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The China Sustainable Energy Program
中国可持续能源项目

The Feasibility and Policy Study on Developing Concentrating Solar Power in China

(Abbreviated Version)

Sponsored by The Energy Foundation

Center for Clean Energy Technology

Chinese Academy of Sciences

Sponsored by the China Sustainable Energy Program (CSEP), this project is to study the feasibilities of developing Concentrating Solar Power (CSP) in China and to provide policy suggestions to help policy makers make informative decisions.

A geographic information system study (GIS) study shows solar power suitable for potential CSP power production in China is 16,000 GW annually, abundant enough to satisfy the entire nation's current and future energy demands. The provinces have the most abundant solar resources coincide with those sparse populated ones, such as Neimenggu，Xinjiang，Qinghai, Xizang and Gansu.

Even the unified state owned grid system in China will work as an advantage as it is more cost effective and systematic planed, additional transmission requirements may act as a barrier for the development of CSP. A national smart grid will be built in China to adjust to the volatility of the electricity generated from renewable energy.

As two major technology branches of utilizing solar power, Photovoltaic (PV) and CSP, CSP will face serious competition from fast growing PV, in terms of sharing natural resources and technology/cost comparison. However, the technical complexity of energy storage of CSP is considerably lower than that of PV. With storage, power production can be shifted according to demand therefore is less dependent on daily weather conditions.

Among all the CSP technologies, parabolic trough is the most mature and has been commercially proven worldwide. Centralized receiver and dish stirling have passed industrial demonstration stages and been undergoing aggressive commercialization progresses. The latter two are both mid-high temperature utilizations with possible higher energy conversion efficiency. Linear Fresnel is a simplified form of parabolic trough.

CSP will eventually become cost competitive when the technology evolves toward maturity and large-scale commercial implementations are achieved. The future cost of CSP and cost reduction in China was estimated through the cost analysis using data abroad. The cost-reduction-potential (CRP) for parabolic trough in China was deducted, which cost can be decreased at least 39%.

Means that can be used to effectively lower LCOE and improve the economic viabilities of CSP were suggested. Price sensitive factors were identified in this process.

- **Technology research and development helps to lower the expenses.** Increasing solar/electricity efficiency is an essential means to reduce the cost.
- **Increased deployment will result in the economies of scale, and economies of learning, and experience-related operation and maintenance cost reductions.**
- **Government support and subsidies are essential to help develop CSP.** However, the dependency of state support can pose risks too, in case that government withdraws or weakens its supporting policies.

China already has the manufacturing abilities to produce most of the key components for centralized tower, but less for parabolic trough. With awakening environmental awareness, China has financed and covered most R&D work related to CSP technology, including parabolic trough, tower, dish, and etc. Through Beijing IEE's demo project of central tower, China has developed its own patented CSP technique and manufactory abilities. Cheaper production prices also help to reduce the cost. Besides, through self research and development Chinese suppliers now are able to export some key parts of CSP abroad too.

For the time being, China has no established commercial plant in operation, except for relative small demo projects. Even so, investors have started paying attention to this rather empty field of clean energy in China, many ambitious projects have been proposed in recent years, but may take years to realize.

Chinese government has already employed most internationally recognized policies to stimulate the development of renewable energies, e.g., mandatory renewable portfolio standards, subsidies, special development funds, feed-in tariff, tax credits and etc., however, current underdeveloped CSP in China makes it hard to attract government's attention.

Based on our policy study, a strategic four-stage developing route for China's CSP was proposed: technology verifying stage (2010-2015), progressive stage (2016-2020), boosting stage (2021-2030), and final free marketing stage (after 2030). Specific policies, transit gradually from strong to mild, were suggested accordingly. By 2050, CSP have the potential to provide up to 8% of China's energy need, and become an essential player in the nation's energy supply scheme.

Table of Contents

Abbreviated Version

1. Background

As a clean sustainable energy that can produce power in utility scale, concentrating solar power (CSP) has once again attracted the world's attention and boosted in deployments in recent years. *CSP Global Outlook*, prepared by Greenpeace International, SolarPACES and ESTELA, predicted CSP could meet up to 7% percent of the global power needs by 2030, and 25% by 2050[1].

A brief review of the global history of CSP development reveals that environmental awareness, fossil fuel crises, and governmental support are important drivers for the development of CSP. Based on the analysis of the current status of CSP in China, we foresee that CSP in China will go through four periodic developmental stages, as **technology verifying stage (2010-2015), progressive stage (2016-2020), boosting stage (2021-2030),** and final **free marketing stage (after 2030).** By 2050, CSP has the potential to provide up to 9% of China's power demands, and becomes an essential player in the nation's energy supply scheme.

This sponsored program is as well designed to help better understand the role of governmental supportive policies in fastening the development of CSP under current developing stage in China. Therefore detailed policy suggestions were made to help government make informative decisions.

2. Resources

2.1. The resources of solar power energy in China are rich and suitable for future large-scale CSP applications.

Solar power stands out from other renewable energies as it is the only energy resource that is abundant enough to satisfy all the future/current energy demands in China.[2] A survey of solar energy in China shows there is about 1700 billion tons of coal equivalent (TCE) from the direct sunlight striking on China's land area annually.

Converting only 1 percent of this solar energy into electricity could match the nation's total energy needs in 2050 (about 10 billion TCE).

Table 1 Approximations of natural reserves of renewable energies in China[2]

Renewable Energies	Solar	Wind	Water	Biomass	Geothermal
TCE (bn)	1700	0.8	0.48-0.64	0.46	3.3[*II]

*[I] According to the data published by National Bureau of Statistics of China on Dec 25, 2009, the total national primary energy demand in 2008 is 2.65 billion TCE.

[*II] Only very limited part of this 3.3 biliion TCE of geothermal energy can be utilized economically.

2.2. answer relative accurately how much the resource potential there is for China to develop CSP[3]

Many influential factors, such as the DNI, land scope, and land availabilities, but not all, which affect the CSP site selection were taken into consideration in the study. Under certain assumptions (please refer to the full report for full details), the GIS study shows China has 16,000 GW of potential suitable for CSP applications (<3% slope and DNI above 5 kWh/m2-day), compared to USA's 15,000 GW and Spain's 720 GW respectively. If China's solar potential is converted into electricity under today's common conversion efficiency, it can produce up to 42000TWh/year electricity, 12 times greater than 3427TWh, the current annual national electricity demand.

Table 2 Total CSP potential capacity in China, USA and Spain

	GW	**TWh/year**	**DNI≥7 kWh/m^2-day（GW）**
China	16,000	42,000	1,400
USA	15,000	40,000	1,300
Spain	720	1,900	0.7

The provinces have the most abundant solar resources coincide with those sparse populated ones. Ranging with descending order, they are: Neimenggu，Xinjiang，Qinghai, Xizang and Gansu. Additional construction of new infrastructure like road and grid connection may be necessary for the new CSP stations. Even overall the unified state owned grid system in China will be more cost efficient than the private grid companies, the installation of a new grid will still bring considerable economic burden to a new CSP plant. Nevertheless, the access to cooling water may still limit the CSP site selections.

Table 3 China's CSP resource distribution by province

	5-6 kWh/m^2-day		**6-7 kWh/m^2-day**		**>7 kWh/m^2-day**	
Province	GW	TWh/yr	GW	TWh/yr	GW	TWh/yr
Neimenggu	6,000	15,000	59	170	0	0
Xinjiang	4,300	11,000	400	1,100	340	1,200
Qinghai	2,000	4,900	720	2,100	31	100
Xizang	320	770	300	860	1,100	3,900
Gansu	440	1,100	15	42	0	0
Sichuan	56	140	0	0	0	0
Hebei	26	64	0	0	0	0
Shanxi	18	44	0	0	0	0
Shaanxi	9	21	0	0	0	0
Heilongjiang	7	17	0	0	0	0
Jilin	4	10	0	0	0	0
Total	**13,180**	**33,000**	**1,500**	**4,300**	**1,471**	**5,200**

3. Overview of CSP technology

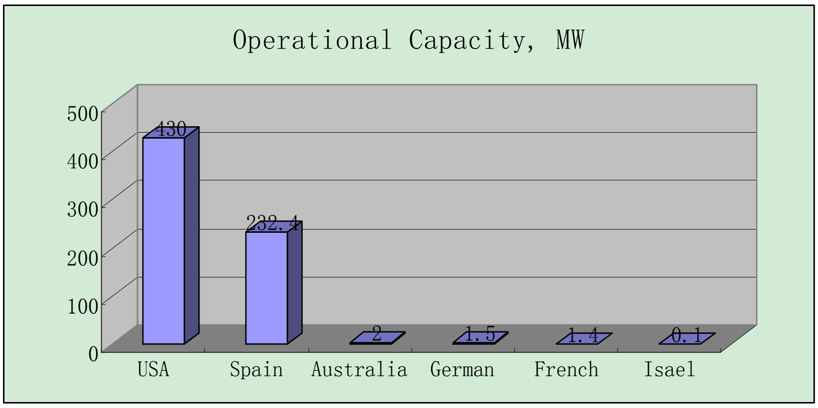
In general, CSP at first converts the light energy into thermal energy, and then uses the same turbine system to generate electricity as the conventional fossil fuel plant, of which technology was mature long before.

