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Power and Energy Systems Technologies & Economics

Case Study Integrated Techno-Economic Model for Solar Tower Power Plants

Notes:

1. Cells with black characters include inputs
2. Cells with red characters include formulas
3. Download of Add-Ins (Macros) from website required

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Proposals for improvements of the contents are welcome and will be considered in upcoming updates!

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TE-CaseStudy-8_Integrated-Model-Techno-economics-Solar-Tower.xls
Summary

Item	Einheit Unit	100 MW		
		TES 9 h	TES 12 h	TES 15 h
Technical parameters				
Rated power output	MW	100		
Site latitude	grd	28		
Number of heliostats	-	7,158	8,978	11,074
Solar irradiation	kWh / m ² a	2,400		
Net electricity production	GWh /a	379.6	476.2	587.3
Financial parameters				
Discount rate in real terms	-	4.6%		
Project lifetime	a	25		
CAPEX, US\$ 2014, ±20	mIn US\$	784	933	1,094
Electricity generation costs in real terms				
Annual costs	mIn US\$ /a	66.9	79.4	92.8
of which capital cost		79.7%	79.9%	80.1%
Levelized electricity cost	US\$ / MWh	176.3	166.7	158.1

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Key Layout&Performance

Item		Unit	100 MW		
			TES 9 h	TES 12 h	TES 15 h
Solar Field					
Latitude		degrees	28		
Design Reference DNI		W /m ²	900		
Design Reference DNI			Solar noon, Equinox		
Solar efficiency (DNI to heat)			80.0%		
Number of Heliostats		-	7,158	8,978	11,074
Aperture area, total	121 m ²	1000 m ²	866	1,086	1,340
Tower height		m	280	315	320
Solar field heat output, design point		MJ /s	624	782	965
Receiver thermal power	72.5%	MJ /s	452	567	699
Solar heat to power block		MJ / s	238	238	238
Solar Multiple		-	1.90	2.38	2.94
Thermal Storage		MWh _t	2,143	2,857	3,571
Technical Parameters, Power Block cycle					
Rated power output, field operation		MW	100	100	100
Live steam parameters		bar / °C	155 / 550		
Electrical efficiency, gross		%	42.0%	42.0%	42.0%
Condenser cooling		-	ACC, air 32°C		

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CAPEX

Item	Item	100 MW		
		TES 9 h	TES 12 h	TES 15 h
Nominal plant size				
Rated electric power, gross	MW _e	100	100	100
Receiver capacity	MW _t	475	594	713
Aperture area of solar field	1000 m ²	866	1,086	1,340
Thermal storage	MWh	2,143	2,857	3,571
Exchange rate	€ / US\$	1.4	1.4	1.4
EPC Contract Costs	mIn US\$	700.4	833.1	976.7
Solar Field	mIn US\$	225.2	282.4	348.4
Receiver	mIn US\$	106.9	133.7	160.4
Tower	mIn US\$	14.0	14.7	15.4
Thermal Energy Storage	mIn US\$	64.3	85.7	107.1
Power Block	mIn US\$	150.0	150.0	150.0
Balance of Plant	mIn US\$	56.0	66.7	78.1
Engineering	mIn US\$	28.0	33.3	39.1
Contingencies	mIn US\$	56.0	66.7	78.1
Owners Costs	mIn US\$	84.1	100.0	117.2
CAPEX Grand Total ± 20%	mIn US\$	784.5	933.1	1,093.9
Specific CAPEX	US\$ / kW	7,845	9,331	10,939

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OPEX

Item		Unit	100 MW		
			TES 9 h	TES 12 h	TES 15 h
Technical-financial constraints					
Exchange rate		EURO / US\$	1.40	1.40	1.40
Aperture Area		1000 m ²	866	1,086	1,340
Power generation, gross		GWh / a	417.2	523.3	645.4
EPC Price					
Solar Field		mIn US\$	225.2	282.4	348.4
Thermal Storage + HTF System		mIn US\$	171.2	219.4	267.6
Power block + BoB		mIn US\$	206.0	216.7	228.1
Number of operating staff		-	45	50	55
Manpower cost (average)		1000 US\$ / a	85.0	85.0	85.0
Raw water	1.5	US\$ / m ³	1.0	1.0	1.0
Annual raw water consumption	0.14 kg/m2 a	1000* m ³ / a	119.5	149.9	184.9
Annual OPEX					
Fixed O&M Costs:					
			12,861	15,027	17,336
Solar field & storage system	1.0%	1000 US\$ / a	3,964	5,018	6,160
Power block	1.0%	1000 US\$ / a	2,060	2,167	2,281
Personnel		1000 US\$ / a	3,825	4,250	4,675
Lease	-	1000 US\$ / a	-	-	-
Insurance	0.5%	1000 US\$ / a	3,012	3,592	4,220
Consumables:					
			745	935	1,153
Water		1000 US\$ / a	120	150	185
Other consumables & residues *)	1.5	1000 US\$ / a	626	785	968
Total OPEX			13,606	15,962	18,489

*) Electricity import, nitorgen, chemicals

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EnergyBalance & LEC Calculation

Item		Unit	100 MW		
			TES 9 h	TES 12 h	TES 15 h
Annual energy balance					
Annual irradiation		kWh /m ² a	2,400	2,400	2,400
Thermal heat from receiver, DNI to heat	50.3%	GWh _t / a	1,046	1,311	1,618
Electricity production	42.0%	GWh _e / a	417	523	645
Auxiliary consumption	9.0%	GWh _e / a	38	47	58
Net electricity production		GWh _e / a	380	476	587
Capacity factor		-	47.6%	59.7%	73.7%
Equivalent operating hours		h / a	4,172	5,233	6,454
Techno-Economic Parameters					
Project lifetime	25	a	25	25	25
Discount rate, in real terms	4.6%	%	4.6%	4.6%	4.6%
CAPEX US\$ 2014, ±20%		mIn US\$	784.5	933.1	1,093.9
Levelized annual costs					
Annualized Capex		mIn US\$ /a	53.3	63.4	74.3
OPEX fixed		mIn US\$ /a	12.9	15.0	17.3
OPEX variable		1000 US\$ /a	0.7	0.9	1.2
Total		1000 US\$ /a	67	79	93
Levelized electricity cost		US\$ / MWh	176.28	166.70	158.06
electricity-to-solar heat (DNI)					
			18.3%	18.3%	18.3%