LESOTHO POWER GENERATION MASTER PLAN

PROJECT # LEC/GEN/1-2009

FINAL MILESTONES REPORT

VOLUME 1

PART 1.3

SOLAR POWER GENERATION OPTION

ABBREVIATIONS

AC	Alternative Current
DOE	Department of Energy
CO2	Carbon Dioxide
CSP	Concentrating Solar Power
CSIR	National Aeronautics and Space Administration
EERE	Energy Efficiency and Renewable Energy
NASA	National Centre for Environmental Prediction
Pv	Photovoltaic
TV	Television

LIST OF MEASUREMENT UNITS

°C	Degree Centigrade
°C-d	Degree Centigrade per day
Gwh	Gigawatt Hour
Kg	kilogram
Km	Kilometre
KPa	Kilo-Pascal
KW	Kilo-Watt
KWh	Kilowatt/hour
KWh/m^2	Kilowatt/hour/square meter
$KWh/m^2/d$	Kilowatt/hour/square meter/day
m	meter
m/s	meter/second
MW	Mega Watt
MVA	Megavolt/Amper
MWh	megawatt-hour
MWh/y	megawatt-hour/year
W/m^2	watt/square meter
ZAR	South African Rand

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1. INTRODUCTION

Amidst increasing awareness of the serious environmental problems now facing the world, solar power generation is a particular interesting source of renewable energy.

Solar generation is the cleanest way of generating power and therefore has a clear edge over other technologies.

2. PURPOSE

The purpose of this report is to indicate the potential sites and establish the technical and economic conditions to install solar power generation equipments based on the radiation map of Lesotho.

3. LESOTHO RADIATION MAP

The radiation levels in Southern Africa are very high especially at high altitude.

We have included radiation data from six independent sources and all these solar maps shows a similar output value.

Factors that make solar viable resource are as follows:

- High Altitude;
- Low pollution;
- Low ambient temperature; and
- High levels of solar radiation.

3.1 Overview of technology

Basically, these systems operate by sending the energy generated by the farm to the grid via an inverter which converts the direct current in to alternating current, optimising the efficiency and ensuring an optimum take-up to the grid.

Photovoltaic technology has reached a tipping point with new factories coming online on a weekly basis.

In the past the industry was built Mono and ***Poly Crystalline*** technology. Almost all of the major suppliers are now producing ***Thin Film Panels***.

Turn Key solar farms traditionally cost the developer R 35 per watt installed. With improvements in the manufacturing process costs reduced to R 29 per watt. Today solar farms are delivered at less than R24 per watt.

The solar developer can now choose from more than 300 different large manufactures or choose to manufacture the solar panels on site. A solar manufacturing plant for thin film technology can now be assembled in a year. A plant producing 7 MW of solar panels per year costs about R 70 Million Rand.

Manufacturing your own panels would create jobs as well as provide a cost effective alternative to paraffin for lighting. Production costs of these panels are about R 7 per watt depending on the size of the plant and cost of transport of the raw components.

3.2 Technologies applicable in Lesotho

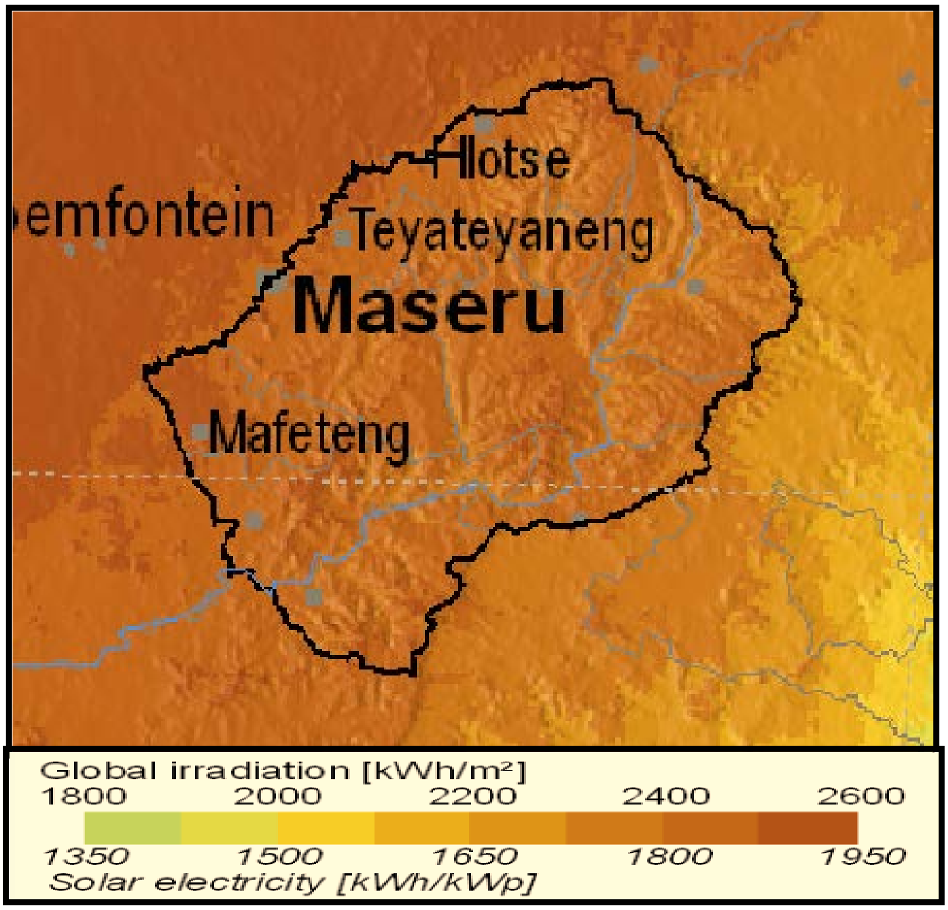
3.2.1 Photo Voltaic

- Pv is a viable solution because of the following factors:
  - The low rural electrification rate lends itself to PV solution as it can be deployed almost anywhere in Lesotho;
  - Pv can be installed in a very short time bring immediate relief on the network; and
  - Pv system have no moving parts and requires very little maintenance reducing the operating cost and risk.

3.2.2 Concentrated Solar

- The radiation levels in Lesotho are high enough to provide a viable return;
- Has the ability to store energy and provide energy during peak demand independently; and
- Provides a very good return on investment on a large scale 10 MW and over.

3.3 Lesotho Radiation Map



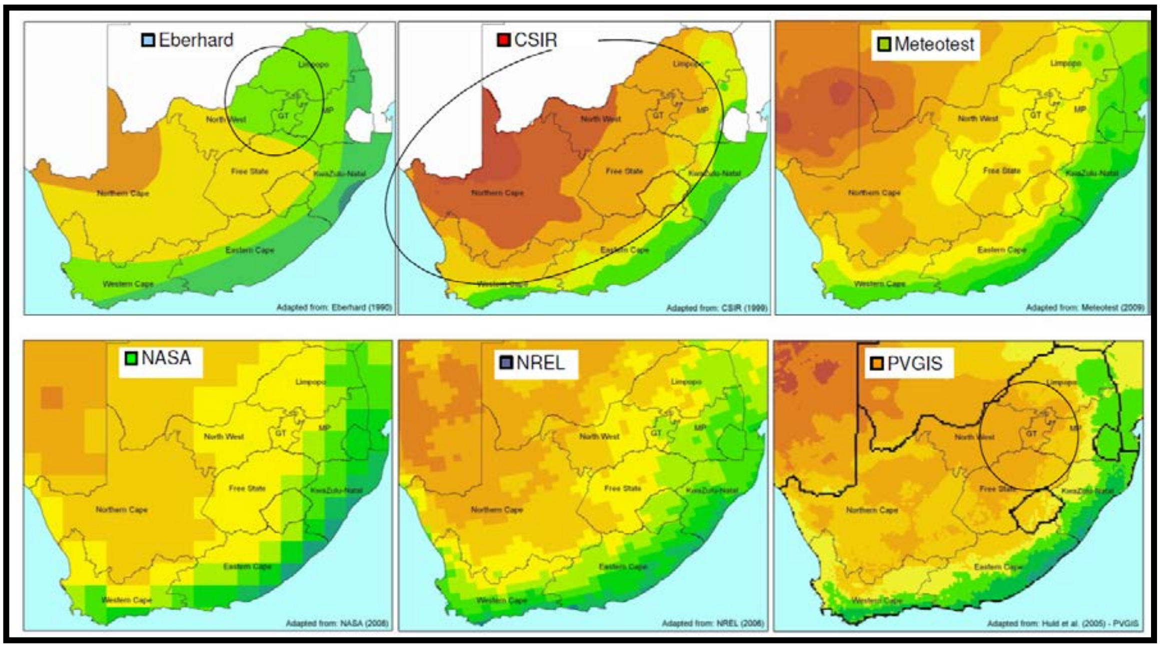


Figure 1: Comparison from multiple radiation sources

3.4 Dataset

The Data set used in this report is based on the following sources

- NASA Radiation data (Satellite based);
- Solar data provided SMA (based in Germany); and
- Cross-reference was done to data from CSIR.

4. SELECTION OF REGIONS OF POTENTIAL DEVELOPMENT

4.1 Methodology

- The sites analysed in this report was based on a geographic spread;
- The second criteria was available land close to existing transmission lines; and
- The sizing of the plants was based on local consumption and available transmission voltage.

4.2 Initial Selection of the zones based in radiation

- We tried to find sites with high radiation but found that it was more beneficial to place the plants close to transmission lines and industrial end-users.

4.3 Further analysis of all proposed zones

- Actual radiation metering is suggested for high priority sites like Maseru.

4.4 Description and Ranking of proposed zones:

4.4.1. Maseru

Maseru is ideally suited for a large solar farm with close access to the grid and good solar radiation.

- Location: 29°19'59.54"S 27°28'47.26"E;
- Potential: 20 MW solar farm installation;
- Grid tie inverter technology reach up to 98% efficiency;
- Grid tie inverters ship in 1.25 MVA blocks; and
- Installation time: 20 months.

4.4.1.1 *Climate data*

The table below indicates the climatic data for Maseru (Location: -29.3° N, 27.5° E). The average solar radiation measured on the horizontal ranges between 3.62 and 7.35 kWh/m^2/day with an annual average of 5.53 kWh/m^2/day.