Among all the CSP technologies, parabolic trough is the most mature and has been commercially proven worldwide. As parabolic type of mirrors are less easy to produce in the mass production and thus not cost effective, linear Fresnel comes in as a simplified form, of which commercial implementation is still in its starting stage. Centralized receiver and dish stirling, are both mid to high temperature utilizations of sun radiation, with higher sun-to-electricity conversion efficiency and more flexibility with the land slope compared to parabolic and Fresnel. Centralized receiver and dish Stirling have passed the demonstration stage and been undergoing aggressive commercialization progresses. Besides, a few Integrated Solar Combined Cycle Systems (ISCCS) have been practiced in several commercial projects around the world.

4. Commercialization

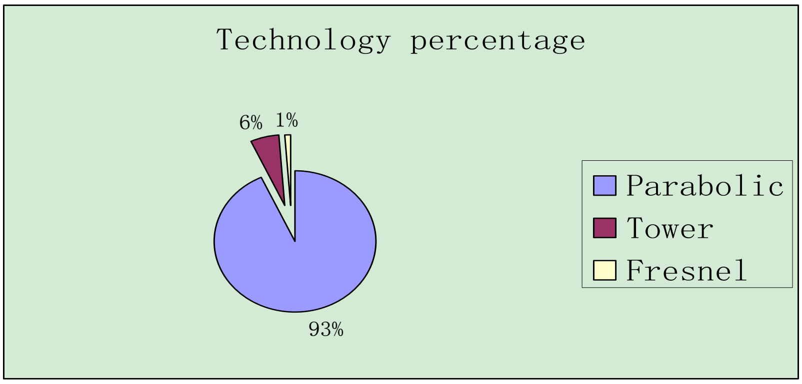
4.1. Progress of CSP commercialization

Figure 1. The CSP total operational capacity world wide by country



By Oct. 2009, the total installed and operational capacity of CSP worldwide was 667.4 MW, while parabolic trough counted for 93%, central receiver 6%, linear Fresnel 1%. USA had so far the largest capacity among all the countries.

Figure 2. Operational capacity worldwide by technology



While the total CSP capacity under construction worldwide is 2133 MW, most of which are clustered in Spain, due to the powerful stimulating policy issued by the government. Among the total announced 12.3 GW capacity, USA once again claims the first place in the chart. The percentage of central receiver and dish stirling have increased to 31% and 13% respectively, which shows the tendency of switching from low-mid temperature applications to more power efficient mid-high temperature utilizations.

4.2. Overview of typical CSP projects worldwide

In the section of full report, several typical CSP projects representing the progress of deferent CSP technologies worldwide were selected and overviewed, which will be bypassed in this abbreviated version.

- **Parabolic Trough—**

Solar Energy Generating Systems (SEGS); Nevada Solar One; and Andasol 1-3

- **Solar Tower—**

The Solar Project：Solar One, Solar two and Solar Tres; PS 10 and PS 20

- **Desertec Industrial Initiative Project—**

5. CSP development—Drivers, barriers and risks

5.1. Drivers

China dose not only face the similar environmental pressures and the urgent need to look for new clean alternative energies as all the other nations in the world, but it also has its own unique impending issues need to be addressed. For example, Chinese unique —“abundant in coal but poor in oil and natural gases”, and ever expanding energy supply-demand gap caused by accelerating national energy demand, the ever rising oil import dependencies, and etc.. These are all adding up to force China to take immediate and active actions to look for clean and renewable alternatives.

In addition, and the recent burst in the world deployment of CSP, caused by technology maturity and significant cost deduction, also make CSP a powerful player in the clean energy market with great potential.

5.2. Barries and risks

5.2.1. High initial capex

Compared to conventional coal plants, CSP power stations require larger tracts of flat spaces, huge amount of additional careful mounted and computer controlled adjustable mirrors, heat transfer/exchange piping system, sometimes heat storage system, all adding up to considerably higher capital costs for CSP stations. The relative high initial capex is indeed the major impediment to the competitiveness of CSP. For example, Andasol 1 in Spain (50 MW, 7.5 hours heat storage capacity) cost around €300 million (US$380 million) to build. According to the developers it costs €0.271 for Andasol to produce per kilowatt-hour electricity. In Spain, solar-thermal electricity receives €0.27/kW·h feed-in tariff for the next 25 years.

5.2.2. The discontinuous power production

Since sole CSP plants totally rely on the sun radiation to produce power, means they can only work during specific time of a day and only under certain weather conditions. Therefore, the discontinuous solar radiation significantly lowers the plants’ output power. Heat storage and hybrid plant, or ISCC systems can serve as feasible solutions to this problem.

5.2.3. Requirement for land

Because sun can only supply rather low intensity power, a normal reasonable sized utility scale CSP plant requires considerable large flat track of land to collect sun radiation. Even locating CSP in the sun radiation abundant deserts seems a sensible solution; it may pose other problems at the same time—such as water availability and power transmission. Dry cooling is less efficient than wet cooling while demands additional cost.

5.2.4. Power transmission

As the solar abundant areas in China are most located in remote areas and far away from load centers, it is inevitable for some new CSP plants to build new infrastructure and especially HVDC/AC lines for power transmission, thus, which will bring additional cost. Therefore, when it comes to real CSP site selection, it is also necessary to consider the tradeoff between building the station in a site with rather moderate DNI but closer to the load center, compare to the choice of building the plant in the area with more abundant solar radiation but farther away from load centre/the existing grid system. As this issue was not addressed in this report, further and more detailed work is expected to be done in the future.

Meanwhile, state owned power grid system in China has advantages over the private owned independently developed grid, which is more fit to unified systematic planning, and can be more cost effective when affiliating into the grid. In addition, to solve the problem of discontinuous power generation of the renewable energies, a national smart grid will be built in China for the renewable energies transmission.

According to the development plan of the national wide grid interconnection in China made by Electric Power Research Institute of China, the nation's total installed capacity of long distant HVDC transmission will reach 500GW in the year 2010. By the year 2010-2020, a nationwide interconnected grid will be basically established, which will cover all major regional and provincial power grids with a total installed capacity of about 750GW by the year 2020. It is worth noting that in this development program there are no HVDC transmission lines built inside West China or between West and Mid China, which have the best solar resources in China. When large scale CSP projects are built in these high solar radiation regions, new dedicated HVDC transmission lines should also be planned and built.

5.2.5. Policy Risk

Similar to other renewable energy industries, the dependency of state policy supports also poses risk to the investors of CSP, whose profits will be conceivably lessened once the governments withdraw or weaken their supporting policies.

5.2.6. Value Chain

A CSP project usually involves the following stages:

a). Project feasibility study and financing;

b). Securing a land and power purchase agreement;

c). Engineering procurement and construction (EPC);

d). Plant actual operation.

Unlike PV technique or conventional power plants, the CSP technology as well relies on the on-site constructing and final assembling work. From existing experience, most CSP technology companies, work not only as technology providers, but also act as de/85/74velopers and EPC, so they can negotiate directly with the suppliers to cut down the m1argins.

In China, the five power production tycoons are more interested in how to fast construct operational solar power plants to meet their mandatory Renewable Portfolio Standard (RPS), instead of investing in technology R&D. As venture capital is far from mature in China’s domestic market, lacking of financing means hinders new technology companies from emerging.

5.3. Means to overcome the major barrier of developing CSP-- relative high initial capex

Technology research and development helps to lower the expenses. Increasing solar/electricity efficiency is an essential means to reduce the cost. Increased deployments result in the economies of scale, and economies of learning, and experience-related operation and maintenance cost reductions. Nevertheless, government support and subsidies are essential to help develop CSP, e.g., cheaper financing, mandatory renewable portfolio standards, feed-in tariff and etc..

6. Cost Analysis of CSP

Due to the high initial capex, the current electricity cost generated by the CSP is still much higher than that of conventional technologies. However, with large scale implementation and technological advancements, the cost of electricity generation from CSP is expected to decrease continuously. According to a study of renewable energy made by the IEA, the current CSP technology systems are implemented in the cost range of 0.19$/kWh to 0.25$/kWh. In the conventional power market, CSP competes with mid-load power in the range of 0.037$/kWh to 0.05$/kWh. As different scenarios have predicted, the costs of CSP can be reduced to competitive levels in the next 10 to 15 years. Competitiveness is affected not only by the cost of the technology itself, but also by potential price increases of fossil energy and by the internalization of associated social costs, such as carbon emissions. Therefore, it is assumed that in the medium to long term, competitiveness will be achieved at a level of 0.05$/kWh to 0.075$/kWh for dispatchable mid-load power.

According to another report prepared by Electric Power Research Institute, when the global cumulative capacity of CSP implementation reaches 4GW,the cost of electricity generation from new plants in 2015 could be as low as 0.08$/kWh (nominal 2015 dollars) or nearly 0.05$/kWh (real 2005 dollars).

