

Solar thermal augmentation of the regenerative feed-heaters in a supercritical Rankine cycle with a coal-fired boiler

WL van Rooy
12991813

Dissertation submitted in fulfilment of the requirements for the degree *Magister* in *Mechanical Engineering* at the Potchefstroom Campus of the North-West University

Supervisor: Prof CP Storm

October 2015

DEDICATION

*This work is dedicated to my late sister Anèl van Rooy (12.01.1984 – 14.06.2012). May your
light shine just as bright up in heaven as it did here on earth.*

KEY WORDS

- Coal-fired power station
 - Concentrating solar power
 - Feedwater heater
 - Fuel saver
 - Levelised cost of electricity
 - Linear Fresnel
 - Regenerative Rankine cycle
 - Solar augmentation
-

ABSTRACT

Conventional concentrating solar power (CSP) plants typically have a very high levelised cost of electricity (LCOE) compared with coal-fired power stations. To generate 1 kWh of electrical energy from a conventional linear Fresnel CSP plant without a storage application, costs the utility approximately R3,08 (Salvatore, 2014), whereas it costs R0,711 to generate the same amount of energy by means of a highly efficient supercritical coal-fired power station, taking carbon tax into consideration.

This high LCOE associated with linear Fresnel CSP technology is primarily due to the massive capital investment required per kW installed to construct such a plant along with the relatively low-capacity factors, because of the uncontrollable solar irradiation. It is expected that the LCOE of a hybrid plant in which a concentrating solar thermal (CST) station is integrated with a large-scale supercritical coal-fired power station, will be higher than that of a conventional supercritical coal-fired power station, but much less than that of a conventional CSP plant. The main aim of this study is to calculate and then compare the LCOE of a conventional supercritical coal-fired power station with that of such a station integrated with a linear Fresnel CST field.

When the thermal energy generated in the receiver of a CST plant is converted into electrical energy by using the highly efficient regenerative Rankine cycle of a large-scale coal-fired power station, the total capital cost of the solar side of the integrated system will be reduced significantly, compared with the two stations operating independently of one another for common steam turbines, electrical generators and transformers, and transmission lines will be utilised for the integrated plants.

The results obtained from the thermodynamic models indicate that if an additional heat exchanger integration option for a 90 MW (peak thermal) fuel-saver solar-augmentation scenario, where an annual average direct normal irradiation limit of $2\,141\text{ kWh/m}^2$ is considered, one can expect to produce approximately 4,6 GWh more electricity to the national grid annually than with a normal coal-fired station. This increase in net electricity output is mainly due to the compounded lowered auxiliary power consumption during high solar-irradiation conditions. It is also found that the total annual thermal energy input required from burning pulverised coal is reduced by 110,5 GWh, when approximately 176,5 GWh of solar energy is injected into the coal-fired power station's regenerative Rankine cycle for the duration of a year. Of the total thermal energy supplied by the solar field, approximately 54,6 GWh is eventually converted into electrical energy. Approximately 22 kT less coal will be required, which will result in 38,7 kT less CO₂ emissions and about 7,6 kT less ash production.

This electricity generated from the thermal energy supplied by the solar field will produce approximately R8,188m in additional revenue annually from the trade of renewable energy certificates, while the reduced coal consumption will result in an annual fuel saving of about R6,189m. By emitting less CO₂ into the atmosphere, the annual carbon tax bill will be reduced by R1,856m, and by supplying additional energy to the national grid, an additional income of approximately R3,037m will be due to the power station. The annual operating and maintenance cost increase resulting from the additional 171 000 m² solar field, will be in the region of R9,71m.

The cost of generating 1 kWh with the solar-augmented coal-fired power plant will only be 0,34 cents more expensive at R0,714/kWh than it would be to generate the same energy with a normal supercritical coal-fired power station.

If one considers that a typical conventional linear Fresnel CSP plant (without storage) has an LCOE of R3,08, the conclusion can be drawn that it is much more attractive to generate electricity from thermal power supplied by a solar field, by utilising the highly efficient large-scale components of a supercritical coal-fired power station, rather than to generate electricity from a conventional linear Fresnel CSP plant.

DECLARATION

By submitting this document I, Willem Ludolph van Rooy, declare that

- I am the sole author of this entire thesis, including all thermodynamic and financial models. All information used from sources other than mine are clearly referenced where used.
- I have not previously submitted this work or any part thereof for a degree or any other qualification at the North-West University or any other institution.



Willem Ludolph van Rooy

ACKNOWLEDGEMENTS

*“The LORD is my light and my salvation; whom
shall I fear? The LORD is the strength of my
life; of whom shall I be afraid?”*

~ Psalm 27:1 ~

Foremost, I want to thank my employer, Eskom Holdings SOC Ltd, Research Testing and Development Department, who has fully financed my studies and allocated a portion of my working time to conduct this research. I specifically want to thank Mr Stephen Koopman, Renewable Energy Technologies Manager, who supported my studies and this project from start to finish.

My sincere thanks also go to my supervisor, Professor Chris Storm, who accepted me as a student and has constantly supported me from day one of this project.

Last, but not least, I want to thank my loving wife, Carien van Rooy, for her ongoing support and motivation.

TABLE OF CONTENTS

Dedication	i
Key words	ii
Abstract	iii
Declaration	v
Acknowledgements	vi
Table of Contents	vii
List of Tables	xii
List of Figures	xiv
Nomenclature.....	xxi
Chapter 1: Introduction	1-1
1.1 Background	1-1
1.2 Problem statement	1-2
1.3 Objectives	1-2
1.4 Research methodology	1-2
1.5 Scope of work and limits.....	1-3
1.6 Paper layout.....	1-4
Chapter 2: Literature Study and existing technologies.....	2-1
2.1 Relevant thermodynamic properties and definitions.....	2-1
2.1.1 Specific heat capacity	2-1
2.1.2 Enthalpy	2-1
2.1.3 Entropy.....	2-2

2.1.4	Heat.....	2-2
2.1.5	Saturated and subcooled liquid.....	2-2
2.1.6	Saturated and superheated vapour.....	2-2
2.1.7	Critical point.....	2-3
2.2	Thermodynamic laws	2-3
2.2.1	The zeroth law of thermodynamics	2-3
2.2.2	First law of thermodynamics	2-3
2.2.3	Second law of thermodynamics	2-4
2.3	Relevant thermodynamic processes.....	2-4
2.3.1	Heat transfer.....	2-4
2.3.2	Constant volume process	2-7
2.3.3	Constant pressure process	2-8
2.3.4	Isothermic process	2-9
2.3.5	Adiabatic process	2-9
2.3.6	Isentropic process	2-10
2.3.7	Throttling process	2-10
2.4	Rankine cycle.....	2-11
2.4.1	Basic Rankine.....	2-11
2.4.2	Reheat Rankine cycle.....	2-15
2.4.3	Regenerative Rankine cycle	2-16
2.5	Conventional coal-fired power generation	2-18
2.5.1	Coal and emissions	2-20
2.5.2	Supercritical and ultra-supercritical generation	2-26

2.5.3	Relevant cycle components condensers.....	2-27
2.6	Relevant economic parameters	2-42
2.6.1	Capacity factor.....	2-42
2.6.2	Levelised cost of electricity	2-42
2.7	Concentrating solar power	2-43
2.7.1	Solar resource	2-44
2.7.2	Concentrating solar power technologies	2-53
2.7.3	Overview	2-63
2.7.4	Eskom Holdings SOC Limited.....	2-67
2.8	Solar augmentation	2-71
2.9	Renewable energy financing	2-75
2.9.1	Tradable renewable energy certificates	2-75
2.9.2	Carbon tax.....	2-76
2.9.3	Accelerated depreciation	2-78
Chapter 3: Project Approach		3-1
3.1	Base-case - Coal-fired power station	3-2
3.1.1	Assumptions.....	3-2
3.1.2	Rankine cycle description	3-7
3.1.3	Air, fuel and emissions.....	3-17
3.2	Rosherville linear Fresnel performance analysis	3-20
3.2.1	Background	3-20
3.2.2	Plant performance parameters	3-22
3.3	Solar augmentation scenario.....	3-28

3.3.1	Assumptions.....	3-28
3.3.2	Additional heat-exchanger scenario.....	3-31
3.4	Financial models	3-33
3.4.1	Assumptions.....	3-34
3.4.2	Financial study approach.....	3-36
Chapter 4: Base-Case Scenario		4-1
4.1	Thermodynamic verification procedure.....	4-1
4.2	Engineering equation-solver model.....	4-7
4.3	Base-case scenario summary	4-18
Chapter 5: Solar Augmentation Scenario.....		5-1
5.1	Engineering equation solver models	5-1
5.1.1	Mostly cloudy day scenario.....	5-2
5.1.2	Very cloudy day scenario.....	5-8
5.1.3	Slightly cloudy day scenario.....	5-17
5.1.4	Cloudless day scenario.....	5-26
5.1.5	Irradiation scenario summary.....	5-35
5.2	Full year solar augmentation scenario summary.....	5-36
Chapter 6: Results Summary.....		6-1
6.1	Annual results summary.....	6-1
Chapter 7: Conclusions		7-1
Chapter 8: Bibliography and References		8-1
Appendix		9-1
9.1	Appendix A: Rosherville linear Fresnel performance evaluation data	9-1

9.2	Appendix B: Typical day solar resource data.....	9-11
9.3	Appendix C-1: Base-case parametric table data	9-21
9.4	Appendix C-2: Mostly cloudy day parametric table data	9-29
9.5	Appendix C-3: Very cloudy day parametric table data.....	9-37
9.6	Appendix C-4: Slightly cloudy day parametric table data.....	9-45
9.7	Appendix C-5: Cloudless day parametric table data.....	9-53
9.8	Appendix D-1: Base-case LCOE calculation.....	9-61
9.9	Appendix D-2: Solar augmentation LCOE calculation	9-73
9.10	Appendix E: Engineering equation solver model.....	9-85
9.11	Appendix F: Thermodynamic array table – No Solar Scenario	9-127
9.12	Appendix G - Thermodynamic array table – Solar Augmentation (1 100 W/m ²)	9-135

LIST OF TABLES

Table 2-1: Technology comparison of three steam cycles (Zhang, 2013)	2-18
Table 2-2: Worldwide distribution of supercritical power plant (Zhang, 2013)	2-26
Table 2-3: Performance characteristics of various CSP technologies (Lovegrove and Stein, 2012).....	2-56
Table 2-4: Concentrating solar tower technology overview (IRENA, 2012)	2-64
Table 2-5: Typical renewable energy technology capacity factor and LCOE estimates (Salvatore, 2014).	2-65
Table 2-6: Eskom atmospheric emissions (Eskom, 2013a)	2-69
Table 2-7: Proposed emissions tax-free thresholds (Government, 2013)	2-78
Table 3-1: Main design parameters.	3-2
Table 3-2: Isentropic efficiencies	3-4
Table 3-3: Feedwater preheater specifications.	3-5
Table 3-4: Coal assumptions.	3-6
Table 3-5: Other efficiencies.....	3-7
Table 3-6: Rosherville plant design parameters.....	3-20
Table 3-7: Fresnel plant performance parameters.....	3-27
Table 3-8: Solar field assumptions	3-28
Table 3-9: Annual solar irradiation breakdown.....	3-31
Table 3-10: Coal-fired station financial parameters.....	3-35
Table 3-11: Solar station financial parameters.....	3-36
Table 3-12: Solar field financial parameters.....	3-36
Table 4-1: Turbine shaft power and electricity output verification results.	4-2

Table 4-2: Turbine bleed steam verification results.....	4-3
Table 4-3: Auxiliary power verification results.....	4-4
Table 4-4: Fuel and emissions verification results	4-5
Table 4-5: Base-case performance parameters.....	4-19
Table 4-6: Base-case input and output parameters.	4-19
Table 4-7: Base-case major expenses.	4-19
Table 5-1: Summary for mostly cloudy day scenario	5-7
Table 5-2: Summary for the very cloudy day scenario	5-16
Table 5-3: Summary for slightly cloudy day scenario.....	5-25
Table 5-4: Summary for cloudless day scenario.	5-34
Table 5-5: Daily solar irradiation comparison summary	5-35
Table 5-6: Boosting mode parameters.....	5-36
Table 5-7: Fuel-saver mode parameters.....	5-37
Table 5-8: Annual input and output parameters for a fuel-saver scenario	5-37
Table 5-9: Solar augmentation major expenses.....	5-38
Table 6-1: Base-case vs solar augmentation results	6-1
Table 7-1: Annual operating cost deviation.....	7-1

LIST OF FIGURES

Figure 2-1: Basic illustration of conduction	2-5
Figure 2-2: Basic illustration of convection.....	2-6
Figure 2-3: Basic illustration of radiation	2-7
Figure 2-4: Basic illustration of an isovolumetric process.....	2-8
Figure 2-5: Basic illustration of an isobaric process	2-8
Figure 2-6: Basic illustration of an isothermic process	2-9
Figure 2-7: Basic illustration of an isentropic process	2-10
Figure 2-8: Illustration of a basic Rankine cycle.....	2-11
Figure 2-9: T-s diagram of the basic Rankine cycle (Sonntag et al., 2003)	2-12
Figure 2-10: Reheat Rankine cycle.....	2-16
Figure 2-11: T - s diagram of the Reheat Rankine cycle (Sonntag et al., 2003)	2-16
Figure 2-12: Regenerative Rankine cycle	2-17
Figure 2-13: T-s diagram of the regenerative Rankine cycle (Sonntag et al., 2003).....	2-17
Figure 2-14: Air-dried coal analysis for Lethabo (left) and Matimba (right) power stations ...	2-21
Figure 2-15: Picture of a typical wet flue-gas desulphurisation plant (Everett et al., 2012c).	2-22
Figure 2-16: Pulse-jet fabric filter plant (Moretti and Jones, 2012)	2-23
Figure 2-17: Electrostatic precipitator plant (Moretti and Jones, 2012)	2-24
Figure 2-18: Emissions reduction with a clean development mechanism	2-25
Figure 2-19: Typical power plant surface condenser (Wordpress, 2014)	2-28
Figure 2-20: Illustration of a direct-acting air-cooled condenser system.....	2-29
Figure 2-21: Illustration of an indirect-acting air-cooled condenser system	2-30

Figure 2-22: Radially split, double-case diffuser multistage boiler feedwater centrifugal pump (Everett et al., 2012d).....	2-31
Figure 2-23: Stork-type deaerator.....	2-32
Figure 2-24: (a) Spray-type deaerator, (b) Spray-scrubber deaerator (Everett et al., 2012a).....	2-34
Figure 2-25: Basis illustration of closed feedwater heater scenarios.....	2-34
Figure 2-26: Two-pass boiler type (left) and tower-boiler type (right) (Zhang et al., 2013) ...	2-36
Figure 2-27: Basic illustration of an attemperator spray-water system	2-37
Figure 2-28: Illustration of (a) impulse and (b) reaction forces (Everett et al., 2012e)	2-39
Figure 2-29: Condensing steam turbine (Everett et al., 2012e).....	2-40
Figure 2-30: Non-condensing steam turbine (Everett et al., 2012e).....	2-40
Figure 2-31: Illustration of an axial-flow fan (Choudhury).....	2-41
Figure 2-32: Historical use of solar power in printing press (Gevorkian)	2-43
Figure 2-33: The motion of the earth around the sun (Kambezidis, 2012)	2-45
Figure 2-34: The apparent daily path of the sun in the sky for a certain place on the earth (Kambezidis, 2012)	2-46
Figure 2-35: Basic illustration of earth's radiation components (Directorate, 2010).....	2-47
Figure 2-36: Basic illustration of the scattering process.....	2-48
Figure 2-37: Basic illustration of the insolation process	2-49
Figure 2-38: Basic illustration of the reflection process.....	2-50
Figure 2-39: Typical pyrliometer with tracking system.....	2-51
Figure 2-40: Typical pyranometer.....	2-52
Figure 2-41: Complete solar radiation measurement station.....	2-52
Figure 2-42: Schematic of the sun and a concentrator on earth (Kalogirou, 2012a).....	2-53

Figure 2-43: Basic illustration of a solar thermal energy conversion system (Kalogirou)	2-54
Figure 2-44: Loss path for a 100 MW central receiver plant (1993) (Gordon and Society, 2001).....	2-55
Figure 2-45: Photograph of BrightSource's Ivanpah STE plant in the Mojave Desert (BrightSource, 2013).	2-56
Figure 2-46: (Left) - Receiver detail (Right) – Illustration of the reflector, receiver and supporting pedestals of a PTC module (Kalogirou, 2012b).....	2-57
Figure 2-47: Graphical illustration of a parabolic trough STE plant (Gevorkian)	2-58
Figure 2-48: A photograph of the SEGS plant in southern California (Alnaser et al., 2006) .	2-59
Figure 2-49: (a) Fresnel lens collector, (b) Linear Fresnel collector (Kalogirou)	2-60
Figure 2-50: Illustration of an element of a linear Fresnel CSP system (Kalogirou, Kalogirou, 2009b).....	2-60
Figure 2-51: Eskom's linear Fresnel pilot and demonstration plant	2-61
Figure 2-52: Schematic of a central receiver system (Kalogirou, 2009b)	2-62
Figure 2-53: Schematic of a central receiver system (Solar Two), with a molten-salt storage application (Kalogirou, 2009a)	2-63
Figure 2-54: World map of direct normal irradiation(SolarGIS, 2013b).....	2-66
Figure 2-55: Direct normal irradiation map of South Africa (SolarGIS, 2013a)	2-67
Figure 2-56: Eskom's generating capacity breakdown (Eskom, 2013a)	2-68
Figure 2-57: Eskom power stations map (Eskom, 2013b).....	2-69
Figure 2-58: Medupi power station construction site (Eskom, 2014b).	2-70
Figure 2-59: Solar augmentation modes: left - no augmentation, middle - fuel-saver mode, right - boosting mode.....	2-71
Figure 2-60: Steam injection into the cold-reheat line	2-73
Figure 2-61: Separate heat exchanger in bypass line	2-74

Figure 2-62: Illustration of TREC system (Volschenk, 2013).....	2-76
Figure 2-63: Breakdown of South Africa's greenhouse gases by sectors (Government, 2013).....	2-77
Figure 3-1: Condenser pressure curve	3-3
Figure 3-2: Main steam pressure curve.	3-4
Figure 3-3: Generator gross capacity vs time of day.....	3-5
Figure 3-4: Assumed coal characteristics.	3-7
Figure 3-5: Assumed coal composition.....	3-7
Figure 3-6: Illustration of turbine bleed steam.....	3-8
Figure 3-7: Illustration of the condensing system.....	3-10
Figure 3-8: First low-pressure heater	3-10
Figure 3-9: Second low-pressure heater.....	3-11
Figure 3-10: Third low pressure heater	3-12
Figure 3-11: Deaerator storage tank.....	3-12
Figure 3-12: Boiler feed pumps	3-13
Figure 3-13: High pressure heater configuration.....	3-13
Figure 3-14: First high-pressure heaters (HPHs 5A and 5B).....	3-14
Figure 3-15: Basic illustration of feedwater/steam flow through a two-pass boiler's components	3-15
Figure 3-16: Illustration of the regenerative Rankine cycle considered for the base case	3-16
Figure 3-17: Illustration of furnace input air and fuel	3-17
Figure 3-18: Illustration of flue gas leaving the furnace.....	3-19
Figure 3-19: Schematic illustration of Rosherville CST cycle (Van Rooy, 2014).....	3-22
Figure 3-20: Solar to thermal losses.....	3-25

Figure 3-21: Direct normal irradiation vs time of day.....	3-25
Figure 3-22: Temperature vs time of day	3-26
Figure 3-23: Pressure vs time of day	3-26
Figure 3-24: Thermal power vs time of day.....	3-27
Figure 3-25: Cloudless day (17.01.2014).....	3-29
Figure 3-26: Slightly cloudy day (16.01.2014).....	3-29
Figure 3-27: Very cloudy day (29.01.2014).....	3-30
Figure 3-28: Mostly cloudy day (06.01.2014).....	3-30
Figure 3-29: Illustration of additional heat-exchanger scenario	3-32
Figure 3-30: Basic illustration of the solar cycle	3-33
Figure 4-1: Screenshot of base-case ThermoFLEX verification model	4-1
Figure 4-2: Shaft and electricity power output verification results	4-2
Figure 4-3: Turbine bleed steam verification results	4-4
Figure 4-4: Auxiliary power consumption verification results.....	4-5
Figure 4-5: Fuel and emissions verification results	4-6
Figure 4-6: Screenshot of base-case EES model diagram window.....	4-7
Figure 4-7: T-s diagram of base-case EES model	4-8
Figure 4-8: Time vs turbine shaft power	4-9
Figure 4-9: Time vs bleed-steam mass flow	4-10
Figure 4-10: Time vs electrical power output and auxiliary consumption	4-11
Figure 4-11: Time vs coal consumption rate	4-12
Figure 4-12: Time vs CO ₂ and ash emission production rate	4-13
Figure 4-13: Time vs attemperation spray water.....	4-14

Figure 4-14: EES Screenshot of base-case turbine train and generator	4-14
Figure 4-15: Base-case cooling system	4-15
Figure 4-16: Base-case low-pressure heater system	4-16
Figure 4-17: Illustration of the base-case DST and boiler feed pump systems.....	4-17
Figure 4-18: Illustration of the base-case HPH system	4-18
Figure 5-1: Screenshot of solar augmentation EES model	5-1
Figure 5-2: Time vs DNI for mostly cloudy day scenario	5-2
Figure 5-3: Time vs high-pressure heater bypass mass flow for mostly cloudy day scenario	5-3
Figure 5-4: Time vs turbine bleed steam for mostly cloudy day scenario	5-4
Figure 5-5: Time vs attemperation spray water for mostly cloudy day scenario	5-5
Figure 5-6: Time vs turbine shaft power for mostly cloudy day scenario	5-6
Figure 5-7: Time vs power output for mostly cloudy day scenario.....	5-6
Figure 5-8: Time vs DNI for very cloudy day scenario.....	5-8
Figure 5-9: Time vs high-pressure heater bypass mass flow for very cloudy day scenario	5-9
Figure 5-10: Time vs turbine bleed-steam mass flow for very cloudy day scenario.....	5-10
Figure 5-11: Time vs attemperation spray-water mass flow for very cloudy day scenario	5-11
Figure 5-12: Time vs turbine shaft power for very cloudy day scenario.....	5-12
Figure 5-13: Time vs power output for very cloudy day scenario	5-13
Figure 5-14: Time vs auxiliary power consumption for very cloudy day scenario	5-14
Figure 5-15: Time vs coal consumption rate for very cloudy day scenario	5-15
Figure 5-16: Time vs auxiliary power consumption for very cloudy day scenario	5-16
Figure 5-17: Time vs DNI for slightly cloudy day scenario	5-17

Figure 5-18: Time vs high-pressure heater bypass mass flow for slightly cloudy day scenario	5-18
Figure 5-19: Time vs turbine bleed-steam mass flow for slightly cloudy day scenario.....	5-19
Figure 5-20: Time vs attemperation spray-water mass flow for slightly cloudy day scenario	5-20
Figure 5-21: Time vs turbine shaft power output for slightly cloudy day scenario.....	5-21
Figure 5-22: Time vs power output for slightly cloudy day scenario	5-22
Figure 5-23: Time vs auxiliary power consumption for slightly cloudy day scenario	5-23
Figure 5-24: Time vs coal consumption rate for slightly cloudy day scenario	5-24
Figure 5-25: Time vs major emissions for slightly cloudy day scenario	5-25
Figure 5-26: Time vs DNI for cloudless day scenario.....	5-26
Figure 5-27: Time vs high-pressure heater bypass mass flow for cloudless day scenario ...	5-27
Figure 5-28: Time vs turbine bleed steam mass flow for cloudless day scenario	5-28
Figure 5-29: Time vs attemperation spray-water mass flow for cloudless day scenario	5-29
Figure 5-30: Time vs turbine shaft power output for cloudless day scenario	5-30
Figure 5-31: Time vs power output for cloudless day scenario	5-31
Figure 5-32: Time vs auxiliary power consumption for cloudless day scenario	5-32
Figure 5-33: Time vs coal consumption rate for cloudless day scenario	5-33
Figure 5-34: Time vs major emissions for cloudless day scenario	5-34
Figure 5-35: Daily solar irradiation scenarios vs heat input from coal, and the solar field compared with the net electricity output.	5-35
Figure 6-1: Annual heat input summary	6-2

NOMENCLATURE

Symbols

$\dot{m}$	- Mass flow [kg/s]
Δ	- Delta
C	- Concentration ratio [%]
h	- Convection heat-transfer coefficient [W/m ² K]
k	- Thermal conductivity coefficient [W/mK]
q	- Heat rate [W]
q''	- Heat flux [W/m ²]
R	- South African rand
δ	- Solar declination angle
η	- Efficiency [%]
Θ	- Zenith angle
θ_s	- Sun acceptance half-angle
Ψ	- Azimuthal angle

Subscripts

a	- Aperture
ave	- Average
conv	- Conversion
e	- Electrical
i	- Isentropic
m	- Mechanical

m	- Million
max	- Maximum
min	- Minimum
p	- Pressure
r	- Receiver
sw	- Spray water
t	- Thermal
th	- Thermal
tot	- Total
v	- Volume
wc	- Water column

Abbreviations

A	- Area [m ²]
ACC	- Air-cooled condenser
AU	- Astronomical unit
CaSO ₃	- Calcium sulphite
CaSO ₄	- Calcium sulphate
CDM	- Clean development mechanism
CDS	- Circulating dry scrubber
CEP	- Condensate extraction pump
CF	- Capacity factor
CH ₄	- Methane

CO ₂	- Carbon dioxide
CR	- Concentration ratio
CRC	- Central receiver collector
CSP	- Concentrating solar power
CST	- Concentrating solar thermal
CV	- Calorific value
C _x	- Carbonates
Demin	- Demineralised
DHI	- Diffuse horizontal irradiation
DNI	- Direct normal irradiation
DSI	- Dry sorbent injection
DST	- Deaerator storage tank
EFP	- Electric feedwater pump
ESP	- Electrostatic precipitator plant
FD	- Forced draft
FFP	- Fabric filter plant
FGD	- Flue-gas desulphurisation
FGD	- Flue-gas desulphurisation
FLC	- Fresnel lens collector
GCV	- Greater calorific value
GHG	- Greenhouse gases
GHI	- Global horizontal irradiation
GIZ	- Deutsche Gesellschaft für Internationale Zusammenarbeit

GST	- Gland steam condenser
GW	- Gigawatt
GWh	- Gigawatt hour
h	- Enthalpy [kJ/kg]
H ₂	- Hydrogen
H ₂ O	- Water
HFC	- Heliostat field collector
Hg	- Mercury
HHV	- Higher heating value
HPH	- High-pressure heater
HPT	- High-pressure turbine
ID	- Induced draft
IPT	- Intermediate-pressure turbine
IRR	- Internal rate of return
IRR	- Internal rate of return
kW	- Kilowatt
kWh	- Kilowatt hour
LCOE	- Levelised cost of electricity
LFC	- Linear Fresnel collector
LHV	- Lower heating value
LPH	- Low-pressure heater
LPT	- Low-pressure turbine
MW	- Megawatt

MWh	- Megawatt hour
N	- Nitrogen
NO	- Nitric oxide
NO ₂	- Nitrogen dioxide
NO _x	- Nitrogen oxides
NPV	- Net present value
O ₂	- Oxygen
OCGT	- Open-cycle gas turbine
P	- Pressure [Pa], [Bar]
P&D	- Pilot and demonstration
PA	- Primary air
PC	- Pulverised coal
PDC	- Parabolic dish collector
PF	- Pulverised fuel
PTC	- Parabolic trough collector
PV	- Photovoltaic
PV	- Present value
REC	- Renewable Energy Certificate
RSA	- Republic of South Africa
s	- Entropy [kJ/kgK]
S	- Sulphur
SAPG	- Solar-assisted power generation
SAM	- System Advisor Model

SC	- Supercritical
SDA	- Spray dryer absorber
SEGS	- Solar electric generating systems
SO	- Sulphur monoxide
SO ₂	- Sulphur dioxide
SO _x	- Sulphur oxides
STE	- Solar thermal electricity
T	- Temperature [K], [°C]
T	- Ton
TREC	- Tradable Renewable Energy Certificate
T-s	- Temperature vs entropy
US	- United States
USC	- Ultra-supercritical
W	- Watt
Wh	- Watt hour

CHAPTER 1: INTRODUCTION

1.1 Background

For the last decade, Eskom's electricity network has been under immense pressure, which has eventually resulted in load shedding and a number of expensive load managing/reduction projects. This electricity shortfall is attributable mainly to an inadequate increase in generation capacity and the fast-growing electricity demand from its consumers. This also has a major impact on the maintenance schedules of the existing power stations, which may snowball into an even greater electricity supply shortfall.

As the literature clearly indicates, renewable energy sources have a relatively poor availability compared with conventional coal-, gas- and nuclear-based power generation methods. But, electricity generation via renewable energy sources has two very important advantages that contribute significantly to the financial feasibility of such projects:

Firstly, the fuel or energy resource is free of charge for renewable energy methods (with the exception of some hydro schemes). This means that a power station utilising such resources will not have a fuel cost incorporated in its levelised cost of electricity calculation.

Secondly, there are no harmful emissions to the environment, which means that no carbon tax and environmental penalty costs are considered. At this stage (May 2014), no green credits or tradable renewable energy certificates (TRECs) have a major impact on the South African renewable energy industry. Even though TRECs are not yet in full effect in South Africa, the potential incorporation thereof is considered in this study.

Renewable energy does, however, also have a huge downside: it has a very high levelised cost of electricity generation. This is mainly because of low capacity factors and high capital and maintenance costs associated with these plants.

Fuel-based (coal, gas, nuclear) electricity generation methods have high capacity factors, but also have a high fuel cost and discharge harmful emissions (SO_x , NO_x , CO_2 , nuclear waste) to the environment. On the other hand, renewable energy power generation methods have low capacity factors, zero fuel costs and zero harmful emissions.

The augmentation concept, specifically solar augmentation, marries the abovementioned methods of power generation. In this hybrid concept, an existing coal-fired power station is integrated with a solar thermal plant, specifically concentrating solar thermal (CST). By doing so, the thermal heat produced by the CST field is fed into the Rankine cycle of the existing coal-fired power station. By doing so, one can either keep the electricity production rate constant and

save fuel, or one can boost/increase the electricity output capacity of the coal-fired station. Except for the fact that the capital cost of the solar field will be very low compared with a conventional CSP plant (because the coal station's turbines, generators, transformers, switchgear and transmission lines are utilised), both these operating modes have their own advantages as well:

In boosting mode, the fuel consumption and harmful emissions levels will not necessarily decrease, but more electricity can be generated and will be available to the constrained grid.

In fuel-save mode, no additional electricity will be generated, but less coal will be burned, less harmful gases will be emitted, and less ash will have to be handled. This mode can also reduce the operating cost of the power station (fuel-cost decrease, carbon-tax decrease, income from TRECs, own electricity consumption decrease, etc).

1.2 Problem statement

It is expected that the LCOE of the hybrid plant will be greater than that of a conventional coal-fired power station, but much less than that of a conventional concentrating solar power (CSP) plant. If the addition of electricity generated from solar power to the national generation mix is a primary objective, will it be more feasible to invest in a conventional CSP plant, or will it be more feasible to invest in a solar augmentation scenario, where solar energy is injected into a coal-fired power station?

1.3 Objectives

The main objective of this study is to compare the LCOE of a normal supercritical coal-fired power station with that of a solar-augmented scenario, where a solar field is integrated with such a coal-fired station. The levelised cost of such a hybrid plant can then also be compared with that of a conventional CSP plant.

1.4 Research methodology

A thermodynamic model of an 800 MW supercritical coal-fired power station, in which all major input and output variables are calculated, was developed with Engineering Equation Solver (EES), a thermodynamic software package. A thermodynamic model of the same power station was then developed with ThermoFLEX, which is also a thermodynamic software package, to verify the EES model's input and output parameters. These parameters are then used to calculate the LCOE of this stand-alone coal-fired power station in Microsoft Excel. Henceforth, this stand-alone power station will also be referred to as the base-case scenario.

A thermodynamic model of a scenario, where thermal energy generated in a solar field is injected into the regenerative Rankine cycle of the base-case scenario, was then developed in EES. Actual data collected from Eskom's linear Fresnel pilot and demonstration plant at Rosherville was used to calculate an accurate "solar to thermal" efficiency for such a CST technology. This efficiency was then used as an input parameter to calculate the amount of thermal energy available to the coal-fired power station, from the solar field in the solar augmentation models.

Parametric tables, in which the direct normal irradiation was varied according to typical irradiation days, were then developed in EES, in which the major input and output parameters were calculated on a five-minute basis. This data was then used to calculate summarised annual parameters that were then used to calculate the LCOE of the solar augmented scenario.

1.5 Scope of work and limits

The scope of work for this study will include the following tasks:

- Base-case thermodynamic model with EES
- Base-case thermodynamic model with ThermoFLEX
- Base-case model verification exercise
- Rosherville linear Fresnel plant performance analysis
- Base-case LCOE calculation with Excel
- Fuel-saver solar augmentation thermodynamic model in EES
- Different irradiation day parametric tables in EES:
 - o No solar
 - o Mostly cloudy day
 - o Very cloudy day
 - o Slightly cloudy day
 - o Cloudless day
- Solar augmentation LCOE calculation in Excel
- Summary of results

Only annualised calculations were conducted for the fuel-saver scenario that is integrated by means of an additional heat exchanger bypassing the high-pressure heaters. No other solar-field integration scenarios or other operating modes (boosting mode), are considered in this study.

1.6 Paper layout

This paper consists of eight chapters, of which the first provides an introduction to this study.

The second chapter includes a literature review of all the relevant thermodynamic and financial principles used in the power-generation sector. This literature review also includes sections about solar-power technologies, solar-radiation parameters and existing hybrid systems.

In Chapter 3, the project approach is discussed in detail. This chapter provides the working method for the thermodynamic and financial models for the base-case and hybrid-case scenarios. All the assumptions made for both scenarios can also be seen in Chapter 3.

The thermodynamic and financial input and output parameters obtained from the EES models for the base-case scenario are discussed in Chapter 4. The model verification results obtained by comparing the EES and ThermoFLEX models are also reflected in this chapter.

Chapter 5 refers to the EES parametric table results obtained from the solar-augmentation scenario for the different solar irradiation days considered, as well as the full-year input and output analysis. The financial implications of such a hybrid plant are also discussed in this chapter.

In Chapter 6 the annual results for the base-case and solar-augmented case scenarios are compared with regard to the major input and output parameters, as well as the expected LCOE deviation, after which the summary of this study is documented in Chapter 7.

The bibliography and references are documented in Chapter 8, after which the Appendixes containing all parametric table data and program codes follow.

CHAPTER 2: LITERATURE STUDY AND EXISTING TECHNOLOGIES

2.1 Relevant thermodynamic properties and definitions

2.1.1 Specific heat capacity

The specific heat capacity (C) of a substance is the amount of heat (Q) required to increase the temperature of 1 kg of the substance by 1 °C.

$$C = \frac{Q}{m \Delta T} \quad 2.1$$

Where:

C_v = Specific heat capacity at constant volume [J/kg.K]

C_p = Specific heat capacity at constant pressure [J/kg.K]

m = Mass [kg]

Q = Heat [J]

ΔT = Change in temperature [K]

2.1.2 Enthalpy

The enthalpy (h) of a substance may be defined as the total energy in the substance, ie the work the substance is capable of, plus the internal energy of the substance. The change in enthalpy of a substance is also equal to the specific heat capacity of the substance, under constant pressure, multiplied by the substance's change in temperature.

$$\Delta h = C_p \Delta T \quad 2.2$$

Where:

ΔT = Change in temperature [K]

C_p = Specific heat capacity at constant pressure [J/kg.K]

Δh = Change in enthalpy [J/kg]

2.1.3 Entropy

The entropy (s) of a substance is used as an absolute reference for the flow of heat at a certain temperature for any substance in any process. This means that a change in entropy indicates a flow of heat at a certain temperature and can be calculated with the following equation:

$$\Delta s = \frac{\Delta q}{T} \quad 2.3$$

Where:

Δs = Change in entropy [J/kg.K]

T = Temperature [K]

Δq = Heat transfer rate [J/s or W]

2.1.4 Heat

The heat flux (q''), is the rate, per metre squared, at which heat is transferred from one medium to another. The heat flux may be multidirectional and is illustrated in [W/m²].

The heat rate (q) is the total rate at which heat is transferred from one medium to another, and is illustrated in [W].

2.1.5 Saturated and subcooled liquid

When a substance exists in a liquid phase, only ($x = 0$) at the saturation temperature for the substance at a specific pressure, the substance is in a saturated liquid phase and is called a saturated liquid.

When the temperature of a liquid substance is below the saturation temperature of the substance for a specific pressure, the substance is called a subcooled liquid or compressed liquid.

2.1.6 Saturated and superheated vapour

When a substance exists in a vapour phase, only ($x = 1$) at the saturation temperature of the substance at a specific pressure, the substance is in a saturated vapour phase and is called a saturated vapour or dry saturated vapour.

When the temperature of a substance is above the saturation temperature of the vapour for a specific pressure, the substance is called a superheated vapour.

2.1.7 Critical point

The critical point of a substance is found at the temperature and pressure of the substance, where the saturated liquid and saturated vapour states are identical. There is also no constant temperature vaporisation process at the critical point of a substance, which means that a two-phase state cannot exist. The temperature and pressure at the critical point of a substance are called the critical temperature and the critical pressure of the substance. For steam it is: $T_{\text{critical}} = 374,14\text{ }^{\circ}\text{C}$ and $P_{\text{critical}} = 22,09\text{ MPa}$.

When the pressure of a substance is above its critical pressure, but below its critical temperature, the substance is in a subcooled or compressed liquid state.

When the pressure of a substance is above its critical pressure, and the temperature of the substance is above its critical temperature, the substance may be referred to as a supercritical substance.

2.2 Thermodynamic laws

2.2.1 The zeroth law of thermodynamics

The zeroth law of thermodynamics states that when two bodies have equality of temperature with a third body, they in turn have equality of temperature with each other (Sonntag et al., 2003).

2.2.2 First law of thermodynamics

As a control mass undergoes a change of state, energy may cross the boundary as either heat or work, and each may be positive or negative. The net change in the energy of the system will be exactly equal to the net energy that crosses the boundary of the system. The energy of the system may change in any of three ways – by a change in internal energy, in kinetic energy or in potential energy (Sonntag et al., 2003). This can also be called the law of conversion of energy and mass. If all the heat in the process is transformed to work:

$$\Delta Q = \Delta W \quad 2.4$$

Where:

ΔQ = Change in heat [J]

ΔW = Change in work [J]

2.2.3 Second law of thermodynamics

There are two classical statements of the second law, known as the Kelvin-Planck statement and the Clausius statement (Sonntag et al., 2003).

The Kelvin-Planck statement: It is impossible to construct a device that will operate in a cycle and produce no effect other than the raising of a weight and the exchange of heat with a single reservoir.

The Clausius statement: It is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a cooler body to a hotter body.

2.3 Relevant thermodynamic processes

2.3.1 Heat transfer

Heat (q) will always flow from a higher temperature to a lower temperature environment, until the two environments are equal in temperature. Heat transfer may occur in three different modes, namely

- conduction
- convection
- radiation

2.3.1.1 Conduction

The transfer of energy (heat) within a stationary medium that can be either a solid or a liquid, is called conduction. A basic illustration of a one-dimensional conduction process can be seen in Figure 2-1.

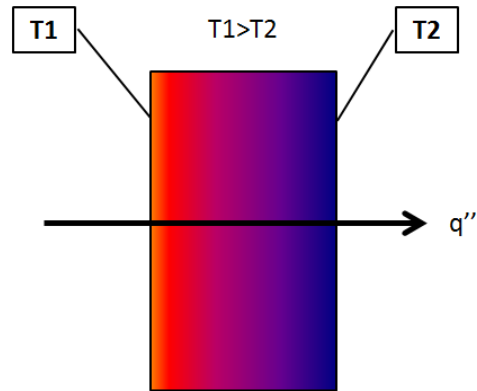


Figure 2-1: Basic illustration of conduction

The heat flux for conduction may be calculated with the following equation:

$$q'' = k \frac{T_1 - T_2}{L} = k \frac{\Delta T}{L} \quad 2.5$$

Where:

q'' = Heat flux [W/m^2]

k = Thermal conductivity [W/mK]

T_1 = Warmer temperature [K]

T_2 = Cooler temperature [K]

L = Substance thickness [m]

The heat rate (q) through conduction may then be calculated by multiplying the heat flux (q'') by the area (A) of the conduction plane.

$$q = q'' A \quad 2.6$$

Where:

q = Heat rate [W]

A = Area of conduction [m^2]

2.3.1.2 Convection

Convection takes place when heat (q) flows to/from a surface with temperature (T_s), from/to a moving fluid with temperature (T_∞). If the movement of the fluid is induced by an external source, such as a fan or a pump, the process is known as forced convection, but when the movement of the fluid is self-induced by means of buoyancy forces, for example, the process is known as free convection. A basic illustration of the convection process can be seen in Figure 2-2.

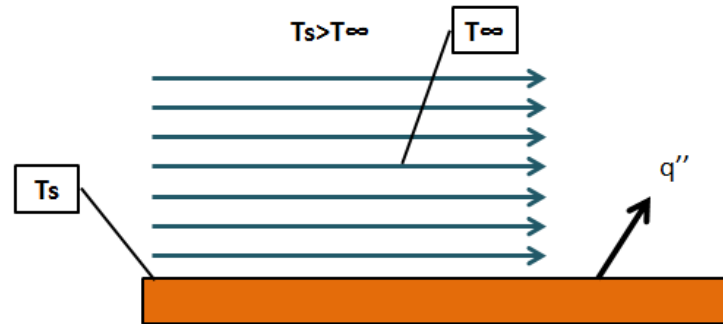


Figure 2-2: Basic illustration of convection

If it is assumed that the surface temperature is warmer than the temperature of the moving fluid, the convective heat flux (q'') may be calculated with the following equation:

$$q'' = h(T_s - T_\infty) \quad 2.7$$

Where:

q'' = Convective heat flux [W/m^2]

h = Convection heat transfer coefficient [$\text{W}/\text{m}^2\text{K}$]

T_s = Surface temperature [K]

T_∞ = Moving fluid temperature [K]

2.3.1.3 Radiation

The energy emitted by gases, solids and fluids, which is at a nonzero temperature, is called radiation. According to (Incropera, 2007), the energy of the radiation field is transported by electromagnetic waves or photons.

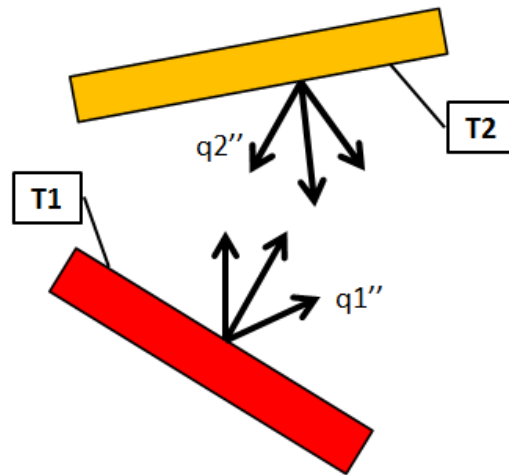


Figure 2-3: Basic illustration of radiation

The heat flux (q'') emitted by a real surface at a certain temperature is given by the following equation:

$$E = \varepsilon \sigma T_s^4 \quad 2.8$$

Where:

W = Emissive power [W/m^2]

ε = Emissivity of the surface [$0 \leq \varepsilon \leq 1$]

σ = Stefan Boltzmann constant [$5.67 \times 10^{-8} \text{W}/\text{m}^2 \text{K}^4$]

T_s = Surface temperature [K]

2.3.2 Constant volume process

In a constant volume process, the temperature and pressure may vary but the volume stays constant. The constant volume process is also called an isovolumetric process.

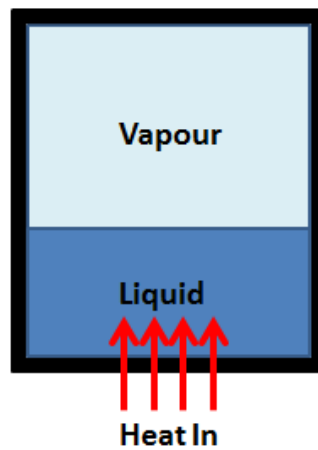


Figure 2-4: Basic illustration of an isovolumetric process

If heat is added through the system boundary in Figure 2-4 above, the temperature and pressure will increase, but no work can be done through this process.

2.3.3 Constant pressure process

In a constant pressure process, the temperature and volume of the system may change, but the pressure must stay constant.

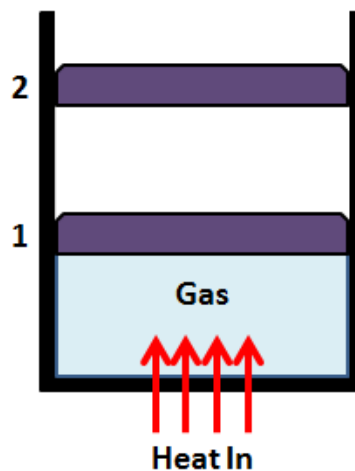


Figure 2-5: Basic illustration of an isobaric process

When heat is supplied to the system in Figure 2-5, the system volume has to increase for the pressure to stay constant. This will result in the piston moving from one position (1) to another

(2) eg positive work will be obtained from the system. The constant pressure process is also called an isobaric process.

2.3.4 Isothermal process

In a constant temperature process, the volume and pressure may change but, the temperature of the system will stay constant.

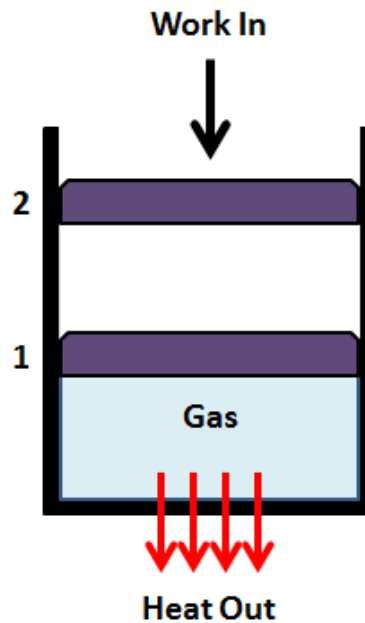


Figure 2-6: Basic illustration of an isothermal process

When work is added to the system to move the piston from position 2 to position 1 in Figure 2-6, the temperature of the system will rise. This heat will then move through the cylinder walls by means of conduction to keep the temperature inside the cylinder constant. Heat (Q) will be rejected from this process.

2.3.5 Adiabatic process

When the cylinder in Figure 2-6 is insulated and work is added to move the piston from position 2 to position 1, no heat can be rejected from this process, which means that the pressure, temperature and volume of the system will change. The heat transfer in an adiabatic process is zero.

2.3.6 Isentropic process

When an adiabatic process takes place without any losses, an isentropic process takes place.

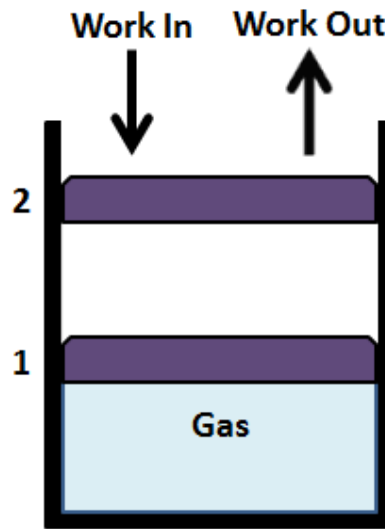


Figure 2-7: Basic illustration of an isentropic process

In the case where work is added to the system to move a piston from one position to another, no heat flow across the system boundary is allowed and the whole process is without losses, the piston will return to the exact same initial position when it is released; and by doing so, the same amount of work will be done as was initially added to the system. Because there is no heat flow across the boundary of the system, the entropy will stay constant throughout the process. This process is also called the reversible adiabatic process.

2.3.7 Throttling process

In a throttling process the temperature and pressure may vary, but the enthalpy of the working fluid stays constant throughout the process. Practical examples of the throttling process are the throttling of steam through a valve and the flashing off of steam in a flash box.

2.4 Rankine cycle

The Rankine cycle is used in most steam-power stations across the world and is used to generate approximately 90% of the entire world's electricity. This thermodynamic cycle is named after Professor William John Macquorn Rankine from Glasgow University.

2.4.1 Basic Rankine

The basic Rankine cycle, shown in Figure 2-8, consists of a four-steady-state-process, of which the first state is saturated liquid and the third state is either saturated vapour or superheated vapour. The four stages of the basic Rankine cycle can be defined as

1. an isentropic pumping process (1–2)
2. a transfer of heat from the boiler in an isobaric process (2–3)
3. an isentropic expansion process (3–4) and
4. a transfer of heat to the condenser in an isobaric process (4–1)

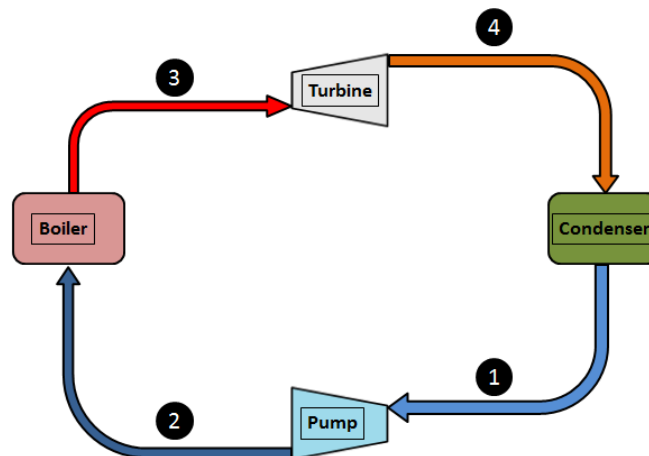


Figure 2-8: Illustration of a basic Rankine cycle

The circulation pump requires external power (W_{Pump}) to pressurise the working fluid from state one to state two. In the ideal cycle, this is a reversible adiabatic process, which means that the entropy of the working fluid remains constant ($s_1 = s_2$).

External heat (Q_{Boiler}) is then introduced to the working fluid in the boiler. In the ideal Rankine cycle, this heat exchange takes place under constant pressure ($P_2 = P_3$). The heat is normally

contracted through the combustion of carbon-based substances, but can also be obtained from any other applicable heat source.

As mentioned in the first paragraph, the working fluid can now be either in a saturated vapour or in a superheated vapour phase, depending on the amount of heat introduced to the cycle. The energetic working fluid can now be expanded in a reversible adiabatic process ($s_3=s_4$) where power (W_{Turbine}) can be extracted from the cycle.

After the fluid has been expanded, it can be either in a saturated vapour or a two-phase state. Heat ($Q_{\text{Condenser}}$) must now be extracted from the cycle to condense the working fluid back to a saturated liquid state, so that it can be recirculated by the pump. The heat extracted from the cycle is normally released to the atmosphere by cooling towers or air-cooled condensers (ACC).

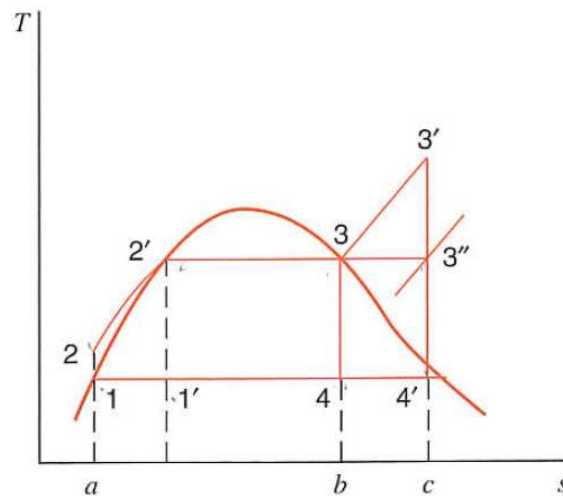


Figure 2-9: T-s diagram of the basic Rankine cycle (Sonntag et al., 2003)

In the scenario where saturated vapour is produced by the steam generator the cycle path 1 – 2 – 3 – 4 – 1 will be followed on the temperature versus entropy (T-s) diagram shown in Figure 2-9. When superheated vapour is produced, the cycle path 1 – 2 – 3 – 3' – 4' – 1 will be followed on the T-s diagram.

The power required by the pump can be calculated by multiplying the mass flow of the working fluid by the difference between the pump's inlet and outlet enthalpies. If a non-ideal pump is considered, the ideal power rating must be divided by the isentropic efficiency of the pump.

$$W_{pump} = \frac{\dot{m}(h_2 - h_1)}{\eta_{pump}} \quad 2.9$$

Where:

- W_{Pump} = Power required by the pump [kW]
- $\dot{m}$ = Mass flow of the working fluid [kg/s]
- h_1 = Specific enthalpy of the working fluid entering the pump [kJ/kg]
- h_2 = Specific enthalpy of the working fluid leaving the pump [kJ/kg]
- η = Mechanical efficiency of the pump [%]

The heat introduced to the boiler may be illustrated by the area: a – 2 – 2' – 3 – 3' – c – a in the T-s diagram and the heat rejected by the cycle through the condenser can be illustrated by the area: a – 1 – 4' – c – a. This may also be calculated from the thermodynamic properties of the working fluid:

$$Q_{boiler} = \dot{m}(h_3 - h_2) \quad 2.10$$

Where:

- Q_{Boiler} = Thermal power injected by the boiler [kWt]
- $\dot{m}$ = Mass flow of the working fluid through the boiler [kg/s]
- h_3 = Enthalpy of the working fluid leaving the boiler [kJ/kg]
- h_2 = Enthalpy of the working fluid entering the boiler [kJ/kg]

As with a pump, the power produced by the turbine may be calculated by multiplying the mass flow of the working fluid by the difference between the turbine's inlet and outlet enthalpies.

If a non-ideal turbine is considered, the ideal turbine power rating must be multiplied by the turbine's isentropic efficiency.

$$W_{turbine} = \dot{m}(h_3 - h_4) \cdot \eta_{turbine} \quad 2.11$$

Where:

- $W_{Turbine}$ = Power produced by the turbine [kW]
- $\dot{m}$ = Mass flow of the working fluid [kg/s]
- h_3 = Specific enthalpy of the working fluid entering the turbine [kJ/kg]
- h_4 = Specific enthalpy of the working fluid leaving the turbine [kJ/kg]
- η = Mechanical efficiency of the turbine [%]

The heat extracted from the cycle, through the condenser, can be calculated by multiplying the mass flow of the fluid by the difference between the fluid's inlet and outlet enthalpies. Note that the fluid, at the condenser outlet must be in a saturated liquid state.

$$Q_{Condenser} = \dot{m}(h_4 - h_1) \quad 2.12$$

Where:

- $Q_{Condenser}$ = Thermal power extracted by the condenser [kWt]
- $\dot{m}$ = Mass flow of the working fluid through the condenser [kg/s]
- h_4 = Enthalpy of the fluid entering the condenser [kJ/kg]
- h_1 = Enthalpy of the fluid leaving the condenser [kJ/kg]

The net power (W_{Net}) produced by the cycle is the output power produced by turbine, minus the input power required to drive the electrical pump and may be illustrated as the area: 1 – 2 – 2' – 3 – 3' – 4' - 1 in the T-s diagram. This may also be calculated from the thermodynamic properties of the working fluid.

The overall efficiency of this basic cycle can be calculated by dividing the net power output of the cycle by the total heat input to the furnace by combusting pulverised fuel. The gross cycle efficiency is calculated by dividing the gross power output or generator power by the heat added to the cycle by the boiler, while the net cycle efficiency is calculated by dividing the net power output of the station by the heat added to the cycle by the boiler. The net power output is the power supplied by the generator minus the total auxiliary power requirement.

$$\eta_{overall} = \frac{W_{net}}{Q_{Furnace}} \quad 2.13$$

$$\eta_{Cycle\ Gross} = \frac{W_{Gross}}{Q_{Boiler}} \quad 2.14$$

$$\eta_{Cycle\ Net} = \frac{W_{net}}{Q_{Boiler}} \quad 2.15$$

Where:

$\eta_{overall}$ = Overall efficiency [%]

$\eta_{Cycle\ Gross}$ = Gross cycle efficiency [%]

$\eta_{Cycle\ Net}$ = Net cycle efficiency [%]

W_{net} = Net power output [kW]

$Q_{Furnace}$ = Heat added in furnace [kW]

W_{Gross} = Gross power or generator power [kW]

Q_{Boiler} = Heat added to cycle by boiler [kW]

W_{net} = Net power output

2.4.2 Reheat Rankine cycle

In the reheat cycle, the main steam (3) is expanded to a certain pressure (4) in the first stages of the turbine. The steam is then reheated (isobaric process) in the boiler's reheaters to the required temperature. Normally the reheated steam temperature is equal to the main steam temperature ($T_4 = T_3$). The reheated steam is then expanded further in the later stages of the turbine. According to (Sonntag et al., 2003), the reheat cycle has been developed to take

advantage of the increased efficiency with higher pressures, and yet avoid excessive moisture from forming in the low-pressure stages of the turbine. An illustration of a basic reheat cycle is seen in Figure 2-10, while the $T-s$ diagram of such a cycle is illustrated in Figure 2-11.

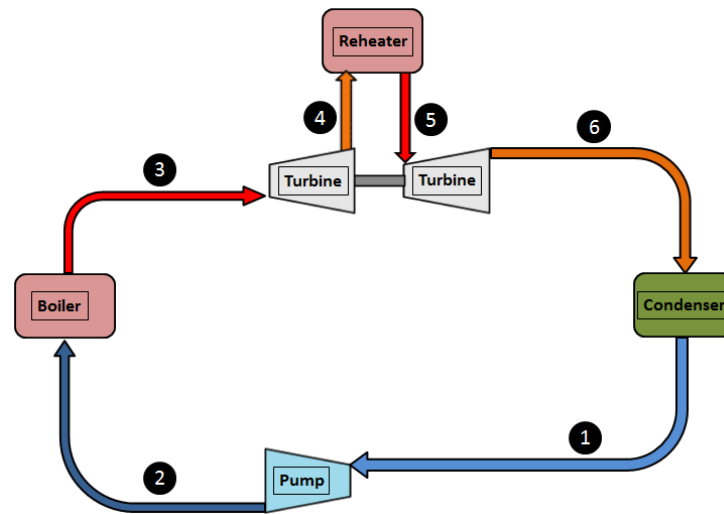


Figure 2-10: Reheat Rankine cycle

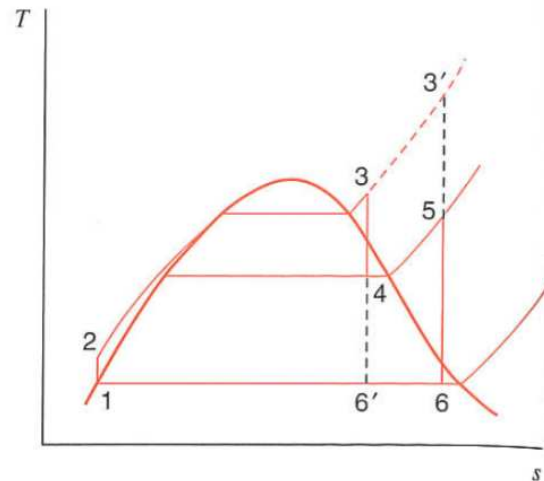


Figure 2-11: $T-s$ diagram of the Reheat Rankine cycle (Sonntag et al., 2003)

2.4.3 Regenerative Rankine cycle

In the regenerative Rankine cycle, steam tapped off from certain turbine interstages, is used to preheat the boiler feedwater to a certain extent. By doing so, less heat is required from the furnace to heat the main steam to its specified temperature.

From the regenerative Rankine cycle illustrated in Figure 2-12, one can note that steam with a mass flow of x times the mass flow of that in section 5 ($x \cdot \dot{m}_5$ or $\dot{m}_6$) is being tapped off from a turbine interstage to power the feedwater heater. In this particular case, an open feedwater heater is used where the bleed steam is mixed with the feedwater. In effect, the turbine inlet steam flow is equal to the heater outlet water flow and is equal to the bleed steam flow plus the heater inlet water flow ($\dot{m}_5 = \dot{m}_3 = \dot{m}_2 + \dot{m}_6$).

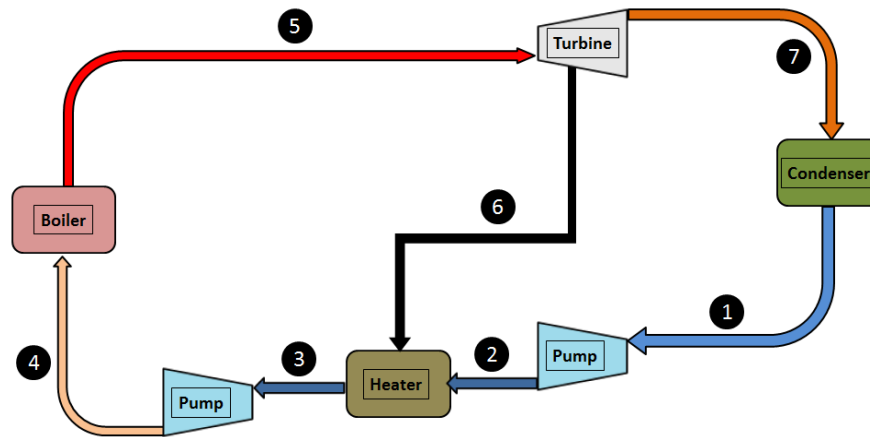


Figure 2-12: Regenerative Rankine cycle

As shown in the T-s diagram in Figure 2-13, line 6-3 illustrates how the bleed steam is condensed in the feedwater heater and line 2-3 illustrates how the feedwater is pre-heated in the heater. The feedwater and condensed bleed steam are mixed at point 3.

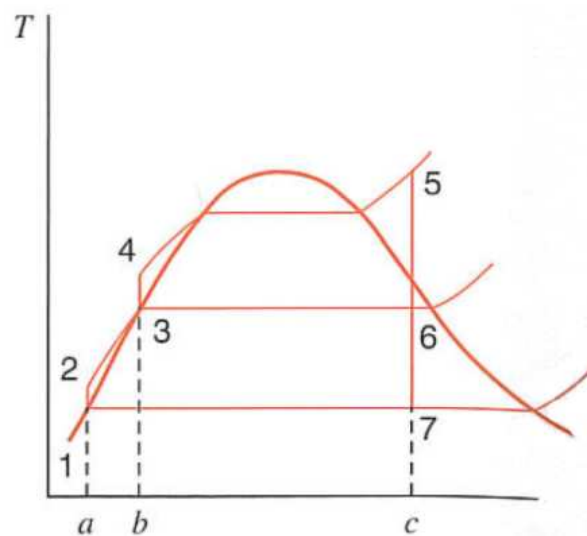


Figure 2-13: T-s diagram of the regenerative Rankine cycle (Sonntag et al., 2003).

2.5 Conventional coal-fired power generation

Modern coal-fired power stations make use of a complex regenerative Rankine cycle. Normally this cycle consists of a steam generator system in which heat is added to the cycle, a turbine train system in which mechanical work is extracted from the cycle, condensers in which the saturated steam is condensed to a saturated liquid state, a number of feedwater preheaters, and the feedwater pumping system.

According to (Zhang, 2013), the efficiency of the Rankine power cycle is normally limited by the working fluid, the turbine entry temperature and the condenser temperature. The turbine entry temperature is typically around 560 °C, and is limited by the creep limit of the stainless steel used in the turbine components. The condenser temperature is normally around 26 °C and is limited by the cooling method and ambient conditions.

In order to increase the efficiency of a given Rankine cycle, one has to increase the main steam pressure and temperature or decrease the condenser temperature.

Coal-fired power stations may also be subclassified into the following categories, and can be seen in Table 2-1:

- Subcritical power plant
- Supercritical (SC) power plant
- Ultra-supercritical (USC) power plant

Table 2-1: Technology comparison of three steam cycles (Zhang, 2013)

Steam Cycle	Ultra-Supercritical	Supercritical	Subcritical
Pressure [MPa]	25 - 34	22 - 24	16 - 17
Temperature [C]	700 - 760	597 - 657	538 - 547
CO ₂ emissions at full load [T/MWh]	1.05	1.09	1.12
Cycle Efficiency [%]	50	45	38

From Table 2-1 above it can be seen that ultra-supercritical plants outperform subcritical and supercritical power stations with regard to the overall cycle efficiency and CO₂ emissions.

Thomas Edison's Pearl Street Station was the first coal-fired power station in the United States (US). The New York based power station supplied its first electricity to its initial 85 customers on 4 September 1882. Almost forty years later (1920s), pulverised-coal or pulverised-fuel (PF) power stations started to come into operation. The first reheat cycle was also introduced in the same decade, after which the main steam temperature was increased to 538 °C in the 1930s.

In 1957, the Ohio based, Philo Unit 6 was the first commercial supercritical (SC) power generator, with main steam conditions of 31 MPa and 621 °C. In 1960, the 325 MW Eddystone Unit 1, with an even higher main steam pressure of 35 MPa, came into operation. According to (Narula et al., 2013) the knowledge gained from the successful operation of both Eddystone 1 and Philo 6 made them models for the SC stations that followed.

According to (Zhang et al., 2013), the supercritical coal-fired boilers have been successfully put into commercial operation with a maximum capacity of 1 100 MW.

2.5.1 Coal and emissions

2.5.1.1 Coal

According to (IEA and CIAB, 2010), coal is the world's most abundant fossil fuel, with reserves for all types of coal estimated to be about 990 billion tonnes. This reserve is enough for approximately 150 years at the current consumption (2010). Globally, approximately 42% of all electricity production is generated by burning coal. According to (IEA and CIAB, 2010), coal is likely to remain a key component of the fuel mix for power generation, especially as a result of the growing demand in developing countries.

According to (Sonntag et al., 2003), coal consists of the remains of vegetation deposits of a past geological age. These vegetation deposits are subjected to biochemical actions, high pressure, temperature and submersion for extended periods. Coal characteristics vary significantly with location, and, in some cases the quality of the coal from the same mine may also vary.

Raw coal can also be broken down into the following groups:

- Volatile matter
- Surface moisture
- Inherent moisture
- Fixed carbon
- Ash

The volatile matter component of coal normally contains hydrogen, mercury (Hg), carbonates (C_x) and methane (CH_4), which means that a typical coal sample will contain mainly the following chemical elements:

- Nitrogen (N)
- Carbon (C)
- Sulphur (S)
- Mercury (Hg)
- Oxygen (O)
- Hydrogen (H)

The ultimate analysis may be given on an “as-received” basis, which includes the surface and inherent moisture on an “air-dried” basis, which does not include the surface moisture, or on a “dry basis”, which does not include any moisture. The pie charts below (Figure 2-14) show coal-sample analyses for Lethabo and Matimba power stations.

The term “heating value” represents the heat transferred from the furnace during combustion at constant temperature. The higher heating value (HHV) or gross calorific value (GCV) of coal is a characteristic that illustrates the heat transfer with liquid water in the coal, while the lower heating value (LHV) is the heat transfer with vapour water products in the coal (Sonntag et al., 2003).

The bulk of the coal in South Africa used for power generation has a GCV value of between 20 and 26 MJ/kg. South Africa's higher-quality coal is normally reserved for export, steel production, fuel production, etc. Kendal and Matimba power stations burn coal with a heating value of 18–21 MJ/kg, while Lethabo power station burns very low-quality coal, with a heating value of between 14 and 16 MJ/kg.

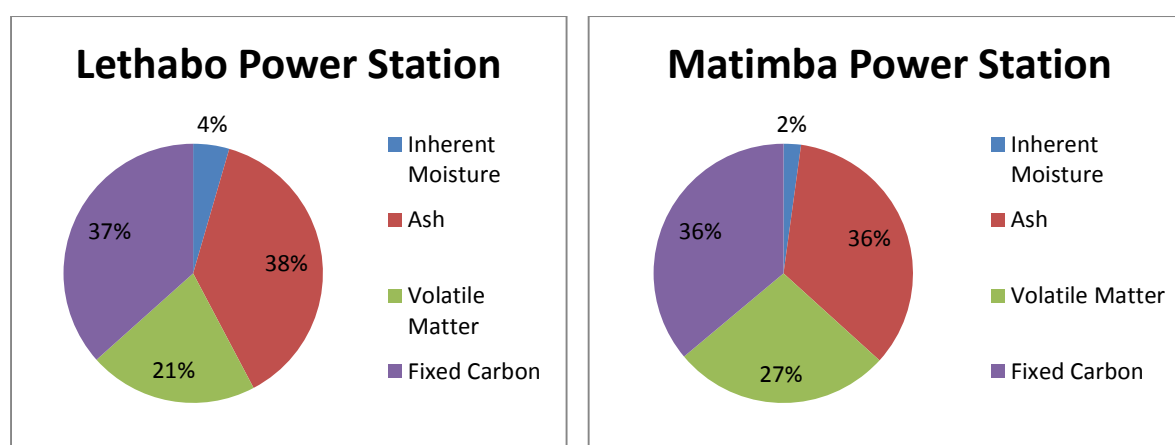


Figure 2-14: Air-dried coal analysis for Lethabo (left) and Matimba (right) power stations

2.5.1.2 Emissions

When raw coal goes through a combustion process with air, pollutants such as NO_x and SO_x are formed (Moretti and Jones, 2012).

NO_x refers to the cumulative emission of NO , NO_2 and small quantities of other nitrogen species created during combustion. The most harmful effects come from NO_2 , which forms from the reaction of NO and O_2 (Moretti and Jones, 2012).

SO_x refer to the cumulative emission of SO_2 and SO_3 . When sulphur-containing coal is burned in the furnace, the sulphur combines with oxygen to form SO_2 , after which some of the SO_2 oxidises to SO_3 (Moretti and Jones, 2012). SO_2 is a throat, eye and nose irritant that is associated with respiratory illness and acid rain.

The formation of SO_2 during the combustion process can be seen in the reaction below:



According to (Moretti and Jones, 2012), the SO_2 content in the flue gas can be managed by selecting a fuel with a lower sulphur content or by utilising a flue gas desulphurisation (FGD) technology to remove the SO_2 from the flue gas.

A number of FGD technologies are available, including dry and wet FGD (Figure 2-15), spray dryer absorber (SDA), circulating dry scrubber (CDS) and dry sorbent injection (DSI). Wet FGD is most commonly used, with limestone as the reagent and gypsum as the by-product.

The SO_2 extraction process begins as the hot flue gas enters the FGD absorber tower where it is cooled and saturated by the limestone slurry. The flue gas then flows upward through the absorber spray zone, where the slurry is sprayed counter-current to the flue gas flow, completing the SO_2 removal process. Typically, the SO_2 removal process also includes a forced-oxidation system where calcium sulphite (CaSO_3) formed by the SO_2 removal process is converted into calcium sulphate (CaSO_4) or gypsum. Limestone forced-oxidation systems have achieved SO_2 removal efficiencies as high as 98%. The overall SO_2 extraction process can be seen in the chemical reaction below:

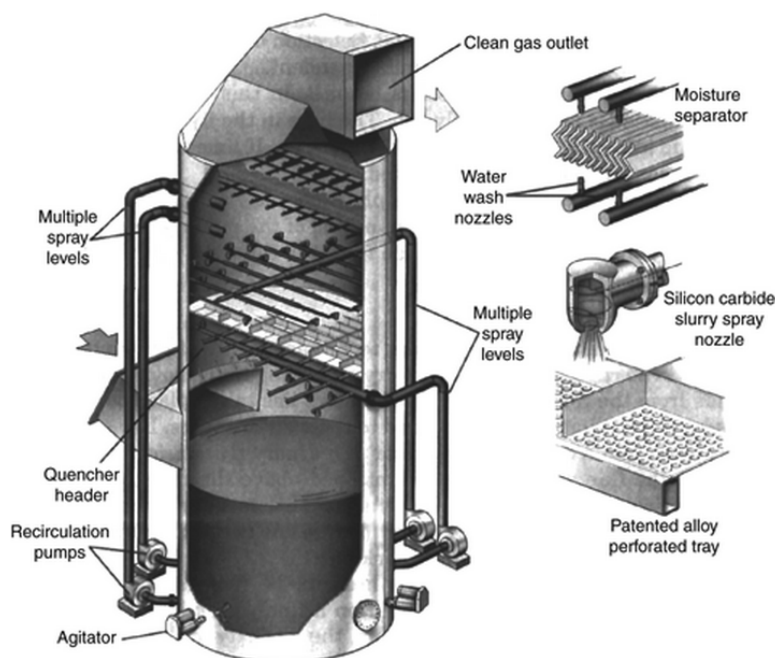
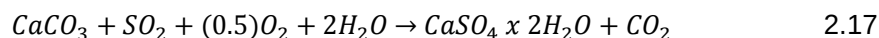


Figure 2-15: Picture of a typical wet flue-gas desulphurisation plant (Everett et al., 2012c).

According to (Moretti and Jones, 2012), particulates are very small-diameter solids or liquids that remain suspended in the flue gas. The solids are typically made up of non-combustible ash or partially combusted soot.

Particulate control equipment is designed to remove the fly ash and other particulates from the flue gas. There are a number of particulate control technologies available, eg fabric filter plant (FFP), electrostatic precipitators (ESP), mechanical collectors and venture scrubbers (Moretti and Jones, 2012). In the FFP, the flue gas passes through a woven fabric, where the particulates in the flue gas are not allowed to pass through the filters and are deposited on the filter surface. In a pulse-jet FFP, the ash is collected on the outside of the filter bags and is removed by a reverse pulse of high-pressure air while the compartment is online. FFPs have high collection efficiencies throughout the particle size range, high reliability and a good resistance to flow inconsistencies. (Moretti and Jones, 2012). An illustration of a pulse-jet fabric filter plant can be seen in Figure 2-16.

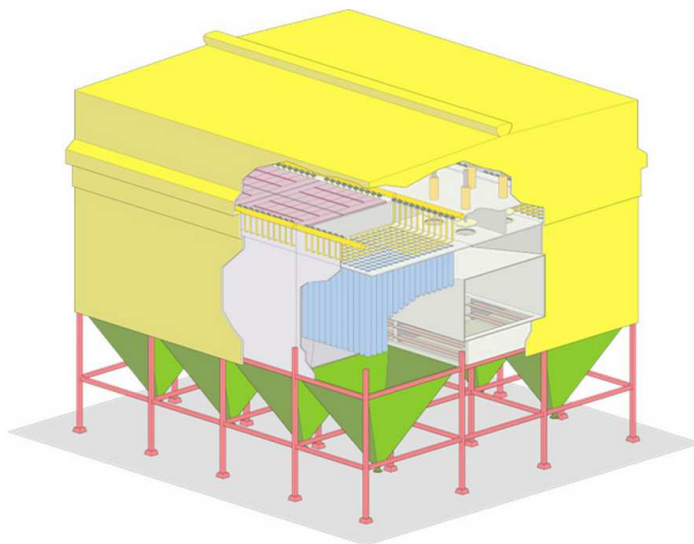


Figure 2-16: Pulse-jet fabric filter plant (Moretti and Jones, 2012)

An ESP comprises a series of parallel vertical plates through which the flue gas passes. The ash particles in the flue gas are charged with a strong electric field, which makes them adhere to the vertical plates. From there the ash is released into hoppers and transported to the ash dumps.

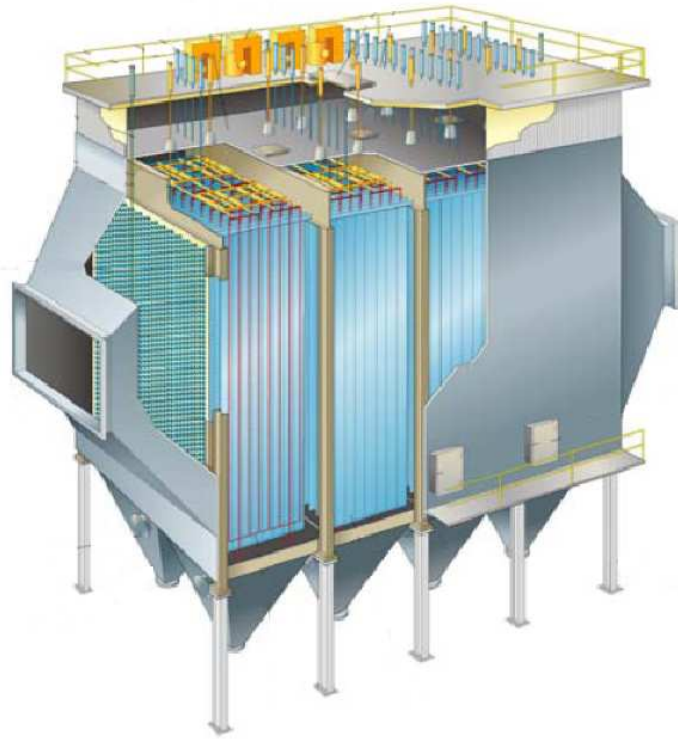


Figure 2-17: Electrostatic precipitator plant (Moretti and Jones, 2012)

Carbon dioxide (CO_2), a major role-playing greenhouse gas, is also a significant by-product of coal's combustion process. The formation of CO_2 can be seen in the reaction below:



The clean development mechanism (CDM) is a project-based mechanism between mostly developing and developed countries that are signatories to the Kyoto protocol (Volschenk, 2013). In effect CDM allows companies to trade in certified emission reductions, sometimes called carbon credits.

When determining the emissions offset a CDM project delivers, one needs to compare the base-case emissions with the emissions after the implementation of a CDM.

