Techno-economic assessment of future perspectives of the concentrated solar power plant in Mongolia

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Abstract

This research presents a techno-economic assessment of future possibilities for the concentrated solar power plants in Mongolia. The study uses data collection and analysis to evaluate the economic, environmental and technical aspects of parabolic trough CSP plant in Mongolia. The cities of Sainshand and Dalanzadgad were cited as examples to assess the direct normal irradiation, land availability, water resources, grid connectivity and infrastructure. The technical evaluation result shows that both sites would be suitable for installation of the Parabolic Trough Concentrated Solar Power plant in the Gobi Desert of Mongolia.

The economic evaluation was investigated by comparing two different power plant models, the first being a 5 MW off-grid CSP plant, and the second a grid connected CSP plant with identical capacities. Both plants would also receive similar Feed-in tariff (FIT) and Tax Incentive. Research showed that both CSP projects would not be economically viable with a borrowing cost of 8 % interest rate and with a project investment of 13.7 to 13.9 million Euros. The government announced to investors that under its FIT policy would provide a maximum FIT of € 0.14/kWh, the results from this research showed that the net present value (NPV) of CSP power plants is 12.7 million Euro while the benefit cost ratio (BCR) is 1.35 to 1.38. It is also indicates that internal rate return (IRR) is between 6.8 to 7.04 % with a payback period of around 8 years. The conclusion of this research is that the Mongolian Government should accept the current structure while also accepting new term similar to the “Adder”, subsidy scheme currently used in Thailand. This will equal the regular consumer energy price plus FIT. However, the Government should carefully consider the financial model before the Government offers the new subsidy policy to the entrepreneurs of the CSP projects. If the Government revised its Renewable Energy Law by adding this new policy, both on and off grid projects would be economically viable at borrowing rates no greater than 8 % including FIT and Tax Incentives.

Keywords: *solar thermal power plant, direct normal irradiance, parabolic trough CSP, economic assessment*

1. Introduction

All solar technologies use radiating sunlight to create energy, but some technologies use heat while others use photovoltaic to generate electricity. One of the solar thermal heat technologies is called concentrated solar power. In this technology the sun’s energy is concentrated by reflective devices such as parabolic troughs or mirror panels and then the resulting concentrated heat energy is transferred to a heat-transfer medium, which is used to power a conventional turbine producing electricity. Concentrated solar power consists of two parts. One part collects the solar energy to convert to heat, and the other part converts the heat to electricity. Concentrating solar power technology has four main types of receivers: Central receiver, Dish–Stirling systems, Parabolic trough, and Fresnel trough technologies [1].

This research is focused on the parabolic trough CSP technology. Parabolic trough technology is simplest mode of CSP when compared of forms. It utilizes a single sun tracking mechanism, is hybrid concept proven, with storage capability, and with more than 12,000 GWh operational experience. It is the most mature and commercially available solar thermal power technology today [2].

The cities of Dalanzadgad and Sainshand were selected in this assessment because of their climate and high levels of solar radiation.

An economic evaluation of the parabolic trough solar field technology can answer questions such as how much capacity could be installed, how much electricity could be generated, and at what are the economic, ecological and investment costs.

It is important to study the development of CSP technology in a Mongolian context in order to decrease the hard currency expenditures of imported power and thus make lower the price of electricity in the future. CSP technology could offer a solution to solve problems of electric power and determine the factors to implement a National Renewable Energy Program to increase the share of renewable energy. CSP technology is seen as one of the major way to reduce the country's dependence on energy imports and to increase currency reserves and to increase domestic energy market.

1.1 Location

The Mongolian Gobi Desert has been selected as the future location of the CSP. In this research paper, the two locations are Dalanzadgad in Umnugobi province and Sainshand in Dornogobi province (See Table 1 and Figure 1). Dalanzadgad is the capital of Umnugobi province, with population of approximately 14 thousand (2006). The city has 7 districts and is supplied by a 6 MW coal-fired heat power plant, providing both heat and electricity. Due to the low capacity of the power plant and unstable operation, heat demand cannot fully be reached when outside temperatures are very low. The government has promised to connect Umnugobi province to the centralized grid with a high voltage electric line by June 2012.

Sainshand is the capital of Dornogobi province located in the eastern Gobi steppe with population of 25 thousand (2006), and has a high level of infrastructure including Trans-Mongolian railway and a main highway. This city is connected with a 110kV transmission line.

Table 1 Different locations which will be considered in this study

City	Province	Geography		
		Latitude (^{o}N)	Longitude (^{o}E)	Altitude (m)
Dalanzadgad	Umnugobi	43.35	104.25	1469
Sainshand	Dornogobi	44.53	110.10	938