As in China, there is still no operating CSP power station and no data available for analyzing and comparing the cost of different CSP technologies. The only data currently ready for analysis are all from abroad. In this chapter, most data we used are from Wen Zhang's thesis[4], which conclusions were mostly based on data from Sargent & Lundy CSP cost report[5], and Fichtner's own projects.

6.1. Methodology

LEC were determined by the simplified IEA method[6]. To keep it simple, any project specific data (e.g. tax influences, or financing conditions) are neglected.

$$LEC = \frac{crf * C_{invest} + C_{O\&M}}{E_{net}}$$

crf : capital recovery factor

value of the total investment cost of the plant.

C_{invest} : total investment cost of the plant

$C_{O\&M}$: annual operating and maintenance costs

E_{net} : annual net electricity output

A capital recovery factor is the ratio of a constant annuity to the present value of the total investment cost of the plant.

$$crf = \frac{k_d (1 + k_d)^n}{(1 + k_d)^n - 1}$$

k_d : real debt interest rate = 8%

n : life time = 25 years

In this research a 25-year life time and an 8% interest rate are assumed.

6.2. Parabolic trough

The cost of parabolic trough was divided into two main categories, investment cost and O&M cost.

- **Investment Cost**

The total investment cost of a parabolic trough power plant includes 6 major cost components:

· Support Structure
· Receivers
· Mirrors
· Solar Balance of Plant
· Power Block/ Balance of Plant
· Thermal Storage

- **Operating & Maintenance Cost**

The operating and maintenance (O&M) costs are those costs associated with operating the CSP power plant and include the costs for the:

· Solar field
· Power block and balance of plant
· Water and process, costs are based on the amount used for the weekly washing of the collectors, cooling water and power plant operating.
· Staffing cost
· Capital equipment and other miscellaneous equipment

  The capital equipment is the equipment for operating and maintaining the solar field and power plant facilities, for example the HTF evacuation rig, mirror wash rig, tractor etc.

  Miscellaneous costs include the cost of vehicle fuel, safety & training, travel, the offices, and first aid equipment etc.

· Spare parts, costs are based on 10% maintenance cost for the solar field and the power block/BOP.

Table 4 Cost analysis of Trough

Trough	Unit	Sargent & Lundy				Fichtner
Power Plant		2003		2008		2008
		SEGS VI	Trough 50	Trough 100	Trough 100	Trough 100
Electrical capacity	MWe	30	50	100	100	100
Capacity factor	%	22%	47%	33%	51%	25%

Annual Electricity output	GWh/yr	58	206	290	451	223
Support Structure	$/m²	67	67	171	172	160
Receivers	$/m²	43	43	53	53	60
Mirrors	$/m²	43	40	63	63	60
Solar BOP	$/m²	234	250	141	141	150
Power Block /BOP	$/kWe	527	306	1183	1183	2500
Thermal Storage	$/kWe	-	958	-	765	-
Total investment cost	M $	92	254	447	671	559
	$/kWe	3052	5073	4471	6708	5594
Annual O&M	$/kWe	63	115	67	78	120
LEC	$/kWhe	0.181	0.143	0.168	0.157	0.293

crf : 9.37%

Remarks and Conclusions:

- The parabolic trough power plant with a hybrid operation and thermal storage system is more cost effective than the simple solar-only power plant.
- From data the total investment costs for a parabolic trough power plant are currently between 4500 – 6700 $/kW.
- The costs for the additional hybrid and storage facilities are still relatively high but will decrease into the future.
- The price of support structure has increased approximately 2.5 fold as a result of the significant rise in the price of steel from the year 2003 to 2008.
- Some components unique to the parabolic trough, e.g. receivers, mirrors, still have very limited suppliers. Lack of competition, high demand and limited production capacities make the prices stay high.

- Thanks to the Research & Development (R&D), the cost of Solar BOP has sharply decreased in the last five years, and is expected to steadily decrease over time.
- The capital costs of the power block balance of plant have shown a massive growth due to the price increase of conventional power generating BOP and the utilization of some cost intensive technologies, for instance, air cooling facilities instead of a water cooling system are employed in water-deficient areas such as deserts.
- The capacity and type of thermal storage have significant impact on the total investment required for the CSP power plant and are key consideration in cost reduction. Two-tank thermal storage system was used in this analysis.

6.3. Solar Power Tower

Similar to parabolic trough, the total cost of solar power tower was divided into two main categories, investment cost and operating and maintenance (O&M) costs.

Investment Cost

In this study the total investment costs of a solar tower power plant has been classified into seven major cost components:

- Site development & Infrastructure
- Heliostat field
- Receiver
- Tower & Piping

  The investment cost of tower is related to its height and the figure given by Fichtner is calculated using the following formula:

  $$C_{Tower} = 552000 * e^{\left(\frac{Height[m]}{100}\right)}$$

  The tower height used in this projection is 150m.
- Power Block/Balance of Plant(BOP)
- Thermal Storage

· Indirect costs

Operating and maintenance (O&M)

Operating and maintenance (O&M) costs are those costs associated with operating the CSP power plant. This includes the costs for the:

· Solar field

· Power block and balance of the plant

· Water and process

· Staffing

· Capital equipment and miscellaneous

· Spare parts

Table 5 Cost analysis of solar tower

Tower	Unit	Sargent & Lundy		Fichtner
Power Plant		2003	2008	2008
		Solar Tres 13.65 MW	Solar Tres 13.65 MW	Tower 47.25 MW
		Storage	Storage	Solar Only
Site development /Infrastructure	$/m²	11.6	-	25.3
Heliostat field	$/m²	160	230.6	191.2
Receiver		280 m^2	280 m^2	155 MWth
		57143 $/m²	121680 $/m²	151.5 $/kWth
Tower & Piping	$/m²	11.6	21.99	18.9
Power Block & Balance of Plant	$/kWe	1397.7	4719.6	1556.6
Thermal storage	$/kWt	49	24.9	-
Total investment cost	M $	119	219	214
	$/kWe	8753	16905	4534

O&M	$/kWh	0.03	0.01	0.05
Annual net electricity output	GWh	93	93	116
LEC	$/kWhe	0.15	0.22	0.22

crf : 9.37%

Remarks and conlusions

- From the figure shown above it is evident that, the current levelized energy cost for the solar tower system is around 22 US cent/ kWh. The price estimated by S&L 2003study is much lower than the current price, because it anticipated a higher scaling factor and a rapid cost reduction for the solar tower system.
- According to this study the total investment cost for solar tower plant is currently from 4500 to 16900$/kW. These costs are much higher than the parabolic trough power plant of 3000 to 6700$/kW.
- The topographic conditions and the price of the land and construction materials are the main influential factors that impact on the cost of site development & infrastructure.
- Through technical advancements, for example thinner glass with better reflectivity, improved aiming techniques and updated control system mass produced heliostats have great potential to reduce costs.
- Through the reduction of heat losses at the receiver, an increase of the receiver absorbance and the scaling up, the cost of the receiver system is expected to drop in the future.
- The investment cost of the tower is influenced by the price of the construction materials, and therefore cost will be different every year. The piping efficiency will increase due to larger piping and shorter lengths per kWe in the large scaled project, ultimately resulting in lower costs.
- The advanced thermal storage concept, for instance the direct thermocline molten-slat storage system will reduce the thermal storage cost significantly.

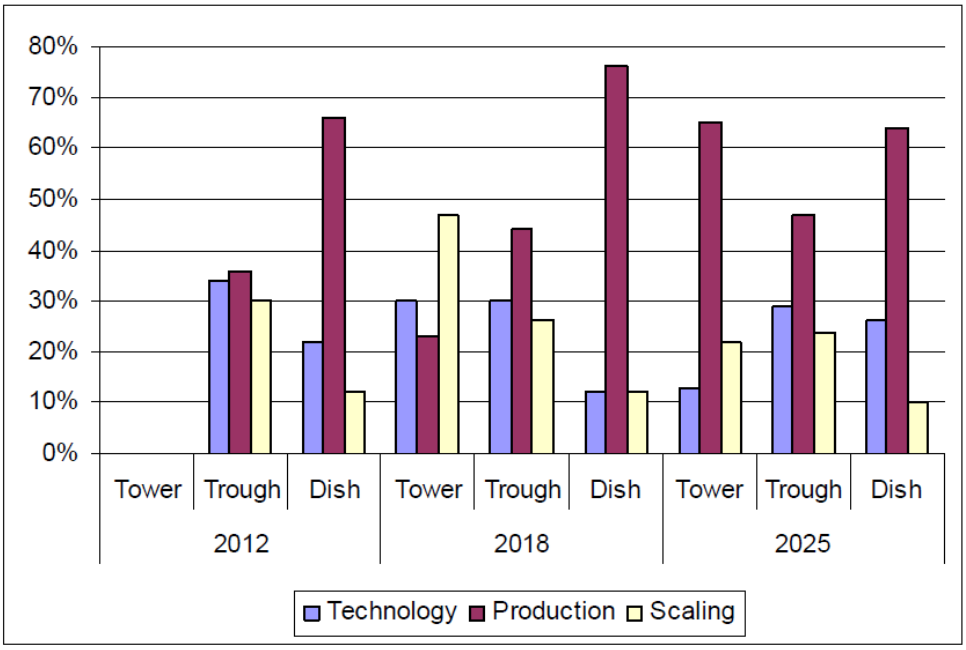
6.4. The Projection of future cost reduction