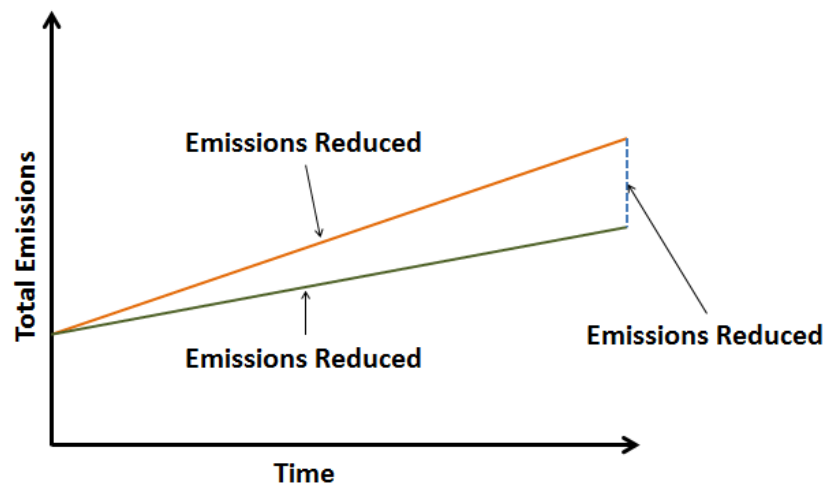


Figure 2-18: Emissions reduction with a clean development mechanism

2.5.2 Supercritical and ultra-supercritical generation

Supercritical power stations operate at parameters above the working fluid's critical point

Typical SC plants operate at pressures between 22 and 24 MPa, with temperatures ranging between 597–657 °C. These power stations can reach cycle efficiencies of up to 45%, which is significantly higher than the efficiency of a typical subcritical power station.

Ultra-supercritical power plants operate at much higher pressures (25–34 MPa) and temperatures of up to 760 °C. Their plants can reach efficiencies approaching 50%. Table 2-2 gives a good indication of where supercritical power stations are already in operation around the world. Eskom Holdings SOC Limited are currently (2014) in the process of constructing two supercritical power stations, Medupi and Kusile. Medupi is situated on the outskirts of Lephalale, in the Limpopo province, while Kusile is situated in the Nkangala District of the Mpumalanga province. Both these stations have 6 units with rated capacities of 800 MW each.

Table 2-2: Worldwide distribution of supercritical power plant (Zhang, 2013)

Region	Number of plants	Unit size [MW]
U.S.	~ 164	300 - 1100
China	> 120	700 - 1300
Europe	> 64	200 - 1000
Japan	> 50	500 - 1000
Russia	~ 240	300 - 1200
South Africa (In construction)	~ 2	800

Even though supercritical and USC plants have higher efficiencies and lower CO₂, NO_x and SO_x emissions, the operating and maintenance (O&M) requirements of such plants are much more intensive. These plants also require advanced, more expensive materials for the turbines and boiler components to withstand these extreme steam conditions.

2.5.3 Relevant cycle components condensers

According to (Everett et al., 2012e), the condenser is one of the steam cycle power plant's main components. The condenser receives low-pressure steam from the last stages of the low-pressure turbines. By rejecting heat from the steam it is then condensed back to a liquid stage, which can then be recirculated through the Rankine cycle. According to (Everett et al., 2012e), there are three main condenser types:

- Direct-contact condensers
- Surface condensers
- Air-cooled condensers

When the steam is fully condensed, the liquid water occupies only a fraction of the space the steam requires, which causes a vacuum in the condenser. This low pressure in the condenser reduces the back pressure on the turbines, which increases their efficiency.

2.5.3.1.1 Direct-contact condensers

In direct-contact condensers, the cooling water is sprayed directly into the exhaust steam leaving the LP turbines. By mixing the exhaust steam with the cold cooling water, the steam condenses to liquid water.

2.5.3.1.2 Surface condensers

According to (Everett et al., 2012e), surface condensers are basically shell and tube heat exchangers. The low-pressure turbine exhaust steam condenses on the exchanger's shell side, while the cooling water flows through the tubes. A series of baffles and plates supports the tubes and distributes the flow of the exhaust steam, directs the non-condensable gas such as O_2 and CO_2 to the outlet and minimises flow-induced vibrations, which could result from high steam velocities. An illustration of a typical surface condenser can be seen in Figure 2-19.

Water boxes are normally located on each end of the tube bundle and distribute the cooling water through the tubes. Most condensers receive steam from the top as the steam leaves the exhaust end of the turbines (Everett et al., 2012e).

According to (Everett et al., 2012e), the cooling medium and the exhaust steam remain separate in a surface condenser. Surface condensers offer the following features (Everett et al., 2012e):

- The vacuum in the condenser maximises the plant's thermal efficiency and reduces the heat rate.
- Because the working fluid in the power cycle is not in direct contact with the cooling medium, high-quality demineralised (demin) water may be reused.
- The condensate is deaerated, which minimises the potential for corrosion.
- A condenser serves as a collection point for condensate drains.

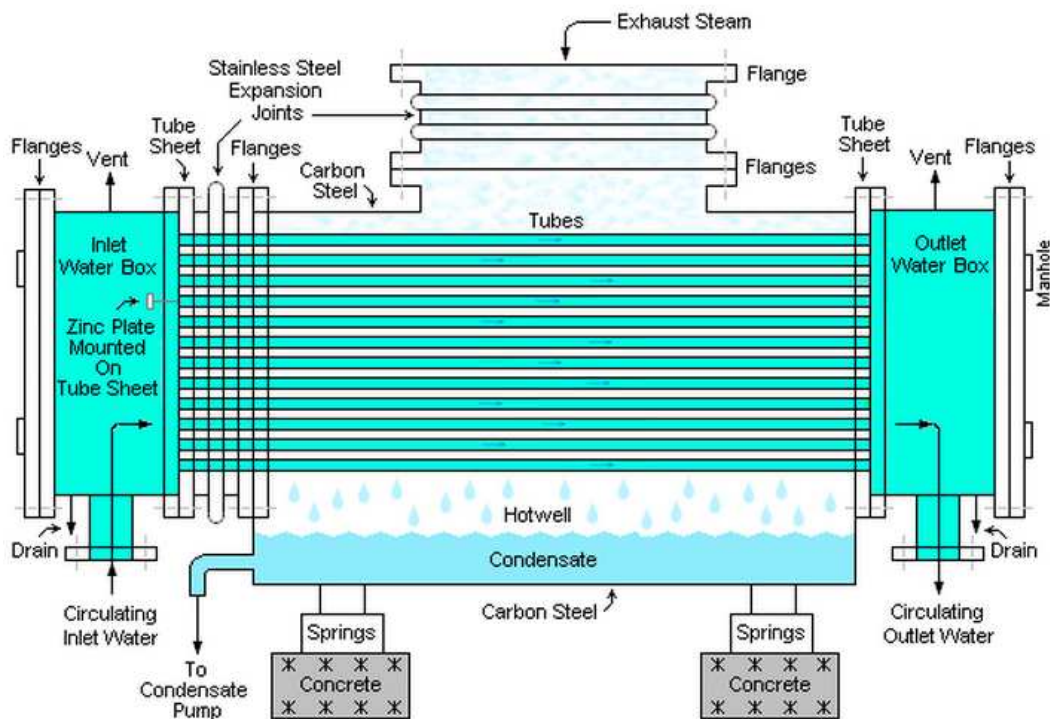


Figure 2-19: Typical power plant surface condenser (Wordpress, 2014)

2.5.3.1.3 Air-cooled condensers

Air-cooled condensers are normally used in regions where water is not freely available, in regions where there are limits to the amount of water that may be discharged from a plant and in regions where the vapour plume, associated with wet-cooling towers, is not permitted (Everett et al., 2012e). ACC may be subcategorised as direct-acting and indirect-acting condensers.

Direct-acting ACC operates like the cooling radiator of a diesel engine. The exhaust steam flows through thin, externally finned tubes. Atmospheric air is then forced over these tubes, via large

electrically driven fans, to extract heat from the steam. This heat extraction causes the steam inside the ACC tubes to condense to liquid water, after which it flows to the condensate storage tank. An illustration of a direct-acting ACC system is shown in Figure 2-20.

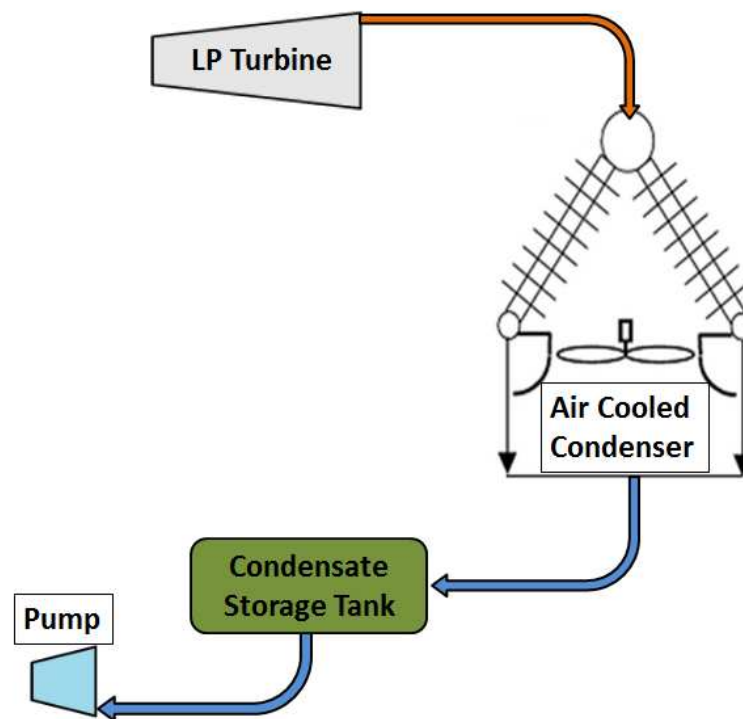


Figure 2-20: Illustration of a direct-acting air-cooled condenser system.

With the indirect-acting ACC, the turbine exhaust steam is condensed by a cooling-water loop in a conventional surface condenser. The cooling water then rejects heat to the atmosphere in a dry cooling tower by means of air flowing across external finned tubes (Everett et al., 2012e). An illustration of an indirect ACC system is shown in Figure 2-21.

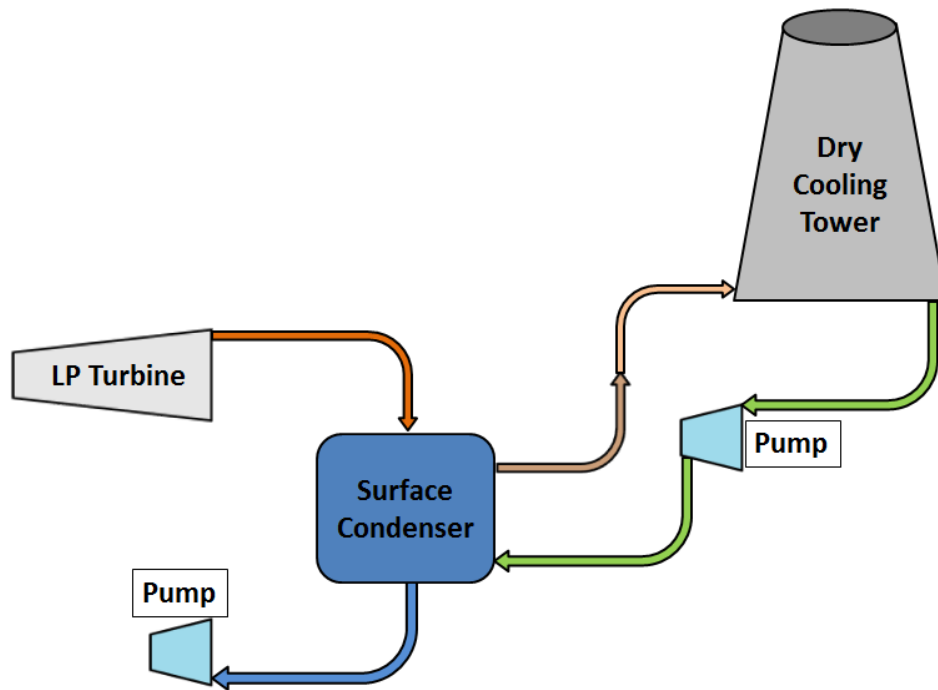


Figure 2-21: Illustration of an indirect-acting air-cooled condenser system

According to (Everett et al., 2012e), direct-acting ACC is the design more often used in conventional power generation.

2.5.3.2 Pumps

According to (Everett et al., 2012d), a number of pumps are found in each power plant, but, the regenerative Rankine cycle only includes a minimum of three pumps:

- Boiler feed pump (BFP)
- Condensate pump
- Circulation pump

In the case of a direct-acting dry-cooling system with ACC, the circulation pump will not be required.

2.5.3.2.1 Boiler feed pumps

The boiler feedwater pumps are responsible for circulating the working fluid through the Rankine cycle. They are normally situated between the deaerator storage tank (DST) and the first high-pressure heaters.

Large-scale power stations typically make use of a number of electrically driven, multistage centrifugal pumps to circulate the feedwater through the cycle. Typically, large power plants have four pump sets that consist of a booster pump and a high-pressure pump in series. The main function of a booster pump is to create the required inlet pressure at the high-pressure pump inlet to avoid cavitation. In most cases, three pump sets are in service, while the fourth is on standby. In some stations, steam-turbine driven pumps are utilised. An illustration of a BFP can be seen in Figure 2-22.

The height to which a fluid can be pumped is influenced by the fluid's temperature and atmospheric pressure.

According to (Everett et al., 2012d), the required total head developed by the pump is normally called the total dynamic head and is made up of the following important parameters:

- The total static head of discharge above the level of the suction water
- The required pressure at the point of discharge
- The friction losses in the pipes and fittings

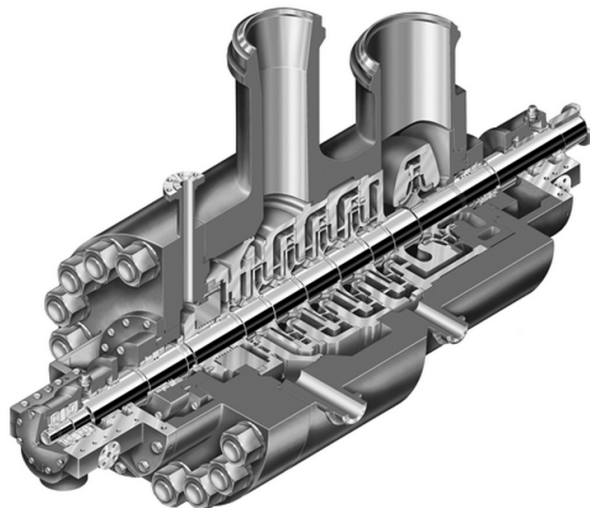


Figure 2-22: Radially split, double-case diffuser multistage boiler feedwater centrifugal pump (Everett et al., 2012d).

2.5.3.3 Feedwater heaters

According to (Everett et al., 2012a), the feedwater preheaters have two main functions in a power station:

1. To increase the feedwater temperature before it enters the boiler
2. To minimise the thermal effects on the boiler

The feedwater preheaters use steam from different turbine-extraction points to preheat the feedwater. Low-pressure feedwater heaters are situated between the condenser and BFPs, while the high-pressure feedwater heaters are found between the BFPs and the boiler's economiser. According to (Everett et al., 2012a), feedwater preheaters can be categorised as open feedwater heaters and closed feedwater heaters.

2.5.3.3.1 Open feedwater heaters

In open feedwater heaters, the bleed steam from the turbines and the feedwater mix. This enables the heater to heat the feedwater to a certain extent and to remove gases, which could cause corrosion of equipment and piping systems from the feedwater (deaerating effect). These heaters are also generally less expensive and have better heat-transfer characteristics than closed feedwater heaters.

Eskom power stations mainly make use of the tray-type and the stork-type deaerators.

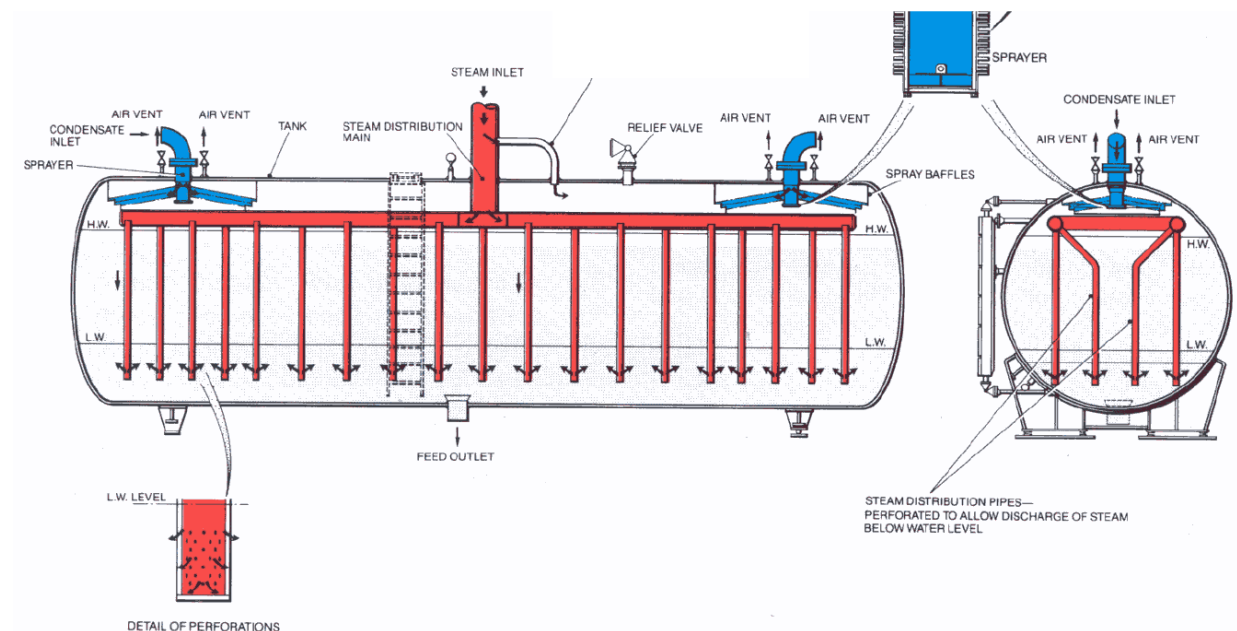


Figure 2-23: Stork-type deaerator

Figure 2-24, shows the working principles of spray- and spray-scrubber type deaerators.

The condensate formed in the high-pressure heaters is also reintroduced into the feedwater at the deaerator. When it is assumed that the feedwater outlet temperature is equal to the saturation temperature of the extraction steam, the following equation may be used to calculate the amount of extraction steam required.

$$\dot{m}_E = \frac{(\dot{m}_o h_o) + (\dot{m}_i h_i) + (\dot{m}_d h_d)}{h_E} \quad 2.19$$

With:

- $\dot{m}_e$ = Mass flow of the extraction steam [kg/s]
- $\dot{m}_i$ = Mass flow of the feedwater entering the deaerator [kg/s]
- $\dot{m}_o$ = Mass flow of the feedwater leaving the heat deaerator [kg/s]
- $\dot{m}_d$ = Mass flow of condensate from the high-pressure heaters [kg/s]
- h_o = Enthalpy of the feedwater leaving the deaerator [kJ/kg]
- h_i = Enthalpy of the feedwater entering the deaerator [kJ/kg]
- h_e = Enthalpy of the extraction steam entering the deaerator [kJ/kg]
- h_d = Enthalpy of the condensate from the high-pressure heaters [kJ/kg]

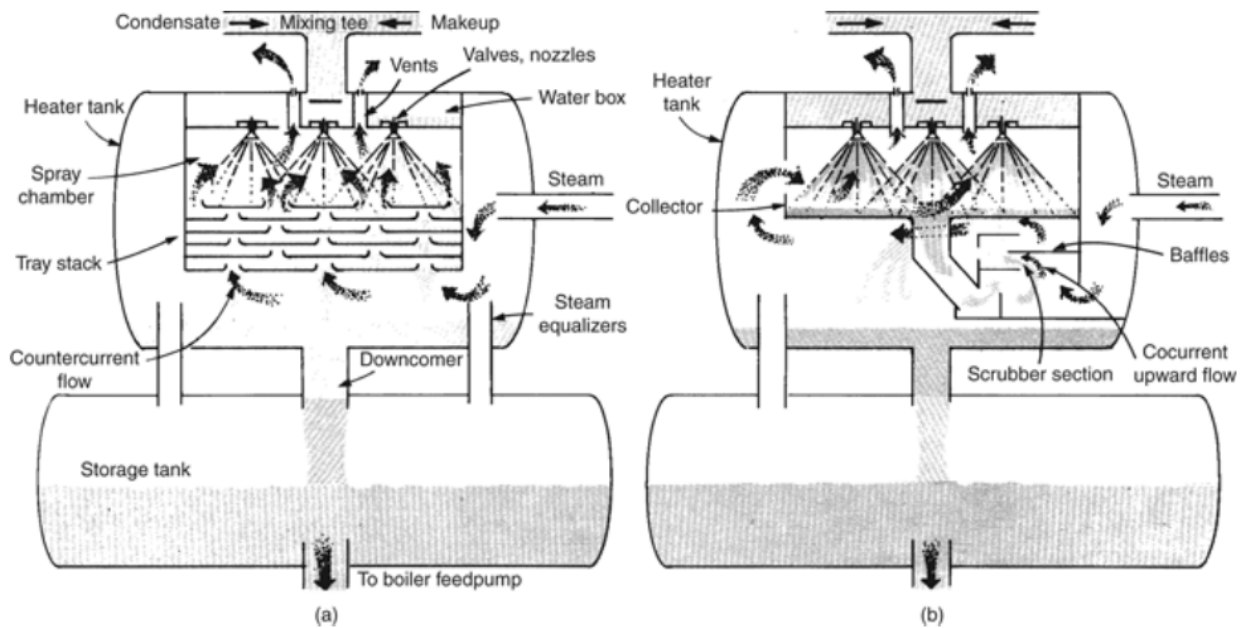


Figure 2-24: (a) Spray-type deaerator, (b) Spray-scrubber deaerator (Everett et al., 2012a)

2.5.3.3.2 Closed feedwater heaters

Unlike in an open feedwater heater, the bleed steam and feedwater do not mix in a closed feedwater heater. According to (Everett et al., 2012a), closed feedwater heaters are specialised shell and tube heat exchangers. The distillate formed in the heaters can either be pumped via the drain pumps into the main feedwater line or it can be introduced, via a trap, to another lower-pressure heater or to the main steam condenser.

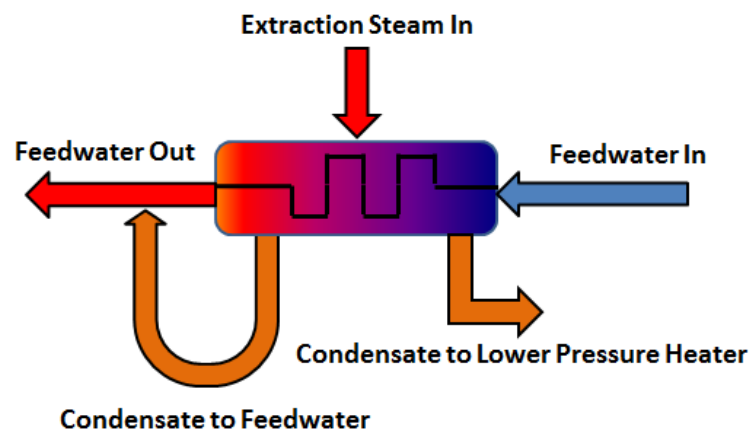


Figure 2-25: Basis illustration of closed feedwater heater scenarios

If it is assumed that the heater can increase the temperature of the feedwater to the temperature of the condensate formed, the following equation may be used to calculate the amount of extraction steam required:

$$\dot{m}_e = \frac{\dot{m}_i(h_o - h_i)}{(h_e - h_c)} \quad 2.20$$

Where:

$\dot{m}_e$ = Mass flow of the extraction steam [kg/s]

$\dot{m}_i$ = Mass flow of the feedwater [kg/s]

h_o = Enthalpy of the feedwater leaving the heat exchanger [kJ/kg]

h_i = Enthalpy of the feedwater entering the heat exchanger [kJ/kg]

h_e = Enthalpy of the extraction steam entering the heat exchanger [kJ/kg]

h_c = Enthalpy of the condensate leaving the heat exchanger [kJ/kg]

The low-pressure closed feedwater heaters are normally situated between the condenser extraction pumps (CEP) and the deaerator storage tank (DST), while the high-pressure closed feedwater heaters are found between the EFP and the economiser.

In some closed feedwater heaters, the feedwater pressure is higher than the bleed steam pressure, which may result in feedwater flowing back into the turbines if a tube leak occurs. For this reason, feedwater heater tube leaks must be avoided at all costs.

2.5.3.4 Steam generator

Steam generators are responsible for transferring the energy released when combusting a fuel, to the working fluid, as efficiently as possible. Modern steam-generator systems consist of a number of components, depending on the type of boiler:

- Boiler wall
- Drum
- Superheaters
- Reheaters
- Economiser

The main types of firing systems used in coal-fired boilers used in the power-generation sector are the entrained-flow pulverised fuel (PF) or pulverised-coal (PC) combustion method and the circulating fluidised-bed (CFB) method. The CFB method will not be discussed further in this study. The more popular of the two is the PC method, where the coal is ground into a fine powder in the mills, after which it is injected into the furnace through a number of burners. This very fine PF is then blown into the furnace with a calculated amount of air, where it burns at temperatures in excess of 1 300 °C.

PC boilers may now be subdivided into the two-pass boiler type and the tower-boiler type (Figure 2-26).

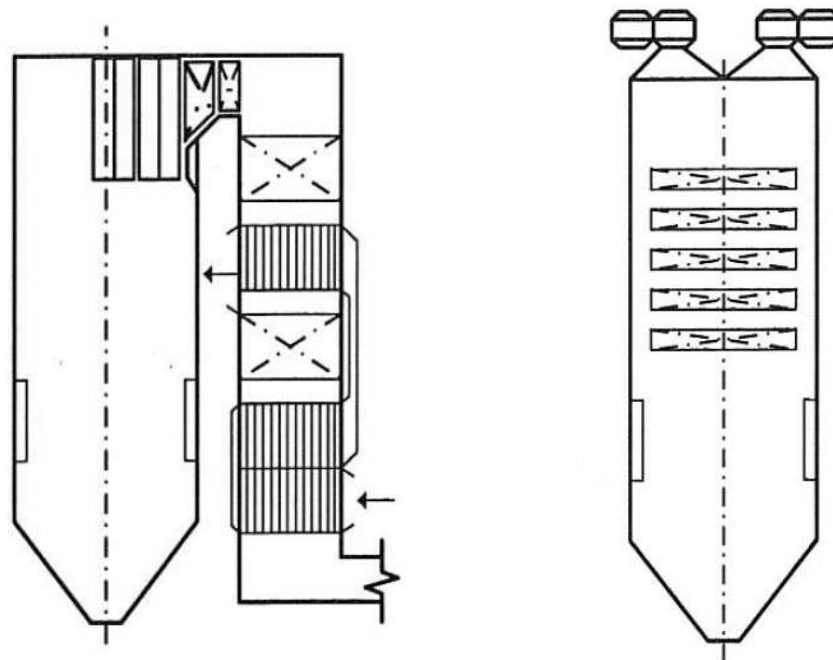


Figure 2-26: Two-pass boiler type (left) and tower-boiler type (right) (Zhang et al., 2013)

The two-pass configuration is more commonly used in modern subcritical to ultra-supercritical steam generators, therefore only the two-pass configuration will be discussed in more detail during this study.

2.5.3.5 Attemperator spray

According to (Everett et al., 2012b), attemperator systems are predominantly used to control steam temperatures at the boiler's superheater and reheater heat exchangers. If a superheater or reheater is designed large enough to produce the desired steam temperature at low loads, it will in effect give a steam temperature higher than the desired temperature at higher loads. If a temperature-control system can lower the temperature to the desired temperature during higher load conditions, a constant temperature over the range of loads may be obtained. Temperature-control mechanisms include, attemperation spray, flue gas and flue-gas recirculation systems.

In the spray-type attemperation method, relatively colder water is sprayed directly into the steam line. This water will then evaporate as its temperature increases, while the temperature of the initial steam will decrease until equilibrium is reached. The amount of spray water injected into the steam determines the amount of cooling.

The attemperator spray water is normally tapped from the feedwater cycle at a certain BFP interstage or after the high-pressure heaters.

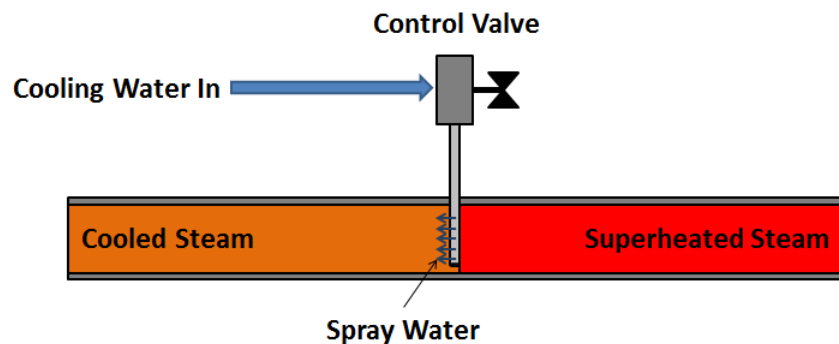


Figure 2-27: Basic illustration of an attemperator spray-water system

The amount of spray water required to cool the steam to a specified temperature may be calculated with the following equation:

$$\dot{m}_{sw} = \frac{\dot{m}_{IN}(h_{IN} - h_{OUT})}{(h_{OUT} - h_{sw})} \quad 2.21$$

Where:

$\dot{m}_{sw}$ = Mass flow of the spray water [kg/s]

h_{sw}	= Enthalpy of the spray water [kJ/kg]
m_{in}	= Mass flow of the steam before cooling [kg/s]
h_{in}	= Enthalpy of the steam before cooling [kJ/kg]
h_{out}	= Enthalpy of the steam, after cooling [kJ/kg]

2.5.3.6 Steam turbines

The turbines are designed to allow the steam to expand to a certain extent, which causes the velocity of the steam to increase. In general, there are two principles according to which the steam turbine converts the velocity energy into mechanical energy.

In the case where a stream of water is directed on a glass sheet at a 90° angle, the sheet will be subjected to a considerable force because of the impulse of the water. A turbine that makes use of the impulsive force of high-velocity fluid is known as an impulse turbine.

The reactionary force exerted on the nozzle by the water is in the opposite direction of the flow of water. A turbine that utilises the reaction force produced by the flow of a fluid through a nozzle can be classified as a reaction turbine.

According to (Everett et al., 2012e), in all commercial turbines, a combination of impulse and reactive forces is utilised. Both impulse and reaction blading on the same shaft must be utilised to extract mechanical energy more efficiently than one alone does. An illustration of impulse and reaction forces can be seen Figure 2-28.

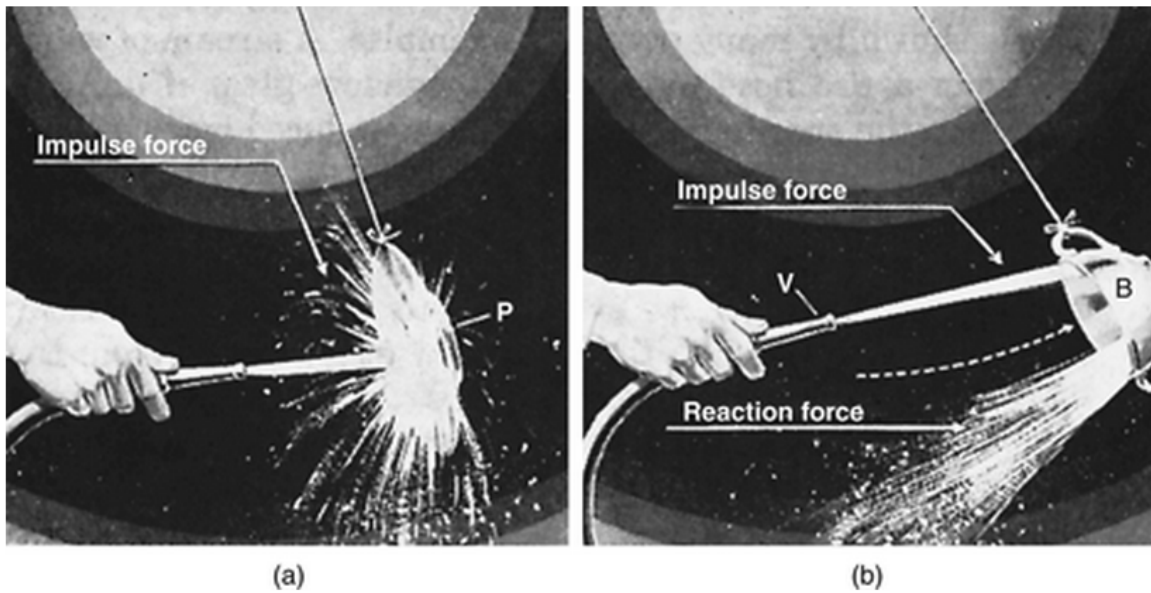


Figure 2-28: Illustration of (a) impulse and (b) reaction forces (Everett et al., 2012e)

Steam turbines can be categorised as condensing, non-condensing, reheat-condensing and extraction and induction turbines.

2.5.3.6.1 Condensing steam turbine

According to (Everett et al., 2012e), condensing steam turbines are mainly used in the power-generation sector and exhaust the steam to the plant's condenser below atmospheric pressure. An illustration of a 100 MW condensing turbine is shown in Figure 2-29.

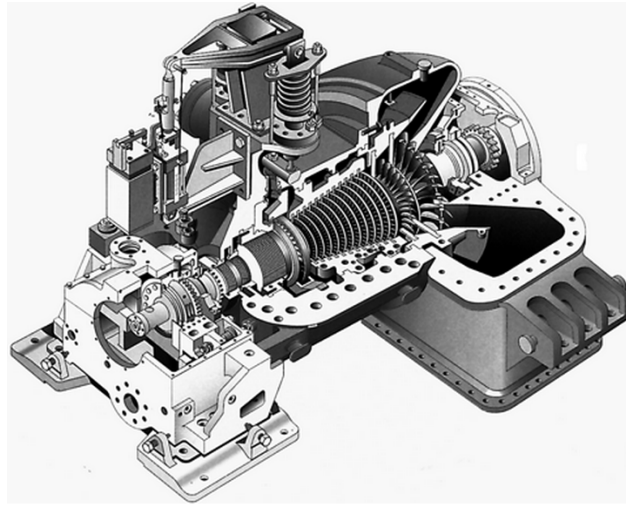


Figure 2-29: Condensing steam turbine (Everett et al., 2012e)

2.5.3.6.2 Non-condensing steam turbine

These types of steam turbines are commonly used in a process plant where the exhaust steam is controlled by a regulating station to supply the process steam to the rest of the plant at a specific pressure (Everett et al., 2012e). An illustration of a non-condensing steam turbine can be seen in Figure 2-30.

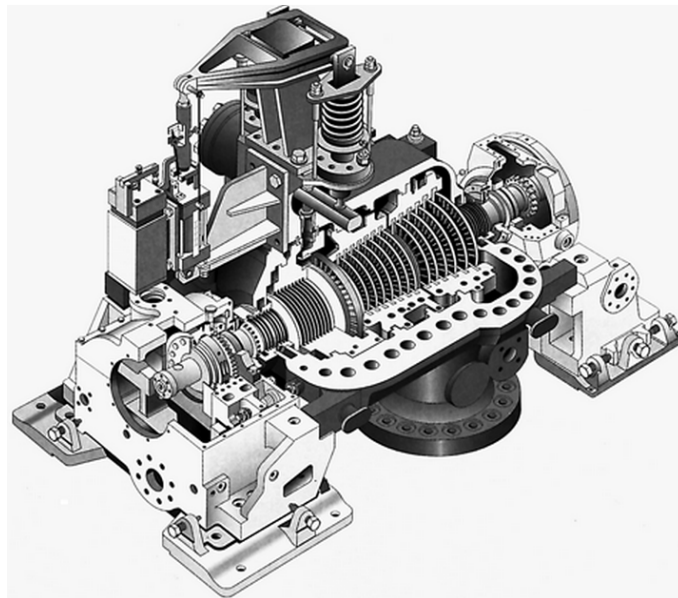


Figure 2-30: Non-condensing steam turbine (Everett et al., 2012e)

2.5.3.6.3 Reheat-condensing turbine

Reheat-condensing turbines are also most commonly used in the power-generation sector. According to (Everett et al., 2012e), the main steam exhausts from the high-pressure stages of the turbine, after which it is returned to the boiler for reheating. The reheated steam, which is at a lower pressure, is then returned to the intermediate-pressure and/or low-pressure stages of the turbine for further expansion.

2.5.3.7 Fans

A large-scale coal-fired power station makes use of a number of fans for the following key tasks in the balanced-draft operating mode:

- Supplying the correct amount of air/oxygen required in the combustion process
- Removing the flue gas from the furnace
- Delivering the PF from the mills to the burners
- Circulating furnace gases for better heat transfer

Figure 2-31 gives a schematic illustration of a large-scale axial-flow fan typically used in modern coal-fired power stations.

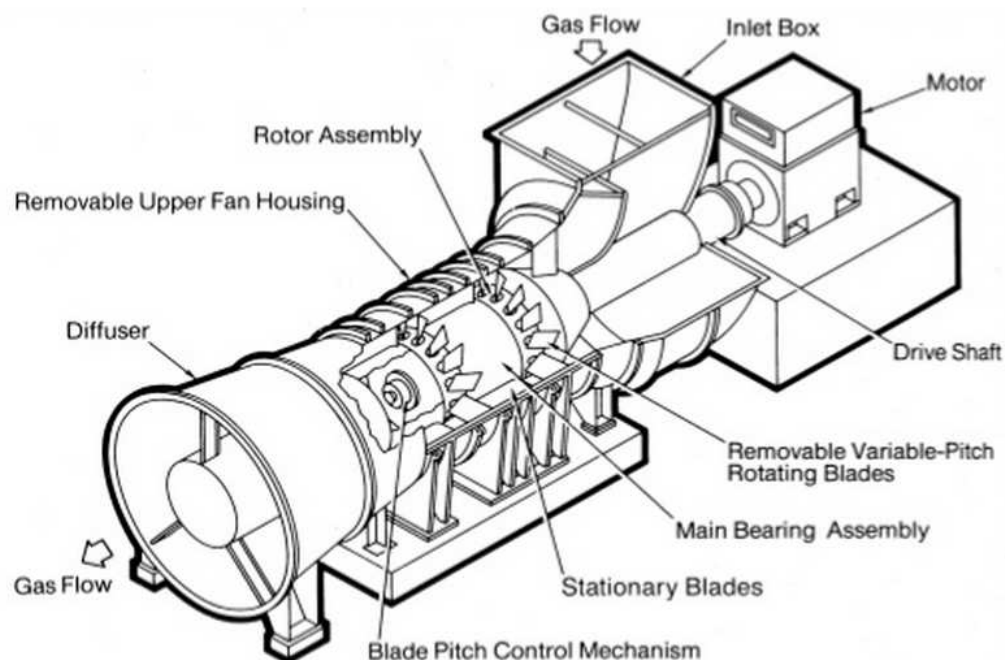


Figure 2-31: Illustration of an axial-flow fan (Choudhury)

2.6 Relevant economic parameters

2.6.1 Capacity factor

The capacity factor (CF) of a plant gives an indication of the degree of utilisation of the plant. A 100% CF means that a plant has been in operation for an entire year, at its peak generating capacity, without any downtime. The higher the CF of a power station, the more electricity is generated and the shorter the payback period becomes. The CF can be calculated with the following equation:

$$CF = \frac{W_a}{(P_{out} \times 365 \times 24)} \quad 2.22$$

Where:

CF = Capacity factor [%]

W_a = Annual electrical energy output [kWh]

P_{out} = Rated power output [kW]

2.6.2 Levelised cost of electricity

The LCOE illustrates the cost of generating one unit of electricity in kWh or MWh and can be used to measure the relative cost competitiveness of different generating technologies. The LCOE can also be used to show how key factors, such as interest rates, fuel cost, etc, affect the cost of different technologies (Allan et al., 2011).

According to (Allan et al., 2011), there are two methods commonly used to calculate the LCOE: the “annuitising” method and the “discounting” method. In the discounting method the yearly costs and electricity production for the life of the plant is discounted back to the present value (PV) or year 0. The following formula can be used to calculate the LCOE with the discounting method:

$$LCOE = \frac{\text{Total discounted expenses}}{\text{Total discounted power production}} = \frac{\sum_{t=0}^n \frac{C}{(1+r)^t}}{\sum_{t=0}^n \frac{E}{(1+r)^t}} \quad 2.23$$

Where:

n = Plant lifetime [years]

t = Relevant year [year]

r = Discount rate [%]

C = Total yearly expenses [R]

E = Total yearly energy production [kWh or MWh]

2.7 Concentrating solar power

According to Plutarch, a Greek historian, Archimedes used the power of the sun as early as 216 BC to destroy an invading Roman fleet before they could attack Syracuse. Legend has it that Archimedes used polished shields to concentrate the sunlight on the approaching wooden ships, which eventually set them alight. True or not, CSP is already mentioned in the Greek mythology.

Concentrating solar power plants make use of mirrors and/or other reflecting surfaces to concentrate sunlight (radiation) on a smaller focus point. By doing so, intense heat can be acquired at this point, which may be used to energise a working fluid.

According to (Gevorkian), a French scientist, Augustin Mouchot used the concentrated power of the sun to create steam for the first steam engine in 1866. As seen in Figure 2-32, one of the first applications for solar power was to power a printing press.



Figure 2-32: Historical use of solar power in printing press (Gevorkian)

There are a number of different techniques to transfer the solar radiation into electricity. In some instances a working fluid, such as bromide with special heat-absorbing properties is used, which heats up very rapidly. In other instances, a working fluid is circulated through the solar receiver by means of pumps. The different CSP technologies are discussed in section 2.7.2 below.

In recent years, thermal storage applications were also introduced to the CSP environment, in which thermal energy is stored in the form of heat to enable a plant to generate electricity during night time or low solar irradiation conditions. Molten salts or compressed steam is normally stored in a well-insulated reservoir until needed.

According to (Gevorkian), the major benefits of CSP electricity generation is the fact that no greenhouse gases, such as nitrogen oxides (NO_x) and sulphur oxides (SO_x), or CO_2/CO_2 equivalent gases are produced. Large-scale CSP technologies have also proved that it is compatible and reliable to feed stable electricity into a grid. The fact that CSP has a storage element associated with it, means that expensive polluting backup systems such as open-cycle gas turbines (OCGT) are no longer required to produce a stable power output.

At the end of 2013, the global CSP generating capacity was about 3 000 MW, which is expected to increase to about 10 GW by the end of 2015 (Cau and Cocco, 2014).

The only significant role-playing disadvantage of CSP electricity generation is the fact that it is still expensive, one has no control over the resource availability and the fact that the footprint per kW is very large compared to fossil-fuel power stations.

2.7.1 Solar resource

The irradiation emitted from the sun is caused by an extremely violent fusion process in the sun's core, where hydrogen and helium atoms are fused together in a nuclear reaction, which, in turn, gives off an enormous amount of energy (Dekker et al., 2012). According to (Munzhedzi and Sebitosi, 2009), it is calculated that the amount of irradiation emitted from the sun's surface is approximately $63\,000\,000\text{ W/m}^2$. By using the conservation of energy principles and energy flux density formulas and by incorporating known facts, such as the distance from the earth to the sun, scientists were able to calculate that approximately $1\,368\text{ W/m}^2$ of the initial 63 MW/m^2 reaches the surface of the earth's atmosphere (Dekker et al., 2012). This figure is known as the solar constant. Because the earth rotates on its own axis and revolves around the sun in an ecliptic plane, the solar radiation received at a specific point on the surface of the earth constantly varies.

It is a well-known fact that the earth moves around the sun in an elliptical orbit. It takes the earth approximately 365,24 days to complete one full revolution. In Figure 2-33 below, the orbit of the earth in relation to the sun, the two equinoxes, the two solstices, the aphelion, the perihelion and the position of the smallest distance between the sun and earth can be seen.

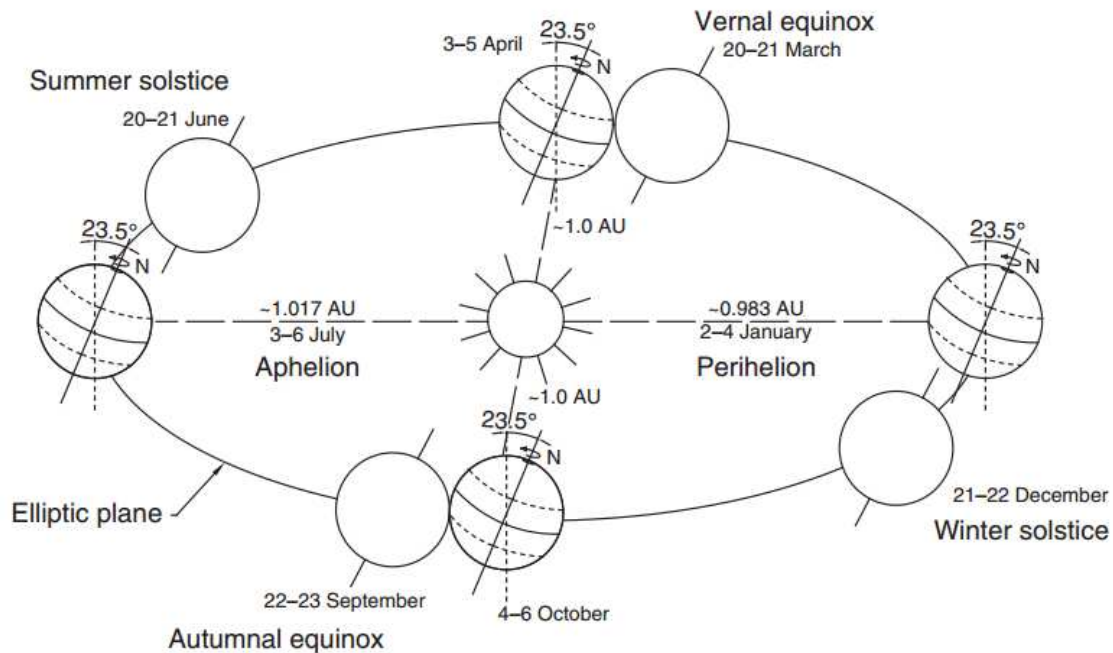


Figure 2-33: The motion of the earth around the sun (Kambezidis, 2012)

In the equinox positions, the length of the day and night are exactly equal. Equinox occurs twice with every revolution the earth makes around the sun, the first occurrence being on 20 - 21 March (vernal equinox) and then again on 22-23 September (autumnal equinox). Solstice is the point on the earth's path around the sun, at which the day is the longest (summer solstice, 20-21 June) or the shortest (winter solstice, 21-22 December). Aphelion (3-6 July) is the point where the distance of the earth from the sun is the greatest ($1\,52.2 \times 10^6$ km), while perihelion (2-4 January) is the point where this distance is the smallest (147.3×10^6 km). The mean distance ($149\,598 \times 10^6$) between the earth and the sun is called an astronomical unit (AU), and occurs twice a year on 3 to 5 April and on the 4 to 6 October (Kambezidis, 2012).

One may also imagine a celestial sphere with the earth at its centre and the sun revolving around it (Figure 2-34). The angle between the lines joining the centres of the sun and the earth to the equatorial plane is called the solar declination angle (δ). According to (Kambezidis, 2012), this angle changes constantly and can vary between $+23.5^\circ$ (summer solstice) and -23.5° (winter solstice).

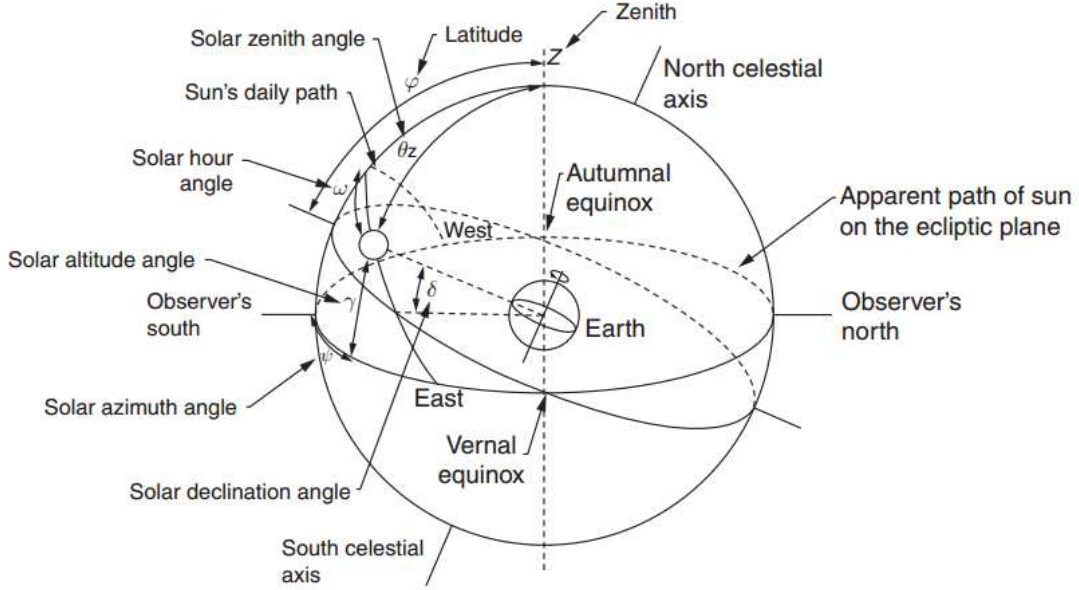


Figure 2-34: The apparent daily path of the sun in the sky for a certain place on the earth (Kambezidis, 2012)

The solar declination angle may be calculated with the following equation (Kambezidis, 2012):

$$\delta = (0.006918 - 0.399912\cos M + 0.070257\sin M - 0.006758\cos 2M + 0.000907\sin 2M - 0.002697\cos 3M + 0.00148\sin 3M) \left(\frac{180}{\pi}\right) \quad 2.24$$

Where M is called the day angle and is given by:

$$M = \frac{2\pi D}{365} \quad 2.25$$

With:

M = Day angle

D = Day number of the year

To describe the sun's path across the sky, as shown in Figure 2-34, one needs to know two parameters (a) the angle of the sun relative to a line perpendicular to the earth's surface (Zenith angle, Θ_z) and (b) the sun's position relative to the observer's north-south axis (Azimuthal angle, Ψ), (Kambezidis, 2012).

By using the abovementioned angles, one can accurately determine where the sun will be, relative to the earth at any given point in time.

According to the physics principle of conservation of energy, the earth's radiation budget represents the accounting of the balance between incoming radiation, which is almost entirely solar radiation, and outgoing radiation, which is partly reflected solar radiation and partly radiation emitted from the earth system, including the atmosphere (Directorate, 2010). Should this budget be out of balance (Figure 2-35), it can cause the heating or cooling of the atmosphere, which will eventually cause global warming or cooling.



Figure 2-35: Basic illustration of earth's radiation components (Directorate, 2010)

2.7.1.1 Parameters affecting the solar resource on the earth's surface

Three main atmospheric processes influence the amount of radiation that will eventually hit the surface of the earth. These processes are known as:

- Scattering
- Insolation
- Reflection

2.7.1.1.1 Scattering

According to (Pidwirny, 2006) the scattering process is, in fact, responsible for our daytime blue skies that would be pitch black if no scattering occurred. Scattering is also responsible for phenomena such as rainbows, where the light from the sun is redirected in water droplets in the atmosphere.

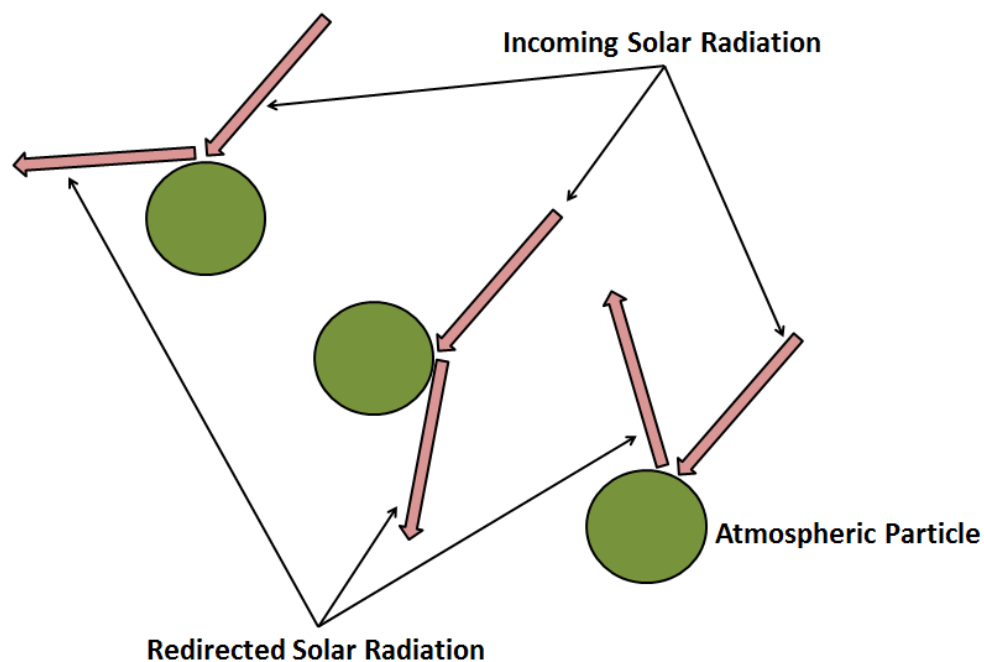


Figure 2-36: Basic illustration of the scattering process

This process (Figure 2-36) occurs when small atmospheric particles and gas molecules diffuse part of the incoming solar radiation into random directions without changing the wavelength of the electromagnetic energy. As a result of the scattering process, a significant amount of radiation is redirected back to space, which means that less of the incoming radiation will reach

the surface of the earth. The magnitude of the scattering process is dependent on the wavelength of the incoming radiation and the size of the scattering particle or gas molecule.

2.7.1.1.2 Insolation

Some particles in the atmosphere have the ability to absorb the incoming radiation. The energy is then retained by the substance and converted into heat energy. According to (Pidwirny, 2006), the absorption of solar radiation by substances within earth's atmosphere results in temperatures no higher than 1 800 °C.

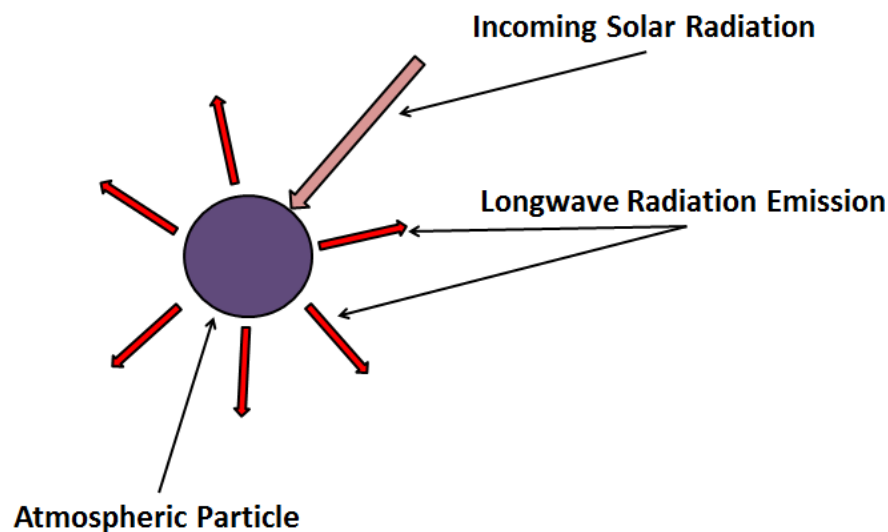


Figure 2-37: Basic illustration of the insolation process

By incorporating Wien's displacement law (Fu, 2006), one can note that substances at these temperatures will emit their radiation in the long-wave band (Figure 2-37). The long-wave radiation is emitted into all directions from the substance, which means that a significant portion of it is sent back to space (Pidwirny, 2006)

2.7.1.1.3 Reflection

During the reflection process (Figure 2-38); the incoming solar radiation is redirected at a 180° angle by atmospheric particles, which means that 100% of the incoming energy is lost in this process. According to (Pidwirny, 2006), most of the sunlight is reflected by liquid or solid water particles in the clouds.

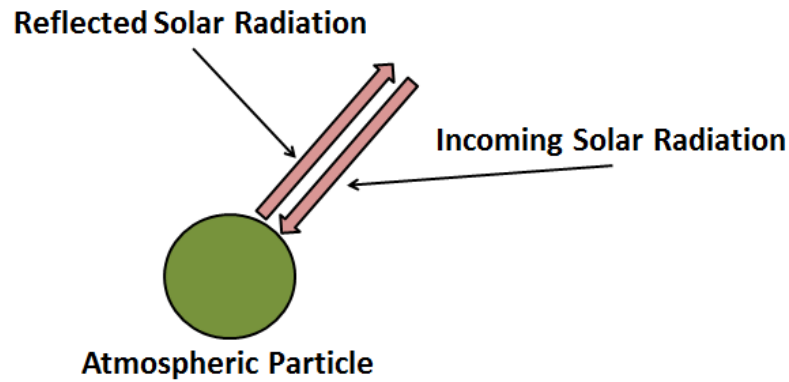


Figure 2-38: Basic illustration of the reflection process

2.7.1.2 Components of solar irradiation

The solar radiation that eventually reaches the surface of the earth may be subcategorised into three main components, namely:

- Global horizontal irradiation (GHI) [W/m^2]
- Direct normal irradiation (DNI) [W/m^2]
- Diffuse horizontal irradiation (DHI) [W/m^2]

2.7.1.2.1 Direct normal Irradiation

The DNI is the rate of solar energy received on a surface perpendicular to the rays directly from the sun. The DNI is typically measured in W/m^2 with a pyrheliometer mounted on a sun tracker system. Because the DNI is the direct (straight line) solar energy rate, it is absolutely dependent on a clear line of sight to the sun, which means that cloud cover has a massive effect on the magnitude of this figure.

This solar quality is of particular interest to CSP plants, because only the direct sunlight can be accurately reflected to the plant's thermal receivers.



Figure 2-39: Typical pyrliometer with tracking system

2.7.1.2.2 Global horizontal irradiation

The GHI is measured in W/m^2 and can be defined as the total amount of shortwave radiation, per metre squared, received from the sun by a surface horizontal to the surface of the earth. This figure is of particular interest to photovoltaic (PV) installations and includes both the DNI and DHI. The GHI is typically measured with a pyranometer (Figure 2-40), but if not measured, the GHI may be calculated with the following equation:

$$GHI = DNI \cos \theta + DHI \quad 2.26$$

Where:

- θ = Zenith angle [$^\circ$]
- GHI = Global horizontal irradiation [W/m^2]
- DNI = Direct normal irradiation [W/m^2]
- DHI = Diffuse horizontal irradiation [W/m^2]



Figure 2-40: Typical pyranometer.

2.7.1.2.3 Diffuse horizontal irradiation

The DHI is the component of the GHI, and may be defined as the amount of solar radiation (W/m^2) on a horizontal surface that has been scattered by atmospheric particles and does not come directly from the sun (direct beam). As with the GHI, the DHI component of the radiation is also typically measured with a pyranometer (Figure 2-40), but with the direct sunlight (DNI) blocked from entering the sensor. In effect, the GHI is measured in the shade.

The sun is normally blocked by a ball or disc (Figure 2-41) which only removes the 5° cone around the sun. A tracking system must be utilised to continually shade only the sensor of the pyranometer.



Figure 2-41: Complete solar radiation measurement station

2.7.2 Concentrating solar power technologies

According to (Gordon and Society, 2001), direct solar conversion is probably the single largest renewable energy resource, and the solar thermal technology is potentially one of the lowest cost options for extracting electricity from this resource.

As already mentioned, CSP technologies make use concave reflective surfaces to concentrate the solar radiation of a large area onto a relatively smaller area to produce vast amounts of heat. The amount of light concentration achieved by a these collectors is called the concentration ratio (CR) and is represented by $[C]$. The CR of flat plate collectors with no reflectors is equal to 1, where $C > 1$ for any application where sunlight is concentrated on a receiver (Kalogirou, 2012a).

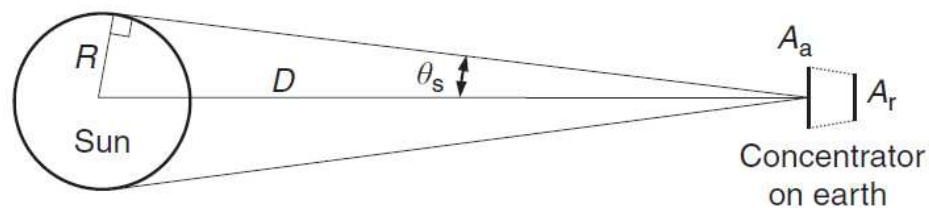


Figure 2-42: Schematic of the sun and a concentrator on earth (Kalogirou, 2012a)

According to (Kalogirou, 2012a), if one considers an aperture with area (A_a) and a receiver with area (A_r) located a distance (D) from the centre of the sun, as illustrated in Figure 2-42, and if it is assumed that the sun is a sphere with radius (R), then, as seen from earth, the sun has a half angle θ_s , which is called the sun acceptance half-angle and is equal to $0,265^\circ$.

If a perfect collector and tracking system is considered, the maximum CR (C_{max}) is only dependent on the sun's acceptance half-angle (Kalogirou, 2012a). For single-axis tracking systems, C_{max} is calculated with the following equation (Kalogirou, 2012a):

$$C_{max} = \frac{1}{\sin \theta_s} = 216 \quad 2.27$$

For a two-axis tracking system, C_{max} is calculated with (Kalogirou, 2012a):

$$C_{max} = \frac{1}{\sin^2 \theta_s} = 46\,747 \quad 2.28$$

A solar field or solar thermal array is like any other heat source and may be used as a substitution in the place of a fossil-fuel furnace or nuclear reactor. For this reason, the same

thermodynamic cycles used in the power-generation sector may be utilised to extract electricity for solar radiation.

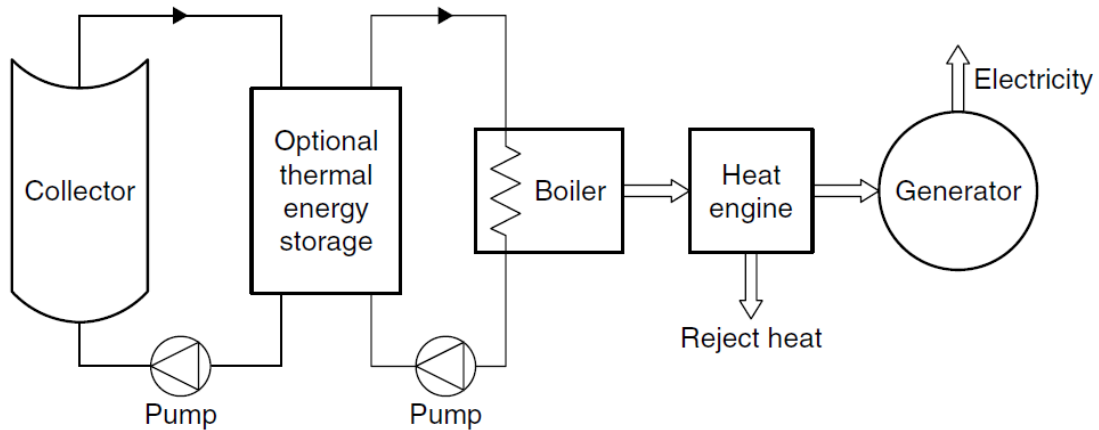


Figure 2-43: Basic illustration of a solar thermal energy conversion system (Kalogirou)

The thermal efficiency (η_{th}) of a CSP plant represents the percentage of the total DNI available to the collectors, which is eventually converted into thermal energy in the plant's receiver. The thermal efficiency can be calculated with the following equation:

$$\eta_{th} = \frac{Q}{E_{DNI}} \quad 2.29$$

Where:

Q = Heat production per unit of absorber area [W/m^2]

E_{DNI} = Total DNI collected [W/m^2]

The total efficiency (η_{tot}) is the percentage of the available solar radiation collected by the plant's collectors, which is eventually converted into electricity. The total efficiency may be calculated with the following equation:

$$\eta_{tot} = \eta_{th} \times \eta_{conv} \quad 2.30$$

Where:

η_{conv} = Conversion efficiency of the power cycle (0 – 50%)

The overall efficiency may also be calculated by dividing the net annual electricity output by the annual incident solar energy (Li et al., 2014).

$$\eta_{tot} = \frac{\text{Net Annual Electricity Output [kWh]}}{\text{Annual Incident Solar Energy [kWh]}} \quad 2.31$$

According to (Gordon and Society, 2001), the total amount of solar energy that is converted to electricity is usually between 10% and 20%. The typical loss path of a large-scale STE plant can be seen in Figure 2-44.

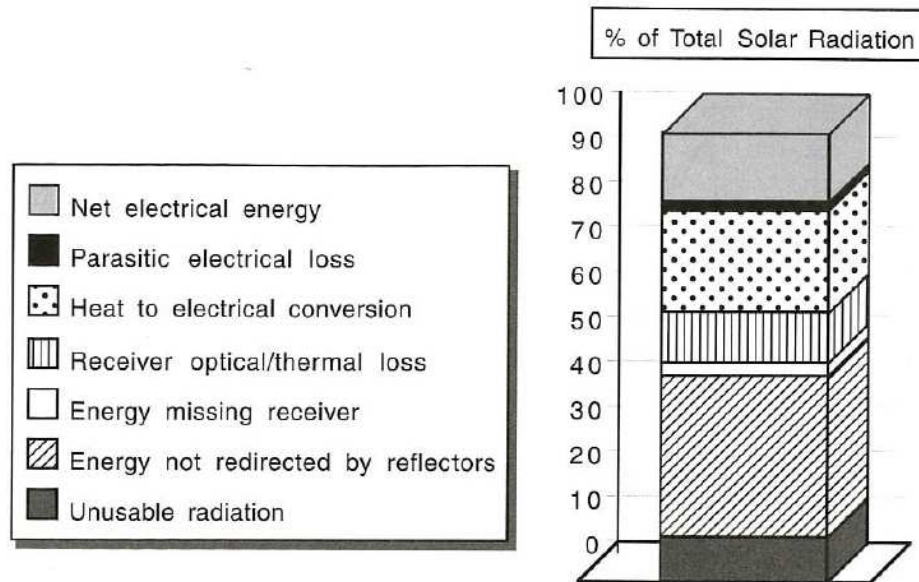


Figure 2-44: Loss path for a 100 MW central receiver plant (1993) (Gordon and Society, 2001)

According to (Gordon and Society, 2001) CSP systems can be subcategorised into point focus systems in which sunlight is concentrated on a certain point and line focus systems.

Line focus systems normally utilise one-dimensional tracking where the sun's energy is concentrated on a fluid-filled tube/pipe, situated in the focal line of a parabolically shaped collector.

Point focus systems, on the other hand, normally make use of two-dimensional tracking systems to track the sun on the x and y planes as it moves across the sky. These systems use multiple large reflectors to concentrate the sun's energy onto a single target/receiver.

For point focus systems, heliostat field collectors (HFCs) or central receiver collector (CRC), Fresnel lens collectors (FLCs) or parabolic dish collectors (PDCs) are normally used, whereas

for line focus systems, parabolic trough collectors (PTCs) and linear Fresnel collectors (LFCs) are normally used. PDCs are not discussed in more detail, as they are not relevant to this study.

The peak solar efficiency, solar to electric efficiency, land requirement, concentration ratios and capacity ranges for the different CSP technologies can be seen in the table below.

Table 2-3: Performance characteristics of various CSP technologies (Lovegrove and Stein, 2012)

Technology	Capacity range (MW)	Concentration	Peak solar efficiency (%)	Solar-electric efficiency (%)	Land use (m ² /MWh-a)
Parabolic trough	10–200	70–80	21	10–15	6–8
Fresnel reflector	10–200	25–100	20	9–11	4–6
Power tower	10–150	300–1000	20	8–10	8–12
Dish-Stirling	0.01–0.4	1000–3000	29	16–18	8–12

Up to date (April 2014) the largest CSP plant ever built, is BrightSource's Ivanpah Solar Electric Generating System (Figure 2-45) in California's Mojave Desert, which started operation in 2013. This plant has a net generating capacity of 377 MW (392 MW_{Gross}) and comprises three central receiver units, which has a footprint of about 14,2 km² (BrightSource, 2013).



Figure 2-45: Photograph of BrightSource's Ivanpah STE plant in the Mojave Desert (BrightSource, 2013).

2.7.2.1 Parabolic trough

Normally the linear receiver of a PTC solar thermal electricity (STE) system is placed along the focal line of the parabolic collector to form an external surface receiver, which normally has a total length of between 25 to 150 m (Kalogirou). The receiver is normally plated with a selective coating that has a high absorbance for solar radiation but a low emittance for thermal radiation loss and is surrounded by a glass tube cover, to minimise convection losses.

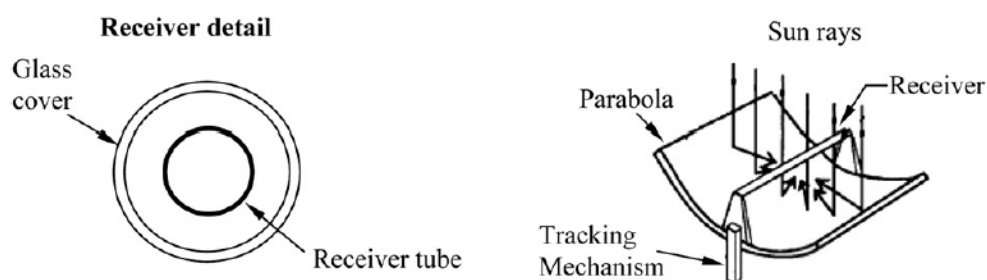


Figure 2-46: (Left) - Receiver detail (Right) – Illustration of the reflector, receiver and supporting pedestals of a PTC module (Kalogirou, 2012b)

PTCs are usually built in modules (Figure 2-46) and are supported by pedestals on either side. These collectors only require single-axis-tracking, and therefore long collector modules are produced.

These modules may be oriented in an east-west direction in which the sun is tracked from north to south, or it can be oriented in a north-south direction in which the sun is tracked from east to west (Kalogirou, 2012b). The advantages of the east-west oriented troughs are that only a small collector adjustment is required during the day, and the full aperture always faces the sun in the middle of the day, but the collector performance during early mornings and late afternoons is greatly reduced because of large incidence angles (cosine loss). On the other hand, north-south orientated plants have their highest cosine loss at noon and the lowest loss in the early mornings and late evenings. Over a 24-month period, a horizontal north-south field normally collects slightly more energy than a horizontal east-west plant. However, the north-south field collects a lot of energy in summer and a significant amount less in the winter months. The east-west field collects more energy in winter than a north-south field and less in summer, providing a more constant annual output (Kalogirou, 2012b).

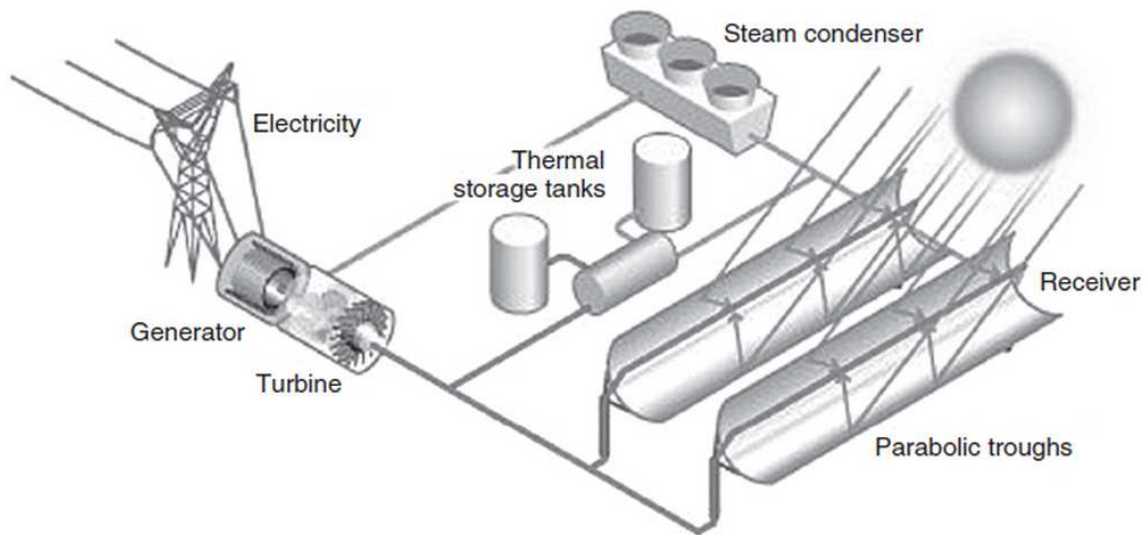


Figure 2-47: Graphical illustration of a parabolic trough STE plant (Gevorkian)

The tracking systems of all CSP plants are of the utmost importance, as they play a vital role in the performance of a plant, as well as in various safety and protection systems. The tracking system is responsible for accurately following the sun, as it moves across the sky, to keep a constant focal point on the plant's receiver. The tracking system is also normally programmed to rotate the collectors to a safe position, should storm or harmful conditions be detected (eg strong winds, hail, heavy rain, etc.)

According to (Kalogirou), the PTCs contain the most advanced technology to generate heat for STE generation and for process heat applications, and can reach temperatures in excess of 400 °C.

The largest application for PTC, STE systems are the southern California power plants known as solar electric generating systems (SEGS) (Figure 2-48) that already had a total installed capacity of 354 MW_e back in 1992 (Kalogirou).

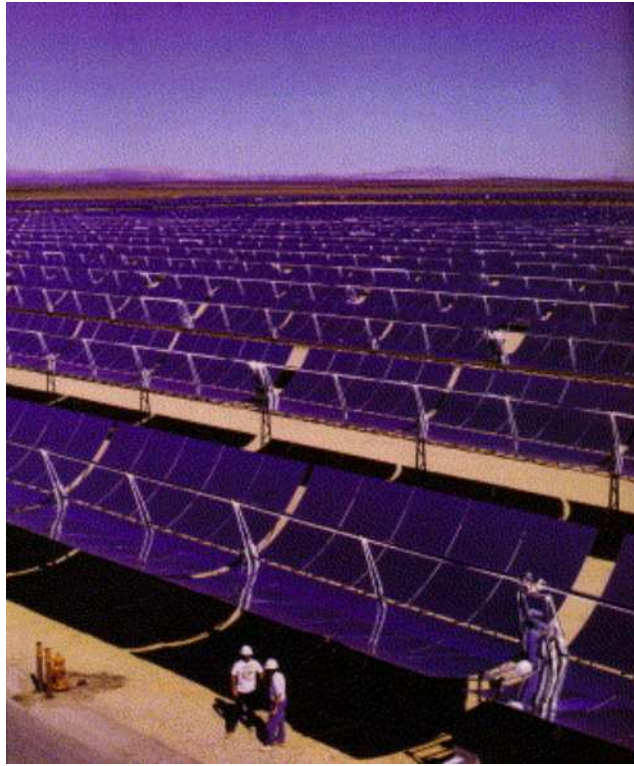


Figure 2-48: A photograph of the SEGS plant in southern California (Alnaser et al., 2006)

2.7.2.2 Linear Fresnel

The LFC technology was first utilised by Giorgio Francia, who developed linear and two-axis tracking Fresnel reflector systems at Genoa, Italy in the 1960s (Kalogirou, 2009b).

According to (Kalogirou, 2013), the Fresnel CSP technology utilises two variations of collectors (Figure 2-49), namely linear Fresnel collector technology and Fresnel lens collector (FLC) technology. The FLC is normally made of a plastic material that is shaped in such a manner that the solar rays passing through the material is focused on a central point. The LFC relies on a number of linear mirror rows to concentrate the solar radiation onto a linear receiver.

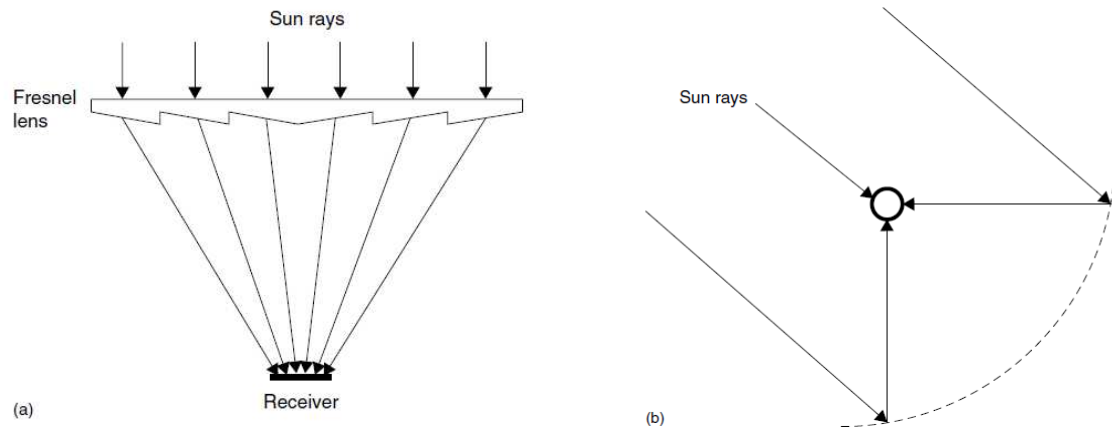


Figure 2-49: (a) Fresnel lens collector, (b) Linear Fresnel collector (Kalogirou)

The Fresnel reflector can be imagined as a massive parabolic trough reflector, but each smaller section has a parabolic shape and can have its own tracking system (Kalogirou, Kalogirou, 2009b).