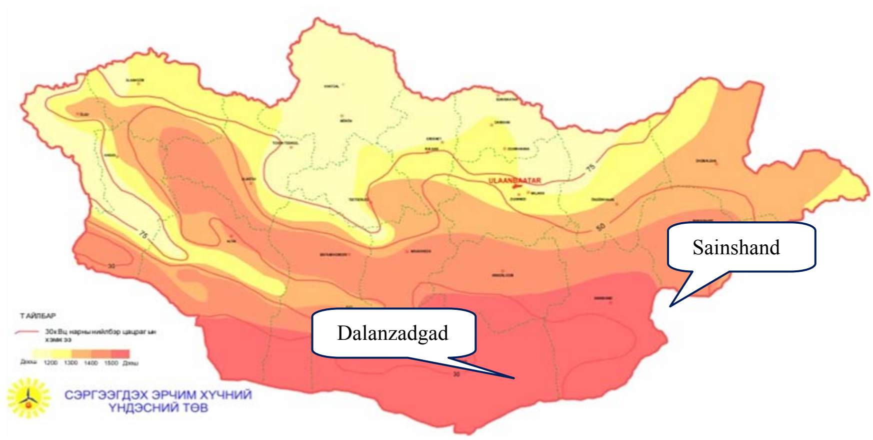


Fig. 1 Global solar radiation map and proposed sites

Source: Mongolian National Renewable Energy Center

1.2 Mongolian energy consumption

Mongolia is served by a power system that consists of four detached segments, the Central Energy System, the Western Energy System, the Eastern Energy System and the Altai-Uliastain Energy System. It is comprised of seven coal-fired heat power plants with heat extraction (CHP), plus two regional hydropower plant and seven distribution systems.

The Central Energy System has five based-load CHPs, which are unable to properly follow the daily power consumption regulated by the Russian Power Grid System. The other three grid systems are relatively small. The Western Energy System is powered by a 12 MW Durgun hydropower plant and imported electricity from Russia. The Eastern Energy System is powered by a 36 MW CHP, supplying 3 isolated provinces and 27 districts. The Altai-Uliastain Energy System includes two provinces, they are remote systems based on diesel power stations and connected with the new 11MW Taishir hydropower plant. The South Gobi region has one small 6 MW CHP supplying electricity with in their 7 districts.

The Altai-Uliastain Energy System and South Gobi region are currently isolated from the Central Energy System. This project has selected the area of the Southern Gobi because its energy demand is expected to grow rapidly as a result of the various mining developments.

1.3 Renewable energy policy

The National Renewable Energy Program aims to be created conditions ensuring ecological balance, increased employment, reduced poverty and increased sustainable socio-economic development by increasing the share of renewable energy in the energy balance. The program hopes to increase the percentage of renewable energy in overall energy production by 20-25 percent of national energy in 2020. The introduction of renewable energy advanced technology is hoped to reduce energy loss by 10 percent by 2020. This goal will be reached by increasing conservation and efficiency of operations in the production, transmission, distribution and supply stages.

The Renewable Energy Law promotes and encourages foreign investment and supports the production of energy from renewable sources by regulating generation, transmission, and pricing of green energy.

This law supports the development of a renewable energy industry in Mongolia in part by fixing tariffs to be paid to private sector companies in a band ranging from US 4.5 cents to 30 cents per kWh for electricity generated with renewable sources **Error! Reference source not found.**. It states that FIT of 0.15 – 0.18 USD/kWh (0.12 – 0.14 €/kWh) will be paid for energy produced by solar technologies which connect to the grid. But for solar technologies to stand alone system will have to be subsidized 0.2 – 0.3 USD/kWh (0.14 – 0.21 €/kWh).

1.4 Solar energy resource

Global solar radiation is measured by using instruments from 130 meteorological stations throughout Mongolia. All meteorological stations belong to the National Agency for Meteorology and Environment Monitoring (NAMEM) the government's implementing agency.

Results of these measurements show that approximately 70 percent of country has good solar resource. Mongolia receives annual global solar radiation between 1,163 kWh/m^2/a to 1,628 kWh /m^2/a, a majority of which comes from the Southern region (Figure 1).

An average entire country observed 270 to 300 clear days and sunshine with durations from 2250 to 3300 hours in an average year. Global solar radiation distribution decreases with the latitude from south to north. Over 17 percent of the territory receives global solar radiation of more than 1600 kWh/m^2, 25 percent receives 1600-1400 kWh/m^2, 51 percent receives 1400-1200 kWh/m^2 and 7 percent receives less than 1200 kWh/m^2 per year. The total yearly solar radiation potential is estimated to be 2.2x10^{12} MW.

This study seeks to assess the direct normal irradiation (DNI) in order to evaluate the feasibility of concentrating solar power plants in the Gobi desert.

2. Methodology of the study

This research has been conducted in four sections. Section 1 is data collection and analysis. Section 2 is the technical evaluation of parabolic trough CSP plants. Section 3 is the economic and environmental evaluation for parabolic trough CSP plant and section 4 is the recommendation for development CSP technology in Mongolia.

Section 1 Data collection and analyses

The data collected in this study can be divided into six sections: solar radiation data, energy demands and policy, infrastructure, geography, water resources, and meteorological data. All information of direct normal solar irradiation data and meteorological data was collected by NAMEN. All of the collected data was analyzed by different methods.

Section 2 Technical assessment of the parabolic trough CSP plant

In order for the CSP plant to be successful six key parameters must be met. These key parameters include: 1) solar resource; 2) land topography 3) land space and use 4) power grid availability and capacity 5) water availability and 6) infrastructure. Table 2 describes the key factors.