According to the independent analysis done by Sargent&Lundy in 2008 for the Department of Energy's Office of Energy Efficiency and Renewable Energy (DOE/EERE)[5], cost reductions will occur in technology, manufacturing and installation, and larger plant sizes, such as technology research and development (R&D) progress, economies of scale, economies of learning resulting from increased deployment, and experience-related operation and maintenance (O&M) cost reductions resulting from deployments. The study indicates that, the current costs are in the range of 9.8 cents per kilowatt-hour (¢/kWh) for trough with 6 hours storage, 12.3¢/kWh for dish, and 20.5¢/kWh for molten salt tower as shown in Table 5 and Figure 3 .With deployment and technology advances, the projection of costs in 2025 are in the range of 6.8¢/kWh for trough with 6 hours storage, 8.6¢/kWh for dish, and 7.4¢/kWh for molten salt tower. The specific values will depend on the total capacity of various technologies deployed and the extent of R&D program success. S&L predicts that the expected cost reductions will be due to technology advances (tower – 22%, trough – 31%, and dish – 23%) , volume production (tower – 44%, trough – 42%, and dish – 66%) and plant scale-up (tower –35%, trough –27%, and dish – 11%) as shown in Table 5 and Figure 3. It is worth noting that for the trough technology the costs will decrease more than due to the high potential for technology advancement and the efficiency increase of solar tower technology.

Table 6 Levelized cost summary –2008 –(¢/kWh)

	Near Term	Mid Term	Long Term
	2012	**2018**	**2025**
Trough no storage	10.48¢	8.75¢	7.71¢
Trough with storage	9.78¢	8.37¢	6.79¢
Tower	20.52¢	8.82¢	7.36¢
Dish	12.3¢	11.03¢	8.59¢

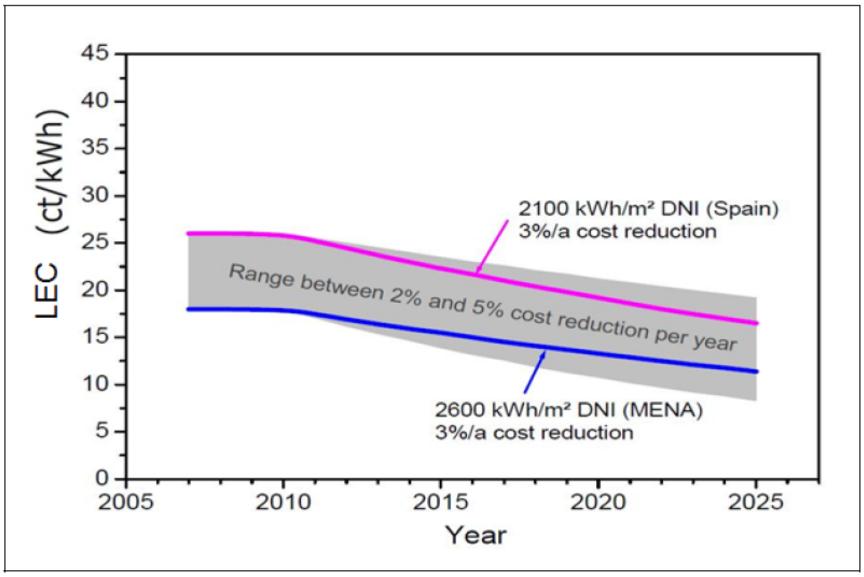
Figure 3 Cost Reduction Summary



For parabolic technology, the potential technological advancements are expected include: enhancing the efficiency of the solar field components, optimizing the thermal storage, technology and improving the compatibility of the conventional power block for the CSP plant operation.

Based on an ESTELA report, the energy sale price of the parabolic trough power plant is expected to reduce from the current 26 US cents to about 15 cents in 2025 with a forecasted 3% reduction rate per year (Figure 4).

Figure 4 Cost Reduction of parabolic power plant until 2025



At present, the technology of the linear Fresnel and dish-Stirling are relatively immature and are still not used in commercial projects. There are only some demonstration plants with small capacity using this technology. As a result, the simple and lower- cost design for linear Fresnel has not met its intended goal. According to data from the Novatec Biosol AG for 1.4MW project Puerto Errado 1 (PE1), the LEC is approximately 0.386$/kWh, which is 30% higher than for the parabolic trough system. The project site is located near Calasparra in the region of Murcia, Southern Spain.

7. Comparison between Photovoltaic and CSP

Photovoltaic (PV) power and CSP, are different in terms of technical aspects, but both techniques are essential clean energy alternatives to utilize solar power.

- PV converts sunlight directly into electricity (DC power) while CSP converts the light energy into thermal energy first, then use traditional turbine to convert heat into electricity (AC power).
- PV can use the solar diffuse radiation while CSP can only convert sun’s direct radiation into power.
- Even they can both work as centralized and distributed power supplies, PV has more flexibilities as distributed power supply as it has less rigid requirement for the sun radiation conditions.
- Unlike PV’s technique relies mostly on developing individual cell and module, the CSP technology relies heavily on the on-site constructing and final assembling and system integration.
- Nevertheless, both technologies do face the similar barrier in commercialization--relative high initial capex.

Compare with PV,

- CSP converts the light energy into thermal energy first, the cost and technical complexity of energy storage of CSP is considerably lower than that of PV. With storage, power production can be shifted according to demand therefore is less dependent on the time period and daily weather conditions.

- In addition, CSP uses the same turbine system to generate electricity just as the conventional fuel powered plant. Therefore, it is also a feasible choice to couple CSP with fossil fuel to form a hybrid CSP plant, or work as supplemental steam generating source to a fuel fired plant, adding the advantage of compensating the discontinuous power production of solar power.

In the ideal world, PV and CSP shall share their similarities and differences, and all work as essential new clean energy alternatives, but not necessarily competitors. However, the fast growth of PV in recent years worldwide does pose serious challenges to the commercialization progress of CSP in China. Besides the competition over the similar natural resources, the quick commercial expansion of PV already proves PV is approaching its technical maturity and more cost competitive. In China, CSP is a still undeveloped industry, which is forced to face the competition and cost challenge come from PV, a boosted gigantic industry with the 1st largest PV production capacity in the world of 4011 MW. To make the competition even fiercer, in 2009, the public tendering of Dunhuang 10 MW PV on-grid power station project was won by the feed-in price of ￥1.09, which will inevitably be taken as a benchmark price for future CSP project.

The feasible way to foster CSP industry in China as soon as possible, is to start building different types of CSP DEMO plants, to test the feasibilities and accumulate the experience in the real practice, meanwhile to make quick technology break through and grasp the key technologies, and also help the domestic CSP manufacturing abilities grow.

8. The current CSP status in China

8.1. History

China has started its own basic technical research and development work since 1970’s.

However, most work conducted during that period was simply to follow what other parts of world were doing, but not to aim for technology innovations or final commercial implementations.

Xiangtan Engine Factory worked with US Space Electronics Co. in the early 1980’s, manufactured two 5 kW dish parabolic concentrating solar thermal devices. The project stopped due to some technical difficulties, more importantly, the unsolvable key issue--high costs. Meanwhile, Tianjing University and Shanghai University of Science and Technology have all done some pioneer works too, constructed 1 kW solar tower device and 1 kW flat panel low temperature device respectively.

In 2005, collaborated by Hehai University and Israel Weizmann Institute, a 75 kW solar/oil tower hybrid demo system had successfully kept running for 2 whole days in Jiangning district, Nanjing. The solar field was consisted of thirty $40m^2$ mirrors. After this project, Hehai University switched their interest to parabolic trough technology.

8.2. Current progress

In recent years, with awakening environmental awareness, clean technology has become hotter than ever. Chinese government had kept increasing its financial support in R&D since 1990s. Simply from 2005-2009, the total money invested in solar R&D by The Ministry of Science and Technology (MOST) of PRC exceeds 100 million Yuan (RMB). China has covered most R&D work related to CSP technologies, including parabolic trough, tower, dish, and etc. Among which, collaborated with several prestigious universities and institutes, Institute of Electrical Engineering (IEE), Chinese Academy of Sciences is a leading R&D team in this field. For the time being, Asia’s 1st MW scale CSP project 1 MW solar tower demo system technically supported by IEE team is under intensive construction. All related key technologies were developed and intellectual patented by their team.