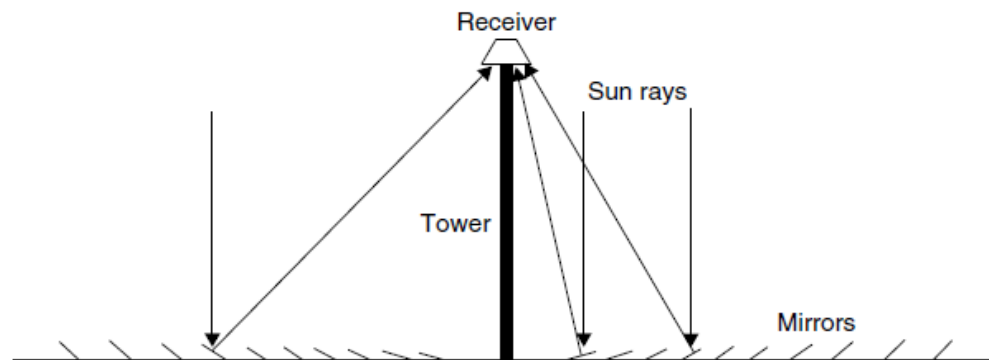


Figure 2-50: Illustration of an element of a linear Fresnel CSP system (Kalogirou, Kalogirou, 2009b).

To minimise shading of one reflector by another, the spacing between the mirrors lines must be increased, which will also increase the plant's physical footprint. The blocking effect, where the reflected beams are blocked from the receiver, by other mirrors can be avoided by increasing the receiver height.

The tracking system for the LFC technology incorporates mainly one-axis tracking only and is very similar to that of PTC.

Eskom's Research Testing and Demonstration Department (RT&D) has constructed a 150 kWt, pilot and demonstration, linear Fresnel concentrated solar thermal (CST) plant for research purposes (Figure 2-51).



Figure 2-51: Eskom's linear Fresnel pilot and demonstration plant

2.7.2.3 Central receiver

This technology, where a number of flat or slightly concave mirrors/heliostats are used, is utilised to obtain extremely high inputs of radiant energy on a central point (Kalogirou, 2009b). According to (Gordon and Society, 2001) the CRC or power-tower technology was proposed by the Russians in 1957. The basic CRC principle can be seen in Figure 2-52.

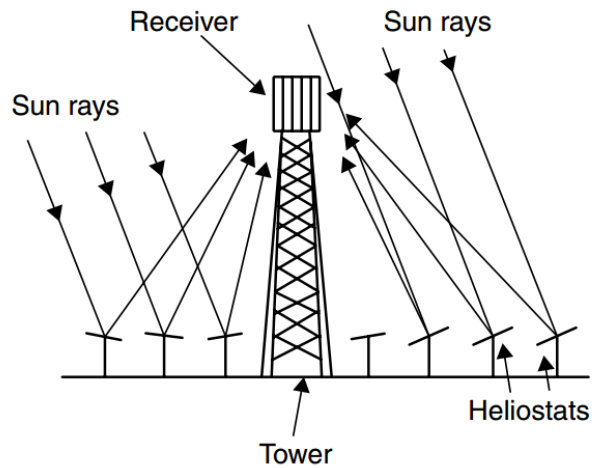


Figure 2-52: Schematic of a central receiver system (Kalogirou, 2009b)

According to (Gevorkian), “Solar One” was the first large-scale power-tower plant and generated about 10 MW of power in the mid-1980s. This plant was built in southern California and used water/steam in as the working fluid.

In 1992, it was decided to retrofit this plant (“Solar Two” project) to accommodate a storage application that can increase the CF to about 65%. The working fluid of the solar cycle was also changed from water to molten salt (Gevorkian).

In this specific storage system, the molten salt was pumped from a relatively cold tank at 288 °C through the central receiver, where it was heated to about 565 °C, and then pumped into the hot storage tank (Gevorkian). This “hot” molten-salt was then utilised as the heat source in the steam generator where steam was produced for a conventional Rankine cycle. This plant had a three-hour storage capacity.

According to (Kalogirou, 2009a) a CRC plant without storage can achieve CFs of about 25%, depending on the solar resource, where a plant with a 15-hour, molten-salt, storage capacity can reach capacity factors of up to 74%.

Solar Two’s heliostat field consisted of 1 818 individually oriented reflectors made of back-silvered glass (Kalogirou, 2009a). The field had a total mirror area of about 71 100 m². The plant’s receiver is a single-pass superheated boiler consisting of 24 elements. Six of these elements are used as feedwater preheaters, and the rest are used as boilers (Kalogirou, 2009a).

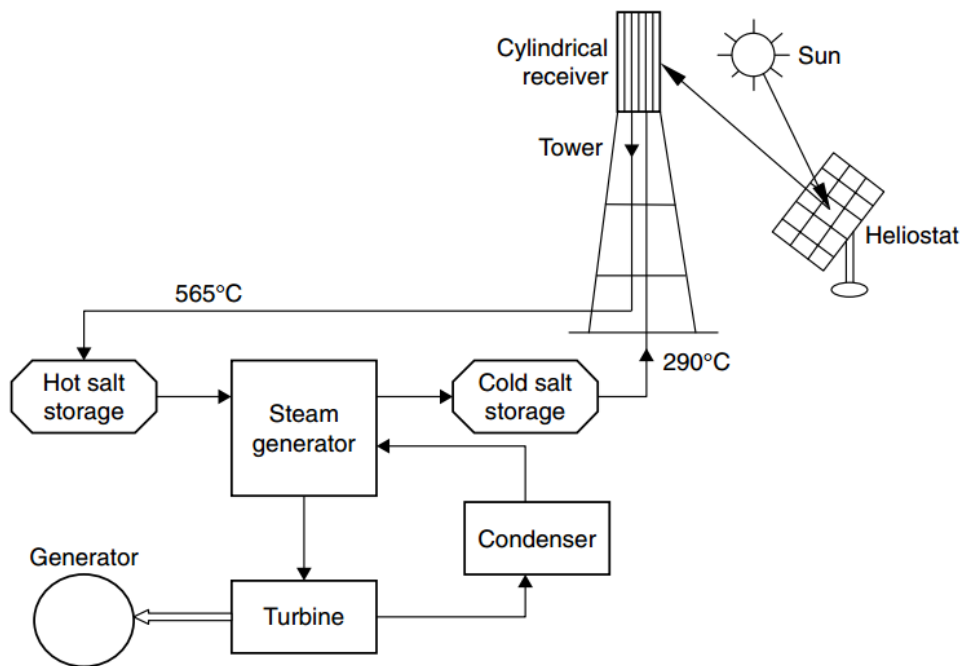


Figure 2-53: Schematic of a central receiver system (Solar Two), with a molten-salt storage application (Kalogirou, 2009a)

According to (Kalogirou, 2009b), central receivers have several advantages:

- All solar energy is transferred to a single receiver, which minimises thermal transport requirements.
- These plants can achieve CRs of 300 to 1 500, which enable them to achieve temperatures of 800 °C to 100 °C, which make them highly efficient.
- Thermal energy can be stored, which will increase the plant's CF significantly.
- They are generally quite large and can benefit from economies of scale.

Each heliostat of a CRC field normally tracks the sun on two axes to enable it to keep a single focal point throughout the day.

2.7.3 Overview

According to (IRENA, 2012), if no storage is assumed, an annual capacity factor of 22-24% can be expected from the linear Fresnel technology, 25-28% from the parabolic-trough technology and approximately 10-25% from a central receiver technology. The annual solar-to-electricity

efficiency for the linear Fresnel technology is expected to be in the region of 13%, while one can expect 11-16% from the parabolic-trough technology and 7-20% from the solar tower technology. A high-level breakdown of some important parameters of the linear Fresnel, parabolic trough and solar tower technologies can be seen in Table 2-4.

Table 2-4: Concentrating solar tower technology overview (IRENA, 2012)

Typical Parameters	Linear Fresnel	Parabolic Trough	Solar Tower
Typical Capacity [MW]	10-200	10-300	10-200
Operating Temperature [C]	390	350-550	250-565
Annual Capacity Factor [%]	22-24	25-28	10-25
Collector Concentration [suns]	>60	70-80	>1000
Annual solar-to-electricity efficiency [%]	13	11-16	7-20
Technology Risk	Medium	Low	Medium

According to a study conducted by Bloomberg New Energy Finance (Salvatore, 2014), the LCOE of a central receiver CSP plant with storage is approximately R2,42/kWh, while one can expect to pay about R2,92/kWh to generate electricity from a parabolic trough CSP plant (with storage). The LCOE of a typical linear Fresnel plant without storage is in the region of R3,08/kWh.

The estimated LCOE's and capacity factors for some other renewable energy technologies, as determined by Bloomberg New Energy Finance (Salvatore, 2014), can be seen in Table 2-5.

Table 2-5: Typical renewable energy technology capacity factor and LCOE estimates
(Salvatore, 2014).

Renewable Energy Technology	Capacity Factor [%]	LCOE [\$/MWh]	LCOE [R/kWh]
Small Scale Hydro	50%	60	0.66
Biomass - Anaerobic Digestion	90%	146	1.61
Large Hydro	50%	77	0.85
Landfill Gas	90%	59	0.65
Geothermal - Flash plant	85%	65	0.72
Biomass - Incineration	77%	119	1.31
Municipal Solid Waste	80%	102	1.12
Wind - Onshore	32%	82	0.90
Geothermal - Binary Plant	80%	97	1.07
Biomass - Gasification	80%	128	1.41
PV - Thin Film	17%	143	1.57
PV - c-Si	17%	142	1.56
PV - c-Si (with tracking)	21%	142	1.56
Wind - Offshore	41%	203	2.23
CSP - Central Receiver (with storage)	61%	220	2.42
CSP - Parabolic Trough (with storage)	42%	265	2.92
CSP - Linear Fresnel (without storage)	27%	280	3.08
Marine - Tidal	35%	442	4.86
Marine - Wave	30%	499	5.49

South Africa

South Africa is the southern- most African country and is situated along the tropic of Capricorn.

As can be seen from the DNI map in Figure 2-54, South Africa has a relatively good solar resource compared to the rest of the world.

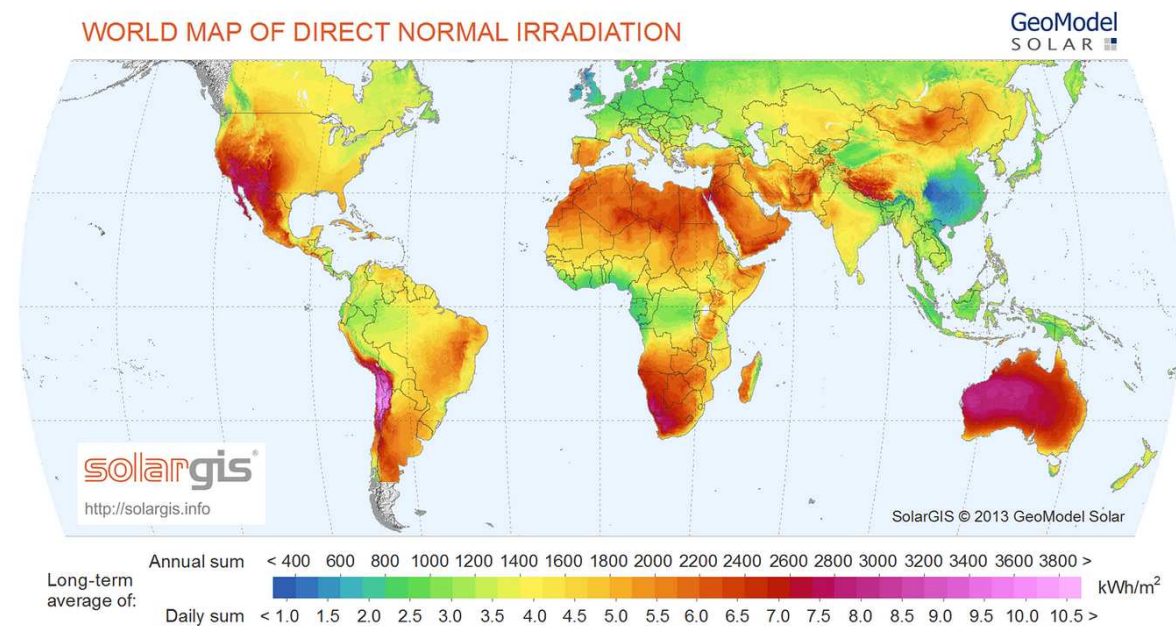


Figure 2-54: World map of direct normal irradiation(SolarGIS, 2013b).

As can be seen from Figure 2-55, the Northern Cape province has the highest DNI, with average annual radiation levels of up to 3 000 kWh/m²/year at some sites. Unfortunately, the Mpumalanga province, where all the major coal-fired power stations are situated, does not have a very good solar resource compared with the Northern Cape, but still receives an annual solar irradiation of approximately 2 250 kWh/m²/year.

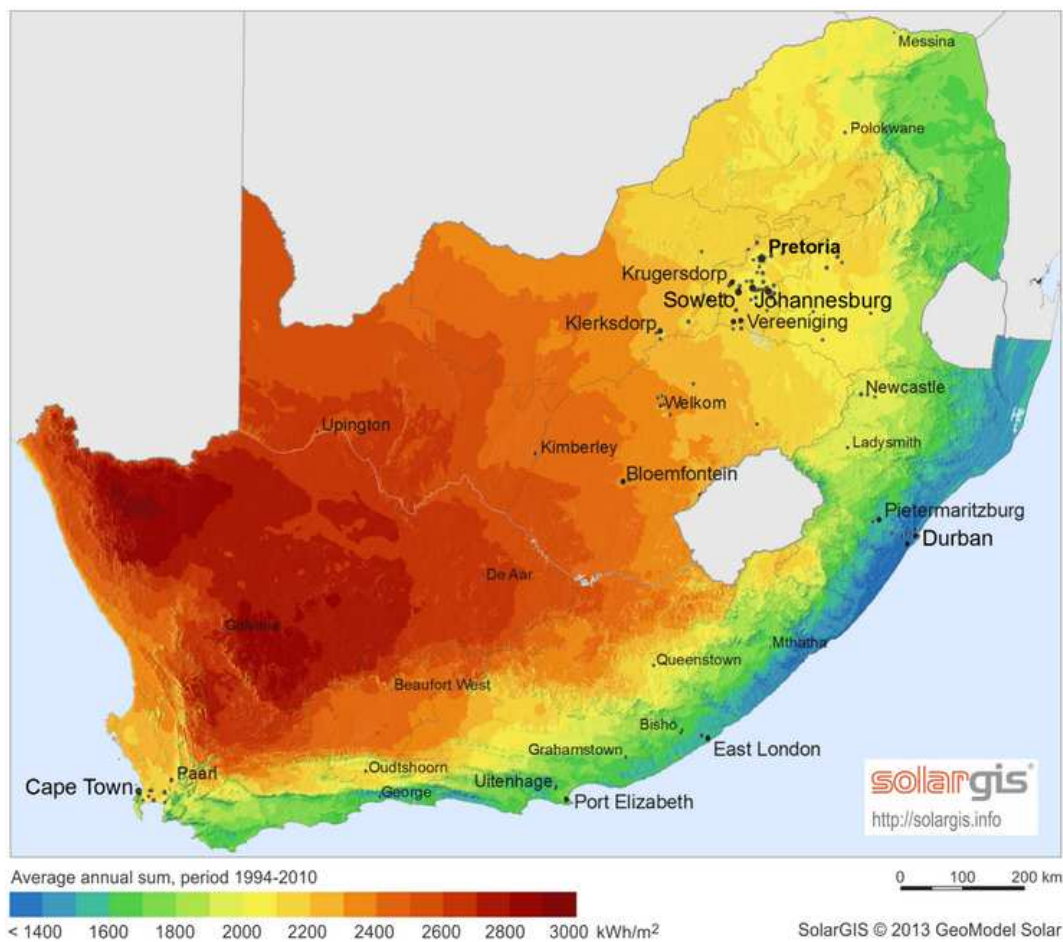


Figure 2-55: Direct normal irradiation map of South Africa (SolarGIS, 2013a)

2.7.4 Eskom Holdings SOC Limited

Eskom Holdings SOC Limited (Eskom) was established in South Africa in 1923 as the Electricity Supply Commission. Eskom is now a hundred percent state-owned electricity utility, strongly supported by the South African government. This power giant supplies 94% of South Africa's electricity and approximately 45% of all electricity used on the African continent (Eskom, 2014a).

Eskom has a wide-ranging generation mix, which includes coal-fired, nuclear, hydroelectric, wind (in construction) and concentrated solar power (to be built), power stations with open-cycle gas turbines (OCGTs) and conventional pumped storage schemes to satisfy the peak and emergency demands. The utility's net maximum generating capacity is approximately 42 GW_e, of which about 85% is generated by combusting pulverised coal (Eskom, 2013a). Eskom's generating capacity breakdown can be seen in Figure 2-56 below.

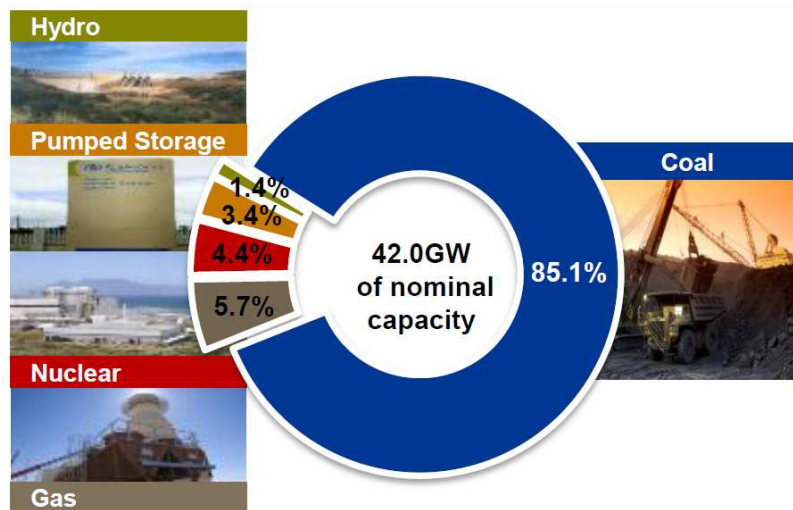


Figure 2-56: Eskom's generating capacity breakdown (Eskom, 2013a)

From Figure 2-57 below, it is very clear that the bulk of all electricity generated from coal in South Africa comes from the coal-rich Mpumalanga province, with the exception of Lethabo power station in the Free State and Matimba power station in Limpopo. Eskom's two new supercritical coal-fired power stations, Medupi and Kusile, are situated in Limpopo and Mpumalanga respectively, and are expected to come online in the next few years.

Most of Eskom's peaking stations OCGTs and pumped storage are situated in the Western Cape province, with the exception of the Port Rex OCGT station in the Eastern Cape and the Drakensberg and Ingula pumped storage schemes in Kwazulu-Natal.

Eskom is currently (April 2014) constructing the 100 MW Sere wind-farm near Vredendal in the Western Cape province and in the advanced planning stages of the Solar One, CSP plant near Upington in the Northern Cape province.



Figure 2-57: Eskom power stations map (Eskom, 2013b)

Because of the enormous amount of coal-fired electricity generation, it comes as no surprise that Eskom is responsible for a huge percentage of South Africa's harmful emissions. In the 2012/2013 financial year alone, Eskom released about 228×10^6 tonnes of carbon dioxide (CO_2), 965×10^3 tonnes of nitrogen oxide (NO_x) and about $1\,843 \times 10^3$ tonnes of sulphur oxide (SO_x) into the atmosphere. More details regarding emissions and water usage can be seen in Table 2-6.

Table 2-6: Eskom atmospheric emissions (Eskom, 2013a)

Atmospheric Emissions	2013
Relative Particulate Emissions	0.35 kg/MWh
Carbon Dioxide Emissions (relative)	0.98 t/MWh
Carbon Dioxide Emissions	227.9 Mt
Nitrogen Oxide Emission	964.8 kt
Sulphur Dioxide Emissions	1843 kt
Nitrous Oxide Emissions	2980 kt

As mentioned above, Eskom is currently constructing two supercritical coal-fired power stations, Medupi and Kusile. Because these two stations are relevant to this specific study, more details about them are supplied in the sections below.

2.7.4.1 Medupi – supercritical coal-fired power station

According to (Eskom, 2014b), Medupi is a greenfield coal-fired power-plant project located west of Lephalale, Limpopo province, South Africa. Medupi is the fourth dry-cooled, base-load station built in 20 years by Eskom after Kendal, Majuba and Matimba power stations. The name “Medupi” is a Sepedi word which means “rain that soaks parched lands, giving economic relief”. The power station will be the fourth largest coal plant in the southern hemisphere, and will be the biggest dry-cooled power station in the world. The planned operational life of the station is 50 years.

Medupi power station will comprise six supercritical units with a gross nominal capacity of 800 MW each, resulting in a total installed capacity of 4 800 MW.



Figure 2-58: Medupi power station construction site (Eskom, 2014b).

2.8 Solar augmentation

The solar augmentation or solar-assisted power generation (SAPG) concept integrates the advantages of a concentrating solar thermal plant with the advantages of a coal-fired power station. Basically explained, the thermal energy generated in a solar field's collectors is injected at strategic integration points of a coal-fired power station's regenerative Rankine cycle and is not directly used for power generation.

According to (Pierce et al., 2013), the annual electricity produced by the solar thermal energy injected into a coal-fired power station is more than 25% greater than can be expected from a stand-alone CSP plant. Also, if it is assumed that the cost of an SAPG plant is approximately 72% of the cost of a stand-alone CSP plant, an SAPG is 1,8 times more cost effective than a stand-alone CSP plant (Pierce et al., 2013).

Depending on the limitation parameters of the coal-fired station, a solar augmentation scenario may be operated in two main operation modes (Yang et al., 2011):

- Boosting mode
- Fuel-saver mode

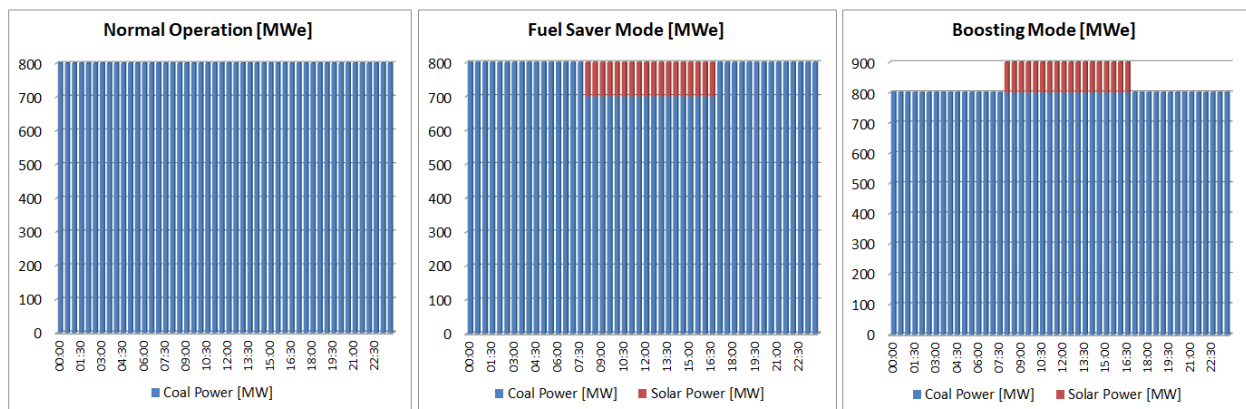


Figure 2-59: Solar augmentation modes: left - no augmentation, middle - fuel-saver mode, right - boosting mode

The three operation modes given in Figure 2-59 are: (left) the normal operation mode, where the coal-fired power stations do not receive any thermal energy from the CST plant, (middle) the fuel-save mode, where the electrical output of the generator stays constant, but the fuel-consumption rate decreases and (right) the boosting mode, where the fuel-consumption rate stays constant, but the generator's electricity output increases.

During normal operation, steam at specific pressure stages of the steam turbines is tapped off for feedwater preheating. This increases the thermal efficiency of the Rankine cycle, because the feedwater entering the boiler is already heated to a certain extent. On the other hand, the decreased mass flow through the later stages of the turbines will result in a lowered mechanical power output.

According to (Hu et al., 2010), the basis of the SAPG concept is to use solar thermal energy to replace the bled-off steam used for feedwater preheating. By doing so, less or no steam will have to be tapped off from the turbines, because the energy required for feedwater preheating comes from the solar field.

(Suresh et al., 2010) found in 2010, during a thermodynamic analysis of a sub- and supercritical coal-fired power station, that approximately 5-6% fuel can be saved when solar energy is used for feedwater preheating. It was also found that the annual reduction in coal consumption is about 49 600 tonnes, the annual reduction in ash production is approximately 24 300 tonnes, while the plant's CO₂ emissions can decrease by up to 62 000 tonnes for a 500 MWe power plant (subcritical) (Suresh et al., 2010).

One integrating option for integrating a solar plant with a coal-fired power station is to tap off feedwater from the Rankine cycle at a specific point. This tapped-off water can then be heated to the desired temperature in the solar field, after which it can be injected back into the Rankine cycle.

In most coal-fired power stations, the EBFPs are responsible for circulating the feedwater through the Rankine cycle. The pressure created by these pumps can be used to circulate a desired amount of feedwater through the solar plant (solar cycle). The pressure in the solar plant can also be manipulated with an automated pressure-control valve to design specifications.

One possibility is to inject the solar-heated steam back into the steam cycle in the cold-reheat line, which among other things, supplies steam to HP heaters 6A and B. By applying additional steam at this point, less steam will be fed to the HP heaters and more steam will pass through the reheater, IP turbine and LP turbines.

For cycle stability, it is important that the steam injected into the cold-reheat line correlates with the steam conditions inside the cold-reheat line. If the steam injected is too cold, the reheater might not be able to heat the steam to the conditions required for optimal operation of the HP turbine. If the injected steam is too hot, the spray-water system may not be able to cool the steam to an acceptable temperature, which might cause damage to HP turbine components. It

must also be taken into account that the spray water injected into the steam cycle will increase the mass flow of the steam through the IP and LP turbines even more. An illustration of a live steam injection into the cold-reheat line scenario can be seen in Figure 2-60.

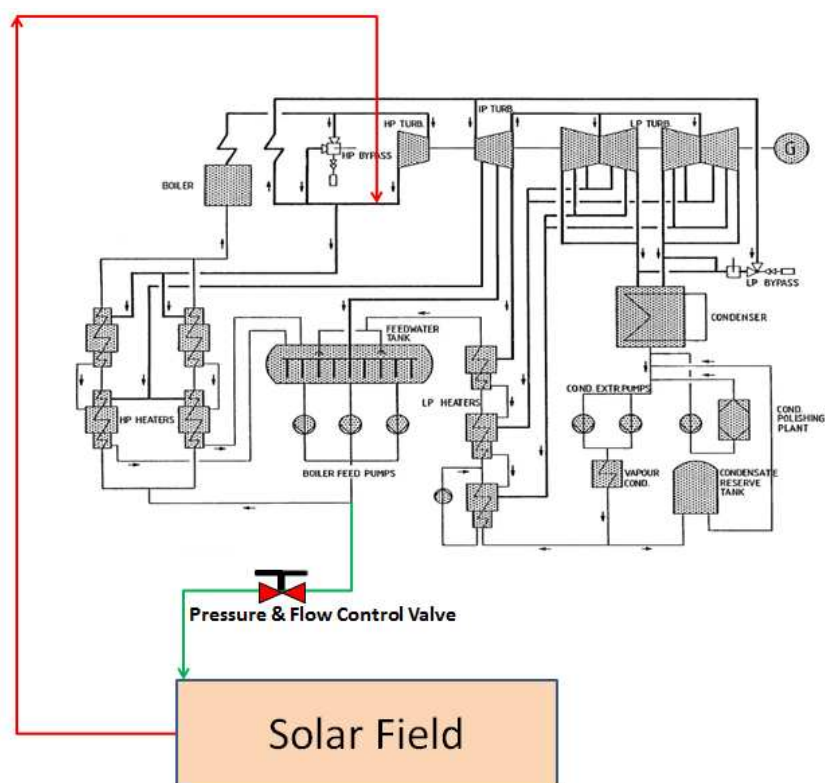


Figure 2-60: Steam injection into the cold-reheat line

In another scenario, an additional heat exchanger powered by the solar field can be installed in a feedwater heater bypass line (Figure 2-61). In this scenario, only a very small quantity of bleed steam will be tapped off to keep the feedwater heaters warm. The mechanical power output by the IP and LP turbines will be increased significantly, as very little steam will be tapped off from the HPT outlet or the first stage of the LPT.

The advantage, when adding an additional heat exchanger, is that one may operate the cycle through the solar field and the additional heat exchanger at a much lower pressure than the pressure felt in the feedwater cycle. Other working fluid options may also be explored; which means that one is not limited to demineralised water in the solar cycle. The rate of heat transfer is also a function of the mass flow of the heating fluid, the specific heat of the fluid, the inlet and outlet temperatures (see equation below) and the efficiency of the exchanger. If we know the efficiency of the device, we know what rate of heat transfer we need to adhere to and we know

what our inlet and outlet temperatures should be, then we can adjust the mass flow through the heat exchanger with the pump velocity or control valve.

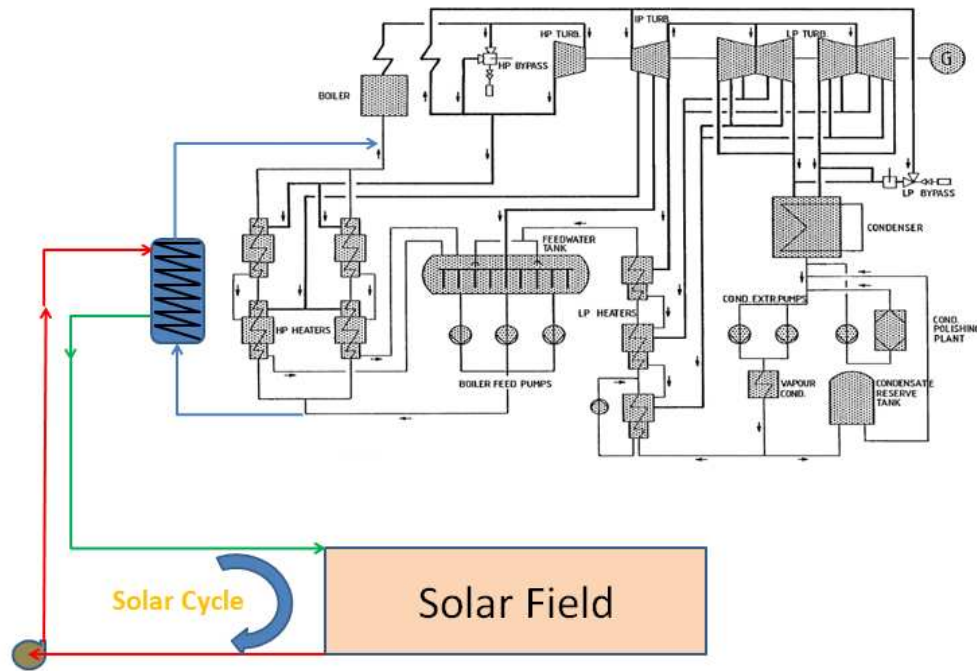


Figure 2-61: Separate heat exchanger in bypass line

According to (Suresh et al., 2010), the thermal energy generated in the CST plant can also be utilised to preheat combustion air before it enters the furnace.

Up to date, the largest SAPG project is the Kogan Creek solar-boosting project currently (November 2014) under construction in Australia (CSEnergy, 2014). At the Kogan Creek plant, subcooled feedwater is tapped off from the main cycle after the BFP system. Heat energy converted from the irradiation of the sun is then added to this water in the solar field's steam generator or receivers until the specified temperature or steam quality is reached. This steam is then injected into the cold-reheat line of the Rankine cycle, between the HPT exhaust and the reheater system.

By adding this steam, there will be an increased steam flow rate in the reheater system, IPT and LPT. The increased steam flow through the reheaters will cause the reheater attenuation spray water to drop to a certain extent, while the increased flow through the IP and LP turbines will cause an increase in mechanical shaft power and in effect generator electrical output.

At peak solar conditions, the solar field will enable Kogan Creek to generate an extra 44 MW of electricity (CSEnergy, 2014).

2.9 Renewable energy financing

Because of the relatively low-capacity factor of renewable energy technologies compared with coal-fired power stations, the LCOE for renewable energy is normally much higher than that of coal. In an attempt to make renewable energy technologies more attractive to investors, a tradable renewable energy certificate (TREC) system was developed in some countries.

Another major role-playing factor, which is currently not yet in full effect (October 2014), is the steep carbon tax rates proposed by the South African government (Government, 2013).

2.9.1 Tradable renewable energy certificates

According to (Volschenk, 2013), TRECs or renewable energy certificates (RECs) represent the beneficial attributes of electricity generated from renewable energy technologies. A wind farm, for example, can sell TRECs to customers who want to put a green label on their companies, therefore, in effect, these companies may say that they use clean electricity (generated from a renewable source) in their factories, stores, etc. These RECs, certified by RECSA in South Africa, and actual electricity generated from the project are traded separately from one another.

These green certificates are normally traded per MWh, where the certificate price depends on the amount of units one purchases. According to Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), as a guideline, one can expect to pay the following prices for RECs:

- R300/REC for (1 – 20 RECs)
- R175/REC for (20 – 50 RECs)
- R150/REC for (50 – 200 RECs)

Also according to GIZ, other countries where REC systems are operational are Australia, Poland, Sweden, the United Kingdom, Italy, Belgium (Wallonia and Flanders), and some states of the United States of America.

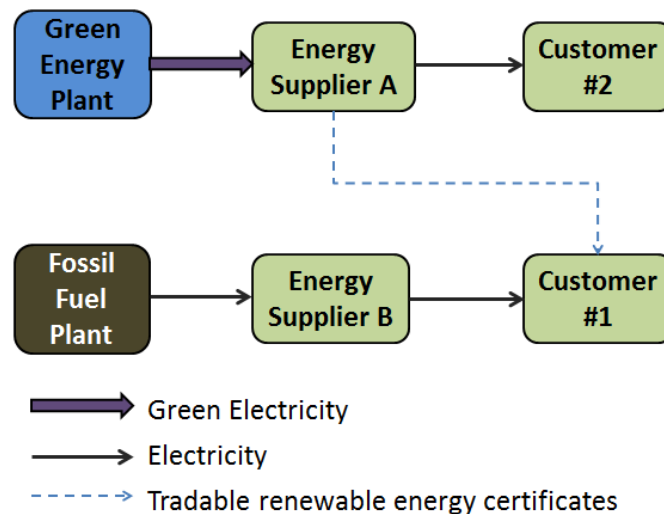


Figure 2-62: Illustration of TREC system (Volschenk, 2013)

The main benefits of TRECs are:

- RECs provide an additional revenue stream to a renewable energy project and therefore make the project more financially feasible.
- RECs give corporations and even individuals the opportunity to offset their electricity consumption from electricity generated by fossil fuels to green, renewable energy without having to invest in an expensive renewable energy technology.
- RECs are inexpensive and can be procured in large or small quantities

2.9.2 Carbon tax

According to (Government, 2013), the main aim of the proposed carbon tax is to correct the existing prices of goods and services that generate excessive levels of anthropogenic greenhouse gas (GHG) emissions, so that it reflects the social costs of such emissions. The breakdown of South Africa's carbon contribution can be seen in Figure 2-63 below.

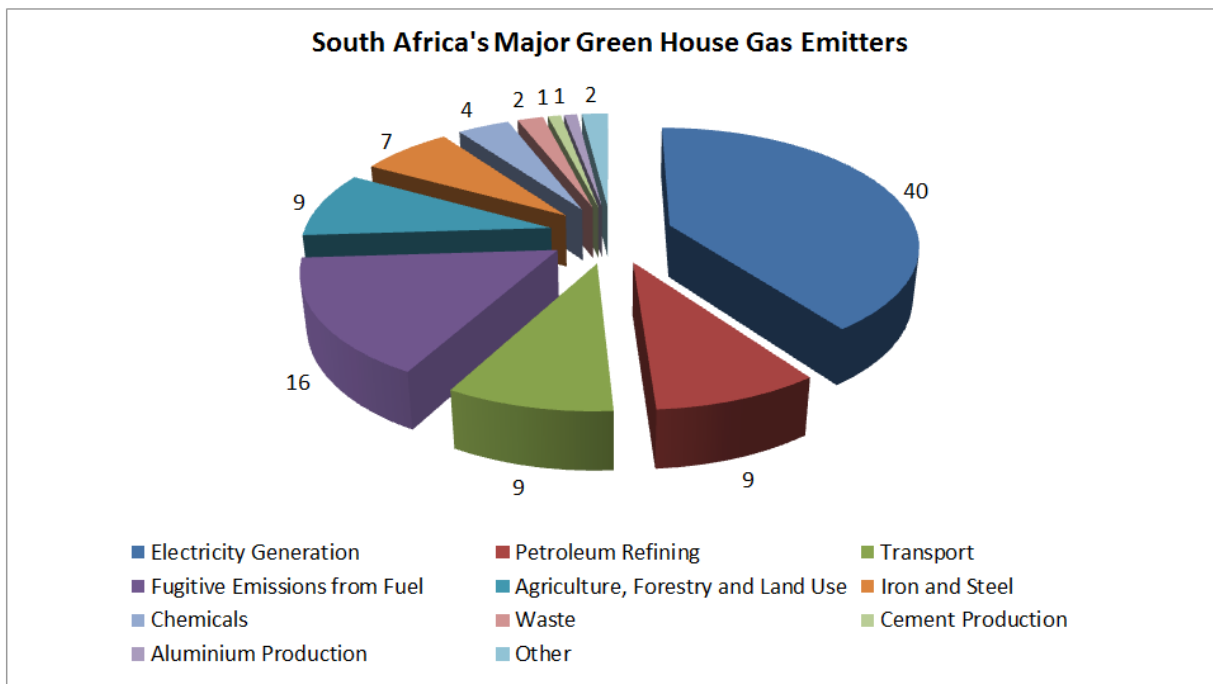


Figure 2-63: Breakdown of South Africa's greenhouse gases by sectors (Government, 2013).

The South African government proposed that a carbon tax be introduced at a rate of R120 per ton (t) CO₂-equivalent above the tax-free thresholds (including the proposed offsets) on 1 January 2015 (Government, 2013). It is further proposed by the government of South Africa that the tax rate of R120/ton CO₂-equivalent be increased at a rate of 10% per annum until 31 December 2019, after which a revised tax rate will be introduced (Government, 2013).

The tax-free thresholds, as proposed by the South African government, can be seen in the (Table 2-7) below:

Table 2-7: Proposed emissions tax-free thresholds (Government, 2013)

Tax Free Thresholds per Sector		
Sector	Basic Tax-Free Threshold [%]	Maximum Offset [%]
Electricity	60	10
Petroleum (coal to liquid)	60	10
Petroleum (oil refinery)	60	10
Iron and steel	60	5
Cement	60	5
Glass and ceramics	60	5
Chemicals	60	5
Pulp and paper	60	10
Sugar	60	10
Agriculture, forestry and land use	60	0
Waste	60	0
Fugitive emissions from coal mining	60	5
Other	60	10

Eskom, which is in the electricity sector, will receive a basic 60% tax-free threshold. This will result in a carbon-tax cost of R48/ton CO₂-equivalent. There is, however, a maximum offset of 10% to the tax-free threshold, which can reduce the carbon tax even further to R36/ton CO₂-equivalent.

2.9.3 Accelerated depreciation

A tax benefit to all renewable energy plants in South Africa was introduced in 2012 to make power generation via renewable energy technologies more attractive to investors (Government, 2012). This benefit states that the value of the plant may be depreciated in full during the first three years of operation. In the first year of operation the plant may be depreciated by 50%, after which the plant can be depreciated by a further 30% in year 2 and the remaining 20% in year 3.

CHAPTER 3: PROJECT APPROACH

In the first section of this project a base-case thermodynamic model will be created for an 800 MW supercritical coal-fired power station. This model will include an Engineering Equation Solver (EES) model of the regenerative Rankine cycle considered in this study. The results obtained from this base-case EES model will then be verified with a ThermoFLEX model. From these models a number of operating-cost parameters can be determined, which include the following:

- Coal consumption rate
- Flue-gas flow rate
- SO₂, CO₂, N₂, H₂O and ash emissions rate
- Electricity generated
- Own electricity consumption by fans, pumps, mills and other auxiliary systems

These parameters can then be used to determine a high-level annual operating cost for the station, which can be used along with the plant's capital and maintenance costs to determine the LCOE.

When the base-case scenario is augmented with a solar field, the CST plant's capital and O&M cost must be incorporated into the coal-fired station's costs. An EES model will be used to determine the parameters affecting the power output and annual operating cost of the solar energy on the coal-fired station. The cost affecting parameters considered in this study include:

- Coal consumption
- Flue-gas flow rate
- SO₂, CO₂, N₂, H₂O and ash emissions rate
- Electricity generated
- Own electricity consumption by fans, pumps, mills and other auxiliary systems of the coal-fired station and the CST plant
- Revenue from CDM mechanism

The solar to thermal efficiency calculated at the Rosherville linear Fresnel pilot and demonstration (P&D) plant will be used to calculate the available thermal energy for a specified radiation limit.

The LCOE will be calculated for the base-case, coal-fired power station and then for the two solar-augmented scenarios.

3.1 Base-case - Coal-fired power station

3.1.1 Assumptions

3.1.1.1 Rankine cycle assumptions

The steam entering the HPT has a temperature of 560 °C at 24,1 MPa and a flow rate of 617 kg/s, while the reheated steam, entering the IPT, has a temperature and pressure of 570 °C and 5 029 kPa.

The steam at the HPT exhaust steam has a pressure of 5 472 kPa. The steam at the IPT's first extraction point has a pressure of 2 732 kPa, the steam at the second extraction point has a pressure of 1 112 kPa, and the steam at the IPT exhaust has a pressure of 586 kPa. It is assumed that the LPT exhaust steam has a pressure of 13 kPa at an atmospheric temperature of 23 °C and 9 kPa at 18 °C, while the steam at the first LPT extraction point has a pressure of 261 kPa and 80,5 at the second. These main design parameters at full load conditions are illustrated in Table 3-1.

Table 3-1: Main design parameters.

Main Steam Parameters	
Temperature	560 C
Pressure	24 100 kPa
Mass Flow	617 kg/s

Re-Heat Steam Parameters	
Temperature	570 C
Pressure	5029 kPa

Turbine Bleed Steam Pressures	
HPT Exhaust	5472 kPa
IPT Stage 1	2732 kPa
IPT Stage 2	1112 kPa
IPT Exhaust	586 kPa
LPT Stage 1	261 kPa
LPT Stage 2	80.5 kPa
LPT Exhaust @ 23C atm.	13 kPa
LPT Exhaust @ 9C atm.	9 kPa

The condenser and main steam pressure will change with the maximum continuous rating (MCR) of the unit. The ACC pressure curve considered for a 23 °C ambient temperature can be seen in Figure 3-1.

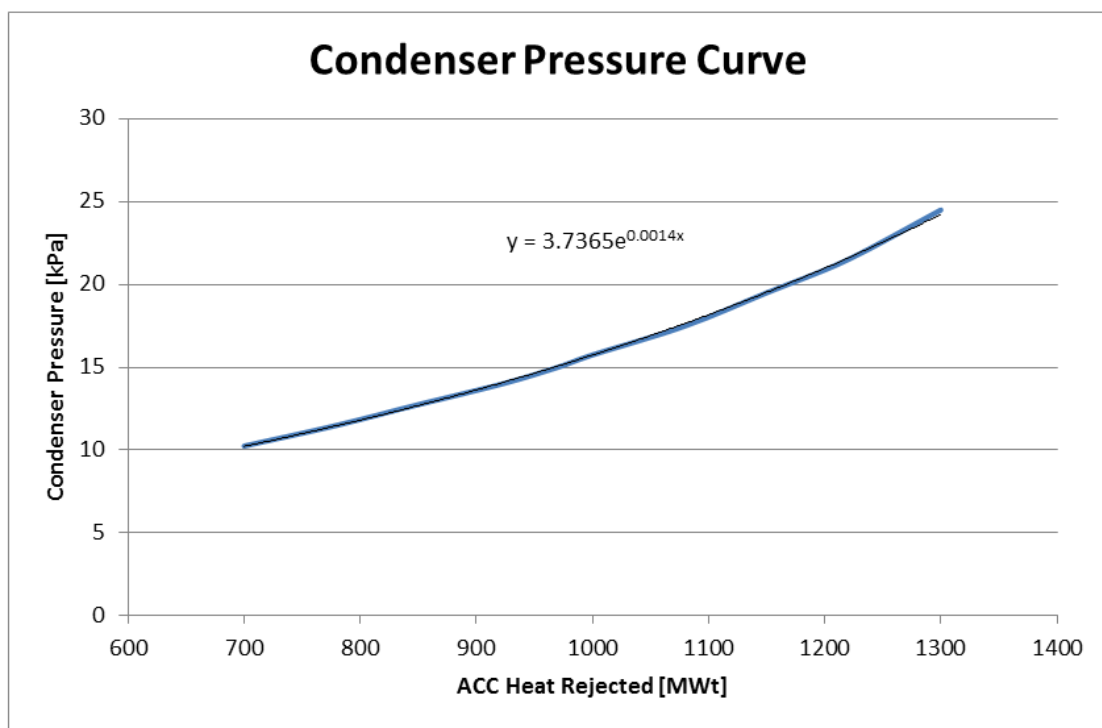


Figure 3-1: Condenser pressure curve

The main steam-pressure curve considered in this model is illustrated in Figure 3-2.

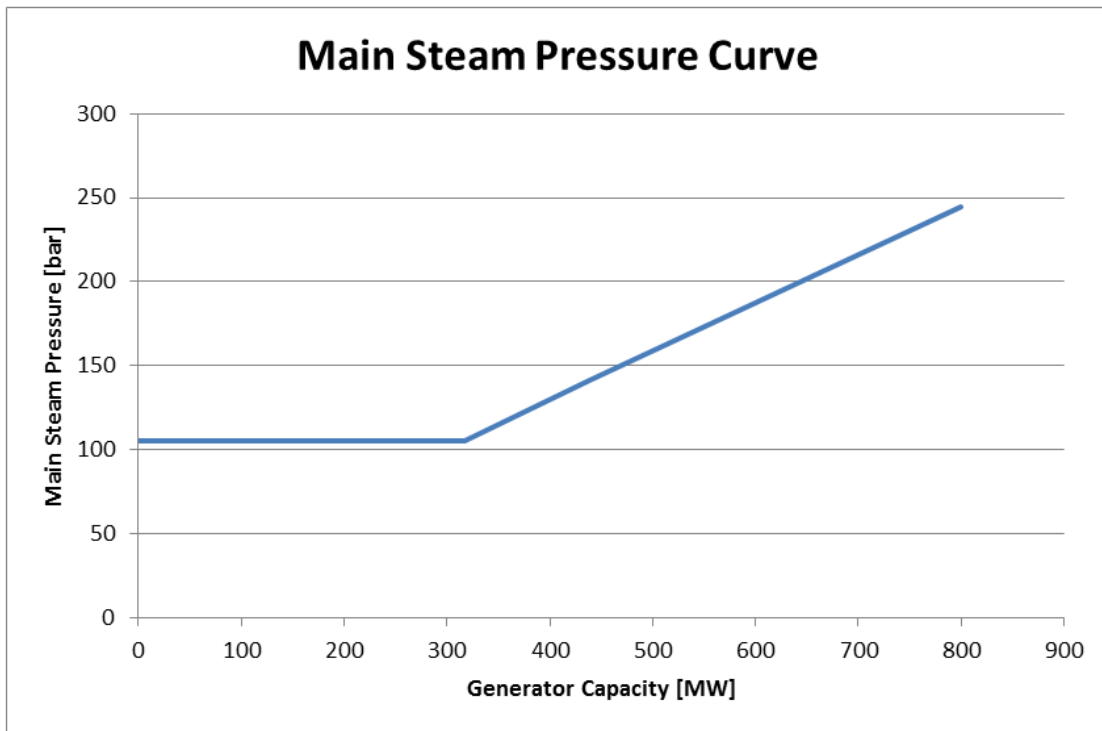


Figure 3-2: Main steam pressure curve.

The isentropic efficiencies assumed for the different stages (stages between extraction points) of the turbine train and major pumps can be seen in Table 3-2 below.

Table 3-2: Isentropic efficiencies

Isentropic Efficiencies	Stage 1	Stage 2	Stage 3
High Pressure Turbine	89%	N/A	N/A
Intermediate Pressure Turbine	85%	91%	95%
Low Pressure Turbine	83%	82%	97%
Boiler Feed Pump	82%	82%	N/A
Condensate Extraction Pump	80%	N/A	N/A

Table 3-3 illustrates the assumptions made for all the feedwater preheaters considered in this cycle. All heaters considered in this study are closed shell and tube heat exchangers, with the exception of the deaerator. Only the second low-pressure heater has a feedback pump, which is responsible for pumping the condensate back into the main feedwater line. The third low-pressure heater and all the high-pressure heaters have subcooling zones, while only the high-pressure heaters contain desuperheating zones.

Table 3-3: Feedwater preheater specifications.

Feedwater Heaters	De-Superheating		Subcooling		Pump	Open	Closed	Cascade to:
	[Y/N]	[C]	[Y/N]	[C]	[Y/N]	[Y/N]	[Y/N]	
LPH #1	✗	1.9	✗	0.0	✗	✗	✓	Condenser Flashbox
LPH #2	✗	2.0	✗	0.0	✓	✗	✓	Feed Water Line
LPH #3	✗	2.0	✓	5.9	✗	✗	✓	LPH #2
Deaerator	✗	0.0	✗	0.0	✗	✓	✗	N/A
HPH #5 A&B	✓	-1.0	✓	8.0	✗	✗	✓	DST
HPH #6 A&B	✓	1.0	✓	8.0	✗	✗	✓	HPH #5 A&B

It is assumed that the specific coal-fired power station's load can be ramped up or down at a rate of 66,67 kW/s. The station will be at 100% MCR from 6:00 to 23:00. During the late nights and early mornings of every day the station will operate at 60% MCR. The gross generator power output for a single day vs time can be seen in below.

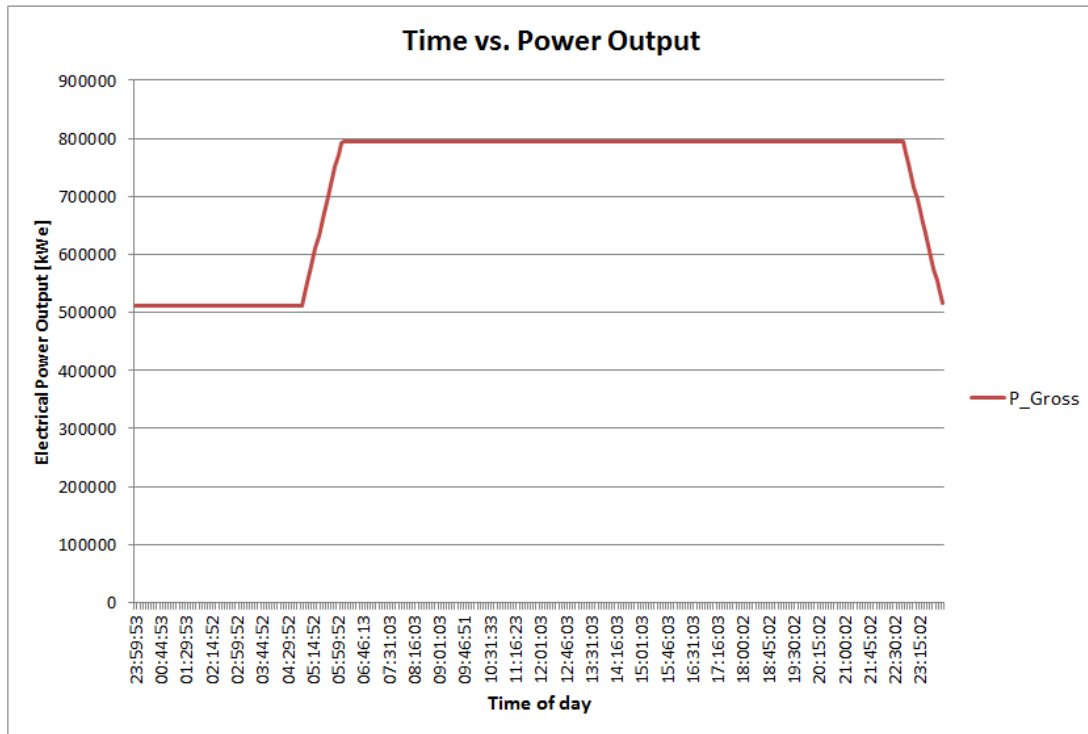


Figure 3-3: Generator gross capacity vs time of day

For this study it is assumed that the attenuation spray-water flow rate may not drop below 3 kg/s, to ensure that adequate reheater temperature control is always available. This will also be the main limiting factor for the hybrid system.

3.1.1.2 Coal assumptions

For the purpose of this study, a simplistic coal composition is considered. Only the ash, carbon hydrogen, nitrogen, sulphur, oxygen, water and carbonates content of the coal is considered. The coal composition and characteristics assumed for this study are illustrated in Table 3-4. It is also assumed that the atmospheric air has an oxygen content of 23,15% and nitrogen content of 76,85%. The coal considered has a greater calorific value of approximately 20,1 MJ/kg.

Table 3-4: Coal assumptions.

Coal Characteristics		Coal Composition	
Greater CV [MJ/kg]	20.1	Ash	34.5%
Inherent Moisture	2.20%	Water	2.20%
Ash	34.5%	Total Carbon	48.2%
Volatile Matter	27.2%	Hydrogen	3.59%
Fixed Carbon	36.1%	Nitrogen	1.16%
		Sulphur	1.09%
		Carbonates	1.12%
		Oxygen	8.15%

Figure 3-4 and Figure 3-5 give a visual illustration of the quality parameters and the composition breakdown of the coal used in this study.

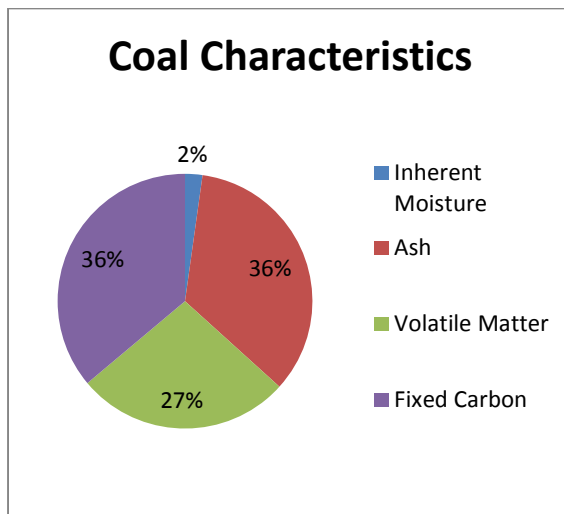


Figure 3-4: Assumed coal characteristics.

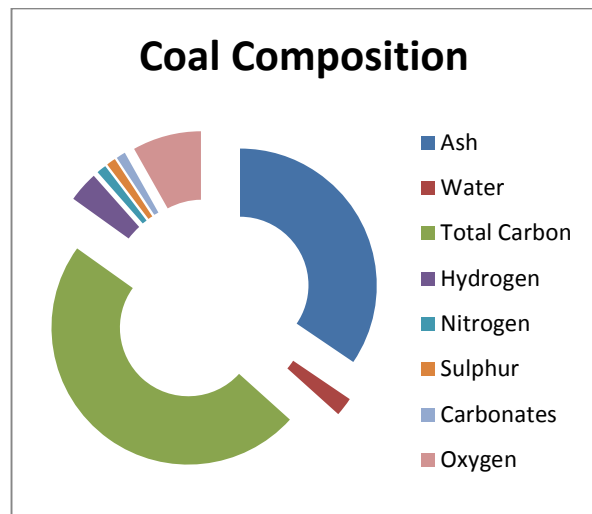


Figure 3-5: Assumed coal composition.

As can be seen in Table 3-5, the assumed overall efficiency for all fans is 75%, the efficiency of the forced-draft ACC motors and mill motors is 95%, and the overall boiler efficiency (fuel to thermal) is assumed to be 90% for all loads.

Table 3-5: Other efficiencies

Other Efficiencies	
Air Cooled Condenser Motors	95%
Primary Air Fan and Motor	75%
Induced Draft Fan and Motor	75%
Forced Draft Fan and Motor	75%
Pulveriser Motors	95%
Boiler (Fuel to Thermal)	90%

3.1.2 Rankine cycle description

For the base case, a generic supercritical power station with parameters similar to those of Kusile power station was assumed. This power station includes a once through, two-pass PC boiler system in which supercritical steam is generated. The main steam is partially expanded in an HP turbine, after which it is reheated to superheated steam in the boiler's reheater. From the reheater, the steam is expanded in the IP turbine and LP turbine stages. A steam attemperator system (see H in Figure 3-16) sprays relatively cold water into the superheated steam to control the temperature of the steam before it enters the IP turbine (Figure 3-6).

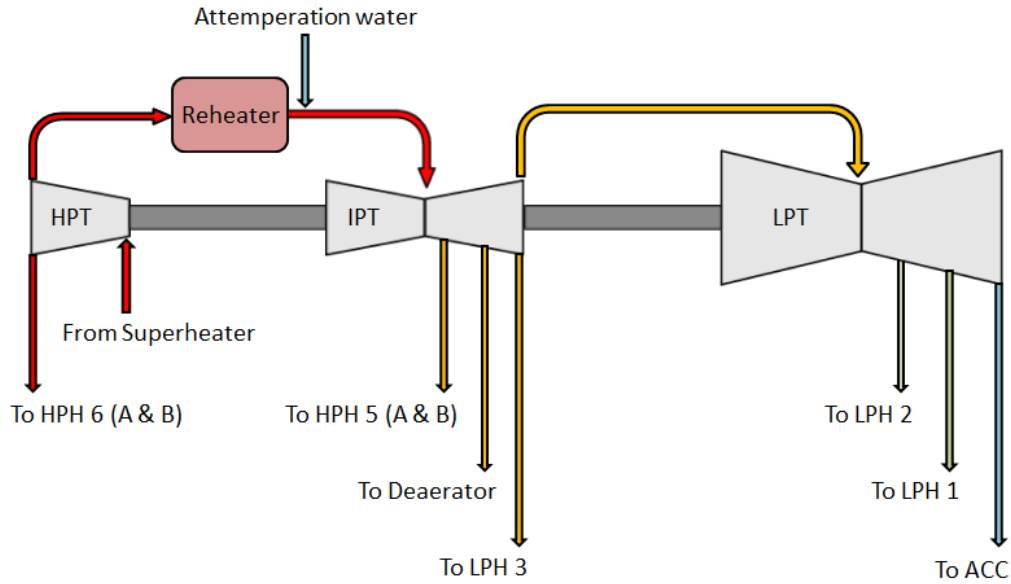


Figure 3-6: Illustration of turbine bleed steam

The theoretical mechanical power generated in each of the turbine stages can be calculated by multiplying the mass flow of the steam through the applicable stage by the change in the steam's specific enthalpy. If an isentropic process is assumed, the specific entropy stays constant, whereas the entropy increases slightly if the isentropic efficiency is less than 100%.

The isentropic entropy (s_i) of steam stays constant during expansion and compression processes in turbines and compressors. Therefore the isentropic enthalpy (h_i) at the turbine exhaust can be obtained from the steam tables by using the pressure and the isentropic entropy as inputs. If the turbine's isentropic efficiency is known, the real exhaust enthalpy can be calculated (see equation below), which, in turn, can be used to obtain the real entropy and temperature.

$$\eta_i = \frac{h_{in} - h_{out}}{h_{in} - h_{out(i)}} \quad 3.1$$

Where:

η_i = Isentropic efficiency of the turbine [%]

h_{in} = Specific enthalpy of the working fluid entering the turbine stage [kJ/kg]

h_{out} = Specific enthalpy of the working fluid leaving the turbine [kJ/kg]

$h_{out(i)}$ = Specific isentropic enthalpy of the working fluid leaving the turbine [kJ/kg]

To obtain the actual turbine power output, the theoretical power output should be multiplied by the turbine's mechanical efficiency. The isentropic and real turbine power output can be calculated with the equations below:

$$P_{t(i)} = \dot{m}(h_{in} - h_{out(i)}) \cdot \eta_m \quad 3.2$$

$$P_{t(real)} = \dot{m}(h_{in} - h_{out}) \cdot \eta_m \quad 3.3$$

Where:

$P_{t(i)}$ = Isentropic power produced by the specific turbine stage [kW]

$P_{t(real)}$ = Actual power produced by the specific turbine stage [kW]

$\dot{m}$ = Mass flow of the working fluid through the specific turbine stage [kg/s]

h_{in} = Specific enthalpy of the working fluid entering the turbine stage [kJ/kg]

h_{out} = Specific enthalpy of the working fluid leaving the turbine [kJ/kg]

$h_{out(i)}$ = Specific isentropic enthalpy of the working fluid leaving the turbine [kJ/kg]

η_m = Mechanical efficiency of the turbine [%]

The total mechanical power can then be calculated by adding the power generated in each of the turbine stages.

The saturated steam from the LP turbine exhaust is condensed to a liquid state by a forced ACC system. The ACCs also receive saturated steam from the flash box, supplied by the cascade from the first low-pressure heater (Figure 3-7). From the condensers, the condensed feedwater flows to the condensate storage tank, from where it is pumped to the first low-pressure heater, by the CEP. The condensate storage tank also receives condensate from the flash box's condensate trap, which can slightly increase the temperature of the feedwater.

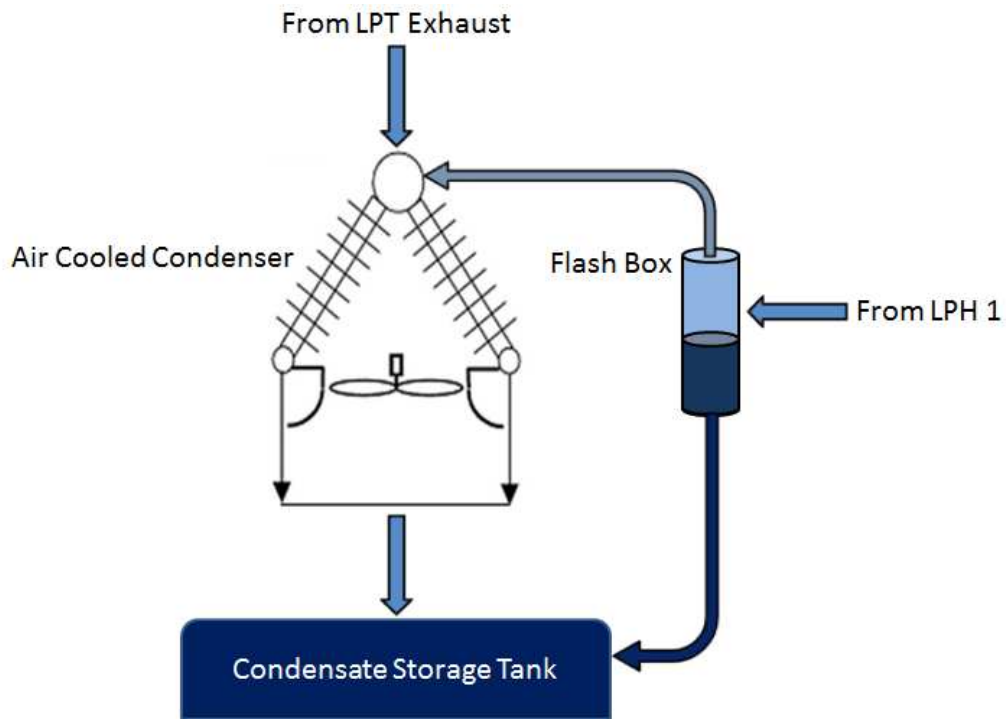


Figure 3-7: Illustration of the condensing system

For this model, three closed low-pressure heaters in series with one another are considered, but no gland steam or ejector steam condensers. The feedwater is heated by bleed steam tapped off from the LP turbine (see F in Figure 3-16) to approximately 2°C below the saturation temperature of the bled-off steam. The condensate formed in this heater is then cascaded to a flash box, at which the pressure is reduced to that of the condenser pressure (see G in Figure 3-16).

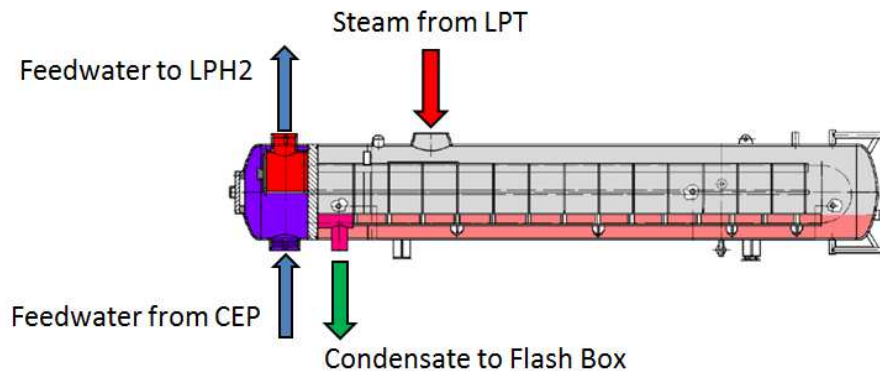


Figure 3-8: First low-pressure heater

The saturated steam created in this flash box because of the lowered pressure, is introduced into the condenser where it is condensed back to a liquid state with the rest of the feedwater, while the saturated water in the flash-box condensate trap flows to the condensate storage tank where it is also mixed with the main feedwater.

From the first LP heater the feedwater enters the second LP heater where its temperature is increased to about 2 °C below the bleed steam saturation temperature. The second LP heater also receives its thermal power from steam tapped off from the LP turbine, but at a stage with a slightly higher pressure (see E in Figure 3-16). This heater also receives the condensate formed in the third LP heater. From this heater, the condensate is pumped back into the main feedwater line between the second and third LP feedwater heaters.

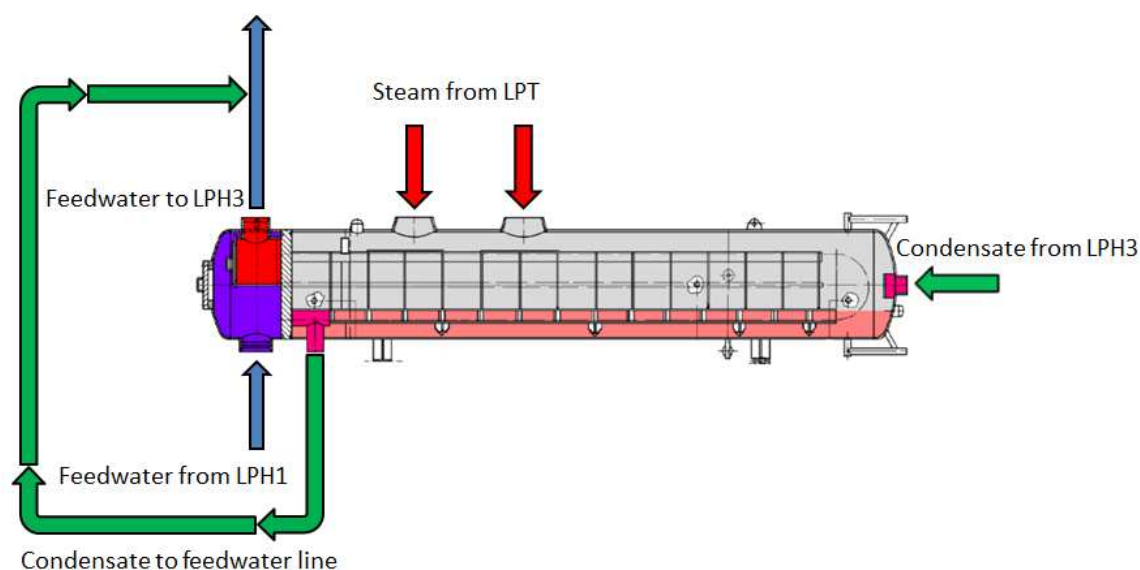


Figure 3-9: Second low-pressure heater

From here the feedwater temperature is increased even further in the third low-pressure heater. Steam from the final stage of the IP turbine is used to increase the feedwater temperature to approximately 2 °C below the saturation temperature of the bled-off steam (See D in Figure 3-16). The condensate formed in this heater is subcooled to a certain extent (approximately 6 °C above the feedwater inlet temperature) after which it is cascaded back to the second LP heater (Figure 3-9).

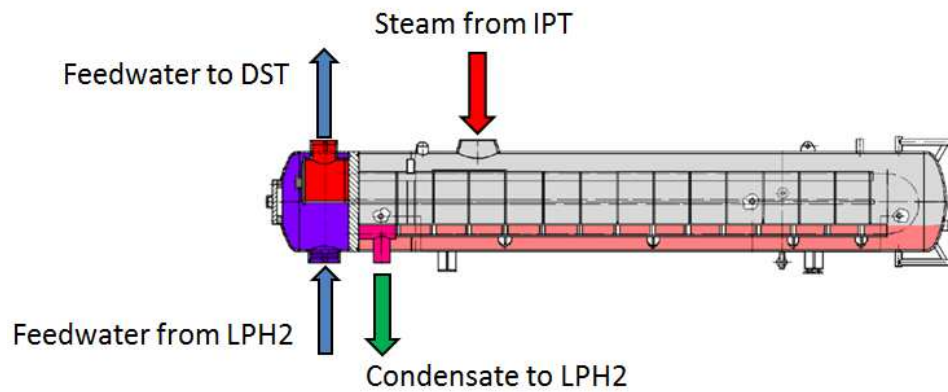


Figure 3-10: Third low pressure heater

The feedwater now enters the deaerator, where bleed steam from the IP turbine (see C in Figure 3-16) is mixed with the feedwater that enters the deaerator from the third low-pressure heater. In this open feedwater heater, the feedwater temperature is increased to the saturation temperature of the tapped-off steam, while dissolved gases are also removed from the feedwater. The DST also receives the condensate formed in the four high-pressure heaters. An illustration of the in and out flows of the deaerator storage tank can be seen in Figure 3-11.

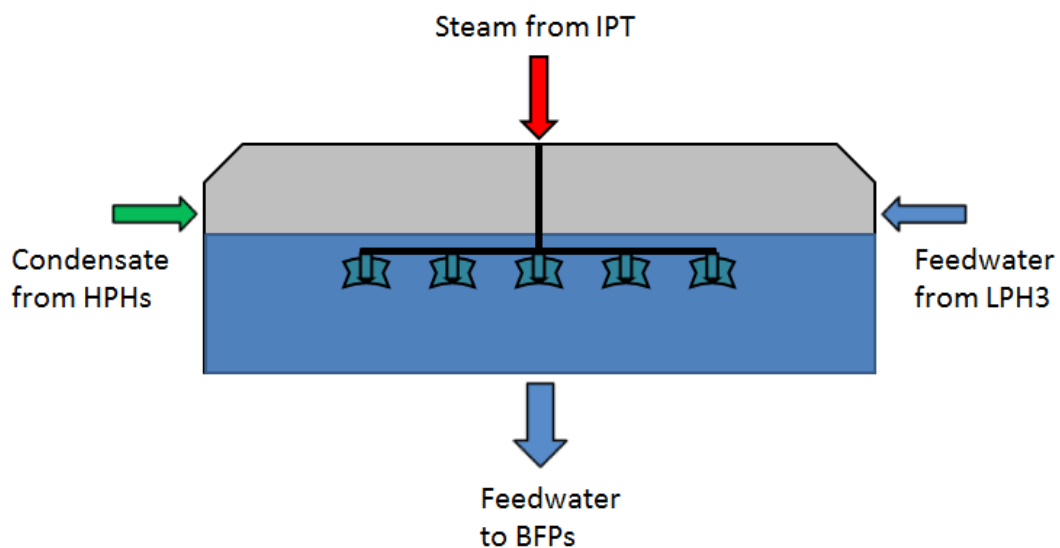


Figure 3-11: Deaerator storage tank

The BFPs take suction in the DST, from where it is pumped to the HPHs. The attenuation spray water used to control the reheated steam temperature before it enters the IP turbine is tapped from a specific BFP interstage (Figure 3-12). The quantity of spray water tapped off from the pump depends mainly on the mass flow through the reheater and the boiler firing rate.

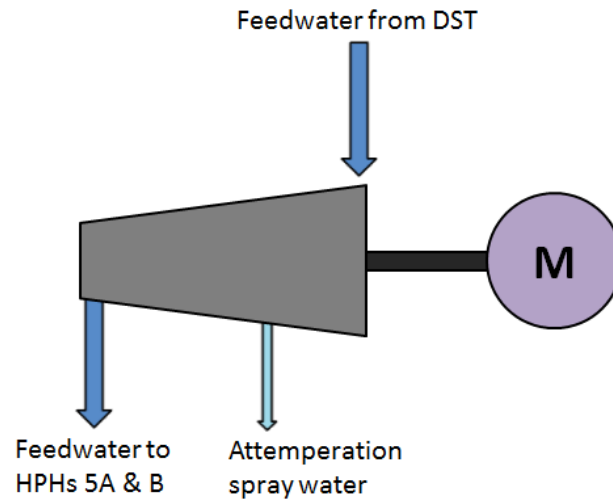


Figure 3-12: Boiler feed pumps

There are typically four high-pressure heaters, HPH 5A and 6A in series and in parallel with 5B and 6B, which are also in series with one another. Figure 3-13 gives an illustration of the HPH configuration.

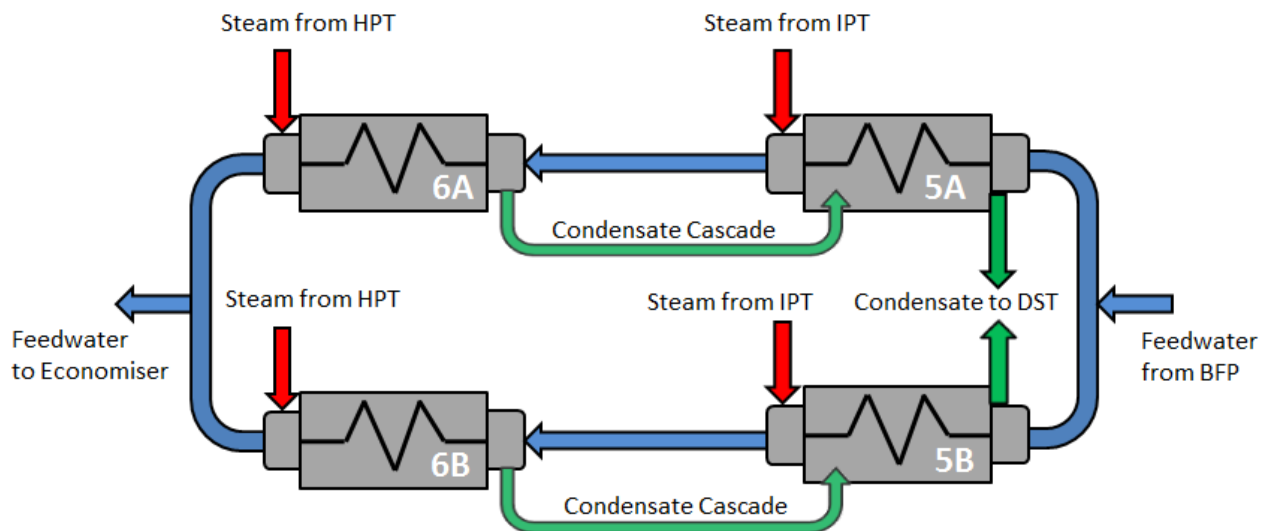


Figure 3-13: High pressure heater configuration

Under normal operating conditions the main feedwater flow is divided so that an equal quantity of feedwater passes through each of the HPH banks (5A and 6A form a bank and 6B and B form a bank). From the BFP the feedwater enters HPHs 5A and B where it is heated to approximately 1 °C above the saturation temperature of the bled-off steam from the IPT. These feedwater heaters receive steam from the IPT (see B in Figure 3-16) and the condensate condensed in HPHs 6A and B (see Figure 3-13). The condensate leaving HPHs 5A and B is subcooled to a certain extent (approximately 8 °C above the feedwater inlet temperature), after which it cascades to the DST where it is reintroduced into the main feedwater cycle (Figure 3-14).