	Unit	Climate data location	Project location
Latitude	°N	-29.3	-29.3
Longitude	°E	27.5	27.5
Elevation	m	1,704	1,704
Heating design temperature	°C	-0.1	
Cooling design temperature	°C	26.5	
Earth temperature amplitude	°C	18.9	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		19.6	57.3%	7.15	83.1	3.6	22.1	0	298
February		19.1	58.6%	6.40	83.2	3.3	21.1	0	254
March		17.5	56.4%	5.58	83.3	3.3	19.3	15	233
April		14.4	52.3%	4.74	83.4	3.4	15.9	107	133
May		10.3	51.4%	4.04	83.5	3.6	11.1	238	10
June		6.2	54.4%	3.62	83.6	3.9	6.4	354	0
July		6.2	51.0%	3.90	83.7	4.0	6.6	365	0
August		9.5	44.2%	4.78	83.6	4.2	10.6	264	0
September		13.7	41.6%	5.68	83.4	4.3	15.8	130	110
October		16.0	50.3%	6.24	83.3	4.0	18.8	62	186
November		17.5	52.6%	6.94	83.2	3.8	20.7	14	226
December		18.8	55.7%	7.35	83.1	3.6	21.8	0	274
Annual		14.0	52.1%	5.53	83.4	3.7	15.8	1,549	1,724
Measured at	m					10.0	0.0		

4.4.1.2 *Potential power generation: 20 MW PV Plant Grid connected*

For the proposed case of a 20 MW grid connected PV plant with no tracking and a panel tilt angle of 28°, the expected average daily solar radiation at a tilt angle of 28° is 6.06kWh/m^2. The estimated yield from the proposed solution is 32 GWh.

Resource assessment					
Solar tracking mode		Fixed			
Slope	°	28.0			
Azimuth	°	180.0			

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate ZAR/MWh	Electricity exported to grid MWh
January	7.15	6.51	600.0	3,576
February	6.40	6.24	600.0	3,097
March	5.58	5.93	600.0	3,277
April	4.74	5.71	600.0	3,087
May	4.04	5.57	600.0	3,160
June	3.62	5.38	600.0	3,005
July	3.90	5.64	600.0	3,248
August	4.78	6.11	600.0	3,457
September	5.68	6.38	600.0	3,442
October	6.24	6.25	600.0	3,473
November	6.94	6.43	600.0	3,446
December	7.35	6.57	600.0	3,621
Annual	**5.53**	**6.06**	**600.00**	**39,891**

Annual solar radiation - horizontal	MWh/m²	2.02
Annual solar radiation - tilted	MWh/m²	2.21

4.4.1.3 Technology proposed:

4.4.1.3.1 Photovoltaic technology

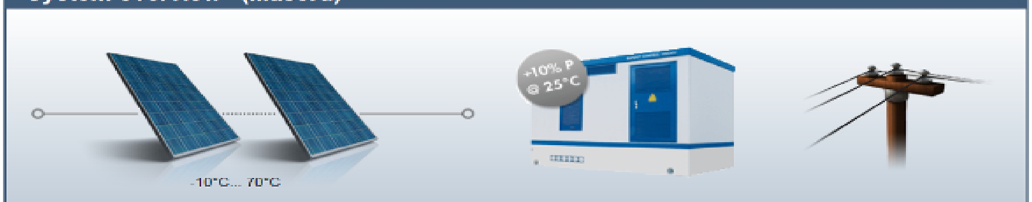
Photovoltaic			
Type		poly-Si	
Power capacity	kW	19,910.00	
Manufacturer		BP Solar	
Model		poly-Si - AC Power Wall	90500 unit(s)
Efficiency	%	10.4%	
Nominal operating cell temperature	°C	45	
Temperature coefficient	% / °C	0.40%	
Solar collector area	m²	191,627	
Miscellaneous losses	%	1.0%	
Inverter			
Efficiency	%	97.0%	
Capacity	kW	20000000.0	
Miscellaneous losses	%	1.0%	
Summary			
Capacity factor	%	22.9%	
Electricity exported to grid	MWh	39,891	

4.4.1.3.2 *Thin Film + grid tie inverter with 20 KVA transformer*

Figure 2: Sample panel and inverter layout

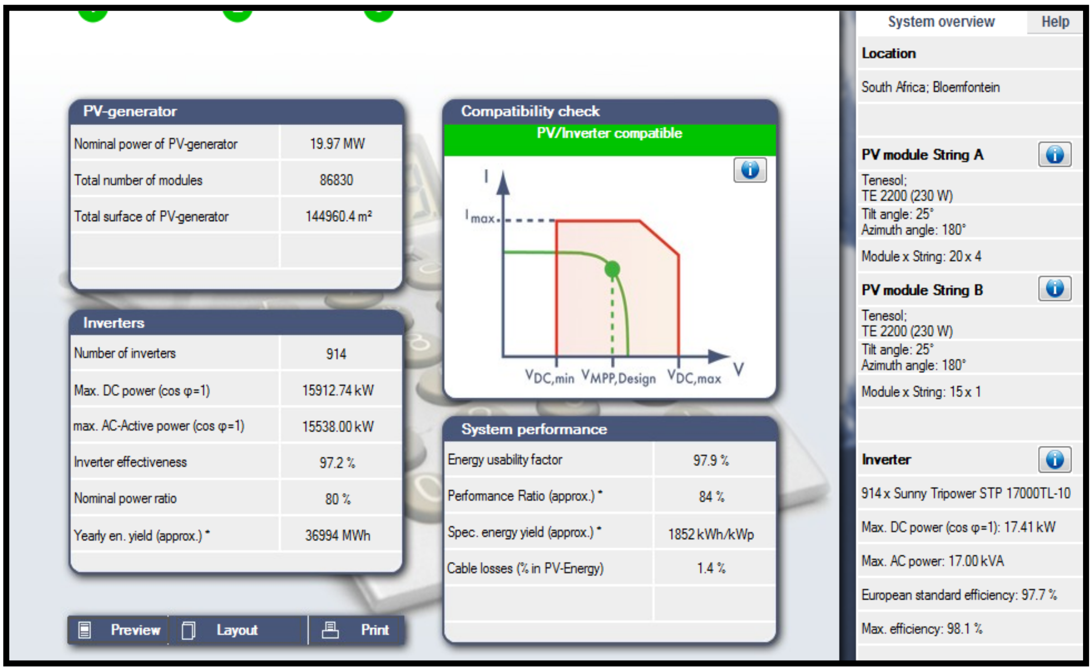
4.4.1.4 *System Overview*

System overview (Maseru)



String A	**Inverter**
First Solar	12 x Sunny Central SC 1250MV-11
FS CTS-262	Max. efficiency: 97.8 %
Module x String:	European standard efficiency: 97.4 %
9 x 2452	Max. AC power: 1250.00 kVA
Inclination / Azimuth:	Max. DC power (cos φ=1): 1284.00 kW
25° / 180°	Power factor (cos φ): 1.00

Technical data	
Nominal power of PV-generator: 16.55 MW	Nominal power ratio: 93 %
Total number of modules: 264816	Yearly en. yield (approx.) *: 31464 MWh
Total surface of PV-generator: 195460.8 m²	Energy usability factor: 99.7 %
Number of inverters: 12	Performance Ratio (approx.) *: 85 %
Max. DC power (cos φ=1): 15408.00 kW	Spec. energy yield (approx.) *: 1901 kWh/kWp
max. AC-Active power (cos φ=1): 15000.00 kW	Cable losses (% in PV-Energy): Not considered
Inverter effectiveness: 97.1 %	



4.4.1.5 CO^2 analysis

The implementation of this project reduces the equivalent amount of carbon dioxide as 3 674 hectares of carbon absorbing forest.

Emission Analysis

Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh	
Lesotho	All types	1.240		1.240	
Electricity exported to grid	MWh	39,891	T&D losses	5.0%	
GHG emission					
Base case	tCO2	49,464.7			
Proposed case	tCO2	2,473.2			
Gross annual GHG emission reduction	tCO2	46,991.5			
GHG credits transaction fee	%	15.0%			
Net annual GHG emission reduction	tCO2	39,942.8	is equivalent to	3,674	Hectares of forest absorbing carbon
GHG reduction income					
GHG reduction credit rate	ZAR/tCO2	110.00			
GHG reduction credit duration	yr	25			
GHG reduction credit escalation rate	%	6.0%			

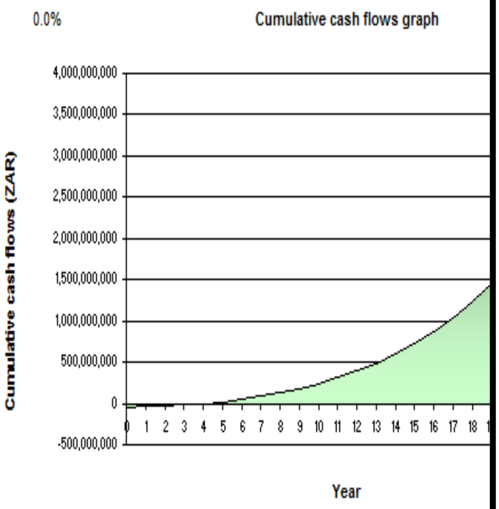
4.4.1.6 *Financial analysis*

The projected project cost amounts to a turnkey amount of R24.00 per watt.

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate ZAR/MWh	Electricity exported to grid MWh
January	7.15	6.42	500.0	2,879
February	6.40	6.18	500.0	2,504
March	5.58	5.92	500.0	2,659
April	4.74	5.74	500.0	2,512
May	4.04	5.64	500.0	2,574
June	3.62	5.47	500.0	2,439
July	3.90	5.73	500.0	2,635
August	4.78	6.16	500.0	2,806
September	5.68	6.38	500.0	2,791
October	6.24	6.21	500.0	2,800
November	6.94	6.35	500.0	2,767
December	7.35	6.47	500.0	2,907
Annual	**5.53**	**6.06**	**500.00**	**32,274**

Financial Analysis

Financial parameters			
Inflation rate	%	12.0%	
Project life	yr	25	
Debt ratio	%	90%	
Debt interest rate	%	7.00%	
Debt term	yr	25	
Initial costs			
Power system	ZAR	420,000,000	100.0%
Other	ZAR		0.0%
Total initial costs	ZAR	420,000,000	100.0%
Incentives and grants	ZAR		0.0%
Annual costs and debt payments			
O&M (savings) costs	ZAR		
Fuel cost - proposed case	ZAR	0	
Debt payments - 25 yrs	ZAR	32,436,376	
	ZAR		
Total annual costs	ZAR	32,436,376	
Annual savings and income			
Fuel cost - base case	ZAR	0	
Electricity export income	ZAR	27,086,967	
GHG reduction income - 20 yrs	ZAR	5,533,480	
	ZAR		
Total annual savings and income	ZAR	32,620,448	
Financial viability			
Pre-tax IRR - equity	%	40.7%	
Pre-tax IRR - assets	%	13.0%	
Simple payback	yr	12.9	
Equity payback	yr	4.1	



4.4.2 Hlotse

Hlotse is ideally suited for a large solar installation as it has very high solar radiation levels. The ability to transmit this power is still under discussion, however.

- Location: 28 51 57 S 25 05 26 E;
- Usable area: 20,000 m²;
- Potential 2 MW solar farm installation;
- Grid tie inverter technology reach up to 98% efficiency;
- Grid tie inverters with a 2 MVA transformer; and
- 11 months to install the farm.