Table 7 CSP R&D work

Technology		Research Units
Parabolic system	Reflector	IEE, Hehai University and etc.
	Absorber	Hi-min Solar, Beijing Sunda, Dezhou Huayuan new energy technology Co. Ltd., and etc.
Heliostat of tower system		IEE, Changchun Institute of Optics, Fine Mechanics and Physics, Hehai University, and etc.
Dish Sterling		Nanjing University of Aeronautics and Astronautics, University of Science and Technology of China, Shanghhai 711 Research Institute, Huazhong University of Science and Technology, Kunming Institute of Physics, Xi'an Aeronautic Power Co. Ltd and etc.
Molten salts and other heat storage exchange systems		Zhongshan University, Beijing University of Technology, Wuhan University of Technology, Huanan University of Technology
Key materials		Institute of Metal Research, Hin-min Solar, Wuhan University of Technology, Beijing General Research Institute of Nonferrous Metals
System integration and control		IEE, Changchun Institute of Optics, Fine Mechanics and Physics

Table 7 lists some examples of CSP technologies R&D works done by Chinese researchers, however, lacking commercial projects makes it hard for these technologies to be tested in the real world practices.

Tianjing Caixi solar Co., Ltd, ventured by USA SETC Co., constructed a 146 solar thermal demo in Tianjing in 2009, and planed to size up to 6 MW and 130 MW in Lasa, Tibet. Their claimed innovated dish technique can raise the focusing temperature up to 1100° C, ensuring the high conversion efficiency between solar and electricity. The unique heat storage system is totally independent of power production system, which can enable continuous power production running without backup of fuel.

8.3. Manufacturing abilities

For the time being, except for relative small demo projects, China has no established operational commercial plant. Nevertheless, China is still working its way up to getting close to forming its own full manufacturing and production chain. For example, the projections of the domestic manufacturing percentage of the Inner Mongolia 50 MW parabolic project was listed in table 4. Development by Inner Mongolia STP Development Co. Ltd, a venture with Solar Millennium Ag., this project has already got the preliminary governmental approvals and in the process of development. Except for some key components, most parts and engineering works can be manufactured and finished within China'.

Many materials utilized in CSP projects, such as glass, metal frames, and molten salts, are just regular supplies without too much high technology involved. Besides those regular supplies, through self research and development China is now not only able to manufacture but also to export some key parts of CSP abroad too. For example Xi'an Aeronautic Power Co. ltd. has been exporting key components of Dish Stirling system to Stirling Energy Systems, Inc. (SEC), USA. In addition, Beijing IEE's central tower demo project has provided a platform for China to culture and test its own patented solar tower technique and suppliers' products too. For the time being, China already has the manufacturing abilities to produce most of the key components for centralized tower, but less for parabolic trough. Cheap domestic made prices also help to reduce the cost.

Table 8 The percentage of domestic manufacturing in the 50 MW parabolic project, by Inner Mongolia STP Development Co. Ltd, a venture with Solar Millennium Ag.

Already can be produced in china	**Imports are needed for now**
Civil Engineering	Mirrors
Steel Structure, pipe and valve	Heat collecting elements
Heat insulation	Control System
Steam cycle and water back up system	Engineering and supervision
Steam turbine unit	Power plant system design
Cooling system	
Heat exchanger	
Electrics, measurement and control	
Electro-Mechanical System	

Supplied in China		
Field and infrastructure	Machinery and equipment	Civil Engineering and installation
Common field engineering	NA	100%
Roads, storage and fence	NA	100%
Infrastructure of water supply	NA	100%
Solar Collecting field		
Heat collecting pipes and mirrors	0%	100%
Steel structure and moving parts	95%	100%
DCS, electronic controls	60%	100%
Heat and transfer fluid	100%	100%
Spare parts	55%	100%
Transportation and loading	90%	NA

Heat transfer system		
HTF heater	0%	100%
HTF steam boiler	100%	100%
HTF tank	100%	100%
Heat exchange pump	0%	100%
Transportation and loading	50%	NA
Balance of Plant		
Common BOP and cooling system	100%	100%
Water Treatment	100%	100%
Fuel Supply	100%	100%
Electrics	100%	100%
Instrumentation and control	90%	90%
Transportation and loading	50%	NA
Power Block		
Steam turbine and generator	0%	100%
Steam and water system	100%	100%
Electrical auxiliary system	100%	100%
Transportation and loading	50%	NA
Engineering	NA	75%
Project Management	NA	65%
Supervision, debugging and startup	NA	45%

9. Cost projections of future CSP projects in China

For the time being, CSP is still lack of economic competitiveness compared to the conventional fuel power. CSP industry in China has to go through several developing stages before it reaches its technical maturity and therefore become economically feasible. However, China is on the accelerating way of reaching this goal, as analyzed in the previous chapter, as many new techniques have been developed, and domestic manufacturing abilities are continuously growing. The data made for the following projections are also mostly from Wen Zhang's thesis[4].

9.1. Investment Cost

The cost-reduction-potential (CRP) of the CSP project in China lies in the lower costs of steam turbine and the generator set, the steel construction works and civil works., which has great potential to reduce the cost compare to the typical price in Europe/North America. The next table shows the product or service and the resulting cost reduction factors.

Table 9 Comparison of costs of relevant products/services and CRP

Product/Service	Price Europe /N. America	Price China	CRP
100 MW STG set	200 $/kW	68 $/kW	~1/3
Steel Construction works	—	—	~0.3
Civil works	—	—	~0.4

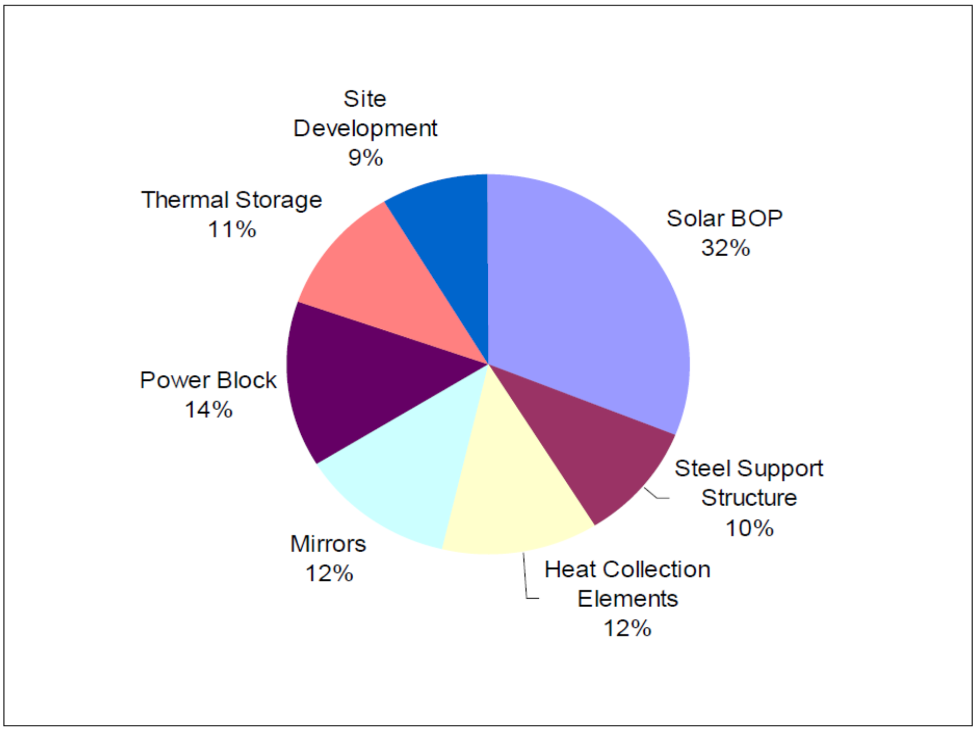
Based on various sources listed under Table 5-5 the price of a 100MW steam turbine and generator set (STG set) in China is approximately one third of the price in Europe/North America. The cost reduction potential of steel construction works and civil works between China and Europe/North America can reach 30% and 40% respectively.

According to Wen Zhang's speculation (Table 9), the specific investment costs for the parabolic trough power plant could decrease by 39%. It is worth noting as described in the previous chapter, that as China is getting to grasp the technology and manufacturing abilities for many key components, such as mirrors and receivers, thermal storage, the cost reduction potential for CSP in China is actually much greater than 39%.