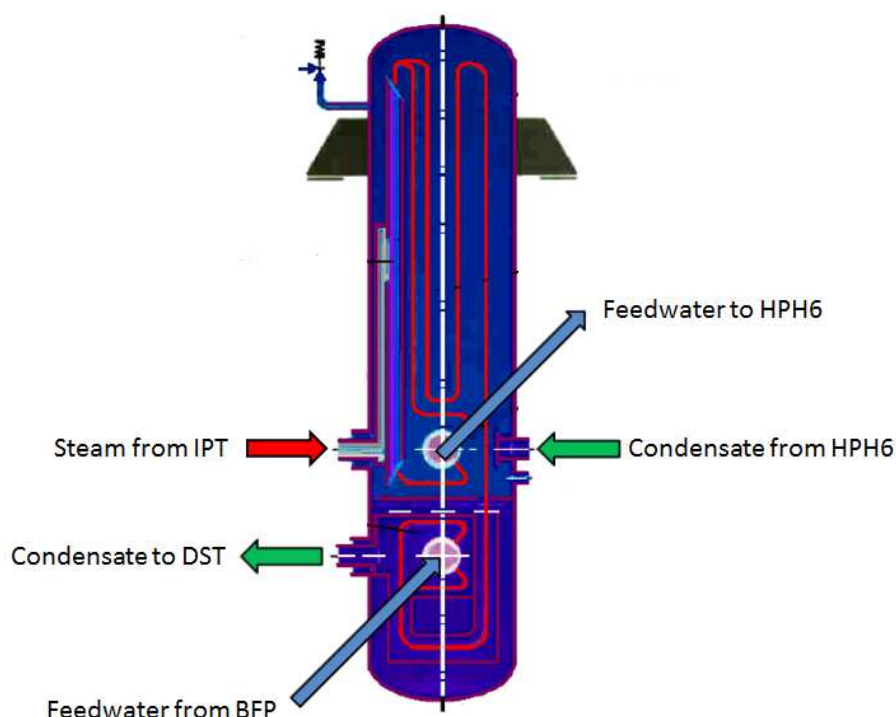


Figure 3-14: First high-pressure heaters (HPHs 5A and 5B)

From HPH 5A and B the feedwater flows to HPH 6A and B, which receive their heat source from the final stage of the HP turbine or the cold-reheat line (See A in Figure 3-16). In these heaters the feedwater temperature is increased to approximately 1 °C below the saturation temperature of the bled-off steam, while the condensate formed in the shell side of the heater is subcooled to approximately 8 °C above the feedwater inlet temperature. This subcooled condensate formed in HPH 6A cascades to HPH 5A, while the condensate formed in HPH 6B cascades to HPH 6B (see Figure 3-13).

From the HPHs, the feedwater flows to the boiler's economiser where it is heated further by the exhaust flue gas leaving the furnace. From the economiser the liquid feedwater enters the vertical boiler tubes (or risers) where it is evaporated to steam without going through a two-phase state. The risers are heated by radiant heat directly absorbed from the fireball in the furnace.

This steam is then passed through the superheaters, where the temperature of the steam is increased to the HP turbine's inlet requirement. A basic illustration of the feedwater and steam flow through the major boiler components can be seen in Figure 3-15.

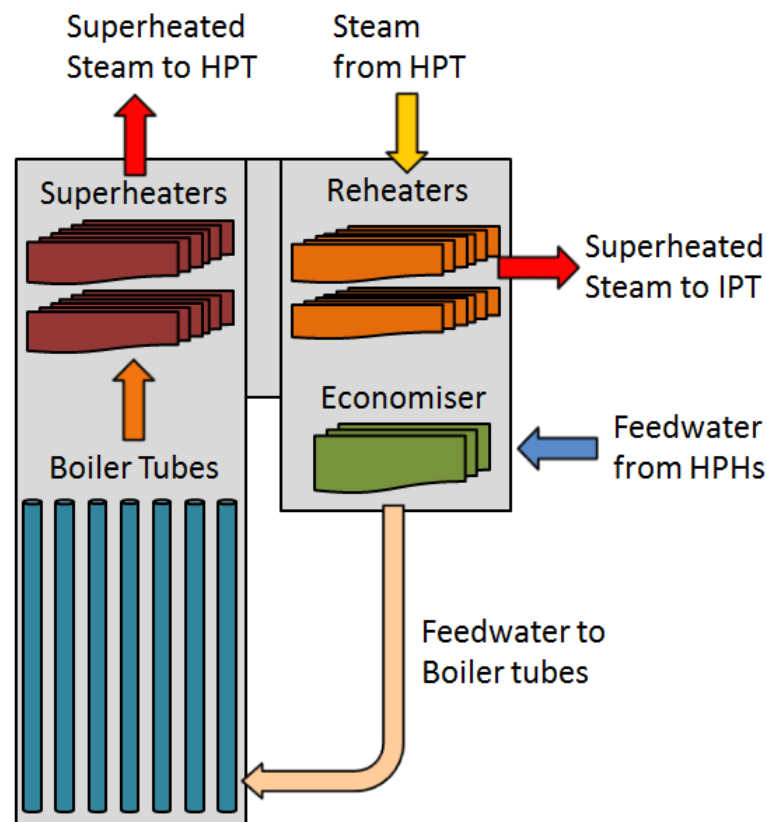


Figure 3-15: Basic illustration of feedwater/steam flow through a two-pass boiler's components

From the superheaters the steam is expanded in the HPT, after which it is returned to the boiler's reheater. The reheater absorbs convective heat from the flue gas to increase the temperature of the steam to the IPT inlet requirement.

An overview of the considered regenerative Rankine cycle can be seen in Figure 3-16 below.

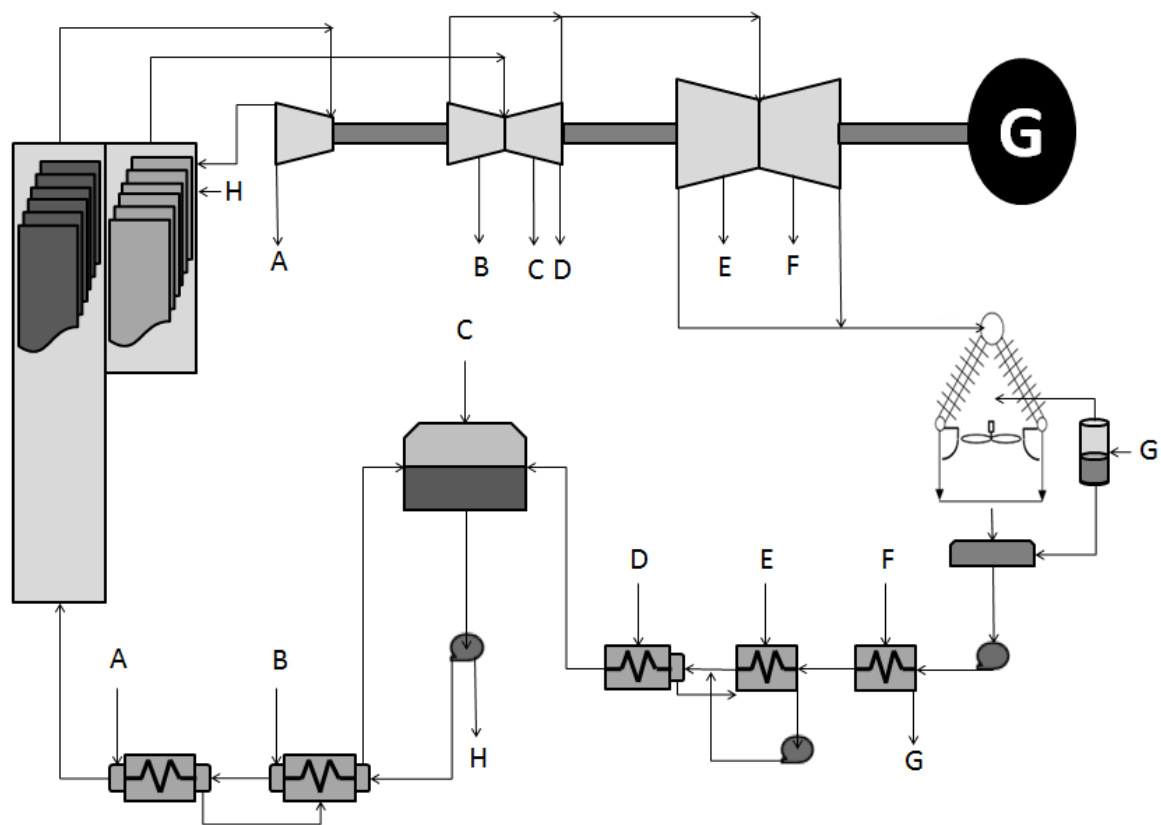


Figure 3-16: Illustration of the regenerative Rankine cycle considered for the base case

Where:

- A = Bled-off steam from HPT exhaust to HPH6 A and B
- B = Bled-off steam from IPT (1st stage) to HPH5 A and B
- C = Bled-off steam from IPT (2nd stage) to deaerator
- D = Bled-off steam from IPT exhaust to LPH 3
- E = Bled-off steam from LPT (1st stage) to LPH2
- F = Bled-off steam from LPT (2nd stage) to LPH1
- G = Condensate from LPH1 to condenser flash box
- H = Spray water from BFP (interstage) to attemperator

3.1.3 Air, fuel and emissions

In this study, three major fans will be utilised to supply fuel and air to the furnace and to suck the exhaust gases from the furnace through the FFP and the FGD plant. The primary air (PA) fan takes suction from within the boiler house (35 °C) and forces the calculated amount of air through the primary air heater into the pulverisers. This PA is then used to transport the PF from the mills to the burners. A calculated amount of PA is bypassed across the air heater and is used to control the temperature in the mills. This air is known as tempering air (TA). The forced draft (FD) fan also takes suction from inside the boiler house and forces the slightly pressurised air through the primary air heater. After this, air is heated to a certain extent, and it is forced through the burners into the furnace to supply the secondary oxygen/air for adequate combustion purposes. A simplified illustration of the air and fuel input process can be seen in Figure 3-17.

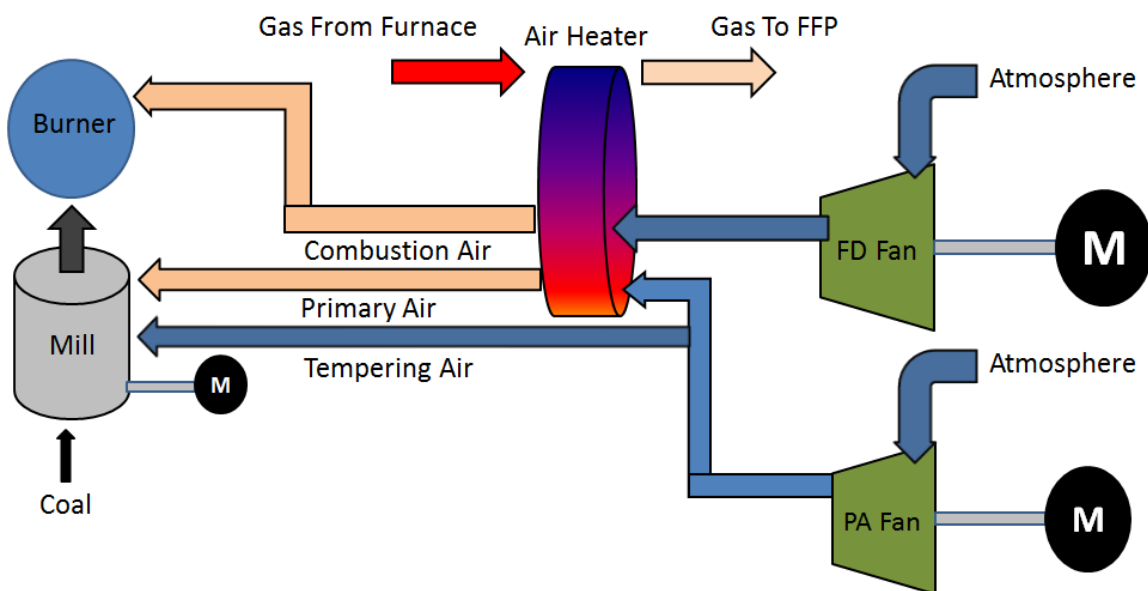


Figure 3-17: Illustration of furnace input air and fuel

One can calculate the coal consumption rate by dividing the heat required by the furnace by the greater calorific value (GCV) of the specific coal.

To calculate the amount air (stoichiometric air) that is required for full combustion of the fuel, one has to determine the quantity of oxygen required to combust all the volatile matter in the coal. From this required oxygen flow rate, one can determine the amount of air that is required by using the gravimetric oxygen content in the air (in this case 23,15%).

During the combustion process, oxygen binds with carbon to form carbon dioxide, sulphur binds with oxygen to form sulphur dioxide and hydrogen binds with oxygen to form water. The chemical processes can be seen below:



When the quantity of the volatile matter in the coal, the heating value of the coal and the heat required by the furnace is known, one can calculate the coal consumption rate, the required air consumption rate and the rate of the flue gas leaving the furnace.

Because of a non-perfect air transport system and to ensure that all fuel particles combust fully, a specified amount of additional air is considered. This air is normally referred to as excess air and can be up to 20% of the theoretical air required.

The theoretical power required by the fans used in this study is a function of the air/flue-gas flow rate through the fan and the differential pressure across the fan (ΔP_{wc}). The equation below can be used to calculate the theoretical power required by a fan:

$$P_f = \frac{\dot{m}(\rho g \Delta P_{wc})}{\eta_f \cdot \eta_m} \quad 3.7$$

Where:

P_f = Electrical power required by fan [We]

$\dot{m}$ = Volume flow of flue gas or air [m^3/s]

ρ = Density of water [kg/m^3]

g = Gravitational constant (9,81) [m/s^2]

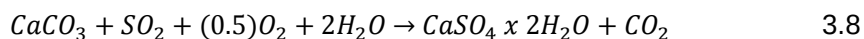
ΔP_{wc} = Pressure differential [m water column]

η_f = Fan efficiency [%]

η_m = Fan motor efficiency [%]

The gases formed during the combustion process, along with the fly ash, is sucked out of the furnace through the fabric filter plant, where approximately 99,5% of the fly ash is removed from

the flue gas by the induced draft (ID) fan. From the FFP the flue gas is sucked through the FGD plant where some of the SO_2 is captured. The desulphured flue gas is then pushed out the stack into the atmosphere. The amount of sorbent, oxygen and water required and the amount of gypsum produced in an FGD plant can be calculated with the following chemical formula:



The overall flue-gas system considered in this study can be seen in Figure 3-18 below.

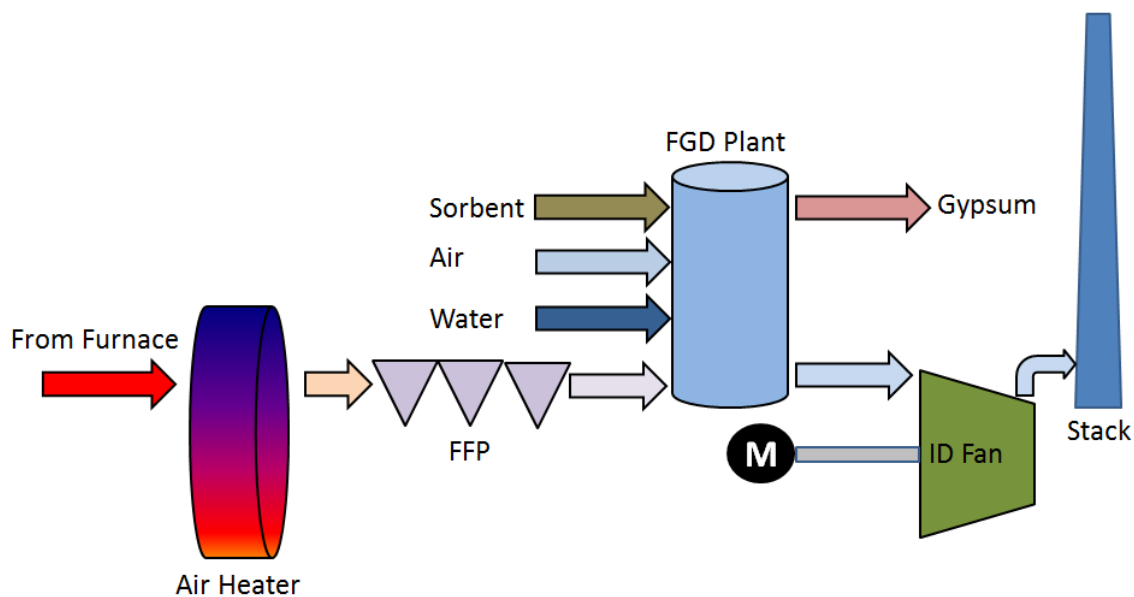


Figure 3-18: Illustration of flue gas leaving the furnace

3.2 Rosherville linear Fresnel performance analysis

3.2.1 Background

This small-scale pilot and demonstration project constructed at Eskom's research facility in Rosherville was initiated by Eskom's RT&D department to determine the power availability and solar to thermal efficiency of this locally sourced LFC technology.

The plant was designed to produce approximately 150 kWt at peak solar irradiation conditions, which can produce a daily energy yield of about 1 400 kWh. The plant utilises subcooled water as the working medium at operating temperatures ranging up to 250 °C at 4 000 kPa (Table 3-6).

Table 3-6: Rosherville plant design parameters

Design Parameters	
Design Temperature	250 C
Design Pressure	4600 kPa
Rated Thermal Power	150 kWt

The plant's collector field has a total mirror area of 234 m² and consists of two identical modules that have six mirror rows each. The corresponding mirror rows in each of the two modules share a driving gearbox/motor assembly that plays a vital role in the mechanics of the tracking system. Each module has 48 slightly concave (2 m x 1,2 m), low iron mirrors that are responsible for reflecting and focusing the sunlight onto the stainless-steel receiver tubes situated approximately 9,5 m above ground level. These mirrors have a reflectivity of approximately 91%.

From the receiver outlet the hot feedwater is pumped through the system by a magnetically coupled centrifugal pump at a flow rate of approximately 3 kg/s. From the circulation pump, the feedwater is pumped through a forced-draft, air-cooled heat exchanger similar to a radiator used in light motor vehicles. The airflow through this heat exchanger can be manipulated by adjusting the fan-motor frequency. By doing so, the thermal load on the LFC plant is also manipulated. The thermal load induced by the heat exchanger can be calculated by the following equation:

$$P_T = \dot{m}(h_{in} - h_{out}) \quad 3.9$$

Where:

P_T = Thermal power [kWt]

$\dot{m}$ = Mass flow of feedwater [kg/s]

h_{in} = Enthalpy of inlet feedwater [kJ/kg]

h_{out} = Enthalpy of outlet feedwater [kJ/kg]

The partially cooled feedwater now flows through the plant's receiver, where heat is added to the system. The receiver tube ($D = 50$ mm) makes four passes of approximately 20 m, which results in a total receiver length of approximately 80 m. From the receiver outlet, the hot feedwater is recirculated by the circulation pump.

The following cycle parameters are measured and logged on a five-minute basis from 6:00 to 21:00 every day (see Figure 3-19):

- Receiver inlet and outlet temperatures [C]
- Radiator inlet temperature [C]
- Receiver inlet and outlet pressures [kPa]
- Feedwater mass flow at receiver outlet [kg/s]
- Circulation pump and fan motor frequencies [Hz]
- Direct normal irradiation [W/m^2]
- Wind velocity [m/s]

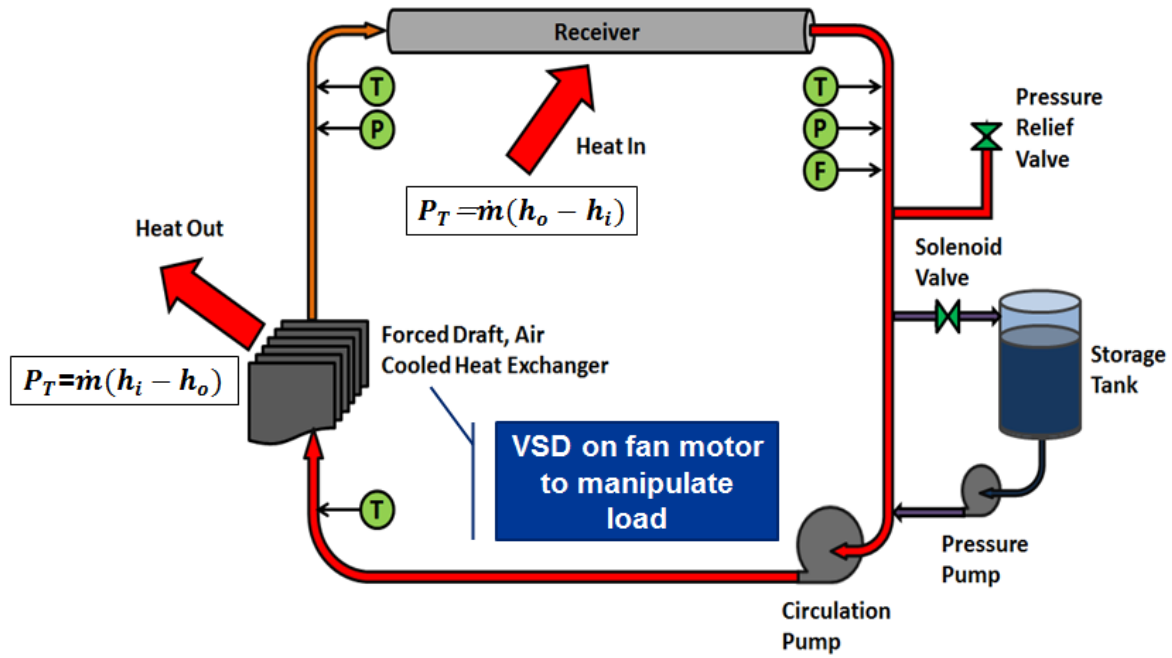


Figure 3-19: Schematic illustration of Rosherville CST cycle (Van Rooy, 2014)

From these measured values, the enthalpy, entropy, density, dynamic viscosity and saturation pressure can be determined.

3.2.2 Plant performance parameters

The amount of solar irradiation available to the 234 m² collector field is measured on a five-minute basis with a solar tracking pyrheliometer in W/m². Therefore, the total amount of irradiation on the entire solar field is calculated with:

$$P_{Solar} = DNI \times Area \quad 3.10$$

Where:

DNI - Direct normal irradiation [W/m²]

Area - Total collector area [m²]

P_{Solar} - Solar power [W/234 m²]

The amount of thermal heat absorbed by the 20 m receiver is calculated with EES. The enthalpy of the subcooled water at the receiver inlet and outlet must first be calculated, after which the heat absorbed by the receiver can be calculated with the following equation:

$$P_{Receiver} = \dot{m}(h_{Receiver\ Outlet} - h_{Receiver\ Inlet}) \quad 3.11$$

Where:

$\dot{m}$ - Mass flow through receiver [kg/s]

$h_{Receiver\ Outlet}$ - Receiver outlet enthalpy [kJ/kg]

$h_{Receiver\ Inlet}$ - Receiver inlet enthalpy [kJ/kg]

The heat rejected by the radiator into the atmosphere is then calculated with the following equation:

$$P_{Radiator} = \dot{m}(h_{Radiator\ Inlet} - h_{Radiator\ Outlet}) \quad 3.12$$

Where:

$\dot{m}$ - Mass flow through radiator [kg/s]

$h_{Radiator\ Outlet}$ - Radiator outlet enthalpy [kJ/kg]

$h_{Radiator\ Inlet}$ - Radiator inlet enthalpy [kJ/kg]

The total available solar energy, the absorbed energy by the receiver and the dispersed energy by the radiator are then calculated by integrating the power curves over the specific time period. Because all available data is logged on a 5-minute interval, it is assumed that the measured value stays constant for the entire 300 seconds until the next reading. The total energy can therefore be calculated with the following equation:

$$E = \frac{\sum_i(P_i \times 300)}{3600} \quad 3.13$$

Where:

P_i - Power reading on 5-minute basis [kW]

E - Total energy over a specified time [kWh]

The solar to thermal efficiency is defined as a percentage of the available solar energy actually absorbed by the receiver of the CST plant. It can therefore be calculated with the following equation:

$$\eta_{ST} = \left(\frac{E_{Thermal\ Absorbed}}{E_{Solar\ Available}} \right) \times 100 \quad 3.14$$

Where:

- η_{ST} - Solar to thermal efficiency [%]
- $E_{Thermal}$ - Total thermal energy absorbed over a certain time period [kWh]
- E_{Solar} - Total solar energy available to the collector field over a certain time period

The capacity factor (CF) of any plant gives an indication of the actual amount of energy the plant had produced over a certain period, compared with the theoretical energy the plant would have produced if it had operated at its rated power for the entire period. The CF is calculated with the following equation:

$$CF = \left(\frac{E_{Actual}}{(P_{Rated} \times T)} \right) \times 100 \quad 3.15$$

Where:

- CF - Capacity factor of the plant [%]
- E_{Actual} - Actual energy produced by the plant [kWh]
- P_{Rated} - Rated power output capacity [kW]
- T - Time period of assessment [hours]

The solar energy available to the plant is significantly larger than the amount of thermal energy absorbed by the receiver of the CST plant. This is due to a number of losses that occur from the instant the light rays hit the glass of the receiver until energy is transferred to the working fluid in the receiver tubes.

The first major loss is due to the fact that the light has to pass through the glass cover twice before it is reflected by the reflector. Even clear glass absorbs some solar energy, which then in

effect is no longer available for reflectance to the receiver. The second and third major losses are due to the unideal reflectivity of the primary and secondary receivers. This simply means that all the light rays that hit the reflectors do not find the absorber tubes. The last major loss occurs because the receiver tubes cannot absorb all the radiation energy. The absorber efficiency can be increased by using a high-absorbent receiver coating. Figure 3-20 below basically illustrates the solar to thermal energy losses.

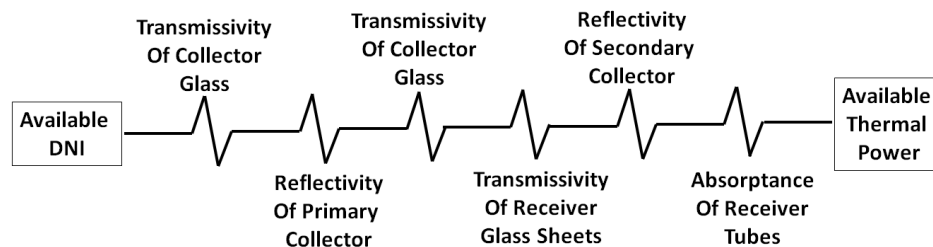


Figure 3-20: Solar to thermal losses

For this solar to thermal efficiency analysis, a single cloudless day is considered, since the DNI climbs steeply from 6:00 AM until approximately 12:00 PM, where it peaks at about 1100 W/m^2 . From here the DNI gradually decreases until sundown at about 6:30 PM.

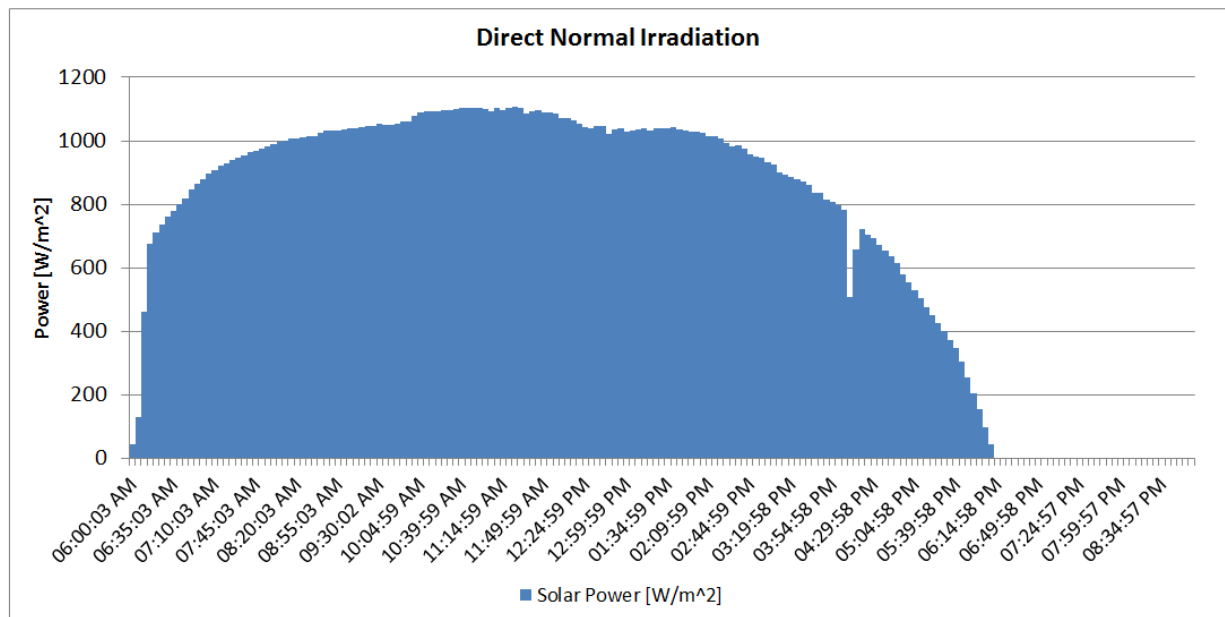


Figure 3-21: Direct normal irradiation vs time of day

On this specific day the following temperatures were recorded. As can be seen in Figure 3-22, the plant's temperature set-point was set at 160 °C .

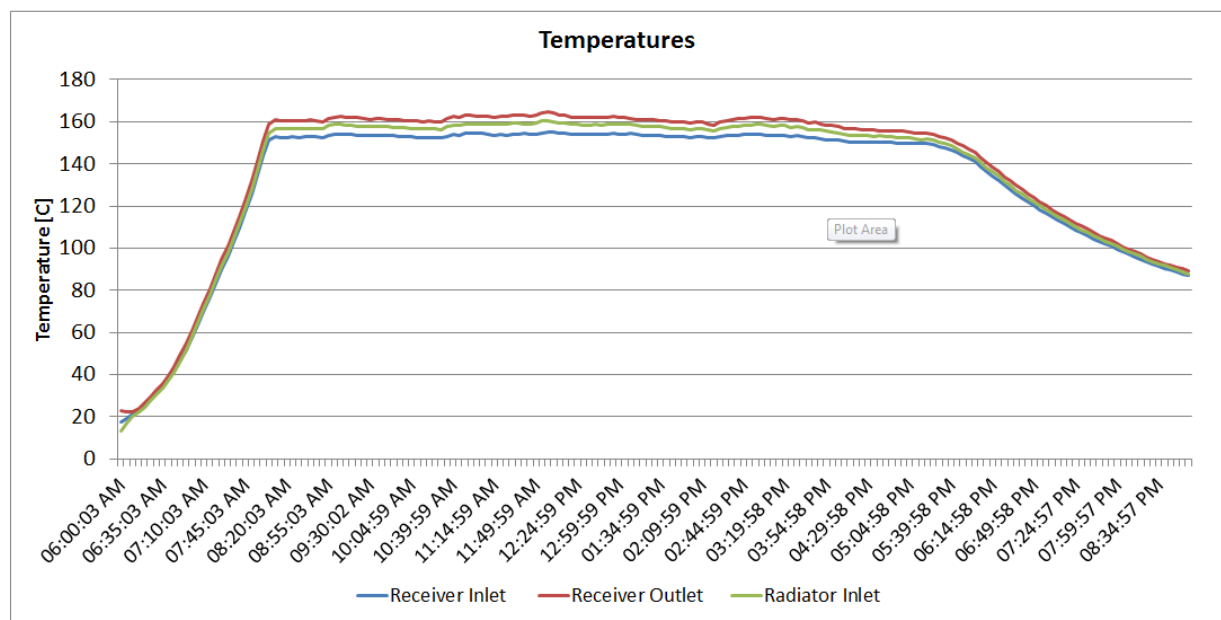


Figure 3-22: Temperature vs time of day

The absolute pressure of the system was kept between 3 950 kPa and 4 360 kPa at all times.

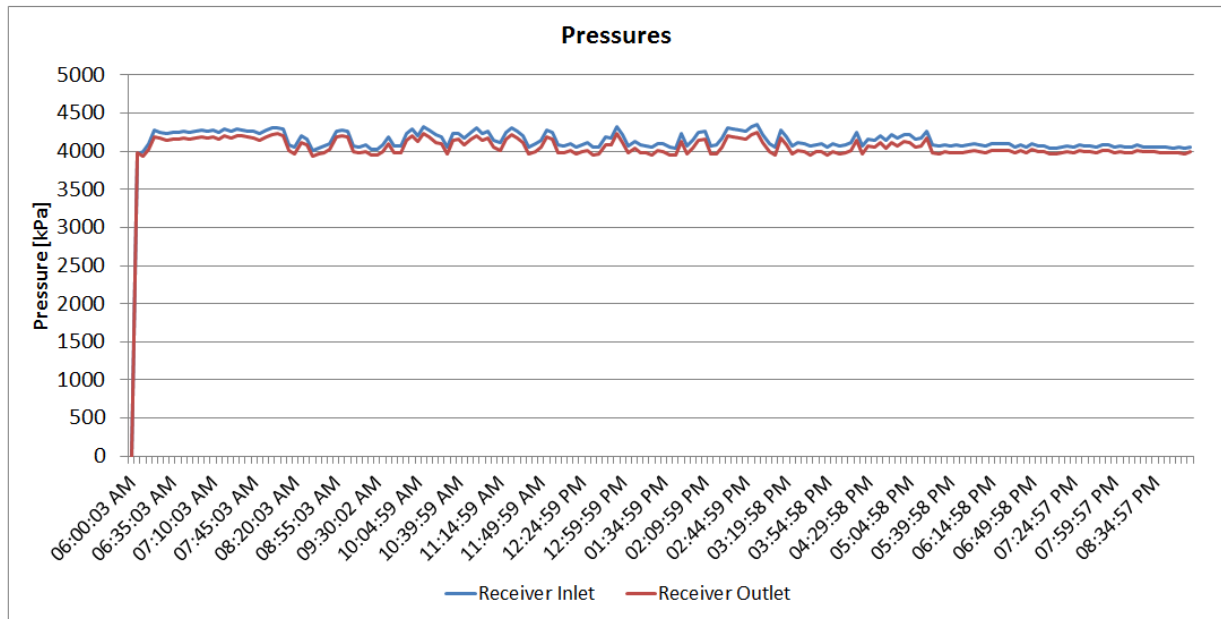


Figure 3-23: Pressure vs time of day

EES was used to determine the enthalpies, power ratings and efficiency parameters for the recorded data. The receiver and radiator thermal power is reflected as zero at about 16:14 PM because the circulation pump was shut down when no irradiation was sensed.

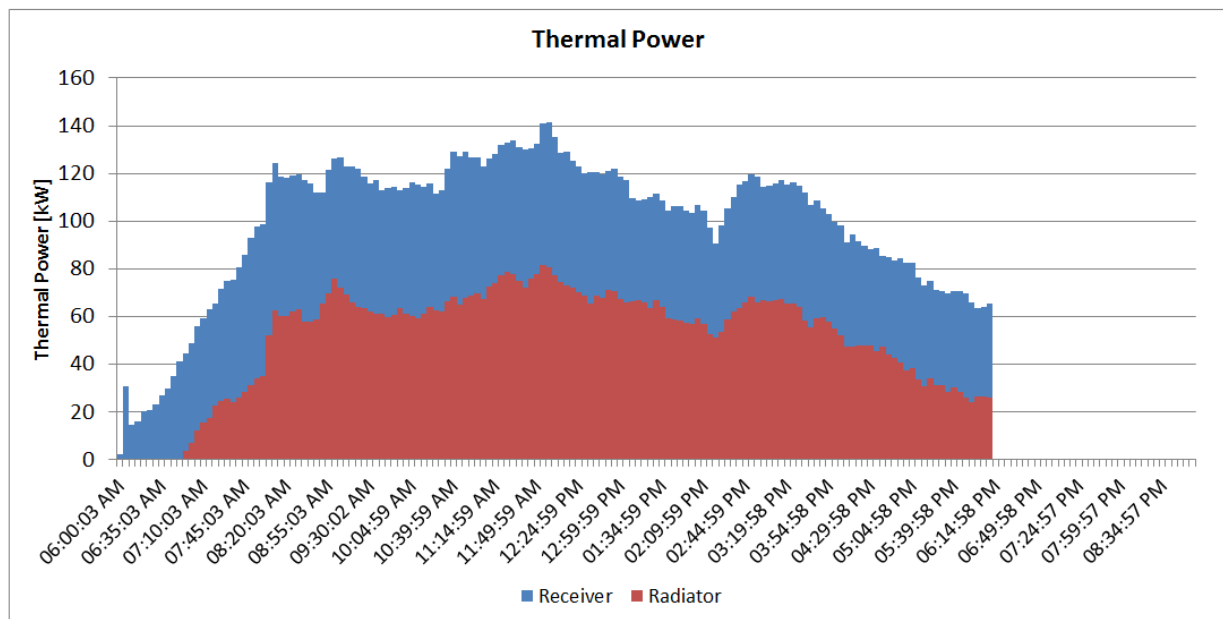


Figure 3-24: Thermal power vs time of day

From the EES analysis, it was found that 2 499 kWh of solar energy was available to the plant's 234 m² collectors for the entire day. Approximately 1 216 kWh was absorbed by the linear receiver and 625,6 kWh was blown into the atmosphere by the load. Therefore a solar to thermal efficiency of 48% is assumed for work to follow.

Table 3-7: Fresnel plant performance parameters

Performance Parameters	
Total Solar Energy Available to Collectors	2499 kWh
Total Thermal Energy Absorbed by Receiver	1216 kWh
Total Thermal Energy Released by Radiator	625.6 kWh
Solar to Thermal Efficiency	48.66 %

The full dataset can be found in Appendix A.

3.3 Solar augmentation scenario

3.3.1 Assumptions

Only one solar augmentation scenario is considered in this study. In this scenario an additional heat exchanger is installed in the HPH bypass line. The quantity of feedwater pumped through the additional heat exchanger will be determined by the available solar radiation at the time. It is assumed that the CST technology can produce temperatures of up to 300 °C at 6 000 kPa (60 bar).

The main limiting parameter for this study is the minimum reheater attemperation spray-water flow rate of 3 kg/s. If the solar to thermal efficiency calculated at the Rosherville P&D plant is assumed to be (48%), it is calculated that under peak solar irradiation conditions (1 100 W/m²), the maximum thermal power that may be injected into the coal-fired power station, before the spray water drops below the minimum value, is 90 MWt.

To generate this thermal power at peak solar conditions, a collector field with a 171 000 m² collector area is required.

Table 3-8: Solar field assumptions

Linear Fresnel CST	
Maximum Output Temperature [C]	300 C
Maximum System Pressure [kPa]	6000 kPa
Thermal Power Output @ 1100W/m ² [kWt]	90288 kWt
Solar to Thermal Eff. [%]	48 %
Total Collector Area [m ²]	171000 m ²

The effect on the power output of the solar field for four different solar resource scenarios will also be determined to give accurate thermal power availability estimates. The four solar resource scenarios were recorded at the Rosherville pilot and demonstration plant and include:

- A clear cloudless day
- A slightly cloudy day
- A very cloudy day
- A mostly cloudy day

The DNI graphs of the abovementioned scenarios can be seen in the solar resource graphs below (Figure 3-25 to Figure 3-28). The solar resource data can be seen in Appendix B.

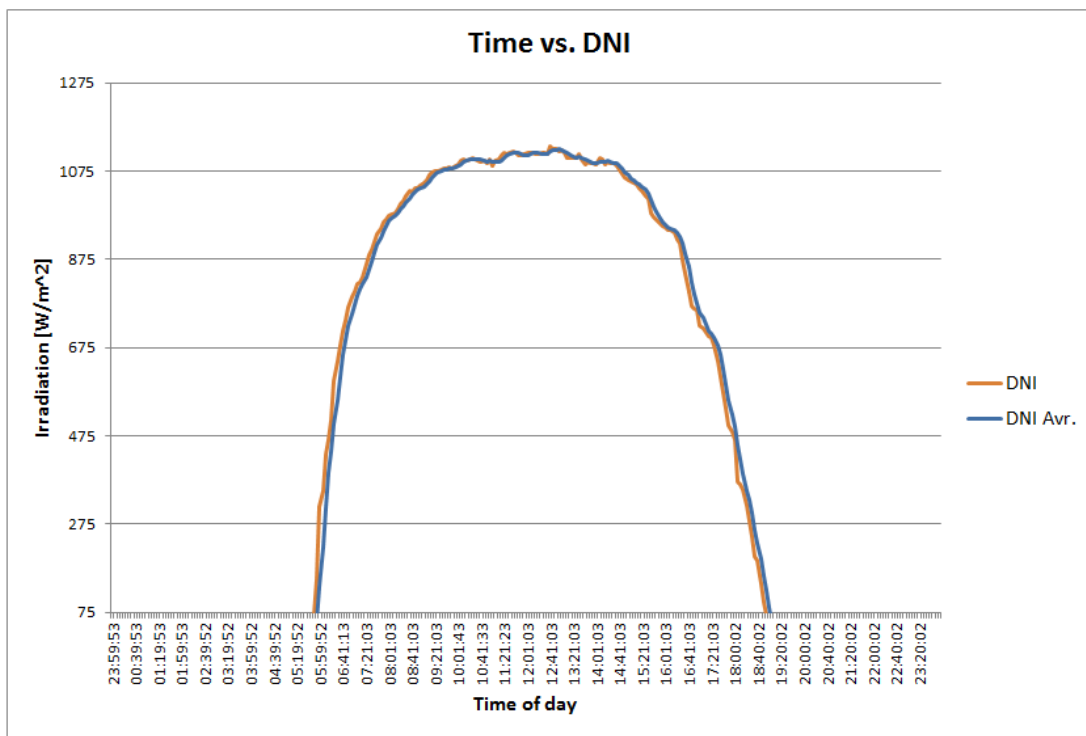


Figure 3-25: Cloudless day (17.01.2014)

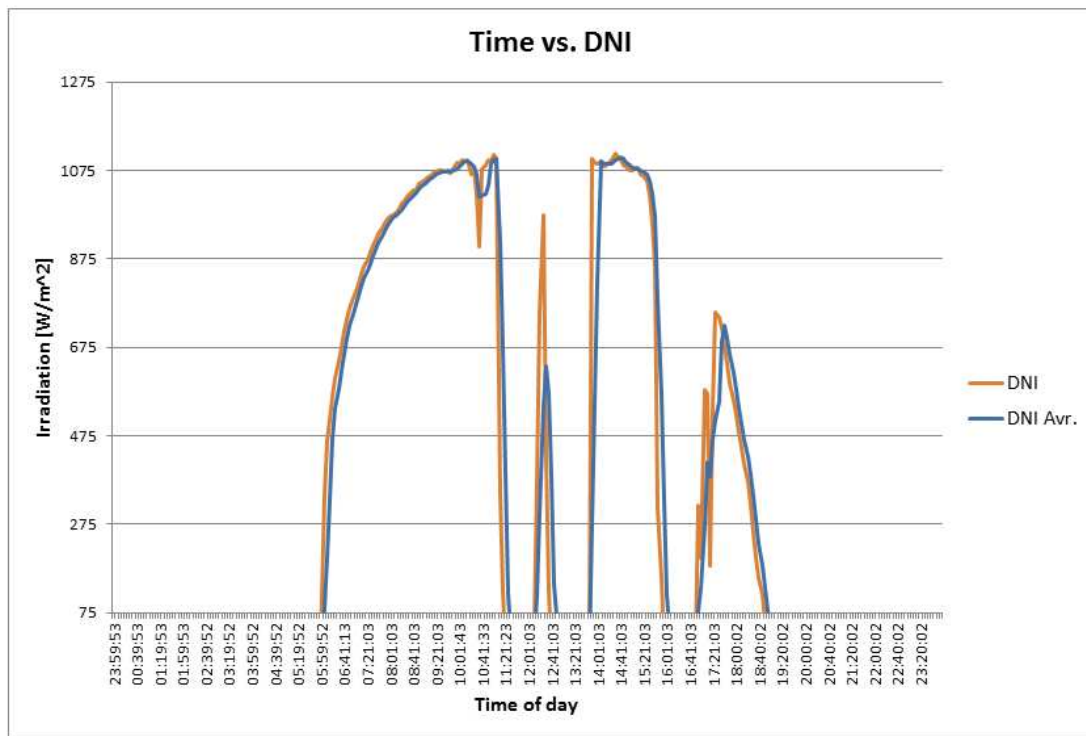


Figure 3-26: Slightly cloudy day (16.01.2014)

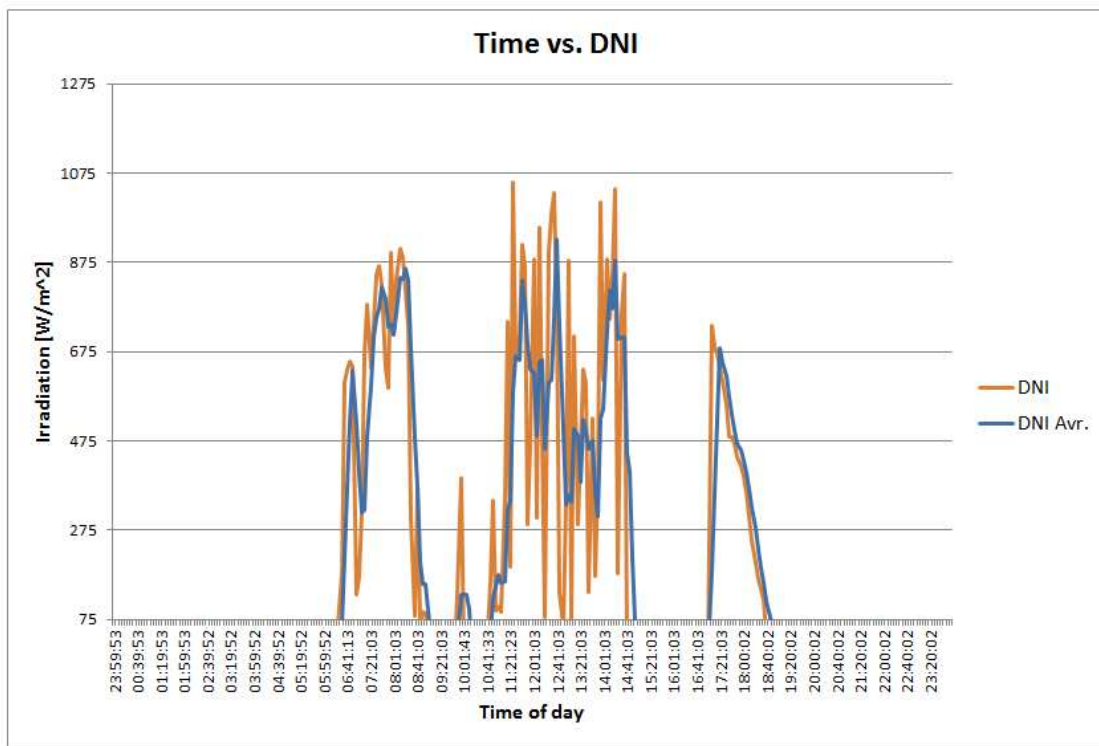


Figure 3-27: Very cloudy day (29.01.2014)

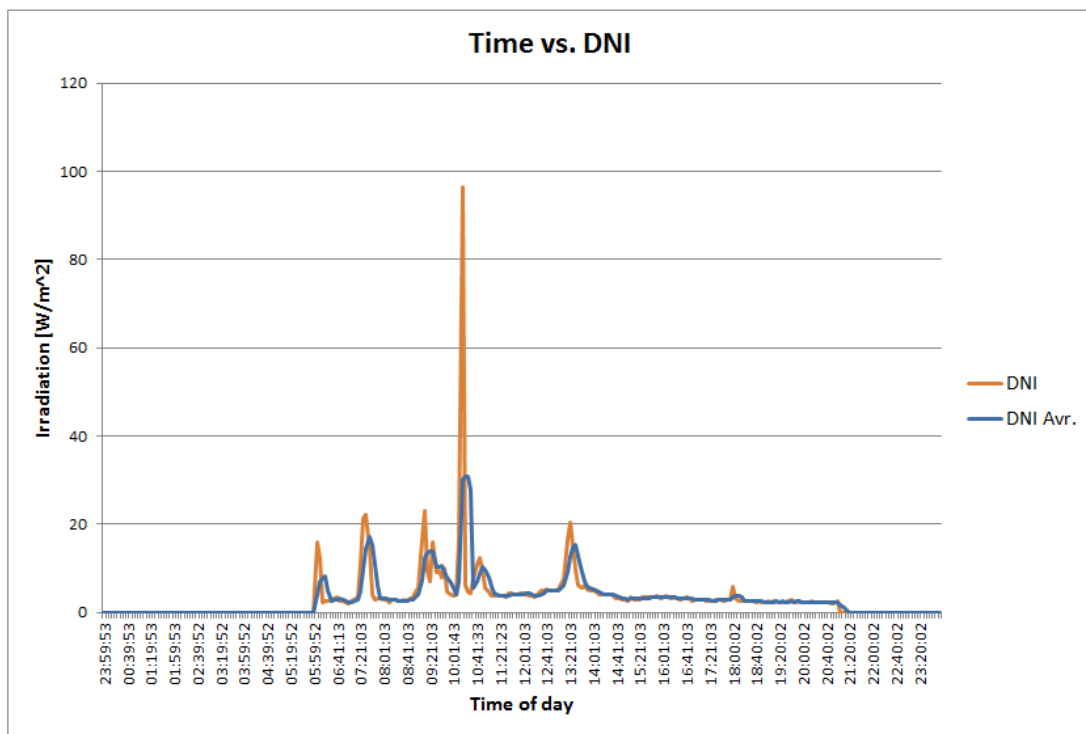


Figure 3-28: Mostly cloudy day (06.01.2014)

The abovementioned daily scenarios will also be used to determine the effect of the relevant solar irradiation on the coal-fired power station. For the total annual solar energy, specific percentage values of each of the abovementioned scenarios will be taken to calculate a realistic figure. It is assumed that the total annual solar energy at the solar field is approximately 2 141 kWh/m²/year. The breakdown of a full year in terms of the four daily irradiation scenarios is illustrated in Table 3-9.

Table 3-9: Annual solar irradiation breakdown

Considered Daily Scenarios	Percentage per Year [%]	Daily Irradiation for 100% [kWh/m²/day]	Yearly Irradiation for 100% [kWh/m²/year]	Yearly Irradiation for X% [kWh/m²/year]
Cloudless Day	5%	11.9	4327.1	216.35
Slightly Cloudy Day	38%	8.0	2925.0	1111.49
Very Cloudy Day	52%	4.3	1561.5	811.99
Mostly Cloudy Day	5%	0.1	28.7	1.44

In effect, it is assumed that 5% of the days in the year will have cloudless days (Figure 3-25), 38% will have slightly cloudy days (Figure 3-26), 52% will have very cloudy days (Figure 3-27) and 5% of the days in the year will have mostly cloudy days (Figure 3-28).

3.3.2 Additional heat-exchanger scenario

Depending on the DNI at the time, an amount of feedwater will be bypassed past the high-pressure heaters. This bypassed water will be heated by an additional closed heat exchanger powered by the working fluid from the solar field (Figure 3-29).

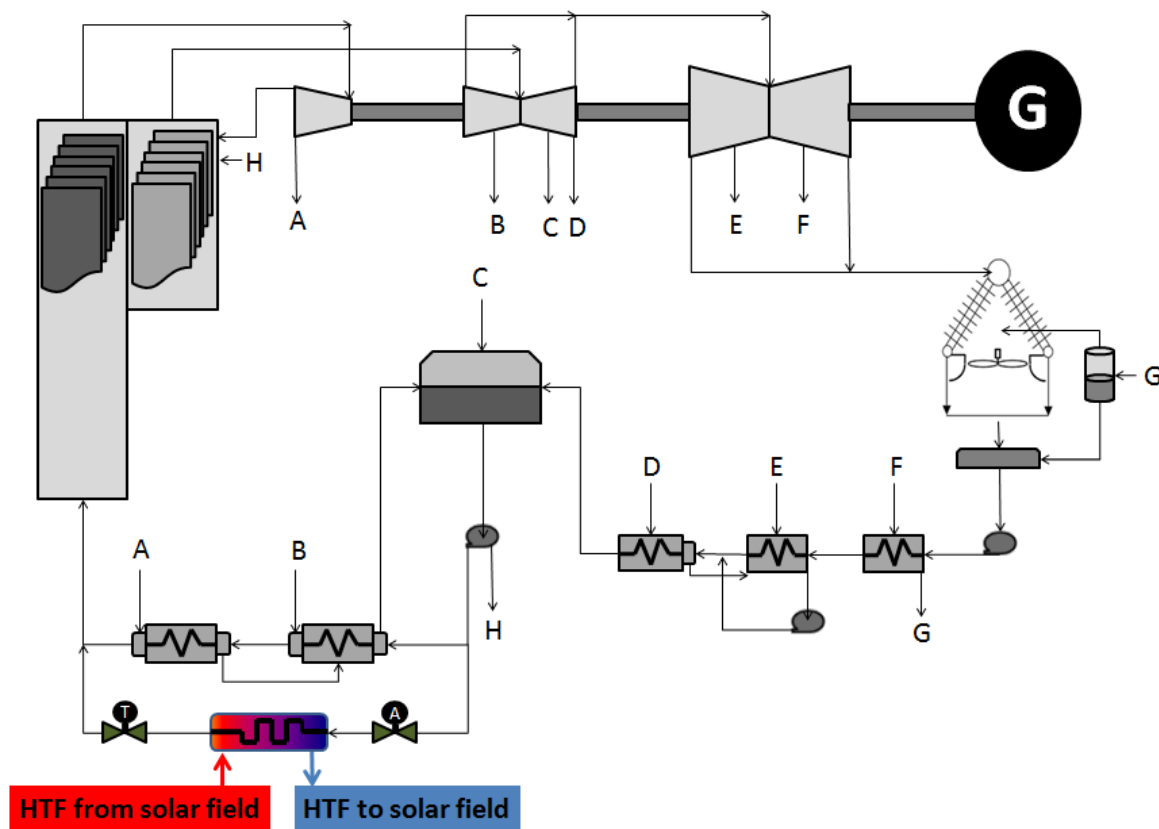


Figure 3-29: Illustration of additional heat-exchanger scenario

The amount of bypassed water will be controlled by the flow-control valve (Figure 3-30) so that the feedwater leaving the additional heat exchanger will be at the same temperature as the water leaving the final high-pressure heaters.

The throttle valve is situated behind the additional heat exchanger and is responsible for throttling the pressure of the bypassed water down to approximately the same pressure as the feedwater leaving the final high-pressure heaters. The throttling process is described in section 2.3.7.

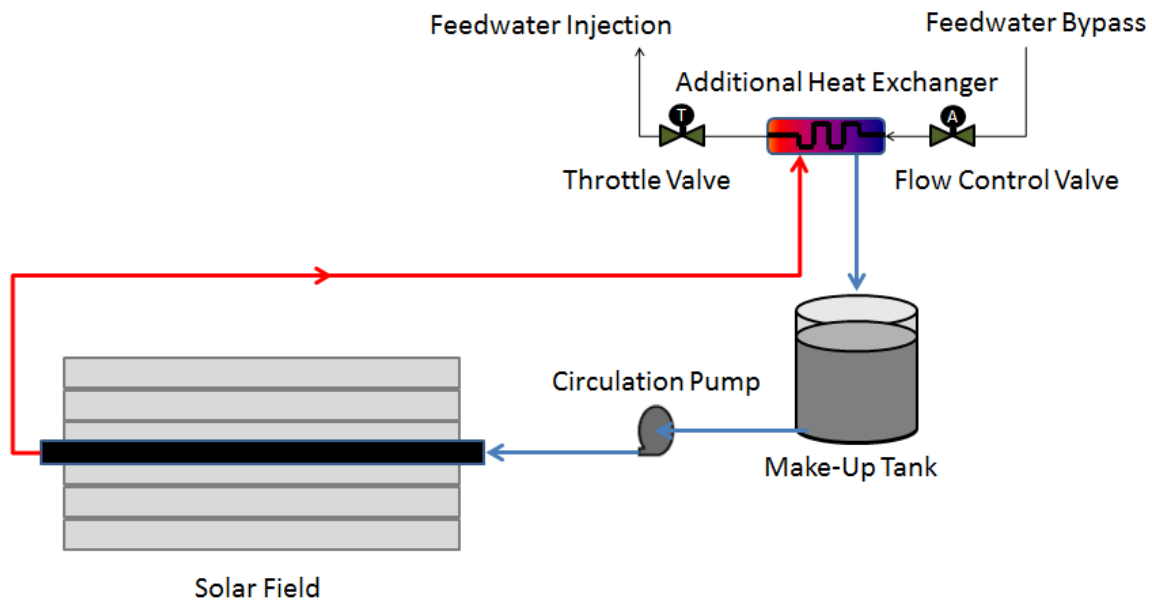


Figure 3-30: Basic illustration of the solar cycle

As the DNI increases from sunrise to midday, the control valve will bypass more water through the additional heat exchanger, as more thermal energy is generated by the solar field to be exchanged to the feedwater. In effect, less feedwater will flow through the conventional high-pressure heaters, which will decrease the bleed steam required to heat the feedwater to the required temperature. This will result in an increased mass flow through the IP and LP turbines, which will increase the shaft power output as well. The mass flow through the reheater will also increase and will affect the attemperation spray water quantity. The spray water flow rate will not be allowed to fall below 3 kg/s to ensure that there is adequate temperature control over the feedwater during the reheat cycle.

3.4 Financial models

Because integrating an additional solar field to an existing coal-fired power station will have a significant capital cost associated with it, and because the operating cost of the coal-fired power station can be lowered to a certain extent, the LCOE must be determined to provide an overall picture. Because a portion of the energy generated from this plant is “green” energy, tradable renewable energy certificates (TRECs) are also assumed for this study and will generate an additional revenue stream. The reduction in carbon production and, in effect, tax will also have a significant impact on the operating cost of the coal-fired station.

During the financial analysis of this study, the levelised cost of electricity (LCOE) is calculated for the base-case scenario (coal-fired power station only), as well as the solar augmentation scenario. By doing so, the offset in the LCOE from the base-case scenario, positive or negative, will be determined.

3.4.1 Assumptions

Most of the financial assumptions seen in Table 3-10, were taken from the Electric Power Research Institute (EPRI) report: "Power Generation Technology Data for Integrated Resource Plan of South Africa" (Bedilion, 2010).

The discount rate for this project is assumed to be 10%, while the capacity factor of the coal-fired power station is assumed to be 90%. It is assumed that it will take 5 years to construct the unit, after which the plant will have a 30-year lifetime. The total capital cost of the station is assumed to be R17 785/MW installed. Five percent of the total capital cost will be spent in year one of construction, 18% in year 2, 35% in year 3, 32% in year 4 and the remaining 10% in year 5.

The operating and maintenance (O&M) cost consists of fixed O&M and variable O&M, where the fixed O&M will cost approximately R455 000 per MW capacity installed per annum, while the variable O&M will cost R44 per MWh (gross) produced by the station. Both the fixed and the variable O&M are expected to increase by 0% over and above the discount rate.

The coal burned at the station will cost approximately R2/kg, while the sorbent used in the FGD plant will cost approximately R2/kg. Neither the coal nor the sorbent cost is expected to increase above the discount rate.

For this study it is assumed that R120 carbon tax is charged for every ton of CO₂ equivalent gases emitted into the atmosphere by the coal-fired power station. It is also assumed that Eskom, as an electricity production company, gets a 60% basic tax-free threshold, as per (Government, 2013). It is also assumed that the carbon tax price does not increase annually over and above the discount rate.

TRECs will be earned, at a rate of R150/MWh for all electrical energy generated from thermal energy injected into the coal-fired station, generated in the CST field. It is also assumed that the TREC price does not increase annually over and above the discount rate.

Table 3-10: Coal-fired station financial parameters

Coal Station Financial Parameters	
Installed Capacity	800 MW
Discount Rate	5.6%
Tax Rate	28%
Construction Time	5 Years
Plant Lifetime (operation)	30 Years
Capital Cost (installed)	R 17 785 /kW
Year #1	5% of total
Year #2	18% of total
Year #3	35% of total
Year #4	32% of total
Year #5	10% of total
O&M Cost	
Fixed O&M Cost	R 455 000 /MW/Year
Variable O&M	R 44 /MWh
Fuel Cost	
Coal Cost	R 14 /GJ
Fuel Heating Value	20100 kJ/kg
Carbon Tax	
Tax Rate (0% tax-free threshold)	R 0.12 /kg CO ₂
Tax Rate (60% tax-free threshold)	R 0.048 /kg CO ₂
Green Credits	
TREC Price	R 150 /MWh

It is assumed that the site preparation work for the CST plant will cost in the region of R220 for every m² of installed collector area. The solar field itself will carry the bulk of the capital cost at R2 585/m² of installed collector area, while the heat-transfer fluid system will cost R385/m² of installed collector area.

The Engineering, Procurement and Construction (EPC) contractors will cost the project approximately 15% of the direct cost of the plant, while the integration into the coal-fired station will cost approximately 16% of the entire CST plant. The operating and maintenance cost for this study is assumed to be 2% of the solar field's capital cost. A contingency cost of 7% of the direct cost is also assumed for this study.

Table 3-11: Solar station financial parameters

Solar Field Cost	United States Dollar Cost	RSA Rand Cost (1\$ = R11)
Site Preparation	\$20 /m ² collector	R 220 /m ² collector
Collector Field	\$235 /m ² collector	R 2 585 /m ² collector
Heat Transfer Fluid System	\$35 /m ² collector	R 385 /m ² collector
Engineering, Procurement and Construction	15% of direct cost	15% of direct cost
Integration with Coal-Fired Station	16% of total cost	16% of total cost
Contingency	7% of direct cost	7% of direct cost
Operations and Maintenance	2% of solar field capital	2% of solar field capital

The financial assumptions seen in Table 3-11 were obtained from the software package, System Advisor Model (SAM) with a Rand/USD ratio of 11:1.

Table 3-12: Solar field financial parameters

Solar Field Financial Parameters	
Installed Capacity	90 MWt
Discount Rate	5.6%
Tax Rate	28%
Accelerated Depreciation Tax Benefit	
Year 1	50%
Year 2	30%
Year 3	20%
Construction Time	2 Years
Plant Lifetime (operation)	30 Years
Capital Cost (installed)	R 670 354 200
Year #1	40% of total
Year #2	60% of total
O&M Cost	R 9 712 800 per year
Green Credits	
TREC Price	R 150 /MWh

3.4.2 Financial study approach

During this study the LCOE for the base-case, coal-fired power station, with the assumption that carbon tax in play (3.4.1), is calculated. The LCOE for the solar augmentation scenario is then calculated, where an additional solar field is constructed. TRECs are earned for all electricity generated with renewable energy, and less carbon tax is paid each year (boosting mode).

The following formula is used to calculate the LCOE with the discounting method:

$$LCOE = \frac{\text{Total discounted expenses}}{\text{Total discounted power production}} = \frac{\sum_{t=0}^n \frac{C}{(1+r)^t}}{\sum_{t=0}^n \frac{E}{(1+r)^t}} \quad 3.16$$

Where:

n = Plant lifetime [years]

t = Relevant year [year]

r = Discount rate [%]

C = Total yearly expenses [R]

E = Total yearly energy production [kWh or MWh].

CHAPTER 4: BASE-CASE SCENARIO

To verify that the EES model used in this study is able to produce accurate thermodynamic parameters with specific inputs, a verification exercise was conducted. During this verification test, a thermodynamic replica of the base-case EES model was built in ThermoFLEX (Figure 4-1), a thermodynamic software package, after which a number of comparison tests were conducted.

4.1 Thermodynamic verification procedure

During these verification tests the boiler for both models (EES and ThermoFLEX) was kept under full-load conditions (100% MCR), after which the major thermodynamic input and output parameters were documented and compared with one another. The relevant parameters monitored during this verification exercise are:

- HPT, IPT and LPT mechanical shaft power
- All bleed steam mass flow rates
- Gross and net electricity output
- Major auxiliary plant power consumption rates
- Coal consumption rate
- Total ash and CO₂ mass flow rates

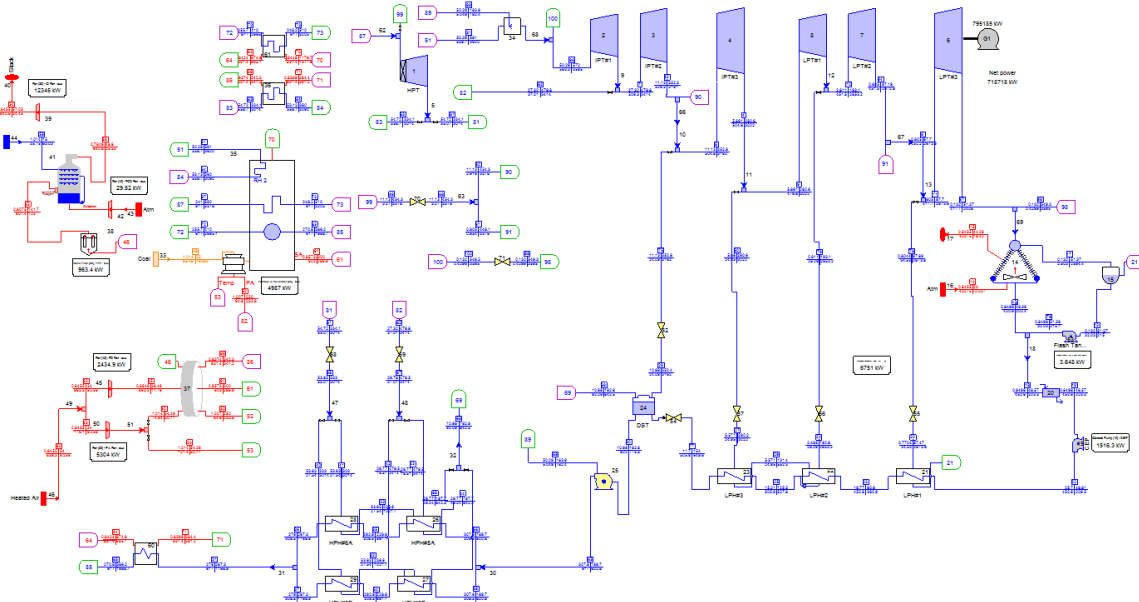


Figure 4-1: Screenshot of base-case ThermoFLEX verification model

The correlation study revealed that the mechanical shaft power output by the HPT was approximately 2% greater in the EES model than in the ThermoFLEX model, while the shaft power by the IPT deviated by about 4%. On the other hand, the LPT shaft power output from the ThermoFLEX model was 5% greater than that of the EES model. This resulted in an insignificant deviation in gross electricity output (Table 4-1).

Table 4-1: Turbine shaft power and electricity output verification results.

Model Verification Results	Turbine Power Output			Electricity Output	
	HPT Shaft Power [kWm]	IPT Shaft Power [kWm]	LPT Shaft Power [kWm]	Gross Electricity Out [kWe]	Net Electricity Out [kWe]
EES Model	226964	316198	260713	795033	729574
ThermoFLEX model	223436	305452	273070	795185	727120

A visual illustration of the turbine shaft power and electricity output verification results can be seen in Figure 4-2.

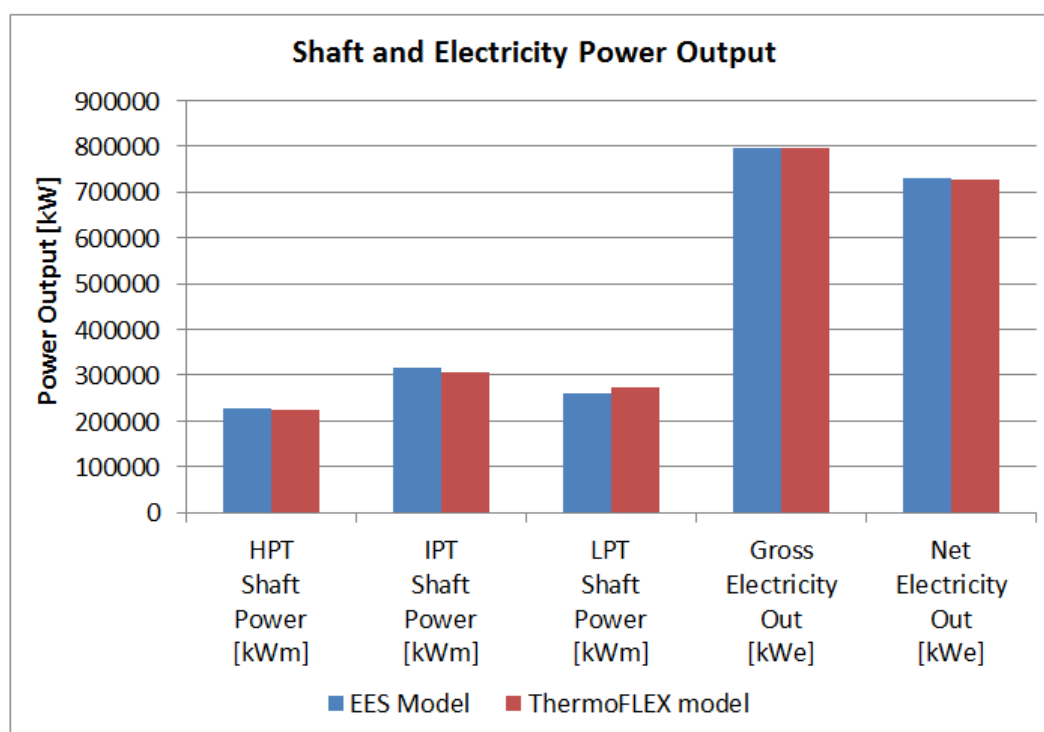


Figure 4-2: Shaft and electricity power output verification results

When the turbine bleed steam mass flow rate was considered, it was found that the bleed steam calculated in the two independent models correlated very well. The HPT exhaust bleed steam flow rates deviated by 0,4%, the flow for first stage of the IPT deviated by approximately 4%, the flow for the second stage of the IPT by about 0,1% while the bleed steam flow rate from the IPT exhaust deviated by 2%.

Table 4-2: Turbine bleed steam verification results

Model Verification Results	Turbine Bleed Steam for Feed Water Preheating					
	HPT Exhaust Bleed [kg/s]	IPT Stage 1 Bleed [kg/s]	IPT Stage 2 Bleed [kg/s]	IPT Exhaust Bleed [kg/s]	LPT Stage 1 Bleed [kg/s]	LPT Stage 2 Bleed [kg/s]
EES Model	54.87	38.37	24.07	25.37	28.2	35.49
ThermoFLEX model	55.07	37.01	24.09	24.95	28.29	34.53

It was also found that the bleed steam flow rate from the first stage of the LPT deviated by 0,3%, while the steam flow from the second stage deviated by about 3%. The turbine bleed steam mass flow rate verification results can be seen in Table 4-2, while a graphic illustration of the results are displayed in Figure 4-3.

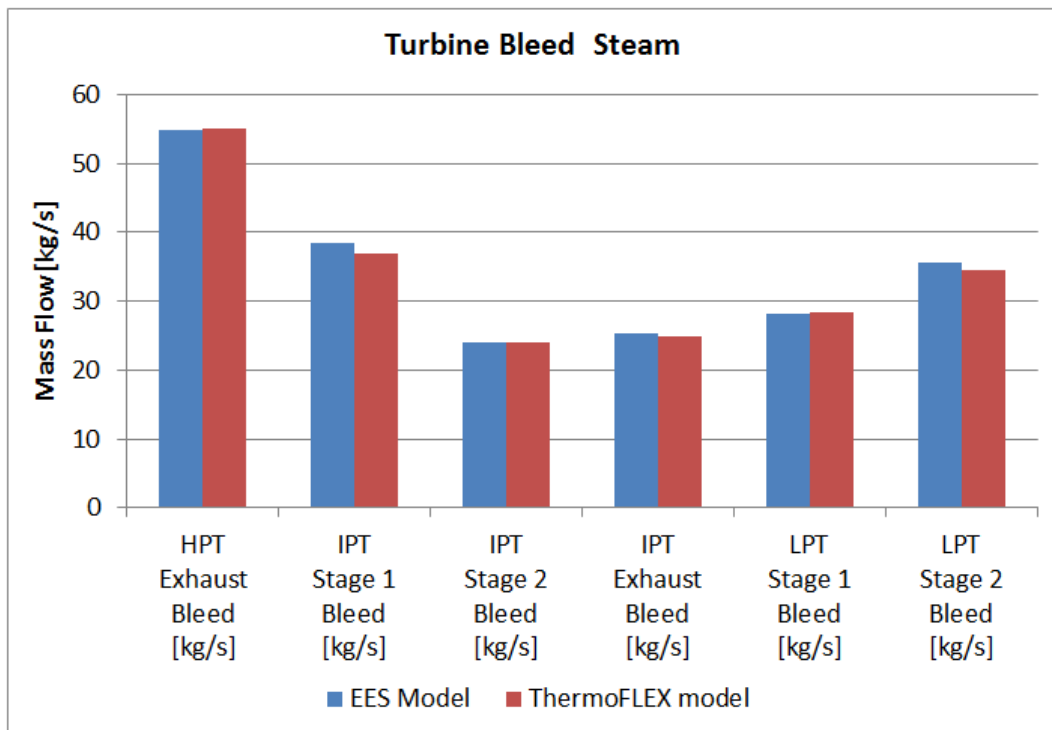


Figure 4-3: Turbine bleed steam verification results

Table 4-3 shows the correlation results for the major auxiliary power consumers of the station. The results indicated that the power consumption estimate for the electric BFP system calculated by the two thermodynamic models deviated by approximately 2%, while the power consumption by the CEP deviated by 1% and the ACC power by 0.4%. It was found that the power consumption by some of the major fans used on the plant correlated slightly worse than that of the other parameters but are still accepted (Table 4-3).

Table 4-3: Auxiliary power verification results

Model Verification Results	Major Auxiliary Plant Power Requirements					
	BFP Power	IDF Power	PAF Power	FDF Power	CEP Power	ACC Power
	[kWe]	[kWe]	[kWe]	[kWe]	[kWe]	[kWe]
EES Model	27232	5338	4484	1540	1507	6775
ThermoFLEX model	27865	6853	4187	1826	1516	6750

A visual illustration of the auxiliary power consumption verification results can be seen in Figure 4-4 below. It was also found that the net electricity output calculated by the two models did not vary by a significant amount (Figure 4-2).

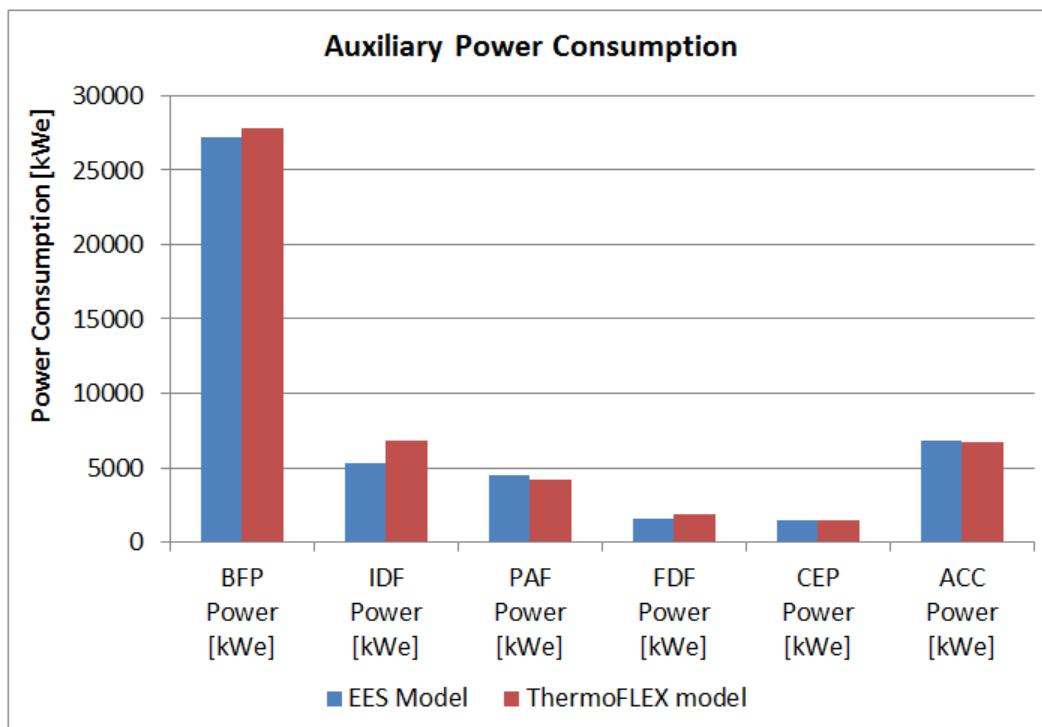


Figure 4-4: Auxiliary power consumption verification results

The coal consumption and ash production rates calculated by the two models both varied by approximately 1%, while the CO₂ production rate deviated by about 3% (Table 4-4).

Table 4-4: Fuel and emissions verification results

Model Verification Results	Fuel and Emissions		
	Coal Flow Rate [kg/s]	CO ₂ Flow Rate [kg/s]	Ash Flow Rate [kg/s]
EES Model	94.35	166.7	32.5
ThermoFLEX model	95.6	172.52	32.96

A visual illustration of the fuel and emissions mass flow correlation results can be seen in Figure 4-5 below.