4.4.2.1 Climate data

	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
Jan	19.2	59.5%	7.22	83.8	3.8	21.6	0	285
Feb	18.7	61.0%	6.54	83.9	3.6	20.5	0	244
Mar	17.1	59.4%	5.62	84.0	3.6	18.5	27	221
Apr	14.3	53.8%	4.65	84.1	3.6	15.3	113	128
May	10.5	51.6%	3.93	84.2	3.9	10.9	233	15
Jun	6.6	53.6%	3.45	84.3	4.2	6.5	341	0
Jul	6.6	50.6%	3.76	84.3	4.2	6.6	352	0
Aug	9.5	45.5%	4.65	84.2	4.3	10.2	264	0
Sep	13.2	44.3%	5.57	84.1	4.4	14.9	145	95
Oct	15.4	52.4%	6.32	84.0	4.2	18.0	81	167
Nov	17.1	53.6%	6.98	83.9	4.0	20.2	27	213
Dec	18.7	56.0%	7.44	83.8	3.7	21.7	0	268

4.4.2.2 Potential power generation: 2 MW PV Plant Grid connected

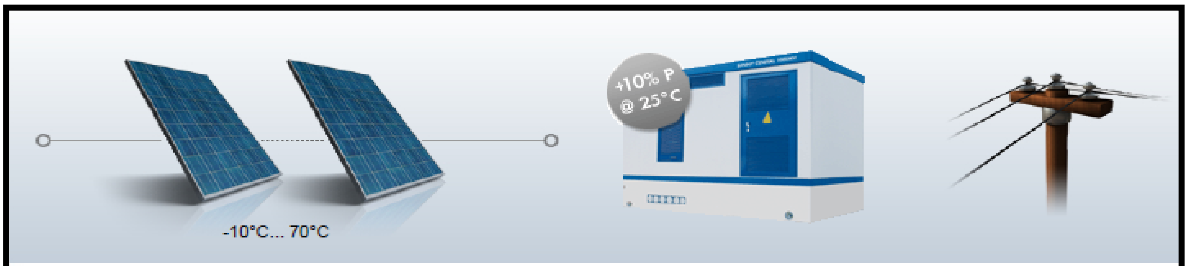
Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate ZAR/MWh	Electricity exported to grid MWh
January	7.15	6.63	600.0	397.9
February	6.40	6.31	600.0	342.0
March	5.58	5.94	600.0	357.3
April	4.74	5.66	600.0	330.0
May	4.04	5.46	600.0	330.4
June	3.62	5.24	600.0	308.5
July	3.90	5.50	600.0	334.7
August	4.78	6.02	600.0	364.2
September	5.68	6.36	600.0	370.9
October	6.24	6.30	600.0	379.4
November	6.94	6.54	600.0	380.4
December	7.35	6.70	600.0	402.7
Annual	**5.53**	**6.05**	**600.00**	**4,298.3**

Figure 3: Approximate range of annual generation: Total 4.1 GW hours per annum

4.4.2.3 Technology proposed: Thin Film + grid tie inverter with 2 MVA Transformer

Figure 4: Sample panel and inverter layout

4.4.2.4 System Overview



String A
Bosch Solar Energy
a-Si plus 90W
Module x String:
6 x 1851
Inclination / Azimuth:
25° / 180°

Inverter
2 x Sunny Central SC 1000MV-11
Max. efficiency: 97.9 %
European standard efficiency: 97.5 %
Max. AC power: 1000.00 kVA
Max. DC power (cos φ=1): 1018.00 kW
Power factor (cos φ): 1.00

Technical data
Nominal power of PV-generator: 2.00 MW
Total number of modules: 22212
Total surface of PV-generator: 32298.4 m²
Number of inverters: 2
Max. DC power (cos φ=1): 2036.00 kW
max. AC-Active power (cos φ=1): 2000.00 kW
Inverter effectiveness: 97.2 %

Nominal power ratio: 102 %
Yearly en. yield (approx.) *: 3775 MWh
Energy usability factor: 100.0 %
Performance Ratio (approx.) *: 84 %
Spec. energy yield (approx.) *: 1888 kWh/kWp
Cable losses (% in PV-Energy): Not considered

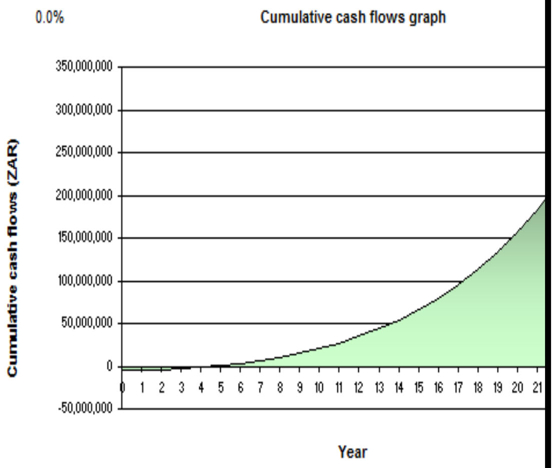
4.4.2.5 CO^2 analysis

Emission Analysis

Base case electricity system (Baseline)		GHG emission factor (excl. T&D)	T&D losses	GHG emission factor	
Country - region	Fuel type	tCO2/MWh	%	tCO2/MWh	
Lesotho	All types	1.240		1.240	
Electricity exported to grid	MWh	39,891	T&D losses	5.0%	
GHG emission					
Base case	tCO2	49,464.7			
Proposed case	tCO2	2,473.2			
Gross annual GHG emission reduction	tCO2	46,991.5			
GHG credits transaction fee	%	15.0%			
Net annual GHG emission reduction	tCO2	39,942.8	is equivalent to	3,674	Hectares of forest absorbing carbon
GHG reduction income					
GHG reduction credit rate	ZAR/tCO2	110.00			
GHG reduction credit duration	yr	25			
GHG reduction credit escalation rate	%	6.0%			

4.4.2.6 *Financial analysis*

Financial parameters			
Inflation rate	%	12.0%	
Project life	yr	25	
Debt ratio	%	90%	
Debt interest rate	%	6.00%	
Debt term	yr	25	
Initial costs			
Power system	ZAR	46,000,000	100.0%
Other	ZAR		0.0%
Total initial costs	ZAR	46,000,000	100.0%
Incentives and grants	ZAR		0.0%
Annual costs and debt payments			
O&M (savings) costs	ZAR		
Fuel cost - proposed case	ZAR	0	
Debt payments - 25 yrs	ZAR	3,238,586	
	ZAR		
Total annual costs	ZAR	3,238,586	
Annual savings and income			
Fuel cost - base case	ZAR	0	
Electricity export income	ZAR	2,578,951	
GHG reduction income - 25 yrs	ZAR	473,422	
	ZAR		
Total annual savings and income	ZAR	3,052,374	
Financial viability			
Pre-tax IRR - equity	%	36.1%	
Pre-tax IRR - assets	%	11.9%	
Simple payback	yr	15.1	
Equity payback	yr	4.8	



The capital cost per watt for solar is typically 24 Rand (but could vary based on location and distance from existing infrastructure).

Existing site access: Easily accessible

Distance from paved road: Dirt road access 500 m

Site requirement civils and base structure:

- Site is very rocky and requires concrete blocks to be used as bases, adding to cost;
- Enclosing the area with 2,00 meters high steel palisade fence;
- Pedestrian Gate 2,00*2,00 meters;
- PV structure, including hot dip-galvanized trapezoidal profiles for foundation, structural beams in galvanised steel, clamps, screw & nuts;
- Anchoring & mounting structure; and
- Formwork & Reinforced Concrete.

4.4.3 Mafeteng

Mafeteng is ideally suited for a large solar installation as it has very high solar radiation levels. The ability to transmit this power is still under discussion however:

- Location: 29 48 50 S   25 05 26 E;
- Usable area: 20,000 m²;
- Potential 2 MW solar farm installation;
- Grid tie inverter technology reach up to 98% efficiency;
- Grid tie inverters with 2 MVA transformer; and
- 15 months to install the farm.

4.4.3.1 Climate data

Month	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed
	°C	%	kWh/m²/d	kPa	m/s
January	19.2	59.5%	7.22	83.8	3.8
February	18.7	61.0%	6.54	83.9	3.6
March	17.1	59.4%	5.62	84.0	3.6
April	14.3	53.8%	4.65	84.1	3.6
May	10.5	51.6%	3.93	84.2	3.9
June	6.6	53.6%	3.45	84.3	4.2
July	6.6	50.6%	3.76	84.3	4.2
August	9.5	45.5%	4.65	84.2	4.3
September	13.2	44.3%	5.57	84.1	4.4
October	15.4	52.4%	6.32	84.0	4.2
November	17.1	53.6%	6.98	83.9	4.0
December	18.7	56.0%	7.44	83.8	3.7
Annual	13.9	53.4%	5.51	84.0	4.0

4.4.3.2 Potential power generation: 2 MW PV Plant Grid connected

Resource assessment

Solar tracking mode		Fixed
Slope	°	27.0
Azimuth	°	180.0

☑ Show data

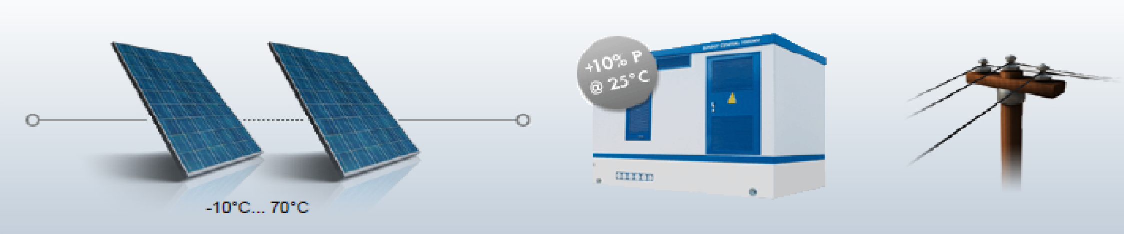
Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate ZAR/MWh	Electricity exported to grid MWh
January	7.22	6.64	600.0	580.0
February	6.54	6.43	600.0	507.0
March	5.62	6.02	600.0	526.3
April	4.65	5.62	600.0	477.2
May	3.93	5.43	600.0	478.4
June	3.45	5.12	600.0	438.2
July	3.76	5.44	600.0	481.0
August	4.65	5.95	600.0	523.7
September	5.57	6.28	600.0	533.2
October	6.32	6.38	600.0	559.1
November	6.98	6.53	600.0	553.0
December	7.44	6.72	600.0	587.3
Annual	**5.51**	**6.05**	**600.00**	**6,244.4**

Annual solar radiation - horizontal	MWh/m²	2.01
Annual solar radiation - tilted	MWh/m²	2.21

