CHAPTER IV

CALCULATION AND DISCUSSION

In this chapter, results from the analyzed data of solar radiation and meteorological data, energy consumption, demand, grid connectivity, water resource, land capacity i.e., and design solar power plant, are presented and discussed. The final evaluation would be techno-economic feasibility parabolic trough solar power plant using Microsoft Excel Software to simulate power output.

Solar radiation data analysis

The Government implementing agency NAMEN provides information of weather forecasting, hydro-meteorology and environmental condition to governmental and private organizations, coordinates all hydro-meteorological observation networks of Mongolia.

130 meteorological stations in the entire country belong to NAMEN, including some stations at the proposed sites Dalanzadgad, and Sainshand. The stations are observed air temperature, surface soil temperature, atmospheric pressure, humidity, velocity and direction of wind, precipitation /amount and intensity/, cloud amount and type, visibility, weather present and past, snow depth and density. Some meteorological stations are observed solar radiation, sunshine duration, and include DNI measurements.

1. Analysis comparison measured DNI data Dalanzadgad and Sainshand

The recorded data has been provided by NAMEN to this research paper for the period 2004 – 2010. The data are recorded at day 5 times starting from 6:30am to 18:30pm between 3 hours interval. (Appendix 5) The assessment of the ground measured data can be summarized as follows:

1.1 Measured data of Dalanzadgad, and Sainshand sites had recorded 2004 – 2010, and 2005, 2006, 2007, 2010 respectively.

1.2 The DNI is measured using an actinometer (Appendix 6). Actinometer is an instrument used to measure the heating power of solar radiation. Instrument is used manually, therefore most measured data were missed and three hours of interval data were inadequately for assessment specific DNI resources. (Figure 7.) Although daily, monthly and annual average DNI can be used for the analysis of possible resource.

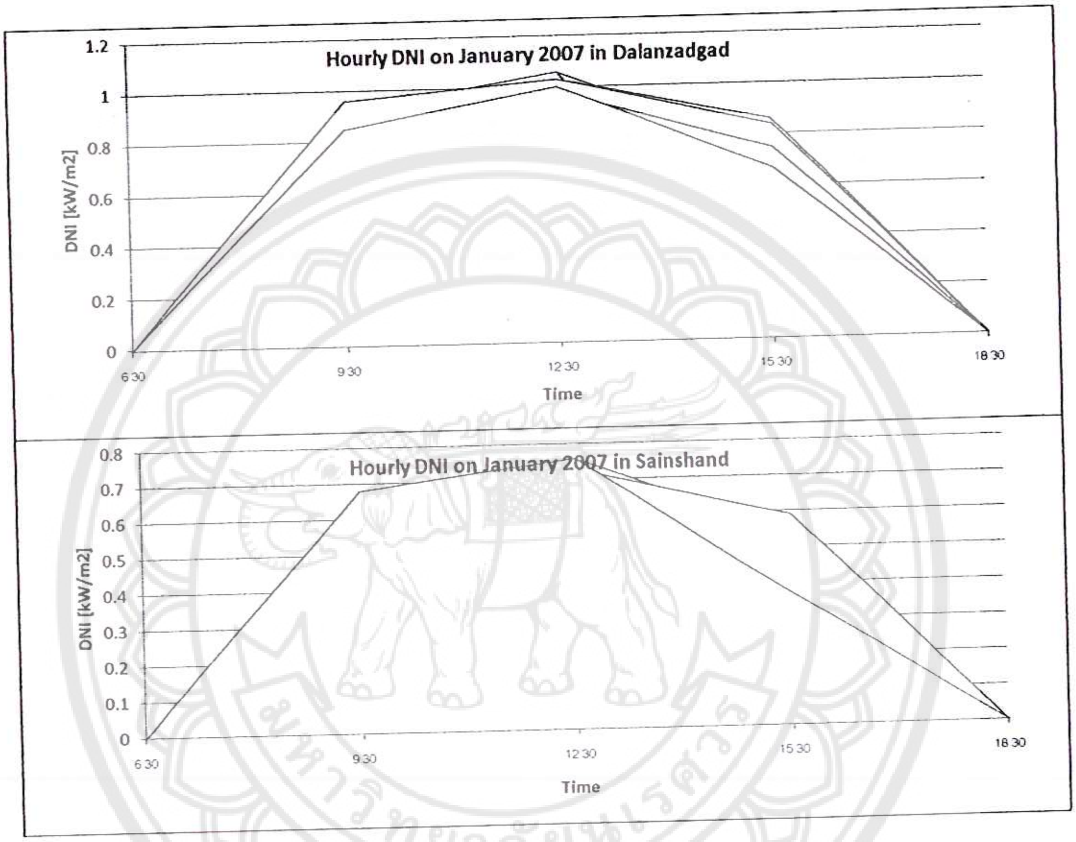

Figure 7 Measured hourly DNI on January 2007, Dalanzadgad and Sainshand

From those figures we can compare with hourly DNI between two locations. In Dalanzadgad on January 2007 hourly DNI was more than in Sainshand.

The results of assessment for daily, monthly and annual measured DNI values at the Dalanzadgad and Sainshand are shown in Table 7. DNI data in Dalanzadgad hadn't been measured several months in 2006, 2007, 2008 and 2010. In the future, analysis data were chosen in years of 2004, 2005, and 2009. In case of Sainshand all data except 2005 were suitable for analysis.

