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APPENDIX

1. NAMEN data for Dalanzadgad

Table 24 Hourly, monthly and annual average DNI (W/m^2) in 2004

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	602.5	627.8	718.3	668.3	590.0	576.7	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	846.4	834.8	917.7	808.7	841.6	802.5	764.6	829.0	866.4	827.9	845.4	777.0
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	951.2	923.3	953.8	848.6	816.5	862.7	787.9	758.2	886.3	889.1	872.1	820.8
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	751.8	737.7	878.7	751.8	751.7	726.9	768.8	728.0	832.5	757.4	653.8	600.0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	526.7	543.3	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
	Average DNI = 775.54 W/m^2											
Sum	159.6	169.1	160.2	164.9	146.0	104.2	151.3	127	140.3	164.1	155.0	123.7
	1765.52 $kWh/m^2/a$											

Table 25 Hourly, monthly and annual average DNI (W/m^2) in 2005

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	630	695	694.4	614.3	652.8	541.4	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	791.5	799.4	849.2	810	807.2	828.5	775	810	873.5	864.4	840	837.2
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	915.2	876.1	938.2	818.4	841	867.3	813.5	850.5	870.6	901.1	864.6	863.1
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	741.8	800	845.6	790.9	800.6	764.5	754.4	822.8	807	746.3	651	608.4
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	525	520	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
	Average DNI = 779.84 W/m^2											
Sum	160.5	144	189.3	135.4	138.4	139.9	123.6	111.3	116.2	184.4	156.9	176
	1775.85 kWh/m^2/a											

Table 26 Hourly, monthly and annual average DNI (W/m^2) in 2009

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	510.0	644.7	700.0	635.0	596.0	0.0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	777.0	845.0	462.9	774.2	832.0	863.3	844.5	806.8	841.1	818.7	776.5	758.7
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	365.6	902.8	579.1	808.4	858.7	880.5	824.1	802.8	838.1	860.0	842.8	775.0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	118.7	778.0	319.0	722.3	783.3	810.0	794.9	788.0	732.9	695.6	0.0	0.0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	440.0	595.0	0.0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
	Average DNI = 717.11 W/m^2											
Sum	53.6	117.6	81	122.0	141	169.9	143.2	148.2	135.6	153.4	85.1	60.1
	1410.57 $kWh/m^2/a$											

2. NAMEN data for Sainshand

Table 27 Hourly, monthly and annual average DNI (W/m^2) in 2006

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	413.0	551.8	553.2	558.6	581.1	478.9	401.1	273.3	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	686.5	825.2	835.8	816.5	749.1	763.3	746.4	684.8	681.3	745.4	783.9	705.8
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	832.0	909.1	955.0	857.4	726.2	727.4	768.0	745.7	710.0	821.6	863.5	816.4
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	581.7	744.5	796.4	706.3	651.3	669.3	711.1	654.3	596.5	667.8	539.1	463.3
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0.0	319.1	373.6	433.8	331.0	0.0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
	Average DNI = 662.63 W/m^2											
Sum	151.7	161.6	205.6	145.8	149.7	136.2	159.8	158.5	150.1	167.1	149.3	145.5
	1880.94 $kWh/m^2/a$											

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Table 28 Hourly, monthly and annual average DNI (W/m^2) in 2007

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	337.0	535.2	616.4	623.3	553.3	541.4	430.6	332.0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	670.0	791.3	812.4	805.6	791.9	808.1	692.2	760.4	762.2	810.7	812.5	750.8
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	741.5	854.8	853.3	800.0	757.7	703.3	772.6	819.2	697.8	828.1	809.6	848.5
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	530.8	715.5	713.9	753.2	628.6	730.0	676.5	703.7	615.2	660.0	584.6	515.5
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0.0	354.4	415.0	366.9	325.5	0.0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
	Average DNI = 666.94 W/m^2											
Sum	146.5	163.2	176.7	192.6	166.5	159.2	153.6	179.5	163.3	183.2	181.9	158.8
	2025.08 $kWh/m^2/a$											

Table 29 Hourly, monthly and annual average DNI (W/m^2) in 2010

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	368.0	457.4	561.7	573.2	0.0	495.0	438.4	352.9	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	566.4	632.7	695.7	765.0	713.5	672.1	553.1	708.1	703.6	784.1	638.5	635.7
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	725.6	736.5	742.8	666.5	835.6	722.2	735.0	786.4	785.2	779.6	705.8	693.3
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	470.8	493.7	592.4	656.8	860.0	632.3	649.1	729.6	654.8	632.9	474.1	395.3
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	120.0	860.0	374.0	354.7	397.8	0.0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
	Average DNI = 603.63 W/m^2											
Sum	130.8	114.1	150.9	157.7	174.0	161.9	125.9	195.0	154.4	171.3	136.1	116.3
	1788.44 $kWh/m^2/a$											

1. Dalanzadgad site, $\varphi = 43^{o}58'$ and Solar constant or G_{sc}=1367W/m^2

Table 30 Clear sky beam radiation (kWh/m^2/d) for Dalanzadgad

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average days	17	16	16	15	15	11	17	16	15	15	14	10
Day of year (n)	17	47	75	105	135	162	198	228	258	288	318	344
δ	-20.9	-12.9	-2.42	9.41	18.8	23.1	21.2	13.5	2.22	-9.60	-18.9	-23.1
ω_S	68.7	77.4	87.7	99.1	109	114	112	103	92.1	80.7	71.0	66.1
$\cos\theta_z$	0.43	0.55	0.69	0.82	0.90	0.93	0.92	0.86	0.74	0.59	0.46	0.39
ω	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5
t_s	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
G_{on}	1345	1322	1322	1339	1339	1360	1344	1322	1339	1339	1381	1326
				a_0*=	0.251	a_1*=	0.660	k*=	0.293			
Subarctic summer				r_o=	0.99	r_1=	0.99	r_k=	1.01			
				a_0=	0.248	a_1=	0.653	k=	0.296			
τ_b	0.57	0.63	0.67	0.70	0.72	0.72	0.72	0.71	0.69	0.64	0.59	0.55
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
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