Table 10 Comparison of major cost components for parabolic trough plant in China and in Europe/North America

Components	Price Europe / N. America	Price China	CRP
Solar BOP ($/m^2)	150	150	
Steel support structure ($/m^2)	160	48	~0.3
Receiver ($/m^2)	60	60	
Mirrors ($/m^2)	60	60	
Power block ($/k We)	2900	957	~1/3
Thermal storage ($/k We)	765	765	
Site development ($/m^2)	30	12	~0.4
Specific investment cost ($/k We)	11140	6810	39%

Figure 5 The distribution of the investment costs of parabolic trough project as an example (41 MWe)

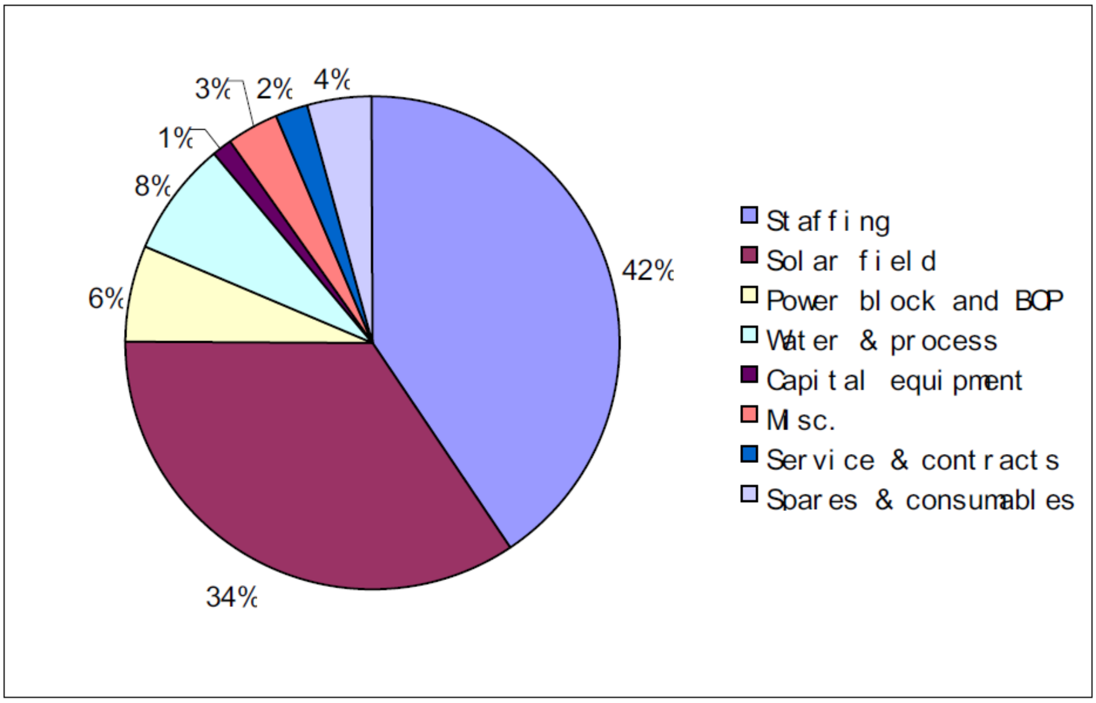


9.2. O&M cost

For a common scenario in Europe and North America O&M costs are usually about

2% of the total investment cost per year. In consideration of all cost reduction factors described below, this proportion could be reduced to 1.25%/yr.

Figure 6 Typical costs for O&M of a 100 MW parabolic trough power plant with storage in North America



Based on Figure 6, it is evident that the largest component of the O&M costs is the staffing costs. The following table 10 shows a comparison of the staffing costs for China and Germany.

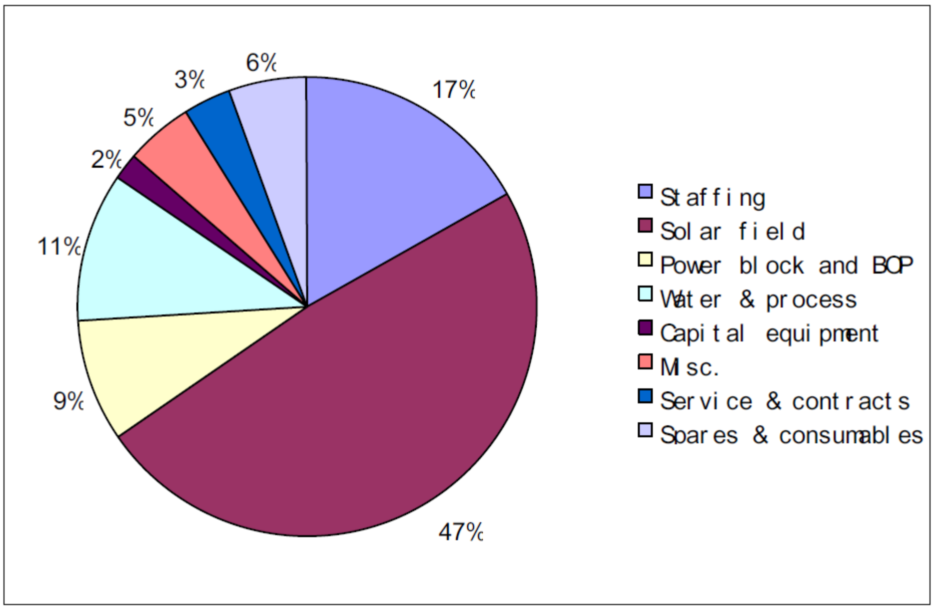
Table 11 Comparison of staffing costs between China and Germany

Staff	Germany $/h	China $/h	CRP %
Industrial workers	24.5	1.6	94%
Seller	15.5	2.5	84%
Chief secretary	23.3	4.1	82%
Engineer	35.8	6.3	72%
Head of department	47.3	9.8	79%
Product manager	41.6	19.1	54%

For the operation and maintenance costs only the staffing cost reduction will be considered. For the calculation of the O&M costs a 72% CRP for an engineer will be used. Due to relatively low productivity in China, a CRP of 0.3 for staffing costs has been chosen. Based on the O&M costs from the Sargent & Lundy Study in 2009 and the proportion of staffing costs, a rough 2.5 $M/a cost reduction is estimated.

Figure illustrates the cost distribution for O&M in China, it can be seen that the cost for the solar field is the largest component.

Figure 7 The cost distribution of O&M in China



9.3. Levelized Energy Cost

Table 12 Comparison of LEC of parabolic trough plant in Europe/North America with in China

Trough	Unit	Fichtner	China
		2008	2009
Power Plant		Trough 41	Trough 41
		Storage	Storage
Annual net electricity output	GWh	196	194
LEC	$/kWhe	0.369	0.208
Cost Reduction	%	44%	

Based on methodology described and data summarized in the previous sections, the levelized energy cost of parabolic trough project in China is calculated. (See Table 12). With the utilization of local products and staffing, it is expected that the electricity cost of a 41MW parabolic trough power plant in China is 44% lower than that in Europe/North America.

According to a report of the CSP industry made by Deutsche Bank, the electricity costs can be reduced by 15-65% until 2020 because of technology advances, mass production, and more competition.

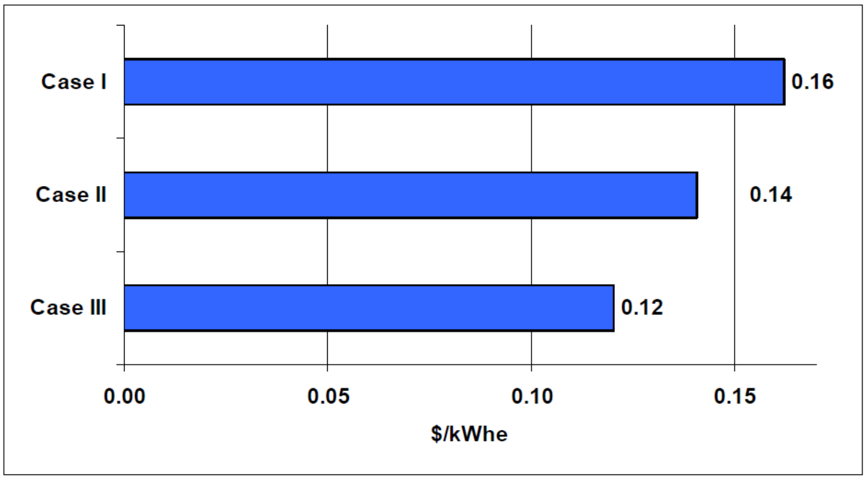
Based on this expected CRP the costs for further parabolic trough plants in China are estimated based on the three scenarios described below..

· **Case I:** 100MW Solar trough power plant, with Chinese market CRP, project in recent years

· **Case II:** 1000MW Solar trough, with Chinese market CRP and economics of scale CRP, project in recent years

· **Case III:** 1000MW Solar trough, with Chinese market CRP, economics of scale CRP and learning factors, project in 2020

Figure 8 Electricity cost for three scenarios in China



In 2020 the electricity cost of 1000 MW parabolic trough project in China is expected to be reduced at 0.12 $/kWhe, which takes only 75% of the cost for current 100 MW plant.

All of the costs shown above are electricity costs at the power plant. However, transmission cost has to be considered too as CSP transmission distances normally range from 200km to 2000km. According to Wen Zhang's calculation[4], the transmission of every 2000km will add additional 2 US cents to the cost compared to the transmission distance of 200km.

10. Case Study: Beijing 1 MW central tower demo project

Sponsored by government 863 and 973 research projects, Beijing IEE 1MW CSP demo pilot plant is the most publicized, 1st and only MW scale CSP plant in Asia. Unlike PV, the on-site construction, assembling and testing are essential links to a successful CSP project. So far this demo project has provided a valid platform for many suppliers to test their technologies and products.

10.1. Parameters

The designed parameters of this demo project are: Solar field is consisted of 100 100m^2 heliostats; the temperature of turbine entrance steam is 390 °C, while the pressure is 2.35MPa. Using heat transfer fluid (350° C) and pressurized steam (2.5 MPa) as two-stage heat storage system, which can maintain the plant 1 hour full load operation without sun radiation. Led by IEE, all related technologies are independently developed by collaborating team, with 34 patents being patented up to date.