Table 7 Daily, monthly and annual average DNI in kWh/m^2

Name	Dalanzadgad				Sainshand			
Year	*2004*	*2005*	*2009*	*Average*	*2006*	*2007*	*2010*	*Average*
Jan	159.6	160.5	53.6	**4.70**	151.7	146.5	130.8	**4.94**
Feb	169.1	144.0	117.6	**5.88**	161.6	163.2	114.1	**5.90**
Mar	160.2	189.3	81.0	**5.31**	205.6	176.7	150.9	**6.34**
Apr	164.9	135.4	122.0	**5.56**	145.8	192.6	157.7	**5.82**
May	146.0	138.4	141.0	**6.08**	149.7	166.5	174.0	**5.93**
Jun	104.2	139.9	169.9	**5.78**	136.2	159.2	161.9	**5.62**
Jul	151.3	123.6	143.2	**5.23**	159.8	153.6	125.9	**5.57**
Aug	127.0	111.3	148.2	**5.19**	158.5	179.5	195.0	**6.00**
Sep	140.3	116.2	135.6	**5.69**	150.1	163.3	154.4	**6.18**
Oct	164.1	184.4	153.4	**6.35**	167.1	183.2	171.3	**5.99**
Nov	155.0	156.9	85.1	**5.34**	149.3	181.9	136.1	**5.62**
Dec	123.7	176.0	60.1	**4.85**	145.5	158.8	116.3	**4.96**
Sum	1765.5	1775.9	1410.6	**1650.67**	1880.9	2025.1	1788.4	**1898.13**

Analysis DNI values present not only Dalanzadgad site for 2004, 2005, and 2009, indicating despite the missing data an average annual DNI of 1650.67 kWh/m^2, but also Sainshand site for years 2006, 2007 and 2010 average annual DNI was 1898.13 kWh/m^2, which confirming the good solar resource in the regions. DNI values of Saishand were quite higher than Dalanzadgad. (Figure 8)

Complete measured data analyses of the DNI in both sites are presented in the Appendix 1.

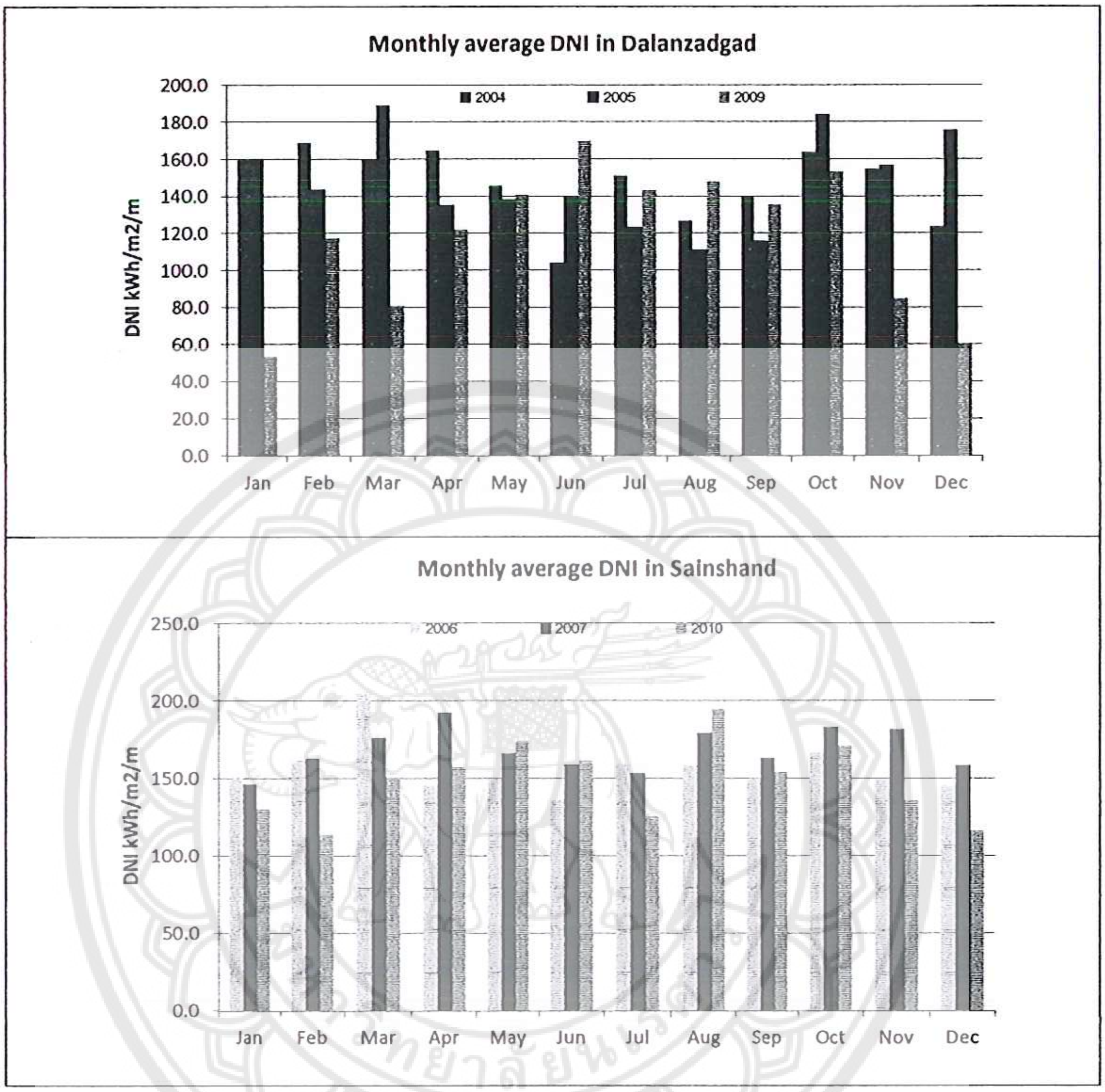

Figure 8 Monthly average DNI in Dalanzadgad and Sainshand

The annual sums DNI values and average hourly DNI of the NAMEN data are summarized in Table 8.