2. Sainshand site, $\varphi = 44^{o}88'$ and Solar constant or G_{sc}=1367W/m^2

Table 31 Clear sky beam radiation (kWh/m^2/d) for Sainshand

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average days	17	16	16	15	15	11	17	16	15	15	14	10
Day of year (n)	17	47	75	105	135	162	198	228	258	288	318	344
δ	-20.9	-12.9	-2.42	9.41	18.79	23.09	21.18	13.45	2.22	-9.60	-18.9	-23.1
ω_S	67.63	76.76	87.59	99.51	109.8	115.1	112.7	103.8	92.21	80.30	70.05	64.93
$\cos\theta_z$	0.404	0.526	0.672	0.808	0.892	0.923	0.910	0.847	0.729	0.575	0.436	0.370
ω	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5
t_s	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
G_{on}	1345	1322	1322	1339	1339	1360	1345	1322	1339	1339	1382	1326
				a_0*=	0.22	a_1*=	0.685	k*=	0.312			
Subarctic summer				r_o=	0.99	r_1=	0.99	r_k=	1.01			
				a_0=	0.217	a_1=	0.678	k=	0.315			
τ_b	0.53	0.59	0.64	0.68	0.69	0.70	0.70	0.68	0.66	0.61	0.55	0.51
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
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

1. Ambient temperature in Dalanzadgad

Table 32 Average ambient temperature in Dalanzadgad

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
2001	-13.2	-8.5	-0.7	7.7	15.1	21.4	24.1	21.5	16.5	7.3	-3.1	-14.6	6.1
2002	-9.2	-5.4	-0.3	6.0	15.3	22.4	24.6	23.6	14.1	3.8	-5.0	-14.1	6.3
2003	-13.9	-9.2	-1.9	6.8	13.6	19.7	21.4	19.2	15.4	4.9	-6.9	-11.9	4.8
2004	-13.6	-6.3	-1.5	11.4	15.2	19.4	23.3	19.7	14.3	5.5	-4.3	-11.5	6.0
2005	-15.7	-18.1	-2.0	8.7	14.2	21.3	24.6	21.0	15.6	6.8	-2.4	-14.9	4.9
2006	-12.8	-9.3	-0.3	6.8	14.1	20.0	22.1	23.2	15.4	9.1	-2.2	-12.4	6.1
2007	-11.9	-2.7	-2.2	6.8	16.5	23.3	22.6	20.9	15.9	4.2	-3.3	-12.5	6.5
2008	-17.3	-12.4	1.6	8.9	13.7	19.7	23.7	21.1	15.9	6.5	-1.9	-12.3	5.6
2009	-13.4	-7.1	-0.6	10.5	15.8	20.3	23.9	22.2	15.0	7.3	-6.7	-12.3	6.2
2010	-15.8	-11.2	-3.8	2.7	14.4	22.7	25.7	20.9	15.6	6.6	-1.9	-10.5	5.5
Average	-13.7	-9.0	-1.2	7.6	14.8	21.0	23.6	21.3	15.4	6.2	-3.8	-12.7	5.8

2. Ambient temperature in Sainshand

Table 33 Average ambient temperature in Sainshand

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
2001	-21.6	-14.7	-3.3	7.3	15.3	22.7	24.7	22.7	16.4	6.7	-5.2	-16.8	4.5
2002	-11.4	-7.1	0.4	6.1	15.4	22.0	24.8	24.2	14.4	1.6	-8.7	-18.5	5.3
2003	-19.5	-13.7	-3.3	7.7	15.0	20.4	23.7	20.3	15.4	5.7	-7.7	-15.3	4.1
2004	-15.8	-8.6	-3.9	9.6	15.3	23.1	25.1	21.5	15.1	6.1	-5.3	-13.4	5.7
2005	-16.0	-17.7	-3.1	7.4	14.6	22.0	25.5	23.8	15.6	7.2	-3.9	-16.2	4.9
2006	-15.0	-12.1	-1.8	4.8	14.3	20.4	23.9	23.9	16.2	7.6	-4.4	-13.8	5.3
2007	-15.4	-5.8	-2.3	7.6	15.8	24.0	26.0	23.4	18.2	5.5	-4.6	-12.3	6.7
2008	-18.5	-12.9	0.4	10.0	12.8	21.0	24.8	22.6	15.5	6.1	-3.5	-13.9	5.4
2009	-16.4	-10.2	-3.0	9.8	16.9	20.1	24.5	22.3	15.0	5.0	-8.4	-15.5	5.0
2010	-21.3	-13.8	-6.3	2.3	15.0	24.0	26.5	21.4	15.9	5.8	-5.4	-14.8	4.1
Average	-17.1	-11.6	-2.6	7.3	15.0	22.0	25.0	22.6	15.8	5.7	-5.7	-15.1	5.1