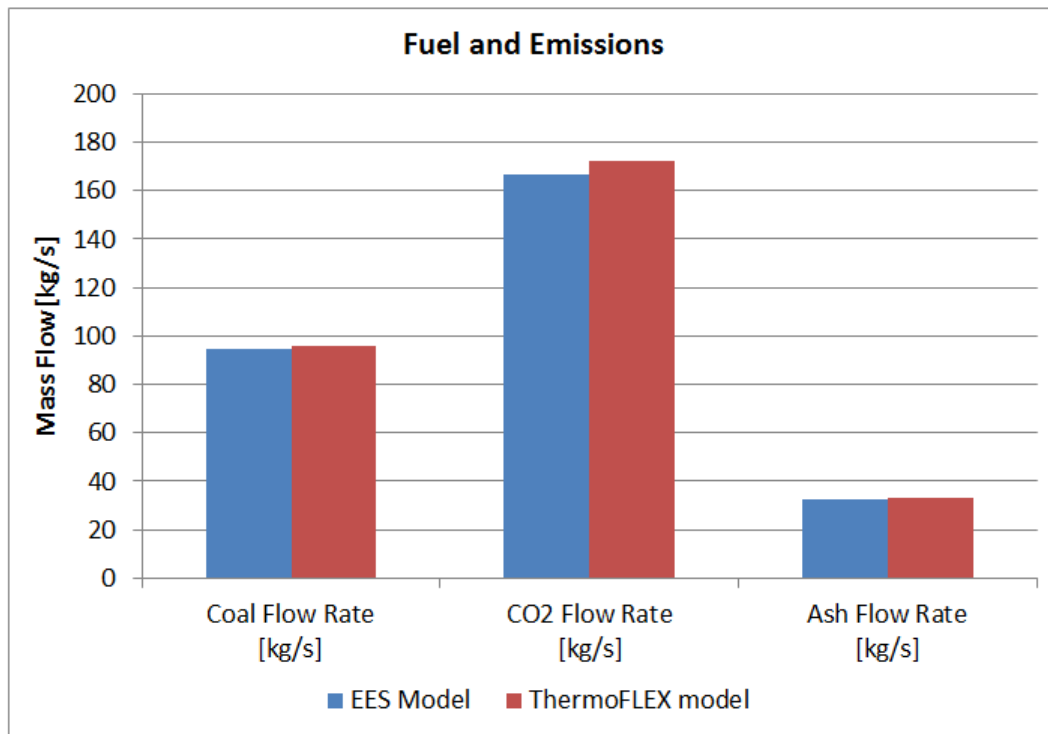


Figure 4-5: Fuel and emissions verification results

It is concluded that the all verified parameters are within an acceptable margin of error and that the EES model produces accurate thermodynamic parameters for specified inputs.

4.2 Engineering equation-solver model

A detailed EES model was developed in which parametric tables were created to calculate all major input and output parameters according to the assumptions made in section 3.1.1. Figure 4-6 gives a screenshot of the developed diagram window for the base-case scenario. The formatted EES code, results, diagram window and plots can be seen in Appendix E while the thermodynamic array table for the base case scenario can be seen in Appendix F.

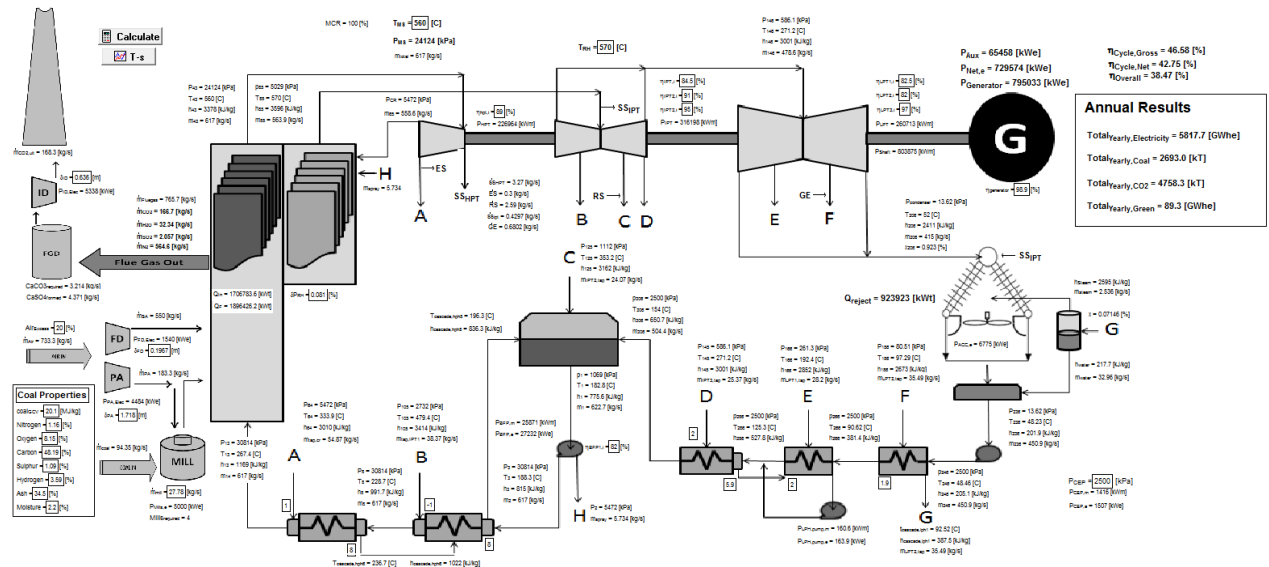


Figure 4-6: Screenshot of base-case EES model diagram window

The T–s diagram (Figure 4-7) of the base-case supercritical coal-fired power station shows the real and isentropic turbine expansions for the HP, IP and LP turbines. This diagram also illustrates the condensation lines for all the bleed steam, used for feedwater pre-heating as well as the main steam in the forced-draft air-cooled condenser.

From this T–s diagram it can also be noted that the main steam never moves into a two-phase mixture; it converts directly to superheated steam from a saturated liquid state.

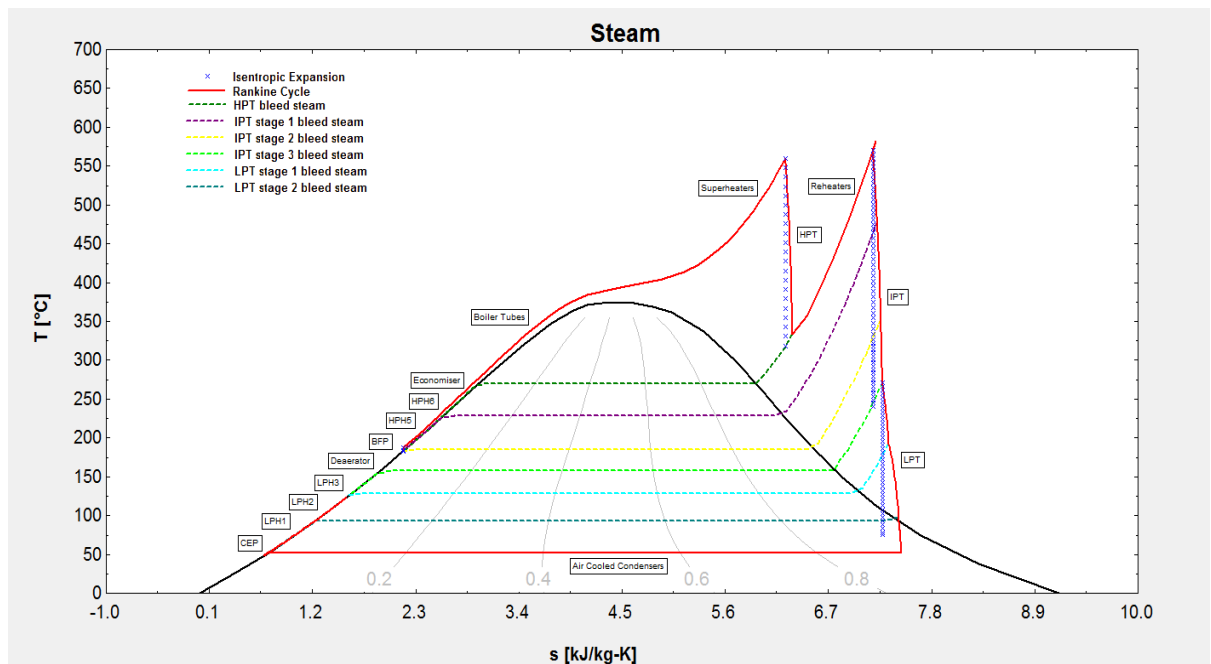


Figure 4-7: T-s diagram of base-case EES model

When a full day is considered, as described in section 3.1.2, where the unit's load is reduced to approximately 60% MCR during late night/early morning periods, the shaft power attributed to the HPT, IPT and LPT can be seen Figure 4-8. The gross and net electrical power output, as well as the total auxiliary power consumption, can be seen in Figure 4-10.

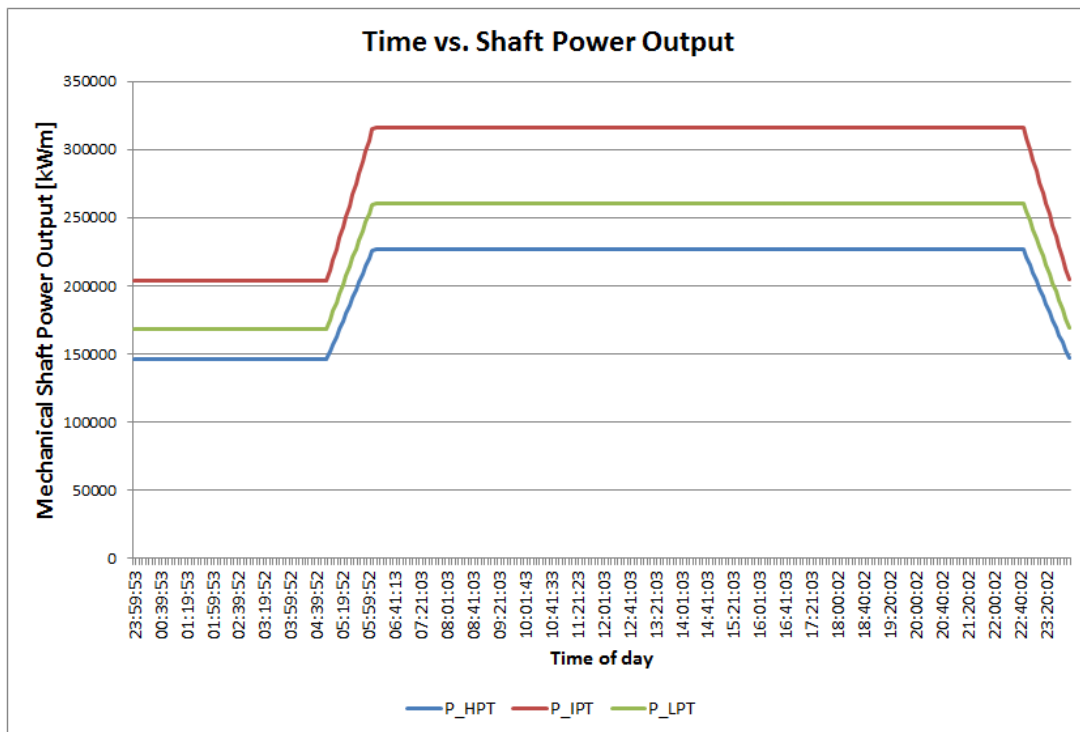


Figure 4-8: Time vs turbine shaft power

The turbine bleed steam for feedwater preheating purposes is illustrated in Figure 4-9. From this graph, it can be seen that the bleed steam tapped off from the turbines has a significant flow rate. The steam tapped off from the HPT exhaust or the cold-reheat line is used to heat the boiler feedwater in HPHs 6A and 6B before it enters the economiser. This steam has a flow rate at 100% MCR of approximately 55 kg/s, while the flow rate is dropped to approximately 26,5 kg/s when the load is at 60% MCR. The steam tapped from the first stage of the IPT is used to power HPHs 5A and 5B and has a flow rate of about 38 kg/s at 100% MCR and 22 kg/s at 60% MCR..

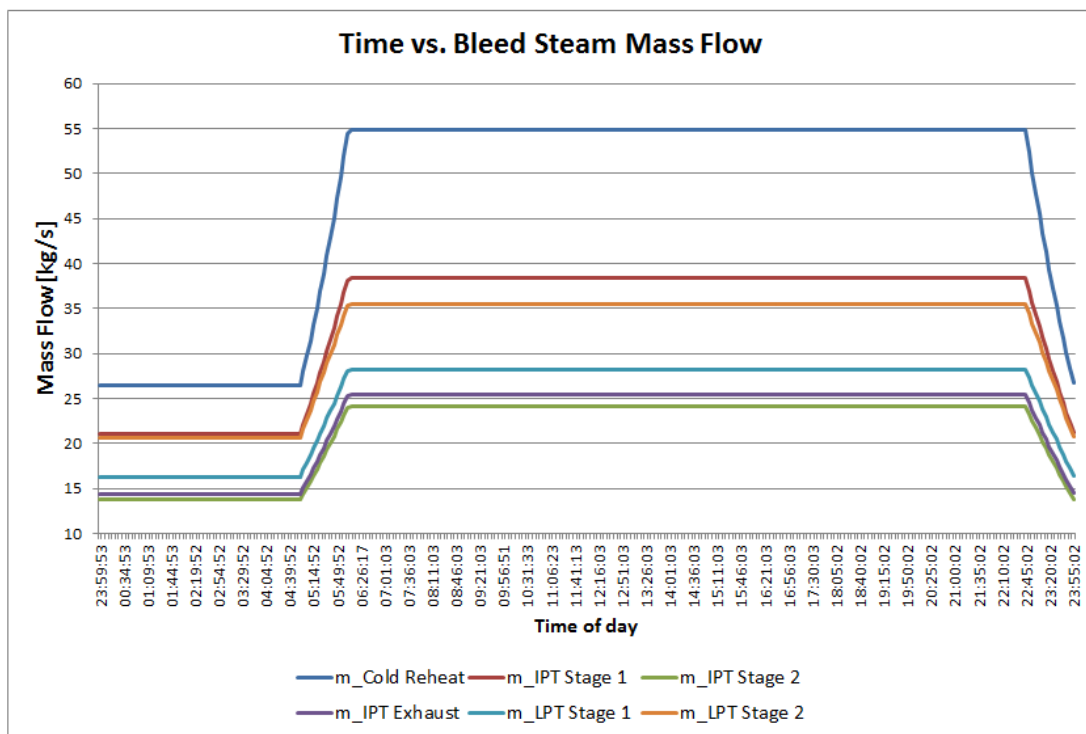


Figure 4-9: Time vs bleed-steam mass flow

Figure 4-10, gives an illustration of the gross generator power output, the total auxiliary power consumption and net electrical power output vs time of day. From this graph one can see how these parameters are affected as the boiler load varies to achieve the net electricity output to the national grid.

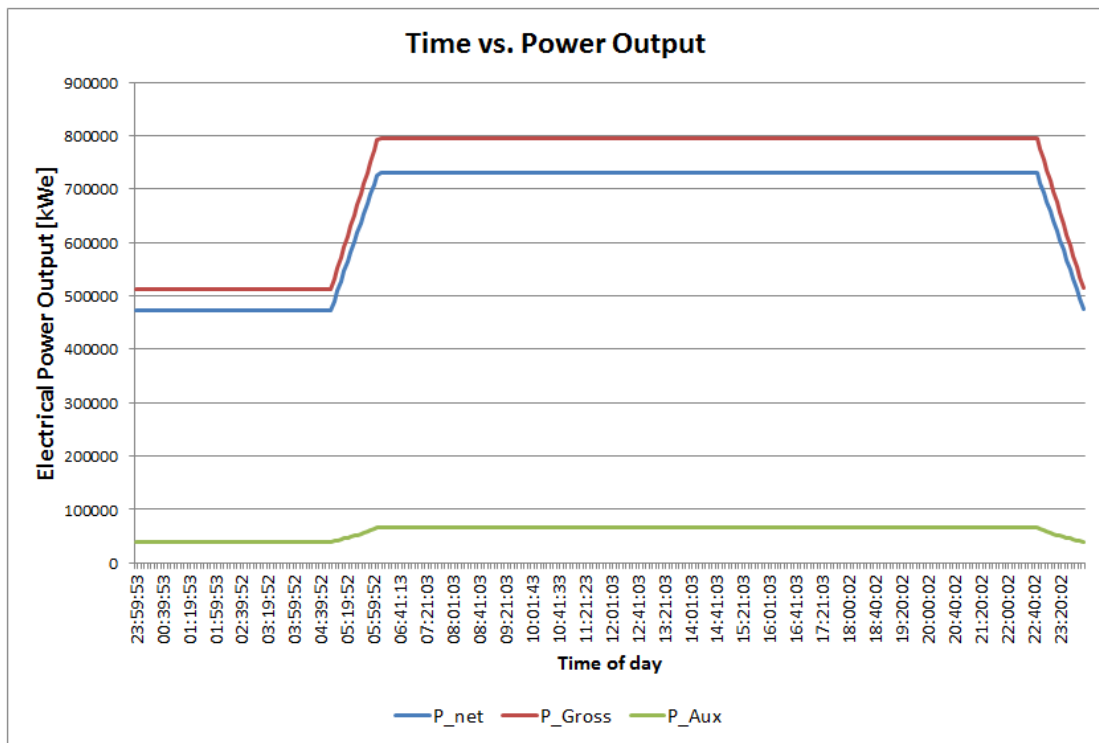


Figure 4-10: Time vs electrical power output and auxiliary consumption

Because the boiler load is reduced during the late night/early morning times, the coal consumption rate will also decrease accordingly. Figure 4-11, illustrates how the fuel consumption rate increases from 62 kg/s at 60% MCR to approximately 94 kg/s at 100% MCR.

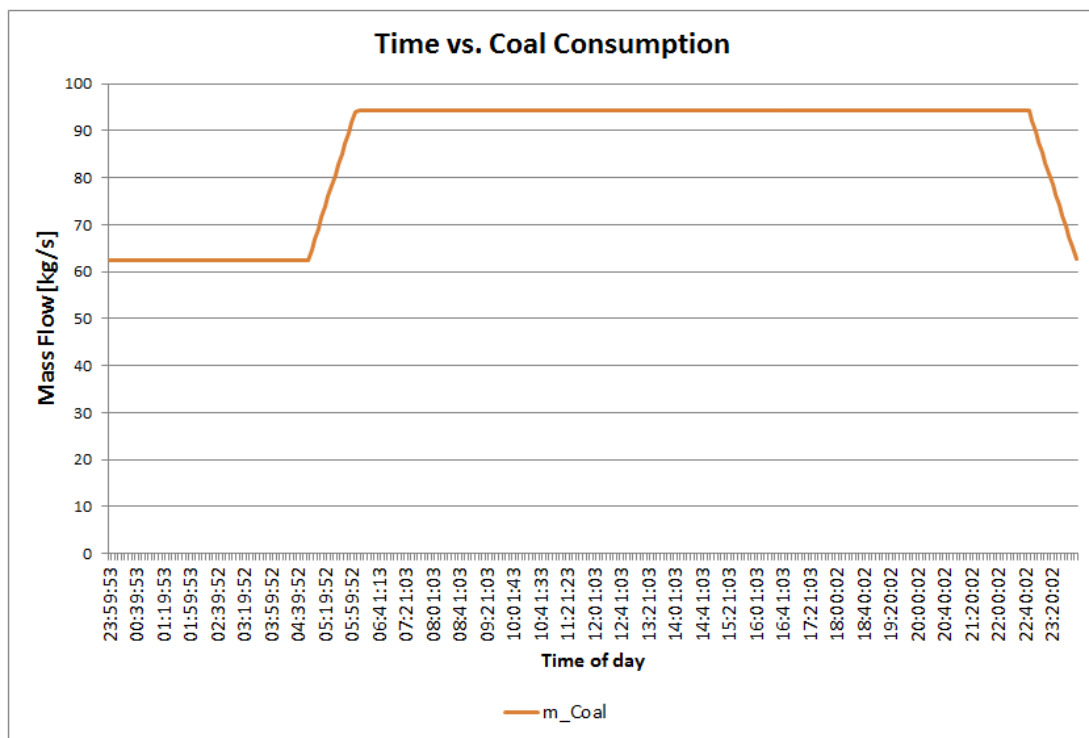


Figure 4-11: Time vs coal consumption rate

When the amount of fuel combusted in the furnace changes with the boiler load, the amount of ash and CO₂ produced will also change accordingly. The graph in Figure 4-12 illustrates how the CO₂ and total ash production rates vary with time as the boiler load changes from 60% to 100% MCR. From this graph it is found that the CO₂ production rate increases from 110 kg/s to approximately 167 kg/s, while the total ash production rate increases from 21,5 kg/s to about 32,5kg/s.

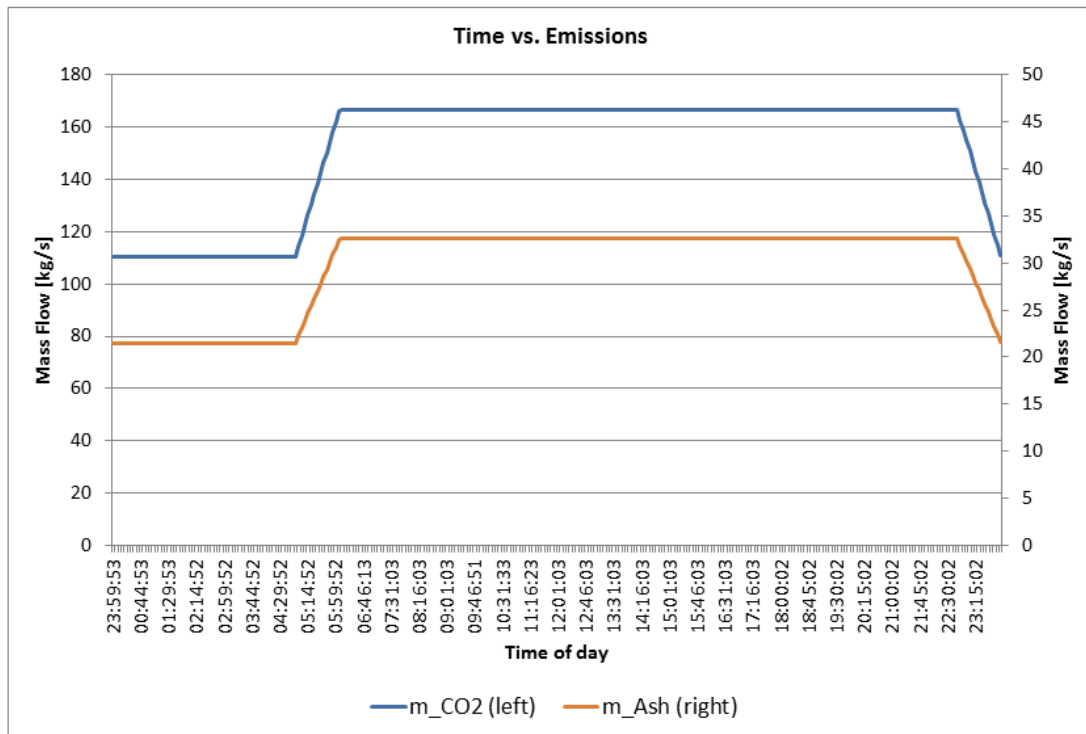


Figure 4-12: Time vs CO₂ and ash emission production rate

When the boiler load is reduced, the main stream flow rate is also reduced accordingly. In effect, the total steam passing through the reheater system is also reduced, which means that the whole reheater, designed for full-load conditions, has a reduced steam flow in its tubes for the same heat exchanger surface area. This means that the heat exchanger will transfer an increased heat flux to the steam, which will cause the attemperation spray-water flow rate to increase significantly. From the graph in Figure 4-13 it can be seen how the spray water drops from 14,8 kg/s at 60% MCR to approximately 5,7 kg/s at 100% MCR.

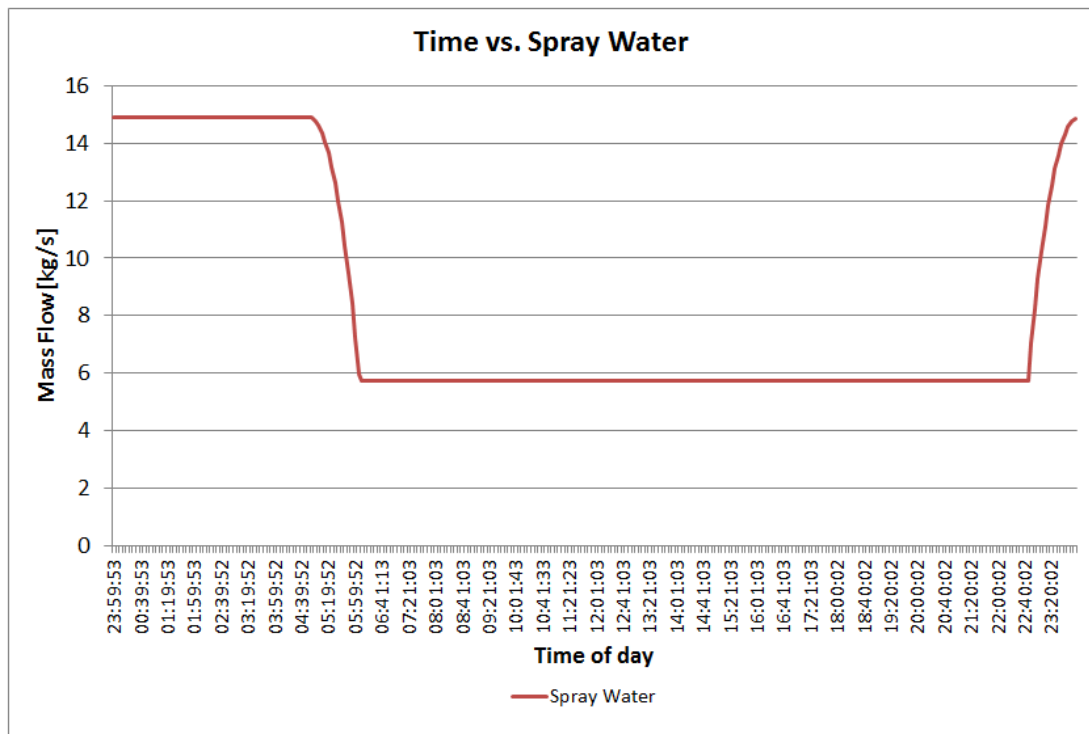


Figure 4-13: Time vs attemperation spray water

Figure 4-14 displays a screenshot of a section of the EES diagram window of the HP, IP and LP turbines at 100% MCR. From the image, the isentropic efficiencies and mechanical shaft- power output of the turbines can be seen, as well as the steam inlet and outlet properties of the HP, IP and LP turbines. The turbine seal steam and reheater attemperation spray-water mass flow rates can also be seen in this figure.

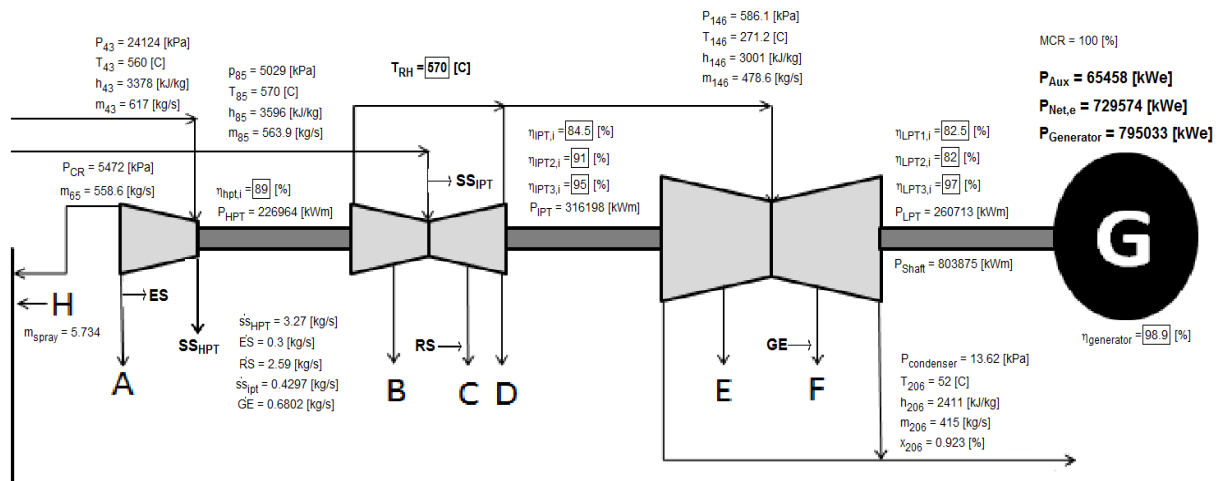


Figure 4-14: EES Screenshot of base-case turbine train and generator

Figure 5-10 displays a screenshot from the EES diagram window showing the forced-draft dry-cooling system, flash tank, condensate storage tank and CEP. From this figure, the inlet and outlet steam parameters of the condenser, flash tank and CEP can be seen, as well as the CEP and ACC fan-power consumption estimates.

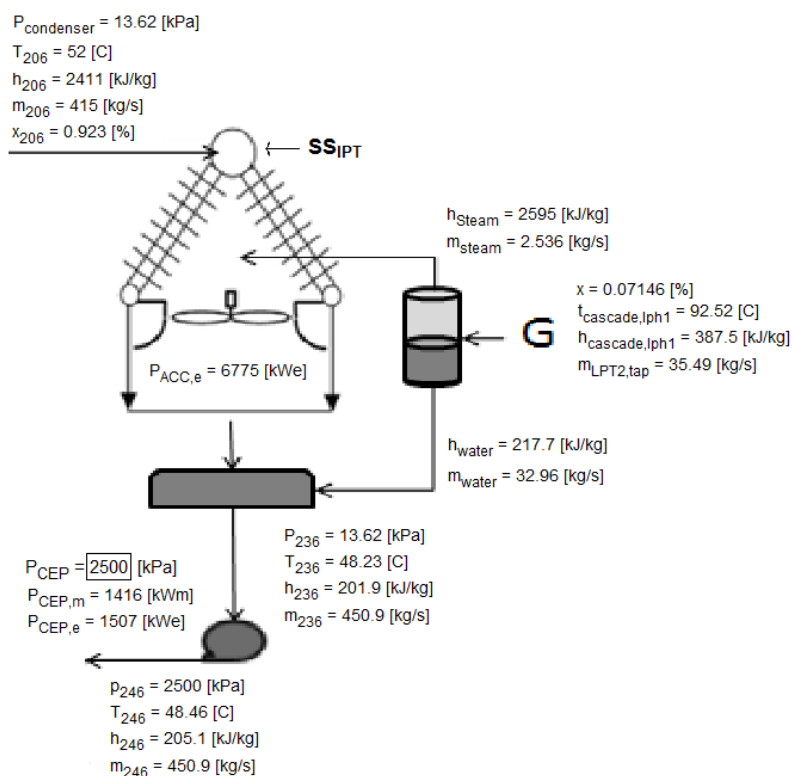


Figure 4-15: Base-case cooling system

Figure 4-16 shows the low-pressure feedwater heaters (LPH #1 situated to the far right, LPH #2 in the middle and LPH #3 to the left), their feedwater inlet and outlet temperatures, pressures, mass flow rates and enthalpies, as well as the turbine bleed-steam parameters. This figure also shows the major desuperheating and subcooling properties of the heaters.

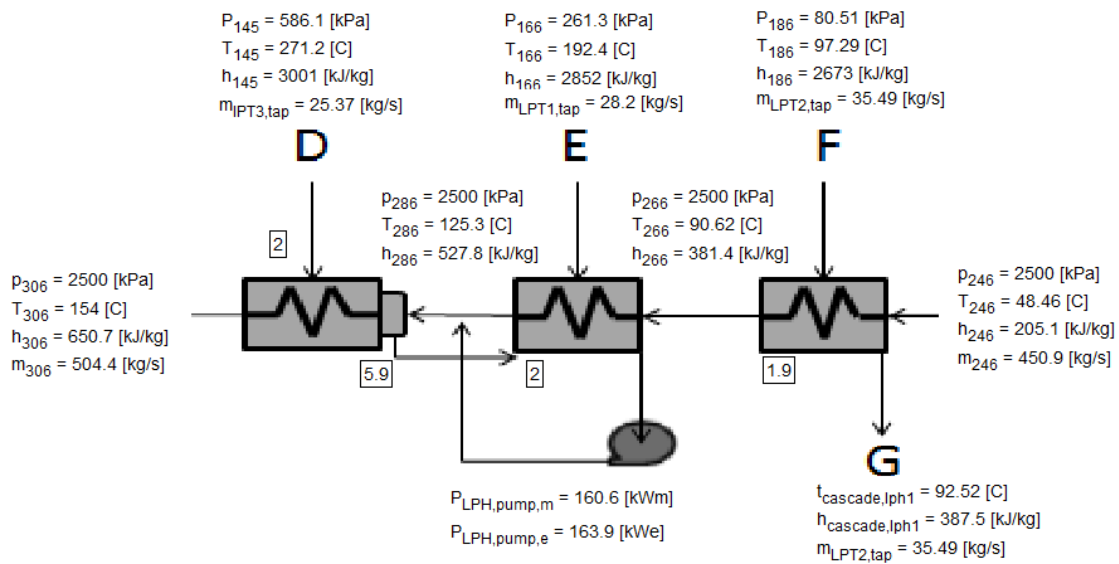


Figure 4-16: Base-case low-pressure heater system

Figure 4-17 gives a screenshot of the EES diagram window, which displays the input and output feedwater properties of the DST and the boiler feed pump system. The bleed steam tapped off from the IPT, as well as the subcooled distillate formed in the high-pressure heaters, is also shown in this diagram. The reheater attemperation spray water tapped from an interstage of the BFP, as well as the BFP power requirements, is also shown.

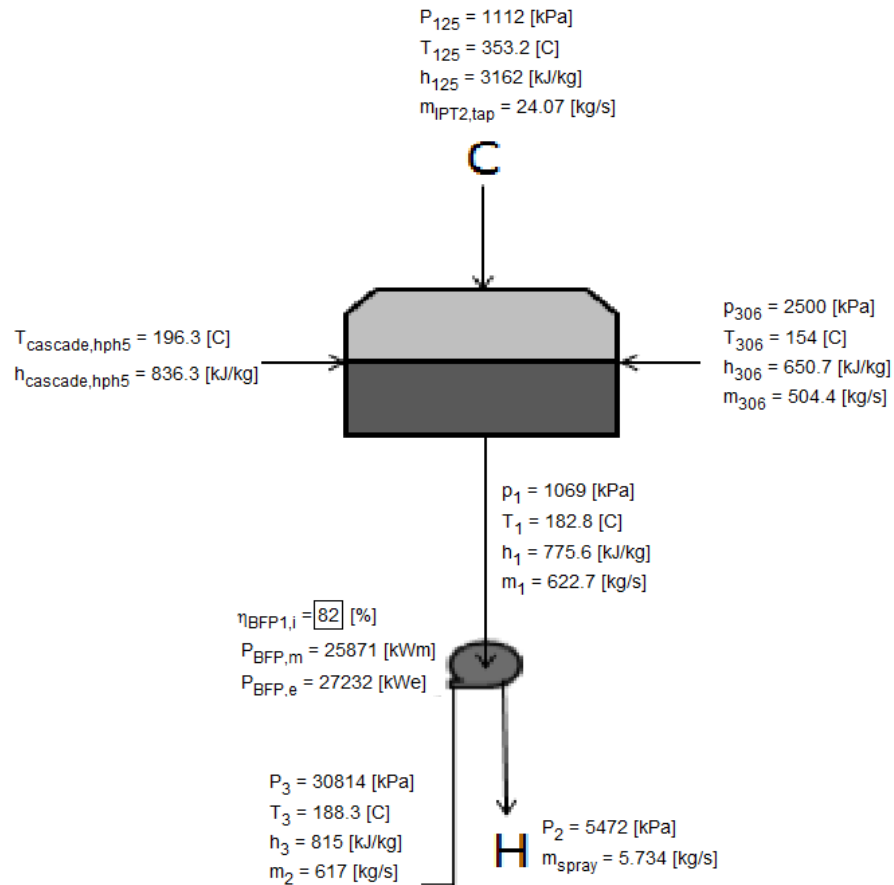


Figure 4-17: Illustration of the base-case DST and boiler feed pump systems

The high-pressure heaters, their feedwater and heating steam inlet and outlet parameters, as well as the distillate cascade system, are shown in the screenshot illustrated in Figure 3-13. The desuperheating and subcooling properties of the heaters are also displayed in the figure.

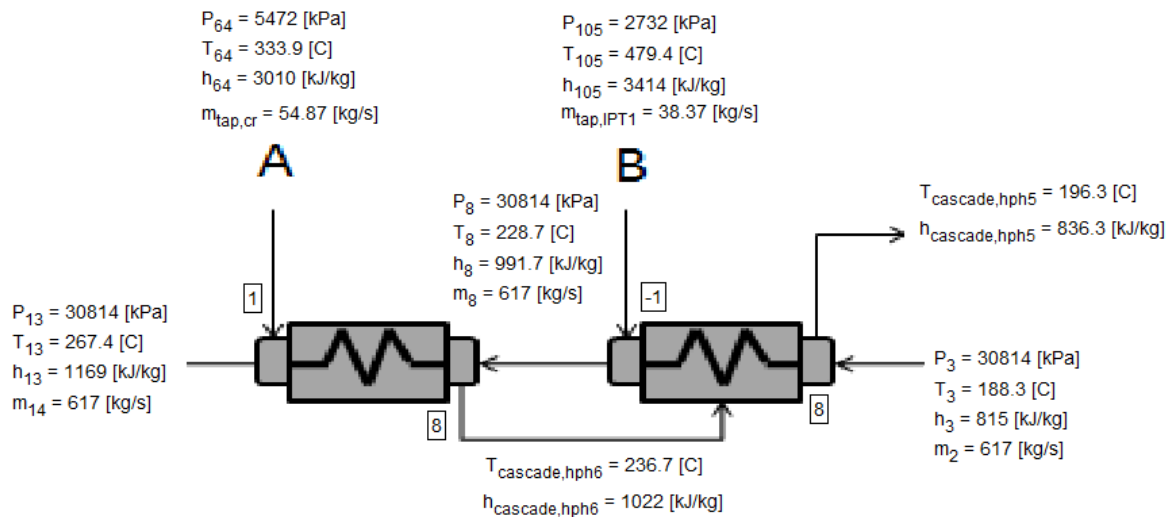


Figure 4-18: Illustration of the base-case HPH system

The EES parametric table results for the base-case study can be seen in Appendix C - 1.

4.3 Base-case scenario summary

From the EES models it is calculated that an 800 MWe supercritical coal-fired power station at 100% MCR, described in section 3.1, can generate approximately 795 033 kWe from the available 803 875 kWm shaft power. The station will be able to push 729 574 kWe into the national grid after the 65 458 kWe for the auxiliary systems is subtracted. The furnace requires a heat input of 1 896 426 kWt from coal, of which approximately 1 706 783 kWt is absorbed into the Rankine cycle for power generation.

The net cycle efficiency of this supercritical unit is 42,7%, while the overall efficiency (coal to electricity out) is around 38,5%. The major performance parameters of this base-case, coal-fired power station can be seen in Table 4-5.

Table 4-5: Base-case performance parameters

Base Case Performance Parameters at 100% MCR	
Total Shaft Power	803875 kWm
Gross Electricity Output	795033 kWe
Total Auxiliary Electricity Consumption	65458 kWe
Net Electricity Output	729574 kWe
Total Heat Added to Furnace	1896426 kWt
Heat Absorbed to Rankine Cycle	1706783 kWt
Net Cycle Efficiency	42.7 %
Gross Cycle Efficiency	46.6 %
Net Overall Efficiency	38.5 %

If a full year is considered, the unit will supply approximately 5 812,7 GWh of electrical energy to the national grid per year from a 13 652,4 GWh thermal heat input by burning pulverised coal.

Approximately 2 716,9 kT of coal will be burned throughout the year, which will result in approximately 937,3 kT of ash, 4 800,4 kT of CO₂ and 59,2 kT of SO₂ per year. The major input and output parameters of the base-case study can be seen in Table 4-6, while the parametric table data can be seen in Appendix C–1.

Table 4-6: Base-case input and output parameters.

Base Case Input and Output Parameters	
Net Electricity Out	5812.7 GWh/Year
Total Heat Input (from coal)	13652.4 GWh/Year
Total Coal Consumption	2716.9 kT/Year
Total CO2 Emissions	4800.4 kT/Year
Total Ash	937.3 kT/Year
Total Solar Energy Input	0.0 GWht/year
Total Electricity from Solar Power	0.0 GWhe/year

The overnight cost of such a coal-fired power station will be in the region of R14 228m, while the fuel will cost approximately R764,5 m per year, the total O&M cost will be about R622m per year and carbon tax will cost the station approximately R230,4 m per year.

Table 4-7: Base-case major expenses.

Major Expenses	
Capital Cost	R 14 228 000 000 once off
Fuel Cost	R 764 539 908 per year
Carbon Tax Cost	R 230 420 938 per year
O&M Cost	R 622 084 163 per year

When all the expenses are discounted back to year zero and divided by the total discounted electricity generated over the lifetime of the plant, it is found that an 800 MWe supercritical coal-fired power station has an LCOE of approximately R0,711 per kWh. The base-case LCOE calculation can be seen in Appendix D - 1.

CHAPTER 5: SOLAR AUGMENTATION SCENARIO

5.1 Engineering equation solver models

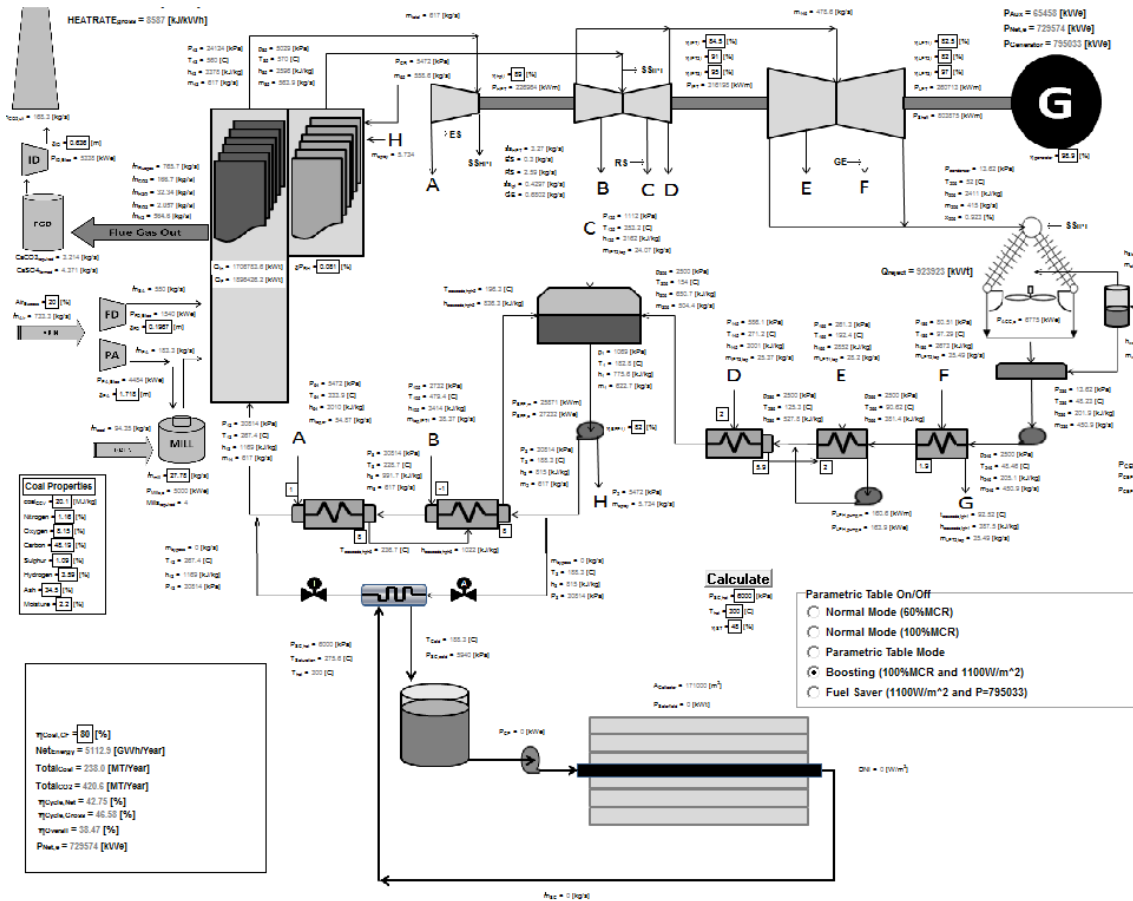


Figure 5-1: Screenshot of solar augmentation EES model

When the irradiation scenarios specified in section 3.3.1 are fed into the EES model, the reaction of the coal-fired power station is calculated with regard to the major input and output parameters. The thermodynamic array table for the solar augmentation scenario (1 100 W/m²) can be seen in Appendix G.

The results for the four daily irradiation scenario, specified in section 3.3.1, are illustrated below with regard to the available DNI, turbine shaft power output, electrical and thermal power output, bleed steam mass flow, coal consumption, auxiliary power consumption, emissions, attemperation spray water mass flow and the amount of feedwater which is bypassed through the additional heat exchanger, powered by the solar field.

5.1.1 Mostly cloudy day scenario

As one can see from Figure 5-2, not much solar energy is available during the mostly cloudy day scenario. The DNI peaked at about 95 W/m^2 for a very short period, which is almost insignificant. As illustrated in Table 5-1, approximately $0,0786 \text{ kWh/m}^2$ of solar energy was available to the solar field during the day, of which $6\,454 \text{ kWh}$ was supplied to the coal-fired power station (Figure 5-7).

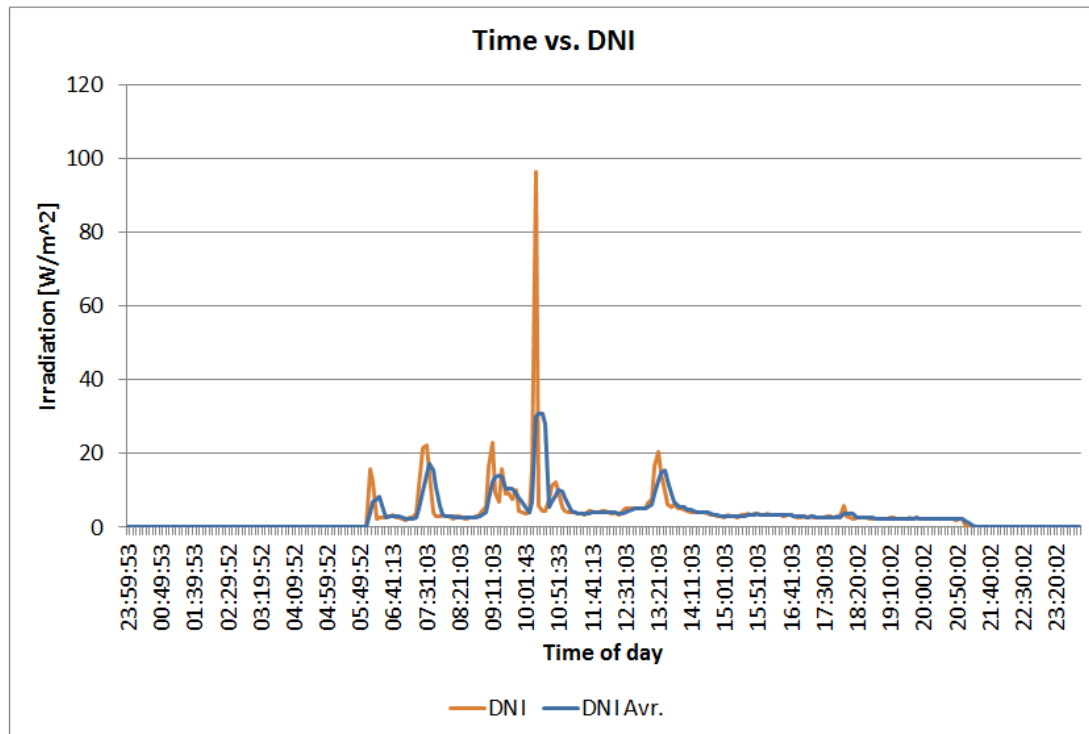


Figure 5-2: Time vs DNI for mostly cloudy day scenario

Because very little thermal energy was delivered to the coal-fired power station during this day, almost no effect was noticed on most parts of the plant, which include the turbine shaft power output, electrical power output, auxiliary power consumption, coal consumption, emissions and attemperation spray-water mass flow rate.

As one can note from Figure 5-3, a maximum peak HPH bypass flow rate of approximately 7 kg/s was achieved during this day, which is rather insignificant if one takes into account that the rated flow through the HPH is 617 kg/s at 100% MCR.

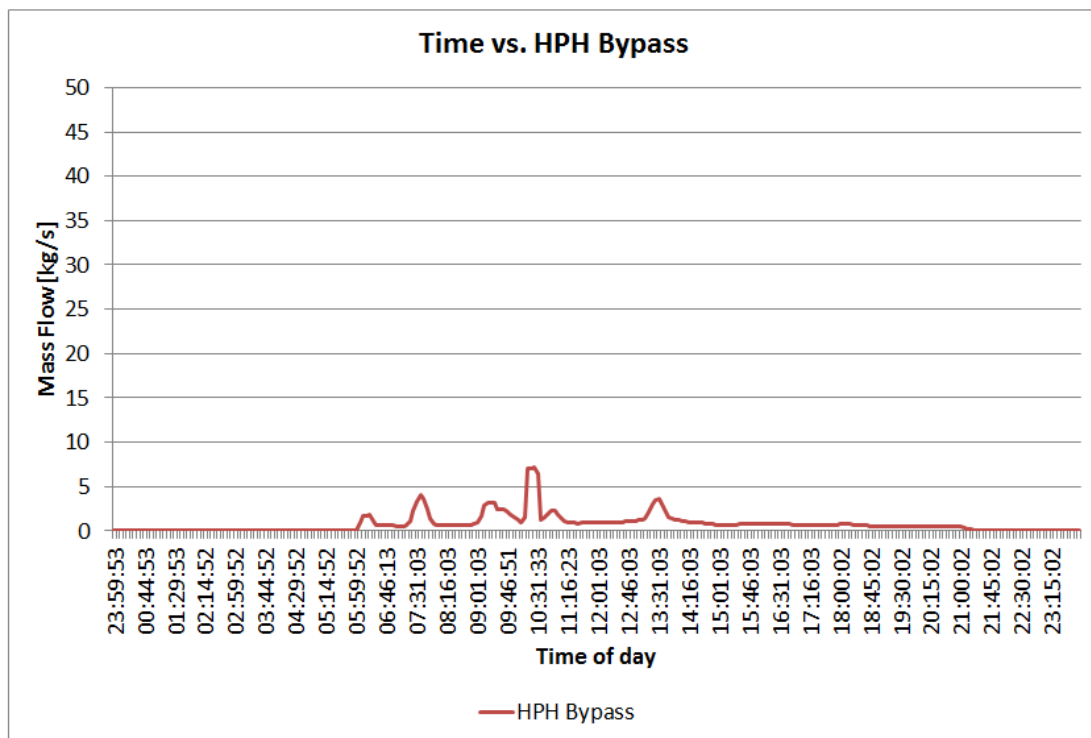


Figure 5-3: Time vs high-pressure heater bypass mass flow for mostly cloudy day scenario

Because very little feedwater is bypassed, the HPHs will not have a significant reduced load, which means that the bleed steam required by them will not change much. The graph in Figure 5-4 illustrates by how little the bleed steam is affected by the thermal heat added to the Rankine cycle.

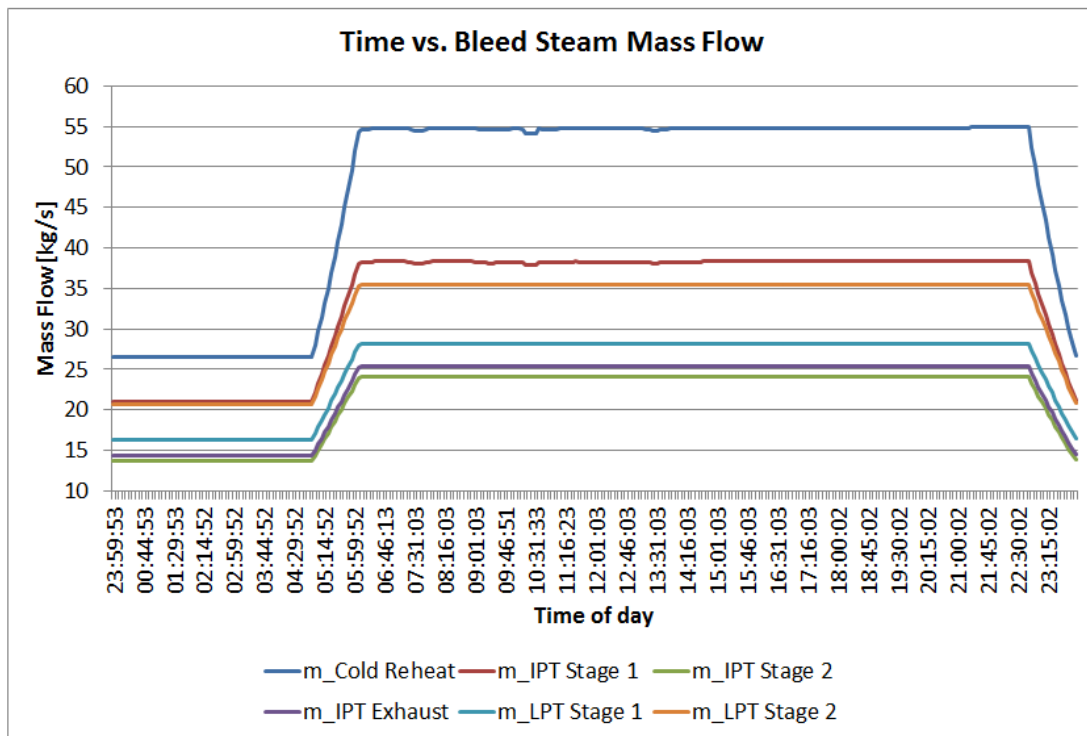


Figure 5-4: Time vs turbine bleed steam for mostly cloudy day scenario

When the bleed steam is not reduced by a significant amount, the steam flow rate passing through reheater will also remain fairly unchanged, which will have very little effect on the attemperation spray-water flow rate illustrated in Figure 5-5.

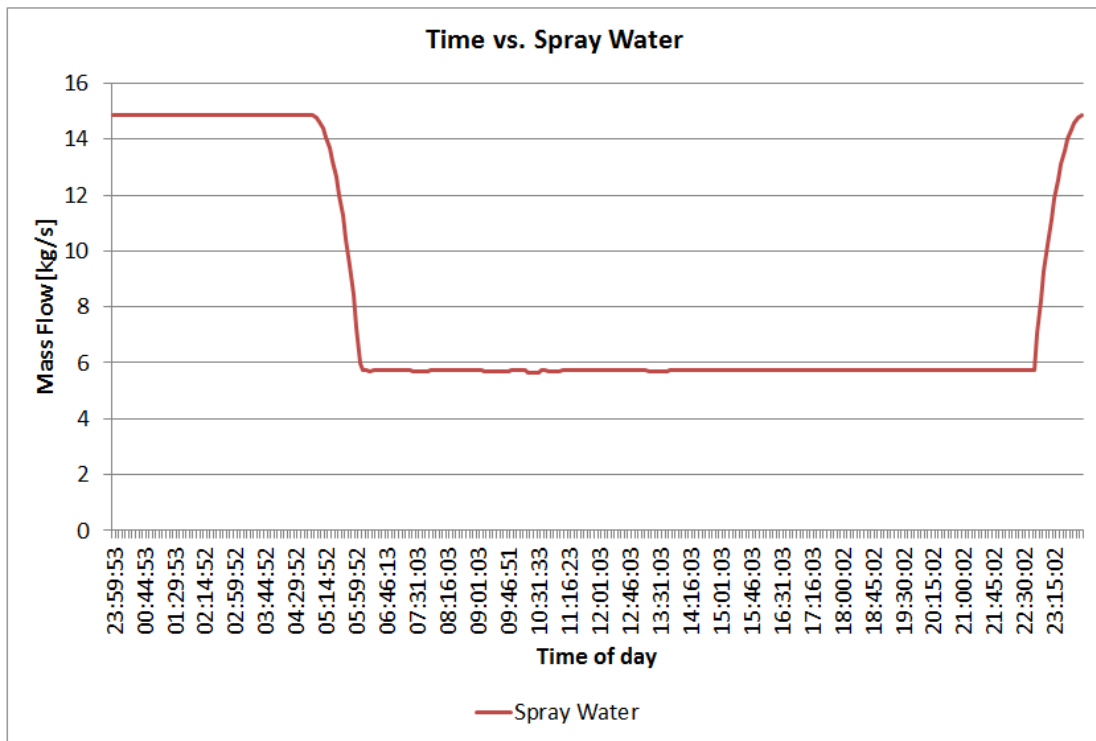


Figure 5-5: Time vs attemperation spray water for mostly cloudy day scenario

When the bleed steam is not noticeably reduced, the flow rate through the HP, IP and LP turbines will not change much, which means that the mechanical shaft power of the applicable turbines will also remain almost unchanged (Figure 5-6).

Because no significant shaft power fluctuations are noticed during a mostly cloudy day scenario, the net electricity output, auxiliary power consumption rate, coal consumption rate and emissions production rate will also remain unchanged.

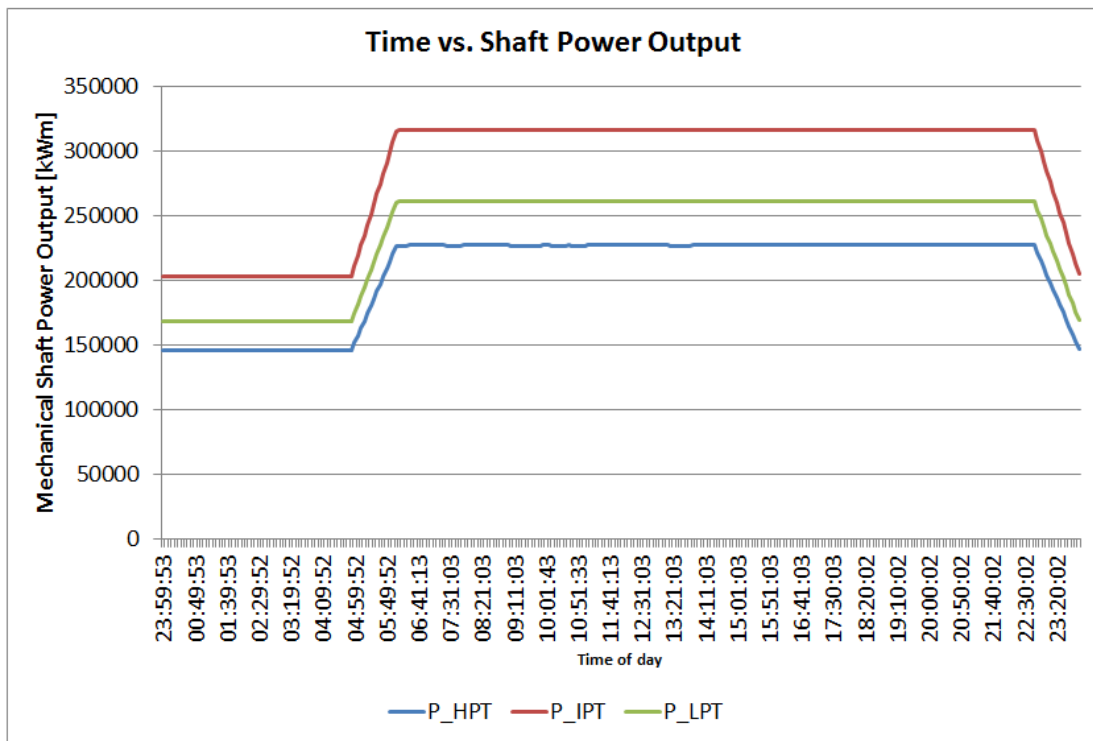


Figure 5-6: Time vs turbine shaft power for mostly cloudy day scenario

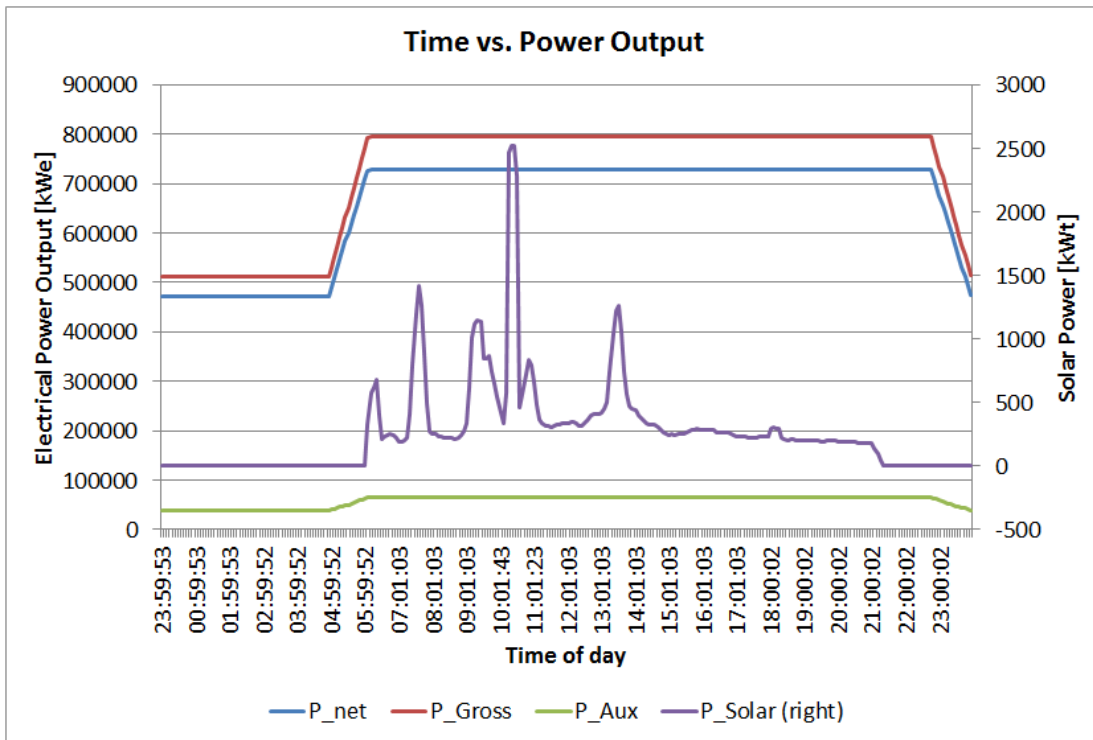


Figure 5-7: Time vs power output for mostly cloudy day scenario

During a typical mostly cloudy day, in which a DNI rating of approximately 0,07 kWh/m²/day is available from the sun, an 800 MWe coal-fired power station integrated with a 90 MWt solar field will generate approximately 167,8 kWh more electricity than without any solar. The solar field will be able to supply about 6 454 kWh of thermal energy during the day. The increased electricity output in the fuel-saver mode is due to the slightly reduced auxiliary power consumption, because of the thermal heat added to the Rankine cycle. Approximately 4,07 MWh less thermal energy will be transferred from the furnace to the Rankine cycle, which means that about 900 kg less coal will have to be burned throughout the day.

Because less fuel is burned, the amount of CO₂ emitted into the atmosphere is reduced by approximately 400 kg, while the amount of ash that has to be disposed of is reduced by about 100 kg per day.

Table 5-1: Summary for mostly cloudy day scenario

	Units	No Solar	Mostly Cloudy	Deviation
Net Electricity Out	kWh/day	15925222.92	15925390.8	167.8
Total Heat Input (from coal)	kWh/day	37403913.53	37399842.6	-4070.9
Total Coal Consumption	T/day	7443.603	7442.7	-0.9
Total CO2 Emissions	T/day	13151.88	13151.4	-0.4
Total Ash	T/day	2567.901	2567.8	-0.1
Total Solar Irradiation	kWh/m ² /day	0	0.1	0.1
Total Solar Energy Input	kWht/day	0	6454.6	6454.6

All parametric table data for the mostly cloudy day scenario can be seen in Appendix C-2

5.1.2 Very cloudy day scenario

The very cloudy day scenario provides a much higher DNI rating at approximately 4,3 kWh/m²/day. This day was mainly overcast, with patches of sunlight coming through the clouds at certain stages of the day, peaking at approximately 900 W/m². The DNI vs time of day graph for the very cloudy day scenario can be seen in Figure 5-8.

When the hybrid power station is in the fuel-saver mode, it will be able to increase the net electrical energy by about 9 312,3 kWh for the day, while burning approximately 44 tons less. The increased electricity generation in the fuel-saver mode is attributed to the reduced auxiliary power consumption because of the lower firing rate of the boiler.

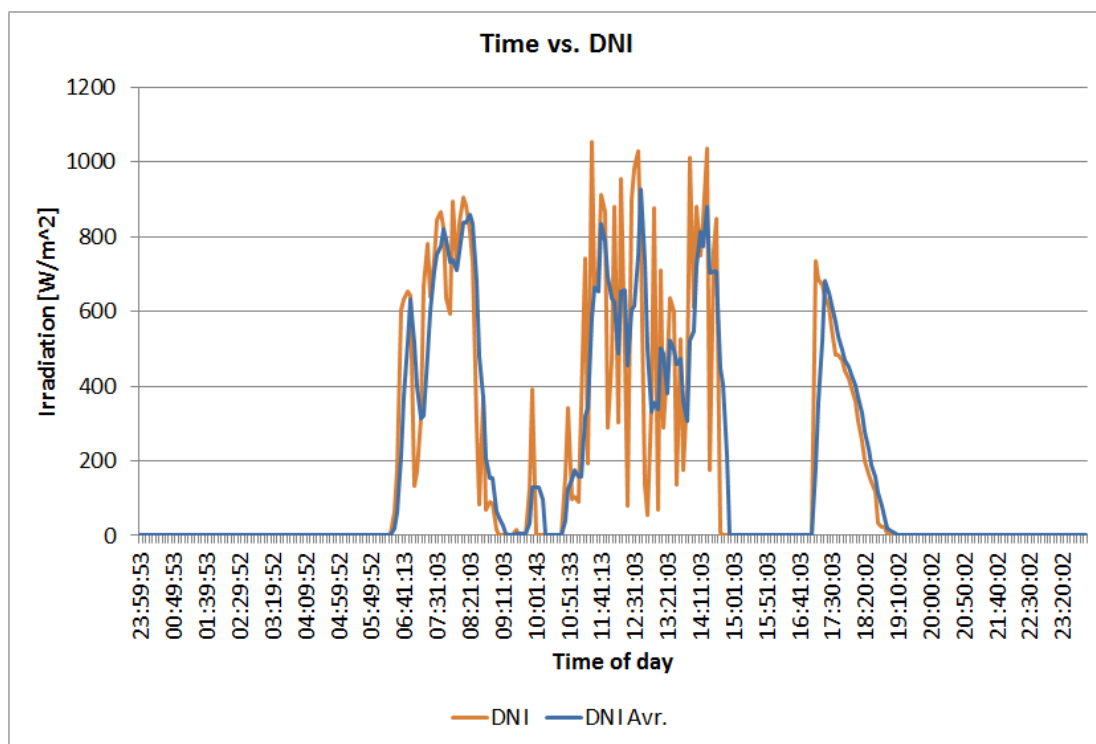


Figure 5-8: Time vs DNI for very cloudy day scenario

Slightly more thermal energy was delivered to the coal-fired power station during the very cloudy day scenario; the thermal energy produced by the solar field was very unstable but peaked at approximately 79 MWt.

The amount of feedwater which is bypassed through the additional heat exchanger also changes as the thermal energy available from the solar field changes. As illustrated in Figure 5-9, the mass flow through the additional heat exchanger gradually increases as the

thermal energy increases. The mass flow through the additional heat exchanger peaked at about 225 kg/s at peak solar power, but dropped back to 0 kg/s as the DNI dropped to zero.

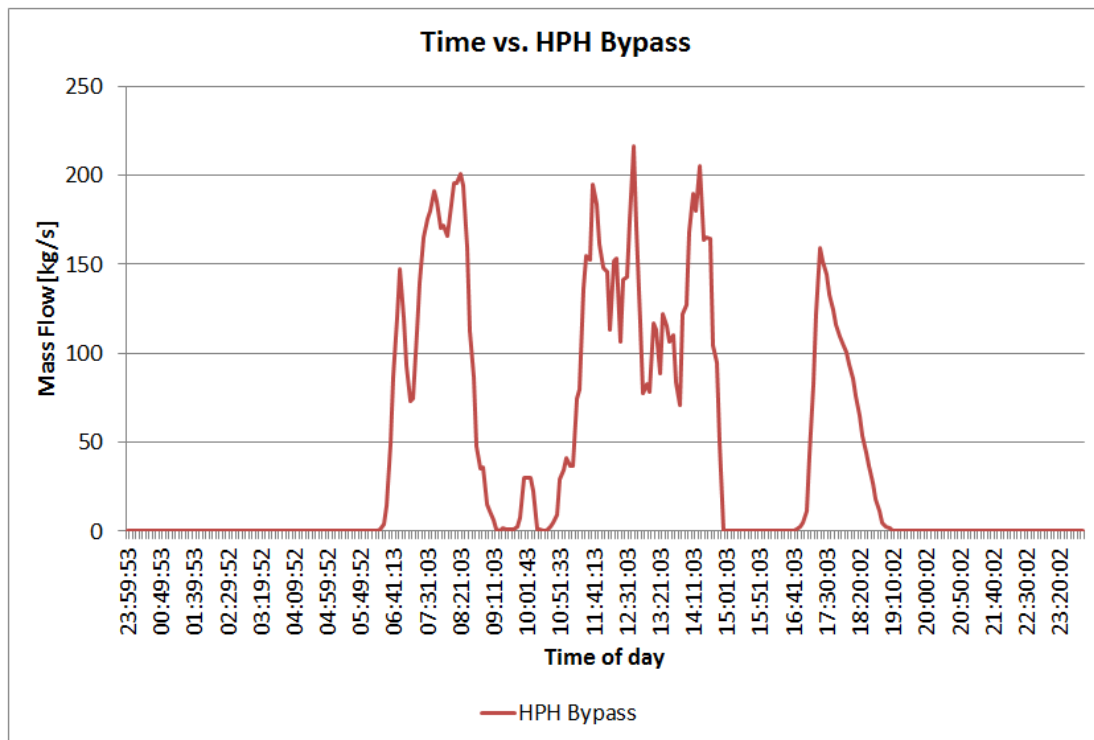


Figure 5-9: Time vs high-pressure heater bypass mass flow for very cloudy day scenario

As the mass flow through the additional heat exchanger increases, the mass flow through the HPH banks decreases accordingly. In effect, less feedwater must be heated by means of the HPHs, which means that less bleed steam must be tapped off from the turbines.

Figure 5-10 illustrates the turbine bleed steam mass flow vs time of day. It is very clear that that the bleed steam tapped off from the HPT exhaust to heat HPHs 5A&B, and the first stage of the IPT to heat HPH 5A&B, decreased significantly, as the thermal power from the solar field increases.

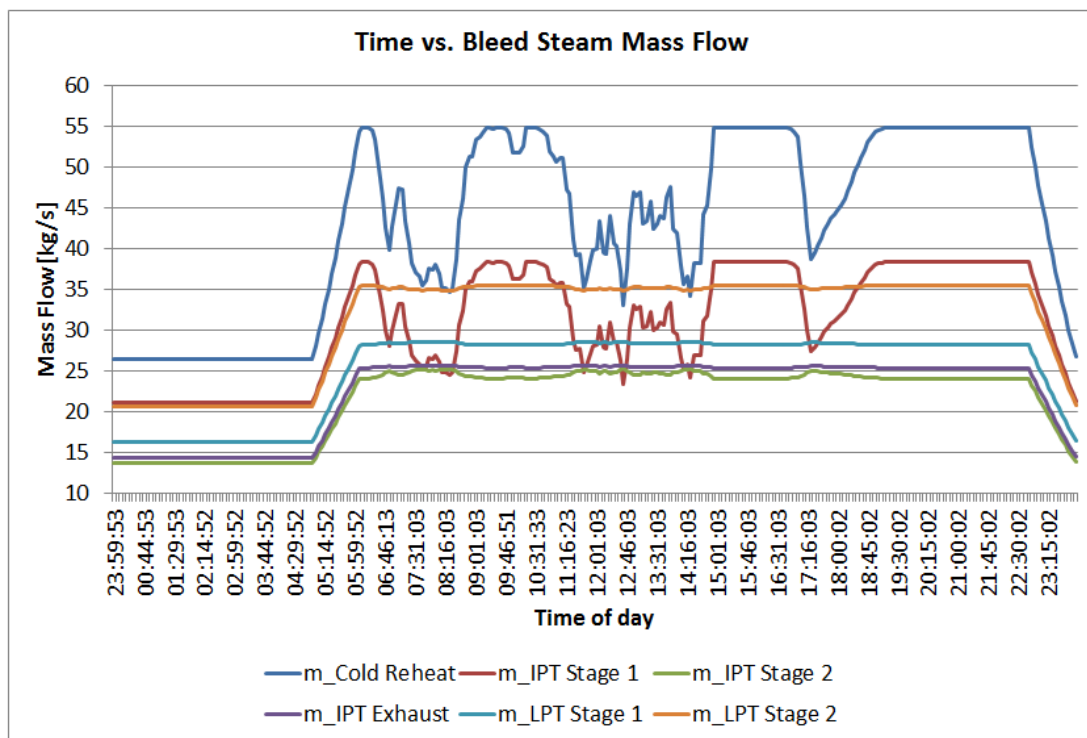


Figure 5-10: Time vs turbine bleed-steam mass flow for very cloudy day scenario

The decrease in HPT exhaust bleed steam increased the steam flow through the reheater, which will cause the attenuation spray-water mass flow to drop. The spray-water mass flow vs time of day is illustrated in Figure 5-11. This increase will also increase the mass flow of steam through the whole IPT and LPT, which, in turn, will increase the mechanical power output.

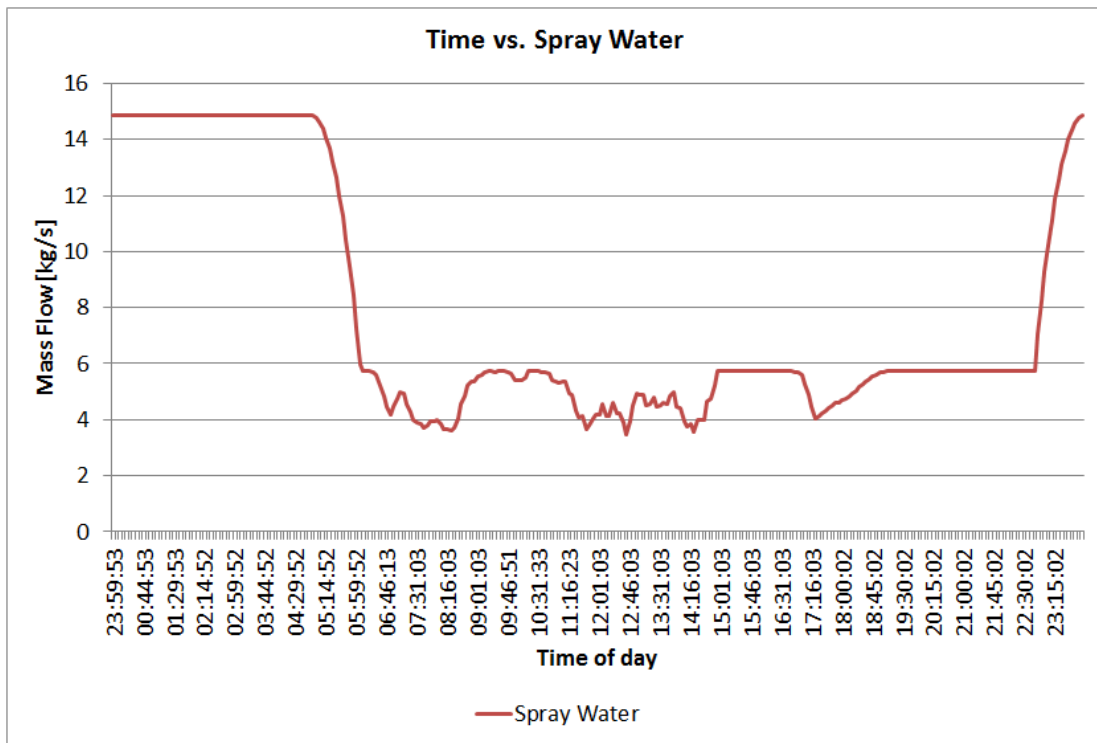


Figure 5-11: Time vs attemperation spray-water mass flow for very cloudy day scenario

Because this system is operating in fuel-saver mode, the boiler will fire less when there is an increase in mechanical shaft power output to keep the generator output constant. In effect, the boiler load will drop, which will result in a lower mass flow through the boiler, superheaters and HPT, which will lower the fuel consumption rate to a certain extent.

Basically, the IP and LP turbines will generate more mechanical shaft power, due to the decreased bleed steam, while the HPT will produce less mechanical shaft power because of the decreased mass flow through the boiler, superheaters and HPT. The gross generator output capacity will remain constant, while the net electricity output may vary because of variations in auxiliary power consumption, owing to boiler load changes.

Figure 5-12 shows the mechanical-shaft power output of the HP, IP and LP turbines vs time of day. From this graph, one can just see how the shaft power of the IP and LP turbines increases with the solar power availability and how the shaft power of the HPT decreases as the boiler load is reduced.