Table 8 Annual averages DNI in kWh/m²/a

	Years	2004	2005	2009	**Average**
Dalanzadgad, DNI	kWh/m²/a	1765.5	1775.9	1410.6	**1650.67**
	W/m²	775.54	779.84	717.11	**757.5**
	Years	2006	2007	2010	**Average**
Sainshand, DNI	kWh/m²/a	1880.9	2025.1	1788.4	**1898.13**
	W/m²	662.63	666.94	603.62	**644.4**

Assessment of DNI in proposed sites

According to predict the DNI, geometric locations of the proposed sites have to be determined. There are the South and Southeast Mongolian province centers Dalanzadgad and Sainshand. Geometry locations are north latitude 43°58' (as known - φ), longitude 104°42' for Dalanzadgad and north latitude 44°88' (as known - φ), longitude 110°16' for Sainshand.

In this paragraph is used to present two method of calculation for DNI. First one is method for beam radiation estimating. Hottel H.C., 1979 [18], has presented method to estimate the beam radiation transmitted through clear atmosphere. The method for the beam radiation estimating is described in chapter II.

The estimation of clear-sky radiation using John A. Duffie& William A. Beckman textbook[17], Solar engineering of thermal process; method for the estimation of the clear sky beam normal radiation on the n-th day of the year are used equations (from 1 to 3) in chapter II. The results are shown in Table 9.

Table 9 Comparison of the clear sky beam radiation between the two sites

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
						Dalanzadgad, [W/m²]							
G_{cnb},	770.9	829.5	889.5	942.2	962.2	983.9	970.0	939.5	919.9	863.2	813.9	734.9	885.0
						[kWh/m²/ day]							
DNI	4.92	6.26	6.90	7.76	9.43	10.06	8.77	8.98	8.30	7.36	6.10	5.10	7.5
						Sainshand, [W/m²]							
G_{cnb},	710.4	779.8	848.0	905.9	928.9	951.1	937.1	905.1	880.5	815.9	754.7	671.9	840.8
						[kWh/m²/ day]							
DNI	4.85	6.00	7.34	7.75	8.92	9.51	9.09	8.68	8.22	6.98	5.34	4.29	7.25

The second method is direct normal irradiation estimation, which gets the data from a pyrheliometer. Solanki C.S., et al., 2008 [19], suggested to obtain DNI by using the model-based approach method. The model-based approach method uses six steps to estimate DNI. Actually, DNI values hadn't been measured previous years by using a pyrheliometer in any Mongolian Energy Authorities.

NASA Surface Meteorology and Solar Energy

The resolution of the NASA data is obtained by latitude and longitude of the selected locations (Dalanzadgad and Sainshand). All solar radiation values are monthly and annual mean values for a 22- year period. Monthly average DNI is shown in Table 10.

Table 10 Monthly Averaged Direct Normal Radiation (kWh/m^2/day)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Dalan-zadgad	6.25	7.25	7.58	7.8	7.44	6.79	6.01	5.78	6.61	6.86	5.8	5.53	6.64
Sain-shand	5.83	6.78	7.63	7.66	7.49	7.13	6.22	5.68	6.27	6.01	5.62	5.10	6.44

Source: http://eosweb.larc.nasa.gov/sse/

Note: Data resource of German Aerospace Center (DLR) for Dalanzadgad ground DNI 1800 – 2200 kWh/m^2 a, for Sainshand DNI 1600 – 2000 kWh/m^2 a.

Comparison of assessed DNI data sources

The monthly mean DNI data of the assessed sources is depicted in Figure 9 and summarized in Table 11.