4.4.3.3 Technology proposed: Thin Film + grid tie inverter with2 MVA Transformer

Figure 5: Sample panel and inverter layout

4.4.3.4 System overview



String A	**Inverter**
Bosch Solar Energy	2 x Sunny Central SC 1000MV-11
a-Si plus 90W	Max. efficiency: 97.9 %
Module x String:	European standard efficiency: 97.5 %
6 x 1851	Max. AC power: 1000.00 kVA
Inclination / Azimuth:	Max. DC power (cos φ=1): 1018.00 kW
25° / 180°	Power factor (cos φ): 1.00

Technical data	
Nominal power of PV-generator: 2.00 MW	Nominal power ratio: 102 %
Total number of modules: 22212	Yearly en. yield (approx.) *: 3775 MWh
Total surface of PV-generator: 32298.4 m²	Energy usability factor: 100.0 %
Number of inverters: 2	Performance Ratio (approx.) *: 84 %
Max. DC power (cos φ=1): 2036.00 kW	Spec. energy yield (approx.) *: 1888 kWh/kWp
max. AC-Active power (cos φ=1): 2000.00 kW	Cable losses (% in PV-Energy): Not considered
Inverter effectiveness: 97.2 %	

4.4.3.5 CO 2 analysis

Emission Analysis

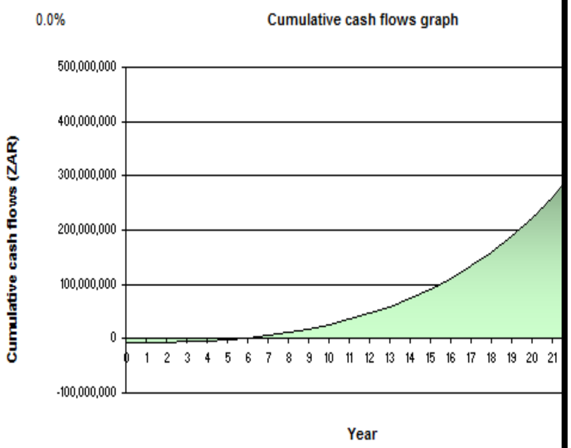
Base case electricity system (Baseline)		GHG emission factor (excl. T&D)	T&D losses	GHG emission factor	
Country - region	Fuel type	tCO2/MWh	%	tCO2/MWh	
Lesotho	All types	1.240		1.240	
Electricity exported to grid	MWh	39,891	T&D losses	5.0%	
GHG emission					
Base case	tCO2	49,464.7			
Proposed case	tCO2	2,473.2			
Gross annual GHG emission reduction	tCO2	46,991.5			
GHG credits transaction fee	%	15.0%			
Net annual GHG emission reduction	tCO2	39,942.8	is equivalent to	3,674	Hectares of forest absorbing carbon
GHG reduction income					
GHG reduction credit rate	ZAR/tCO2	110.00			
GHG reduction credit duration	yr	25			
GHG reduction credit escalation rate	%	6.0%			

4.4.3.6 Financial analysis

The capital cost per watt for solar is typically 24 Rand (but could vary based on location and distance from existing infrastructure).

Financial Analysis

Financial parameters			
Inflation rate	%	12.0%	
Project life	yr	25	
Debt ratio	%	90%	
Debt interest rate	%	6.00%	
Debt term	yr	25	
Initial costs			
Power system	ZAR	71,000,000	100.0%
Other	ZAR		0.0%
Total initial costs	ZAR	71,000,000	100.0%
Incentives and grants	ZAR		0.0%
Annual costs and debt payments			
O&M (savings) costs	ZAR		
Fuel cost - proposed case	ZAR	0	
Debt payments - 25 yrs	ZAR	4,998,687	
	ZAR		
Total annual costs	ZAR	4,998,687	
Annual savings and income			
Fuel cost - base case	ZAR	0	
Electricity export income	ZAR	3,742,704	
GHG reduction income - 25 yrs	ZAR	687,054	
	ZAR		
Total annual savings and income	ZAR	4,429,759	
Financial viability			
Pre-tax IRR - equity	%	33.3%	
Pre-tax IRR - assets	%	11.2%	
Simple payback	yr	16.0	
Equity payback	yr	5.4	



Existing Site Access: Easily accessible

Distance from paved road: Dirt road access; 5 Km to power line access

Site requirement civils and base structure:

- Site is very rocky and requires concrete blocks to be used as bases, adding to cost;
- Enclosing the area with 2,00 meters high steel palisade fence;
- PV structure including hot dip-galvanized trapezoidal profiles for foundation, structural beams in galvanised steel, clamps, screw & nuts;
- Anchoring & mounting structure; and
- Formwork & Reinforced Concrete.

4.4.4 Maputsoe

Maputsoe is ideally suited for a large solar installation as it has very high solar radiation levels. The solution is based on utilising the existing roof space of the surrounding factories:

- Location: 29 48 50"S   27.14 28" E;
- Usable area: 10,000 m²;
- Potential 1 MW solar farm installation;
- Grid tie inverter technology reach up to 98% efficiency;
- Grid tie inverters with 1 MVA transformer; and

- 12 months to install the farm.

4.4.4.1 *Climate data*

Month	Air temperature	Relative Humidity	Daily solar radiation – horizontal-	Atmospheric pressure	Wind Speed
	°C	%	kWh/m²/d	kPa	m/s
Jan	17.8	65.9%	6.90	82.3	3.6
Feb	17.5	66.4%	6.28	82.3	3.3
Mar	16.3	63.3%	5.49	82.4	3.3
Apr	13.6	56.4%	4.70	82.5	3.4
May	10.1	52.1%	4.09	82.6	3.6
Jun	6.5	52.7%	3.64	82.7	4.0
Jul	6.5	50.0%	3.91	82.8	4.0
Aug	9.4	45.8%	4.75	82.7	4.2
Sep	13.1	46.0%	5.66	82.5	4.3
Oct	14.8	56.4%	6.04	82.5	4.1
Nov	16.1	59.6%	6.74	82.4	3.8
Dec	17.3	62.9%	7.02	82.3	3.5
Annual	13.2	56.4%	5.43	82.5	3.7

4.4.4.2 Potential power generation: 1 MW PV Plant Grid connected

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate ZAR/MWh	Electricity exported to grid MWh
January	7.15	6.63	650.0	192.8
February	6.40	6.31	650.0	165.9
March	5.58	5.94	650.0	174.1
April	4.74	5.66	650.0	162.2
May	4.04	5.46	650.0	164.3
June	3.62	5.24	650.0	155.4
July	3.90	5.50	650.0	168.3
August	4.78	6.02	650.0	180.8
September	5.68	6.36	650.0	182.0
October	6.24	6.30	650.0	185.6
November	6.94	6.54	650.0	185.5
December	7.35	6.70	650.0	195.6
Annual	**5.53**	**6.05**	**650.00**	**2,112.4**

4.4.4.3 Technology proposed: Thin Film + grid tie inverter with 1 MVA Transformer

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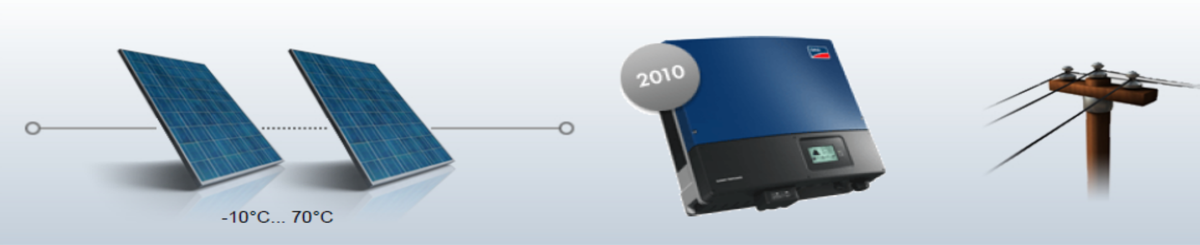
Figure 6: Sample panel and inverter layout

4.4.4.4 System overview



String A	String B	Inverter
Sun Tech Solar	Sun Tech Solar	46 x Sunny Tripower STP 17000TL-10
XTP180-34	XTP180-34	Max. efficiency: 98.1 %
Module x String:		European standard efficiency: 97.7 %
17 x 6	18 x 1	Max. AC power: 17.00 kVA
Inclination / Azimuth:		Max. DC power (cos φ=1): 17.41 kW
25° / 180°	25° / 180°	Power factor (cos φ): 1.00

Technical data

- Nominal power of PV-generator: 0.99 MW
- Total number of modules: 5520
- Total surface of PV-generator: 6987.4 m²
- Number of inverters: 46
- Max. DC power (cos φ=1): 800.86 kW
- max. AC-Active power (cos φ=1): 782.00 kW
- Inverter effectiveness: 97.5 %

- Nominal power ratio: 81 %
- Yearly en. yield (approx.) *: 1817 MWh
- Energy usability factor: 98.1 %
- Performance Ratio (approx.) *: 81 %
- Spec. energy yield (approx.) *: 1828 kWh/kWp
- Cable losses (% in PV-Energy): Not considered

4.4.4.5 CO 2 analysis

Emission Analysis

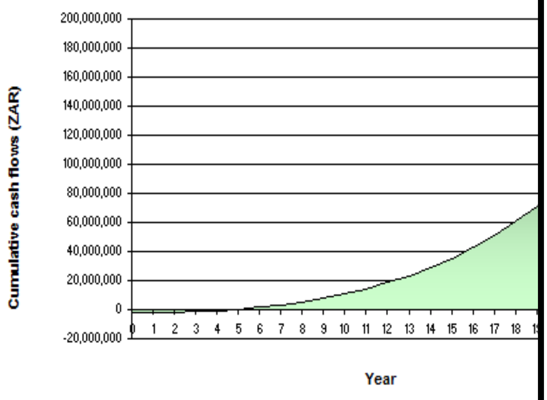
Base case electricity system (Baseline)		GHG emission factor (excl. T&D)	T&D losses	GHG emission factor	
Country - region	Fuel type	tCO2/MWh	%	tCO2/MWh	
Lesotho	All types	1.240		1.240	
Electricity exported to grid	MWh	39,891	T&D losses	5.0%	
GHG emission					
Base case	tCO2	49,464.7			
Proposed case	tCO2	2,473.2			
Gross annual GHG emission reduction	tCO2	46,991.5			
GHG credits transaction fee	%	15.0%			
Net annual GHG emission reduction	tCO2	39,942.8	is equivalent to	3,674	Hectares of forest absorbing carbon
GHG reduction income					
GHG reduction credit rate	ZAR/tCO2	110.00			
GHG reduction credit duration	yr	25			
GHG reduction credit escalation rate	%	6.0%			

4.4.4.6 *Financial Analysis*

Financial Analysis

Financial parameters			
Inflation rate	%	12.0%	
Project life	yr	25	
Debt ratio	%	90%	
Debt interest rate	%	6.00%	
Debt term	yr	25	
Initial costs			
Power system	ZAR	24,000,000	100.0%
Other	ZAR		0.0%
Total initial costs	ZAR	24,000,000	100.0%
Incentives and grants	ZAR		0.0%
Annual costs and debt payments			
O&M (savings) costs	ZAR		
Fuel cost - proposed case	ZAR	0	
Debt payments - 25 yrs	ZAR	1,689,697	
	ZAR		
Total annual costs	ZAR	1,689,697	
Annual savings and income			
Fuel cost - base case	ZAR	0	
Electricity export income	ZAR	1,373,028	
GHG reduction income - 25 yrs	ZAR	232,661	
	ZAR		
Total annual savings and income	ZAR	1,605,689	
Financial viability			
Pre-tax IRR - equity	%	36.6%	
Pre-tax IRR - assets	%	12.0%	
Simple payback	yr	14.9	
Equity payback	yr	4.7	

Cumulative cash flows graph



Existing Site Access: Easily accessible

Distance from paved road: Dirt road access; 1 Km to power line access

Site requirement civils and base structure:

- Site is very rocky and requires concrete blocks to be used as bases, adding to cost;
- Enclosing the area with 2,00 meters high steel palisade fence;
- PV structure including hot dip-galvanized trapezoidal profiles for foundation, structural beams in galvanised steel, clamps, screw & nuts; and
- Anchoring & mounting structure.

