologies; (3) incentivizing private investments by tax exemption in CSP technologies; and (4) giving favorable permits for CSP technology investors in land use.

IX. Barriers in GEF Investments in CSP Technologies

Several barriers were found among the GEF CSP Projects. First, capital costs for CSP technologies were higher than expected. Host countries were required to address additional costs for the projects that could not produce the rated power on a firm basis. Among the GEF funded projects, the incremental costs exceeded the GEF's grants. Countries had to provide significant cash subsidies to operationalize the plants. To resolve this issue, government feed-in tariff policies should be effective to guarantee reasonable return of the CSP technologies.

Second, institutional capacity for CSP projects in developing countries was necessary for successful demonstration and deployment of CSP technologies. Even though the projects were intended to be demonstrations, it proved difficult for developing countries to adopt technologies that were not fully commercialized. Insufficient market viability for CSP technologies in developed countries was associated with low institutional capacity development in developing countries. To resolve this issue, government policies need to be developed to foster capacity building and institutional development for CSP technology deployment in developing countries.

Third, the projects were not mature enough to attract financing from the private sector. The co-financing resources for the GEF projects were from the government, international organizations, and multilateral development banks. Commercial banks have not yet been involved in CSP financing for GEF projects. To resolve this issue, more public funding or grant is needed to overcome cost gaps for private investments, or mass investments are needed to scale-up CSP technologies and therefore reduce the capital investment and production costs.

Fourth, an undeveloped power transmission infrastructure makes it difficult for CSP development in developing countries. Access to electricity market added complexity and reduced private sector interest. Governments in developing countries should have policies that request power grid companies to purchase CSP energy mandatorily. Without a reformed government policy and regulatory framework, which encourage local grid utilities to purchase renewable power at reasonable prices, the private sector would not have incentives to invest in CSP technologies.

X. Future Policy Direction to Unlock Barriers

The GEF has a unique position to unlock the aforementioned barriers. First, the barrier of high capital investment cost per kilowatt can be unlocked by an international joint policy effort. If countries can jointly develop and deploy 15 GW to 30 GW of CSP plants, it will form a large economic scale. In addition, CSP technology breakthrough as announced by China would substantially cut manufacturing costs of CSP technologies in these developing countries. With rich experience in CSP investments in developing countries, the GEF will continue its catalytic, innovative, and cost-effective role in developing policy, building capacities and facilitating reforms on energy tariffs and energy systems in these countries. To do so, the GEF is in cooperation with the Clean Technology Fund (CTF) on financing a CSP program in the Middle East in the period of 2014-2018. The objectives of this program are to develop energy policies that foster CSP technology investments in developing countries, and to install 710 MW of CSP in the region, including 460 MW in Morocco, 100 MW in Jordan, 100 MW in Egypt, and 50 MW in Tunisia. The CTF is planning to finance US$650 million for the program. The first project under this program has been approved for Ouarzazate-I in Morocco. The GEF and its partners are on the way to assist developing countries and countries with economies in transition in scaling up CSP technologies and reducing capital investment costs.

XI. Conclusions and Policy Recommendations

CSP technologies are promising due to their capabilities to store renewable energy and to be developed at a large scale. However, these technologies are not competitive in the current energy market because of several barriers including high front cost per kilowatt investment, lack of government incentives, low electricity tariffs in the energy market, and lack of local capacity in technology development. These barriers can be unlocked by more effective national government policies and international joint policy effort.

Governments of developing countries need to enact appropriate energy policies to support the development and deployment on a competitive market basis. These policies should:

(1) provide sufficient financial incentives to the private sector to make sure that private investments in CSP could make a profit at the average rate of return of the market;

(2) ensure that these financial incentive policies are sustained long enough to cover capital investments of the private sector. Meanwhile, the designed policies should reflect decreasing investment cost of CSP over

time. This is to avoid over investments in CSP in the future.

(3) establish national risk guarantee funds to reduce risk premium of a commercial bank loan to private investments in CSP technologies;

(4) reform power tariffs from flat power tariffs to time-of-use power tariffs. This is to remunerate the flexible power supply provided by CSP to more accurately reflect its benefit to the energy system; and

(5) provide concessional use of government owned land to the private sector in a reasonably long-term. This is to reduce risk for private investors who want to acquire land and use it for renewable energy technology development.