10.2. Location

IEE demo plant is located at west of Datuo Village in Badaling, Yanqing, Beijing. With total annual sun radiation hours greater than 2600, it is among the areas where sun radiations are the most abundant around Beijing. The demo location was intentionally selected in Yanqing is also because its weather condition is similar to the one of the future CSP site--the deserts. With 5.4-5.8 m/s average wind velocity at 10 meter's height, and 7.0-7.1m/s at 70 meter's height, it is perennial windy. Therefore, this location is ideal for testing the endurance and longevities of deferent types of heliostats too.

10.3. Progress

The ground foundation work for of the heliostats was completed at the end of Sep. 2009, and the 1st series of 32 mirrors were undergoing assembling work. The demo plant is scheduled to generate and synchronize to grid in 2010.

10.4. Economics

Designed for technology verification, integration and demonstration, IEE Beijing demo plant is not oriented toward commercial profit. Financing need not to be the top issue for the researchers and developers as the project was sufficiently supported by major national technology R&D funds. Therefore, IEE demo project is not an ideal model used to justify the economic viability of CSP project in China.

Table 13 Cost and LCOE of Beijing Demo Project

Items	Cost (million RMB)
Mirror Field (including wires controls and installation)	20
Tower	10
Steam Turbine	1.8
HTF and system	2
Heat storage	3
Annual O&M	2
Annual equivalent full load operating hours	1300
Feed-in price (LCOE)	>￥4.15/kWh

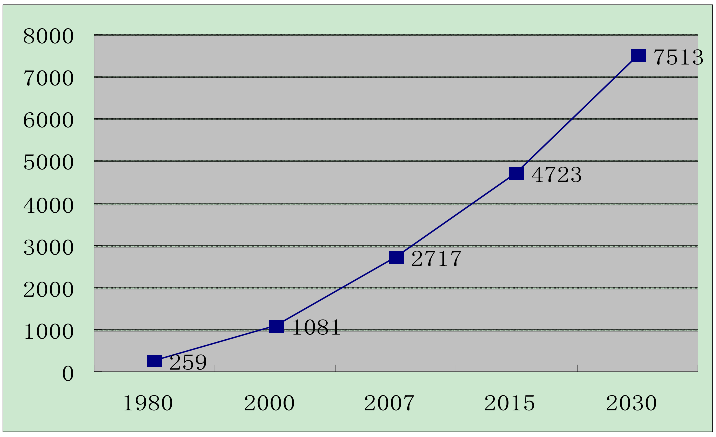
Table 13 shows only a rough estimation of the levelized cost of energy (LCOE) of Beijing IEE demo plant. The cost of mirrors has run from the initial budget 130 thousand Yuan (RMB) per mirror to 200 thousand Yuan/mirror. In addition, the budget of the central tower also run over from 2 million Yuan (RMB) to 10 million or even more, as the local government intends to construct the solar tower as a future local landmark which requires considerably much money to meet the higher standards for the exterior, functionalities and structure. Even without calculating the cost of the land, the LCOE (over 20 years)will be over ￥4.00 Yuan (RMB) per kWh. Another significant reason for high LCOE is due to the rather low capacity factor of the plant, which can only operate approximate 1300 equivalent full load operating hours annually.

11. Projections of future CSP development of China

11.1. The energy consumption will continue to increase rapidly as China's economy continues its fast developing pace.

The national demand for electricity had experienced continuous high growth duo to the accelerated industrialization in China in the recent years, for example, an average annual 14% increase from 2000 to 2007. In the future, even China will still face high growth in the power demand but it will eventually slow down as Chinese industries become more mature and energy efficient. According to the analysis of IEA[7], the national demand for electricity in 2030 will still be tripled of that of 2007. The average annual increase of electricity demand from 1980 to 2030 is 4.5%.

Figure 9 IEA projection of the demand of electricity in China



For the time being, there is no commercial CSP project operating in China. Due to the nature of long investment and constructing cycle of CSP projects, it is not expected to see an immediate burst of CSP deployment in China shortly. However, investors indeed have started turning their attention to this rather vacant territory of clean energy in China. During the past two years, numerous CSP projects – many being very ambitious, have been proposed and going around the table. Governmental policies may play an important role in the future, whether those projects can actually be materialized into real implementation.

11.2. Four-stage developing route for China's CSP development

Accurate CSP deployment projections may hard to make on the basis of current Chinese underdeveloped CSP market. Based on our observation and considerations, a strategic four-stage developing route for China's CSP was proposed.

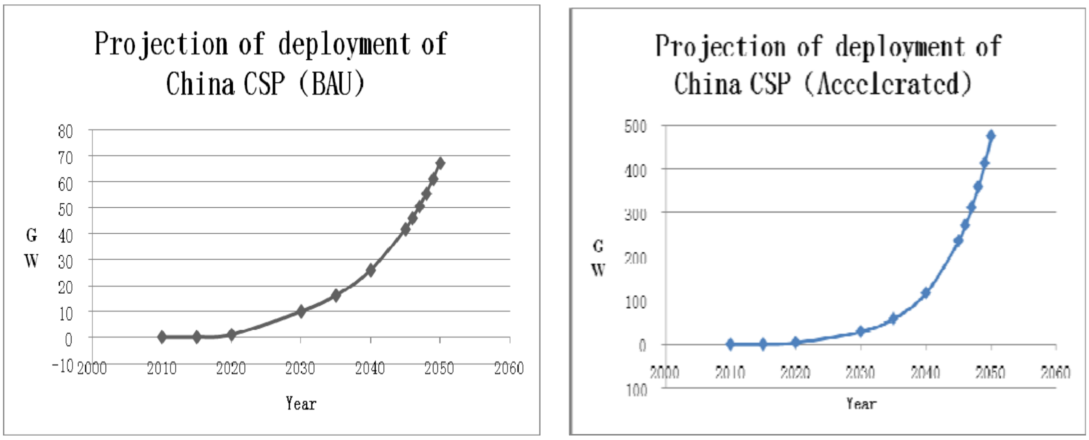
- **Technology Verification Stage (2010-2015),** most CSP technologies are not commercially proven in China yet. Under conservative scenarios, just demo plants for different types of technologies being constructed now and then, here and there**.**
- **Progressive Stage (2016-2020): or** Commercialization starting up stage. After the initial technology verifying stage of CSP, most technologies have been tested under the real world condition, thus technology risks should be reduced to reasonable levels. The deployment of CSP commercialization starts to grow. In constructing utility scale plants, CSP has become more common choice of technology. However, the economy of deployment has not taken shape at all.
- **Boosting Stage (2020-2030):** During this stage, we expect the technology of CSP is becoming rather mature. The economy of deployment and experience has formed. With improvements of more advanced heat storage technologies, CSP has become more cost competitive. It will attract the investors with great enthusiasm into investing into CSP projects, and CSP will grow like never before.
- **Free Marketing Stage （2030-):** CSP has become a major choice of power supply and competitive enough for free market competition.

11.3. Projections of the future deployment

According to the above periodic strategic developing route, projections of the future deployment of CSP in China were also made. Projections based on this 4 stage route were proposed, under two scenarios, one is business as usual, and the other one is accelerated.

By our predictions, CSP has the potential to provide up to 1-8% of China's electricity power demands by 2050, and become an important player in the nation's energy supply scheme.

Figure 10 The projections of CSP deployments in China under conservative and business as usual scenarios



(a) Business as Usual (b) Accelerated

Table 14 Basic assumptions made for the projections are:

Time Duration	Deployment	
	Business as Usual	Accelerated
Technology Verification Stage (2010-2015)	1-2 MW	10-100 MW
Progressive Stage (2016-2020)	100-200 MW	500-1000 MW
Boosting Stage (2020-2030)	500-1000 MW	1000-5000 MW
Free marketing stage (2030-2050)	10%	15%
The percentage of national demand for electricity CSP can satisfy by 2050	1-2%	7-9%

Basis and some necessary assumptions made for our projections are:

- The power demand of year 2050 was based on the prediction of IEA, assume the increase rate from 2030 to 2050 will slow down to 2-3% annually as the energy structure adjusts to a more energy efficient one.
- After 2030, under business as usual and accelerated scenarios, assumptions of annual 10% or 15% growth of the deployment of CSP, which were deduced from the statistics 10-15% of annual growth rates of conventional fuel plant during 1999-2009.
- The annual equivalent full load hours of CSP plants are adopted at 2000 hours per year.

Table 15 The percentage of increased amount of electricity generated by CSP to the total growth of electricity demand during specified period

Time period (year)	During this period , the percentage of increased amount of electricity generated by CSP to the total growth of electricity demand *[1]
2031-2035	5-7.5%
2036-2040	8.5-14%
2041-2045	15-25%
2046	20-35%
2047	23-39%
2048	25-44%
2049	28-50%
2050	31-57%

*[1]As the annual growth rate of the all electricity is a range value; 2%-3%, therefore the calculated ratio of the increased amount of electricity generated by CSP to the

total growth of electricity demand is also a range.