Table 2 Summary of key factors

Factors	Requirements
DNI	> 1800 kWh/m^2 per yr or 5 kWh/m^2 per day for economical operation
Land Topography	0% to 3% grade as potential. Less than 1% grade most economical
Land Space	5 acres or 20 km^2 per MWe
Grid Availability & Capacity	Close by.
Water Availability	Water required for steam turbine. Water required 2.9 – 3.5 m^3/MWh
Transportation Infrastructure	Proximity to roads and railways necessary for access and construction

Source: Q. Hang et al. [4]

DNI can be evaluated by analyzing three sources of data: measuring ground data, data taken from NASA and theoretically predicted data. Predicted DNI data is used to estimate the clear sky beam radiation. H.C.Hottel has presented a method for estimating beam radiation transmitted through clear atmospheres which takes into account the zenith angle and altitude for a standard atmosphere covering four climate types [5].

The clear sky beam normal radiation is then estimated by equation (1.a).

$$G_{cb} = G_{on}\tau_b \tag{1.a}$$

$$G_{on} = G_{sc}\left(1 + 0.033\cos\frac{360n}{365}\right) \tag{1.b}$$

Where:

G_{on} – the extraterrestrial radiation incident on the plane normal, W/m^2

n – the day of the year

The final analysis shows that both selected cities would be suitable locations for a 5 MW CSP plant. The basic design of the CSP plant is determined after analyzing the thermal efficiency concentrating collector, DNI, and sufficient heat. In this paper DNI is calculated for both sites in order to find the sufficient heat. Thermal efficiency for parabolic trough and the area of collector fields are determined by following two equations:

$$\eta_{thermal} = \frac{Q_u}{A_c I_t} = \eta_o - \frac{U_L(T_r - T_a)}{I_t C} \tag{2}$$

Where:

Q_u – sufficient heat to turbine, kJ/s

A_c – collector area

I_t – direct normal radiation, kWh/m^2/a

η_o – the optical efficiency

C – concentration ratio

U_L – overall heat loss coefficient (W/m^2 ^{o}C)

T_r – average temperature of inlet and outlet collector (^{o}C)

T_a – ambient temperature (^{o}C)

To calculate area of parabolic trough collector field using below relationship:

$$A_c = \frac{P}{\left(G_b \rho \gamma \alpha \cos\phi \eta_p - \frac{U_L T_a}{C} \right)} \tag{3}$$

Where:

P – power output for turbine

G_b – beam irradiance (W/m^2)

η_p – pipe system efficiency

γ – interception coefficient

Section 3 Economic and environmental evaluation of the parabolic trough CSP plant

The economic efficiency of the CSP plant was chosen through a method of the cost benefit-analysis. Cost benefit-analysis was used to calculate the resource distribution criteria of the government for the most efficient resource use. Government evaluates the cost and benefit of the project from the standpoint of social welfare. The project evaluation for cost and benefit analysis is done for public resources without reference to the market price [6] .

There are four factors presented as the criteria for Cost – Benefit Analysis:

a) Net Present Value (NPV)
b) Benefit to Cost Ratio (BCR)
c) Internal Rate of Return (IRR)
d) Payback period (PBP)

The economic analysis of this study is focused the levelized cost of energy (LCOE). If annual electricity production is estimated, then the cost of kWh electricity is defined as [7] :

$$LCOE = \frac{f_{cf} C_{invest} + C_{OM} + C_{fuel}}{E_{net}} \tag{4}$$

Where: f_{cr} – the annuity factor =9.88%

C_{invest} – total investment of the plant

C_{OM} – annual operation and maintenance costs

C_{fuel} – annual fuel costs

E_{net} – annual net electricity production

M.J. Montes et al. analyzed the economic efficiency of the solar multiple optimization for a solar-only parabolic trough plant. In this study, the economic analysis considers five CSP plants of similar capacity at approximately 50MW. The data for economic analysis is shown in Table 3 [7]. This data is used to calculate the investment cost for this research.

Table 3 Investment cost data for economic analysis of parabolic trough thermal plants

No	Item	Cost	Unit
1	Solar field	206.00	€/m^2
2	Power block	700.00	€/kWe
3	Preheater	1.54	€/kWe
4	Evaporator	10.45	€/kWe
5	Superheater	1.625	€/kWe
6	Reheater	4.221	€/kWe
7	Surcharge for construction, engineering and contingencies	20.00	(%)

Ishan Purohit et al. had studied the clean development mechanism (CDM) which is an instrument under the Kyoto Protocol for promoting technology transfer and investment from industrialized (Annex-I) countries to the developing (non-Annex-I) countries for projects focused on mitigating emissions of greenhouse gases. It provides for Annex-I countries to invest in emission-reducing projects in non-Annex-I countries and to use the resulting Certified Emissions Reductions (CER) credits towards their own compliance with the emission limitation targets set forth by the Kyoto Protocol [8] .

3. Calculation and discussion

3.1 Solar resources assessment

DNI evaluation was done by three sources of data: measuring ground data, data taken from NASA and theoretically predicted data. The ground measured data was obtained by NAMEN from 2004 to 2010. The result from the ground measuring showed that the average annual DNI was 1898.13 kWh/m^2/a for Sainshand while the DNI in Dalanzadgad was 1650.67 kWh/m^2/a (Table 4). This data was lower than the data from NASA and the theoretically predicted data. It can be seen that the measured data from both sites is close to the nominal level of 1800 kWh/m^2/a.