1. Dalanzagad off-grid 5MW parabolic trough solar thermal power plant design

Table 34 Parabolic trough collector area of off-grid CSP plant

Item	Unit	Parameters	Notes
Design point			
Capacity power plant	kW	5,000.00	
DNI	W/m^2	757.5	Annual average DNI in Dalanzadgad
Turbine Man "Marc-2"			
Inlet temperature	°C	400	
Inlet pressure	bar	40	Superheat steam table: at P_{in}=40bar, T=400°C
Enthalpy superheat steam	kJ/kg	3,213.00	
Outlet temperature	°C	180	Saturated vapour table: at P_{out}=10bar, T=180°C
Outlet pressure	bar	10	
Enthalpy saturated vapour	kJ/kg	2,015.20	$\rightarrow h_g$=2778kJ/kg, h_f=762.8kJ/kg
Variation Enthalpy	kJ/kg	1,197.80	
Efficiency of turbine	%	29	
Calculate the input power which we have to provide for the turbine			
W_{input} =	kW	17,241.4	Chapter 2, paragraph 2.5, equation 13
Calculate for the flow rate			
Mass flow rate, $\dot{m}$ =	t/hr	51.78	Chapter 2, paragraph 2.5, equation 14
Calculate for the optical efficiency			
η_o =	%	75.0	Chapter 4, table 16

Table 34 (Cont.)

Item	Unit	Parameters	Notes
Calculate for heat loss coefficient			
U_L =	W/m^2K	24.32	Chapter 2, paragraph 2.5, equation 16, where average ambient temperature in table 32, T_{amb}=5.8°C, average wind speed V=3.5 m/s
Calculate for thermal efficiency			
$\eta_{thermal}$=	%	61.64	Chapter 2, paragraph 2.5, equation 11
Calculate for area of parabolic trough			
A_a =	m^2	36,924.59	Chapter 2, paragraph 2.5, equation 17

2. Sainshand grid-connected 5MW parabolic trough solar thermal power plant design

Table 35 Parabolic trough collector area of grid-connected CSP plant

Item	Unit	Parameters	Notes
Design point			
Capacity power plant	kW	5,000.00	
DNI	W/m^2	644.4	Annual average DNI in Sainshand
Turbine Man "Marc-2"			
Inlet temperature	°C	400	
Inlet pressure	bar	40	Superheat steam table: at
Enthalpy superheat steam	kJ/kg	3,213.00	P_{in}=40bar, T=400°C

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Table 35 (Cont.)

Item	Unit	Parameters	Notes
Outlet temperature	°C	180	Saturated vapour table: at P_{out}=10bar, T=180°C →h_g=2778kJ/kg, h_f=762.8kJ/kg
Outlet pressure	bar	10	
Enthalpy saturated vapour	kJ/kg	2,015.20	
Variation Enthalpy	kJ/kg	1,197.80	
Efficiency of turbine	%	29	
Calculate the input power which we have to provide for the turbine			
W_{input} =	kW	17,241.4	Chapter 2, paragraph 2.5, equation 13
Calculate for the flow rate			
Mass flow rate, $\dot{m}$ =	t/hr	51.78	Chapter 2, paragraph 2.5, equation 14
Calculate for the optical efficiency			
η_o =	%	75.0	Chapter 4, table 16
Calculate for heat loss coefficient			
U_L =	W/m^2K	24.30	Chapter 2, paragraph 2.5, equation 16, where average ambient temperature in table 32, T_{amb}=5.1°C, average wind speed V=4.3 m/s
Calculate for thermal efficiency			
$\eta_{thermal}$=	%	61.62	Chapter 2, paragraph 2.5, equation 11
Calculate for area of parabolic trough			
A_a =	m^2	36,938.36	Chapter 2, paragraph 2.5, equation 17

Table 36 Measured DNI recourse of NAMEN (kW/m^2) in January 2004 /Dalanzadgad/

Days	Time				
	6:30	9:30	12:30	15:30	18:30
1	0	0.76	0.86	0.62	0
2	0	0.82	0.83	0	0
3	0	0.82	0.97	0	0
4	0	0.89	1.03	0	0
5	0	0.82	0.89	0	0
6	0	0.78	0.99	0	0
7	0	0.82	0.99	0	0
8	0	0.79	0.93	0	0
9	0	0.87	0.96	0	0
10	0	0.70	0.76	0	0
11	0	0.74	0.81	0	0
12	0	0.85	0.95	0	0
13	0	0	0	0	0
14	0	0.86	0.91	0	0
15	0	0	0	0	0
16	0	0	0	0	0
17	0	0.87	0.99	0	0
18	0	0.92	0.99	0.80	0
19	0	0.91	1.06	0.74	0
20	0	0.93	1.00	0	0
21	0	0.92	1.06	0	0
22	0	0.91	0	0.75	0
23	0	0.94	1.01	0	0

Table 36 (Cont.)

Days	Time				
	6:30	9:30	12:30	15:30	18:30
24	0	0.84	0.96	0.83	0
25	0	0.87	1.03	0.86	0
26	0	0.96	1.03	0.84	0
27	0	0	0.79	0.74	0
28	0	0.72	0.98	0.75	0
29	0	0	0	0	0
30	0	0	0	0.67	0
31	0	0.85	1.00	0.67	0