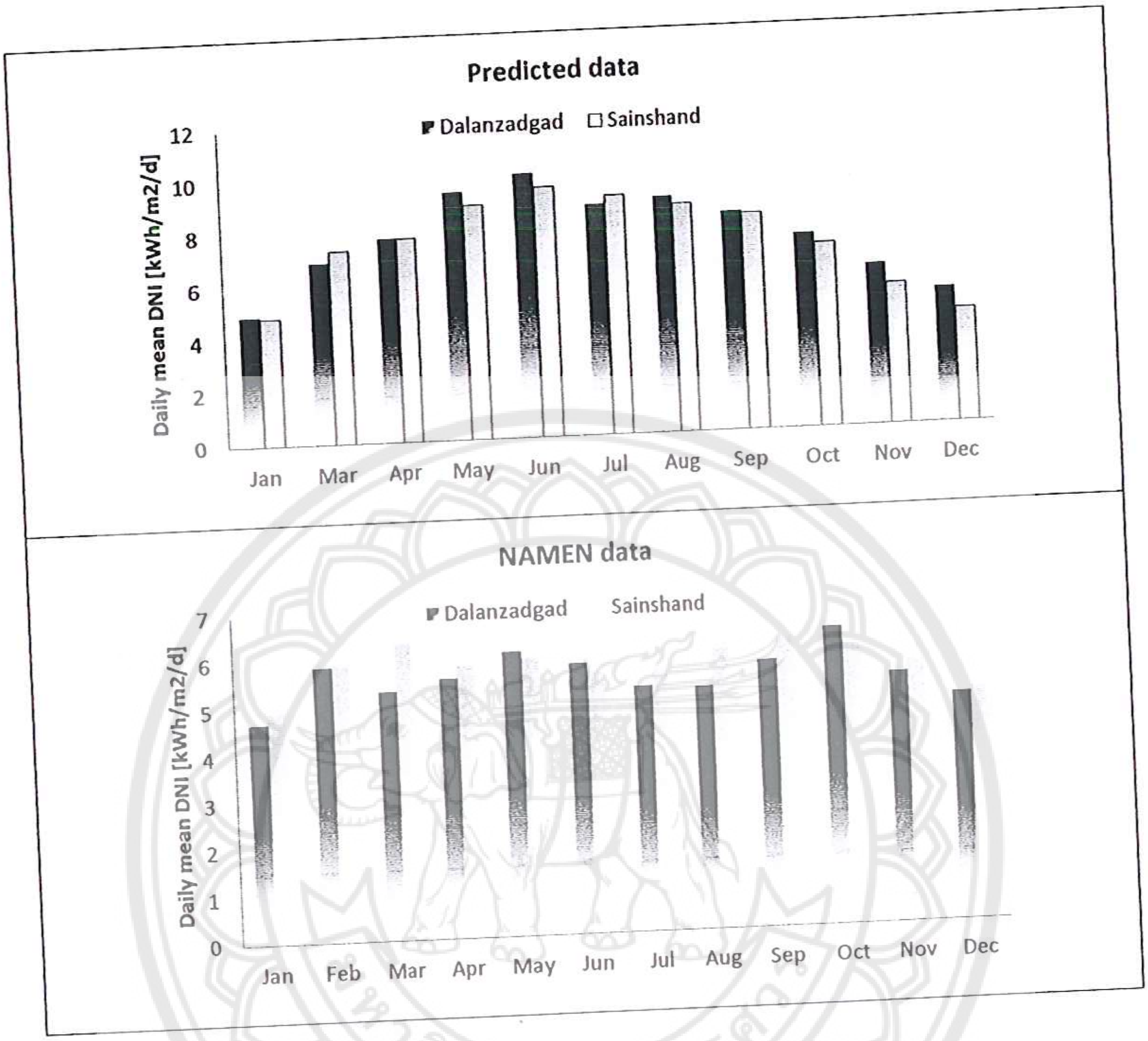

Figure 9 Comparison of assessed DNI data sources

Table 11 Comparison of assessed DNI data sources (kWh/m²/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
Annual	**2737.36**	**2421.95**	**1650.67**	**2647.36**	**2352.07**	**1898.13**

The meteorological data analysis

Ambient temperature

During last 10 years meteorological data has been obtained by NAMEN for two selected sites. Actually, Dalanzadgad and Sainshand are the warmest center compared to the rest of the country. Typically, average ambient temperature in the Dalanzadgad is about 23.6°C during summer, −13.7°C during winter, and annual mean temperature of around 5.8°C, whereas average ambient temperature in the Sainshand is about 25.0°C during summer, −17.1°C during winter, and annual mean ambient temperature of around 5.1°C (see Appendix 3). In winter, cold frost can occur, but usually sunny. The hottest months are June, July, and August with a maximum ambient temperature of around 39.9°C (July, 2010) in Dalanzadgad but 41.3°C (July, 2010) in Sainshand. The coldest months are December and January with a minimum temperature of −16.1°C (January, 2008) in Dalanzadgad but −19.0°C (January, 2001) in Sainshand.

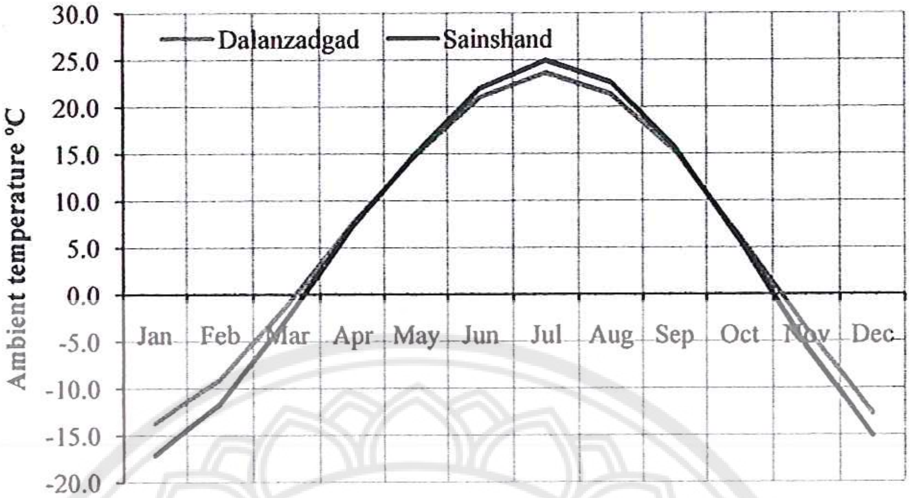

Figure 10 Average ambient temperatures during 10 years

Wind speed

The annual average wind speed both two sites are similar and quite low with only 2.3-5.1 m/s in Dalanzadgad but 3.6 – 5.7 m/s in Sainshand. However, there are wind gusts with maximum wind speeds detected March 2010, 34 m/s in Dalanzadgad, April 2002, 34 m/s in Sainshand which have to be considered especially in the design of the solar field. As can be seen in the Figure 11 depicted below, the prevailing wind directions two sites are similar west and north-west.

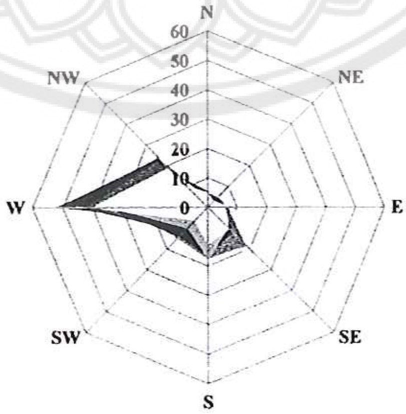

Figure 11 Wind direction frequency

Precipitation and evaporation

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

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. As proposed two sites are a low intensively populated area, very little cultivated land, and much of area is covered by steppe. Topographical location of Dalanzadgad and Sainshand is depicted in Figure 12a, b.