Table 4 Comparison of assessed DNI data sources (kWh/m^2/day)

Site	Dalanzadgad			Sainshand		
Compare	Predicted	NASA	NAMEN	Predicted	NASA	NAMEN
Jan	4.92	6.25	4.70	4.85	5.83	4.94
Feb	6.26	7.25	5.88	6.00	6.78	5.90
Mar	6.90	7.58	5.31	7.34	7.63	6.34
Apr	7.76	7.8	5.56	7.75	7.66	5.82
May	9.43	7.44	6.08	8.92	7.49	5.93
Jun	10.06	6.79	5.78	9.51	7.13	5.62
Jul	8.77	6.01	5.23	9.09	6.22	5.57
Aug	8.98	5.78	5.19	8.68	5.68	6.00
Sep	8.30	6.61	5.69	8.22	6.27	6.18
Oct	7.36	6.86	6.35	6.98	6.01	5.99
Nov	6.10	5.8	5.34	5.34	5.62	5.62
Dec	5.10	5.53	4.85	4.29	5.10	4.96
Average, W/m^2	885.0	-	747.5	840.8	-	644.4
Annual, kWh/m^2/a	2737.36	2421.95	1650.67	2647.36	2352.07	1898.13

3.2 The meteorological data analysis

During last 10 years meteorological data has been obtained by NAMEN for the two selected sites. The average ambient temperature in the Dalanzadgad is about 23.6^{o}C during summer, −13.7°C during winter, and annual mean temperature of around 5.8^{o}C, whereas average ambient temperature in the Sainshand is about 25.0^{o}C during summer, −17.1°C during winter, and annual mean ambient temperature of around 5.1^{o}C (see Figure 2).

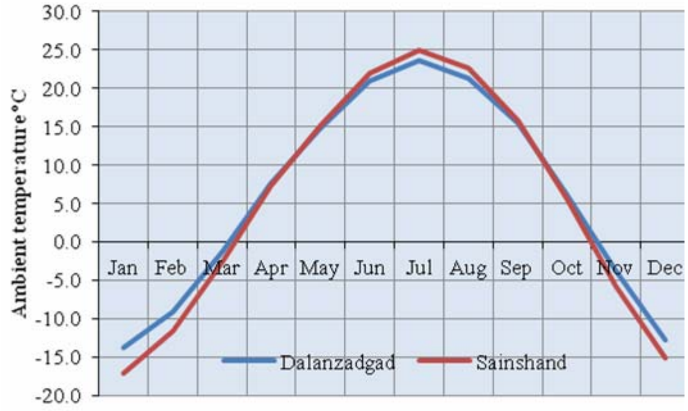


Fig. 2 Average ambient temperatures

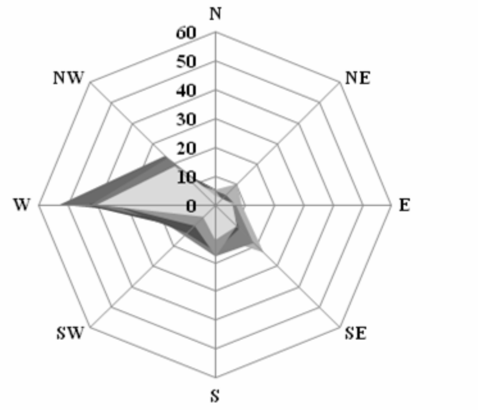


Fig. 3 Wind direction frequency

The average annual wind speed for both sites are similar and quite low with only 2.3-5.1 m/s in Dalanzadgad and 3.6 – 5.7 m/s in Sainshand. However, there are wind gusts with maximum wind speeds of 34 m/s detected in March 2010 in Dalanzadgad, and 34 m/s in April 2002 in Sainshand. These possible gusts should be taken into account while designing the solar field. As can be seen in the Figure 3 depicted above, the prevailing wind directions in the two sites are similar, with a majority of the wind traveling west and north-west.

The annual average rainfall for Dalanzadgad and Sainshand varies between 1.8-23.2 mm and 0.7-20.5 mm. Rainfall occurs mainly during May and September. In the south is the Gobi Desert, some regions of the Gobi receive little to no precipitation throughout the year. The humidity varies between 34% and 40% during the summer month and slightly higher in winter with values from 40-66%.