12. The analysis of existing international renewable energy policies

As the negative environmental impacts, such as green house gases emissions, and the consequential cost of environmental cleaning up caused by conventional power plants, have not been considered and reflected in the current prices of conventional electricity yet. Plus the high initial capex of the new energy generation technology, clean energies are lack of competitiveness with the conventional energy on the current market. Therefore, government support is essential in the initial stage of developing new sustainable energy technology.

The advantages and disadvantages of major exiting policies used by governments worldwide to stimulate the development of clean energy, and their consequent effects were examined.

- **Investment subsidies –** works the best to give the new renewable energy a big push forward in the starting stage, while it does not encourage the technology R&D progress in the long run. Meanwhile government procurement may lessen the quality of the purchased instruments, and latter maintenance too.
- **Tax credits –** Government provides certain tax deductions to encourage investors to invest in the new energy industries.
- **Renewable Portfolio Standard (RPS) –** is a major way for US to promote the fast growing of renewable energies. The advantage of RPS is that it only poses a limit of renewable energy for the utility companies to meet during a certain time period, but not to interfere with the market directly. Therefore, it still allows the free market competition to lower the cost/price while assures the percentage of renewable energy generated by the power suppliers.
- **Feed-in tariffs –** Simple and clear, easy to execute, has been one of the major means used to stimulate clean energy industry in Europe, e.g. has helped Spain

boost its CSP industries. The disadvantage is lack of flexibility during a certain period of time.

- **Fixed-premium systems –** A variant of feed-in tariffs, e.g. environmental premium, which compensates renewable energies' contributions to the environment – low CO_2 emission and savings on curbing environmental pollutions in the long run. This policy is also simple to carry out, given the clean energy extra margin to compete with conventional energies.
- **Tendering Systems –** Using commercial competition to regulate the market, yet has to be well designed to ensure the valid implementation.
- **Tradable green certificate systems –** Flexible as the certificates are tradable. Prices may reflect the real costs of the renewable energies. However, the trading system is complicated and prices may drift with the short term market demand, which will pose risks for the investors too.

Chinese government has already employed most internationally recognized policies to stimulate the development of renewable energies, e.g., mandatory renewable portfolio standards, subsidies, special development funds, feed-in tariff, tax credits and etc., however, current underdeveloped CSP in China makes it hard to attract government‘s attention.

13. Current domestic policies

- **From none to several, from simple fixed feed-in price to mandatory quota for consumption market, China has taken a leap forward in the new energy policy making.** "*Renewable Energy Law of People's Republic of China*" was first launched in 2006, followed by "*Medium and long term development plan for renewable energy development*" and then "*The eleventh five-year plan for renewable energy development*" in 2008. According to these programs and regulations, the proportion of renewable energy in China's primary energy consumption will be increased to 10% by 2010, and 15% by 2020. China's utilities, total capacities greater than 50million kW, are obligated to meet 3% of their total power capacity from non-hydro renewable by 2010, and 8% by 2020. Out of targeted 1800MW of the solar powered energy, the specific goal for CSP is 200 MW by 2020, counting for only about 11% of the total solar energy deployments. Many other supportive regulations were issued to assure the implementation of Renewable energy law such as *Regulations of the renewable energy electricity generations, Tentative regulation for the renewable energy electricity price and cost apportionments, Temporary administrative measures for allocating the supplementary income of the sale price of renewable energy electricity, Guidance for renewable energy industry, Temporary administrative measures for renewable energy development special fund* and etc..

- **Only three years after its launch, "*Renewable Energy Law of People's Republic of China*" is undergoing its first revision.** The draft proposed a guaranteed full purchase system to enforce the full purchase of renewable energy. Meanwhile, a special renewable energy fund, financially funded by both national treasury and income from the renewable energy electricity supplementary price, will be established to help develop technologies of renewable energies and electricity grid.

- **Under new regulations "*Suggestions to Accelerate the Applications of Building-mounted Solar Photovoltaic*", and "*Interim regulations to Building-mounted Solar Photovoltaic Financial Assistance Fund*", the "*Solar Roofs Program*" was launched by the Ministry of Finance and the Ministry of Housing and Urban-Rural Development in March 2009.** The subsidy's upper limit was set at 20 Yuan/Wp for the year of 2009, which can cover 30-50% the production cost of the manufactures. This can be interpreted as a strong policy driver for solar energy utilization, especially PV utilization.

- **An extreme powerful financial support program "Golden Sun Project" aiming at accelerating the PV industries was launched in July, 2009.** The subsidies can go as high as 50% of the initial investments for the on-grid electricity and its dispersion systems, 70% for the independent electricity generating system for the remote areas.

- **A new "*Developing plan for new emerging energy industry*" will be launched in near future, according to the latest news from NDRC.** In this plan, the new development targets of related new energies will be reset; some of the target numbers are expected to be several holds larger than the previous ones. E.g., the new total installed capacity of solar power will extend to 20,000 MW, 11 times greater than the number set by the former plan. Although out of 20,000 MW, the ratio for CSP is still unknown, it is conceivable that the new target is still inclined to PV. The total amount of capital intended to invest into new energy industry will reach to 4500 billion RMB in 2020.
- **Various tax-credit programs are also available to encourage the development of renewable energy, while CSP should applicable for these policies.** There might be some obstacles at first due to the lack of practices.

14. Policy recommendation details

14.1. Political challenges and other barriers to new policy options:

- **Current underdeveloped CSP in China makes it hard to attract the government policy maker's attention.** Due to PV's previous high-profile publicities, exploding deployment, and successful commercial operations, PV industries receive considerable size of subsidies under current new energy policies while CSP has almost none. Some established CSP demo plants in the future might help the policy makers see the potential alternatives.
- **Accurate policy suggestions may not easy to make based on almost none CSP commercialization deployment in China.** Policy suggestions can only be made by experiences and predictions at this stage, while it is difficult already to foresee accurately the future development of CSP e.g., the future market/cost/price in China based on very limited available data.

14.2. General Recommendations

- **The long term development of CSP industry needs the support of steady and long term policies.** Only consistent and long term policies can establish a relative steady and desirable market perspective to boost the confidence of the investors thus reduce the posed policy risks for the new energy technologies.
- **Corresponding to the central government policies, local or provincial government should make similar efforts in providing the supportive policies.**
- **Policy should truly be able to stimulate the commercial demand of the new energy and technology progress in the long run**, but not for the temporary speculation or demonstration purpose only.
- **The scope of policy should go wider, some new energy support policies should be technology independent in stead of being "technology defined".** The support policy for solar energy should not be limited to PV, but be able to apply to CSP too.
- **The power generation and grid companies should be more involved in the decision making process, and eventually have the power to choose their projects.** In order to push this industry into genuine market driven system instead of government policy driven, the real capital players must be actively involved in the process and play vital roles in the value stream.
- **The technical administration department should set up series of technical standards for new CSP plants at a timely manner.**

14.3. Policy suggestions aiming at the specific four-stage-route

As four-stage-route was proposed for the development of China's CSP based on our observations and studies, periodic policies have to apply for those stages accordingly.

- **Technology Verifying Stage (2010-2015):** As CSP technologies are still under verification for commercialization during this stage, strong stimulating policies are particularly needed.
  - ✧ The focus of this phase will be expanded R&D and pilot projects, which

would require heightened R&D funding, investment support, and electricity tariffs that make up any gap in project profitability.

- ✧ Therefore, continuous and strong governmental financial supports for technology R&D are still essential in this period. Deferent demo plants for deferent types of CSP technologies are essential platforms to test technology maturities, manufacturing abilities, and economic competiveness for each type of each technology.
- ✧ Strong investments subsidies would work very efficiently, e.g. state pay for a certain percentage of the initial investment. Ideally there would be a specific subsidy program specially designed for CSP just as strong as “Golden Sun Project”.
- ✧ Strong feed-in tariffs policies particular designed for the demo plants are also expected. It’s still impossible in this period to establish a nationwide tariff law for CSP industry but to only follow “one tariff for one particular project” rule.

➢ **Progressive Stage (2016-2020):** After the initial commercialization stage of CSP, even technology risks should be reduced to reasonable levels, the economy of deployment has not taken into shape at all.

- ✧ Strong policies such as investment subsidies, feed-in tariffs, tax credits are still essential.
- ✧ It is very important for the government to conduct bidding for several larger CSP projects in order to better understand the price of CSP.
- ✧ Once those prices are known, then the CSP policy can switch over to a more-stable form of feed-in tariff, which is differentiated based on the region of the country, with somewhat higher tariffs where the solar resource is less significant.

➢ **Boosting Stage (2020-2030):** During this stage, we expect the technology of CSP is becoming rather mature; the economy of deployment has formed. With financial subsides and advanced heat storage technologies, CSP has become cost competitive compared to the conventional fuel energies. It will attract the investors with great enthusiasm into investing into CSP projects, and CSP will grow like never before. Government shall withdraw the policy influence with caution during this time period and more let the market run on its own. Investment subsides are no longer needed. Government mainly uses RSP and feed-in tariff support to stimulate the market.

- **Free Marketing Stage （2030-):** CSP has grown into a major choice of power supply and is competitive enough for free market competition. Specific policies regarding to only CSP industry may not be necessary any more, market support policies can be removed at this stage.

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