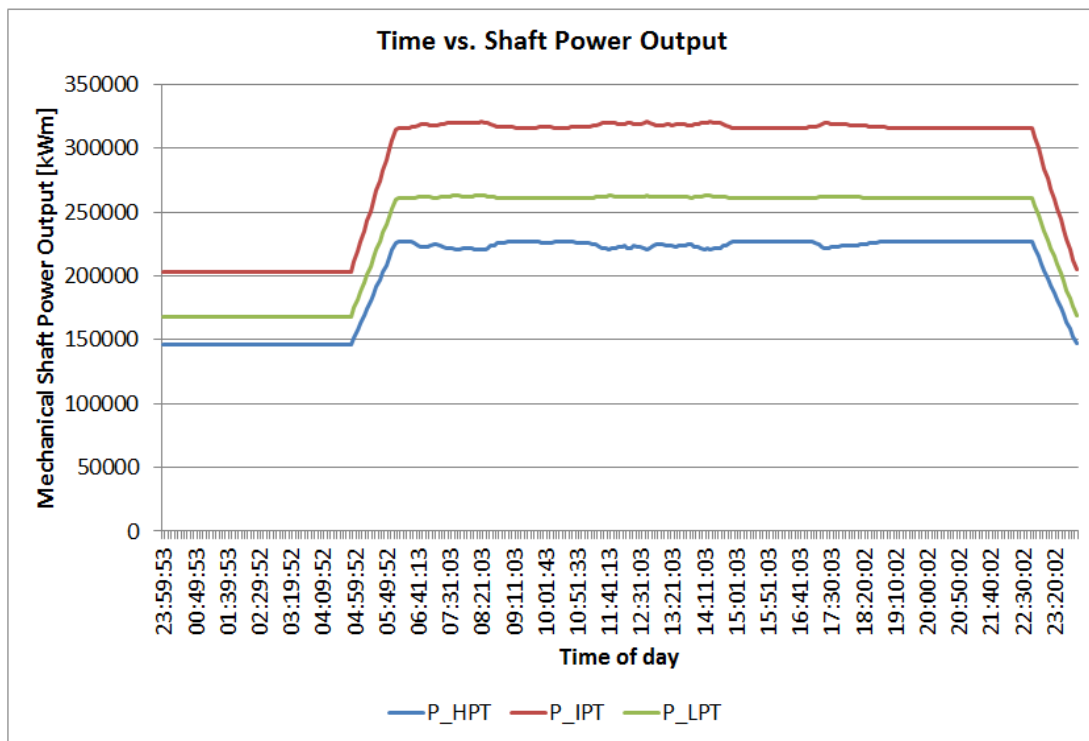


Figure 5-12: Time vs turbine shaft power for very cloudy day scenario

Figure 5-13 shows the gross generator power output, net electricity output, total auxiliary power consumption and thermal power available from the solar field vs time of day for the very cloudy day scenario.

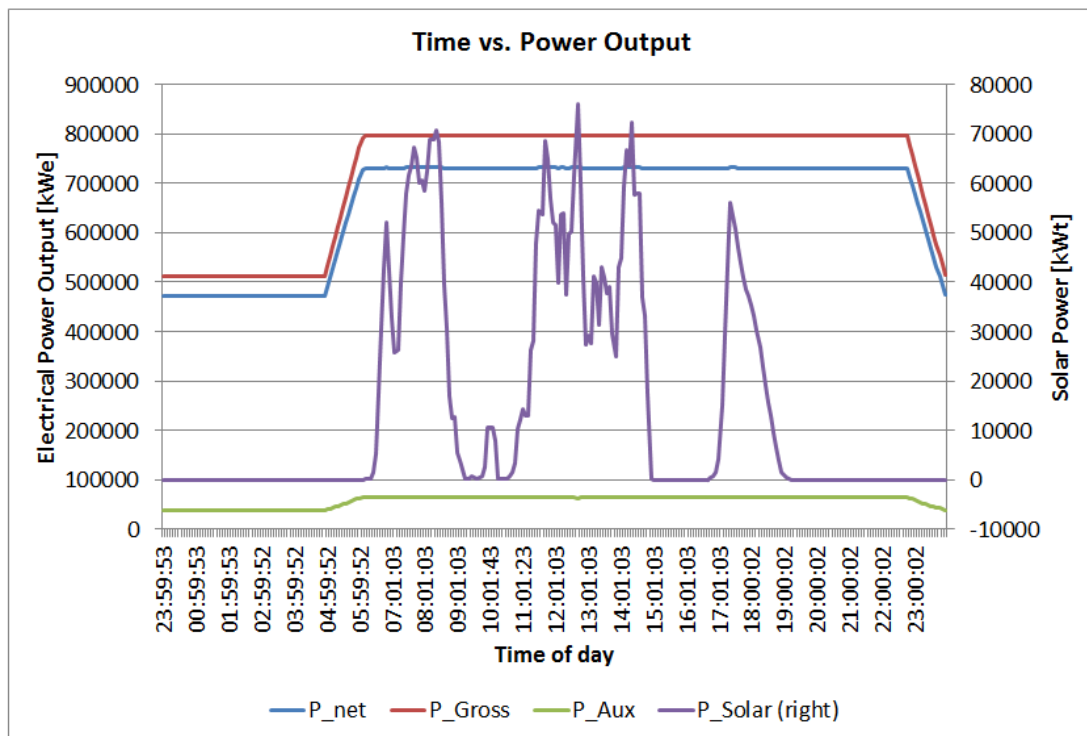


Figure 5-13: Time vs power output for very cloudy day scenario

As one can see from Figure 5-14, the BFP power consumption is noticeably reduced as the boiler load drops, because of the thermal energy injected from the solar field. Figure 5-14 also shows the power consumption of the other major auxiliary plant components.

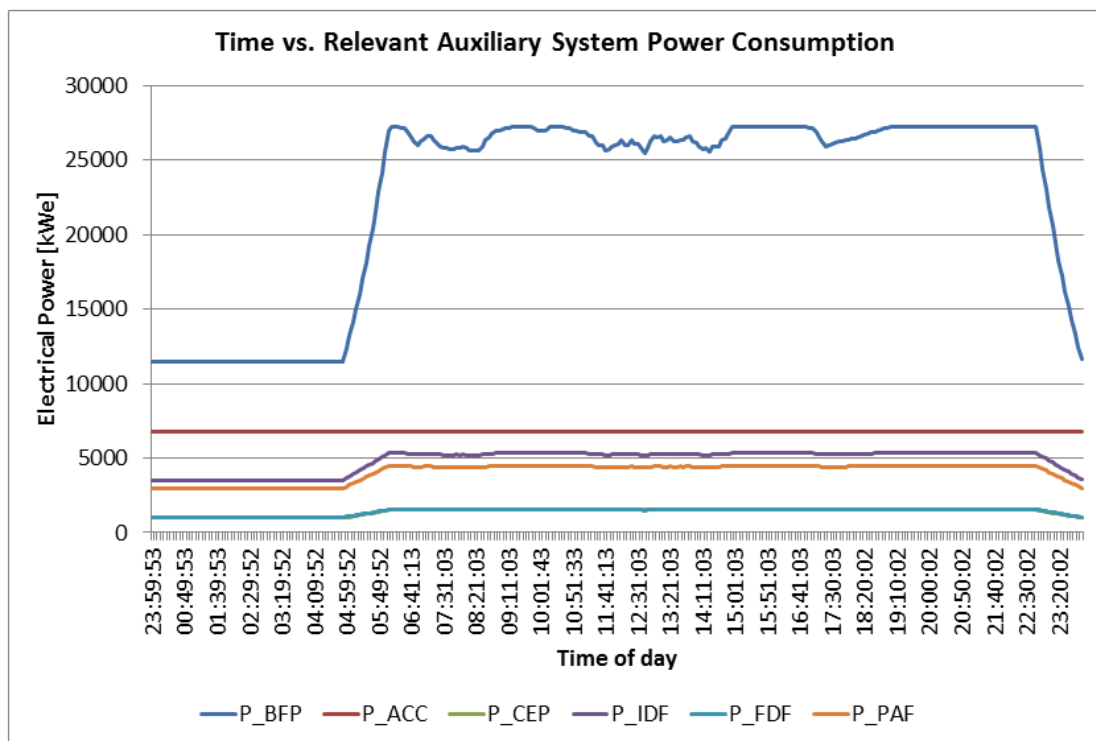


Figure 5-14: Time vs auxiliary power consumption for very cloudy day scenario

Because the boiler load decreases as the thermal power from the solar field increases, the coal consumption rate will also decrease as the thermal power from the solar field increases. The coal consumption rate vs time of day can be seen in Figure 5-15.

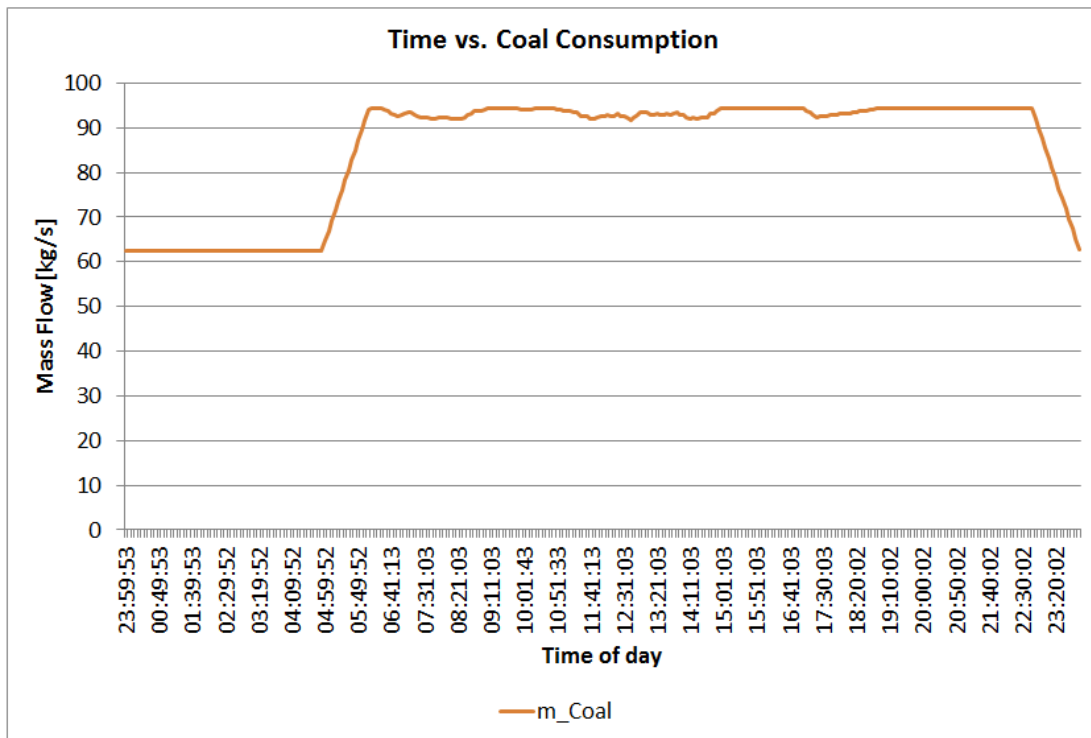


Figure 5-15: Time vs coal consumption rate for very cloudy day scenario

When the amount of coal burnt is reduced, the amount of emissions and ash produced will also decrease accordingly. Figure 5-16 shows the CO₂ and ash produced mass flows vs time of day for the specific scenario.

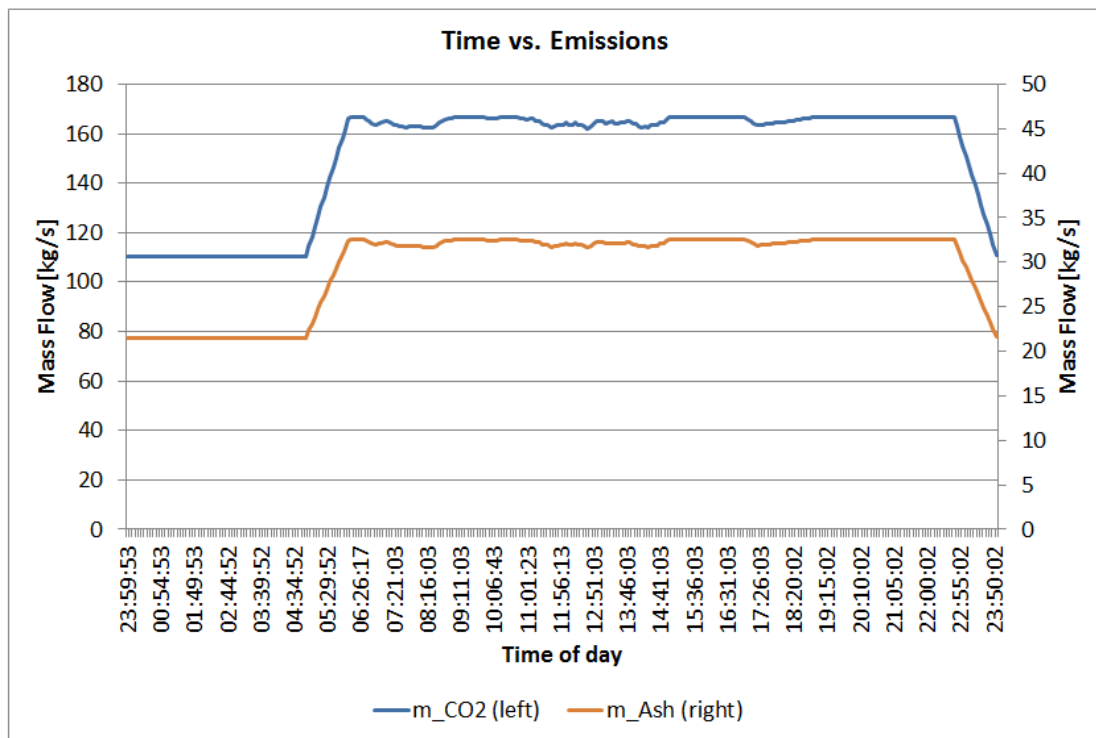


Figure 5-16: Time vs auxiliary power consumption for very cloudy day scenario

Table 5-2 illustrates the very cloudy scenario compared with a base-case scenario where no solar power is injected into the Rankine cycle.

In summary, by injecting 352,1 MWh of thermal energy from the solar field into the Rankine cycle during a very cloudy day, the net electricity output will be increased by 9,31 MWh while the coal consumption will be reduced by 44 tonnes. The CO₂ emissions will be reduced by 77 tonnes while the amount of ash produced will be reduced by 15 tonnes.

Table 5-2: Summary for the very cloudy day scenario

		No Solar	Very Cloudy	Deviation
Net Electricity Out	kWh/day	15925222.92	15934535.2	9312.3
Total Heat Input (from coal)	kWh/day	37403913.53	37182700.2	-221213.4
Total Coal Consumption	T/day	7443.603	7399.6	-44.0
Total CO2 Emissions	T/day	13151.88	13074.6	-77.3
Total Ash	T/day	2567.901	2552.8	-15.1
Total Solar Irradiation	kWh/m ² /day	0	4.3	4.3
Total Solar Energy Input	kWh/t/day	0	352148.1	352148.1

All parametric table data for the very cloudy day scenario can be seen in Appendix C - 3.

5.1.3 Slightly cloudy day scenario

When the solar scenario illustrated in Figure 5-17 is considered, where large clouds are present during noon and during the late afternoon, approximately 8 kWh/m² of solar energy is available from the sun for the duration of the day. This solar energy can then be converted into about 658,9 MWh of thermal energy in the solar field, which can be injected into the supercritical coal-fired power station.

The DNI for the slightly cloudy day peaked at about 1 100 W/m², but dropped back to zero because of cloud cover on three occasions throughout the day.

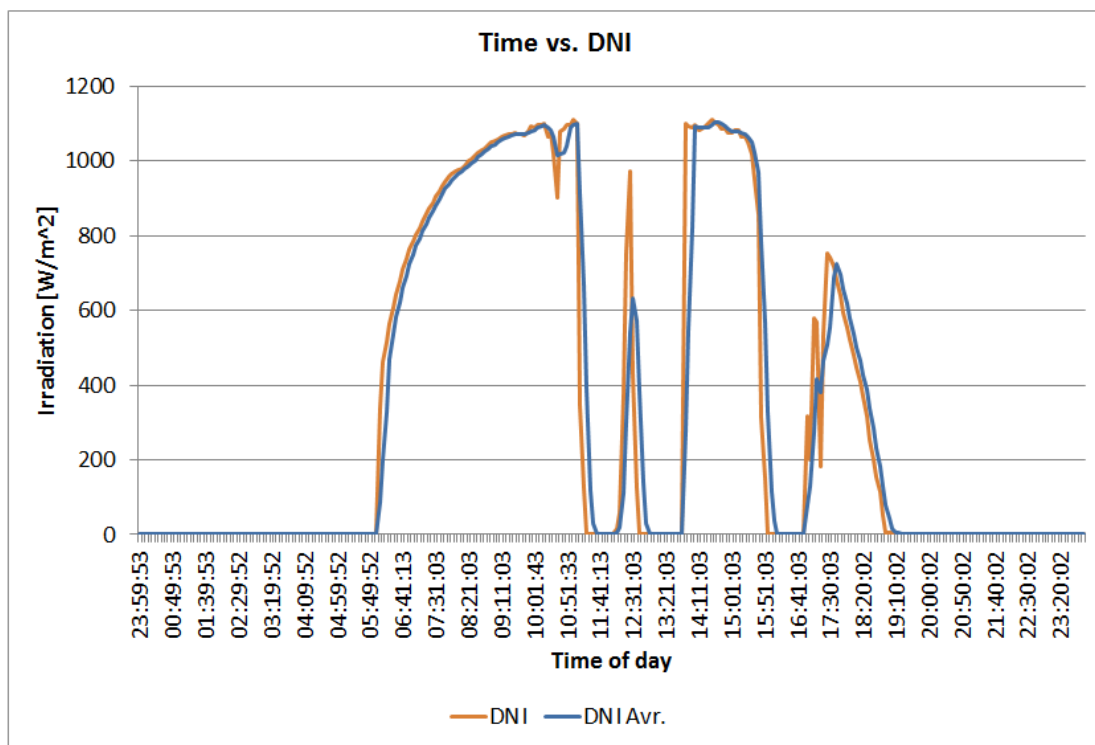


Figure 5-17: Time vs DNI for slightly cloudy day scenario

When more thermal power is available from the solar field to the additional heat exchanger, the mass flow through the exchanger can increase by still providing a stable outlet temperature. As displayed in Figure 5-18, the mass flow through the additional heat exchanger will peak at around 210 kg/s before it drops back to nothing when large clouds block out the sun.

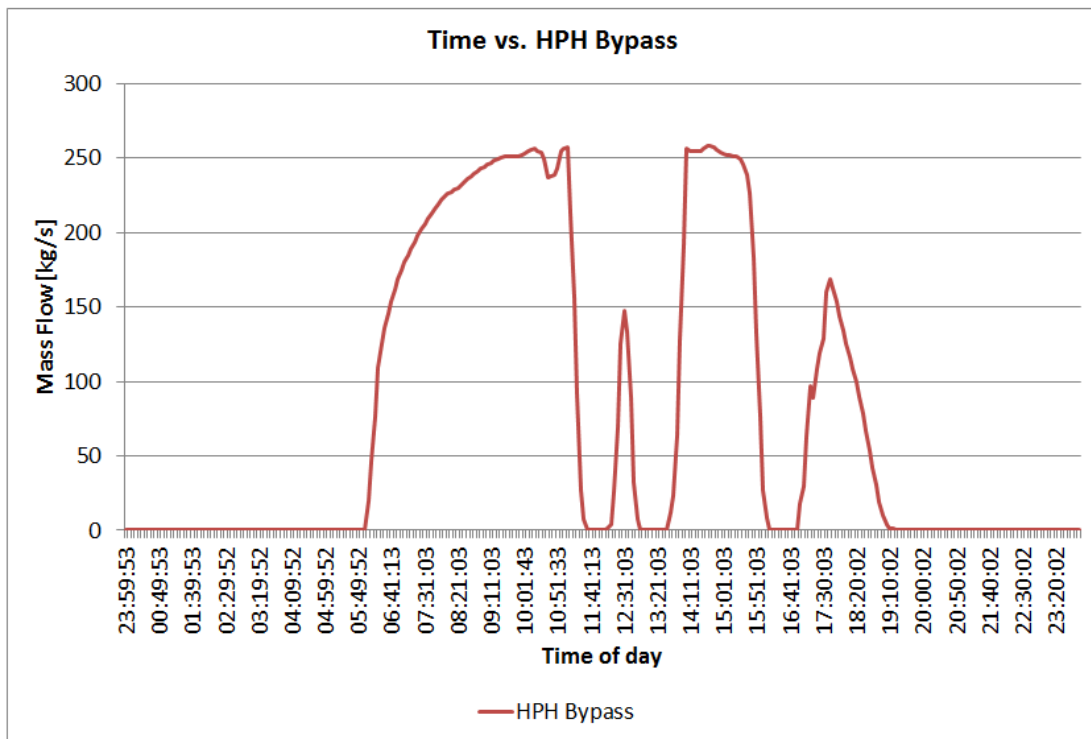


Figure 5-18: Time vs high-pressure heater bypass mass flow for slightly cloudy day scenario

By increasing the flow through the additional heat exchanger, the flow through the HPH banks will in effect be reduced, which will also reduce the amount of turbine bleed steam needed to heat the feedwater to the required temperature. The steam tapped off from the HPT exhaust is used to heat HPHs 6A and 6B, while the steam tapped off from the first stage of the IPT is used for heating in HPHs 5A & 5B.

Figure 5-19 illustrates how the steam tapped from the HPT exhaust drops from 55 kg/s to approximately 28 kg/s at peak solar conditions, while the steam tapped from the first stage of the IPT drops from 38 kg/s to about 21 kg/s.

As an effect of this, more bleed steam (approximately 2 kg/s) from the second stage of the IPT will be required by the DST to achieve its set-point feedwater temperature outlet. This increase in bleed steam for the DST is due to the fact that the subcooled water flow rate from the HPH cascades will be reduced by an equal amount to that of the bleed steam for all the HPHs.

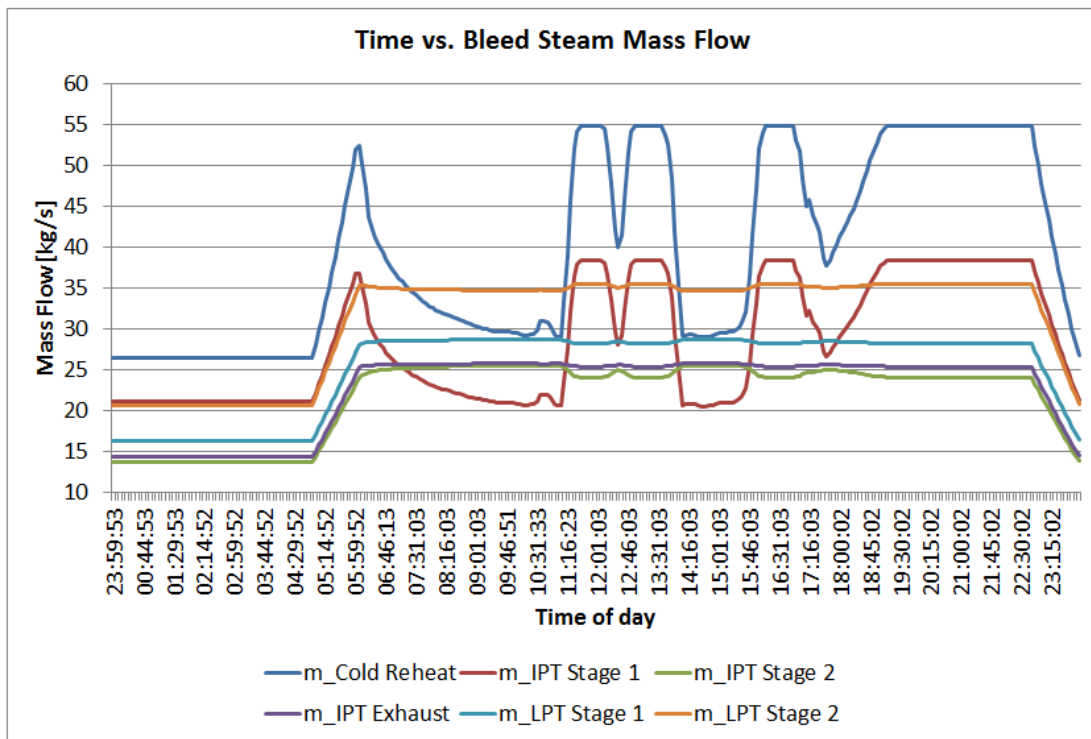


Figure 5-19: Time vs turbine bleed-steam mass flow for slightly cloudy day scenario

When the HPT exhaust bleed steam is reduced, the amount of steam passing through the reheater is also increased, this in turn will lower the spray-water required to control the reheater exit temperature. The attenuation spray-water mass flow for the slightly cloudy day scenario can be seen in Figure 5-20.

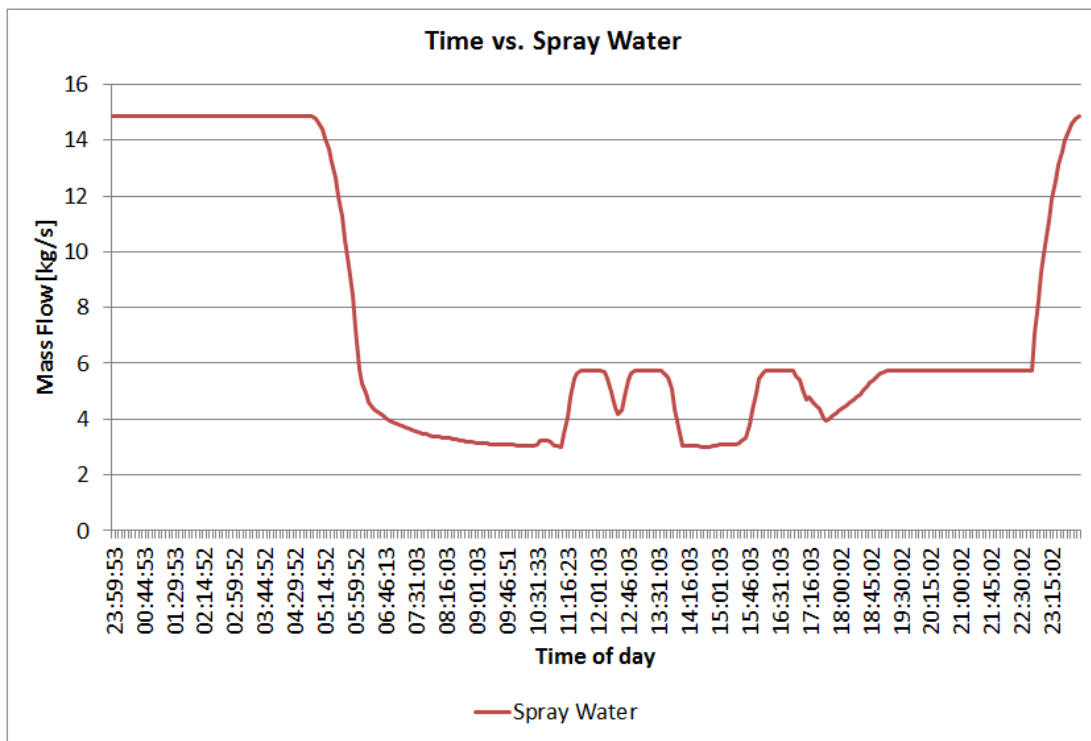


Figure 5-20: Time vs attemperation spray-water mass flow for slightly cloudy day scenario

Because this system is operating in fuel-saver mode, the boiler will fire less when there is an increase in mechanical shaft power output to keep the generator output constant. In effect, the boiler load will drop, which will result in a lower mass flow through boiler, superheaters and HPT, which will lower the fuel consumption rate to a certain extent.

Basically, the IP and LP turbines will generate more mechanical shaft power, owing to the reduced bleed steam, while the HPT will produce less mechanical shaft power owing to the reduced mass flow through the boiler, superheaters and HPT.

Figure 5-21 illustrates how the mechanical shaft power output of the HP, IP and LP turbines changes as the DNI varies with the time of day. From this graph, one can see how the shaft power of the IP and LP turbines increase with the solar power availability and how the shaft power of the HPT decreases as the boiler load is reduced.

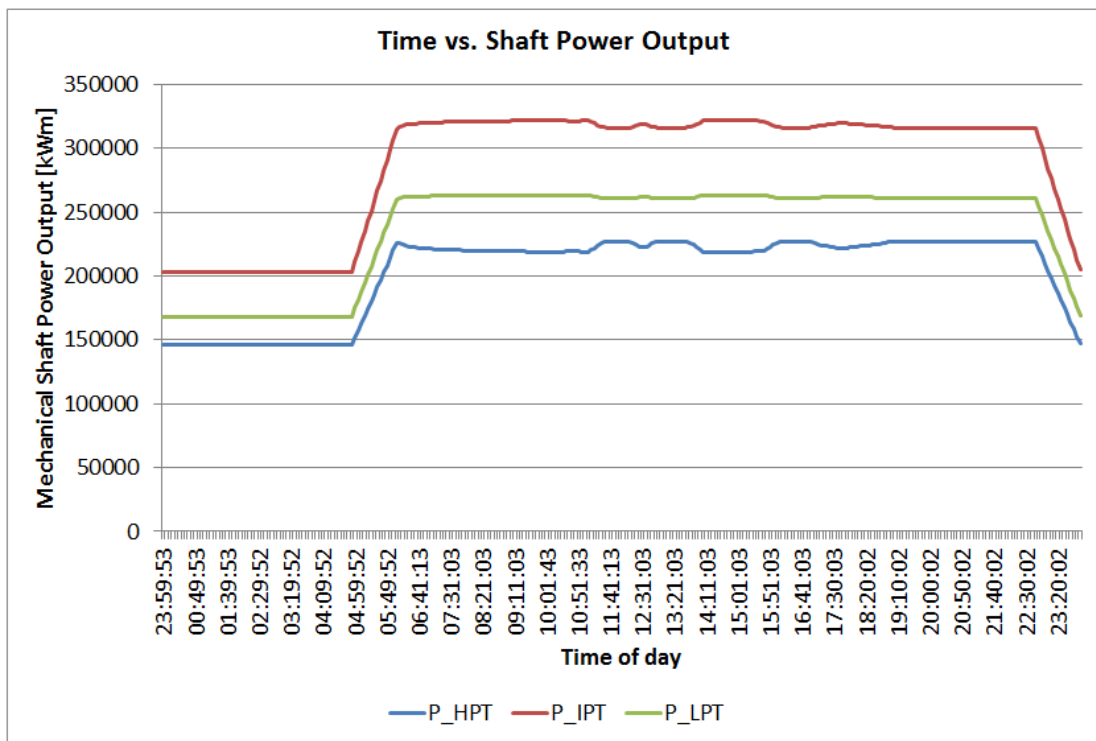


Figure 5-21: Time vs turbine shaft power output for slightly cloudy day scenario

As seen in Figure 5-22, the gross generator output capacity will remain constant, while the net electricity output may vary because of variations in auxiliary power consumption, owing to boiler load changes. This graph also shows the solar power available from the solar field to the coal-fired station during the specific scenario.

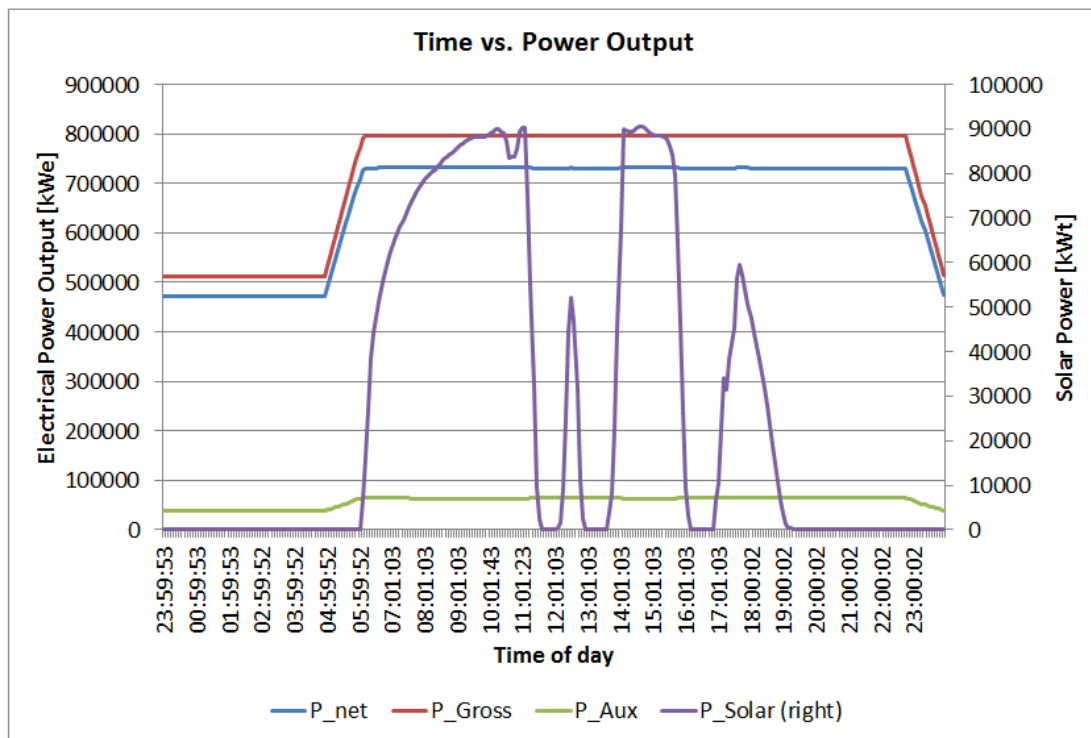


Figure 5-22: Time vs power output for slightly cloudy day scenario

Figure 5-23 shows how the power consumption of major auxiliary systems is influenced by the change in boiler load, owing to the injection of thermal energy from the solar field during the slightly cloudy day scenario. From the graph, one can see that the boiler feed-pump power consumption is greatly influenced by the boiler load variations, owing to solar power injection.

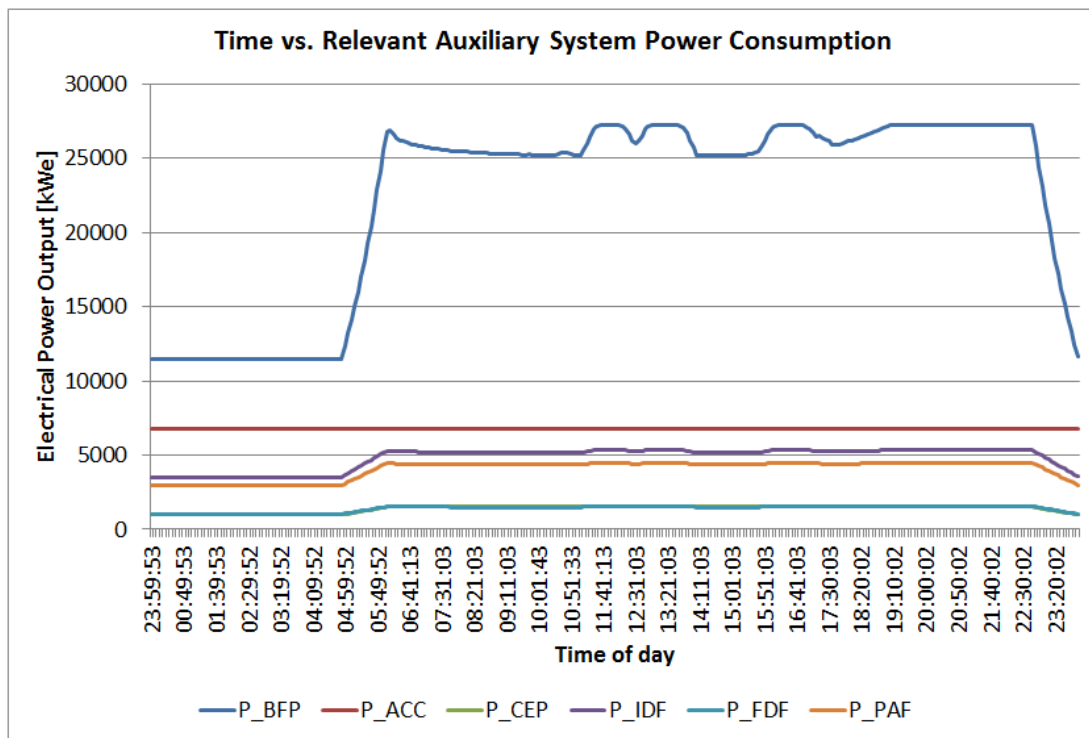


Figure 5-23: Time vs auxiliary power consumption for slightly cloudy day scenario

Because of the boiler load reduction during solar power injection from the solar field, the coal consumption rate decreases according to the increase in solar power. From Figure 5-24 one can see that the coal consumption rate is reduced by approximately 4 kg/s during peak solar conditions.

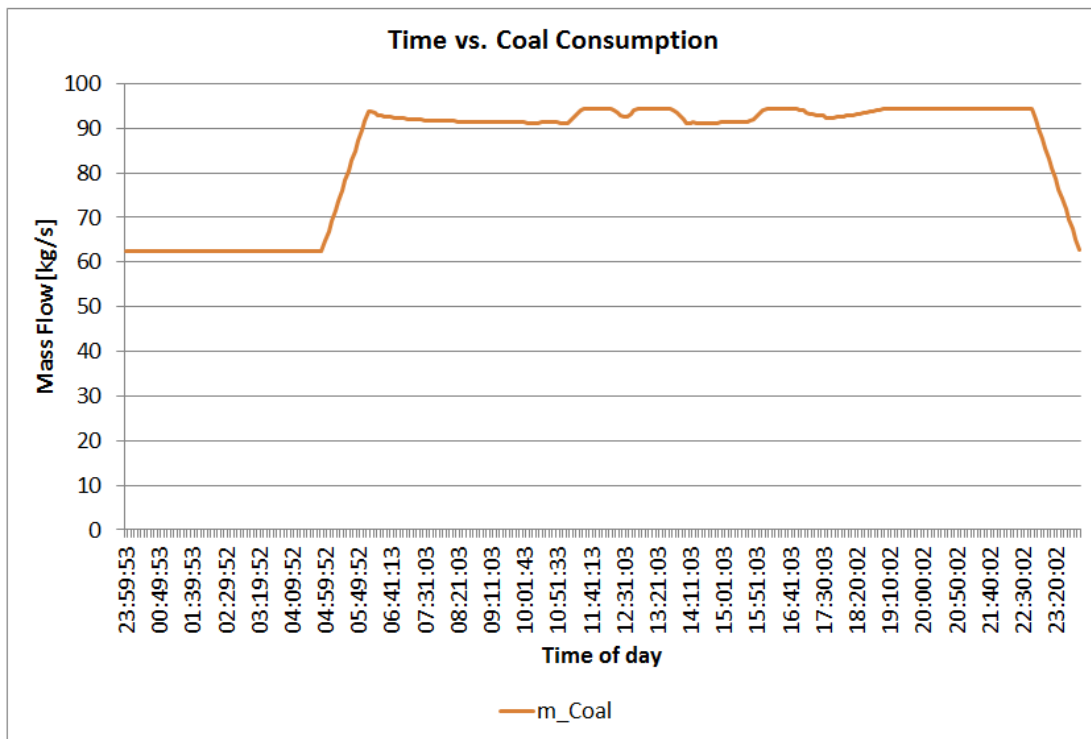


Figure 5-24: Time vs coal consumption rate for slightly cloudy day scenario

Because the coal combustion rate is decreased with the boiler load reduction, all harmful attributes, such as harmful emissions, ash production, etc, thereof are also reduced accordingly. Figure 5-25 shows how the CO₂ and ash production rates are reduced, as solar energy is injected into the Rankine cycle.

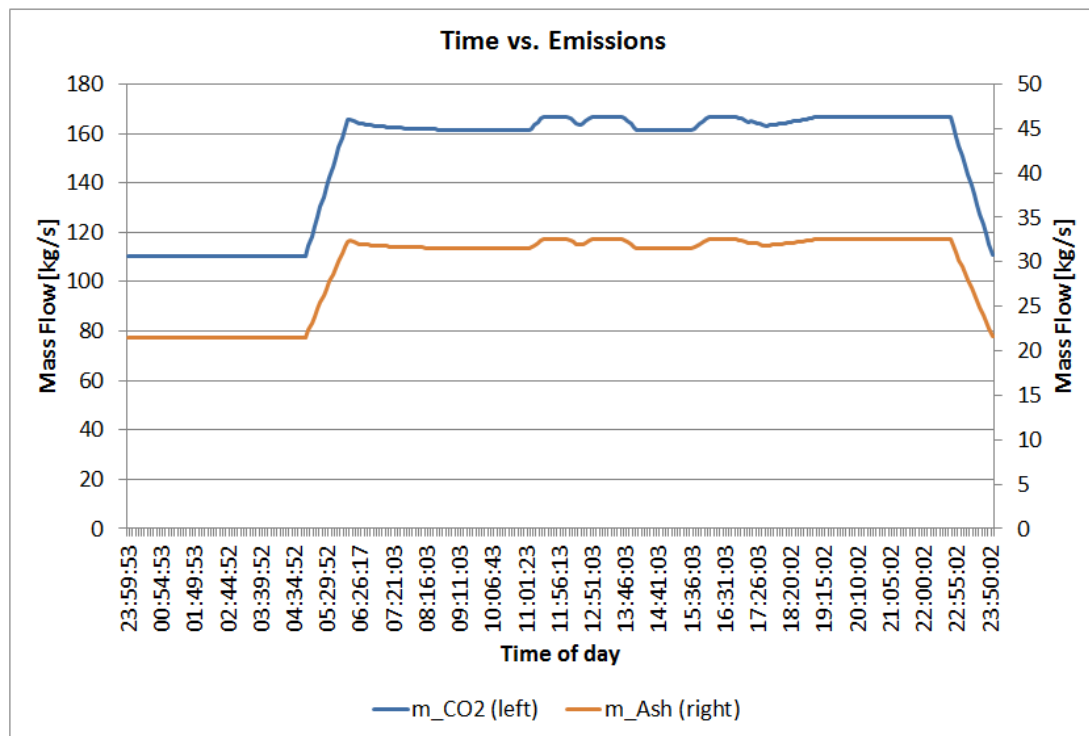


Figure 5-25: Time vs major emissions for slightly cloudy day scenario

Table 5-3 shows a summary of the major role-playing factors when injecting a specific solar energy scenario (Figure 5-17) into the Rankine cycle of a coal-fired power station.

In summary, by injecting 658,9 MWh of thermal energy from the solar field into the Rankine cycle during a slightly cloudy day, the net electricity output will be increased by 17,3 MWh while the coal consumption will be reduced by 82,2 tonnes. The CO₂ emissions will be reduced by 144,8 tonnes while the amount of ash produced will be reduced by 28,3 tonnes.

Table 5-3: Summary for slightly cloudy day scenario.

		No Solar	Slightly Cloudy	Deviation
Net Electricity Out	kWh/day	15925222.92	15942478.8	17255.8
Total Heat Input (from coal)	kWh/day	37403913.53	36990932.9	-412980.7
Total Coal Consumption	T/day	7443.603	7361.4	-82.2
Total CO ₂ Emissions	T/day	13151.88	13007.1	-144.8
Total Ash	T/day	2567.901	2539.6	-28.3
Total Solar Irradiation	kWh/m ² /day	0	8.0	8.0
Total Solar Energy Input	kWh/day	0	658884.0	658884.0

All parametric table data for the slightly cloudy day scenario can be seen in Appendix C - 4.

5.1.4 Cloudless day scenario

When a perfect solar day is considered (Figure 5-26), with a total irradiation level of 119 kWh/m² for the day, the solar field will be able to deliver approximately 973 MWh of thermal energy to the coal-fired power station via the additional heat exchanger.

From Figure 5-26, it can be seen how the DNI rapidly increases from zero, at about 5:50 AM, to approximately 1 075 W/m² at 8:30 AM, after which it stays fairly constant until it begins to decrease as the sun goes under. It can also be seen from the graph that there were no clouds present over the plant during the day.

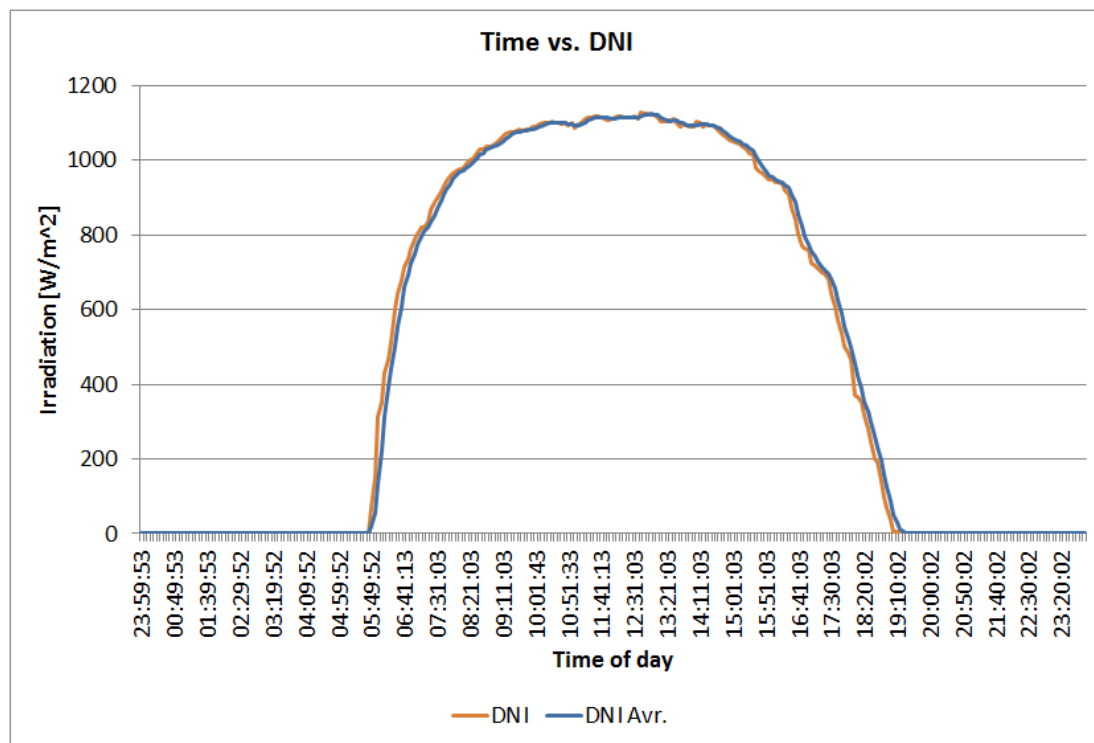


Figure 5-26: Time vs DNI for cloudless day scenario

From the graph in Figure 5-27, it can be seen that the amount of feedwater heated by the additional heat exchanger rapidly increases with the rising DNI up to about 260 kg/s. By bypassing water through the additional heat exchanger, an equal amount less water flows through the conventional HPH banks.

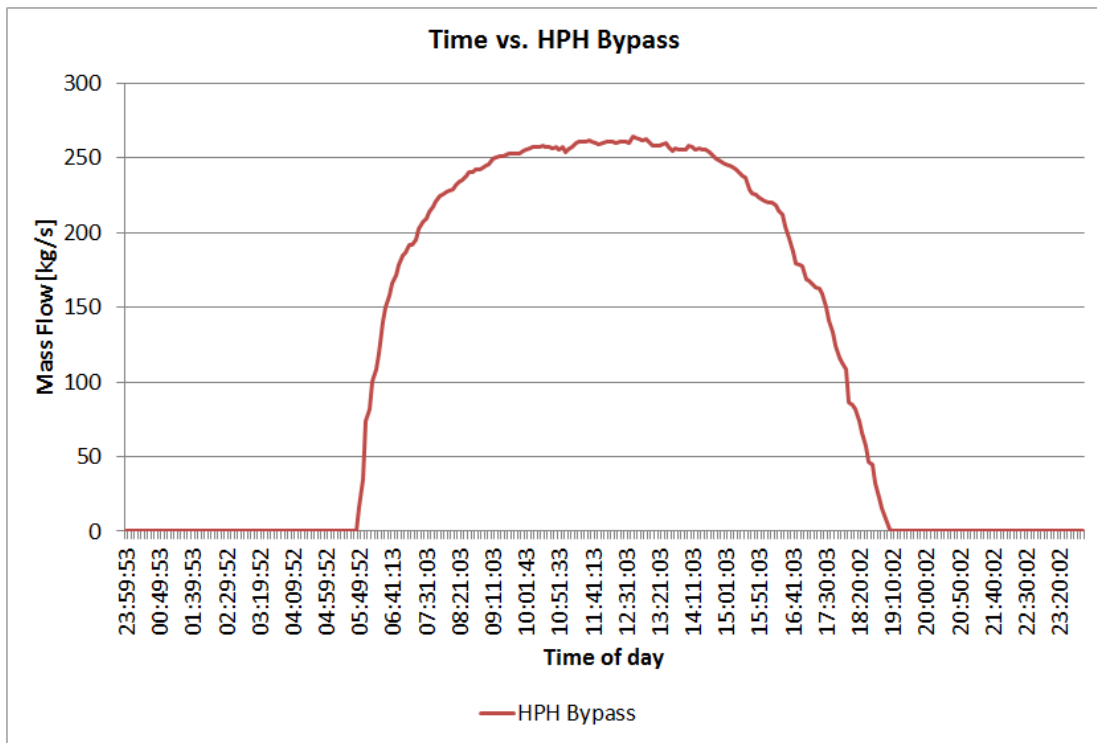


Figure 5-27: Time vs high-pressure heater bypass mass flow for cloudless day scenario

The first set of HPHs (5A and 5B) normally utilises bleed steam from the first stage of the IPT, while the second set (6A and 6B) uses steam from the HPT exhaust to heat the feedwater to the required temperature. The DST normally utilises steam from the second stage of the IPT, and subcooled saturated water from the HPH cascades to preheat the feedwater to a certain extent.

If less feedwater passes through the HPH banks, a reduced amount of bleed steam is required by the heat exchangers to comply with their requirements, but more bleed steam from the second stage of the IPT will be required by the DST to achieve its set-point feedwater temperature outlet. This increase in bleed steam for the DST is due to the fact that the subcooled water flow rate from the HPH cascades will be reduced by an equal amount to that of the bleed steam for all the HPHs.

The graph in Figure 5-28 illustrates how the bleed steam from the HPT exhaust and first stage of the IPT are reduced by about 26 kg/s and 18 kg/s and how the bleed steam from the second stage of the IPT increases by about 2 kg/s as the thermal power from the solar field increases.

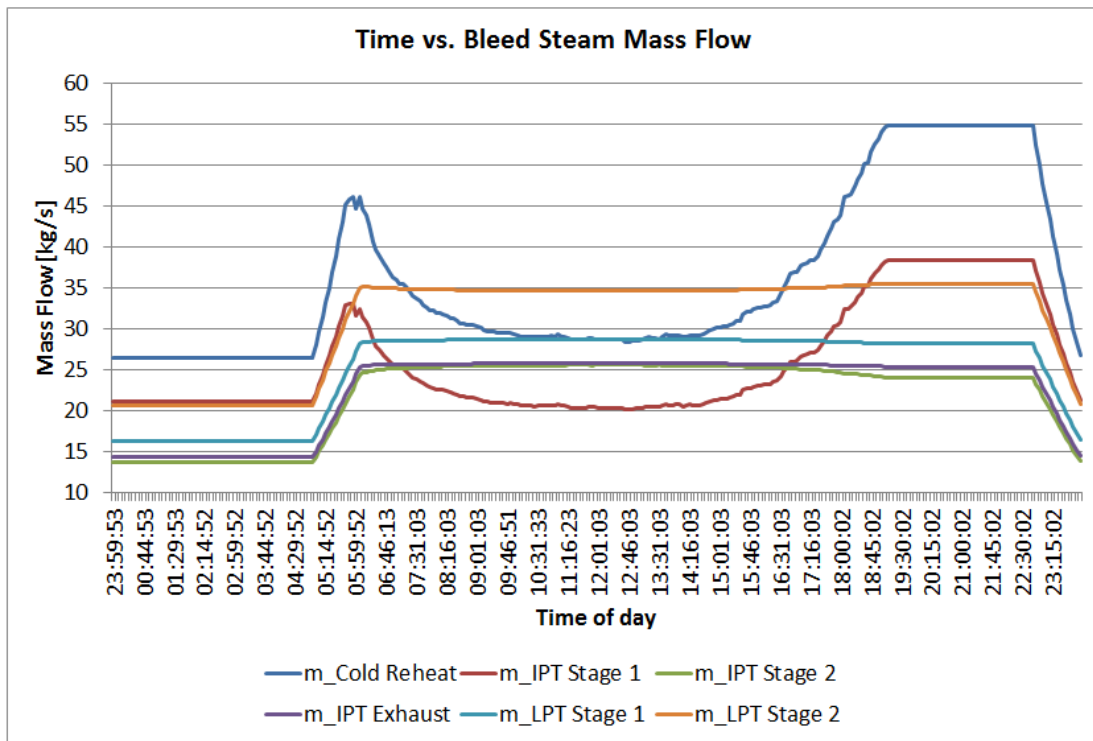


Figure 5-28: Time vs turbine bleed steam mass flow for cloudless day scenario

Because less steam is bled from the first stage of the IPT, more steam will be available for the later stages of the IPT and LPT for mechanical power generation. Because less steam is also tapped from the HPT exhaust, more steam is passed through the whole IPT and IPT, which will increase their mechanical power output to a certain extent.

As a result of the reduction in HPH exhaust bleed steam, more steam will flow through the reheater, which will reduce the attemperation spray-water mass flow rate to a certain extent.

Figure 5-29 illustrates how the spray-water mass flow rate is affected by the injection of solar energy into the Rankine cycle. The spray-water mass flow drops from approximately 5,7 kg/s, when no solar power is injected, to about 3 kg/s during peak solar irradiation conditions.

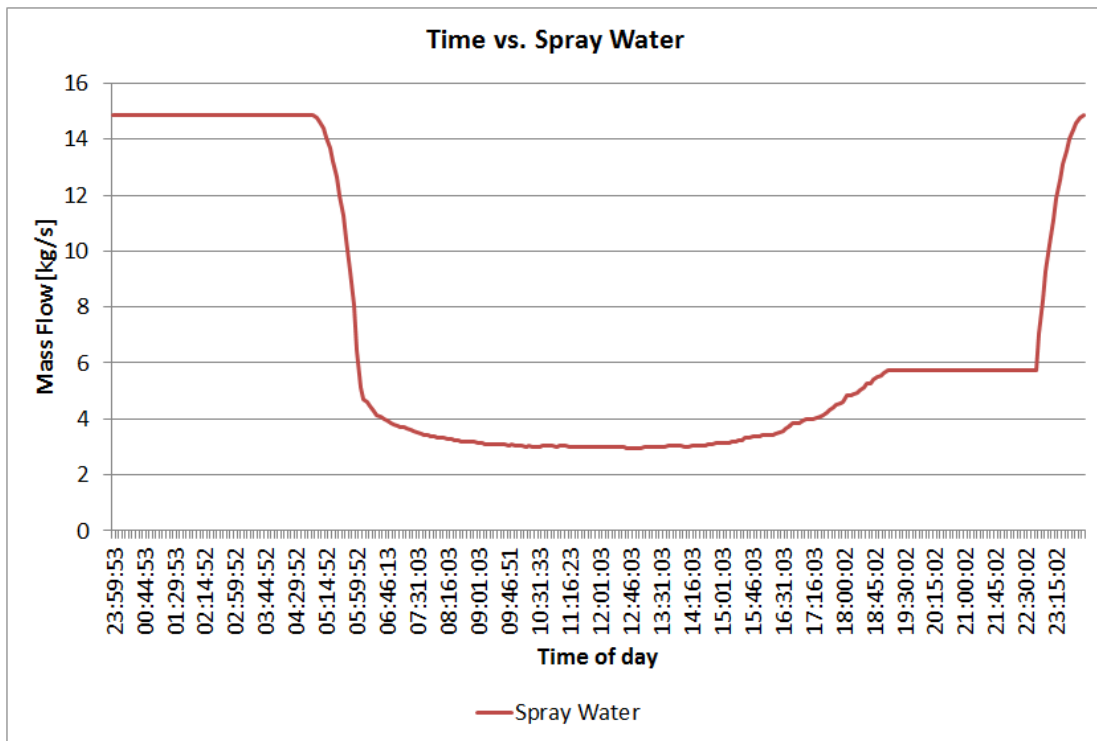


Figure 5-29: Time vs attemperation spray-water mass flow for cloudless day scenario

Because the system is operating in fuel-saver mode, the boiler will fire less when there is an increase in mechanical shaft power output to keep the generator output constant. In effect, the boiler load will drop, which will result in a lower mass flow through boiler, superheaters and HPT, which will, in effect, lower the fuel consumption rate to a certain extent.

Basically, the IP and LP turbines will generate more mechanical shaft power because of the decreased bleed steam, while the HPT will produce less mechanical shaft power owing to the decreased mass flow through the boiler, superheaters and HPT.

Figure 5-30 illustrates how the mechanical shaft power output of the HP, IP and LP turbines changes as the DNI varies with the time of day. From this graph, one can see how the shaft power of the IP and LP turbines increases with the solar power availability and how the shaft power of the HPT decreases as the boiler load is reduced.

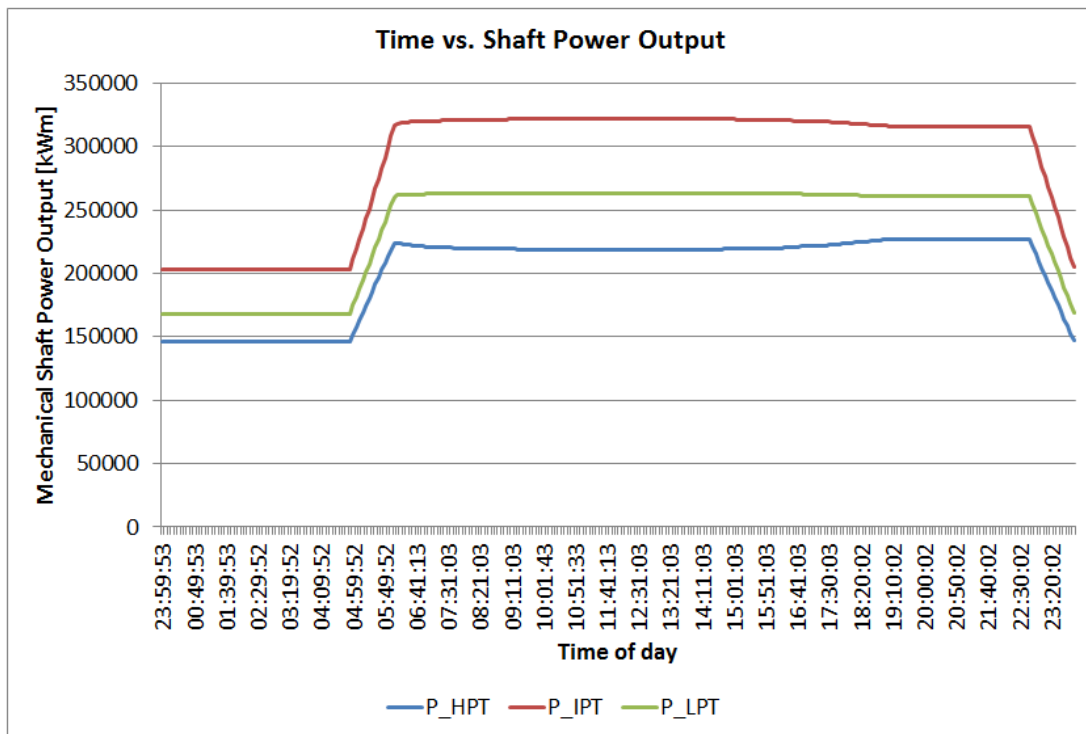


Figure 5-30: Time vs turbine shaft power output for cloudless day scenario

As can be seen in the graph in Figure 5-31, the gross generator output capacity will remain constant, while the net electricity output may vary, owing to variations in auxiliary power consumption, because of boiler-load changes. This graph also shows the amount of solar power available to the coal-fired station during this specific scenario.

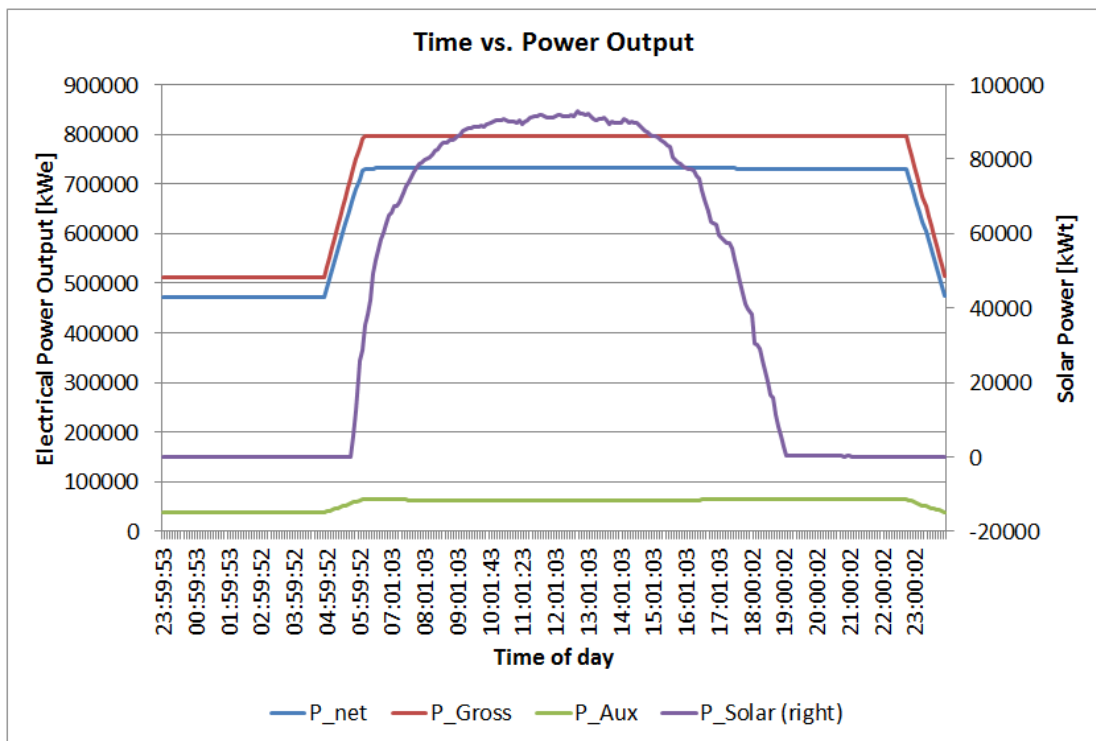


Figure 5-31: Time vs power output for cloudless day scenario

Figure 5-32 shows how the power consumption of the major auxiliary systems is influenced by the change in boiler load, because of the injection of thermal energy from the solar field during a cloudless day scenario. From the graph, one can also see that the boiler feed-pump power consumption is greatly influenced by the boiler load variations.

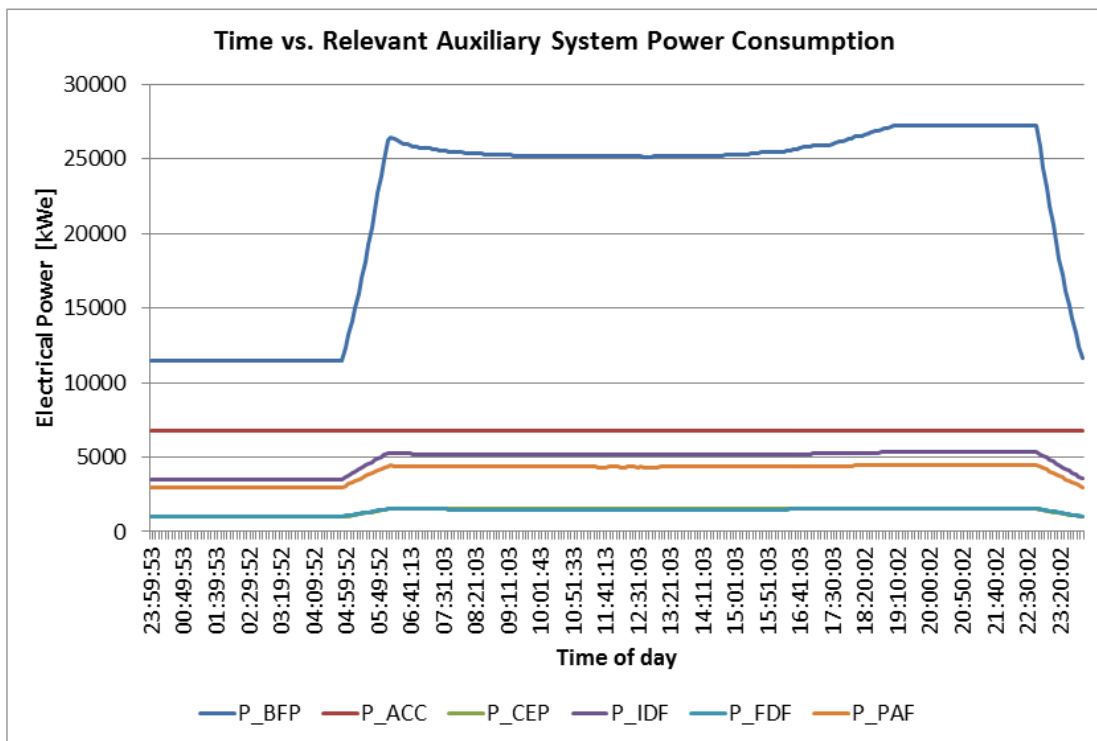


Figure 5-32: Time vs auxiliary power consumption for cloudless day scenario

Due to the boiler load reduction during solar-power injection from the solar field, the coal consumption rate decreases according to the solar-power increase. From Figure 5-33 one can see that the coal consumption rate is reduced by approximately 4 kg/s during peak solar conditions.

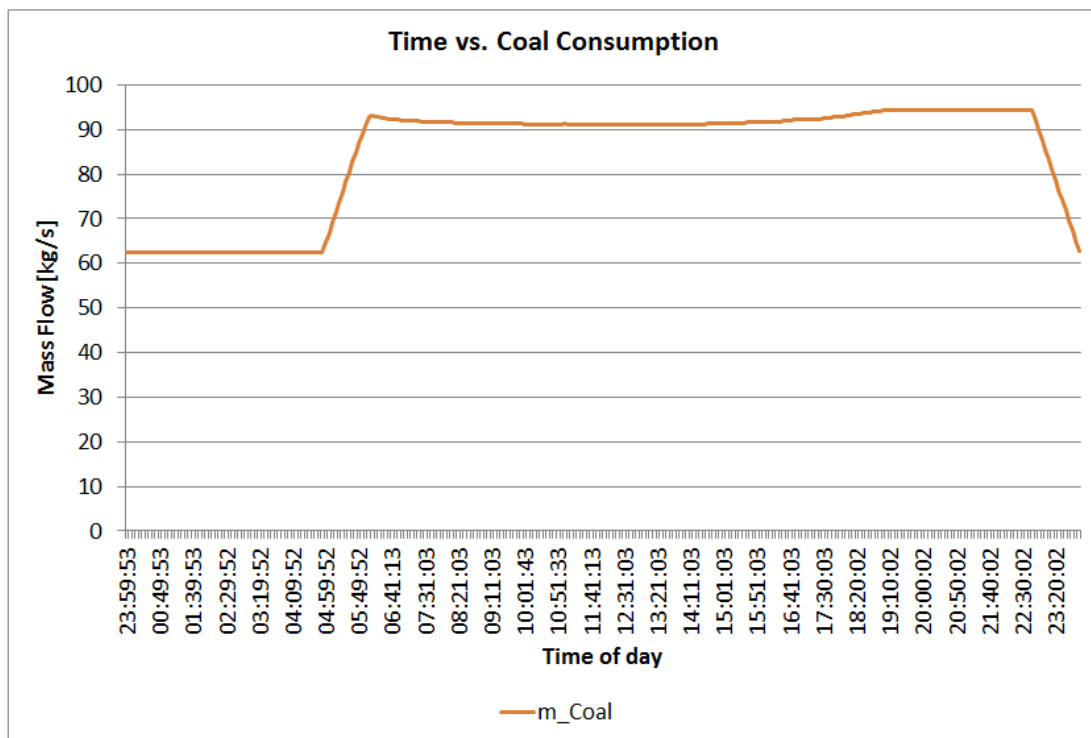


Figure 5-33: Time vs coal consumption rate for cloudless day scenario

Because the coal combustion rate is decreased with the boiler load reduction, all harmful attributes, such as emissions, ash production, etc, thereof are also reduced accordingly. Figure 5-34 shows how the CO₂ and ash production rates are reduced as solar energy is injected into the Rankine cycle.

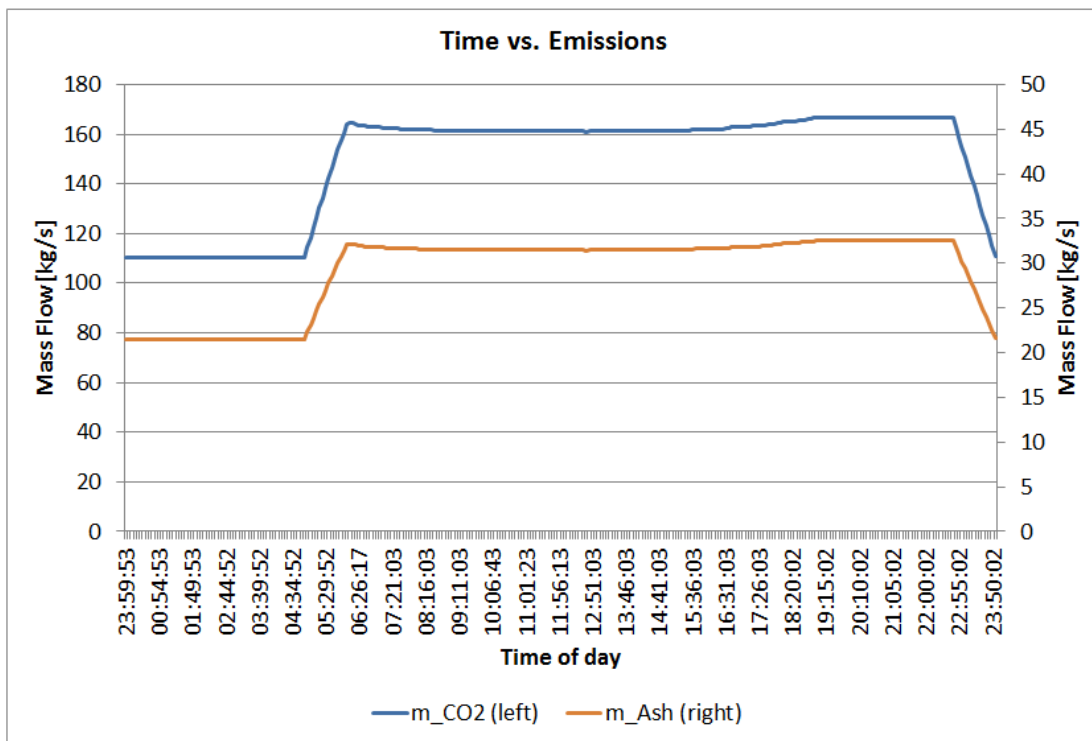


Figure 5-34: Time vs major emissions for cloudless day scenario

Table 5-4 shows a summary of the major role-playing factors when injecting a specific solar-energy scenario (Figure 5-26) into the Rankine cycle of a coal-fired power station.

In summary, by injecting 973 MWh of thermal energy from the solar field into the Rankine cycle of an 800 MWe supercritical coal-fired power station during a cloudless day, the net electricity output will be increased by 25,4 MWh while the coal consumption will be reduced by 121,4 tonnes. The CO₂ emissions will be reduced by 213,9 tonnes while the amount of ash produced will be reduced by 41,8 tonnes.

Table 5-4: Summary for cloudless day scenario.

		No Solar	Cloudless	Deviation
Net Electricity Out	kWh/day	15925222.92	15950642.6	25419.7
Total Heat Input (from coal)	kWh/day	37403913.53	36794319.3	-609594.3
Total Coal Consumption	T/day	7443.603	7322.2	-121.4
Total CO2 Emissions	T/day	13151.88	12938.0	-213.9
Total Ash	T/day	2567.901	2526.1	-41.8
Total Solar Irradiation	kWh/m ² /day	0	11.9	11.9
Total Solar Energy Input	kWht/day	0	973057.4	973057.4

All parametric table data for the cloudless day scenario can be seen in Appendix C - 4.

5.1.5 Irradiation scenario summary

When the four irradiation scenarios considered in section 5.1 are compared with one another the obvious becomes clear: as the daily solar energy increases, the amount of heat that has to be added to the Rankine cycle by burning coal decreases significantly. The net electricity output also rises as the solar energy increases, mainly because the auxiliary power consumption rate decreases as the boiler load drops to keep the generator output constant.

Table 5-5: Daily solar irradiation comparison summary

Daily Scenario Summary	Units	No Solar	Mostly Cloudy	Very Cloudy	Slightly Cloudy	Cloudless
Net Electricity Out	MWh/day	15925.22	15925.39	15934.54	15942.48	15950.64
Total Heat Input (from coal)	MWht/day	37403.91	37399.84	37182.70	36990.93	36794.32
Total Coal Consumption	T/day	7443.603	7442.7	7399.6	7361.4	7322.2
Total CO2 Emissions	T/day	13151.88	13151.4	13074.6	13007.1	12938.0
Total Ash	T/day	2567.901	2567.8	2552.8	2539.6	2526.1
Total Solar Irradiation	kWh/m ² /day	0	0.1	4.3	8.0	11.9
Total Solar Energy Input	MWht/day	0.00	6.45	352.15	658.88	973.06

Figure 5-35 provides a graphical illustration of the results in Table 5-5.

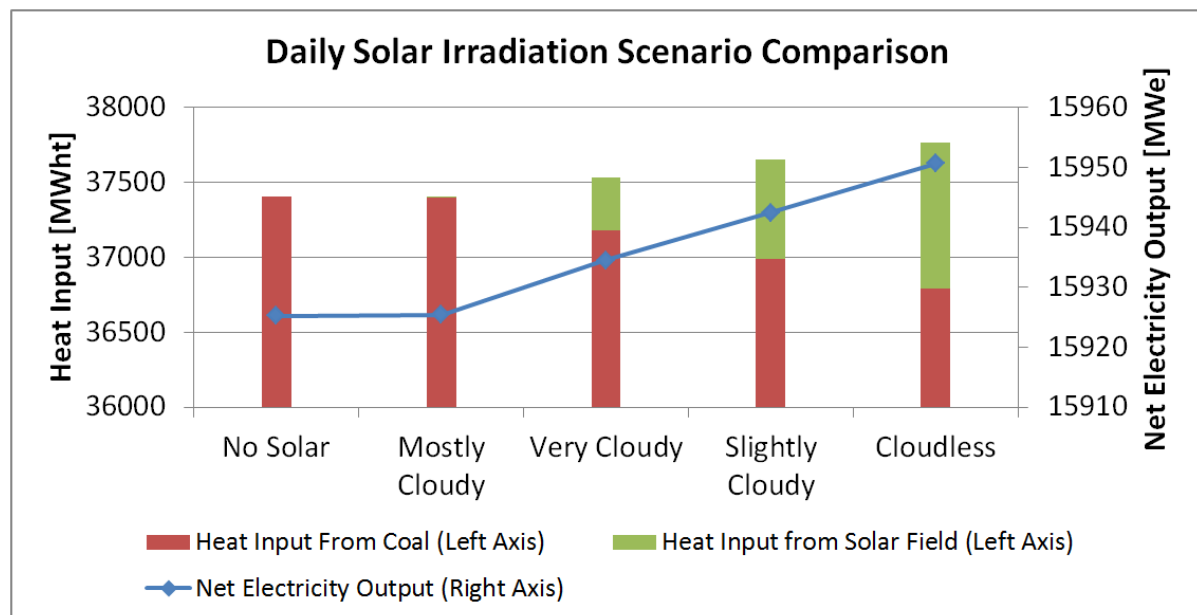


Figure 5-35: Daily solar irradiation scenarios vs heat input from coal, and the solar field compared with the net electricity output.

5.2 Full year solar augmentation scenario summary

When the 90 MWt solar field is integrated into the 800 MWe supercritical coal-fired power station, the following is calculated:

When a boosting scenario is considered, where the coal-fired station is kept at full load while the solar field injects additional thermal energy into the Rankine cycle, it is found that approximately 822 982 kWe can be generated from the 832 135 kWm shaft power available to the generator at peak solar irradiation conditions ($1\ 100\ \text{W/m}^2$). Approximately 31% of the thermal energy injected into the Rankine cycle was converted into electrical power. The amount of heat added to the system by means of burning coal remains the same at 1 896 426 kWt, as per the base-case study for the boiler continues to operate at full load.

Table 5-6: Boosting mode parameters

Boosting Mode at 100% MCR & 1100W/m²	
Total Shaft Power	832136 kWm
Gross Electricity Output	822982 kWe
Total Auxiliary Electricity Consumption	65990 kWe
Net Electricity Output	756968 kWe
Total Heat Added to Furnace	1896426 kWt
Heat Absorbed to Rankine Cycle	1706783 kWt
Thermal Energy	90288 kWt
Net Cycle Efficiency	44.4 %
Gross Cycle Efficiency	48.2 %
Net Overall Efficiency	39.9 %
Solar to Electricity Efficiency	31.0 %

When a fuel-save scenario, where the generator output capacity has a maximum value of 795 033 kWe and the peak solar irradiation rating of $1\ 100\ \text{W/m}^2$, is considered, it is found that the boiler requires only 1 833 633 kWt from coal to reach full generating capacity. In effect, the generator is operating at full load but the boiler is only at 95% MCR. It is also found that the net electrical output to the national grid is slightly higher at 731 926 kWe because of the reduced auxiliary power consumption (63 083 kWe). The major performance parameters for the fuel-saver scenario are shown in Table 5-7.