Site studies have generally found that a land slope between 0% – 3% level as potential, less than 1% are the most economic to develop. Potential sites should have reasonable land costs, and close to transmission line, water, and fuel resource.

Northern area of Dalanzadgad city has area of land slope for the requirement grade. It's not connected central transmission line. It's off-grid system. Sainshand city as same as northern area is a suitable location which can be found from topographical map.

Water consumption for the solar thermal power plant would be similar to a conventional thermal power plant of 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 for dry cooling system was introduced only 0.327 m^3/MWh (3.43 ML/a). [29]

Underground water resources map of Dalanzadgad and Sainshand is depicted in Figure 13 a, b. In the map, underground water resources are marked as ▲ symbol.

a) b)

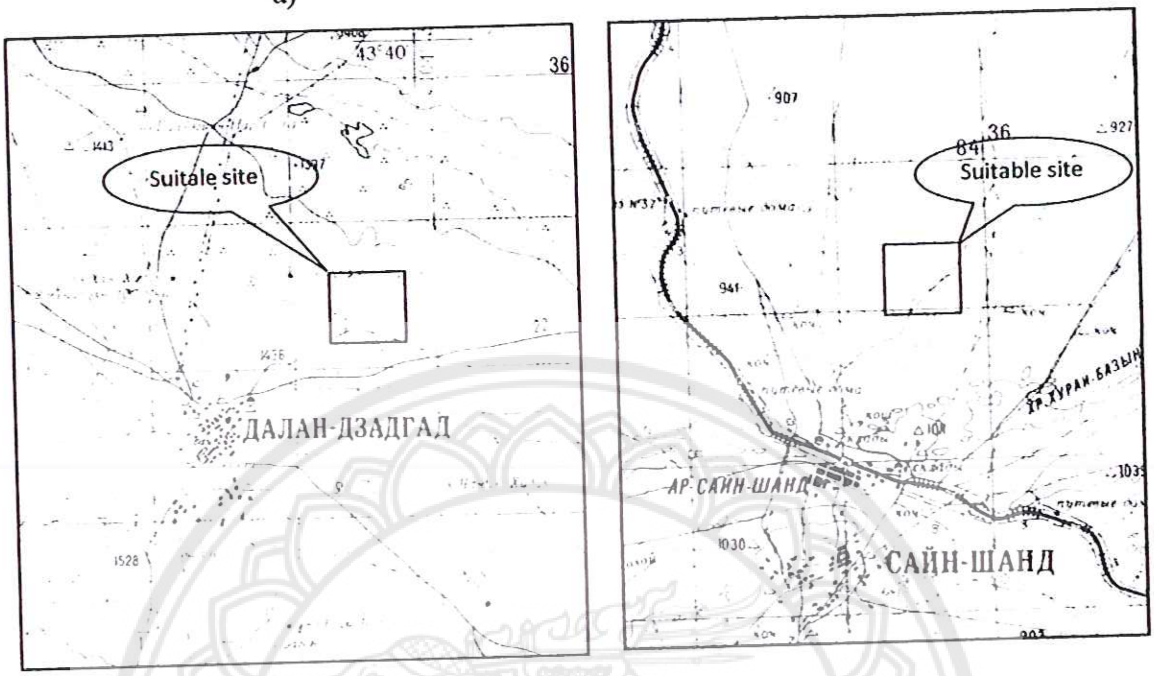

Figure 12 Topographical location a) Dalanzadgad b) Sainshand

a) b)

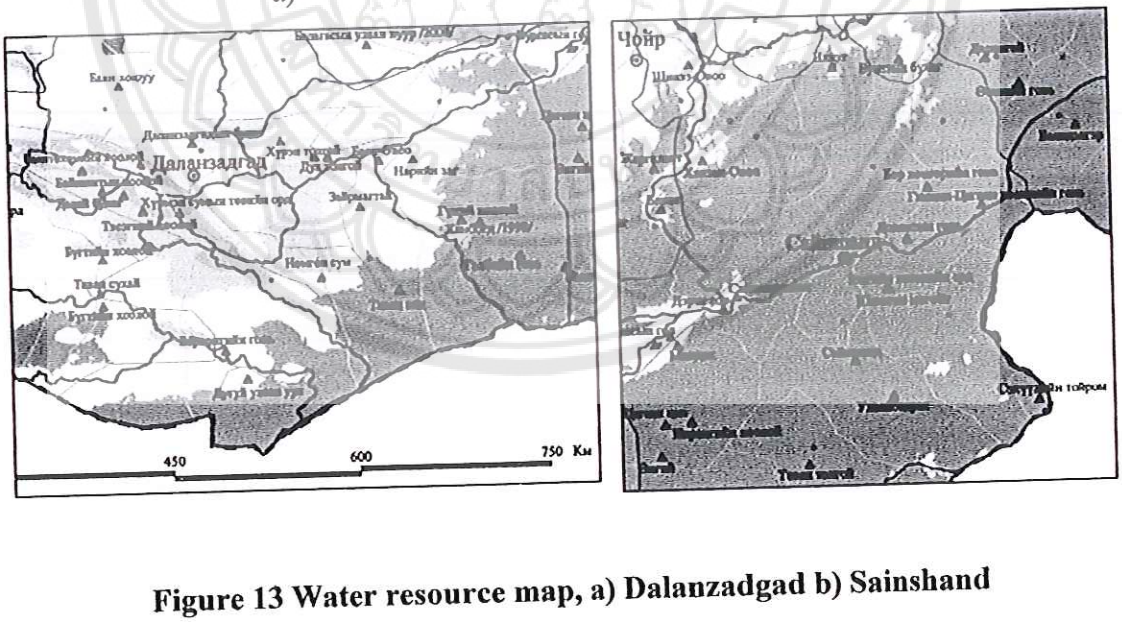

Figure 13 Water resource map, a) Dalanzadgad b) Sainshand

Table 12 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

Land slope is an important characteristic during the site investigation of a CSP plant. The specific slope and topography of the land will then determine the comparative acceptability of competing sites through their impact on site costs for leveling and preparation. Land characteristics are most effectively used as screening tools in acceptable sites selecting for further evaluation.