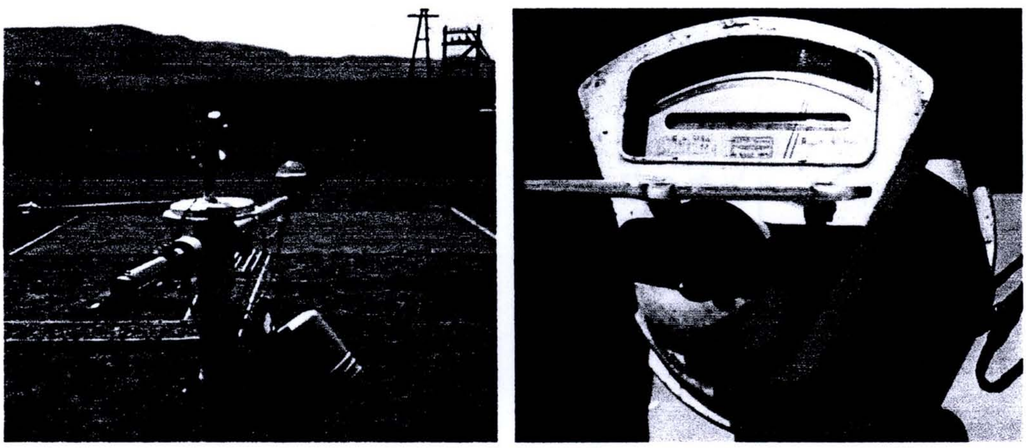

Figure 19 Measuring instrument for direct normal irradiance

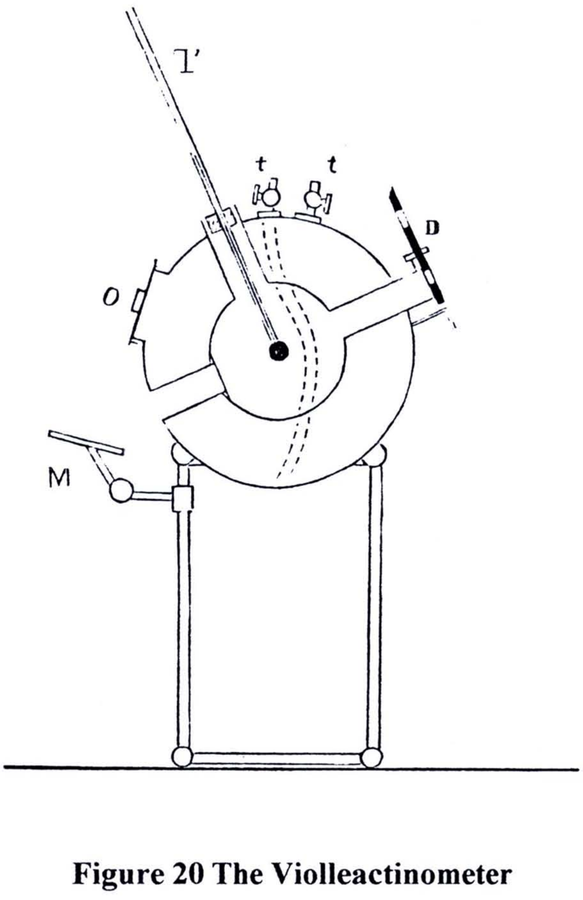

Figure 20 The Violleactinometer

Source: http://en.wikipedia.org/wiki/Actinometer

Table 36 Economic evaluation for 5 MWe Dalanzadgad CSP plant (Investment costs = 15,718,686.97 €, Interest Rate = 8%)

	25 Years	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Income CSP Plant							
Power of plant in kWe		5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00
Sunhours per year		2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00
Price per kWh in €		0.18	0.18	0.18	0.18	0.18	0.18
Electric Sale in €	46,723,797.01	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88
CO_2 reduction benefit in €		43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00
Total Sale in €	**46,723,797.01**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**
Operation costs CSP (incl. 2% Inflation)							
Spare parts (2 % of Invest; €)	3,143,737.39	314,373.74	314,373.74	314,373.74	314,373.74	314,373.74	314,373.74
Maintenance and operation (0.01 % of Invest; €)	15,718.69	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87
Total operation costs (2% Inflation/year) in €	3,183,034.11	315,945.61	315,945.61	315,945.61	315,945.61	315,945.61	315,945.61
Profit CSP Plant in €	46,723,797.01	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88
Gross Profit in €	**43,540,762.90**	**1,596,518.27**	**1,596,518.27**	**1,596,518.27**	**1,596,518.27**	**1,596,518.27**	**1,596,518.27**
CSP Plant							
Liquid action in €	15,718,686.97	785,934.35	785,934.35	785,934.35	785,934.35	785,934.35	785,934.35
Rest to pay	0.00	14,932,752.62	14,146,818.27	13,360,883.92	12,574,949.57	11,789,015.22	11,003,080.88
Interests 8% / year	11,946,202.09	1,194.620.21	1,131.745.46	1,068.870.71	1,005,995.97	943,121.22	880,246.47
Total payment in €	**27,664,889.06**	**1,980,554.56**	**1,917,679.81**	**1,854,805.06**	**1,791,930.31**	**1,729,055.57**	**1,666,180.82**
Net Profit CSP Plant in €	**16,963,673.84**	**-384,036.29**	**-321,161.54**	**-258,286.79**	**-195,412.04**	**-132,537.29**	**-69,662.55**
	18 Months	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
at CSP Plant							
Total Casbflow	-15,718,686.97	1,596,518.27	1,596,518.27	1,596,518.27	1,596,518.27	1,596,518.27	1,596,518.27
Cumulated Casbflow	-15,718,686.97	-14,122,168.69	-12,525,650.42	-10,929,132.15	-9,332,613.88	-7,736,095.60	-6,139,577.33
NPV to date	-15,718,686.97	-13,185,582.69	-11,918,215.01	-10,744,726.42	-9,658,162.91	-8,652,085.59	-7,720,532.51

Table 36 (Cont.)

Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17
5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00
2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00
0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88
43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00
1,912,463.88	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**
314,373.74	314,373.74	314,373.74	314,373.74							
1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87
315,945.61	315,945.61	315,945.61	315,945.61	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87
1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88
1,596,518.27	**1,596,518.27**	**1,596,518.27**	**1,596,518.27**	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**
785,934.35	785,934.35	785,934.35	785,934.35	785,934.35	785,934.35	785,934.35	785,934.35	785,934.35	785,934.35	785,934.35
10,217,146.53	9,431,212.18	8,645,277.83	7,859,343.48	7,073,409.13	6,287,474.79	5,501,540.44	4,715,606.09	3,929,671.74	3,143,737.39	2,357,803.04
817,371.72	754,496.97	691,622.23	628,747.48	565,872.73	502,997.98	440,123.24	377,248.49	314,373.74	251,498.99	188,624.24
1,603,306.07	**1,540,431.32**	**1,477,556.57**	**1,414,681.83**	**1,351,807.08**	**1,288,932.33**	**1,226,057.58**	**1,163,182.84**	**1,100,308.09**	**1,037,433.34**	**974,558.59**
-6,787.80	**56,086.95**	**118,961.70**	**181,836.45**	**559,084.93**	**621,959.68**	**684,834.43**	**747,709.18**	**810,583.92**	**873,458.67**	**936,333.42**
Year 7	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**
1,596,518.27	1,596,518.27	1,596,518.27	1,596,518.27	1,910,892.01	1,910,892.01	1,910,892.01	1,910,892.01	1,910,892.01	1,910,892.01	1,910,892.01
-4,543,059.06	-2,946,540.79	-1,350,022.52	246,45.76	2,157,387.77	4,068,279.78	5,979,171,79	7,890,063.80	9,800,955.81	11,711,847.83	13,622,739.84
-6,857,983.37	-6,059,326.75	-5,319,829.88	-4,635,110.56	-3,876,269.05	-3,173,638.02	-2,523,053.74	-1,920,660.88	-1,362,889.72	-846,434.94	-368,236.07

Table 36 (Cont.)

Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00
2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00
0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88	1,868,951.88
43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00
1,912,463.88	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**	**1,912,463.88**
1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87
1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87	1,571.87
1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88	1,912,463.88
1,910,892.01	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**
785,934.35	785,934.35	785,934.35	0.00	0.00	0.00	0.00	0.00
1,571,868.70	785,934.35	0.00	0.00	0.00	0.00	0.00	0.00
125,749.50	62,874.75	0.00	0.00	0.00	0.00	0.00	0.00
911,683.84	**848,809.10**	**785,934.35**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
999,208.17	**1,062,082.92**	**1,124,957.66**	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**	**1,910,892.01**
Year 18	**Year 19**	**Year 20**	**Year 21**	**Year 22**	**Year 23**	**Year 24**	**Year 25**
1,910,892.01	1,910,892.01	1,910,892.01	1,910,892.01	1,910,892.01	1,910,892.01	1,910,892.01	1,910,892.01
15,533,631.85	17,444,523.86	19,355,415.87	21,266,307.88	23,177,199.90	25,088,091.91	26,988,983.92	28,909,875.93
74,540.66	484,519.12	864,128.80	1,215,619.24	1,541,073.36	1,842,419.76	2,121,444.21	2,379,800.18

Source: PBP (20 yrs) = 7.22, NPV = 16,651,946.07, IRR = 8.75%, BCR = 1.57

Table 37 Economic evaluation for 5 MWe Sainshand CSP plant (Investment costs = 15,933,905.38 €, Interest Rate = 8%)

	25 Years	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Income CSP Plant							
Power of plant in kWe		5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00
Sunhours per year		2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00
Price per kWh in €		0.18	0.18	0.18	0.18	0.18	0.18
Electric Sale in €	47,363,533.74	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35
CO_2 reduction benefit in €		43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00
Total Sale in €	47,363,533.74	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**
Operation costs CSP (incl. 2% Inflation)							
Spare parts (2 % of Invest; €)	3,186,781.08	318,678.11	318,678.11	318,678.11	318,678.11	318,678.11	318,678.11
Maintenance and operation (0.01 % of Invest; €)	15,933.91	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39
Total operation costs (2% Inflation/year) in €	3,226,615.84	320,271.50	320,271.50	320,271.50	320,271.50	320,271.50	320,271.50
Profit CSP Plant in €	47,363,533.74	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35
Gross Profit in €	**44,136,917.90**	**1,617,781.85**	**1,617,781.85**	**1,617,781.85**	**1,617,781.85**	**1,617,781.85**	**1,617,781.85**
CSP Plant							
Liquid action in €	15,933,905.38	796,695.27	796,695.27	796,695.27	796,695.27	796,695.27	796,695.27
Rest to pay	0.00	15,137,210.11	14,340,514.84	13,543,819.57	12,747,124.30	11,950,429.04	11,153,733.77
Interests 8% / year	12,109,768.09	1,210,976.81	1,147,241.19	1,083,505.57	1,019,769.94	956,034.32	892,298.70
Total payment in €	**28,043,673.47**	**2,007,672.08**	**1,943,936.46**	**1,880,200.83**	**1,816,465.21**	**1,752,729.59**	**1,688,993.97**
Net Profit CSP Plant in €	**17,181,044.43**	**-389,890.23**	**-326,154.60**	**-262,418.98**	**-198,683.36**	**-134,947.74**	**-71,212.12**
	18 Months	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
at CSP Plant							
Total Casbflow	-15,933,905.38	1,617,781.85	1,617,781.85	1,617,781.85	1,617,781.85	1,617,781.85	1,617,781.85
Cumulated Casbflow	-15,933,905.38	-14,316,123.53	-12,698,341.68	-11,080,559.83	-9,462,777.7	-7,844,996.12	-6,227,214.27
NPV to date	-15,933,905.38	-13,366,628.91	-12,082,381.52	-10,893,263.56	-9,792,228.42	-8,772,751.43	-7,828,791.26

Table 37 (Cont.)

Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17
5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00
2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00
0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35
43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00
1,938,053.35	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**
318,678.11	318,678.11	318,678.11	318,678.11							
1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39
320,271.50	320,271.50	320,271.50	320,271.50	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39
1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35
1,617,781.85	**1,617,781.85**	**1,617,781.85**	**1,617,781.85**	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**
796,695.27	796,695.27	796,695.27	796,695.27	796,695.27	796,695.27	796,695.27	796,695.27	796,695.27	796,695.27	796,695.27
10,357,038.50	9,560,343.23	8,763,647.96	7,966,952.69	7,170,257.42	6,373,562.15	5,576,866.88	4,780,171.61	3,983,476.35	3,186,781.08	2,390,085.81
828,583.08	764,827.46	701,091.84	637,356.22	573,620.59	509,884.97	446,149.35	382,413.73	318,678.11	254,942.49	191,206.86
1,625,258.35	**1,561,522.73**	**1,497,787.11**	**1,434,051.48**	**1,370,315.86**	**1,306,580.24**	**1,242,844.62**	**1,179,109.00**	**1,115,373.38**	**1,051,637.76**	**987,902.13**
-7,476.50	**56,259.12**	**119,994.75**	**183,730.37**	**566,144.10**	**629,879.72**	**693,615.34**	**757,350.96**	**821,086.58**	**884,822.20**	**948,557.83**
Year 7	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**
1,617,781.85	1,617,781.85	1,617,781.85	1,617,781.85	1,936,459.96	1,936,459.96	1,936,459.96	1,936,459.96	1,936,459.96	1,936,459.96	1,936,459.96
-4,609,432.42	-2,991,650.57	-1,373,868.72	243,913.14	2,180,373.09	4,116,833.05	6,053,293.01	7,989,752.97	9,926,212.93	11,862,672.89	13,799,132.85
-6,954,754.06	-6,145,460.36	-5,396,114.34	-4,702,275.44	-3,933,280.54	-3,221,248.23	-2,561,959.06	-1,951,506.12	-1,386,271.92	-862,906.92	-378,309.69

Table 37 (Cont.)

Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00
2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00
0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35	1,894,541.35
43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00	43,512.00
1,938,053.35	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**	**1,938,053.35**
1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39
1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39	1,593.39
1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35	1,938,053.35
1,936,459.96	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**
796,695.27	796,695.27	796,695.27	0.00	0.00	0.00	0.00	0.00
1,593,390.54	796,695.27	0.00	0.00	0.00	0.00	0.00	0.00
127,471.24	63,735.62	0.00	0.00	0.00	0.00	0.00	0.00
924,166.51	**860,430.89**	**796,695.27**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1,012,293.45	**1,076,029.07**	**1,139,764.69**	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**	**1,936,459.96**
Year 18	**Year 19**	**Year 20**	**Year 21**	**Year 22**	**Year 23**	**Year 24**	**Year 25**
1,936,459.96	1,936,459.96	1,936,459.96	1,936,459.96	1,936,459.96	1,936,459.96	1,936,459.96	1,936,459.96
15,735,592.81	17,672,052.77	19,608,512.73	21,544,972.69	23,481,432.65	25,417,892.61	27,354,352.56	29,290,812.52
70,391,44	485,855.46	870,544.36	1,226,737.78	1,556,546.51	1,861,924.96	2,144,682.79	2,406,495.59

Source: PBP (20 yrs) = 7.22, NPV = 16,874,093.29, IRR = 8.75%, BCR = 1.57

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Economic assessment of future perspectives of the concentrated solar power plant in Mongolia

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Abstract

In this study, a preliminary attempt towards the economic assessment of parabolic trough concentrating solar power (CSP) technology in Mongolia has been made. To analyze the economic assessment of parabolic trough CSP technology in Mongolian conditions, project capacity of 5 and 50MW have been taken as the reference cases for this study. These projects have been simulated at South Gobi region of Mongolia. The preliminary results indicate that the use of parabolic trough CSP technology in Mongolia for 5 MW and 50 MW have high investment costs of 16.7 million Euros and 167.4 million Euros respectively (particularly in Sainshand and Dalanzadgad cities). Payback period is 7.8 years for both projects. IRR is more than 7% of interest rate and the both projects are regarded as profitable for the high FIT. The results obtained that it can be used as preliminary indicators to identify financial aspect for investment in CSP generation in Mongolia.

Key Words: Solar thermal power plant, direct normal irradiance, parabolic trough CSP, economic assessment

Introduction

This research work is focused on the parabolic trough concentrating solar power (CSP) technology. Parabolic trough CSP technology is the most mature and economic solar thermal power generation technology today. This study aims to find the most suitable site for utilization of parabolic trough CSP technology and to compare economic efficiency analysis between 5 and 50MW capacities in Mongolia.

CSP is a technology by which sunlight is focused by the mirrors or reflectors to heat the working fluid, called the heat transfer fluid. The heated fluid flows from the collector to a heat engine where a portion of the heat (up to 30%) is converted to electricity. CSP plants consist of two parts: one that collects solar energy and converts it to heat, and another that converts the heat energy to electricity. The main components of the system are the solar collector assembly, the power generation system, the thermal storage, the cooling tower, and the fluid transfer piping. Solar collector assembly is an independently tracking parabolic trough collector made of metal support structure on which the parabolic reflectors are installed, together with the receiver pipes and supports. The tracking system includes the drive, sensors and controller.

Economic evaluation of the parabolic trough solar field technology can give answer such as questions on how much capacity could be installed, how much electricity could be generated, and at what economic, ecological and investment cost?