Table 5-7: Fuel-saver mode parameters

Fuel Saver Mode at P_{gen}=795MWe & 1100W/m²	
Total Shaft Power	803876 kWm
Gross Electricity Output	795033 kWe
Total Auxiliary Electricity Consumption	63083 kWe
Net Electricity Output	731926 kWe
Total Heat Added to Furnace	1833633 kWt
Heat Absorbed to Rankine Cycle	1650269 kWt
Thermal Energy	90288 kWt
Net Cycle Efficiency	44.4 %
Gross Cycle Efficiency	48.2 %
Net Overall Efficiency	39.9 %

When a full year is considered, where an annual solar irradiation rating of 2 141 kW/m² is assumed with a linear Fresnel thermal capacity factor of 22,2%, the following annual input and output parameters for a fuel-saver scenario are calculated.

A total amount of 5 817,3 GWh of electrical energy can be fed into the national grid by burning only 2 694,9 kT of coal. The CO₂ emission rate is lowered to 4 761,8kT per year, while the amount of ash produced during a year is reduced to 929,7 kT. The annual fuel-saver scenario performance parameters can be seen in Table 5-8.

Table 5-8: Annual input and output parameters for a fuel-saver scenario

Annual Fuel Saver Input and Output Parameters	
Net Electricity Out	5817.3 GWh/Year
Total Heat Input (from coal)	13542.0 GWh/Year
Total Coal Consumption	2694.9 kT/Year
Total CO2 Emissions	4761.8 kT/Year
Total Ash	929.7 kT/Year
Total Solar Energy Input	176.1 GWht/year
Total Electricity from Solar Power	54.6 GWhe/year

The overnight cost of such a hybrid power station, where renewable resources and fossil fuels are utilised, will be in the region of R14 898,354m, while the fuel cost will come down to approximately R758,35m per year, the total O&M cost will increase to about R631,796m per year and carbon tax will cost only R228,56m per year. Because 54,6 GWh of electrical energy is generated with a renewable resource, R8,188m is earned by selling TRECs.

Table 5-9: Solar augmentation major expenses

Major Expenses	
Capital Cost	R 14 898 354 200 once off
Fuel Cost	R 758 350 166 per year
Carbon Tax Cost	R 228 564 755 per year
O&M Cost	R 631 796 963 per year

When all the expenses are discounted back to year zero and divided by the total discounted electricity generated over the lifetime of the hybrid plant, it is found that an 800 MWe supercritical coal-fired power station, combined with a 90 MWt solar field, has an LCOE of approximately R0,715 per kWh. The solar augmentation LCOE calculation can be seen in Appendix D - 2.

CHAPTER 6: RESULTS SUMMARY

6.1 Annual results summary

The results from the thermodynamic models indicate that if an additional heat exchanger integration option for a fuel-saver solar augmentation scenario is considered, one can expect to produce approximately 4,6 GWh of net electricity in addition to what can be generated in the base-case scenario. This increase in net electricity output is mainly due to the lowered auxiliary power consumption during high solar irradiation conditions.

It is also found that the total thermal energy input required from burning pulverised coal is reduced by 110,5 GWh, while approximately 176,5 GWh of solar energy is injected into the coal-fired power station's regenerative Rankine cycle throughout the year. Of this total thermal energy supplied by the solar field, approximately 54,6 GWh is eventually converted into electrical energy. Approximately 22 kT less coal will be required, which will result in 38,7 kT less CO₂ emissions and about 7,6 kT less ash production.

All major input and output parameters, as well as the LCOE for the base-case vs the solar augmentation case, are summarised in Table 6-1.

Table 6-1: Base-case vs solar augmentation results

	Units	Base Scenario	Augmentation Scenario	Offset
Net Electricity Out	GWh/Year	5812.7	5817.3	4.6
Total Heat Input (from coal)	GWh/Year	13652.4	13542.0	-110.5
Total Coal Consumption	kT/Year	2716.9	2694.9	-22.0
Total CO2 Emissions	kT/Year	4800.4	4761.8	-38.7
Total Ash	kT/Year	937.3	929.7	-7.6
Total Solar Energy Input	GWht/year	0	176.1	176.1
Total Electricity from Solar Power	GWhe/year	0	54.6	54.6
Levelised Cost of Electricity	R/kWh	0.7116	0.715	0.0034

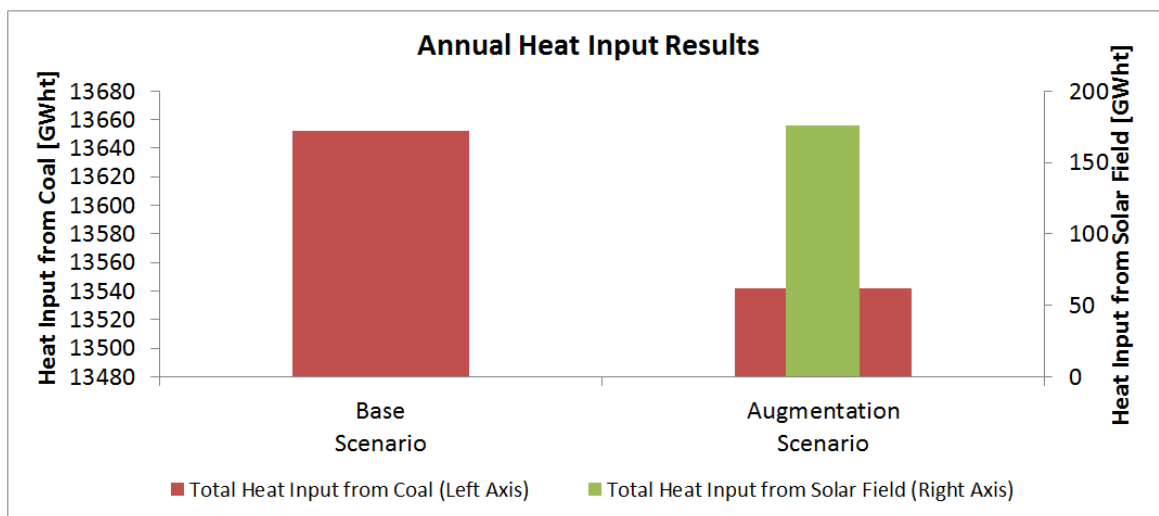


Figure 6-1: Annual heat input summary

If all input and output parameters are considered for a 35-year plant lifetime, it is found that the levelised cost of electricity for the solar augmentation scenario described in section 3.3 is approximately R0,715 per kWh.

CHAPTER 7: CONCLUSIONS

This electricity generated from the thermal energy supplied by the solar field will annually produce approximately R8,188m additional revenue from the trade of renewable energy certificates, while the lowered coal consumption will result in an annual fuel saving of about R6,189m. By emitting less CO₂ into the atmosphere, the annual carbon tax bill is reduced by R1,856m and supplying additional energy to the national grid, an additional income of approximately R3,037m will be due to the power station. The annual operating and maintenance cost increase, due to the additional 171 000 m² solar field, will be in the region of R9,71m, while the overnight capital cost for the additional solar field and integration requirements will be about R670,354m.

Table 7-1: Annual operating cost deviation.

Annual Operating Cost Deviation	
Fuel Cost Saving	R 6 189 741.81
Carbon Tax Saving	R 1 856 182.68
TREC Income	R 8 188 697.12
Additional Electricity Sales	R 3 037 063.87
Increased O&M	R -9 712 800.00

The cost of generating 1 kWh with the solar augmented coal-fired power plant will only be 0,34 cents more expensive than it will be to generate the same energy with a normal supercritical coal-fired power station.

If one considers that a typical conventional linear Fresnel CSP plant (without storage) has an LCOE of about R3,08, the conclusion can be drawn that it will be more feasible by far to generate electricity from thermal power supplied by a solar field by utilising highly efficient large-scale components from a supercritical coal-fired power station.

CHAPTER 8: BIBLIOGRAPHY AND REFERENCES

- ALLAN, G., GILMARTIN, M., MCGREGOR, P. & SWALES, K. 2011. Levelised costs of Wave and Tidal energy in the UK: Cost competitiveness and the importance of “banded” Renewables Obligation Certificates. *Energy Policy*, 39, 23-39.
- ALNASER, W. E., PROBERT, S. D., EL-MASRI, S., AL-KHALIFA, S. E., FLANAGAN, R. & ALNASER, N. W. 2006. Bahrain’s Formula-1 racing circuit: energy and environmental considerations. *Applied Energy*, 83, 352-370.
- BEDILION, B., COLEMAN, ENTRIKEN, HAMEL, MCGOWIN, PLATT, RAMACHANDRAN. 2010. Power Generation Technology Data for Integrated Resource Plan of South Africa. Palo Alto, CA: Electric Power Research Institute (EPRI).
- BRIGHTSOURCE. 2013. *Ivanpah Project Factsheet* [Online]. Available: http://www.brightsourceenergy.com/FD12D27C-76E4-4AAF-852B-AB729011F9C5/FinalDownload/DownloadId-82FBE9019B126E458742D7DAB6D1D055/FD12D27C-76E4-4AAF-852B-AB729011F9C5/stuff/contentmgr/files/0/8a69e55a233e0b7edfe14b9f77f5eb8d/folder/ivanpah_fact_sheet_3_26_14.pdf [Accessed 29 April 2014].
- CAU, G. & COCCO, D. 2014. Comparison of Medium-size Concentrating Solar Power Plants based on Parabolic Trough and Linear Fresnel Collectors. *Energy Procedia*, 45, 101-110.
- CHOUDHURY, S. *Fans in thermal power plants* [Online]. Available: <http://www.slideshare.net/SHIVAJICHOUDHURY/fans-in-thermal-power-plants> [Accessed 3 July 2014].
- CSENERGY. 2014. *Kogan Creek Solar Boost Project* [Online]. Available: <http://kogansolarboost.com.au/> [Accessed 26 May 2014].
- DEKKER, J., NTHONTHO, M., CHOWDHURY, S. & CHOWDHURY, S. P. 2012. Investigating the effects of solar modelling using different solar irradiation data sets and sources within South Africa. *Solar Energy*, 86, 2354-2365.
- DIRECTORATE, S. M. 2010. *The Earth’s Radiation Budget* [Online]. National Aeronautics and Space Administration. Available: http://missionscience.nasa.gov/ems/13_radiationbudget.html.
- ESKOM. 2013a. *Key Facts and Figures* [Online]. Available: http://www.eskom.co.za/OurCompany/CompanyInformation/Pages/Key_Facts.aspx [Accessed 29 April 2014].
- ESKOM. 2013b. *Map of Eskom Power Stations* [Online]. Available: <http://www.eskom.co.za/Whatweredoing/ElectricityGeneration/PowerStations/Documents/EskomGenerationDivMapREV81.pdf> [Accessed 29 April 2014].
- ESKOM. 2014a. *Company Information* [Online]. Available: http://www.eskom.co.za/OurCompany/CompanyInformation/Pages/Company_Information.aspx [Accessed 29 April 2014].
- ESKOM. 2014b. *Medupi Power Station Fact Sheet* [Online]. Available: http://www.eskom.co.za/Whatweredoing/NewBuild/MedupiPowerStation/Documents/NB_0002MedupiFactSheetSept2013.pdf [Accessed 29 April 2014].
- EVERETT, B. W., HERBERT, B. L. & THOMAS, F. L. 2012a. Auxiliary Steam-Plant Equipment. *Steam Plant Operation, Ninth Edition*. McGraw Hill Professional, Access Engineering.
- EVERETT, B. W., HERBERT, B. L. & THOMAS, F. L. 2012b. Boilers. *Steam Plant Operation, Ninth Edition*. McGraw Hill Professional, Access Engineering.
- EVERETT, B. W., HERBERT, B. L. & THOMAS, F. L. 2012c. Environmental Control Systems. *Steam Plant Operation, Ninth Edition*. McGraw Hill Professional, Access Engineering.
- EVERETT, B. W., HERBERT, B. L. & THOMAS, F. L. 2012d. Pumps. *Steam Plant Operation, Ninth Edition*. McGraw Hill Professional, Access Engineering.
- EVERETT, B. W., HERBERT, B. L. & THOMAS, F. L. 2012e. Steam Turbines, Condensers, and Cooling Towers. *Steam Plant Operation, Ninth Edition*. McGraw Hill Professional, Access Engineering.

- FU, W. Q. 2006. 4 - Radiative Transfer. In: WALLACE, J. M. & HOBBS, P. V. (eds.) *Atmospheric Science (Second Edition)*. San Diego: Academic Press.
- GEVORKIAN, P. *Large-scale solar power system design [electronic resource] : an engineering guide for grid-connected solar power generation / Peter Gevorkian*, New York ; Singapore : McGraw-Hill, c2011.
- GORDON, J. & SOCIETY, I. S. E. 2001. *Solar Energy: The State of the Art : ISES Position Papers*, James & James.
- GOVERNMENT, S. A. 2012. Taxation Laws Amendment Act, 2012. South Africa.
- GOVERNMENT, S. A. 2013. Carbon Tax Policy Paper. In: TREASURY, N. (ed.). Republic of South Africa: Department of National Treasury.
- HU, E., YANG, Y., NISHIMURA, A., YILMAZ, F. & KOUZANI, A. 2010. Solar thermal aided power generation. *Applied Energy*, 87, 2881-2885.
- IEA, I. E. A. & CIAB, C. I. A. B. 2010. Power Generation from Coal. *Measuring and Reporting, Efficiency Performance and CO₂ emissions*.
- INCROPERA, F. P. 2007. *Fundamentals of heat and mass transfer*, Hoboken, NJ : John Wiley, c2007.6th ed. / Frank P. Incropera ... [et al.].
- IRENA 2012. Renewable Energy Technologies: Cost Analysis Series. *Concentrating Solar Power*. International Renewable Energy Agency.
- KALOGIROU, S. *Solar energy engineering [electronic resource] : processes and systems / Soteris A. Kalogirou*, Burlington, MA : Elsevier/Academic Press, c2009.
- KALOGIROU, S. A. 2009a. Chapter ten - Solar Thermal Power Systems. In: KALOGIROU, S. A. (ed.) *Solar Energy Engineering*. Boston: Academic Press.
- KALOGIROU, S. A. 2009b. Chapter three - Solar Energy Collectors. In: KALOGIROU, S. A. (ed.) *Solar Energy Engineering*. Boston: Academic Press.
- KALOGIROU, S. A. 2012a. 3.05 - Low Concentration Ratio Solar Collectors. In: SAYIGH, A. (ed.) *Comprehensive Renewable Energy*. Oxford: Elsevier.
- KALOGIROU, S. A. 2012b. A detailed thermal model of a parabolic trough collector receiver. *Energy*, 48, 298-306.
- KALOGIROU, S. A. 2013. *Solar Energy Engineering: Processes and Systems*, Elsevier Science.
- KAMBEZIDIS, H. D. 2012. 3.02 - The Solar Resource. In: SAYIGH, A. (ed.) *Comprehensive Renewable Energy*. Oxford: Elsevier.
- LI, Y., LIAO, S., RAO, Z. & LIU, G. 2014. A dynamic assessment based feasibility study of concentrating solar power in China. *Renewable Energy*, 69, 34-42.
- LOVEGROVE, K. & STEIN, W. 2012. *Concentrating Solar Power Technology: Principles, Developments and Applications*, Elsevier Science.
- MORETTI, A. L. & JONES, C. S. 2012. Advanced Emissions Control Technologies for Coal-Fired Power Plants. Power-Gen Asia: Babcock & Wilcox Power Generation Group, Inc.
- MUNZHEDZI, R. & SEBITOSI, A. B. 2009. Redrawing the solar map of South Africa for photovoltaic applications. *Renewable Energy*, 34, 165-169.
- NARULA, R. G., KOZA, D. & WEN, H. 2013. 2 - Impacts of steam conditions on plant materials and operation in ultra-supercritical coal power plants. In: ZHANG, D. (ed.) *Ultra-Supercritical Coal Power Plants*. Woodhead Publishing.
- PIDWIRNY, M. 2006. *Atmospheric Effects on Incoming Solar Radiation* [Online]. Available: <http://www.physicalgeography.net/fundamentals/7f.html> [Accessed 17 April 2014].
- PIERCE, W., GAUCHÉ, P., VON BACKSTRÖM, T., BRENT, A. C. & TADROS, A. 2013. A comparison of solar aided power generation (SAPG) and stand-alone concentrating solar power (CSP): A South African case study. *Applied Thermal Engineering*, 61, 657-662.
- SALVATORE, J. 2014. H2 2014 Global LCOE Outlook. Bloomberg New Energy Finance.
- SOLARGIS. 2013a. *Direct Normal Irradiation map of South Africa* [Online]. Available: <http://solargis.info/doc/pics/freemaps/1000px/dni/SolarGIS-Solar-map-DNI-South-Africa-en.png> [Accessed 29 April 2014].
- SOLARGIS. 2013b. *World Map of Direct Normal Irradiation* [Online]. Available: <http://solargis.info/doc/pics/freemaps/1000px/dni/SolarGIS-Solar-map-DNI-World-map-en.png> [Accessed 29 April 2014].

- SONNTAG, R. E., BORGNAKKE, C. & VAN WYLEN, G. J. 2003. *Fundamentals of thermodynamics* / Richard E. Sonntag, Claus Borgnakke, Gordon J. Van Wylen, New York : Wiley, c2003.6th ed.
- SURESH, M. V. J. J., REDDY, K. S. & KOLAR, A. K. 2010. 4-E (Energy, Exergy, Environment, and Economic) analysis of solar thermal aided coal-fired power plants. *Energy for Sustainable Development*, 14, 267-279.
- VAN ROOY, W. L. 2014. Performance evaluation of Eskom's linear Fresnel concentrating solar thermal pilot plant. *ICUE*. Cape Town: IEEE.
- VOLSCHENK, J. 2013. *Financing Renewable Energy*, Stellenbosch University, Stellenbosch University.
- WORDPRESS. 2014. *Thermal Power Plant* [Online]. Wordpress. Available: <https://thermalpowerplant.wordpress.com/condenser/> [Accessed 13 May 2014].
- YANG, Y., YAN, Q., ZHAI, R., KOUZANI, A. & HU, E. 2011. An efficient way to use medium-or-low temperature solar heat for power generation – integration into conventional power plant. *Applied Thermal Engineering*, 31, 157-162.
- ZHANG, D. 2013. 1 - Introduction to advanced and ultra-supercritical fossil fuel power plants. In: ZHANG, D. (ed.) *Ultra-Supercritical Coal Power Plants*. Woodhead Publishing.
- ZHANG, K., ZHANG, Y., GUAN, Y. & ZHANG, D. 2013. 5 - Boiler design for ultra-supercritical coal power plants. In: ZHANG, D. (ed.) *Ultra-Supercritical Coal Power Plants*. Woodhead Publishing.
-

APPENDIX

9.1 Appendix A: Rosherville linear Fresnel performance evaluation data

	#	DNI [W/m ²]	Fan Speed [Hz]	HTF Flow [kg/s]	Temp Receiver In [C]	Temp Receiver Out [C]	Temp Radiator In [C]	Pressure Receiver Out [kPa]	Pressure Receiver In [kPa]	Enthalpy Radiator In [kJ/kg]	Enthalpy Receiver Out [kJ/kg]	Enthalpy Receiver In [kJ/kg]	Heat Radiator kWt	Heat Receiver kWt	Power Solar kW
06:00:03	1	47.45	0	0.09	17.67	22.65	13.33	3969	3974	59.75	77.84	98.62	0	1.87	11.1
06:05:03	2	134.2	0	2.6	19.37	22.21	17.13	3992	3938	75.56	84.95	96.75	0	30.67	31.41
06:10:03	3	464.6	0	3.55	21.2	22.18	20.19	4101	4019	88.4	92.69	96.7	0	14.24	108.7
06:15:03	4	680.8	0	3.56	22.84	23.91	22.1	4277	4189	96.52	99.69	104.1	0	15.6	159.3
06:20:03	5	714.7	0	3.57	25.25	26.62	24.69	4254	4170	107.3	109.7	115.4	0	20.13	167.2
06:25:03	6	741.9	0	3.57	28.07	29.46	27.49	4234	4147	119	121.5	127.2	0	20.42	173.6
06:30:03	7	764.8	0	3.58	31.07	32.61	30.47	4250	4162	131.4	134	140.3	0	22.72	179
06:35:03	8	784.8	0	3.59	34.17	35.96	33.78	4250	4162	145.2	146.9	154.3	0	26.53	183.7
06:40:03	9	803.9	0	3.59	37.62	39.6	37.13	4260	4171	159.2	161.3	169.5	0	29.38	188.1
06:45:03	10	824.1	0	3.6	41.5	43.83	41.15	4253	4164	176	177.5	187.2	0	34.72	192.8
06:50:03	11	852.8	0	3.62	46.29	49.03	46.15	4258	4170	196.8	197.5	208.9	0	41.1	199.5
06:55:03	12	870.6	0	3.62	51.76	54.73	52.02	4273	4186	221.4	220.3	232.7	3.657	44.59	203.7
07:00:03	13	885.1	0	3.62	57.57	60.82	58.02	4263	4176	246.4	244.6	258.1	6.532	48.84	207.1
07:05:03	14	900.4	0	3.63	63.6	67.3	64.42	4278	4192	273.1	269.8	285.1	12.17	55.82	210.7
07:10:03	15	913.9	0	3.63	69.98	73.88	71.01	4246	4161	300.6	296.4	312.6	15.37	58.91	213.9
07:15:03	16	926	0	3.62	76.67	80.85	77.84	4287	4201	329.2	324.4	341.8	17.46	63.06	216.7
07:20:03	17	934.2	0	3.62	83.36	87.68	84.85	4259	4174	358.5	352.3	370.4	22.35	65.29	218.6
07:25:03	18	943.8	0	3.62	89.68	94.39	91.3	4289	4207	385.6	378.9	398.6	24.37	71.34	220.8
07:30:03	19	952.3	0	3.61	96.25	101.2	97.93	4277	4197	413.4	406.4	427.1	25.27	74.63	222.8
07:35:03	20	959.5	0	3.6	103	108	104.6	4270	4190	441.5	434.8	455.8	23.9	75.36	224.5
07:40:03	21	968.3	0	3.59	109.8	115.1	111.5	4257	4177	470.7	463.5	485.9	25.72	80.5	226.6
07:45:03	22	972.7	0	3.57	117	122.7	118.9	4230	4148	501.8	493.9	518	28.22	85.89	227.6
07:50:03	23	981.5	0	3.55	125.7	131.9	127.8	4274	4192	539.6	530.8	557	31.19	92.84	229.7
07:55:03	24	986.8	0	3.53	134.7	141.2	137	4307	4225	578.8	569.2	596.8	33.86	97.7	230.9
08:00:03	25	995.2	0	3.5	144	150.6	146.3	4315	4234	618.8	608.9	637.1	34.64	98.7	232.9
08:05:03	26	1003	21	3.48	151.2	159	154.7	4291	4207	654.8	639.8	673.2	51.98	116.1	234.7
08:10:03	27	1006	24	3.47	152.7	161	156.9	4090	4004	664.2	646.2	682	62.52	124.5	235.5
08:15:03	28	1012	21	3.47	152.6	160.5	156.6	4051	3968	663	645.7	679.9	59.83	118.5	236.8
08:20:03	29	1012	23	3.47	152.5	160.4	156.5	4203	4120	662.8	645.4	679.4	60.27	118.2	236.8

	#	DNI [W/m ²]	Fan Speed [Hz]	HTF Flow [kg/s]	Temp Receiver In [C]	Temp Receiver Out [C]	Temp Radiator In [C]	Pressure Receiver Out [kPa]	Pressure Receiver In [kPa]	Enthalpy Radiator In [kJ/kg]	Enthalpy Receiver Out [kJ/kg]	Enthalpy Receiver In [kJ/kg]	Heat Radiator kWt	Heat Receiver kWt	Power Solar kW
08:25:03	30	1015	23	3.46	152.7	160.7	156.9	4159	4079	664.1	646.2	680.6	61.9	118.9	237.4
08:30:03	31	1019	24	3.46	152.6	160.6	156.8	4016	3938	663.8	645.7	680.3	62.81	119.6	238.5
08:35:03	32	1021	25	3.47	152.9	160.7	156.8	4041	3959	663.7	647	680.8	57.89	117.3	239
08:40:03	33	1031	26	3.46	153	160.8	156.9	4074	3988	664.1	647.5	681	57.57	115.9	241.2
08:45:03	34	1036	23	3.47	152.8	160.3	156.7	4107	4025	663.6	646.6	678.8	58.79	111.7	242.5
08:50:03	35	1036	21	3.47	152.3	159.8	156.7	4269	4193	663.3	644.6	676.9	65.07	112.1	242.4
08:55:03	36	1038	31	3.46	153.4	161.5	158.1	4272	4197	669.4	649.3	684.4	69.7	121.3	242.9
09:00:02	37	1040	29	3.46	153.9	162.3	159	4268	4194	673.4	651.5	687.9	75.86	126	243.4
09:05:02	38	1043	31	3.47	154	162.5	158.8	4073	3994	672.4	651.8	688.2	71.73	126.6	244.1
09:10:02	39	1043	28	3.46	153.9	162.1	158.5	4062	3982	671.3	651.3	686.8	69.13	122.9	244.1
09:15:02	40	1049	30	3.46	153.9	162.1	158.3	4080	3998	670.4	651.3	686.8	65.83	122.7	245.4
09:20:02	41	1050	27	3.46	153.7	161.9	158	4031	3952	669	650.4	685.7	64.04	122	245.6
09:25:02	42	1050	26	3.46	153.6	161.5	157.9	4030	3947	668.3	650	684.3	63.28	118.5	245.6
09:30:02	43	1060	27	3.46	153.4	161.2	157.6	4078	3991	667	649.2	682.7	61.77	115.9	248
09:35:02	44	1055	29	3.46	153.5	161.4	157.6	4195	4107	667.3	649.7	683.5	61.02	117.1	247
09:40:02	45	1054	28	3.46	153.7	161.3	157.8	4069	3984	668.1	650.5	683.1	61.04	113	246.7
09:44:59	46	1060	28	3.46	153.6	161.2	157.6	4067	3982	667.2	650	682.9	59.39	113.9	248
09:49:59	47	1066	26	3.46	153.3	161	157.4	4231	4147	666.4	648.8	681.9	60.72	114.3	249.5
09:54:59	48	1066	25	3.46	153.2	160.8	157.5	4290	4207	666.7	648.5	681.1	63.25	113.1	249.3
09:59:59	49	1083	24	3.47	153	160.6	157.1	4207	4124	665.1	647.5	680.4	60.89	114	253.3
10:04:59	50	1096	24	3.46	152.8	160.6	156.9	4322	4233	664.2	646.7	680.4	60.24	116.3	256.5
10:09:59	51	1098	22	3.46	152.6	160.3	156.6	4281	4191	663	645.9	679.2	59.18	115.4	256.8
10:14:59	52	1099	23	3.47	152.4	160	156.5	4213	4122	662.5	645	677.9	61	114.2	257.1
10:19:59	53	1099	21	3.47	152.6	160.3	156.9	4190	4095	664.2	645.8	679.1	63.69	115.6	257.3
10:24:59	54	1102	18	3.47	152.3	159.8	156.5	4058	3969	662.4	644.4	676.6	62.35	111.5	257.8
10:29:59	55	1101	23	3.47	152.2	159.8	156.4	4239	4151	662	644.1	676.6	62.04	112.9	257.7
10:34:59	56	1106	31	3.46	153.2	161.4	157.7	4241	4155	667.6	648.4	683.7	66.24	122.1	258.9
10:39:59	57	1108	27	3.46	153.8	162.5	158.4	4173	4087	670.6	651	688.3	68.06	129.2	259.2
10:44:59	58	1110	30	3.46	153.7	162.2	158.1	4255	4167	669.3	650.6	687.3	64.91	127.2	259.8
10:49:59	59	1108	32	3.45	154.5	163.2	159.1	4301	4211	673.6	654.1	691.5	67.58	129.1	259.4

	#	DNI [W/m²]	Fan Speed [Hz]	HTF Flow [kg/s]	Temp Receiver In [C]	Temp Receiver Out [C]	Temp Radiator In [C]	Pressure Receiver Out [kPa]	Pressure Receiver In [kPa]	Enthalpy Radiator In [kJ/kg]	Enthalpy Receiver Out [kJ/kg]	Enthalpy Receiver In [kJ/kg]	Heat Radiator kWt	Heat Receiver kWt	Power Solar kW
10:54:59	60	1107	32	3.45	154.4	162.9	159	4232	4145	673.4	653.6	690.3	68.48	126.6	259
10:59:59	61	1106	32	3.45	154.3	162.8	159	4267	4177	673.3	653.2	689.9	69.36	126.7	258.9
11:04:59	62	1098	30	3.45	154.5	162.8	159	4150	4057	673.4	654	689.7	66.99	123.1	257
11:09:59	63	1110	28	3.46	154.1	162.6	159	4108	4017	673.2	652.2	688.7	72.55	126.3	259.7
11:14:59	64	1102	29	3.46	153.6	162.2	158.6	4254	4165	671.5	650.2	687.1	73.72	127.9	257.8
11:19:59	65	1108	27	3.46	153.8	162.6	159	4306	4218	673.4	651	689.1	77.32	131.7	259.2
11:24:59	66	1111	29	3.46	153.7	162.6	159	4263	4175	673.4	650.6	689	78.81	133	259.9
11:29:59	67	1109	30	3.46	154.1	163.1	159.3	4209	4119	674.7	652.3	691	77.49	134	259.6
11:34:59	68	1089	32	3.46	154.2	163	159.2	4058	3964	674.2	652.6	690.4	74.65	130.8	254.8
11:39:59	69	1098	32	3.46	154.3	163	159.1	4098	4002	673.9	653.1	690.6	71.95	129.9	257
11:44:59	70	1100	30	3.46	154	162.7	159.1	4150	4057	673.7	651.8	689.5	75.69	130.5	257.5
11:49:59	71	1095	32	3.45	154.2	163.1	159.4	4282	4191	675.2	652.8	691.2	77.56	132.5	256.3
11:54:59	72	1095	35	3.46	154.7	164.1	160.2	4255	4161	678.4	654.9	695.6	81.4	140.8	256.2
11:59:59	73	1089	34	3.45	155.1	164.6	160.5	4081	3986	679.8	656.5	697.6	80.45	141.6	254.9
12:04:59	74	1077	35	3.46	154.9	164	160.1	4071	3977	678	655.6	694.8	77.23	135.4	251.9
12:09:59	75	1077	30	3.46	154.4	163	159.4	4097	4005	675	653.5	690.6	74.51	128.4	252.1
12:14:59	76	1070	31	3.46	154.4	163	159.3	4053	3960	674.5	653.5	690.7	72.87	128.9	250.3
12:19:59	77	1059	28	3.46	153.9	162.3	158.7	4084	3992	672.1	651.3	687.5	71.95	125.1	247.7
12:24:59	78	1048	29	3.46	153.9	162.1	158.6	4109	4016	671.6	651.4	686.9	70	122.9	245.3
12:29:59	79	1043	27	3.46	153.8	161.9	158.4	4051	3956	670.7	650.9	685.6	68.65	120.1	244.1
12:34:59	80	1052	30	3.46	153.8	161.9	158.2	4061	3966	669.7	650.9	685.7	65.21	120.3	246.3
12:39:59	81	1052	30	3.46	154.2	162.3	158.8	4186	4088	672.5	652.7	687.6	68.5	120.6	246.1
12:44:59	82	1026	30	3.47	153.8	161.8	158.3	4177	4085	670.5	651	685.4	67.79	119.4	240.1
12:49:59	83	1040	30	3.46	154	162.1	158.8	4328	4232	672.4	651.9	686.9	71.03	121.2	243.2
12:54:59	84	1045	31	3.46	154.3	162.5	159.1	4217	4115	673.6	653.1	688.4	70.74	122.1	244.6
12:59:59	85	1032	29	3.46	154.2	162.1	158.7	4075	3974	672	652.6	686.8	67	118.4	241.5
13:04:59	86	1036	32	3.46	154.2	162.1	158.6	4136	4035	671.7	652.7	686.5	65.81	117.2	242.4
13:09:59	87	1039	31	3.46	154.4	161.7	158.8	4088	3987	672.6	653.5	685.1	66.11	109.4	243.2
13:14:59	88	1043	29	3.46	153.9	161.2	158.4	4073	3976	670.6	651.3	682.7	66.55	108.6	244
13:19:59	89	1038	28	3.46	153.6	160.9	158	4057	3957	669.1	650	681.5	65.94	109	242.8

#		DNI [W/m ²]	Fan Speed [Hz]	HTF Flow [kg/s]	Temp Receiver In [C]	Temp Receiver Out [C]	Temp Radiator In [C]	Pressure Receiver Out [kPa]	Pressure Receiver In [kPa]	Enthalpy Radiator In [kJ/kg]	Enthalpy Receiver Out [kJ/kg]	Enthalpy Receiver In [kJ/kg]	Heat Radiator kWt	Heat Receiver kWt	Power Solar kW
13:24:59	90	1046	27	3.47	153.4	160.8	157.6	4105	4006	667.4	649.2	680.9	63.27	109.9	244.7
13:29:59	91	1045	27	3.46	153.3	160.8	157.8	4095	3995	668.1	648.8	681	66.82	111.6	244.6
13:34:59	92	1043	25	3.46	153.3	160.6	157.6	4055	3953	667.2	648.7	680.2	63.83	108.7	244
13:39:59	93	1048	24	3.46	153.2	160.2	157.2	4048	3945	665.4	648.3	678.4	59.19	104.1	245.2
13:44:59	94	1042	26	3.47	152.8	159.9	156.7	4241	4135	663.5	646.7	677.2	58.43	106	243.7
13:49:59	95	1036	25	3.47	153	160.1	156.9	4072	3964	664.2	647.5	678.1	58.14	106.4	242.5
13:54:59	96	1035	23	3.47	152.8	159.8	156.6	4147	4039	663.1	646.6	676.7	57.23	104.5	242.2
13:59:59	97	1032	24	3.47	152.6	159.5	156.4	4251	4146	662.2	645.8	675.7	56.93	103.6	241.5
14:04:59	98	1031	25	3.47	152.8	159.9	156.8	4266	4160	663.7	646.7	677.4	58.88	106.6	241.3
14:09:59	99	1018	23	3.47	152.9	159.9	156.7	4074	3967	663.4	647	677.1	56.79	104.5	238.3
14:14:59	100	1020	23	3.47	152.6	159.1	156.1	4082	3972	660.8	645.7	673.8	52.28	97.4	238.7
14:19:59	101	1011	22	3.47	152.3	158.4	155.7	4169	4059	659.2	644.5	670.6	51.07	90.63	236.7
14:24:59	102	999.6	27	3.46	153.1	159.7	156.7	4313	4202	663.4	648	676.5	53.33	98.33	233.9
14:29:59	103	986.8	29	3.46	153.6	160.7	157.5	4294	4185	667.1	650.2	680.6	58.58	105.3	230.9
14:34:59	104	989.3	28	3.46	153.6	161	157.8	4285	4177	668.1	650.2	681.9	62.17	109.8	231.5
14:39:59	105	979.5	28	3.46	153.6	161.3	157.9	4269	4163	668.5	650.2	683.5	63.37	115.4	229.2
14:44:59	106	962.5	29	3.46	153.8	161.6	158.2	4322	4219	670.1	651.1	684.8	65.93	116.7	225.2
14:49:59	107	956.4	31	3.46	153.9	161.9	158.5	4359	4250	671.2	651.5	686	68.16	119.5	223.8
14:54:59	108	952.7	31	3.46	154.2	162.1	158.6	4221	4111	671.7	652.7	687	65.63	118.5	222.9
14:59:59	109	935.6	30	3.46	154.1	161.8	158.6	4105	3996	671.5	652.2	685.2	66.83	114.3	218.9
15:04:59	110	930	26	3.46	153.7	161.4	158.2	4060	3958	669.7	650.5	683.6	66.38	114.7	217.6
15:09:58	111	905.8	28	3.46	153.3	161.1	157.8	4272	4168	668.1	648.9	682.4	66.65	115.9	211.9
15:14:58	112	898.4	30	3.46	153.7	161.6	158.2	4195	4089	669.9	650.5	684.5	67.12	117.4	210.2
15:19:58	113	891.3	26	3.46	153.7	161.4	158.1	4071	3968	669.3	650.5	683.8	65.19	115.2	208.6
15:24:58	114	884.2	27	3.47	153.1	160.9	157.5	4118	4014	666.8	647.9	681.4	65.5	116.2	206.9
15:29:58	115	875.6	26	3.47	153.3	161	157.6	4100	3995	667.2	648.8	681.8	63.85	114.7	204.9
15:34:58	116	864.3	23	3.46	153.1	160.6	157	4064	3957	664.7	647.9	680.2	58.28	111.8	202.3
15:39:58	117	840.1	21	3.46	152.4	159.6	156.1	4092	3989	660.9	644.9	675.7	55.27	106.6	196.6
15:44:58	118	839.3	21	3.47	152.4	159.7	156.4	4095	3993	661.9	644.9	676.1	59.18	108.4	196.4
15:49:58	119	820.4	18	3.47	152	159.1	156	4055	3956	660.3	643.1	673.5	59.62	105.5	192

	#	DNI [W/m²]	Fan Speed [Hz]	HTF Flow [kg/s]	Temp Receiver In [C]	Temp Receiver Out [C]	Temp Radiator In [C]	Pressure Receiver Out [kPa]	Pressure Receiver In [kPa]	Enthalpy Radiator In [kJ/kg]	Enthalpy Receiver Out [kJ/kg]	Enthalpy Receiver In [kJ/kg]	Heat Radiator kWt	Heat Receiver kWt	Power Solar kW
15:54:58	120	812.5	19	3.47	151.6	158.5	155.5	4102	4002	658.1	641.4	671.1	57.66	102.8	190.1
15:59:58	121	802.7	17	3.47	151.5	158.2	155.2	4065	3964	656.8	641	669.7	54.81	99.76	187.8
16:04:58	122	786.1	16	3.48	151.3	157.9	154.8	4091	3986	655.1	640.1	668.3	51.95	98.07	184
16:09:58	123	512	12	3.48	150.7	156.8	153.9	4118	4018	651.2	637.6	663.8	47.44	91.13	119.8
16:14:58	124	663.4	13	3.48	150.5	156.8	153.7	4249	4148	650.3	636.8	663.8	47.13	94.11	155.2
16:19:58	125	726.8	11	3.48	150.5	156.6	153.7	4064	3966	650.4	636.7	663	47.59	91.58	170.1
16:24:58	126	708.9	11	3.48	150.3	156.3	153.5	4167	4071	649.6	635.9	661.7	47.58	89.76	165.9
16:29:58	127	696.8	12	3.48	150.4	156.3	153.6	4149	4052	650.1	636.3	661.7	47.89	88.26	163.1
16:34:58	128	677.8	12	3.48	150.2	156.1	153.2	4209	4111	648.5	635.5	661	45.18	88.69	158.6
16:39:58	129	660.5	0	3.48	150.2	155.9	153.4	4138	4039	648.9	635.4	659.9	46.98	85.09	154.6
16:44:58	130	641.3	13	3.48	150.1	155.8	153.1	4213	4109	647.7	635.1	659.5	44.11	84.92	150.1
16:49:58	131	619	0	3.48	150.1	155.7	153	4168	4064	647.2	635	659	42.46	83.27	144.8
16:54:58	132	585	10	3.48	149.8	155.4	152.5	4225	4123	645.4	633.8	658	40.36	84.31	136.9
16:59:58	133	559.8	0	3.49	149.9	155.4	152.4	4215	4113	644.9	634.2	657.8	37.17	82.45	131
17:04:58	134	535.4	0	3.48	149.8	155.3	152.4	4162	4062	644.6	633.7	657.4	37.97	82.22	125.3
17:09:58	135	508.1	0	3.49	149.5	154.6	151.7	4172	4073	642	632.5	654.4	33.42	76.42	118.9
17:14:58	136	482.1	0	3.49	149.6	154.5	151.6	4269	4171	641.7	632.9	653.9	30.41	73.11	112.8
17:19:58	137	455.5	0	3.49	149.6	154.6	151.9	4078	3982	642.6	632.8	654.2	34.03	74.63	106.6
17:24:58	138	432.1	0	3.49	149.2	154	151.3	4065	3973	640	631.1	651.5	31.17	71.16	101.1
17:29:58	139	404.8	0	3.49	148.2	152.9	150.3	4083	3991	635.7	626.8	647.1	31.01	70.67	94.73
17:34:58	140	378.1	0	3.5	147.7	152.4	149.6	4067	3978	632.7	624.7	644.6	28.08	69.8	88.47
17:39:58	141	352.9	0	3.5	146.8	151.5	148.8	4078	3986	629.4	620.8	641	30.17	70.66	82.58
17:44:58	142	309.5	0	3.51	145.2	149.9	147.1	4073	3984	621.9	613.9	634	27.97	70.35	72.42
17:49:58	143	260	0	3.5	144	148.7	145.7	4085	3994	616.2	608.8	628.7	25.91	69.65	60.84
17:54:58	144	209	0	3.51	142.9	147.3	144.5	4096	4007	610.9	604.1	622.8	24.02	65.59	48.89
17:59:58	145	159.3	0	3.51	141.2	145.4	143	4084	3994	604.3	596.8	614.9	26.25	63.57	37.28
18:04:58	146	101.6	0	3.52	138.7	142.9	140.5	4073	3986	593.5	586.1	604.2	26.15	63.67	23.77
18:09:58	147	48.09	0	3.52	136.5	140.9	138.2	4101	4016	584.1	576.7	595.3	25.97	65.26	11.25
18:14:58	148	0	0	0	134.4	138.6	136.2	4098	4014	575.2	567.8	585.6	0	0	0
18:19:58	149	0	0	0	132.3	136.4	134	4099	4016	565.9	558.8	576.2	0	0	0

	#	DNI [W/m ²]	Fan Speed [Hz]	HTF Flow [kg/s]	Temp Receiver In [C]	Temp Receiver Out [C]	Temp Radiator In [C]	Pressure Receiver Out [kPa]	Pressure Receiver In [kPa]	Enthalpy Radiator In [kJ/kg]	Enthalpy Receiver Out [kJ/kg]	Enthalpy Receiver In [kJ/kg]	Heat Radiator kWt	Heat Receiver kWt	Power Solar kW
18:24:58	150	0	0	0	129.9	133.9	131.5	4097	4018	555.5	548.6	565.7	0	0	0
18:29:58	151	0	0	0	128	131.9	129.7	4062	3983	547.5	540.5	557.1	0	0	0
18:34:58	152	0	0	0	125.8	129.8	127.4	4088	4010	538	531.1	548.1	0	0	0
18:39:58	153	0	0	0	123.7	127.6	125.6	4053	3976	530.2	522.2	538.7	0	0	0
18:44:58	154	0	0	0	121.9	125.7	123.6	4104	4026	521.8	514.6	530.5	0	0	0
18:49:58	155	0	0	0	120.1	123.8	121.8	4074	3997	514	506.9	522.6	0	0	0
18:54:58	156	0	0	0	118.4	122	120.1	4074	3999	506.7	499.7	514.8	0	0	0
18:59:58	157	0	0	0	116.8	120.2	118.2	4047	3972	498.9	492.9	507.3	0	0	0
19:04:58	158	0	0	0	114.9	118.3	116.5	4046	3973	491.6	484.9	499.2	0	0	0
19:09:57	159	0	0	0	113.2	116.5	114.8	4062	3988	484.4	477.7	491.8	0	0	0
19:14:57	160	0	0	0	111.6	114.9	113.1	4066	3993	477.3	471	484.7	0	0	0
19:19:57	161	0	0	0	110	113.3	111.6	4058	3985	470.7	464.2	477.9	0	0	0
19:24:57	162	0	0	0	108.5	111.8	110	4085	4010	464	457.9	471.8	0	0	0
19:29:57	163	0	0	0	107.2	110.4	108.6	4068	3994	458.1	452.4	465.8	0	0	0
19:34:57	164	0	0	0	105.7	108.8	107.2	4074	4000	452.2	446.1	459.1	0	0	0
19:39:57	165	0	0	0	104.4	107.4	105.8	4056	3982	446.5	440.6	452.9	0	0	0
19:44:57	166	0	0	0	103.1	106.1	104.6	4086	4011	441.2	435.1	447.6	0	0	0
19:49:57	167	0	0	0	102	104.8	103.3	4085	4013	435.7	430.5	442.3	0	0	0
19:54:57	168	0	0	0	100.8	103.5	102	4051	3979	430.4	425.4	436.7	0	0	0
19:59:57	169	0	0	0	99.57	102.2	100.8	4073	4000	425.4	420.2	431	0	0	0
20:04:57	170	0	0	0	98.28	100.7	99.54	4057	3987	420	414.8	425.1	0	0	0
20:09:57	171	0	0	0	97.1	99.45	98.31	4057	3987	414.9	409.8	419.7	0	0	0
20:14:57	172	0	0	0	95.9	98.31	97.18	4084	4017	410.1	404.8	414.9	0	0	0
20:19:57	173	0	0	0	94.77	97.08	96.02	4057	3989	405.2	400	409.7	0	0	0
20:24:57	174	0	0	0	93.57	95.84	94.81	4062	3994	400.2	395	404.5	0	0	0
20:29:57	175	0	0	0	92.24	94.59	93.51	4058	3990	394.7	389.4	399.2	0	0	0
20:34:57	176	0	0	0	91.22	93.53	92.55	4054	3986	390.7	385.1	394.8	0	0	0
20:39:57	177	0	0	0	90.32	92.56	91.68	4051	3982	387	381.4	390.7	0	0	0
20:44:57	178	0	0	0	89.55	91.9	90.82	4045	3975	383.4	378.1	387.9	0	0	0
20:49:57	179	0	0	0	88.74	91.1	89.88	4050	3982	379.5	374.7	384.6	0	0	0

	#	DNI [W/m^2]	Fan Speed [Hz]	HTF Flow [kg/s]	Temp Receiver In [C]	Temp Receiver Out [C]	Temp Radiator In [C]	Pressure Receiver Out [kPa]	Pressure Receiver In [kPa]	Enthalpy Radiator In [kJ/kg]	Enthalpy Receiver Out [kJ/kg]	Enthalpy Receiver In [kJ/kg]	Heat Radiator kWt	Heat Receiver kWt	Power Solar kW
20:54:57	180	0	0	0	87.82	90.14	88.89	4039	3973	375.3	370.9	380.5	0	0	0
20:59:57	181	0	0	0	86.85	89.1	87.9	4062	3995	371.2	366.8	376.2	0	0	0

9.2 Appendix B: Typical day solar resource data

Time	Very Cloudy Day DNI [W/m^2]	Slightly Cloudy Day DNI [W/m^2]	Cloudless Day DNI [W/m^2]	Mostly Cloudy Day DNI [W/m^2]
23:59:53	0.0	0.0	0.0	0.0
00:04:53	0.0	0.0	0.0	0.0
00:09:53	0.0	0.0	0.0	0.0
00:14:53	0.0	0.0	0.0	0.0
00:19:53	0.0	0.0	0.0	0.0
00:24:53	0.0	0.0	0.0	0.0
00:29:53	0.0	0.0	0.0	0.0
00:34:53	0.0	0.0	0.0	0.0
00:39:53	0.0	0.0	0.0	0.0
00:44:53	0.0	0.0	0.0	0.0
00:49:53	0.0	0.0	0.0	0.0
00:54:53	0.0	0.0	0.0	0.0
00:59:53	0.0	0.0	0.0	0.0
01:04:53	0.0	0.0	0.0	0.0
01:09:53	0.0	0.0	0.0	0.0
01:14:53	0.0	0.0	0.0	0.0
01:19:53	0.0	0.0	0.0	0.0
01:24:53	0.0	0.0	0.0	0.0
01:29:53	0.0	0.0	0.0	0.0
01:34:53	0.0	0.0	0.0	0.0
01:39:53	0.0	0.0	0.0	0.0
01:44:53	0.0	0.0	0.0	0.0
01:49:53	0.0	0.0	0.0	0.0
01:54:53	0.0	0.0	0.0	0.0
01:59:53	0.0	0.0	0.0	0.0
02:04:52	0.0	0.0	0.0	0.0
02:09:52	0.0	0.0	0.0	0.0
02:14:52	0.0	0.0	0.0	0.0
02:19:52	0.0	0.0	0.0	0.0
02:24:52	0.0	0.0	0.0	0.0
02:29:52	0.0	0.0	0.0	0.0
02:34:52	0.0	0.0	0.0	0.0
02:39:52	0.0	0.0	0.0	0.0
02:44:52	0.0	0.0	0.0	0.0
02:49:52	0.0	0.0	0.0	0.0
02:54:52	0.0	0.0	0.0	0.0
02:59:52	0.0	0.0	0.0	0.0
03:04:52	0.0	0.0	0.0	0.0
03:09:52	0.0	0.0	0.0	0.0
03:14:52	0.0	0.0	0.0	0.0
03:19:52	0.0	0.0	0.0	0.0
03:24:52	0.0	0.0	0.0	0.0
03:29:52	0.0	0.0	0.0	0.0
03:34:52	0.0	0.0	0.0	0.0
03:39:52	0.0	0.0	0.0	0.0
03:44:52	0.0	0.0	0.0	0.0

Time	Very Cloudy Day DNI [W/m^2]	Slightly Cloudy Day DNI [W/m^2]	Cloudless Day DNI [W/m^2]	Mostly Cloudy Day DNI [W/m^2]
03:49:52	0.0	0.0	0.0	0.0
03:54:52	0.0	0.0	0.0	0.0
03:59:52	0.0	0.0	0.0	0.0
04:04:52	0.0	0.0	0.0	0.0
04:09:52	0.0	0.0	0.0	0.0
04:14:52	0.0	0.0	0.0	0.0
04:19:52	0.0	0.0	0.0	0.0
04:24:52	0.0	0.0	0.0	0.0
04:29:52	0.0	0.0	0.0	0.0
04:34:52	0.0	0.0	0.0	0.0
04:39:52	0.0	0.0	0.0	0.0
04:44:52	0.0	0.0	0.0	0.0
04:49:52	0.0	0.0	0.0	0.0
04:54:52	0.0	0.0	0.0	0.0
04:59:52	0.0	0.0	0.0	0.0
05:04:52	0.0	0.0	0.0	0.0
05:09:52	0.0	0.0	0.0	0.0
05:14:52	0.0	0.0	0.0	0.0
05:19:52	0.0	0.0	0.0	0.0
05:24:52	0.0	0.0	0.0	0.0
05:29:52	0.0	0.0	0.0	0.0
05:34:52	0.0	0.0	0.0	0.0
05:39:52	0.0	0.0	0.0	0.0
05:44:52	0.0	0.0	0.0	0.0
05:49:52	0.0	0.0	70.0	0.0
05:54:52	0.0	0.0	150.0	0.0
05:59:52	0.0	0.0	315.0	0.0
06:04:52	2.2	339.9	351.0	15.9
06:09:52	2.1	462.2	432.0	12.2
06:14:52	2.5	514.5	465.0	2.2
06:19:52	5.7	565.1	512.0	2.6
06:26:17	63.9	606.8	601.0	2.5
06:31:13	178.0	644.3	644.0	3.0
06:36:13	605.6	678.0	680.0	3.1
06:41:13	634.0	712.2	713.0	3.4
06:46:13	652.7	740.0	735.0	2.6
06:51:13	641.4	761.9	765.0	2.5
06:56:13	131.2	786.6	790.0	2.3
07:01:03	171.6	802.6	801.0	2.0
07:06:03	315.9	819.9	820.0	2.6
07:11:03	667.3	839.7	821.0	2.7
07:16:03	779.8	858.2	835.0	3.5
07:21:03	638.0	873.7	865.0	11.2
07:26:03	743.0	889.2	886.0	21.4
07:31:03	845.2	905.0	898.0	22.1
07:36:03	865.9	918.5	915.0	14.2

Time	Very Cloudy Day DNI [W/m^2]	Slightly Cloudy Day DNI [W/m^2]	Cloudless Day DNI [W/m^2]	Mostly Cloudy Day DNI [W/m^2]
07:41:03	824.1	932.0	931.0	4.0
07:46:03	637.3	944.8	945.0	2.8
07:51:03	593.5	957.1	960.0	3.0
07:56:03	895.3	964.0	964.0	3.3
08:01:03	719.2	971.8	973.0	3.0
08:06:03	837.2	975.3	977.0	2.9
08:11:03	904.9	980.2	981.0	2.4
08:16:03	885.8	987.8	990.0	2.8
08:21:03	811.8	999.4	1001.0	2.9
08:26:03	730.7	1005.7	1006.0	2.5
08:31:03	301.7	1016.1	1018.0	2.4
08:36:03	81.6	1024.1	1030.0	2.8
08:41:03	368.0	1030.8	1028.0	2.6
08:46:03	69.8	1031.4	1035.0	3.1
08:51:03	91.7	1043.7	1037.0	3.4
08:56:03	87.9	1049.3	1041.0	4.5
09:01:03	15.4	1053.2	1048.0	5.5
09:06:03	0.0	1059.2	1053.0	16.5
09:11:03	0.0	1063.7	1065.0	22.9
09:16:03	0.0	1069.6	1071.0	9.4
09:21:03	0.0	1072.7	1074.0	6.9
09:26:03	0.0	1073.4	1075.0	16.0
09:31:03	14.0	1074.1	1078.0	9.1
09:36:03	0.0	1073.1	1081.0	9.3
09:41:51	0.0	1073.3	1080.0	7.8
09:46:51	0.0	1070.2	1083.0	10.1
09:51:51	129.9	1078.8	1081.0	4.5
09:56:51	390.8	1093.5	1088.0	4.0
10:01:43	0.0	1089.8	1091.0	3.7
10:06:43	0.0	1097.6	1098.0	4.0
10:11:43	0.0	1095.8	1101.0	16.1
10:16:43	0.0	1099.7	1100.0	96.4
10:21:43	0.0	1065.3	1102.0	6.0
10:26:43	0.0	1076.5	1104.0	4.5
10:31:33	0.0	1017.1	1102.0	4.5
10:36:33	0.0	902.2	1099.0	7.6
10:41:33	0.0	1077.9	1097.0	11.0
10:46:33	161.1	1087.5	1098.8	12.3
10:51:33	341.2	1097.6	1092.3	9.8
10:56:33	95.4	1095.6	1101.4	5.5
11:01:23	105.0	1109.3	1086.7	4.6
11:06:23	90.9	1100.3	1098.4	3.9
11:11:23	344.5	345.0	1100.2	3.9
11:16:23	741.6	124.0	1110.0	3.9
11:21:23	193.4	0.0	1115.0	3.6
11:26:23	1054.1	0.0	1114.0	3.9

Time	Very Cloudy Day DNI [W/m^2]	Slightly Cloudy Day DNI [W/m^2]	Cloudless Day DNI [W/m^2]	Mostly Cloudy Day DNI [W/m^2]
11:31:13	667.1	0.0	1117.0	3.5
11:36:13	705.4	0.0	1118.0	4.2
11:41:13	913.5	0.0	1116.0	4.3
11:46:13	866.5	0.0	1110.0	3.9
11:51:13	287.2	0.0	1109.0	3.9
11:56:13	470.4	0.0	1112.0	4.5
12:01:03	881.4	0.0	1115.0	4.3
12:06:03	302.6	15.0	1117.0	4.2
12:11:03	954.5	58.0	1117.0	3.9
12:16:03	487.1	375.0	1113.0	3.9
12:21:03	80.5	752.0	1114.0	3.4
12:26:03	900.1	974.0	1115.0	4.1
12:31:03	984.3	432.0	1116.5	5.0
12:36:03	1029.0	124.0	1112.3	5.1
12:41:03	788.5	0.0	1130.0	5.1
12:46:03	136.8	0.0	1125.0	5.0
12:51:03	55.8	0.0	1124.0	5.0
12:56:03	346.9	0.0	1120.0	5.1
13:01:03	878.6	0.0	1121.0	5.3
13:06:03	68.8	0.0	1115.0	6.5
13:11:03	708.9	0.0	1104.9	7.6
13:16:03	288.1	0.0	1103.4	16.6
13:21:03	461.0	0.0	1104.6	20.4
13:26:03	635.5	0.0	1105.9	14.9
13:31:03	601.8	0.0	1112.0	9.7
13:36:03	135.4	0.0	1100.6	6.1
13:41:03	525.9	0.0	1089.9	5.6
13:46:03	173.4	0.0	1096.4	6.3
13:51:03	386.8	1101.7	1092.4	5.1
13:56:03	1010.5	1093.0	1091.5	5.1
14:01:03	611.9	1089.3	1091.1	4.9
14:06:03	881.1	1095.1	1104.2	4.6
14:11:03	749.0	1083.9	1101.0	3.9
14:16:03	850.0	1086.7	1091.0	3.9
14:21:03	1038.0	1093.2	1095.3	4.1
14:26:03	176.6	1099.2	1092.6	4.0
14:31:03	763.4	1112.2	1092.4	4.0
14:36:03	849.0	1105.0	1085.2	3.6
14:41:03	8.4	1097.5	1076.3	3.2
14:46:03	0.0	1086.8	1068.1	3.2
14:51:03	0.0	1084.7	1060.9	3.0
14:56:03	0.0	1075.7	1054.7	3.0
15:01:03	0.0	1075.2	1050.0	2.7
15:06:03	0.0	1080.9	1048.0	3.5
15:11:03	0.0	1081.5	1044.5	2.9
15:16:03	0.0	1066.1	1035.0	3.0

Time	Very Cloudy Day DNI [W/m ²]	Slightly Cloudy Day DNI [W/m ²]	Cloudless Day DNI [W/m ²]	Mostly Cloudy Day DNI [W/m ²]
15:21:03	0.0	1064.3	1029.4	2.8
15:26:03	0.0	1052.2	1019.3	3.5
15:31:03	0.0	1019.6	1013.8	3.4
15:36:03	0.0	953.0	980.0	3.6
15:41:03	0.0	854.0	970.0	3.4
15:46:03	0.0	312.0	965.0	3.6
15:51:03	0.0	150.0	956.7	3.7
15:56:03	0.0	0.0	949.2	3.2
16:01:03	0.0	0.0	946.7	3.5
16:06:03	0.0	0.0	940.8	3.7
16:11:03	0.0	0.0	941.1	3.3
16:16:03	0.0	0.0	936.6	3.2
16:21:03	0.0	0.0	920.0	3.4
16:26:03	0.0	0.0	910.0	3.2
16:31:03	0.0	0.0	874.4	3.0
16:36:03	0.0	0.0	842.0	3.2
16:41:03	0.0	0.0	803.1	3.4
16:46:03	0.0	0.0	770.0	3.1
16:51:03	0.0	0.0	764.0	2.7
16:56:03	0.0	316.0	761.0	2.7
17:01:03	0.0	199.6	724.0	3.0
17:06:03	734.5	578.2	719.0	2.8
17:11:03	686.1	569.8	709.0	3.0
17:16:03	670.9	181.3	701.0	2.6
17:21:03	639.1	534.3	698.0	2.7
17:26:03	609.7	753.9	680.4	2.6
17:30:03	556.1	742.6	644.2	2.8
17:35:03	483.0	719.1	608.1	3.0
17:40:03	483.7	680.5	572.0	2.9
17:45:03	469.5	639.3	535.9	2.6
17:50:03	440.4	592.7	499.8	2.8
17:55:02	419.2	556.0	485.0	2.8
18:00:02	395.0	522.0	466.8	5.9
18:05:02	358.4	481.6	370.0	3.2
18:10:02	305.1	447.1	365.0	2.6
18:15:02	252.4	409.8	352.6	2.4
18:20:02	200.6	371.8	317.2	2.6
18:25:02	166.1	317.1	281.8	2.5
18:30:02	142.7	254.8	246.3	2.5
18:35:02	118.6	200.0	201.2	2.6
18:40:02	33.8	154.7	192.3	2.4
18:45:02	21.1	115.5	139.0	2.4
18:50:02	21.7	49.8	98.5	2.4
18:55:02	4.0	4.0	67.0	2.4
19:00:02	3.0	5.1	36.5	2.4
19:05:02	0.0	4.1	5.3	2.3

Time	Very Cloudy Day DNI [W/m^2]	Slightly Cloudy Day DNI [W/m^2]	Cloudless Day DNI [W/m^2]	Mostly Cloudy Day DNI [W/m^2]
19:10:02	0.0	2.8	3.2	2.5
19:15:02	0.0	0.0	0.0	0.0
19:20:02	0.0	0.0	0.0	0.0
19:25:02	0.0	0.0	0.0	0.0
19:30:02	0.0	0.0	0.0	0.0
19:35:02	0.0	0.0	0.0	0.0
19:40:02	0.0	0.0	0.0	0.0
19:45:02	0.0	0.0	0.0	0.0
19:50:02	0.0	0.0	0.0	0.0
19:55:02	0.0	0.0	0.0	0.0
20:00:02	0.0	0.0	0.0	0.0
20:05:02	0.0	0.0	0.0	0.0
20:10:02	0.0	0.0	0.0	0.0
20:15:02	0.0	0.0	0.0	0.0
20:20:02	0.0	0.0	0.0	0.0
20:25:02	0.0	0.0	0.0	0.0
20:30:02	0.0	0.0	0.0	0.0
20:35:02	0.0	0.0	0.0	0.0
20:40:02	0.0	0.0	0.0	0.0
20:45:02	0.0	0.0	0.0	0.0
20:50:02	0.0	0.0	0.0	0.0
20:55:02	0.0	0.0	0.0	0.0
21:00:02	0.0	0.0	0.0	0.0
21:05:02	0.0	0.0	0.0	0.0
21:10:02	0.0	0.0	0.0	0.0
21:15:02	0.0	0.0	0.0	0.0
21:20:02	0.0	0.0	0.0	0.0
21:25:02	0.0	0.0	0.0	0.0
21:30:02	0.0	0.0	0.0	0.0
21:35:02	0.0	0.0	0.0	0.0
21:40:02	0.0	0.0	0.0	0.0
21:45:02	0.0	0.0	0.0	0.0
21:50:02	0.0	0.0	0.0	0.0
21:55:02	0.0	0.0	0.0	0.0
22:00:02	0.0	0.0	0.0	0.0
22:05:02	0.0	0.0	0.0	0.0
22:10:02	0.0	0.0	0.0	0.0
22:15:02	0.0	0.0	0.0	0.0
22:20:02	0.0	0.0	0.0	0.0
22:25:02	0.0	0.0	0.0	0.0
22:30:02	0.0	0.0	0.0	0.0
22:35:02	0.0	0.0	0.0	0.0
22:40:02	0.0	0.0	0.0	0.0
22:45:02	0.0	0.0	0.0	0.0
22:50:02	0.0	0.0	0.0	0.0
22:55:02	0.0	0.0	0.0	0.0

Time	Very Cloudy Day DNI [W/m ²]	Slightly Cloudy Day DNI [W/m ²]	Cloudless Day DNI [W/m ²]	Mostly Cloudy Day DNI [W/m ²]
23:00:02	0.0	0.0	0.0	0.0
23:05:02	0.0	0.0	0.0	0.0
23:10:02	0.0	0.0	0.0	0.0
23:15:02	0.0	0.0	0.0	0.0
23:20:02	0.0	0.0	0.0	0.0
23:25:02	0.0	0.0	0.0	0.0
23:30:02	0.0	0.0	0.0	0.0
23:35:02	0.0	0.0	0.0	0.0
23:40:02	0.0	0.0	0.0	0.0
23:45:02	0.0	0.0	0.0	0.0
23:50:02	0.0	0.0	0.0	0.0
23:55:02	0.0	0.0	0.0	0.0

9.3 Appendix C-1: Base-case parametric table data

Time	DNI	DNI Avr	MCR	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWt]	BFP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	FDF Power [kWt]	PAF Power [kWt]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWt]	Net Power [kWt]	n _O [%]	n _G [%]	n _N [%]	Heat_In [kWt]
04:04:52	0	0	60	0	0.00	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:05:52	0	0	60	0	0.00	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:14:52	0	0	60	0	0.00	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:14:52	0	0	60	0	0.00	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:24:52	0	0	60	0	0.00	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:24:52	0	0	60	0	0.00	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:34:52	0	0	60	0	0.00	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:34:52	0	0	60	0	0.00	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:44:52	0	0	60	0	0.00	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:44:52	0	0	60	0	0.00	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:54:52	0	0	60	0	0.00	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:54:52	0	0	62.61	0	0.00	151497	211235	174671	28.07	22.14	14.38	15.05	17.09	21.67	531492	12333	1013	6775	3660	1056	3075	64.7	502.9	22.32	525.1	114.3	1.41	14.78	40734	490758	37.74	45.4	41.93	1170453.3
05:04:52	0	0	65.24	0	0.00	157200	219134	181291	29.73	23.25	15.06	15.77	17.87	22.69	551492	13197	1088	6775	3789	1093	3183	66.98	520.6	23.11	543.6	118.3	1.46	14.61	42251	509241	37.83	45.52	42.03	1211652.8
05:08:52	0	0	67.91	0	0.00	162907	227044	187897	31.45	24.37	15.75	16.49	18.66	23.72	571492	14099	1088	6775	3918	1130	3291	69.25	538.2	23.89	562	122.4	1.51	14.37	43807	527685	37.91	45.62	42.12	1252780.6
05:19:52	0	0	73.32	0	0.00	174335	242892	201066	35.05	26.68	17.16	17.98	20.28	25.78	591492	15041	1125	6775	4046	1167	3399	71.52	555.8	24.67	580.4	126.4	1.559	14.05	45401	546091	37.99	45.72	42.21	1293780.4
05:24:52	0	0	76.08	0	0.00	180055	250833	207628	36.93	27.87	17.88	18.74	21.1	26.83	611492	16023	1162	6775	4174	1204	3507	73.78	573.4	25.45	598.8	130.4	1.608	13.66	47035	564457	38.06	45.81	42.29	1334715.1
05:29:52	0	0	78.87	0	0.00	185779	258784	214375	38.88	29.08	18.6	19.51	21.93	27.87	651492	17048	1237	6775	4429	1278	3721	78.29	608.5	27.01	635.4	138.3	1.707	12.63	50431	601061	38.19	46	42.44	1375568.4
05:34:52	0	0	81.7	0	0.00	191506	266747	220707	40.89	30.3	19.34	20.29	22.77	28.92	671492	19230	1275	6775	4557	1315	3828	80.54	626	27.91	653.7	142.3	1.756	11.99	52195	619297	38.25	46.09	42.5	1416340.8
05:39:52	0	0	84.56	0	0.00	197238	274722	227224	42.97	31.55	20.83	21.68	24.32	29.97	691492	20391	1312	6775	4884	1351	3935	82.79	643.4	28.56	671.9	146.3	1.805	11.25	54007	637485	38.31	46.17	42.57	1457035.7
05:44:52	0	0	87.46	0	0.00	202733	282708	233725	45.11	32.82	20.83	22.77	25.35	32.09	711492	21691	1350	6775	4810	1388	4041	85.03	660.9	29.34	690.1	150.2	1.854	10.41	57117	654375	38.29	46.25	42.54	1497634.6
05:49:52	0	0	90.39	0	0.00	208711	290705	240210	47.32	34.11	21.59	22.7	25.35	32.09	731492	22862	1387	6775	4937	1425	4147	87.27	680.8	30.11	708.3	154.2	1.902	9.471	59027	672465	38.38	46.34	42.6	1518672.7
05:54:52	0	0	93.37	0	0.00	214453	298717	246680	49.61	35.43	22.36	23.53	26.24	33.16	751492	24176	1425	6775	5063	1461	4254	89.5	695.6	30.88	726.4	158.1	1.951	8.422	60991	690501	38.34	46.41	42.65	1579072.7
06:04:52	0	0	96.39	0	0.00	220198	306740	253135	51.98	36.76	23.14	24.37	27.13	34.23	771492	25546	1462	6775	5190	1497	4360	91.73	712.9	31.65	744.5	162.1	2	7.259	63009	708483	38.43	46.49	42.7	1659403.7
06:09:52	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	26974	1507	6775	5315	1534	4465	93.96	730.2	32.41	762.5	166	2.048	5.975	65085	726407	38.46	46.57	42.74	1699663.6
06:14:52	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
06:19:52	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
06:26:17	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
06:31:13	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
06:36:13	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
06:41:13	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
06:46:13	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
06:51:13	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
06:56:13	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
07:01:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
07:06:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6																

Time	DNI	DNI Avr	Solar Field Power [kWt]	MCR [%]	HPH Bypass [kWm]	HPT [kWm]	IPT [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWw]	BPP Power [kWw]	CEP Power [kWw]	ACC Power [kWw]	IDF Power [kWw]	PDF Power [kWw]	PAF Power [kWw]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWw]	Net Power [kWw]	n _O [%]	n _G [%]	n _N [%]	Heat_In [kWt]
16:21:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
16:26:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
16:31:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
16:36:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
16:41:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
16:46:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
16:51:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
16:56:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
17:01:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
17:06:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
17:11:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
17:16:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
17:21:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
17:26:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
17:30:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
17:35:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
17:40:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
17:45:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
17:50:03	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
18:00:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
18:05:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
18:10:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
18:15:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
18:20:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
18:25:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
18:30:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
18:35:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
18:40:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
18:45:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
18:50:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
18:55:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
19:00:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
19:05:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
19:10:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
19:15:0																																		

Time	DNI	DNI Avr	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPH Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH6 Bleed [kg/s]	HPH5 Bleed [kg/s]	DST	LPH3 Bleed [kg/s]	LPH2 Bleed [kg/s]	LPH1 Bleed [kg/s]	Gross Power [kWt]	BFP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	FDF Power [kWt]	PAF Power [kWt]	m _{Coat} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWt]	Net Power [kWt]	n _O [%]	n _G [%]	n _N [%]	Heat In [kWt]	
20:25:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
20:30:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
20:35:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
20:40:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
20:45:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
20:50:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
20:55:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:00:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:05:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:10:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:15:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:20:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:25:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:30:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:35:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:40:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:45:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:50:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:55:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:00:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:05:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:10:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:15:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:20:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:25:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:30:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:35:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:40:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:45:02	0	0	100	0	0.00	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:50:02	0	0	96.93	0	0.00	221216	308161	254276	52.41	37	23.28	24.52	27.29	34.42	775033	25795	1469	6775	5212	1504	4378	92.12	716	31.78	747.7	162.8	2.008	7.041	63372	711661	38.43	46.51	42.7	1666537
22:55:02	0	0	93.9	0	0.00	215470	300137	247824	50.03	35.66	22.5	23.68	26.4	33.35	755033	24415	1431	6775	5086	1467	4272	89.9	698.7	31.01	729.6	158.8	1.96	8.225	61344	693689	38.39	46.43	42.66	1626218.5
23:00:02	0	0	90.92	0	0.00	209728	292124	241357	47.72	34.34	21.73	22.85	25.51	32.28	735033	23091	1394	6775	4959	1431	4166	87.66	681.3	30.24	711.5	154.9	1.911	9.294	59371	675662	38.35	46.35	42.61	1585839.2
23:05:02	0	0	87.97	0	0.00	203989	284123	234874	45.5	33.05	20.97	22.03	24.64	31.22	715033	21821	1356	6775	4833	1395	4060	85.43	663.9	29.47	693.3	150.9	1.862	10.25	57451	657582	38.3	46.27	42.55	1545370.7
23:10:02	0	0	85.07	0	0.00	198253	276135	228376	43.34	31.77	20.21	21.22	23.77	30.16	695033	20602	1319	6775	4706	1358	3953	83.19	646.5	28.7	675.1	147	1.813	11.11	54332	640701	38.32	46.19	42.58	1504838.6
23:15:02	0	0	82.2	0	0.00	192521	268158	221862	41.25	30.52	19.47	20.43	22.92	29.11	675033	19432	1281	6775	4579	1321														

9.4 Appendix C-2: Mostly cloudy day parametric table data

Time	DNI	DNI	Solar	HPH	HPT	IPT	LPT	HPH 6	DST	LPH 3	LPH 2	LPH 1	Gross	BFP	CEP	ACC	IDF	FDF	PAF	m _{Coal}	m _{Air}	m _{Ash}	m _{FG}	m _{CO2}	m _{SO2}	m _{Spray}	Aux	Net	n _O	n _G	n _N	Heat_in
	Avr	Avr	Field	ByPass	Power	Power	Power	Bleed	Bleed	Bleed	Bleed	Bleed	Power	Power	Power	Power	Power	Power	Power	[kg/s]	[kg/s]	[kg/s]	[kg/s]	[kg/s]	[kg/s]	[kg/s]	[kg/s]	[kg/s]	[%]	[%]	[%]	[kWt]
04:04:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:09:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:14:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:19:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:24:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:29:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:34:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:39:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:44:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:49:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:54:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:59:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
05:04:52	0.0	0.0	65.2	0.0	0.0	151497	211235	174671	28.07	22.14	14.38	15.05	17.09	21.67	1050	6775	3789	1093	3183	66.98	502.9	22.32	525.1	114.3	1.41	14.78	40734	490758	37.74	45.41	41.93	1170453.3
05:09:52	0.0	0.0	67.9	0.0	0.0	162907	227044	187897	31.45	24.37	15.75	16.49	18.66	23.72	1088	6775	3918	1130	3291	69.25	555.8	23.89	582	122.4	1.51	14.37	43807	527685	37.91	45.62	42.12	125760.6
05:14:52	0.0	0.0	70.6	0.0	0.0	168616	234963	194489	33.22	25.52	16.45	17.23	19.46	25.78	1125	6775	4046	1167	3399	71.52	580.4	24.67	580.4	126.4	1.559	14.05	45401	546091	37.99	45.72	42.21	1293780.4
05:19:52	0.0	0.0	73.3	0.0	0.0	174335	242892	201066	35.05	26.68	17.16	17.98	20.28	25.78	1162	6775	4174	1204	3507	73.78	573.4	25.45	598.8	130.4	1.608	13.66	47035	564457	38.06	45.81	42.29	1334715.1
05:24:52	0.0	0.0	76.1	0.0	0.0	180055	250833	207628	36.93	27.87	17.88	18.74	21.1	26.83	1162	6775	4302	1241	3614	76.04	591	26.23	617.1	134.4	1.658	13.19	48711	582781	38.13	45.91	42.37	1375588.4
05:29:52	0.0	0.0	78.9	0.0	0.0	185779	258784	214175	38.88	29.08	18.6	19.51	21.93	27.87	1237	6775	4429	1278	3721	78.29	608.5	27.01	635.4	138.3	1.707	12.63	50431	601061	38.19	46	42.44	1416340.8
05:34:52	0.0	0.0	81.7	0.0	0.0	191506	266747	220707	40.89	30.3	19.34	20.29	22.77	28.92	1275	6775	4557	1315	3828	80.54	626	27.79	653.7	142.3	1.756	11.99	52195	619297	38.25	46.09	42.5	1457035.7
05:39:52	0.0	0.0	84.6	0.0	0.0	197238	274722	227224	42.97	31.55	20.08	21.08	23.62	29.97	1312	6775	4684	1351	3935	82.79	643.4	28.56	671.9	146.3	1.805	11.25	54007	637485	38.31	46.17	42.57	1497654.6
05:44:52	0.0	0.0	87.5	0.0	0.0	202973	282708	233725	45.11	32.82	20.83	21.88	24.48	31.03	1350	6775	4810	1388	4041	85.03	660.9	29.34	690.1	150.2	1.854	10.41	57117	654375	38.29	46.25	42.54	1538199.8
05:49:52	0.0	0.0	90.4	0.0	0.0	208711	290706	240210	47.32	34.1	21.59	22.7	25.35	32.09	1387	6775	4937	1425	4147	87.27	678.2	30.11	708.3	154.2	1.902	9.471	59027	672465	38.34	46.34	42.6	1578672
05:54:52	0.0	0.0	93.4	0.0	0.0	214453	298717	246880	49.61	35.43	22.36	23.53	26.24	33.16	1425	6775	5063	1461	4254	89.5	695.6	30.88	726.4	158.1	1.951	8.422	60991	690501	38.38	46.41	42.65	1619072.7
05:59:52	0.0	0.0	96.4	0.0	0.0	220198	306740	253135	51.98	36.76	23.14	24.37	27.13	34.23	1462	6775	5190	1497	4360	91.73	712.9	31.65	744.5	162.1	2	7.259	63009	708483	38.43	46.49	42.7	1659403.7
06:04:52	15.9	4.0	99.4	325.4	0.9	225917	316233	259584	54.33	38.06	23.94	25.22	28.04	35.3	1500	6775	5315	1534	4465	93.94	730.1	32.41	762.4	166	2.048	5.965	65076	726416	38.47	46.57	42.74	1699438.4
06:09:52	12.2	7.0	100.0	576.1	1.6	226942	316233	260730	54.7	38.24	24.08	25.37	28.2	35.49	1507	6775	5336	1540	4483	94.33	733.1	32.54	765.6	166.7	2.056	5.716	65441	729590	38.48	46.59	42.76	1706392.7
06:14:52	2.2	7.6	100.0	621.4	1.8	226908	316236	260732	54.69	38.24	24.08	25.37	28.2	35.49	1507	6775	5336	1540	4483	94.33	733.1	32.54	765.6	166.7	2.056	5.716	65441	729590	38.48	46.59	42.76	1706392.7
06:19:52	2.6	8.2	100.0	674.9	1.9	226903	316239	260733	54.67	38.23	24.08	25.37	28.2	35.49	1507	6775	5336	1540	4483	94.33	733.2	32.55	765.7	166.7	2.056	5.722	65447	729585	38.48	46.59	42.75	1706393.4
06:24:52	2.5	4.9	100.0	401.5	1.1	226948	316223	260725	54.75	38.29	24.08	25.37	28.2	35.49	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706650.9
06:29:52	3.1	2.8	100.0	231.3	0.7	226943	316213	260720	54.8	38.32	24.08	25.37	28.2	35.49	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706650.9
06:34:52	3.4	3.0	100.0	247.0	0.7	226942	316213	260720	54.8	38.32	24.08	25.37	28.2	35.49	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706628.8
06:39:52	2.6	3.0	100.0	248.6	0.7	226943	316213	260720	54.8	38.32	24.08	25.37	28.2	35.49	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.59	42.75	1706627.9
06:44:52	2.3	2.7	100.0	221.8	0.6	226944	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706634.1
06:49:52	2.4	2.4	100.0	193.5	0.5	226947	316210	260719	54.81	38.33	24.08	25.37	28.2	35.49	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706662.5
06:54:52	2.6	2.4	100.0	193.9	0.5	226947	316210	260719	54.81	38.33	24.08	25.37	28.2	35.49	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706662.5
06:59:52	2.7	2.4	100.0	198.9	0.6	226947	316211	260719	54.81	38.33	24.08	25.37	28.2	35.49	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7								