3.3 Land availability, water resources and grid connectivity

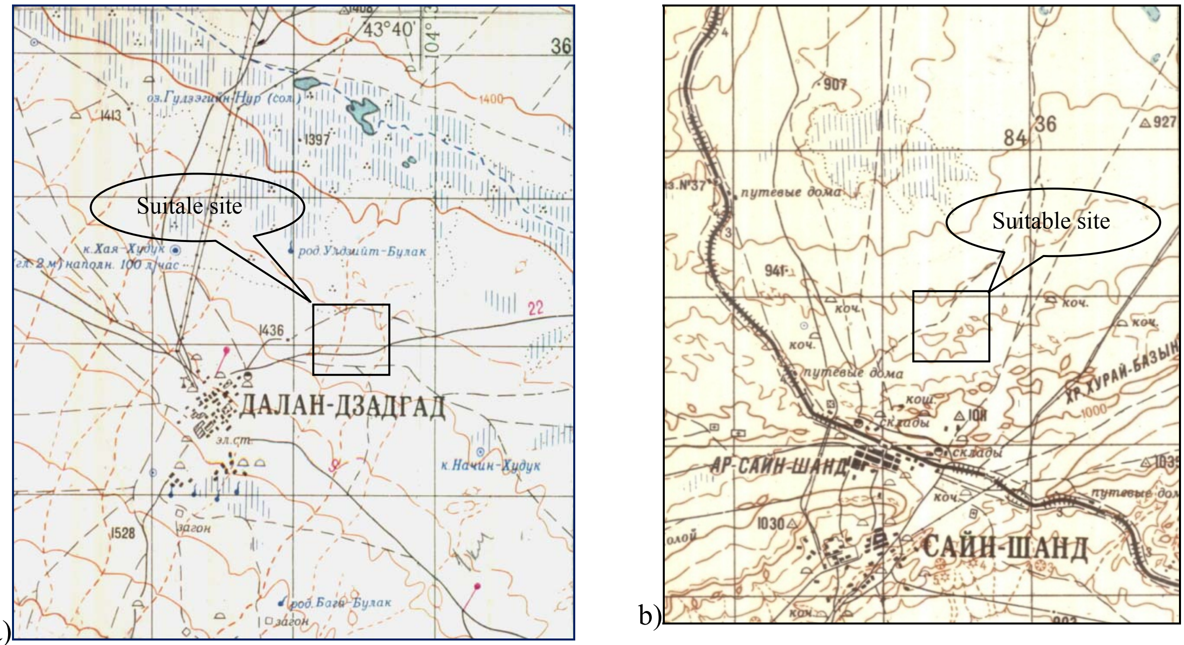
A parabolic trough solar power plant requires approximately 5 acres (4046.86 m^2 or 20 km^2) per MW of plant capacity. The proposed sites have relatively low population and very little arable land, and much of area is covered by steppe. The topographical location of Dalanzadgad and Sainshand is depicted in Figure 4 a, b.

Site studies have generally found that the land slope is between 0% – 3% level as potential, with land sloping less than 1% being the most economical to develop. The potential sites should have reasonable land costs, and be located close to transmission lines, water, and fuel resources.

The area north-west of Dalanzadgad meets the requirement for land slope. But the city isn't connected to a central transmission line. The northern area of Sainshand has a suitable location which can be found on the topographical map and is connected to a transmission line.

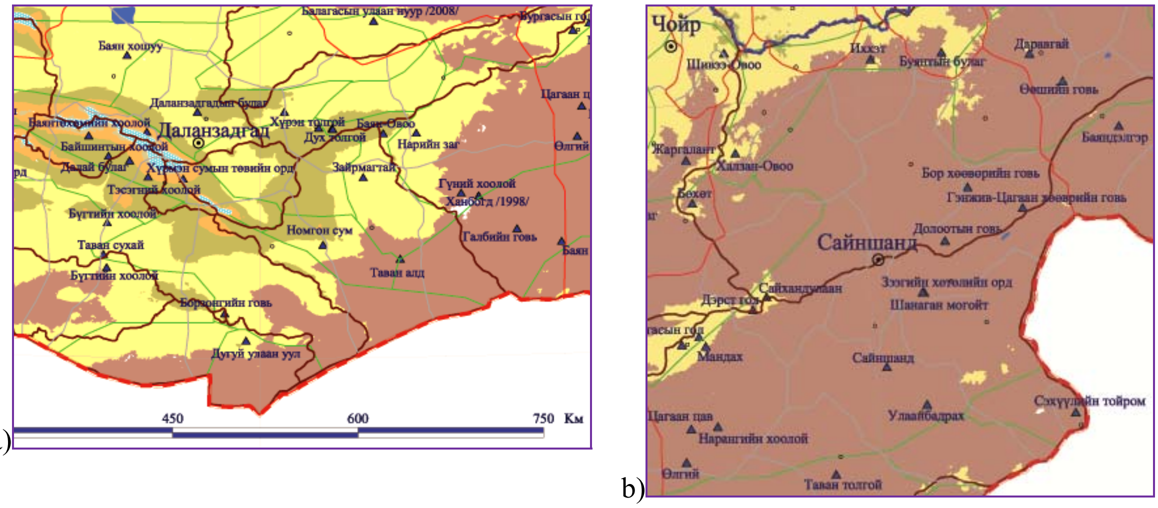
Water consumption for the solar thermal power plant would be similar to a conventional thermal power plant with similar output, plus additional water that would be used for solar reflector cleaning. For a wet cooled system, the total water consumption would be 4.11 m^3/MWh (43.15 ML/a). But a dry cooling system would only require 0.327 m^3/MWh (3.43 ML/a). But it would be more energy intensive [9]

The underground water resource map of Dalanzadgad and Sainshand is depicted in Figure 5 a, b. In the map, underground water resources are marked as ▲ symbol.