4.4.5 *Mohale's Hoek*

Mohale's Hoek is ideally suited for a large solar installation as it has very high solar radiation levels. The ability to transmit this power is still under discussion however.

- Location: 30.08 36"S 27.29 31"E;
- Usable area: 75,000 m²;
- Potential 5 MW solar farm installation;

- Grid tie inverter technology reach up to 98% efficiency;
- Grid tie inverters with 3 MVA transformer; and
- 18 months to install the farm.

Month	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed
	°C	%	kWh/m²/d	kPa	m/s
January	19.2	59.5%	7.22	83.8	3.8
February	18.7	61.0%	6.54	83.9	3.6
March	17.1	59.4%	5.62	84.0	3.6
April	14.3	53.8%	4.65	84.1	3.6
May	10.5	51.6%	3.93	84.2	3.9
June	6.6	53.6%	3.45	84.3	4.2
July	6.6	50.6%	3.76	84.3	4.2
August	9.5	45.5%	4.65	84.2	4.3
September	13.2	44.3%	5.57	84.1	4.4
October	15.4	52.4%	6.32	84.0	4.2
November	17.1	53.6%	6.98	83.9	4.0
December	18.7	56.0%	7.44	83.8	3.7
Annual	13.9	53.4%	5.51	84.0	4.0

4.4.5.1 Climate data

4.4.5.2 Potential power generation: 5 MW PV Plant Grid connected

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate ZAR/MWh	Electricity exported to grid MWh
January	7.22	6.72	600.0	977.7
February	6.54	6.47	600.0	850.8
March	5.62	6.02	600.0	877.8
April	4.65	5.58	600.0	789.7
May	3.93	5.35	600.0	785.8
June	3.45	5.02	600.0	717.1
July	3.76	5.35	600.0	788.2
August	4.65	5.89	600.0	863.9
September	5.57	6.26	600.0	886.3
October	6.32	6.41	600.0	936.5
November	6.98	6.60	600.0	931.2
December	7.44	6.81	600.0	991.3
Annual	**5.51**	**6.04**	**600.00**	**10,396.4**
MWh/m²	2.01			

Approximate generation capacity (MWs or kWs): 5 MW Peak Watts output

Approximate range of annual generation: Total 10 GW hours per annum:

4.4.5.3 Technology proposed: Thin Film + grid tie inverter with 5 MVA Transformer

Figure 7: Sample panel and inverter layout

4.4.5.4 System Overview

System overview (South Africa / Bloemfontein)

String A
Bosch Solar Energy
amorph 90W
Module x String:
6 x 206
Inclination / Azimuth:
25° / 180°

Inverter
45 x Sunny Central SC 100 Outdoor (EVR)
Max. efficiency: 97.6 %
European standard efficiency: 97.0 %
Max. AC power: 100.00 kW
Max. DC power : 105.00 kW

Technical data

- Nominal power of PV-generator: 5.01 MW
- Total number of modules: 55620
- Total surface of PV-generator: 80878.5 m²
- Number of inverters: 45
- Max. DC power : 4725.00 kW
- max. AC-Active power : 4500.00 kW
- Inverter effectiveness: 94.6 %

- Nominal power ratio: 94 %
- Yearly en. yield (approx.) *: 9192 MWh
- Energy usability factor: 99.9 %
- Performance Ratio (approx.) *: 82 %
- Spec. energy yield (approx.) *: 1836 kWh/kWp
- Cable losses (% in PV-Energy): Not considered

4.4.5.5 CO 2 analysis

Emission Analysis

Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh	
Lesotho	All types	1.240		1.240	
Electricity exported to grid	MWh	39,891	T&D losses	5.0%	
GHG emission					
Base case	tCO2	49,464.7			
Proposed case	tCO2	2,473.2			
Gross annual GHG emission reduction	tCO2	46,991.5			
GHG credits transaction fee	%	15.0%			
Net annual GHG emission reduction	tCO2	39,942.8	is equivalent to	3,674	Hectares of forest absorbing carbon
GHG reduction income					
GHG reduction credit rate	ZAR/tCO2	110.00			
GHG reduction credit duration	yr	25			
GHG reduction credit escalation rate	%	6.0%			

4.4.5.6 *Financial Analysis*

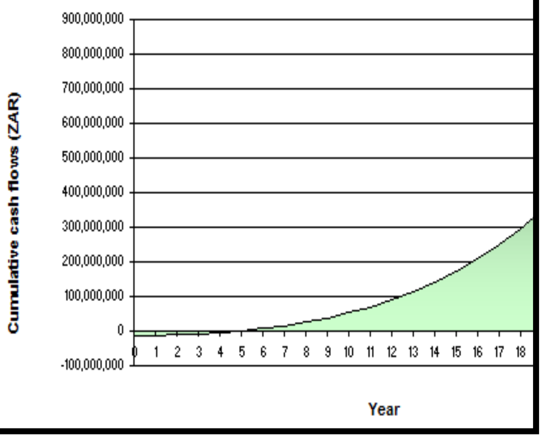
The capital cost per watt for solar is typically 24 Rand (but could vary based on location and distance from existing infrastructure).

Existing Site Access: Easily accessible

Financial Analysis

Financial parameters			
Inflation rate	%	12.0%	
Project life	yr	25	
Debt ratio	%	90%	
Debt interest rate	%	6.00%	
Debt term	yr	25	
Initial costs			
Power system	ZAR	120,000,000	100.0%
Other	ZAR		0.0%
Total initial costs	ZAR	120,000,000	100.0%
Incentives and grants	ZAR		0.0%
Annual costs and debt payments			
O&M (savings) costs	ZAR		
Fuel cost - proposed case	ZAR	0	
Debt payments - 25 yrs	ZAR	8,448,486	
	ZAR		
Total annual costs	ZAR	8,448,486	
Annual savings and income			
Fuel cost - base case	ZAR	0	
Electricity export income	ZAR	6,757,660	
GHG reduction income - 25 yrs	ZAR	1,145,091	
	ZAR		
Total annual savings and income	ZAR	7,902,751	
Financial viability			
Pre-tax IRR - equity	%	35.8%	
Pre-tax IRR - assets	%	11.9%	
Simple payback	yr	15.2	
Equity payback	yr	4.9	

Cumulative cash flows graph



Distance from paved road: Farm road existing and accessible - 4 KM

Site requirement civil and base structure:

- Site is very rocky and requires concrete blocks to be used as bases, adding to cost;
- Enclosing the area with 2,00 meters high steel palisade fence;
- PV structure including hot dip-galvanized trapezoidal profiles for foundation, structural beams in galvanised steel, clamps, screw & nuts;
- Anchoring & mounting structure; and
- Formwork & Reinforced Concrete.

5. CONCENTRATED SOLAR POWER GENERATION

5.1 Evaluation of CSP

Concentrating solar power (CSP), also referred to as concentrating solar thermal power, represents a powerful, clean, endless, and reliable source of energy with the capacity to entirely satisfy the present and future electricity needs.

Concentrating solar power plants produce no carbon dioxide (CO2), thus reducing carbon emissions from electricity generation by approximately 1000kg per megawatt-hour.

The evolution of CO2 emissions regulations, the pressure of international fossil fuel prices, and the experience, knowledge, and technological readiness amassed during several decades of CSP research has launched the technology into a new era of commercial reality.

The first thing to understand about concentrated solar power is that the primary form of energy it generates is solar thermal energy, also known as heat. This is very important because heat is able to be efficiently stored at significantly less cost than electricity.

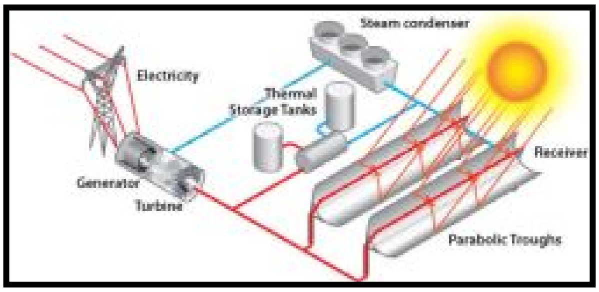
For solar technologies, energy storage is critical since the Sun isn't always available for energy production. Most often, oil or molten salt is used to store the heat generated by the *concentrated solar energy*. This is very cost effective compared to using batteries for storing solar electricity.

The second thing to understand about concentrated solar power is that the heat it generates is used to drive a turbine or engine**.** The turbine or engine then powers a generator which produces electricity. This electricity is then delivered to the grid.