International policies are also needed to support and deploy CSP technologies on an international market basis. These policies may need to:

(1) transfer CSP technologies from countries with successful experiences to countries in need;

(2) develop standards and codes that are particularly suitable for CSP technology development in developing countries; and

(3) involve multiple countries jointly in investing, developing, and deploying large scale CSP plants.

REFERENCES

[1] G. Beatriz. *Slow development of CSP industry in India caused by policy approach*, 2014. http://social.csptoday.com/markets/slow-development-csp-industry-india-caused-policy-approach

[2] CPI – Climate Policy Initiative (2014) *The Role of Public Finance in CSP Case Study: Eskom CSP, South Africa*, June 2014, Venice, Italy.

[3] CSP World (2013) *Spain's Government Changes Rules for CSP... Again* http://www.csp-world.com/news/20130202/00730/spains-government-changes-rules-csp-again

[4] EPIA – European Photovoltaic Industry Association (2012) *Global Market Outlook: For Photovoltaic Until 2016*, May 2012, Brussels, Belgium.

[5] ESMAP – World Bank Energy Sector Management Assistance Program (2011) *Regulatory and Financial Incentives for Scaling Up Concentrating Solar Power in Developing Countries*, June 2011, Washington D.C.

[6] GEF PMIS - Global Environment Facility Project Management Information System (2014), a database of the GEF for project management. Cited 5 July 2014.

[7] Hamilton J. (2013) *Careers in Solar Power*, The Bureau of Labor Statistics, accessed on November 18, 2013. http://www.bls.gov/green/solar_power/

[8] IRENA (2013a) *Concentrating Solar Power Technology Brief*, IEA-ETSAP and IRENA E10 – January 2013. www.etsap.org

[9] IRENA (2013b) Renewable Power Generation Costs in 2012: An Overview. (2013b) www.irena.org/DocumentDownloads/Publications/Overview_Renewable%20Power%20Generation%20Costs%20in%202012.pdf

[10] IEA - International Energy Agency (2010) *Technology Roadmap.* Concentrating Solar Power., Paris. http://www.iea.org/publications/freepublications/publication/csp_roadmap.pdf

[11] IEA - International Energy Agency (2011) *Solar Energy Perspectives*, ISBN 978-92-6412-457-8, Paris, France.

[12] NREL – National Renewable Energy Laboratory: *Concentrating Solar Power Projects* http://www.nrel.gov/csp/solarpaces/ Cited 12 July 2014

[13] SEIA - Solar Energy Industry Association (2014) U.S. Solar Market Grows 41%, Has Record Year in 2013; March, 2014. http://www.seia.org/news/new-report-us-solar-market-grows-41-has-record-year-2013

[14] Solar Thermal Energy News (2014) http://www.helioscsp.com/indice_tags.php?tag=China

[15] UNDP (2012) *Concentrating Solar Power Technology Transfer for Electricity Generation in Namibia*, Request for CEO Endorsement/approval. Re-submission: December 10, 2012. GEF Project Management Information System

[16] Vagliasindi M, and Besant-Jones J (2013) *Power Market Structure: Power Market Structure, Chapter 6: Arab Republic of Egypt*, World Bank Publications, March 2013.

[17] P. Viebahn, S. Kronshage, F. Trieb, and Y. Lechon (2008) *Final Report on Technical Data, Costs, and Life Cycle Inventories of Solar Thermal Power Plants.* Deliverable 12.2—RS Ia of EUIP-NEEDS. www.needs-project.org

[18] World Bank (2006) Morocco GEF Project Document, Integrated Solar Combined Cycle Power Project, November 2006 . Report No: 36485.

[19] World Bank (2012a) *Implementation Completion and Results Report (TF-91289)* Report No: ICR2173.

[20] World Bank (2012b) *Egypt and Morocco: Concentrated Solar power* http://go.worldbank.org/2R0W5H1010 Cited 5 July 2014

[21] SASTELA - Southern Africa Solar Thermal and Electricity Association (2012), CSP in South Africa. http://www.sastela.org/csp-in-south-africa.html Cited 5 July 2014.