a) b)

Fig. 4 Topographical location a) Dalanzadgad b) Sainshand



a) b)

Fig. 5 Water resource map, a) Dalanzadgad b) Sainshand

Table 5 Comparison results

Items	Dalanzadgad	Sainshand
Land Space	yes	yes
Land Topography	From centre 2-3 km in North	From centre 4-8 km in North
Grid Availability & Capacity	Off-grid system	Near to connect 110kV line
Water Availability	Under ground water	Under ground water
Transportation Infrastructure	low	Good

3.4 Design for parabolic trough solar thermal power plant

Dalanzadgad is provided heat and electricity by a 6 MW CHP. This means that the new CSP plant must generate up to 6MW in output power. In this situation a proposed CSP plant can be operated in combination with the CHP. The capacity CSP plants of both cities are assumed to be 5 MW. This means that the CSP plants will be capable of producing up to 5 MW of power each.

In this research, the parabolic trough collector and turbine–generator were selected by the recommendation from the Solarlite Company, specification is listed in Table 6 and 7. The T-s diagram for a steam turbine and steam cycle of 5 MW parabolic troughs CSP plant are shown in Figure 6 and 7.

Table 6 Specification of "Marc-2" turbine & generator to set-up

Inlet condition operational	400°C/40 bar
Exhaust condition operational	180°C/10 bar
Speed (RPM) after gear box	11000 RPM
Output Power	5,000 kW
Dimension (length – width – height)	1.5 x 2.5 x 2.5 m
Efficiency turbine-generator	26%

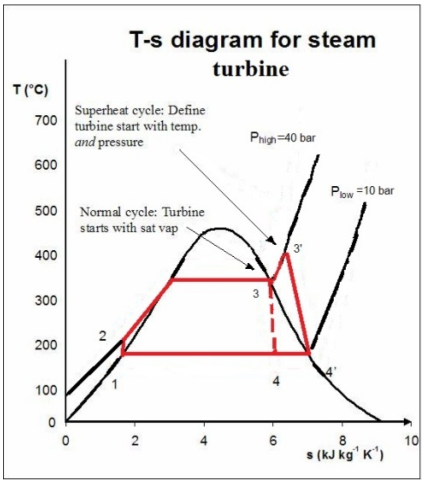


Fig. 6 T-s diagram for 5 MW steam turbine

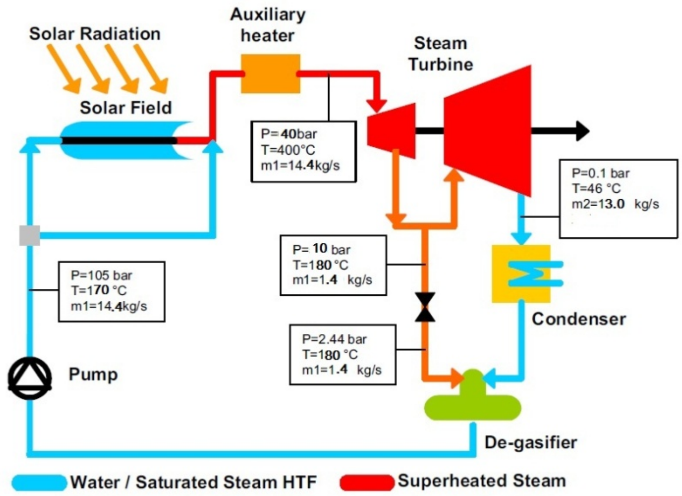


Fig. 7 Steam cycle of 5MW parabolic trough CSP plant

In order to find the most efficient power operation the heat loss coefficient and thermal efficiency must be calculated, as in equation 2. The optical efficiency calculation is based in the specification of the producer "Solarlite". The research was started with a DNI equal to 757.5 W/m^2 for Dalanzadgad and 644.4 W/m^2 for Sainshand, which were analyzed in ground measured data, Table 4. Finally the total area of the parabolic trough collector assembly was estimated by using equation 3. The summary is described in the Table 7.

Table 7 Specific parameter of solar thermal plant

Sizing of solar thermal plant	Unit	Dalanzadgad	Sainshand
Input power to turbine	kW	17,241.38	17,241.38
Mass flow HTF	kg/s	14.39	14.39
Optical efficiency*	%	0.75	0.75
Heat loss coefficient	%	24.32	24.30
DNI	W/m^2	757.5	644.4
Thermal efficiency	%	0.62	0.62
Area of parabolic trough collector	m^2	36,924.59	36,938.36

* - optical efficiency of "Solarlite-4600" parabolic trough collector.
Source: http://www.solarlite.de/en/products.cfm

3.5 Economic evaluation

This study compares the economic analysis between a grid connected 5 MW solar thermal power plant project and an off-grid 5MW hybrid project that uses parabolic trough CSP technology in order to select the best economic option. This study seeks to use imported solar thermal applications, similar to existing CSP plant elsewhere. The analysis starts with the investment cost of the CSP plant; most components of the plant are imported from Europe which is the leading supplier of the CSP technology [10].

The estimated value of the investment cost including power block, collector field, steam heat exchanger, site works, construction surcharge, transportation, transmission line cost and tax are presented in Table 8 and illustrated in Figure 8.