It is important to study on the development of CSP technology in Mongolian context so that it can decrease the hard currency expenditures in power import and thus make a good possibility to get lower price of electricity. CSP technology could be a solution to solve problems of electric power and determine the factors to implement 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, to increase currency reserve and domestic energy market.

Mongolian energy consumption

Mongolia is served by a power system that consists of four detached segments: the Central Energy System (CES), the Western Energy System (WES), the Eastern Energy System (EES) and the Altai-Uliastain Energy System (AUES), comprising seven thermal power plants with heat extraction (combined heat and power plants), plus two regional hydropower plant and seven distribution systems.

The CES is based on five coal-fired power generating plants, but the essentially base-load plants are unable to properly follow the daily system demand and demand is regulated by the Russian Power Grid System. The other three grid systems are quite small. The WES operates on imports of electricity from the Russia and the local 12MW Durgun hydropower plant supplied parallel electricity to some parts of the region. The EES is powered by thermal power station, supplying 3 isolated provinces. The AUES includes two provinces, which are remote system based on diesel power stations and connected with new 11MW Taishir hydropower plant. The South Gobi region has one small 6MW thermal power plant supplying electricity to consumers.

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

In the 2009 assessment, 3989.7 million kWh of electricity was generated by coal-fired power plants and 11.05 million kWh of electricity was generated by hydropower plants. Moreover, 180.8 million kWh of electricity was imported from Russia and 21.2 million kWh of electricity was exported to Russia. The imported electricity price is higher than current tariff of regulated by Government. It's one of the major problem that power sector is facing and needs to be solved at an earliest period.

The analysis assumes that electricity demand on the CES grows at an average of 3.5% annually. The demand in the South Gobi region is assumed to increase up to 600MW by 2020, driven by the opening from 2012 of the open-cast operations of the Oyu Tolgoi copper and gold mine with a demand of 200MW and to 300MW from 2016 with expansion and the beginning of underground mining and of differing areas of the Tavan Tolgoi coal mine with a demand rising to 300MW by 2018.

Solar energy resource

Approximately 70 percent of Mongolia has good solar resource. The northern and southern regions of the country receive annual solar radiation ranging from 1,163 kWh per square meter to 1,628 kWh per square meter, respectively. The good solar resource area has approximately 2,900 - 3,000 sunshine hours per year. A majority of this solar resource area is the South Gobi region (Gobi desert). Studies are being proposed to assess the feasibility of installing a large PV or concentrating solar power plant in the Gobi desert.

Almost in entire country observed from 270 to 300 clear days and sunshine duration from 2250 to 3300 hours in an average year. Solar radiation distribution is decreasing with the latitude from south to north. The 17, 25, 51 and 7 percent of the territory receive global solar radiation more than 1600, 1600-1400, 1400-1200, and less than 1200 kW*hour /m^2-y respectively. The total yearly solar radiation potential in entire country is estimated as $2.2*10^{12}$ MW.

Renewable energy policy

The Mongolian Government policy is National Renewable Energy Program, which was approved by the State Great Hural (Parliament) of Mongolia, on June 9, 2005. The program aims to create the conditions ensuring ecological balance, unemployment and poverty reduction, and sustainable social and economic development by increasing the share of renewable energy in the energy mix. The Program maintains following ambitious targets for renewable energy development in the country:

- An increase of renewable energy share in the total energy supply to 20-25% by 2020 (up from 0.9% in 2005).
- To decrease in overall energy losses by 10 percentage points by 2020 through the introduction of advanced energy efficiency and renewable energy technologies.

In order to satisfy the increasing demand in a cost efficient and environmentally sustainable way of energy supply, the State Great Hural (Parliament) of Mongolia adopted in January 11, 2007 the Law on Renewable Energy, which promotes and encourages foreign investment and supports the production of energy from renewable sources by regulating generation, transmission, and green energy pricing.

This law supports the development of a renewable energy industry in Mongolia in part by fixing tariffs to be paid to private sector companies (known as Feed-In Tariffs (FIT)) in a band ranging from US 4.5 cents to 30 cents per kWh for electricity generated with renewable sources.

Methodology of the study

There are 4 main steps of the research methodology as the following: the data collection and data analysis, the technical evaluation the best site of parabolic trough CSP plant, the economical and environmental evaluation parabolic trough CSP plant, and the roadmap for development CSP technology in Mongolia.

This paper has concentrated only on the economical evaluation parabolic trough CSP plant in Mongolia. The analyzed economic efficiency method such as net present value (NPV), benefit to cost ratio (BCR), internal rate of return (IRR) and payback period (PBP) [9] are used for economic evaluation in this research.

The NPV method for evaluating the desirability of investment can be defined as follows:

$$NPV = \sum_{n=0}^{N} \frac{B_n}{(1+i)^n} - \sum_{n=0}^{N} \frac{C_n}{(1+i)^n} = PVB - PVC$$

Where,

B_n	=	Expected benefit at the end of year n
C_n	=	Expected cost at the end of year n
i	=	Discount rate, i.e., the required minimum annual rate on new investment
n	=	Project's duration in years
N	=	Project's period
PVB	=	Present Value Benefit
PVC	=	Present Value Cost

The BCR is attempting to identify the relationship between the cost and benefits of a proposed project.

$$BCR = \frac{PVB}{PVC}$$

The IRR is another time – discounted measure of investment worth. The IRR is defined as the rate of discount which equates the present value of the stream of net receipt with the initial investment outlay. An alternative and equivalent definition of the IRR is the rate of discount which equates the NPV of the cash flow to zero:

$$NPV = \sum_{n=0}^{N} \frac{B_n}{(1+i)^n} - \sum_{n=0}^{N} \frac{C_n}{(1+i)^n} = 0$$

Where, "i" denotes the IRR.