5.2 Types of concentrated solar power systems

5.2.1 Trough system

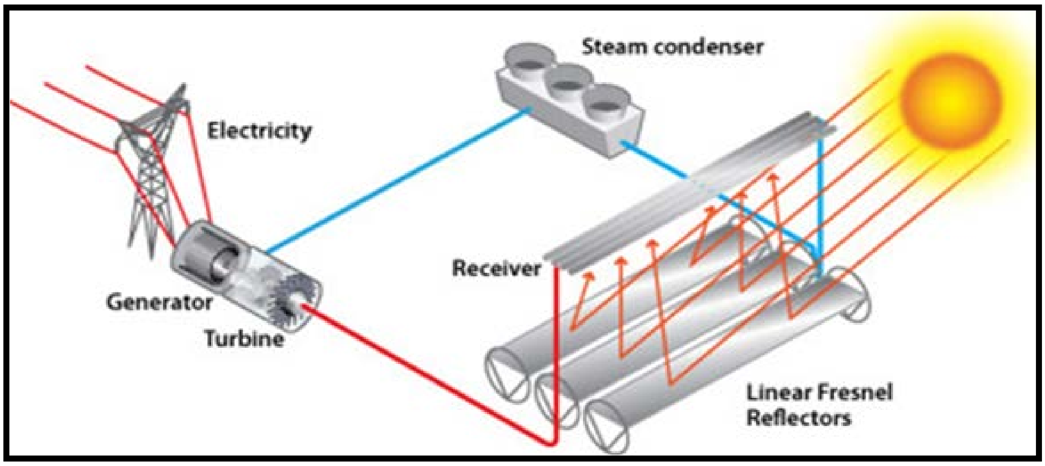
Parabolic Trough Systems use parabola-shaped reflectors to focus sunlight onto a tube that runs along the focal-line of the reflectors. A heat-transfer fluid inside the tube is heated and used to generate steam to drive a conventional turbine generator which then produces electricity



Parabolic Trough System
Image: Courtesy U.S. DOE/EERE

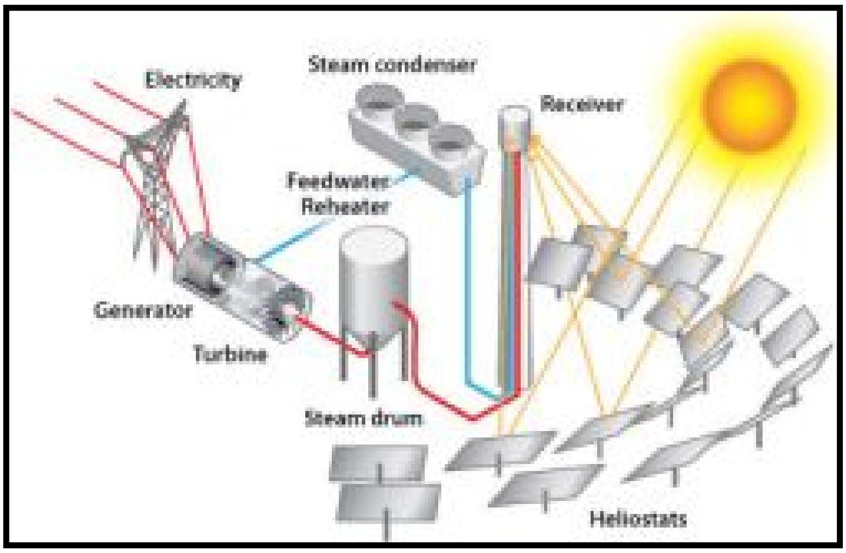
5.2.2 *Linear fresnel system*

Linear Fresnel Reflectors which reflect and concentrate the solar radiation onto a receiver tube, positioned in the focal line. A Heat Transfer Fluid flows in the absorber tube and transfers the heat to a thermo-electrical turbine generator. During its operation the plant, is automatically oriented to capture and reflect the solar radiation towards the receiver tube. A thermal storage system guarantees the continuity of production. A solar field consists of several reflectors assembled in modules. The same module can be used either for large plants with high operating temperatures (>400°C) and medium scale plants with operating temperatures in the range >200°C - 400°C.



5.2.3 *Tower System*

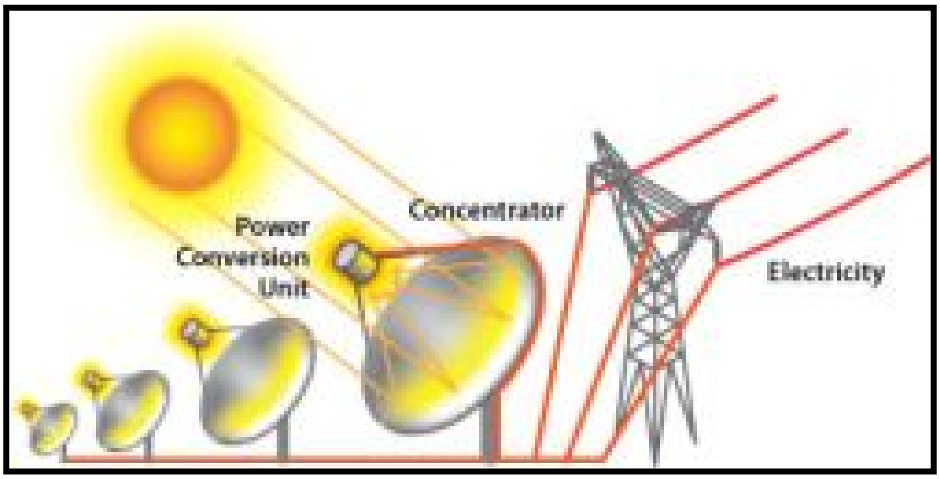
Power Tower Systems use a large field of Sun-tracking mirrors known as *heliostats* to focus sunlight onto a central receiver at the top of a tower. The receiver contains a heat-transfer fluid which is heated by the concentrated sunlight. The heat-transfer fluid is used to create steam which drives a conventional turbine generator to produce electricity.



Power Tower System
Image: Courtesy U.S. DOE/EERE

5.2.4 *Dish / Engine system*

Dish/Engine Systems use a parabolic dish to focus sunlight onto a receiver located at the focal point of the dish. The dish tracks the Sun in order to take full advantage of the available solar energy. The receiver contains a fluid or gas which is heated by he concentrated sunlight. The heated fluid is used to drive a Stirling engine to produce electricity.



Dish/Engine System
Image: Courtesy U.S. DOE/EERE

5.3 References

The United States and Spain have integrated CSP into their national electricity supply grids through large-scale commercial plants. Eight of the 13 biggest planned CSP projects in the world will be located in California and Arizona

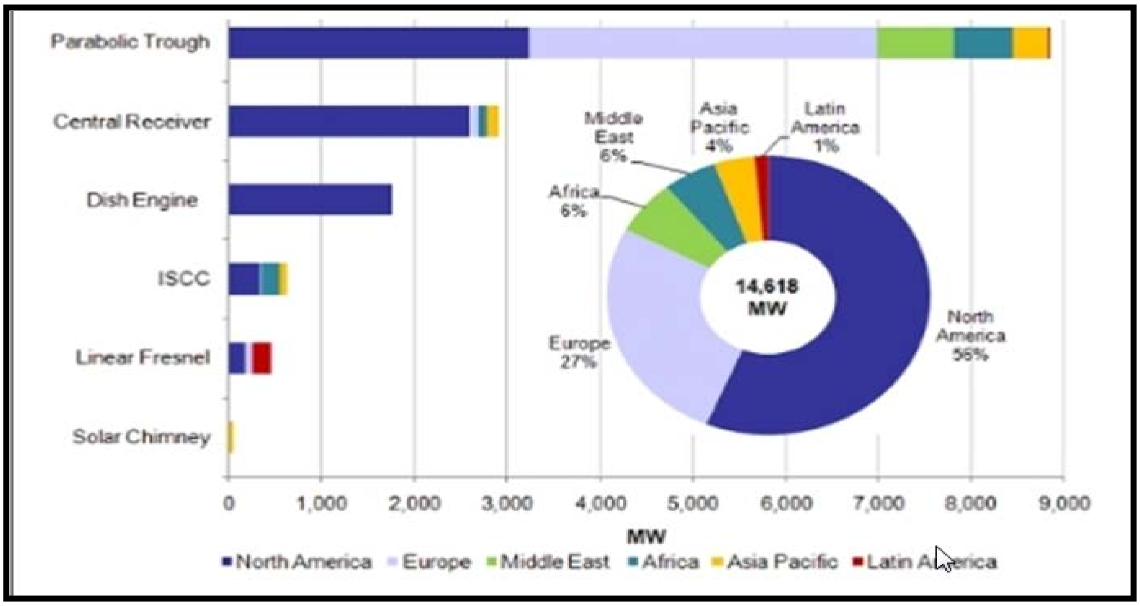
Spain and USA are the 2 leading countries in Solar Thermal Technology and Installations.

These 2 countries have installed 90% of the World's CSP capacity and are home to leading companies in this technology. While USA boasts of pure play companies like Bright source Energy, eSolar etc., Spain's CSP Leadership is bolstered by the likes of Energy Conglomerates like Abengoa and Acciona. Solar Thermal Technology has been getting traction recently with California approving a number of Solar Thermal plants.

These utility scale plants will be built over the next 4-5 years as CSP projects have a long gestation period. Spain on the other hand has forcefully delayed the commissioning of CSP projects as it faces a massive Fiscal Deficit problem.

To reduce the outgo of Renewable Subsidies, the government has arrived at an agreement with the Solar Thermal Industry to go slow in commission new plants. Bengal has been affected by this agreement though it is a much less drastic cut on Renewable than was expected earlier.

Spanish CSP Leader Abengoa thinks Solar Thermal Technology won't reach Grid Parity till 2020.



5.4 Financial analysis for CSP site outside Maseru 10 MW

Many companies are advertising mini-CSP or "low-cost" CSP technologies that come in at an extremely affordable cost per installed watt. Let us not forget that the size of a mini-CSP plant of 5-10 MW is still likely to require about R100m upfront capital. For this to be raised at a reasonable interest rate they will need a period of testing, and for this reason we believe these technologies are likely to be built in South Africa initially as government or other grant-funded research projects.