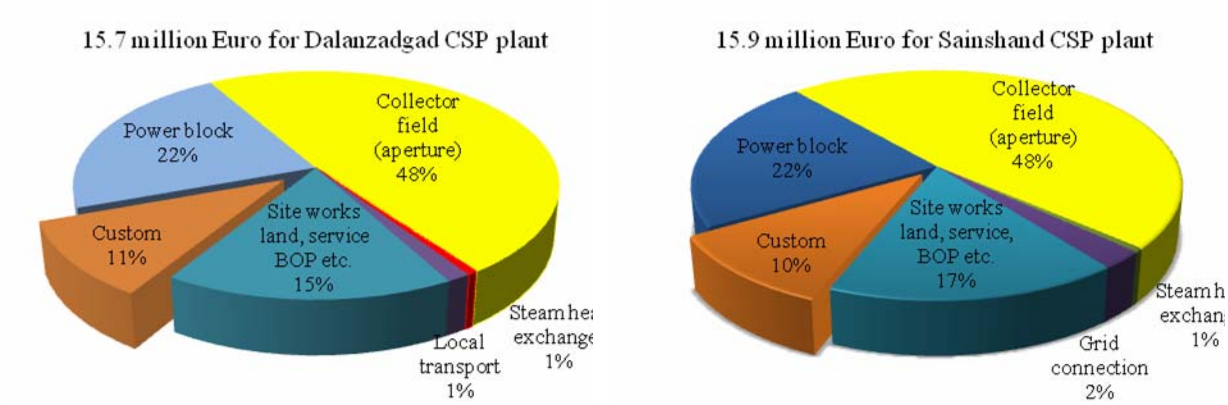


Fig. 8 Structure of investment cost 5MW parabolic trough power plant

The investment cost was taken from reference number [7] , which was presented in Table 3.

Table 8 Investment cost of solar thermal power plant

Capital cost /Dalanzadgad/	Capital cost /Sainshand/	Unit	Notes
3,500,000.00	3,500,000.00	Euro	- Power block;
7,606,465.66	7,609,302.16	Euro	- Collector field;
89,200.00	89,200.00	Euro	- Steam heat exchanger
223,912.92	---	Euro	- Local transportation
---	400,000.00	Euro	- 20km, 35kV transmission line
2,619,781.16	2,655,650.9	Euro	- Surcharge for construction, engineering and contingencies;
1,679,346.90	1,679,775.32	Euro	- Custom tax
15,718,686.97	15,933,905.38	Euro	Total cost

The levelized cost of energy is calculated by using equation 4. The annual net electricity production of a 5MW solar thermal power plant is simulated for one year. Simulated values are presented in Table 9. This is a starting point for the electricity kWh calculation of the proposed solar thermal power plant.

Table 9 Levelized cost of energy

Costs	Dalanzadgad	Sainshand	Notes
O&M per year	315,945.6 **€**	320,271.5 **€**	O&M equipment cost 2% of investment per year Labour cost 0.01% of investment per year
First year Investment cost	15,718,687.0 €	15,933,905.4 €	From Table 8
Fuel cost	-	-	
Annual net electricity	10,500,000.0 kWh		Assume 2100 h/year operation
LCOE	17.8 c€/kWh	18 c€/kWh	

Cost benefit analysis is used to calculate an initial capital cost, NPV, BCR, IRR and PBP. This analysis shows CSP plants will be a profitable venture in Mongolia.

Solar thermal power projects offer many interesting possibilities under the CDM because they directly displace greenhouse gas emissions. The CO_2 emissions mitigation benefits associated with the CSP plants is dependent upon the amount of electricity generated. Starting 2010, two renewable energy projects are registered by the CDM Executive Board with grid emission factor 0.8 tCO_2/MWh in Mongolia. In this study, that factor is used as a reference for greenhouse gas estimation. Key project assumptions in the study are identified in Table 10.

Table 10 Key parameters for economic evaluation

Parameter	Value	Notes
Currency	€ and $	1 Euro (€) = 1.31 US dollar ($), Bank of Mongolian exchanged date on 2012.02.19
Project life time	25 years	Typical for a project of this nature
Interest rate	8%	Montes M.J. et al. 2009 [7]
Liquidation	20 years	
Power price (selling)		
- Price	c€ 5/kWh	(Source: http://www.era.energy.mn/)
FIT		
- Grid	c€ 13.7/kWh	- for Grid-connected c$ 15–18/kWh
35 kV transmission line cost for 5 MW	€ 20,000/km	(Source: http://www.ea.energy.mn/)
Local transport cost	2%	Total investment cost
O&M cost	2%	Investment cost per year
Labour cost	0.01%	Investment cost per year
Custom tax rate	15%	Source: http://www.ecustoms.mn/tax
Grid emission	0.8 tCO_2/MWh	Dorjpurev J. 2008 [11]
CER	€ 5.18/tCO_2	Source: http://carbonmarket.tgo.or.th/index.php

The economical evaluation of the off-grid and grid connected 5 MW parabolic troughs CSP plant proposed in this study was calculated by using Microsoft Excel Program. The final results are shown in Table 11, 12, and 13.