Energy consumption and demand analysis

Mongolia's production capacity in 2009 comprises 7 conventional CHP's (832MW), 13 hydroelectric power plants (26.15 MW), hundreds of diesel generators (41.1 MW), more than 90,000 solar home PV systems, 5 wind power stations and 15 hybrid solar/wind/diesel power stations (10.03 MW) [4].

Table 13 Installed capacity energy system

Power plant	Start year of operation	Installed Capacity (MW)	Region
Ulaanbaatar CHP-2	1961, 1969	21.5	
Ulaanbaatar CHP-3	1973-1979	136	
Ulaanbaatar CHP-4	1983-1991	560	CES
Erdenet CHP	1987-1989	28.8	
Darkhan CHP	1965	48	
Choibalsan CHP	1969-1982	36	EES
Durgun HPP	2008	12	WES
Taishir HPP	2010	11	AUES
Dalanzadgad CHP	2000	6	South Gobi
Total		859.3	

Consumption of CES was progressively raised last 5 years. In the assessment 2006, 3.4 GWh of electricity was generated by CHP's but 2010, 4.1 GWh was generated. Moreover, imported electricity from Russia was grown by 32.3 million kWh from 2006 – 2010 [3]. The imported electricity price is higher than current tariff of regulated by Government.

Table 14 CES basic statistic

	GWh unless stated				
Years	2006	2007	2008	2009	2010
CES generation gross output	3,433	3,594	3,874	3,874	4,127
CES generation self-consumption	17.5%	16.5%	16.1%	15.9%	15.6%
CES generation net output	2,832	3,000	3,249	3,259	3,482
Import	125.2	130	132.4	120	157.5
CES net supply	2,957	3,132	3,381	3,379	3,640
Transmission and distribution losses	18.4%	17.4%	16.8%	17.7%	17.3%
CES final supply	2,413	2,587	2,813	2,781	3,010

Source: 2006 – 2010 Licensee statistics, ERA

The report made by World Bank 2009 [24] for Infrastructure strategy southern Mongolia, which in the analysis assumes that electricity demand on the CES grows at an average of 3.5% annually. The South Mongolian electricity demand by 2020 expected to grow to 600 MW, due to the opening copper and gold mining project OyuTolgoi with a demand of 200 MW in 2012 and 300 MW in 2016 with the expansion of underground mining. Moreover a variety of areas TavanTolgoi coal mine, electricity demand will increase up to 300 MW by 2018.

Peak demand requires the need for additional capacities. Figure 12 illustrates the forecast growth of peak electricity demand in the CES and Southern Mongolia.

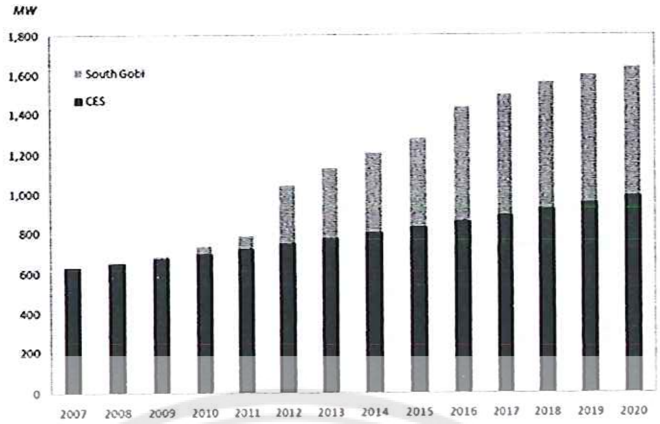

Figure 14 Peak electricity demand forecast, 2007-2020

Source: www.worldbank.org/southgobi.

This thesis also considers energy demand and consumption in Umnugovi province, which is located 6MW CHP. In Figure 13 shows energy consumption and energy lost in last the 10 years.

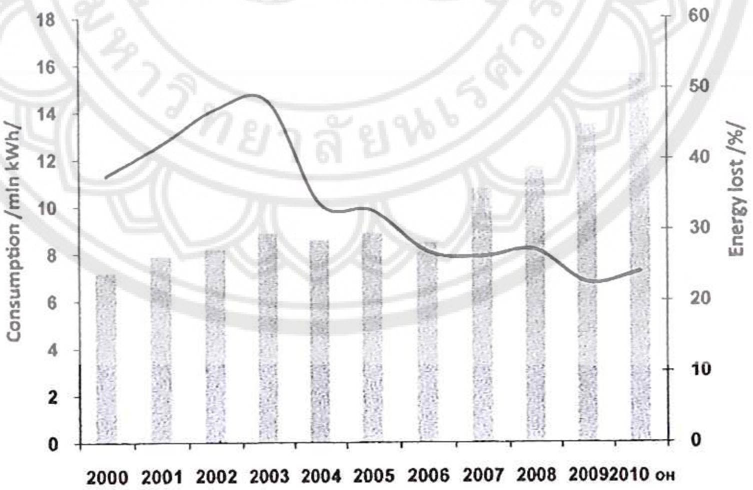

Figure 15 Electricity consumption and lost Umnugovi, 2000-2010

In 2010 Dalanzadgad CHP was produced 20.6 million kWh/a electricity, which was distributed 15.6 million kWh/a electricity to consumers, technical lost of energy was 3.8 million kWh/a.