Proposed case power system

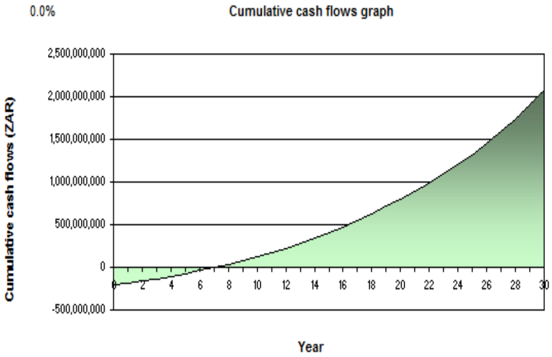
Technology		Solar thermal power
Solar thermal power		
Power capacity	kW	10,000
Manufacturer		Solel
Model		UVAC 2008
Capacity factor	%	32.0%
Electricity exported to grid	MWh	28,032
Electricity export rate	ZAR/MWh	800.00

Emission Analysis

Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh	
South Africa	All types	1.000	5.0%	1.053	
Electricity exported to grid	MWh	28,032	T&D losses	2.0%	
GHG emission					
Base case	tCO2	29,507.4			
Proposed case	tCO2	590.1			
Gross annual GHG emission reduction	tCO2	28,917.2			
GHG credits transaction fee	%	10.0%			
Net annual GHG emission reduction	tCO2	26,025.5	is equivalent to	2,394	Hectares of forest absorbing carbon
GHG reduction income					
GHG reduction credit rate	ZAR/tCO2	190.00			
GHG reduction credit duration	yr	20			
GHG reduction credit escalation rate	%	4.0%			

Financial Analysis

Financial parameters			
Inflation rate	%	8.0%	
Project life	yr	30	
Debt ratio	%	0%	
Initial costs			
Power system	ZAR	210,000,000	100.0%
Other	ZAR		0.0%
Total initial costs	ZAR	210,000,000	100.0%
Incentives and grants	ZAR		0.0%
Annual costs and debt payments			
O&M (savings) costs	ZAR	5,000,000	
Fuel cost - proposed case	ZAR	0	
	ZAR		
Total annual costs	ZAR	5,000,000	
Annual savings and income			
Fuel cost - base case	ZAR	0	
Electricity export income	ZAR	22,425,600	
GHG reduction income - 20 yrs	ZAR	4,944,845	
	ZAR		
Total annual savings and income	ZAR	27,370,445	
Financial viability			
Pre-tax IRR - assets	%	17.9%	
Simple payback	yr	9.4	
Equity payback	yr	7.0	



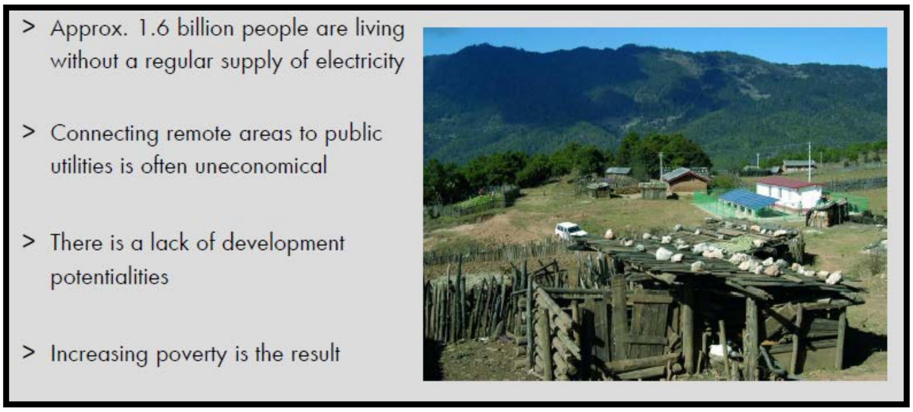
6. RURAL ELECTRIFICATION

On the rural level electrification will have a profound impact; the simply basic lighting could make big difference in the population life.

With the installation of small of grid solutions, it is possible supply enough AC power for a small fridge and some TV and other basic requirements.

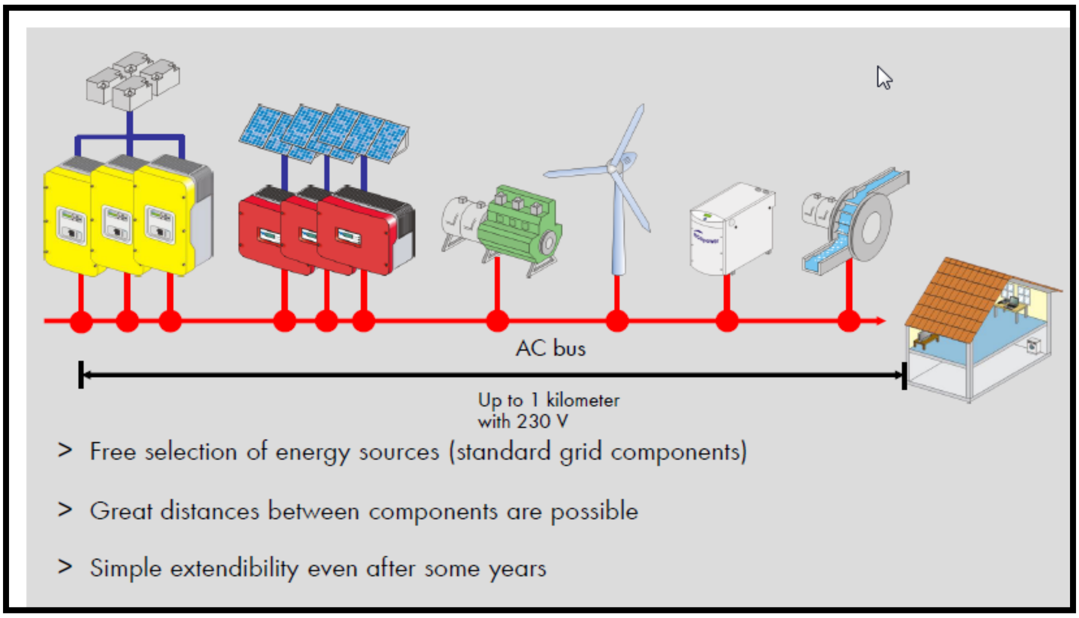
The next few pages will show some of the examples of hybrid power solutions; the power is distributed in an off grid fashion, but uses a hub and spoke topology to distribute the power between small villages; this solution for a small village can start with 5KW and expand to 300KW. Could be installed small wind, PV and hydro single or combined.

6.1 OFF grid communities sharing and generating power together



6.2 Hybrid systems

This system can use a self regulating AC bus to share power between users and producers, If the house is build on the hill it is possible share his wind power with the user in the valley with the mini hydro turbine.



6.2.1 Advantages of AC coupling: planning:

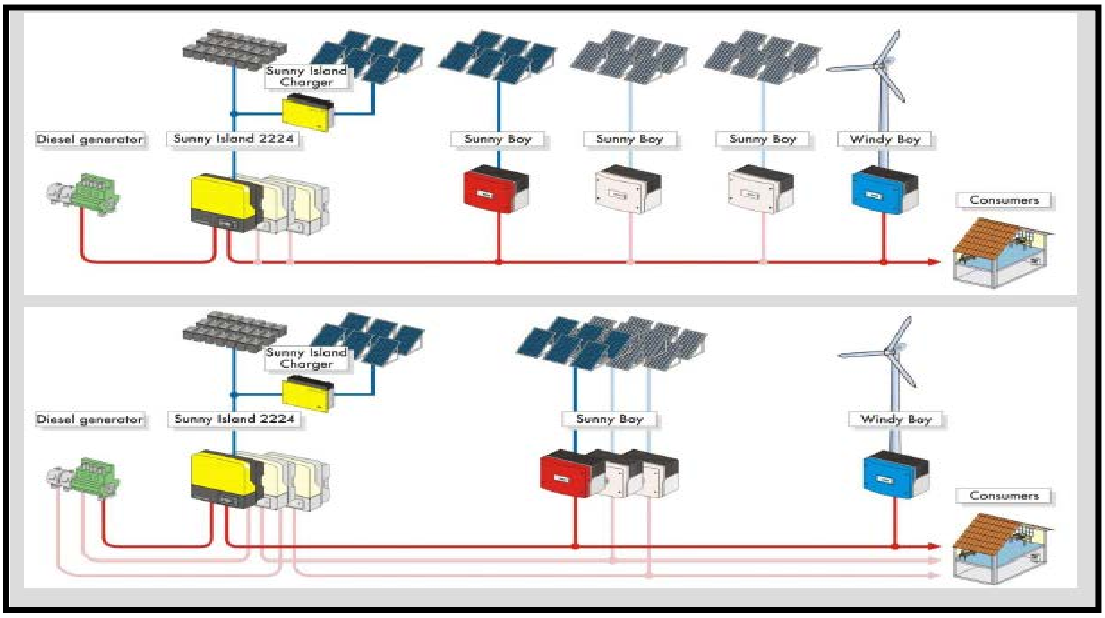
- Simple design;
- Manageable;
- Modular;
- Special knowledge is not required;
- Standard energy sources;
- Standard installation technologies can be used;

- Little efforts;
- Low planning costs; and
- Little planning time.

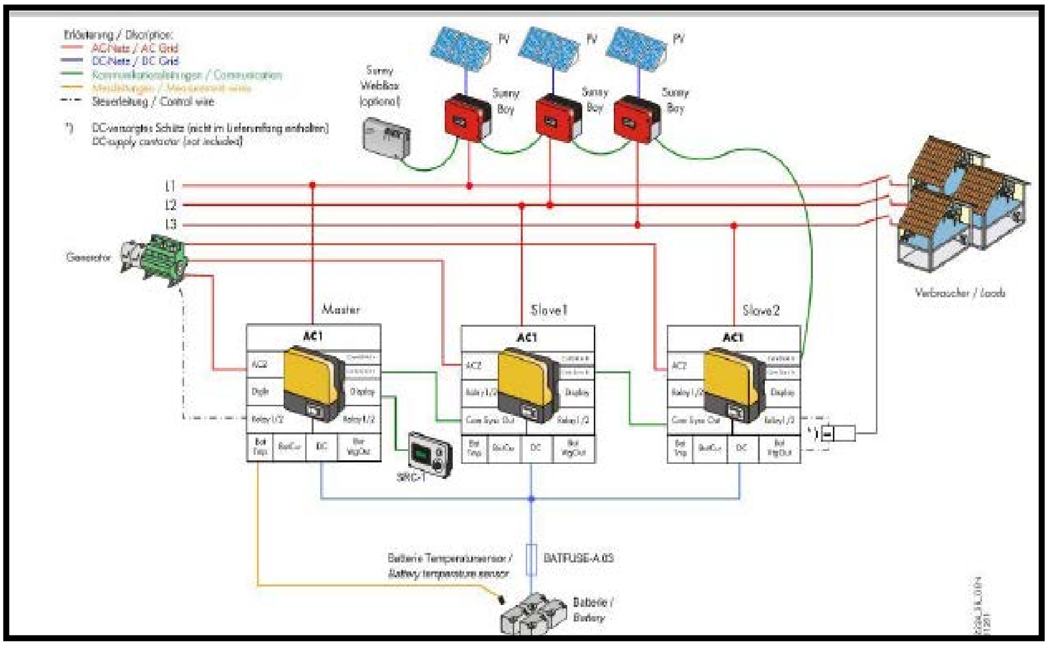
6.2.2 *Adding additional inverters*

- without changing other components;
- without reconfiguring the lines;
- independent of distances;
- Extension of phase number;
- from 1-phase to 3-phase;
- from 1-phase to split phase;
- Increase of source power without additional costs; and
- Extension of loads without additional costs.