Table 11 Project with FIT 17.8 and 18 c€/kWh

Parameters	Unit	5MW parabolic trough CSP plant	
		Off-grid	Grid connected
Investment	Euro	15,718,687.0	15,933,905.4
FIT	c€/kWh	17.8	18
NPV	Euro	16,651,946.1	16,874,093.3
BCR	-	1.57	1.57
IRR	%	8.75	8.75
PBP	Year	7.22	7.22

Table 11 shows the economic data for a 5MW off-grid and grid connected parabolic trough solar thermal power plants. Both CSP projects would be economically viable with a 8% interest rate. If the selling electricity is sold at c€ 18/kWh and the investment is for 15.9 million Euro, LCOE of c€ 18/kWh, NPV of 16.9 million Euro, BCR of 1.57, IRR of 8.75%, and PBP of 7.22 years.

Table 12 Project with FIT 13.7 c€/kWh

Parameters	Unit	5MW parabolic trough CSP plant	
		Off-grid	Grid connected
Investment	Euro	15,718,687.0	15,933,905.4
FIT	c€/kWh	13.7	13.7
NPV	Euro	12,417,347.0	12,388,253.0
BCR	-	1.18	1.17
IRR	%	5.21	5.03
PBP	Year	9.6	9.74

Table 12 shows the economic data for a 5MW off-grid and grid connected parabolic trough solar thermal power plants in case with FIT presented that both CSP projects would not be economically viable with a 8% interest rate and the investment is for 15.9 million Euro because the FIT would not exceed c€14/kWh, NPV of 12.4 million Euro, BCR of 1.18, IRR of 5.21%, and PBP of 9.6 years.

Table 13 Project with FIT 13.7 c€/kWh and Tax Incentive

Parameters	Unit	5MW parabolic trough CSP plant	
		Off-grid	Grid connected
Investment	Euro	13,703,470.7	13,918,178.6
FIT	c€/kWh	13.7	13.7
NPV	Euro	12,689,770.9	12,660,745.9
BCR	-	1.38	1.35
IRR	%	7.04	6.83
PBP	Year	8.26	8.4

Table 13 shows the economic data for a 5MW off-grid and grid connected parabolic trough solar thermal power plants. In this case includes FIT and Tax Incentive. Despite the added Tax Incentive both CSP projects would not be economically viable with a 8% interest rate and investment from 13.7 to 13.9 million Euro, because the FIT is still too low c€14/kWh, NPV of 12.7 million Euro, BCR from 1.35 to 1.38, IRR from 6.8 to 7.04%, and PBP around 8 years.

4. Conclusion

This research provides techno-economic assessment of future perspectives of the CSP plant in Mongolia. The technical evaluation of CSP plant was analyzed and estimated in terms of solar resources, land topography, land space, power grid availability, water resources, and infrastructure. The cities of Sainshand and Dalanzadgad in Gobi desert were site selected for this research. The result from ground measurements showed that the average annual DNI from both sites was close to the nominal of 1800 $kWh/m^2/a$. In order to evaluate the economic assessment, electricity generation from both CSP plants was calculated based on the measured DNI value.

The land topography showed that both cities had a slope of less than 1%. This low grade was required by economical land leveling. And these two cities have sufficient land for 5 MW parabolic trough power plants. Both areas also have underground water resourses. In case of Power Grid availability, Sainshand has already developed infrastructure but Dalanzadgad has not been developed well yet.

The meteorological data for last 10 years analysis indicates that the average ambient temperature in both cities is about 23.6 to 25.0 ^oC during summer, −13.7 to −17.1 °C during winter, and the annual mean temperature is around 5.1 to 5.8 ^oC. The annual average wind speed in both sites are similar and quite low with only 2.3 to 5.7 m/s.

Base on regional electricity demand, 5 MW parabolic trough solar thermal power plant was designed for each selected site. Dalanzadgad off-grid 5 MW parabolic trough solar thermal power plant required about 36,924.59 m^2 for its parabolic collector field whereas the Sainshand grid connected 5 MW solar thermal power plant required 36,938.36 m^2 of area.

The technical evaluation results showed that both Dalanzadgad, Sainshand sites can be recommended to install the Parabolic Trough Solar Thermal Power plant.

The economic evaluation was performed in terms of the comparison between 5 MW off-grid and grid connected parabolic trough solar thermal power plants in case of FIT and Tax Incentive. It showed that both CSP projects would not be economically viable at 8 % interest rate and project investment of 13.7 to 13.9 million Euros. According to the government FIT policy recently announced to the investors as maximum FIT of c€ 13.7/kWh. The conclusion of this research paper is that in order to create an economically viable model the Government would have to create an “Adder” subsidy scheme similar to the one in Thailand. This would guarantee in combination with a tax incentives a regular consumer energy price of 5 c€/kWh plus FIT 13.7 c€/kWh. For an example, the Government could offer about c€ 19/kWh to the investors.

However, the Government should carefully consider the financial model before the Government offers the new subsidy policy to the entrepreneurs of CSP projects. If the Government revised its Renewable Energy Law adding a new policy, CSP projects both on and off-grid would be economically viable at 8 % interest rate, FIT and Tax Incentive.

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