Design for parabolic trough solar thermal power plant

First chapter mentioned energy situation Dalanzadgad city, which is provided heat and electricity of 6MW CHP. It means to design the solar thermal power plant in order to set-up generator up to 6MW output power. In this situation proposed solar thermal plant can be operated hybrid with CHP. Capacity parabolic trough solar thermal plant is assumed 5MW. Also the comparison is used to select grid connected of 5MW solar thermal power plant in Sainshand.

In this research, due to the design of solar thermal power plant, the specification of parabolic trough collector and turbine–generator were selected by the recommendation from Solarlite Company. There are described in Table 15 and 16. The T-s diagram for a steam turbine and Solarlite-4600 collector are shown in Figure 15 and 16.

Table 15 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%

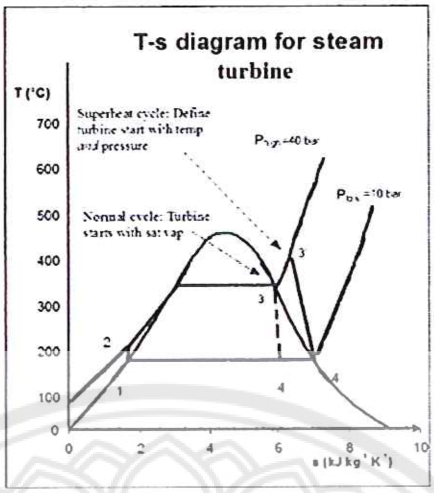

Figure 16 T-s diagram for 5 MW steam turbine

Figure 17 Parabolic trough collector; Solarlite -4600

Source: TRESERT project, School of Renewable Energy Technology, Thailand

Table 16 Specification of "Solarlite-4600" parabolic trough collector

Technical details	Unit	Solarlite 4600
Materials used		Thin-film glass mirror, GRP, steel, vacuum receiver
Segment length	m	12
Collector width	m	4.6
Glass pipe diameter	m	0.13
Absorber diameter	m	0.07
Max. operating temperature	°C	400
Focal line	m	1.2
Concentration factor		66
Heat transfer medium		water / steam
Optical efficiency, η_o	%	0.75

Source:http://www.solarlite.de/en/products.cfm

To find necessary heat and mass flow of heat transfer fluid to operate turbine and to produce 5MW, output electric power are determined by using equation 13, 14 in chapter II. The optical efficiency is used from Table 16. Heat loss coefficient and thermal efficiency are calculated by equation 15, 11 in the chapter II. To set up design point obtain DNI equal to 757.5 W/m^2 for Dalanzadgad and 644.4 W/m^2 for Sainshand, which are determined in paragraph 4.2, Table 8. Finally total area of parabolic trough collector is estimated by using equation 10, in the equation substitute input power to turbine, thermal efficiency and DNI. Summary are described in the Table 17. Detailed assessment of design off-grid and grid connected solar thermal power plants are described in Appendix 4.

Table 17 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
The 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

Economic evaluation

This study compares economic analysis between grid connected 5 MW solar thermal power plant project and off-grid 5MW hybrid project that uses parabolic trough CSP technology in order to select the best economic option similar as new overseas plants in the Gobi Desert Mongolia. The analysis has started from investment cost of CSP plant; most components of the plant are imported from Europe which is located leading suppliers of the CSP technology.

Vallentin and Viebahn, 2010 [11] focused on the economic opportunities of German technology providers since companies such as Schott Solar, Flabeg or Solar Millennium are among the leading suppliers of CSP technologies in the global market. Also about parabolic trough collector and steam turbine in the study contacted with Solarlite company.

The estimated values of investment cost included power block, collector field, steam heat exchanger, site works, surcharge construction, transportation, transmission line cost and custom tax presented in Table 18 and illustrated in the Figure 15.