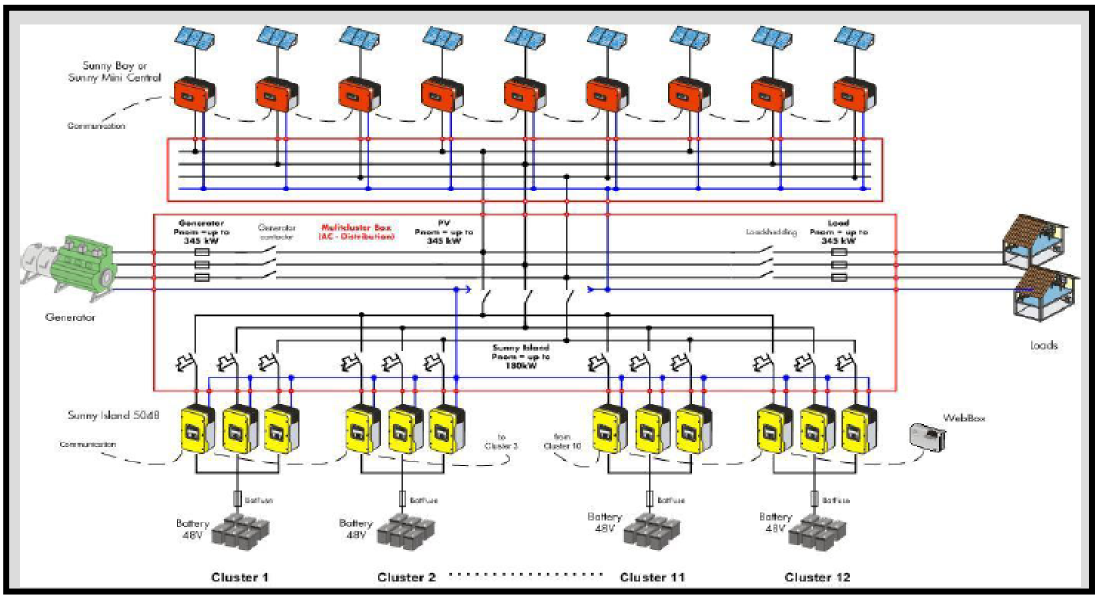
6.2.3 *Single phase solutions can easily be extended to 3 phase systems*



6.2.4 Then upgrades to 3 phase system



6.2.5 Additional 3 phase clusters to supply 500KVA Peak.



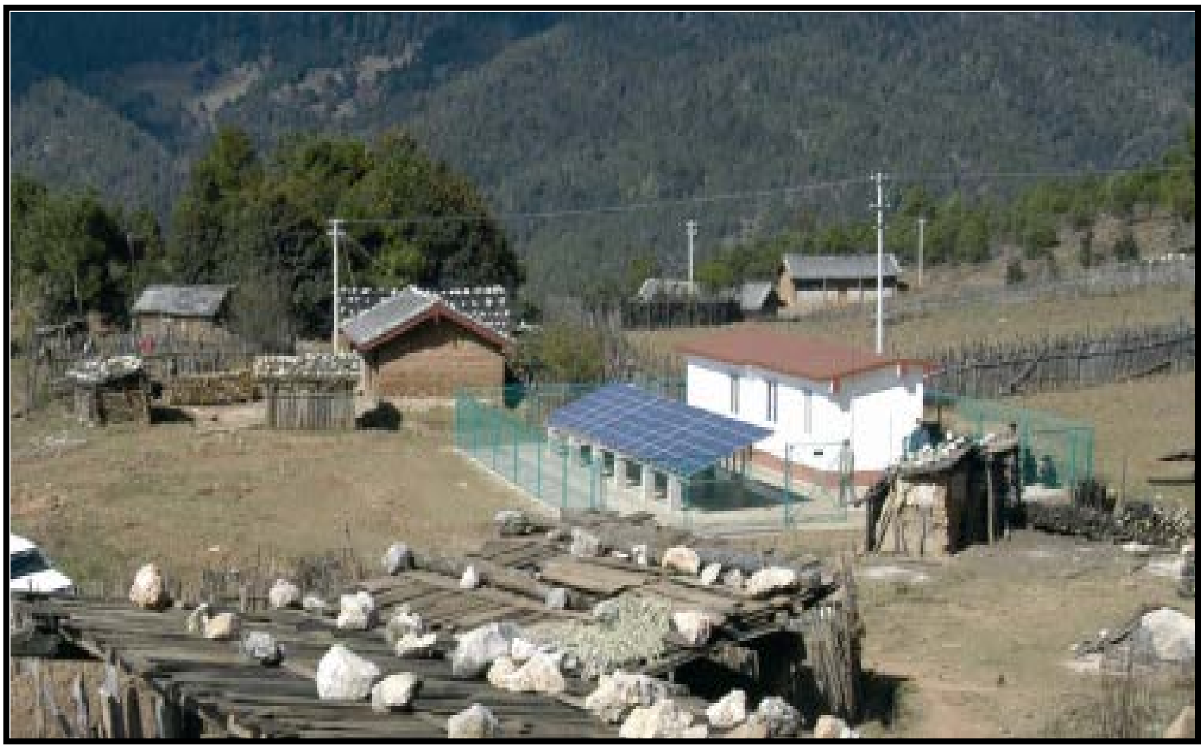


Figure 8: Village starts on a single phase system

Figure 9: Tsoelike off grid system sample

6.3 Comparison between Diesel Generation and Solar power generation

The proposal is based on providing a hybrid power solution for a small village using solar wind and diesel generator.

The solution is compared to using a diesel generator to run the community.

Power project	Unit		
Base case power system			
Grid type		Off-grid	
Technology			
Fuel type		Diesel (#2 oil) - L	
Fuel rate	ZAR/L	10.000	
Capacity	kW	80	
Heat rate	kJ/kWh	13,000	
Annual O&M cost	ZAR	50,000	
Electricity rate - base case	ZAR/kWh	3.507	
Total electricity cost		ZAR	1,467,830
Base case load characteristics			
Month		**Power gross average load kW**	
January		40	
February		45	
March		50	
April		55	
May		60	
June		60	
July		50	
August		45	
September		40	
October		40	
November		40	
December		40	
System peak electricity load over max monthly average		50.0%	
Peak load - annual		90	
Electricity	MWh	419	

RETScreen Energy Model - Power project

Proposed case power system | **Increme**

Base load power system

Technology		Photovoltaic
Analysis type		○ Method 1 / ◉ Method 2

Resource assessment

Solar tracking mode		Fixed
Slope	°	27.0
Azimuth	°	180.0

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate ZAR/MWh	Electricity exported to grid MWh
January	6.75	6.23		0.000
February	6.19	6.08		0.000
March	5.39	5.75		0.000
April	4.53	5.45		0.000
May	3.87	5.33		0.000
June	3.41	5.04		0.000
July	3.65	5.24		0.000
August	4.50	5.71		0.000
September	5.39	6.05		0.000
October	5.90	5.94		0.000
November	6.60	6.18		0.000
December	6.91	6.27		0.000
Annual	**5.25**	**5.77**	**0.00**	**0.000**

Annual solar radiation - horizontal	MWh/m²	1.92
Annual solar radiation - tilted	MWh/m²	2.11

Photovoltaic #1

Photovoltaic #1

Type		mono-Si	
Power capacity	kW	35.00	ZAR 1,000,000
Manufacturer		Q-Cells	
Model		a-Si - SN2-125.0W	20000 unit(s)
Efficiency	%	7.0%	
Nominal operating cell temperature	°C	45	
Temperature coefficient	% / °C	0.40%	
Solar collector area	m²	498	
Control method		Maximum power point tracker	
Miscellaneous losses	%	1.0%	

Inverter

Efficiency	%	97.5%
Capacity	kW	80.0
Miscellaneous losses	%	1.0%

Summary

Capacity factor	%	21.9%
Electricity delivered to load	MWh	0.000
Electricity exported to grid	MWh	0.000

Intermediate load power system

Technology		Wind turbine			

Wind turbine #2

Power capacity	kW	20	22.2%	ZAR 400,000	*See product database*
Manufacturer		ReDriven			
Model		20 KW	1 unit(s)		
Capacity factor	%	32.0%			
Electricity delivered to load	MWh	56	13.4%		
Electricity exported to grid	MWh	0			

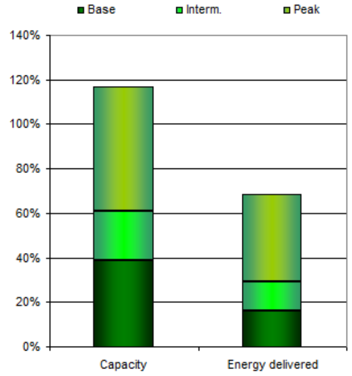
Electricity rate - base case	ZAR/MWh	3,506.73
Fuel rate - proposed case power system	ZAR/MWh	0.00
Electricity rate - proposed case	ZAR/MWh	

Operating strategy	Electricity delivered to load MWh	Electricity exported to grid MWh	Remaining electricity required MWh	Power system fuel MWh	Operating profit (loss) ZAR	Efficiency %
Full power capacity output	56	0	295	0	1,232,242	-
Power load following	**56**	**0**	**295**	**0**	**1,232,242**	-

Select base load power system	Power system #1	Photovoltaic #1
Select operating strategy	Power load following	

Proposed case system characteristics	Unit	Estimate	%	Incremental initial costs
Power				
Base load power system				
Technology		Photovoltaic		
Operating strategy		Full power capacity output		
Capacity	kW	35	38.9%	
Electricity delivered to load	MWh	67	16.1%	
Electricity exported to grid	MWh	0		
Intermediate load power system				
Technology		Wind turbine		
Operating strategy		Power load following		
Capacity	kW	20	22.2%	
Electricity delivered to load	MWh	56	13.4%	
Electricity exported to grid	MWh	0		
Peak load power system				
Technology		Reciprocating engine		
Fuel type		Diesel (#2 oil) - L		
Fuel rate	ZAR/L	10.000		
Suggested capacity	kW	90.0		
Capacity	kW	50	55.6%	
Electricity delivered to load	MWh	164	39.2%	
Manufacturer			See PDB	
Model				
Heat rate	kJ/kWh	13,000		
Back-up power system (optional)		Peak load not met		
Technology				
Capacity	kW	0		

System design graph



Proposed case system summary	Fuel type	Fuel consumption - unit	Fuel consumption	Capacity (kW)	Energy delivered (MWh)
Power					
Base load	Solar			35	67
Intermediate load	Wind			20	56
Peak load	Diesel (#2 oil)	L	55,576	50	164
			Total	105	287

Financial Analysis

Financial parameters			
Inflation rate	%	8.0%	
Project life	yr	25	
Debt ratio	%	0%	
Initial costs			
Power system	ZAR	1,400,000	80.0%
Other	ZAR	350,000	20.0%
Total initial costs	ZAR	1,750,000	100.0%
Incentives and grants	ZAR		0.0%
Annual costs and debt payments			
O&M (savings) costs	ZAR		
Fuel cost - proposed case	ZAR	555,757	
	ZAR		
Total annual costs	ZAR	555,757	
Annual savings and income			
Fuel cost - base case	ZAR	1,467,830	
GHG reduction income - 25 yrs	ZAR	21,639	
	ZAR		
Total annual savings and income	ZAR	1,489,469	
Financial viability			
Pre-tax IRR - assets	%	65.6%	
Simple payback	yr	1.9	
Equity payback	yr	1.7	

Cumulative cash flows graph