The criteria based on payback time often have been applied for selection of projects both in planned economies and in private enterprise. In general, the payback time "N" is defined by equation:

PBP:

$$\sum_{n=1}^{N} (B_n - C_n) = 0$$

Calculation and discussion

This study compares economical analysis between 5MW pilot project and 50 MW commercial projects that use parabolic trough CSP technology in order to select the best and cheapest option similar as new overseas plants in the Gobi Desert in Mongolia. The analysis has started from capital cost of CSP plant that the component initial cost of new commercial plants in the Europe is used for lesson learn.

Valllentin and Viebahn study 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 on the global market. The assumptions used by them (Table 1) to calculate a starting point for the cost analysis of the specific CSP investment costs have been used in this paper.

Al-Soud and Hrayshat studied the technical and economic feasibility of a 50MW CSP plant for Jordan. From this study report would like to use design characteristics of the proposed CSP plant (Table 1).

Rainer and Henry presented the typical parabolic trough CSP plant's investment cost structure (Figure 1). This structure would help to analyze for assumption project investment cost.

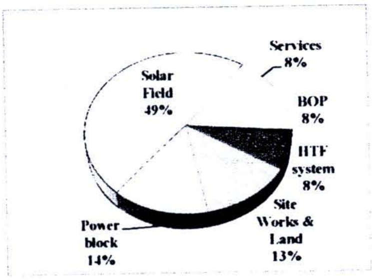

Figure 1: Typical cost distribution of parabolic trough power plant

The economical evaluation used 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 to be shown beneficial for investment such project and to deduct main factor for financial analysis in CSP technology in Mongolia. Key project assumptions on which the study was based are identified in Table 1.

Table 1 Evaluation assumptions

Parameter	Value	Notes
Currency	€ and $	1 Euro (€) = 1.45 US dollar (₮).
		Bank of Mongolian exchanged date on 2011.04.15
Project life time	25 years	Typical for a project of this nature
Power price (selling)	Low	The FIT tariff solar resources:
	€ 0.12/kWh (FIT)	for Grid-connected $ 0.15 - 0.18 /kWh
		for Standalone $ 0.2 - 0.3 /kWh
	High	(Source: Renewable energy law of Mongolia. The Energy
	€ 0.21/kWh (FIT)	Regulatory Authority of Mongolia.
		http://www.era.energy.mn/)
Specific investment costs	€268/m² aperture	Collector field:
	€1140/kW	Power block:
	€1380/kW	Site works and land, service, BOP, etc.;
		(Source: Vallentin and Viebahn, 2010)
Collector field:		
	Eurotrough 100	Collector type
For 50MW CSP	305,200 m²	Aperture
	1,200,000 m²	Land use
		(Source: Al-Soud and Hrayshat, 2009)
Interest rate	6%	
Transportation,	9.4%	Source: http://www.ecustoms.mn/tax
Insurance,	1.3%	
Custom rate	15%	

To calculate economical evaluation for CSP projects uses Microsoft Excel Program. Final results to be shown as the following: For 5MW pilot CSP project,

Power price - for low FIT € 0.12/kWh		Power price - for high FIT € 0.21/kWh, Tax Intensive or Free Custom Duty	
Investment:	18.826.355.52 Euro	Investment:	16.744.451.52 Euro
NPV	10.022.687.79 Euro	NPV	18.875.238.13 Euro
BCR	0.82	BCR	1.64
Project IRR	-0.13%	Project IRR	7.0%
Payback period	15.6 years	Payback period	7.8 years

For 50MW commercial CSP project,

Power price - for low FIT € 0.12/kWh		Power price - for high FIT € 0.21/kWh, Tax Intensive or Free Custom Duty	
Investment:	181. 363.555.20 Euro	Investment:	167.444.515.20 Euro
NPV	101,250. 484.16 Euro	NPV	188.752.381.33 Euro
BCR	0.85	BCR	1.8
Project IRR	0.26%	Project IRR	7.44%
Payback period	15 years	Payback period	7.8 years

Conclusion

The Mongolian Gobi Desert has excellent solar resource more than 2,900 sunshine hours per year and this territory is receiving global solar radiation more than 1600 kW*hour /m^2-y. It is good result for implementation the CSP project.

Parliament of Mongolia approved the special higher tariffs for energy generated by renewable energy resources within the framework of Renewable Energy Law. It states that FIT of 0.15 - 0.18 USD/kWh (0.10 - 0.12 €/kWh) will be paid for energy produced by solar technologies which connect to the grid. But for solar technologies standalone system will be paid of 0.2 - 0.3 USD/kWh (0.14 - 0.21 €/kWh). This study has assumed power price between low FIT of 0.12 €/kWh and high FIT 0.21 €/kWh. Calculation results shows the comparison of the economic efficiency of solar parabolic trough power plant between 5MW pilot project and 50 MW commercial project in Mongolian Gobi Desert. Two projects have both high investment costs of 16.7 million Euros and 167.4 million Euros. Payback period for both projects is about 7.8 years. IRR is more than 7% of interest rate and the both projects are regarded as profitable for the high FIT.

Results from this study will be useful for government's policy leaders to be proactive in the development of solar energy and revision of law and Renewable Energy Policy. This research work will assess a roadmap, which is given advisement to the renewable energy policy and assessment of possibility to connect power grid and future demand of electricity.

Mongolia interest to use more solar energy technologies as the solar technologies seems to be one of the solutions for climate change issue. Although the government supports renewable energy development and government partners, donors, international agencies, GO also interest in supporting the progress of new green energy development in Mongolia, the current economic situation of the country is not strong enough to support such projects. Mongolia still needs grants providing, technical assistance, and funding from international agencies.

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