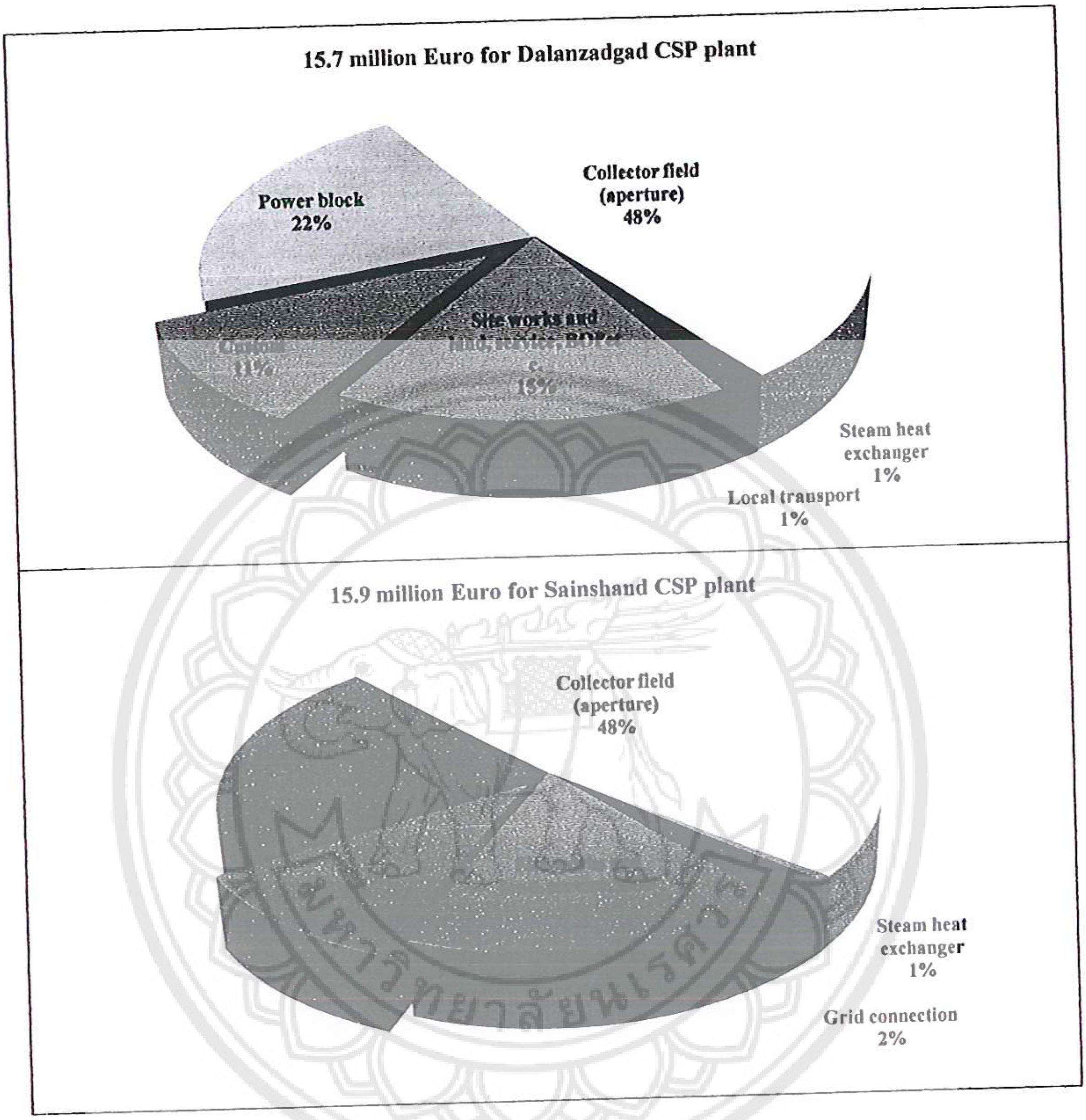

Figure 18 Structure of investment cost 5MW parabolic trough power plant

Rainer, et al., 1999 [28] presented solar power projects from the financier's perspective. In a typical parabolic trough Solar Energy Generating System type plant, the solar field represents approximately 50% of the total plant's investment costs. This structure would help to analyze and compare with investment cost in this assumption of the project.

Investment cost was taken from reference number [26], which was presented in Table 4 in Chapter II.

Table 18 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 17 in the chapter II. Annual net electricity production of 5MW solar thermal power plant is simulated in one year. Simulated values are presented in Table 19. This is a starting point for the electricity kWh calculation of the proposed solar thermal power plant.

Table 19 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 18
Fuel cost	-	-	
Annual net electricity	10,500,000.0 kWh		Assume 2100 h/year operation
LCOE	17.8 c€/kWh	18 c€/kWh	

The economical evaluation used cost benefit analysis such as an initial capital cost (CC) to calculate a net present value (NPV), benefit to cost ratio (BCR), internal rate of return (IRR) and payback period (PBP). This analysis has been shown beneficial for investment such project and to detect main factor for financial analysis in CSP technology in Mongolia.

Solar thermal power projects could be interesting under the CDM because they directly displace greenhouse gas emissions. The CO_2 emissions mitigation benefits associated with the CSP plants depends upon the amount of electricity generated. Till 2010 in Mongolia, renewable energy 2 projects are registered by the CDM Executive Board with grid emission factor 0.8 tCO_2/MWh. In this study, that factor is used as reference for greenhouse gas estimation. Key project assumptions on the study are identified in Table 20.

Table 20 Key parameters for economic evaluation

Parameter	Value	Notes
Currency	€ and $	1 Euro (€) = 1.31 US dollar ($), Bank of Mongolian exchanged date on 2012.02.19
Project life time	25 years	Typical for a project of this nature
Interest rate	8%	Montes M.J., et al. 2009 [26]
Liquidation	20 years	
Power price (selling)		
- Price	c€ 5/kWh	(Source: http://www.era.energy.mn/)
FIT		
- Grid	c€ 13.7/kWh	- for Grid-connected c$ 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 [31]
CER	€ 5.18/tCO_2	Source: http://carbonmarket.tgo.or.th/index.php

The economical evaluation of 5 MW parabolic trough solar thermal power plant in Dalanzadgad is calculated by using Microsoft Excel Program. Final results are shown in Table 21, 22 and 23.

Table 21 Comparison between two projects for investor

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

Comparison between 5MW off-grid and grid connected parabolic trough solar thermal power plants in case of presenting to the investors, both CSP projects would be economically viable at 8% discount rate, selling electricity price is c€ 18/kWh and investment of 15.9 million Euro, LCOE of c€ 18/kWh, NPV of 16.9 million Euro, BCR of 1.57, IRR of 8.75%, and payback period of 7.22 years.

Table 22 Comparison between two projects in case with FIT

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

Comparison between 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 at 8% discount rate and investment of 15.9 million Euro, FIT of c€0.14/kWh, NPV of 12.4 million Euro, BCR of 1.18, IRR of 5.21%, and payback period of 9.6 years.

Table 23 Comparison between two projects in case with FIT & 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

Comparison between 5MW off-grid and grid connected parabolic trough solar thermal power plants in case with FIT and Tax Incentive presented that both CSP projects would not be economically at 8% discount rate and investment from 13.7 to 13.9 million Euro, FIT of € 0.14/kWh, NPV of 12.7 million Euro, BCR from 1.35 to 1.38, IRR from 6.8 to 7.04%, and payback period around 8 years.