Time	DNI	DNI Avr	MCR	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWt]	IPT Power [kWt]	LPT Power [kWt]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWt]	BFP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	FDF Power [kWt]	PAF [kWt]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWt]	Net Power [kWt]	n _O [%]	n _G [%]	n _N [%]	Heat _{In} [kWt]
08:11:03	2.4	2.9	100.0	236.7	0.7	226943	316213	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65432	729581	38.47	46.58	42.75	1706635.3
08:16:03	2.8	2.8	100.0	227.7	0.6	226944	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65432	729581	38.47	46.58	42.75	1706641.3
08:21:03	2.9	2.7	100.0	225.6	0.6	226944	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65432	729581	38.47	46.58	42.75	1706642.3
08:26:03	2.5	2.7	100.0	218.5	0.6	226944	316212	260720	54.81	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65432	729580	38.47	46.58	42.75	1706646.8
08:31:03	2.4	2.7	100.0	219.1	0.6	226944	316212	260720	54.81	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65432	729581	38.47	46.58	42.75	1706646.4
08:36:03	2.8	2.7	100.0	217.6	0.6	226944	316212	260720	54.81	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65432	729580	38.47	46.58	42.75	1706647.3
08:41:03	2.6	2.6	100.0	211.9	0.6	226945	316211	260719	54.81	38.32	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65433	729580	38.47	46.58	42.75	1706650.7
08:46:03	3.1	2.7	100.0	223.3	0.6	226944	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65432	729581	38.47	46.58	42.75	1706643.8
08:51:03	3.4	2.9	100.0	242.1	0.7	226942	316213	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65432	729581	38.47	46.58	42.75	1706631.9
08:56:03	4.5	3.4	100.0	278.0	0.8	226939	316215	260721	54.79	38.31	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.726	65431	729582	38.48	46.59	42.75	1706609.3
09:01:03	5.5	4.1	100.0	338.8	1.0	226934	316219	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.724	65449	729584	38.48	46.59	42.75	1706572.2
09:06:03	16.5	7.5	100.0	612.3	1.7	226909	316236	260731	54.69	38.25	24.08	25.37	28.2	35.49	795033	27218	1507	6775	5336	1540	4483	94.34	733.1	32.54	765.4	166.6	2.056	5.716	65442	729591	38.48	46.59	42.76	1706398.4
09:11:03	22.9	12.3	100.0	1013.0	2.9	226873	316260	260743	54.57	38.17	24.09	25.37	28.2	35.49	795033	27209	1507	6775	5336	1540	4482	94.31	733	32.54	765.4	166.6	2.056	5.704	65431	729602	38.49	46.6	42.76	1706145.4
09:16:03	9.4	13.6	100.0	1114.0	3.1	226864	316266	260746	54.55	38.15	24.09	25.37	28.2	35.48	795033	27206	1507	6775	5336	1540	4482	94.31	733	32.54	765.4	166.6	2.056	5.701	65428	729605	38.49	46.6	42.76	1706082.4
09:21:03	6.9	13.9	99.9	1143.0	3.2	226861	316268	260747	54.54	38.14	24.09	25.37	28.2	35.48	795033	27206	1507	6775	5335	1540	4482	94.31	733	32.54	765.4	166.6	2.056	5.7	65427	729605	38.49	46.6	42.77	1706063.7
09:26:03	16.0	13.8	100.0	1133.0	3.2	226862	316267	260747	54.54	38.14	24.09	25.37	28.2	35.48	795033	27206	1507	6775	5335	1540	4482	94.31	733	32.54	765.4	166.6	2.056	5.7	65428	729605	38.49	46.6	42.77	1706070.2
09:31:03	9.1	10.4	100.0	849.6	2.4	226887	316250	260738	54.62	38.2	24.09	25.37	28.2	35.49	795033	27213	1507	6775	5336	1540	4483	94.32	733	32.54	765.5	166.7	2.056	5.709	65435	729598	38.48	46.6	42.76	1706248.6
09:36:03	9.3	10.3	100.0	848.2	2.4	226888	316250	260738	54.62	38.2	24.09	25.37	28.2	35.49	795033	27213	1507	6775	5336	1540	4483	94.32	733	32.54	765.5	166.7	2.056	5.709	65435	729597	38.48	46.6	42.76	1706249.6
09:41:51	7.8	10.6	100.0	866.4	2.4	226886	316251	260739	54.62	38.2	24.09	25.37	28.2	35.49	795033	27212	1507	6775	5336	1540	4483	94.32	733	32.54	765.5	166.7	2.056	5.708	65435	729598	38.48	46.6	42.76	1706238.1
09:46:51	10.1	9.1	100.0	744.9	2.1	226897	316244	260735	54.65	38.22	24.08	25.37	28.2	35.49	795033	27215	1507	6775	5336	1540	4483	94.32	733.1	32.54	765.5	166.7	2.056	5.712	65438	729595	38.48	46.59	42.76	1706314.8
09:51:51	4.5	7.9	100.0	651.1	1.8	226905	316238	260732	54.68	38.24	24.08	25.37	28.2	35.49	795033	27217	1507	6775	5336	1540	4483	94.33	733.1	32.54	765.5	166.7	2.056	5.715	65441	729592	38.48	46.59	42.76	1706373.9
09:56:51	4.0	6.6	100.0	540.8	1.5	226915	316231	260729	54.71	38.26	24.08	25.37	28.2	35.49	795033	27220	1507	6775	5337	1540	4483	94.33	733.1	32.54	765.5	166.7	2.056	5.718	65444	729589	38.48	46.59	42.75	1706443.5
10:01:43	3.7	5.6	100.0	457.3	1.3	226923	316226	260727	54.74	38.28	24.08	25.37	28.2	35.49	795033	27222	1507	6775	5337	1540	4483	94.33	733.2	32.55	765.6	166.7	2.056	5.72	65446	729587	38.48	46.59	42.75	1706496.1
10:06:43	4.0	4.1	100.0	333.6	0.9	226934	316219	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.724	65449	729584	38.48	46.59	42.75	1706574.2
10:11:43	16.1	9.1	100.0	571.1	1.6	226934	316233	260730	54.7	38.25	24.08	25.37	28.2	35.49	795033	27219	1507	6775	5337	1540	4483	94.33	733.1	32.54	765.6	166.7	2.056	5.717	65443	729590	38.48	46.59	42.76	1706424.5
10:16:43	96.4	30.1	99.9	2468.0	7.0	226742	316348	260786	54.15	37.88	24.11	25.38	28.21	35.47	795033	27175	1508	6775	5333	1539	4480	94.26	732.6	32.52	765	166.6	2.055	5.661	65391	729641	38.51	46.62	42.79	1705228.5
10:21:43	6.0	30.6	99.9	2515.0	7.1	226737	316351	260788	54.14	37.87	24.11	25.38	28.21	35.47	795033	27174	1508	6775	5333	1539	4480	94.26	732.6	32.52	765	166.6	2.055	5.659	65390	729642	38.51	46.62	42.79	1705198.7
10:26:43	4.5	30.8	99.9	2525.0	7.1	226736	316351	260788	54.14	37.87	24.11	25.38	28.21	35.47	795033	27174	1508	6775	5333	1539	4480	94.26	732.6	32.52	765	166.6	2.055	5.659	65390	729643	38.51	46.62	42.79	1705192.6
10:31:33	4.5	27.9	99.9	2886.0	6.5	226758	316337	260781	54.21	37.92	24.11	25.38	28.21	35.47	795033	27179	1508	6775	5333	1539	4480	94.27	732.7	32.52	765.1	166.6	2.055	5.666	65396	729636	38.51	46.62	42.79	1705343.3
10:36:33	7.6	5.6	100.0	462.9	1.3	226922	316226	260727	54.73	38.27	24.08	25.37	28.2	35.49	795033	27222	1507	6775	5337	1540	4483	94.33	733.1	32.54	765.6	166.7	2.056	5.72	65446	729587	38.48	46.59	42.75	1706437.8
10:41:33	11.0	6.9	100.0	565.7	1.6	226913	316233	260730	54.7	38.25	24.08	25.37	28.2	35.49	795033	27219	1507	6775	5337	1540	4483	94.33	733.1	32.54	765.6	166.7	2.056	5.717	65443	729590	38.48	46.59	42.76	1706427.8
10:46:33	9.8	10.2	100.0	726.1	2.1	226899	316242	260735	54.66	38.22	24.08	25.37	28.2	35.49	795033	27216	1507	6775	5336	1540	4483	94.32	733.1	32.54	765.5	166.7	2.056	5.712	65439	729594	38.48	46.59	42.76	1706326.9
10:51:33	5.8	9.7	100.0	835.2	2.4	226889	316249	260738	54.63	38.2	24.09	25.37	28.2	35.49	795033	27213	1507	6775	5336	1540	4483	94.32	733.1	32.54	765.5	166.7	2.056	5.709	65436	729597	38.48	46.6	42.76	1706257.9
10:56:33	5.5	9.7	100.0	792.3	2.2	226893	316246	260737	54.64	38.21	24.09	25.37	28.2	35.49	795033	27214	1507	6775	5336	1540	4483	94.32	733.1	32.54	765									

Time	DNI	DNI Avr	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWt]	BPP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	PAF Power [kWt]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWt]	Net Power [kWt]	n _O [%]	n _G [%]	n _N [%]	Heat In [kWt]		
12:16:03	3.9	4.1	100.0	333.1	0.9	226934	316219	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.724	65449	729584	38.48	46.59	42.75	1706574.4
12:21:03	3.4	3.8	100.0	315.7	0.9	226936	316218	260722	54.78	38.3	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65450	729583	38.48	46.59	42.75	1706585.5
12:26:03	4.1	3.8	100.0	313.6	0.9	226936	316217	260722	54.78	38.3	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65450	729583	38.48	46.59	42.75	1706586.8
12:31:03	5.0	4.1	100.0	336.6	1.0	226934	316219	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.724	65449	729584	38.48	46.59	42.75	1706572.3
12:36:03	5.1	4.4	100.0	361.0	1.0	226934	316220	260724	54.76	38.3	24.08	25.37	28.2	35.49	795033	27224	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.723	65449	729584	38.48	46.59	42.75	1706556.9
12:41:03	5.1	4.8	100.0	394.9	1.1	226928	316222	260725	54.75	38.29	24.08	25.37	28.2	35.49	795033	27223	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.056	5.722	65447	729585	38.48	46.59	42.75	1706535.5
12:46:03	5.0	5.0	100.0	413.1	1.2	226927	316223	260725	54.75	38.28	24.08	25.37	28.2	35.49	795033	27223	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.056	5.722	65447	729586	38.48	46.59	42.75	1706524.1
12:56:03	5.1	5.0	100.0	413.0	1.2	226927	316223	260725	54.75	38.28	24.08	25.37	28.2	35.49	795033	27223	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.056	5.722	65447	729586	38.48	46.59	42.75	1706522.1
13:01:03	5.3	5.1	100.0	416.2	1.2	226927	316224	260725	54.75	38.28	24.08	25.37	28.2	35.49	795033	27223	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.056	5.721	65446	729587	38.48	46.59	42.75	1706524.1
13:06:03	6.5	5.4	100.0	446.9	1.3	226924	316226	260726	54.74	38.28	24.08	25.37	28.2	35.49	795033	27222	1507	6775	5337	1540	4483	94.33	733.2	32.55	765.6	166.7	2.056	5.721	65446	729588	38.48	46.59	42.75	1706502.7
13:11:03	7.6	6.1	100.0	500.9	1.4	226919	316229	260728	54.72	38.27	24.08	25.37	28.2	35.49	795033	27221	1507	6775	5337	1540	4483	94.33	733.1	32.54	765.6	166.7	2.056	5.719	65445	729588	38.48	46.59	42.75	1706468.7
13:16:03	16.6	9.0	100.0	737.0	2.1	226898	316243	260735	54.66	38.22	24.08	25.37	28.2	35.49	795033	27215	1507	6775	5336	1540	4483	94.32	733.1	32.54	765.5	166.7	2.056	5.712	65438	729594	38.48	46.59	42.76	1706319.8
13:21:03	20.4	12.8	100.0	1047.0	3.0	226870	316262	260744	54.57	38.16	24.09	25.37	28.2	35.48	795033	27208	1507	6775	5336	1540	4482	94.31	733	32.54	765.4	166.6	2.056	5.703	65430	729603	38.49	46.6	42.77	1706015.1
13:26:03	14.9	14.9	99.9	1220.0	3.4	226854	316272	260749	54.51	38.13	24.09	25.38	28.2	35.48	795033	27204	1507	6775	5335	1539	4482	94.31	732.9	32.54	765.4	166.6	2.056	5.698	65425	729603	38.49	46.6	42.77	1705987.6
13:31:03	9.7	15.4	99.9	1264.0	3.6	226850	316275	260751	54.5	38.12	24.09	25.38	28.2	35.48	795033	27203	1507	6775	5335	1539	4482	94.31	732.9	32.54	765.4	166.6	2.056	5.698	65425	729603	38.49	46.6	42.77	1705987.6
13:36:03	6.1	12.8	100.0	1049.0	3.0	226869	316262	260744	54.56	38.16	24.09	25.37	28.2	35.48	795033	27208	1507	6775	5336	1540	4482	94.31	733	32.54	765.4	166.6	2.056	5.703	65430	729603	38.49	46.6	42.77	1706124.4
13:41:03	5.6	9.1	100.0	746.1	2.1	226897	316244	260735	54.65	38.22	24.08	25.37	28.2	35.49	795033	27215	1507	6775	5336	1540	4482	94.31	733	32.54	765.5	166.7	2.056	5.703	65430	729603	38.49	46.6	42.77	1706124.4
13:46:03	6.3	6.9	100.0	568.8	1.6	226913	316233	260730	54.7	38.25	24.08	25.37	28.2	35.49	795033	27219	1507	6775	5337	1540	4483	94.33	733.1	32.54	765.5	166.7	2.056	5.712	65438	729595	38.48	46.59	42.76	1706123
13:51:03	5.1	5.8	100.0	474.6	1.3	226921	316227	260727	54.73	38.27	24.08	25.37	28.2	35.49	795033	27221	1507	6775	5337	1540	4483	94.33	733.1	32.54	765.5	166.7	2.056	5.712	65443	729595	38.48	46.59	42.76	1706423.8
13:56:03	5.1	5.5	100.0	452.9	1.3	226925	316226	260727	54.74	38.28	24.08	25.37	28.2	35.49	795033	27221	1507	6775	5337	1540	4483	94.33	733.1	32.54	765.5	166.7	2.056	5.712	65446	729587	38.48	46.59	42.75	1706485.2
14:01:03	4.9	5.3	100.0	403.4	1.1	226928	316223	260725	54.75	38.29	24.08	25.37	28.2	35.49	795033	27222	1507	6775	5337	1540	4483	94.33	733.2	32.55	765.6	166.7	2.056	5.721	65446	729587	38.48	46.59	42.75	1706498.9
14:06:03	4.6	4.9	100.0	403.4	1.1	226930	316221	260724	54.76	38.29	24.08	25.37	28.2	35.49	795033	27222	1507	6775	5337	1540	4483	94.33	733.2	32.55	765.6	166.7	2.056	5.721	65446	729587	38.48	46.59	42.75	1706508.2
14:11:03	3.9	4.6	100.0	379.1	1.1	226933	316219	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27224	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.722	65447	729586	38.48	46.59	42.75	1706530.2
14:16:03	4.1	4.1	100.0	340.0	1.0	226933	316220	260724	54.77	38.3	24.08	25.37	28.2	35.49	795033	27224	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.722	65447	729586	38.48	46.59	42.75	1706530.2
14:21:03	4.0	4.0	100.0	327.7	0.9	226934	316218	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.722	65449	729584	38.48	46.59	42.75	1706560.3
14:26:03	4.0	4.0	100.0	328.1	0.9	226934	316218	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.722	65449	729584	38.48	46.59	42.75	1706577.9
14:31:03	3.6	3.9	100.0	321.5	0.9	226934	316218	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.722	65449	729584	38.48	46.59	42.75	1706577.9
14:36:03	3.6	3.9	100.0	321.5	0.9	226934	316218	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.722	65449	729584	38.48	46.59	42.75	1706577.9
14:41:03	3.2	3.7	100.0	302.8	0.9	226937	316217	260722	54.78	38.31	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.6	166.7	2.057	5.724	65450	729583	38.48	46.59	42.75	1706581.7
14:46:03	3.2	3.5	100.0	286.5	0.8	226938	316216	260722	54.79	38.31	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65450	729583	38.48	46.59	42.75	1706593.6
14:51:03	3.0	3.2	100.0	266.1	0.8	226940	316215	260721	54.79	38.31	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.726	65451	729582	38.48	46.59	42.75	1706603.9
14:56:03	3.0	3.1	100.0	253.2	0.7	226941	316214	260721	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65451	729581	38.47	46.59	42.75	1706615.8
15:01:03	2.7	3.0	100.0	243.2	0.7	226942	316213	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65451	729581	38.47	46.59	42.75	1706624.7
15:06:03	3.5	3.0	100.0	248.9	0.7	226942	316214	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7								

Time	DNI	DNI Avr	MCR	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWm]	BFP Power [kWm]	CEP Power [kWm]	ACC Power [kWm]	IDF Power [kWm]	FDF Power [kWm]	PAF Power [kWm]	m_Coal [kg/s]	m_Air [kg/s]	m_Ash [kg/s]	m_FG [kg/s]	m_CO2 [kg/s]	m_SO2 [kg/s]	m_Spray [kg/s]	Aux Power [kWm]	Net Power [kWm]	n_O [%]	n_G [%]	n_N [%]	Heat_In [kWt]	
16:21:03	3.4	3.4	100.0	278.9	0.8	226939	316215	260721	54.79	38.31	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.726	65451	729582	38.48	46.59	42.75	1706608.7
16:26:03	3.2	3.3	100.0	267.8	0.8	226940	316215	260721	54.79	38.31	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.726	65451	729582	38.48	46.59	42.75	1706615.7
16:31:03	3.0	3.2	100.0	260.4	0.7	226941	316214	260721	54.79	38.31	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.726	65451	729582	38.48	46.59	42.75	1706620.3
16:36:03	3.2	3.2	100.0	261.2	0.7	226940	316214	260721	54.79	38.31	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.726	65451	729582	38.48	46.59	42.75	1706619.9
16:41:03	3.4	3.2	100.0	262.0	0.7	226940	316214	260721	54.79	38.31	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.726	65451	729582	38.48	46.59	42.75	1706619.3
16:46:03	3.1	3.2	100.0	259.7	0.7	226941	316214	260721	54.79	38.32	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.726	65451	729582	38.48	46.59	42.75	1706620.8
16:51:03	2.7	3.1	100.0	253.6	0.7	226941	316214	260721	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.726	65451	729581	38.47	46.59	42.75	1706624.6
16:56:03	2.7	3.0	100.0	243.8	0.7	226942	316213	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706630.8
17:01:03	3.0	2.9	100.0	234.8	0.7	226943	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706640.3
17:06:03	2.8	2.8	100.0	228.6	0.6	226943	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706640.3
17:11:03	3.0	2.9	100.0	235.8	0.7	226943	316213	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706638.3
17:16:03	2.6	2.8	100.0	231.9	0.7	226943	316213	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706635.9
17:21:03	2.7	2.8	100.0	226.5	0.6	226944	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706638.3
17:26:03	2.6	2.7	100.0	222.4	0.6	226944	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706644.7
17:31:03	2.8	2.6	100.0	217.4	0.6	226944	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706647.5
17:36:03	3.0	2.7	100.0	225.7	0.6	226944	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706642.2
17:41:03	2.9	2.8	100.0	229.9	0.6	226943	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706639.1
17:46:03	2.6	2.8	100.0	230.7	0.7	226943	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706638.8
17:51:03	2.8	2.8	100.0	228.4	0.7	226943	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706640.4
17:56:03	2.6	3.6	100.0	297.8	0.8	226938	316216	260722	54.78	38.31	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65451	729582	38.48	46.59	42.75	1706601.9
18:00:02	5.9	3.5	100.0	289.7	0.8	226938	316216	260722	54.78	38.31	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65451	729582	38.48	46.59	42.75	1706594.9
18:05:02	3.2	3.7	100.0	300.9	0.9	226937	316217	260722	54.78	38.31	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65451	729582	38.48	46.59	42.75	1706601.9
18:10:02	2.6	3.5	100.0	297.8	0.8	226937	316216	260722	54.78	38.31	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65451	729582	38.48	46.59	42.75	1706601.9
18:15:02	2.4	3.5	100.0	289.7	0.8	226938	316216	260722	54.79	38.31	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.725	65452	729581	38.47	46.58	42.75	1706653.2
18:20:02	2.6	2.7	100.0	221.1	0.6	226944	316212	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706655.2
18:25:02	2.5	2.5	100.0	208.3	0.6	226945	316211	260719	54.81	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706655.4
18:30:02	2.5	2.5	100.0	205.4	0.6	226946	316211	260719	54.81	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706655.4
18:35:02	2.6	2.6	100.0	206.1	0.6	226945	316211	260719	54.81	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706652.6
18:40:02	2.4	2.5	100.0	201.7	0.6	226946	316211	260719	54.81	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706655.4
18:45:02	2.4	2.5	100.0	204.2	0.6	226946	316211	260719	54.81	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706655.4
18:50:02	2.4	2.5	100.0	201.7	0.6	226946	316211	260719	54.81	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706657.4
18:55:02	2.4	2.4	100.0	197.3	0.6	226946	316210	260719	54.81	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706660.1
19:00:02	2.3	2.4	100.0	198.2	0.6	226946	316210	260719	54.81	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706659.6
19:05:02	2.3	2.4	100.0	196.1	0.6	226946	316210	260719	54.81	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580				

Time	DNI	DNI Av	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWm]	BFP Power [kWm]	CEP Power [kWm]	ACC Power [kWm]	IDF Power [kWm]	FDF Power [kWm]	PAF Power [kWm]	m_Coal [kg/s]	m_Air [kg/s]	m_Ash [kg/s]	m_FG [kg/s]	m_CO2 [kg/s]	m_SO2 [kg/s]	m_Spray [kg/s]	Aux Power [kWm]	Net Power [kWm]	n_O [%]	n_G [%]	n_N [%]	Heat_in [kWm]	
20:25:02	2.3	2.3	100.0	190.8	0.5	226947	316210	260719	54.81	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706664.3
20:30:02	2.2	2.3	100.0	186.2	0.5	226947	316210	260719	54.82	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.729	65453	729580	38.47	46.58	42.75	1706667.1
20:35:02	2.1	2.2	100.0	180.0	0.5	226948	316209	260718	54.82	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.729	65453	729580	38.47	46.58	42.75	1706670.1
20:40:02	2.2	2.2	100.0	181.6	0.5	226948	316209	260718	54.82	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.729	65453	729580	38.47	46.58	42.75	1706671.1
20:45:02	2.2	2.2	100.0	180.0	0.5	226948	316209	260718	54.82	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.729	65453	729580	38.47	46.58	42.75	1706672.1
20:50:02	2.1	2.2	100.0	178.2	0.5	226948	316209	260718	54.82	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.729	65453	729580	38.47	46.58	42.75	1706673.1
20:55:02	2.3	2.2	100.0	181.2	0.5	226948	316209	260718	54.82	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.729	65453	729580	38.47	46.58	42.75	1706674.2
21:00:02	2.4	2.3	100.0	185.1	0.5	226947	316210	260719	54.82	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.729	65453	729580	38.47	46.58	42.75	1706675.2
21:05:02	0.0	1.7	100.0	139.6	0.4	226951	316207	260717	54.83	38.34	24.07	25.37	28.2	35.49	795033	27230	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.729	65453	729580	38.47	46.58	42.75	1706676.3
21:10:02	0.0	1.2	100.0	96.5	0.3	226955	316204	260716	54.84	38.35	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706677.3
21:15:02	0.0	0.6	100.0	49.7	0.1	226960	316201	260715	54.85	38.36	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706678.4
21:20:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706679.5
21:25:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706680.6
21:30:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706681.6
21:35:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706682.6
21:40:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706683.6
21:45:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706684.6
21:50:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706685.6
21:55:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706686.6
22:00:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706687.6
22:05:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706688.6
22:10:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706689.6
22:15:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706690.6
22:20:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706691.6
22:25:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706692.6
22:30:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706693.6
22:35:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706694.6
22:40:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706695.6
22:45:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706696.6
22:50:02	0.0	0.0	96.9	0.0	0.0	221216	308162	254276	52.41	37	23.28	24.52	27.29	34.42	775033	25795	1469	6775	5212	1504	4378	92.12	71.6	31.78	747.7	162.8	2.008	7.041	63372	711661	38.43	46.51	42.7	1666537
22:55:02	0.0	0.0	93.9	0.0	0.0	215470	300136	247824	50.03	35.66	22.5	23.68	26.4	33.35	755033	24415	1431	6775	5086	1467	4272	89.9	698.7	31.01	729.6	158.8	1.96	8.225	61944	693689	38.39	46.43	42.66	1626218.3
23:00:02	0.0	0.0	90.9	0.0	0.0	209728	292124	241357	47.72	34.34	21.73	22.85	25.51	32.28	735033	23091	1394	6775	4959	1431	4166	87.66	681.3	30.24	711.5	154.9	1.911	9.294	59371	675662	38.35	46.35	42.61	1585830.2
23:05:02	0.0	0.0	88.0	0.0	0.0	203988	284123	234874	45.5	33.05	20.97	22.03	24.64	31.22	715033	21821	1356	6775	4833	1395	4060	85.43	663.9	29.47	693.3	150.9	1.862	10.25	57451	657582	38.3	46.27	42.55	1545370.7
23:10:02	0.0	0.0	85.1	0.0	0.0	198253	276135	228376	43.34	31.77	20.21	21.22	23.77	30.16	695033	20602	1319	6775	4706	1358	3953	83.19	646.5	28.7	675.1	147	1.813	11.11	54332	640701	38.32	46.19	42.58	1504838.7

9.5 Appendix C-3: Very cloudy day parametric table data

Time	DNI	DNI Avr	Solar Power [kWt]	MCR [%]	HPH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWt]	BFP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	PDF Power [kWt]	PAF Power [kWt]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO₂} [kg/s]	m _{SO₂} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWt]	Net Power [kWt]	n _O [%]	n _G [%]	n _N [%]	Heat_in [kWt]
04:09:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:14:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:19:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:24:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:29:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:34:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:39:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:44:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:49:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:54:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
05:04:52	0.0	0.0	62.6	0.0	0.0	151497	211235	174671	28.07	22.14	14.38	15.05	17.09	21.67	531492	12333	1013	6775	3660	1056	3075	64.7	502.9	23.32	525.1	114.3	1.41	14.78	40734	490758	37.74	45.4	41.93	1170458.3
05:09:52	0.0	0.0	65.2	0.0	0.0	157200	219134	181291	29.73	23.25	15.06	15.77	17.87	22.69	551492	13197	1050	6775	3789	1093	3183	66.98	520.6	23.11	543.6	118.3	1.46	14.61	42251	509241	37.83	45.2	42.03	12111652.8
05:14:52	0.0	0.0	70.6	0.0	0.0	168619	234963	194489	33.22	25.52	16.45	17.23	19.46	24.75	591492	15041	1125	6775	4046	1167	3399	71.52	555.8	24.67	580.4	126.4	1.55	14.37	43807	527685	37.91	45.6	42.12	1252780.7
05:19:52	0.0	0.0	73.3	0.0	0.0	174335	242892	201066	35.05	26.68	17.16	17.98	20.28	25.78	631492	16023	1162	6775	4174	1204	3507	73.78	573.4	25.45	598.8	130.4	1.608	13.66	47035	564457	38.06	45.8	42.29	1334715.2
05:24:52	0.0	0.0	76.1	0.0	0.0	180055	250833	207628	36.93	27.87	17.88	18.74	21.1	26.83	631492	17048	1200	6775	4302	1241	3614	76.04	591	26.23	617.1	134.4	1.658	12.63	50431	601061	38.19	46	42.44	1416340.8
05:29:52	0.0	0.0	78.9	0.0	0.0	185779	258784	214175	38.88	29.08	18.6	19.51	21.93	27.87	651492	18116	1237	6775	4429	1278	3721	78.29	608.5	27.1	635.4	138.3	1.707	11.99	52195	619297	38.25	46.09	42.5	1457035.6
05:34:52	0.0	0.0	81.7	0.0	0.0	191506	266747	220707	40.89	30.3	19.34	20.29	22.77	28.92	671492	19230	1275	6775	4557	1315	3828	80.54	626	27.79	653.7	142.3	1.756	11.99	52195	619297	38.25	46.09	42.5	1457035.6
05:39:52	0.0	0.0	84.6	0.0	0.0	197238	274722	227224	42.97	31.55	20.08	21.08	23.62	29.97	691492	20391	1312	6775	4684	1351	3935	82.79	643.4	28.56	671.9	146.3	1.805	11.25	54007	637485	38.31	46.17	42.57	1497654.7
05:44:52	0.0	0.0	87.5	0.0	0.0	202973	282708	233725	45.11	32.82	20.83	21.88	24.48	31.03	711492	21601	1350	6775	4810	1388	4041	85.03	660.9	29.34	690.1	150.2	1.854	10.41	57117	654375	38.29	46.25	42.54	1538199.8
05:49:52	0.0	0.0	90.4	0.0	0.0	208711	290706	240210	47.32	34.11	21.59	22.7	25.35	32.09	731492	22862	1387	6775	4937	1425	4147	87.27	678.2	30.11	708.3	154.2	1.902	9.471	59027	672465	38.34	46.34	42.6	1578671.9
05:54:52	0.0	0.0	93.4	0.0	0.0	214453	298717	246800	49.61	35.43	22.36	23.57	26.24	33.16	751492	24176	1425	6775	5063	1461	4254	89.5	695.6	30.88	726.4	158.1	1.951	8.422	60991	690501	38.38	46.41	42.65	1619072.7
05:59:52	0.0	0.0	96.4	0.0	0.0	220198	306740	253133	51.98	36.76	23.14	24.37	27.13	34.23	771492	25546	1462	6775	5190	1497	4360	91.73	712.9	31.65	744.5	162.1	2	7.259	63003	708483	38.43	46.49	42.7	1659403.5
06:04:52	2.2	0.6	99.5	45.4	0.1	225942	314777	259576	54.41	38.11	23.93	25.22	28.04	35.3	791492	26973	1507	6775	5315	1534	4465	93.75	733.3	32.55	765.7	166.7	2.057	5.731	65456	729577	38.47	46.52	42.75	1706679.1
06:09:52	2.1	1.1	100.0	138.4	0.2	226956	316204	260717	54.83	38.34	24.07	25.37	28.2	35.49	795033	27230	1507	6775	5337	1540	4494	94.34	733.2	32.55	765.7	166.7	2.057	5.731	65456	729577	38.47	46.52	42.75	1706679.1
06:14:52	2.5	1.7	100.0	254.6	0.7	226956	316204	260717	54.83	38.34	24.07	25.37	28.2	35.49	795033	27230	1507	6775	5337	1540	4494	94.34	733.2	32.55	765.7	166.7	2.057	5.731	65456	729577	38.47	46.52	42.75	1706679.1
06:19:52	5.7	3.1	100.0	254.6	0.7	226956	316204	260717	54.83	38.34	24.07	25.37	28.2	35.49	795033	27230	1507	6775	5337	1540	4494	94.34	733.2	32.55	765.7	166.7	2.057	5.731	65456	729577	38.47	46.52	42.75	1706679.1
06:24:52	63.9	18.5	99.9	1521.0	4.3	226827	316291	260758	54.43	38.07	24.1	25.38	28.21	35.48	795033	27197	1508	6775	5335	1539	4482	94.3	732.9	32.53	765.3	166.6	2.056	5.689	65417	729581	38.49	46.51	42.77	1705825.3
06:29:52	178.0	62.5	99.8	5132.0	14.5	226502	316509	260865	53.38	37.35	24.16	25.39	28.22	35.45	795033	27113	1509	6775	5328	1537	4476	94.17	731.9	32.49	764.3	166.4	2.053	5.581	65319	729713	38.55	46.67	42.83	1703549.4
06:34:52	605.6	213.3	99.2	17507.0	49.6	225388	317160	261128	49.8	34.91	24.36	25.44	28.25	35.34	795033	26826	1515	6775	5303	1530	4455	93.74	728.5	32.34	760.8	165.6	2.043	5.212	64985	730043	38.75	46.88	43.05	1695758.3
06:39:52	634.0	370.4	98.5	30400.0	86.1	224231	318044	261601	46.08	32.37	24.57	25.49	28.33	35.23	795033	26531	1521	6775	5278	1523	4434	93.29	725.1	32.19	757.1	164.8	2.034	4.827	64640	730384	38.95	47.11	43.28	1687658.7
06:44:52	652.7	517.6	98.0	42482.0	120.5	223149	318781	261945	42.61	29.98	24.77	25.54	28.41	35.12	795033	26257	1526	6775	5254	1516	4414	92.87	721.8	32.04	753.8	164.1	2.025	4.465	64320	730701	39.14	47.32	43.49	1680084.6
06:49:52	641.4	633.4	97.5	51990.0	147.6	222300	319362	262213	39.89	28.12	24.92	25.57	28.46	35.03	795033	26044	1530	6775	5236	1511	4398	92.54	719.3	31.93	751.1	163.5	2.017	4.179	64071	730948	39.3	47.49	43.66	1674134.7
06:54:52	131.2	514.8	98.0	42482.0	112.6	223398	318611	261866	43.41	30.54	24.72	25.53	28.4	35.14	795033	26233	1519	6775	5286	1525	4440	93.43	726.1	32.04	758.4	165.1	2.037	4.963	64761	730265	38.88	47.03	43.2	1690511.3
06:59:52	638.0	600.3	97.6	49263.0	139.9	222543	319196	262137	40.67	28.65	24.88	25.56	2																					

Time	DNI	DNI Avr	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWt]	IPT Power [kWt]	LPT Power [kWt]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWt]	BFP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	FDF Power [kWt]	PAF Power [kWt]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWt]	Net Power [kWt]	n _O [%]	n _G [%]	n _N [%]	Heat_In [kWt]	
08:26:03	730.7	833.3	96.7	68398.0	194.5	220838	320368	262669	35.22	24.88	25.18	25.64	28.54	34.88	795033	25680	1588	6775	5704	1501	4371	91.98	714.9	31.73	746.5	162.5	2.005	3.684	63644	731371	39.56	47.78	43.95	1663890.8
08:31:03	301.7	682.5	97.3	56020.0	159.1	221940	319609	262326	38.74	27.32	24.99	25.59	28.48	34.99	795033	25954	1582	6775	5288	1508	4392	92.41	718.2	31.88	750	163.3	2.014	4.057	63965	731053	39.36	47.56	43.73	1671615.9
08:36:03	81.6	481.5	98.1	39518.0	112.1	223414	318600	261861	43.46	30.57	24.71	25.53	28.4	35.14	795033	26324	1525	6775	5260	1518	4419	92.98	722.6	32.08	754.6	164.3	2.027	4.553	64399	730624	39.1	47.27	43.44	1681940.8
08:41:03	368.0	370.5	98.5	30411.0	86.2	224230	318045	261601	46.08	32.37	24.57	25.49	28.35	35.23	795033	26531	1521	6775	5278	1523	4434	93.29	725.1	32.19	757.1	164.8	2.034	4.822	64640	730385	38.95	47.11	43.28	1687651.3
08:46:03	69.8	205.3	98.2	16850.0	47.7	225447	317220	261209	49.99	35.04	24.35	24.48	28.28	35.35	795033	26842	1514	6775	5305	1531	4456	93.76	728.7	32.35	761	165.7	2.044	5.236	65003	730026	38.74	46.87	43.04	1696171.5
08:51:03	91.7	152.8	99.4	12539.0	35.5	225835	316958	261083	51.23	35.89	24.28	25.42	28.26	35.38	795033	26941	1513	6775	5313	1533	4463	93.91	729.9	32.4	762.2	165.9	2.047	5.361	65119	729911	38.67	46.8	42.96	1698884
08:56:03	87.9	154.3	99.4	12667.0	35.8	225823	316966	261086	51.2	35.87	24.28	25.42	28.26	35.38	795033	26938	1513	6775	5313	1533	4463	93.91	729.9	32.4	762.2	165.9	2.047	5.361	65119	729911	38.67	46.8	42.96	1698884
09:01:03	15.4	66.2	99.7	5432.0	15.4	226674	316527	260874	53.29	37.29	24.16	25.39	28.23	35.46	795033	27106	1509	6775	5327	1537	4475	94.16	731.8	32.49	764.2	166.4	2.053	5.572	65311	729914	38.67	46.8	42.97	1703860.2
09:06:03	0.0	48.7	99.8	3999.0	11.3	226674	316441	260832	53.71	37.58	24.14	25.39	28.23	35.46	795033	27106	1509	6775	5327	1537	4475	94.16	731.8	32.49	764.2	166.4	2.053	5.572	65311	729914	38.67	46.8	42.97	1703860.2
09:11:03	0.0	25.8	99.9	2118.0	6.0	226773	316327	260776	54.25	37.95	24.11	25.38	28.21	35.48	795033	27183	1508	6775	5334	1539	4481	94.28	732.7	32.53	765.1	166.6	2.055	5.671	65401	729632	38.5	46.82	42.78	1705448.6
09:16:03	0.0	3.8	100.0	315.3	0.9	226936	316218	260723	54.78	38.3	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65450	729583	38.48	46.59	42.75	1706585.6
09:21:03	0.0	0.0	100.0	164.2	0.5	226949	316208	260718	54.82	38.33	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65450	729583	38.48	46.59	42.75	1706585.6
09:26:03	0.0	0.0	100.0	78.7	0.2	226977	316243	260735	54.65	38.22	24.08	25.37	28.2	35.49	795033	27225	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65450	729583	38.48	46.59	42.75	1706585.6
09:31:03	14.0	3.5	100.0	410.4	1.2	226927	316223	260725	54.75	38.29	24.08	25.37	28.2	35.49	795033	27223	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65447	729586	38.48	46.59	42.75	1706585.6
09:36:03	0.0	3.5	100.0	328.3	0.9	226934	316218	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27223	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65447	729586	38.48	46.59	42.75	1706585.6
09:41:51	0.0	3.5	100.0	410.4	1.2	226934	316218	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27223	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65447	729586	38.48	46.59	42.75	1706585.6
09:46:51	0.0	3.5	100.0	820.8	2.3	226890	316248	260737	54.63	38.2	24.09	25.37	28.2	35.49	795033	27213	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65447	729586	38.48	46.59	42.75	1706585.6
09:51:51	129.9	32.5	99.9	2665.0	7.5	226724	316360	260792	54.1	37.84	24.12	25.38	28.21	35.47	795033	27170	1508	6775	5332	1539	4480	94.26	732.6	32.52	765	166.5	2.055	5.655	65386	729646	38.51	46.63	42.79	1705103.8
09:56:51	390.8	130.2	99.5	10685.0	30.2	226001	316846	261028	51.77	36.26	24.25	25.41	28.25	35.4	795033	26984	1512	6775	5317	1534	4466	93.98	730.4	32.42	762.7	166.1	2.049	5.416	65169	729861	38.64	46.77	42.93	1700051.2
10:01:43	0.0	130.2	99.5	10685.0	30.2	226001	316846	261028	51.77	36.26	24.25	25.41	28.25	35.4	795033	26984	1512	6775	5317	1534	4466	93.98	730.4	32.42	762.7	166.1	2.049	5.416	65169	729861	38.64	46.77	42.93	1700051.2
10:06:43	0.0	130.2	99.5	10685.0	30.2	226001	316846	261028	51.77	36.26	24.25	25.41	28.25	35.4	795033	26984	1512	6775	5317	1534	4466	93.98	730.4	32.42	762.7	166.1	2.049	5.416	65169	729861	38.64	46.77	42.93	1700051.2
10:11:43	0.0	97.9	99.6	8019.0	22.7	226241	316684	260950	52.54	36.78	24.2	25.4	28.24	35.42	795033	27046	1510	6775	5322	1536	4471	94.07	731.1	32.45	763.5	166.2	2.051	5.495	65241	729790	38.6	46.72	42.89	1701729.8
10:16:43	0.0	0.0	100.0	246.2	0.7	226842	316213	260720	54.8	38.32	24.08	25.37	28.2	35.49	795033	27227	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706629.3
10:21:43	0.0	0.0	100.0	328.3	0.9	226934	316218	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27223	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65447	729586	38.48	46.59	42.75	1706585.6
10:26:43	0.0	0.0	100.0	164.2	0.5	226949	316208	260718	54.82	38.33	24.08	25.37	28.2	35.49	795033	27223	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65447	729586	38.48	46.59	42.75	1706585.6
10:31:33	0.0	0.0	100.0	82.1	0.2	226957	316203	260716	54.85	38.35	24.07	25.37	28.2	35.49	795033	27213	1507	6775	5338	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.727	65452	729581	38.47	46.58	42.75	1706681.1
10:36:33	0.0	0.0	100.0	820.8	2.3	226890	316248	260737	54.63	38.2	24.09	25.37	28.2	35.49	795033	27213	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.725	65447	729586	38.48	46.59	42.75	1706585.6
10:41:33	0.0	0.0	99.9	1642.0	4.6	226816	316298	260762	54.39	38.04	24.1	25.38	28.21	35.48	795033	27194	1508	6775	5334	1539	4484	94.34	733.2	32.55	765.6	166.6	2.056	5.685	65414	729619	38.5	46.61	42.77	1705749.4
10:46:33	161.1	40.3	99.8	3306.0	9.3	226666	316399	260811	53.91	37.71	24.13	25.38	28.21	35.47	795033	27155	1508	6775	5331	1538	4479	94.23	732.4	32.51	764.8	166.5	2.054	5.636	65369	729664	38.52	46.64	42.8	1704700
10:51:33	341.2	125.6	99.5	10308.0	29.2	226035	316823	261017	51.88	36.33	24.24	25.41	28.25	35.4	795033	26993	1512	6775	5317	1534	4467	93.99	730.5	32.43	762.8	166.1	2.049	5.427	65179	729851	38.63	46.76	42.93	1700288.8
10:56:33	95.4	149.4	99.4	1245.0	4.0	225859	316942	261075	51.31	35.95	24.27	25.42	28.26	35.39	795033	26993	1512	6775	5314	1533	4464	93.92	730	32.4	762.3	166	2.047	5.369	65126	729904	38.66	46.79	42.96	1699056.4
11:01:23	105.0	175.7	99.3	14419.0	34.8	225866	317072	261138	50.69	35.52	24.31	25.43	28.27	35.37	795033	26998	1513	6775	5309	1532	4460	93.85	729.4	32.38	761.7	165.8	2.046	5.305	65068	729961	38.7	46.83	43	1697700.7
11:06:23	90.9	158.1	99.4	12978.0	36.7	225789	316985	261096	51.11	35.81	24.29	25.42	28.26	35.38	795033	26931	1513	6775	5312	1533	4463	93.9	729.8	32.39	762.1	165.9	2.047	5.348	65107	729923	38.67	46.8	42.97	1698607.6
11:11:23	244.5	158.9	99.4	13045.0	36.9																													

Time	DNI	DNI Air	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPN 3 Bleed [kg/s]	LPN 2 Bleed [kg/s]	LPN 1 Bleed [kg/s]	Gross Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	PDF Power [kWt]	m_PAF [kg/s]	m_Air [kg/s]	m_Ash [kg/s]	m_FG [kg/s]	m_CO2 [kg/s]	m_SO2 [kg/s]	m_Spray [kg/s]	Aux Power [kWt]	Net Power [kWt]	n_O [%]	n_N [%]	Heat In [kWt]			
12:41:03	788.5	925.5	96.4	75963.0	216.2	220166	320834	262876	33.07	23.39	25.31	25.67	28.58	34.81	795033	25513	1541	6775	5189	4359	91.72	712.8	31.64	744.4	162.1	1.999	3.455	63449	731564	39.68	47.92	44.09	1659177.5
12:46:03	1368	784.7	97.1	60300.0	171.4	221559	319872	262445	37.52	26.48	25.05	25.61	28.5	34.95	795033	25859	1534	6775	5219	4385	92.26	717	31.83	748.8	163	2.011	3.928	63854	731163	39.43	47.64	43.81	1668947.7
12:51:03	55.8	502.5	98.0	41248.0	177.0	223259	318706	261910	42.97	30.23	24.75	25.53	28.41	35.13	795033	26285	1525	6775	5257	4416	92.92	722.1	32.06	754.1	164.2	2.026	4.502	64353	730669	39.12	47.3	43.47	1680857.7
12:56:03	348.9	332.0	98.7	27251.0	172.7	224513	317853	261510	46.99	32.99	24.52	25.48	28.34	35.25	795033	26603	1519	6775	5284	4439	93.4	725.9	32.22	758	165	2.036	4.921	64724	730301	38.9	47.05	43.22	1689635
13:01:03	878.6	354.5	98.6	29100.0	82.5	224947	317965	261563	46.46	32.63	24.55	25.48	28.34	35.24	795033	26561	1520	6775	5280	4438	93.34	725.4	32.2	757.5	164.9	2.036	4.866	64675	730350	38.93	47.09	43.26	1688474.7
13:06:03	68.8	337.5	98.7	27704.0	78.5	224472	317880	261523	46.86	32.9	24.53	25.48	28.34	35.25	795033	26593	1519	6775	5283	4438	93.39	725.8	32.22	757.9	165	2.036	4.908	64712	730313	38.91	47.06	43.23	1689350.5
13:11:03	708.9	500.8	98.0	41105.0	116.6	223270	318697	261906	43.01	30.26	24.75	25.53	28.41	35.13	795033	26288	1525	6775	5257	4416	92.92	722.2	32.06	754.1	164.2	2.026	4.506	64357	730665	39.12	47.3	43.43	1689046.7
13:16:03	288.1	486.1	98.1	39859.0	113.2	223302	318623	261872	43.35	30.5	24.73	25.53	28.4	35.14	795033	26316	1525	6775	5259	4416	92.96	722.5	32.07	754.5	164.3	2.023	4.542	64389	730634	39.1	47.28	43.45	1681702.6
13:21:03	461.0	381.7	98.5	31328.0	88.8	224148	318101	261627	45.81	32.19	24.59	25.49	28.36	35.22	795033	26510	1521	6775	5276	4432	93.26	724.8	32.07	756.9	164.8	2.033	4.799	64616	730409	38.96	47.12	43.29	1687076.1
13:26:03	635.5	523.4	97.9	42958.0	121.9	223107	318810	261959	42.48	29.9	24.78	25.54	28.41	35.11	795033	26247	1526	6775	5253	4432	92.86	721.7	32.04	753.6	164.1	2.024	4.645	64449	730574	39.15	47.33	43.5	1679786.4
13:31:03	601.8	496.6	98.0	40761.0	115.6	223303	318676	261897	43.11	30.33	24.74	25.52	28.39	35.16	795033	26296	1525	6775	5258	4417	92.93	722.3	32.06	754.2	164.2	2.026	4.516	64366	730656	39.12	47.29	43.46	1681162.2
13:36:03	135.4	458.4	98.2	37627.0	106.7	223583	318485	261807	44	30.95	24.69	25.53	28.39	35.16	795033	26367	1524	6775	5264	4420	93	722.8	32.08	754.7	164.3	2.027	4.57	64443	730574	39.07	47.24	43.41	1683126
13:41:03	525.9	474.6	98.1	38959.0	110.5	223464	318566	261845	43.62	30.68	24.71	25.52	28.39	35.17	795033	26377	1524	6775	5261	4420	93	722.8	32.08	754.7	164.3	2.027	4.57	64443	730574	39.07	47.24	43.41	1683126
13:46:03	173.4	359.1	98.6	29476.0	83.5	224314	317988	261574	46.35	32.55	24.56	25.49	28.35	35.23	795033	26552	1520	6775	5280	4435	93.32	725.3	32.2	757.4	164.9	2.034	4.854	64665	730360	38.94	47.09	43.26	1682238.4
13:51:03	386.8	305.4	98.8	25064.0	71.0	224709	317719	261447	47.62	33.42	24.48	25.47	28.32	35.27	795033	26653	1518	6775	5288	4443	93.48	726.5	32.25	758.7	165.2	2.038	4.987	64783	730244	38.87	47.02	43.18	1679746.7
13:56:03	1010.5	524.1	97.9	43021.0	122.1	223101	318814	261961	42.46	29.88	24.78	25.54	28.41	35.11	795033	26245	1526	6775	5253	4413	92.85	721.7	32.03	753.6	164.1	2.024	4.448	64306	730715	39.15	47.33	43.5	1679746.7
14:01:03	611.9	545.6	97.9	44786.0	127.1	222943	318922	262010	41.95	29.53	24.81	25.55	28.42	35.1	795033	26205	1527	6775	5255	4410	92.79	721.2	32.01	753.1	164	2.023	4.395	64260	730761	39.18	47.36	43.53	1678641.9
14:06:03	881.1	722.6	97.2	59309.0	168.5	221647	319811	262418	37.81	26.67	25.04	25.6	28.5	34.96	795033	25881	1534	6775	5221	4386	92.29	717.3	31.84	749	163.1	2.012	3.958	63880	731137	39.41	47.62	43.79	1669561.8
14:11:03	749.0	813.1	96.8	66742.0	189.8	220985	320267	262623	35.69	25.21	25.16	25.63	28.53	34.89	795033	25786	1536	6775	5203	4379	92.04	715.3	31.75	746.9	162.6	2.006	3.734	63687	731328	39.53	47.75	43.93	1664923.6
14:16:03	850.0	778.0	97.0	63447.0	180.3	221279	320065	262532	36.63	25.86	25.11	25.62	28.52	34.92	795033	25916	1533	6775	5224	4389	92.35	717.7	31.86	749.5	163.2	2.013	3.997	63913	731104	39.39	47.6	43.77	1670381.2
14:21:03	1038.0	879.5	96.6	72190.0	205.4	220501	317602	262773	34.14	24.14	25.24	25.65	28.56	34.84	795033	25596	1540	6775	5204	4389	92.35	717.7	31.86	749.5	163.2	2.013	3.997	63913	731104	39.39	47.6	43.77	1670381.2
14:26:03	176.6	703.4	97.2	57734.0	164.0	221788	319714	262382	38.25	26.98	25.02	25.6	28.49	34.97	795033	25909	1533	6775	5224	4388	92.34	717.6	31.86	749.4	163.2	2.013	3.997	63913	731104	39.39	47.6	43.77	1670381.2
14:31:03	763.4	707.0	97.2	58029.0	164.9	221761	319732	262382	38.18	26.93	25.02	25.6	28.49	34.97	795033	25910	1533	6775	5224	4388	92.34	717.6	31.86	749.4	163.2	2.013	3.997	63913	731104	39.39	47.6	43.77	1670381.2
14:36:03	849.0	706.7	97.2	58009.0	164.8	221763	319731	262382	38.18	26.93	25.02	25.6	28.49	34.97	795033	25910	1533	6775	5224	4388	92.34	717.6	31.86	749.4	163.2	2.013	3.997	63913	731104	39.39	47.6	43.77	1670381.2
14:41:03	8.4	449.3	98.2	36882.0	104.6	223650	318439	261786	44.22	31.09	24.68	25.52	28.38	35.17	795033	26384	1523	6775	5265	4423	93.07	723.3	32.11	755.3	164.4	2.029	4.638	64468	730555	39.05	47.22	43.33	1685865
14:46:03	0.0	405.2	98.4	33259.0	94.3	223975	318218	261683	45.26	31.81	24.62	25.5	28.37	35.2	795033	26466	1522	6775	5272	4429	93.19	724.3	32.15	756.3	164.7	2.032	4.741	64564	730460	39	47.16	43.33	1685865
14:51:03	0.0	214.3	99.2	17594.0	49.8	225390	317265	261230	49.77	34.9	24.36	25.44	28.29	35.34	795033	26824	1515	6775	5303	4455	93.74	728.5	32.34	760.8	165.6	2.043	5.21	64983	730046	38.75	46.89	43.05	1695703.9
14:56:03	0.0	21.0	100.0	171.9	0.5	226949	316209	260718	54.82	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5338	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.729	65454	729579	38.47	46.58	42.75	1706784.6
15:01:03	0.0	100.0	0.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
15:06:03	0.0	100.0	0.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
15:11:03	0.0	100.0	0.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
15:16:03	0.0	100.0	0.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
15:21:03	0.0	100.0	0.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
15:26:03	0.0	100.0	0.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
15:31:03	0.0	100.0	0.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.																			

Time	DNI	DNI	MCR	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWm]	BFP Power [kWm]	CEP Power [kWm]	ACC Power [kWm]	IDF Power [kWm]	PDF Power [kWm]	PAF Power [kWm]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO₂} [kg/s]	m _{SO₂} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWm]	Net Power [kWm]	n _O [%]	n _G [%]	n _N [%]	Heat_In [kWm]
16:56:03	0.0	0.0	99.9	1642.0	4.6	226816	316298	260762	54.39	38.04	24.1	25.38	28.21	35.48	795033	27194	1508	6775	5334	1539	4481	94.29	732.8	32.53	765.3	166.6	2.056	5.685	65414	729619	38.5	46.61	42.77	1705749.3
17:01:03	0.0	0.0	99.8	4104.0	11.6	226594	316447	260935	53.68	37.56	24.14	25.39	28.22	35.46	795033	27137	1509	6775	5330	1538	4477	94.21	732.2	32.5	764.6	166.5	2.054	5.612	65347	729685	38.54	46.65	42.82	1704197
17:06:03	734.5	183.6	99.3	15072.0	42.7	225607	317112	261157	50.5	35.39	24.32	25.43	28.27	35.36	795033	26882	1514	6775	5308	1532	4459	93.82	729.2	32.37	761.5	165.8	2.045	5.285	65050	729978	38.71	46.84	43.01	1697290
17:11:03	686.1	355.1	98.6	29150.0	82.6	224343	317968	261566	46.44	32.62	24.55	25.48	28.34	35.24	795033	26560	1520	6775	5280	1524	4436	93.34	725.4	32.2	757.5	164.9	2.035	4.864	64674	730352	38.93	47.09	43.26	1688442.9
17:16:03	670.9	322.9	97.9	42916.0	121.8	223110	318808	261958	42.49	29.9	24.77	25.54	28.41	35.11	795033	26248	1526	6775	5253	1516	4436	92.86	721.7	32.04	753.6	164.1	2.024	4.51	64309	730713	39.15	47.33	43.5	1679812.5
17:21:03	639.1	682.6	97.3	56031.0	159.2	221939	319610	262226	38.74	27.32	24.99	25.59	28.48	34.99	795033	25954	1532	6775	5228	1508	4392	92.41	718.2	31.88	749.9	163.3	2.014	4.057	63965	731053	39.36	47.56	43.73	1671605.2
17:26:03	609.7	651.4	97.4	54707.0	151.8	222168	319453	262255	39.47	27.82	24.95	25.58	28.47	35.02	795033	26011	1531	6775	5233	1510	4396	92.49	718.9	31.91	750.7	163.4	2.016	4.134	64032	730987	39.32	47.52	43.69	1673205.6
17:30:03	556.1	618.9	97.6	50803.0	144.2	222406	319290	262180	40.23	28.35	24.9	25.57	28.45	35.04	795033	26070	1530	6775	5238	1511	4400	92.59	719.6	31.99	751.4	163.6	2.018	4.214	64102	730918	39.28	47.47	43.64	1674877.3
17:35:03	483.0	572.0	97.7	46949.0	133.2	222750	319054	262072	41.33	29.11	24.84	25.55	28.43	35.08	795033	26157	1528	6775	5235	1511	4407	92.72	720.6	31.99	752.5	163.8	2.021	4.33	64203	730818	39.21	47.4	43.57	1677288.2
17:40:03	463.7	533.1	97.9	43760.0	124.2	223035	318859	261982	42.25	29.74	24.79	25.54	28.42	35.11	795033	26229	1527	6775	5252	1515	4412	92.83	721.5	32.03	753.4	164	2.024	4.426	64287	730734	39.16	47.34	43.51	1679284.1
17:45:03	469.5	498.1	98.0	40883.0	116.0	223292	318684	261900	43.75	30.3	24.74	25.52	28.4	35.13	795033	26293	1525	6775	5257	1517	4417	92.93	722.2	32.06	754.2	164.2	2.026	4.513	64363	730659	39.12	47.29	43.46	1681086
17:50:03	440.4	469.2	98.2	38508.0	109.2	223502	318539	261832	43.07	30.39	24.75	25.49	28.35	35.15	795033	26377	1524	6775	5262	1518	4420	93.01	722.9	32.09	754.9	164.3	2.028	4.584	64425	730597	39.08	47.25	43.42	1682574
17:55:02	419.2	453.2	98.2	37197.0	105.5	223622	318459	261795	44.13	31.03	24.68	25.52	28.39	35.16	795033	26347	1524	6775	5262	1518	4420	93.01	722.9	32.09	754.9	164.3	2.028	4.584	64425	730597	39.08	47.25	43.42	1682574
18:00:02	395.0	431.0	98.3	35376.0	100.3	223785	318348	261743	44.65	31.39	24.65	25.51	28.38	35.18	795033	26418	1523	6775	5262	1518	4420	93.01	722.9	32.09	754.9	164.3	2.028	4.584	64425	730597	39.08	47.25	43.42	1682574
18:05:02	358.4	403.2	98.4	33096.0	93.8	223969	318209	261678	45.31	31.84	24.62	25.5	28.36	35.2	795033	26377	1524	6775	5262	1518	4420	93.01	722.9	32.09	754.9	164.3	2.028	4.584	64425	730597	39.08	47.25	43.42	1682574
18:10:02	305.1	369.4	98.5	30321.0	85.9	224238	318039	261598	46.1	32.39	24.57	25.49	28.35	35.23	795033	26533	1521	6775	5278	1521	4429	93.2	724.3	32.15	755.4	165.1	2.036	4.932	64734	730292	38.99	47.05	43.22	1688955.5
18:15:02	252.4	327.7	98.7	26900.0	76.2	224545	317831	261500	47.09	33.06	24.51	25.48	28.33	35.26	795033	27081	1517	6775	5285	1525	4440	93.41	726	32.23	758.1	165.1	2.036	4.932	64734	730292	38.99	47.05	43.22	1688955.5
18:20:02	211	291.1	99.1	18967.0	64.9	224902	317588	261385	48.24	33.85	24.45	25.46	28.31	35.29	795033	26793	1515	6775	5300	1529	4458	93.69	728.1	32.32	760.4	165.5	2.042	5.169	64946	730082	38.77	46.91	43.08	1694840.1
18:25:02	166.1	231.1	99.1	15867.0	53.7	225257	317349	261270	49.38	34.63	24.38	25.44	28.29	35.33	795033	26870	1514	6775	5307	1531	4458	93.81	729	32.36	761.3	165.7	2.045	5.268	65035	729993	38.72	46.85	43.02	1696936.9
18:30:02	142.7	190.5	99.2	15633.0	44.2	225556	317146	261173	50.34	35.28	24.33	25.43	28.28	35.36	795033	26870	1514	6775	5307	1531	4458	93.81	729	32.36	761.3	165.7	2.045	5.268	65035	729993	38.72	46.85	43.02	1696936.9
18:35:02	118.6	157.0	99.4	12887.0	36.5	225803	316979	261093	51.13	35.82	24.29	25.42	28.26	35.38	795033	26933	1513	6775	5312	1533	4463	93.9	729.8	32.4	762.1	165.9	2.047	5.35	65109	729920	38.67	46.8	42.97	1698665
18:40:02	93.8	115.3	99.5	9464.0	28.8	226111	316772	260992	52.12	36.5	24.23	25.41	28.25	35.41	795033	27012	1511	6775	5315	1535	4468	94.02	730.7	32.47	763.9	166.1	2.052	5.541	65202	729829	38.62	46.74	42.91	1700820.3
18:45:02	79.0	99.7	99.8	6487.0	18.3	226379	316591	260935	52.99	37.09	24.18	25.4	28.23	35.44	795033	27081	1510	6775	5325	1536	4477	94.12	731.5	32.47	763.9	166.1	2.052	5.541	65202	729829	38.62	46.74	42.91	1700820.3
18:50:02	21.7	48.8	99.8	4005.0	11.3	226603	316441	260832	53.71	37.58	24.14	25.39	28.22	35.46	795033	27139	1509	6775	5330	1538	4477	94.21	732.2	32.5	764.6	166.5	2.054	5.615	65350	729682	38.53	46.65	42.82	1704255.1
18:55:02	4.0	20.1	99.9	1653.0	4.7	226815	316299	260762	54.39	38.04	24.1	25.38	28.21	35.48	795033	27194	1508	6775	5334	1539	4481	94.29	732.8	32.53	765.3	166.6	2.056	5.685	65413	729619	38.5	46.61	42.77	1705745.2
19:00:02	3.0	12.4	100.0	1021.0	2.9	226912	316234	260731	54.7	38.25	24.08	25.37	28.2	35.49	795033	27209	1507	6775	5336	1540	4482	94.31	733	32.54	765.4	166.6	2.056	5.704	65434	729602	38.49	46.6	42.76	1706140.4
19:05:02	0.0	7.2	100.0	588.9	1.7	226911	316234	260731	54.7	38.25	24.08	25.37	28.2	35.49	795033	27209	1507	6775	5336	1540	4482	94.31	733	32.54	765.4	166.6	2.056	5.704	65434	729602	38.49	46.6	42.76	1706140.4
19:10:02	0.0	1.7	100.0	143.1	0.4	226951	316207	260717	54.83	38.34	24.07	25.37	28.2	35.49	795033	27219	1507	6775	5337	1540	4484	94.33	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
19:15:02	0.0	0.8	100.0	61.9	0.2	226958	316202	260715	54.85	38.35	24.07	25.37	28.2	35.49	795033	27219	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
19:20:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
19:25:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
19:30:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
19:35:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
19:40:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37</																						

Time	DNI	DNI Avr	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWt]	BFP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	FDF Power [kWt]	PAF Power [kWt]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWt]	Net Power [kWt]	n _O [%]	n _G [%]	n _N [%]	Heat_In [kWt]
21:10:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:15:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:20:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:25:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:30:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:35:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:40:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:45:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:50:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:55:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:00:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:05:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:10:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:15:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:20:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:25:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:30:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:35:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:40:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:45:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:50:02	0.0	0.0	100.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:55:02	0.0	0.0	93.9	0.0	221216	308161	254276	52.41	37	23.28	24.52	27.29	34.42	775033	25795	1489	6775	5212	1504	4378	92.12	716	31.78	747.7	162.8	2.008	7.041	63372	711661	38.43	46.51	42.7	1666536.9
23:00:02	0.0	0.0	90.9	0.0	209728	292124	241357	47.72	34.34	21.73	22.85	25.51	32.28	735033	23091	1394	6775	4959	1431	4166	87.66	681.3	30.24	711.5	154.9	1.911	9.294	59371	675662	38.35	46.35	42.61	1595830.4
23:05:02	0.0	0.0	88.0	0.0	209728	292124	241357	47.72	34.34	21.73	22.85	25.51	32.28	735033	23091	1394	6775	4959	1431	4166	87.66	681.3	30.24	711.5	154.9	1.911	9.294	59371	675662	38.35	46.35	42.61	1595830.4
23:10:02	0.0	0.0	85.1	0.0	198253	276135	228376	43.34	31.77	20.21	21.22	23.77	30.16	695033	20602	1319	6775	4706	1358	3953	83.19	646.5	28.7	675.1	147	1.813	11.11	54332	640701	38.32	46.27	42.58	1545370.6
23:15:02	0.0	0.0	82.2	0.0	198253	276135	228376	43.34	31.77	20.21	21.22	23.77	30.16	695033	20602	1319	6775	4706	1358	3953	83.19	646.5	28.7	675.1	147	1.813	11.11	54332	640701	38.32	46.27	42.58	1545370.6
23:20:02	0.0	0.0	79.4	0.0	186792	260193	215333	39.23	29.29	18.73	19.64	22.08	28.06	655033	18310	1244	6775	4452	1285	3740	78.69	611.6	27.15	638.7	139	1.715	12.53	50740	604293	38.2	46.01	42.45	1423551.6
23:25:02	0.0	0.0	76.6	0.0	181058	252240	208788	37.27	28.08	18	18.87	21.24	27.01	615033	16201	1169	6775	4197	1211	3526	74.18	576.5	25.59	602.1	131.1	1.617	13.58	47329	567704	38.07	45.83	42.3	1341954.2
23:30:02	0.0	0.0	73.8	0.0	175947	244297	202229	35.38	26.89	17.29	18.11	20.42	25.97	615033	16201	1169	6775	4197	1211	3526	74.18	576.5	25.59	602.1	131.1	1.617	13.58	47329	567704	38.07	45.83	42.3	1341954.2
23:35:02	0.0	0.0	71.1	0.0	169631	236366	195655	33.54	25.72	16.58	17.36	19.61	24.93	595033	15211	1131	6775	4069	1174	3418	71.92	559	24.81	583.7	127.1	1.568	13.99	45687	549346	38	45.74	42.22	1301034
23:40:02	0.0	0.0	68.4	0.0	163918	228445	189065	31.76	24.58	15.88	16.62	18.8	23.9	575033	14263	1094	6775	3941	1137	3310	69.65	541.3	24.03	565.3	123.1	1.518	14.32	44086	530947	37.92	45.64	42.14	1260029.6
23:45:02	0.0	0.0	65.7	0.0	158210	220534	182462	30.03	23.45	15.19	15.9	18.01	22.87	555033	13354	1057	6775	3812	1100	3202	67.38	523.7	23.25	546.9	119.1	1.469	14.57	42524	512509	37.84	45.53	42.05	1218937.5
23:50:02	0.0	0.0	63.1	0.0	152506	212633	175844	28.36	22.34	14.5	15.18	17.23	21.85	535033	12483	1020	6775	3683	1063	3084	65.11	506	22.46	528.4	115	1.419	14.75	41000	494033	37.75	45.43	41.95	117754.6
23:55:02	0.0	0.0	60.5	0.0	146807	204741	169214	26.74	21.25	13.83	14.47	16.45	20.84	515033	11649	982.5	6775	3554	1026	2986	62.82	488.3	21.67	509.9	111	1.37	14.87	39512	475521	37.66	45.32	41.84	1136476.9

9.6 Appendix C-4: Slightly cloudy day parametric table data

Time	DNI	DNI Avr	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWw]	BFP Power [kWw]	CEP Power [kWw]	ACC Power [kWw]	IDF Power [kWw]	FDF Power [kWw]	PAE Power [kWw]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Net Power [kWw]	n _O [%]	n _G [%]	n _N [%]	Heat_In [kWt]		
23:59:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
00:04:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
00:09:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
00:14:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
00:19:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
00:24:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
00:29:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
00:34:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
00:39:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
00:44:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
00:49:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
00:54:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
00:59:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
01:04:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
01:09:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
01:14:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
01:19:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
01:24:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
01:29:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
01:34:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
01:39:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
01:44:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
01:49:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
01:54:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
01:59:53	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
02:04:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
02:09:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
02:14:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
02:19:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
02:24:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
02:29:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
02:34:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
02:39:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
02:44:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20																				

Time	DNI	DNI Avr	Solar Power [kW]	HPH Bypass [kg/s]	HPT Power [kW]	IPT Power [kW]	LPT Power [kW]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kW]	BFP Power [kW]	CEP Power [kW]	ACC Power [kW]	IDF Power [kW]	FDF Power [kW]	PAF Power [kW]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO₂} [kg/s]	m _{SO₂} [kg/s]	m _{Spray} [kg/s]	Aux Power [kW]	Net Power [kW]	n _O [%]	n _G [%]	n _N [%]	Heat_In [kW]	
04:09:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3331	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:14:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3331	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:19:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3331	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:24:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3331	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:29:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3331	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:34:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3331	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:39:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3331	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:44:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3331	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:49:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3331	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:54:52	0.0	0.0	60.0	0.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3331	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
05:04:52	0.0	0.0	65.2	0.0	0.0	151497	211235	174671	28.07	22.16	14.38	15.05	17.09	21.67	531492	12333	1013	6775	3660	1056	3075	64.7	502.9	22.32	525.1	114.3	1.41	14.78	40734	490758	37.74	45.41	41.93	1170453.3
05:09:52	0.0	0.0	67.9	0.0	0.0	162907	227044	187897	31.45	24.37	15.75	16.49	18.66	23.72	571492	14099	1088	6775	3789	1093	3183	66.98	520.6	23.11	543.6	118.3	1.46	14.61	42251	509241	37.83	45.52	42.03	1211652.8
05:14:52	0.0	0.0	70.6	0.0	0.0	168619	234963	194489	33.22	25.52	16.45	17.23	19.46	24.75	591492	15041	1125	6775	4046	1167	3399	71.52	555.8	24.67	580.4	126.4	1.559	14.05	43807	527685	37.91	45.62	42.12	1252760.7
05:19:52	0.0	0.0	73.3	0.0	0.0	174335	242892	201066	35.05	26.68	17.16	17.98	20.28	25.78	611492	16023	1200	6775	4174	1204	3507	73.78	573.4	25.45	598.8	130.4	1.608	13.66	47035	564457	38.06	45.81	42.29	1334715.2
05:24:52	0.0	0.0	76.1	0.0	0.0	180055	250833	207628	36.93	27.87	17.88	18.74	21.1	26.83	631492	17048	1200	6775	4302	1241	3614	76.04	591	26.23	617.1	134.4	1.658	13.19	48711	582781	38.13	45.91	42.37	1375568.4
05:29:52	0.0	0.0	78.9	0.0	0.0	185779	258784	214175	38.88	29.08	18.6	19.51	21.93	27.87	651492	18116	1237	6775	4429	1278	3721	78.29	608.5	27.01	635.4	138.3	1.707	12.63	50431	601061	38.19	46	42.44	1416340.8
05:34:52	0.0	0.0	81.7	0.0	0.0	191506	266747	220707	40.89	30.3	19.34	20.29	22.77	28.92	671492	19230	1275	6775	4557	1315	3828	80.54	626	27.79	653.7	142.3	1.756	11.99	52195	619297	38.25	46.09	42.5	1457035.6
05:39:52	0.0	0.0	84.6	0.0	0.0	197238	274722	227224	42.97	31.5	20.08	21.08	23.62	29.97	691492	20391	1312	6775	4684	1351	3935	82.93	643.4	28.56	670.1	146.3	1.805	11.25	54007	637485	38.31	46.17	42.57	1497654.7
05:44:52	0.0	0.0	87.5	0.0	0.0	202973	282708	233725	45.11	32.82	20.83	21.88	24.48	31.03	711492	21601	1350	6775	4810	1388	4041	85.03	660.9	29.34	690.1	150.2	1.854	10.41	57177	654375	38.29	46.25	42.54	1597199.8
05:49:52	0.0	0.0	90.4	0.0	0.0	208711	290706	240210	47.32	34.1	21.59	22.7	25.35	32.09	731492	22862	1387	6775	4937	1425	4147	87.27	678.2	30.11	708.3	154.2	1.902	9.471	59027	672465	38.34	46.34	42.6	1578671.9
05:54:52	0.0	0.0	93.4	0.0	0.0	214453	298717	246880	49.61	35.43	22.36	23.53	26.24	34.23	751492	24176	1425	6775	5063	1461	4254	89.5	695.6	30.88	726.4	158.1	1.951	8.422	60991	690501	38.38	46.41	42.65	1619072.7
05:59:52	0.0	0.0	96.4	0.0	0.0	220198	306740	253630	51.38	36.76	23.14	24.37	27.13	36.23	771492	25546	1462	6775	5190	1497	4360	91.73	712.9	31.65	740.6	165.6	2.043	5.766	64896	726594	38.43	46.49	42.7	16659403.5
06:04:52	339.9	85.0	99.1	6975.0	19.7	225317	315197	259782	52.41	36.75	24.05	25.25	28.07	35.24	791492	26812	1503	6775	5302	1530	4454	93.71	728.3	32.33	760.6	165.6	2.043	5.766	64896	726594	38.43	46.49	42.7	16659403.5
06:09:52	462.2	200.5	99.2	16460.0	46.6	225482	317196	261197	50.1	35.12	24.34	25.43	28.38	35.35	795033	26850	1514	6775	5305	1531	4457	93.78	728.8	32.35	761.1	165.7	2.044	5.766	64896	726594	38.43	46.49	42.7	16659403.5
06:14:52	514.5	329.2	98.7	27018.0	76.5	221445	317938	261503	47.05	33.04	24.52	25.48	28.33	35.26	795033	26850	1514	6775	5305	1531	4457	93.78	728.8	32.35	761.1	165.7	2.044	5.766	64896	726594	38.43	46.49	42.7	16659403.5
06:19:52	565.1	470.4	98.1	38614.0	109.5	223495	318545	261835	43.72	30.74	24.71	25.52	28.33	35.15	795033	26345	1524	6775	5262	1518	4439	93.6	726.1	32.09	753.3	164.3	2.028	4.581	64423	730600	39.08	47.35	43.42	1687981.4
06:24:52	606.8	537.2	97.9	44090.0	125.1	223005	318879	261991	42.15	29.67	24.79	25.54	28.42	35.1	795033	26137	1528	6775	5244	1513	4405	92.69	720.4	31.98	752.2	163.8	2.021	4.304	64180	730840	39.23	47.35	43.52	1679077.8
06:29:52	644.3	582.7	97.7	47826.0	135.7	222672	319108	262096	41.08	28.94	24.81	25.57	28.46	35.07	795033	26082	1530	6775	5237	1511	4400	92.57	719.5	31.94	751.3	163.6	2.018	4.203	64092	730927	39.28	47.47	43.65	1676739.5
06:34:52	678.0	623.5	97.5	51181.0	145.3	222372	319313	262191	40.12	28.27	24.95	25.56	28.44	35.07	795033	26082	1530	6775	5237	1511	4400	92.57	719.5	31.94	751.3	163.6	2.018	4.203	64092	730927	39.28	47.47	43.65	1676739.5
06:39:52	712.2	660.3	97.4	54199.0	153.9	222103	319498	262275	39.26	27.68	24.96	25.58	28.47	35.01	795033	26082	1530	6775	5237	1509	4395	92.47	718.7	31.9	750.5	163.4	2.014	4.112	64013	731005	39.33	47.53	43.7	1677553.8
06:44:52	740.0	693.6	97.3	56933.0	161.7	221859	319665	262352	38.48	27.14	25	25.59	28.49	34.98	795033	25934	1533	6775	5226	1508	4390	92.37	717.9	31.87	749.7	163.2	2.014	4.03	63942	731076	39.37	47.58	43.75	1671045.7
06:49:52	761.9	723.0	97.2	59346.0	168.6	221644	319813	262419	37.79	26.67	25.04	25.6	28.5	34.96	795033	25880	1534	6775	5221	1507	4386	92.29	717.3	31.84	749	163.1	2.012	3.957	63879	731138	39.41	47.62	43.79	1669538.4
06:54:52	786.6	750.2	97.1	61574.0	175.0	221445	319950	262481	37.16	26.23	25.08	25.61	28.51	34.94	795033	25880	1535	6775	5213	1505	4383	92.21	716.7	31.81	748.4	162.9	2.01	3.89	63821	731196	39.45	47.66	43.83	1668147.5
07:01:52	802.6	772.8	97.0	63430.0	180.3	221280	320063	262532	36.63	25.86	25.11																							

Time	DNI	DNI	Solar Field Power [kWt]	MCR [%]	HPH Bypass [kg/s]	HPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWm]	BTP Power [kWm]	CEP Power [kWm]	ACC Power [kWm]	IDF Power [kWm]	FDF Power [kWm]	PAF Power [kWm]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWm]	Net Power [kWm]	n _O [%]	n _G [%]	n _N [%]	Heat In [kWt]	
08:26:03	1005.7	993.2	96.1	81525.0	232.1	219672	321176	263027	31.5	22.3	25.39	25.69	28.61	34.75	795033	25392	1544	6775	5178	1494	4350	91.53	711.3	31.58	742.8	161.7	1.995	3.287	63306	731705	39.77	48.02	44.29	1655715.9
08:31:03	1016.1	1002.2	96.1	82262.0	234.2	219607	321221	263047	31.29	22.15	25.41	25.69	28.61	34.75	795033	25376	1544	6775	5177	1494	4349	91.5	711.1	31.57	742.6	161.7	1.995	3.265	63287	731723	39.79	48.03	44.21	1655257.7
08:36:03	1024.1	1011.3	96.0	83008.0	236.4	219541	321267	263067	31.08	22	25.42	25.7	28.62	34.74	795033	25359	1544	6775	5175	1493	4347	91.48	710.9	31.56	742.4	161.6	1.994	3.242	63268	731742	39.8	48.04	44.22	1654793.8
08:41:03	1030.8	1019.2	96.0	83652.0	238.2	219484	321307	263085	30.9	21.88	25.43	25.7	28.62	34.73	795033	25345	1545	6775	5174	1493	4346	91.45	710.8	31.55	742.2	161.6	1.994	3.222	63252	731758	39.81	48.06	44.23	1654393.5
08:46:03	1031.4	1025.6	96.0	84179.0	239.8	219437	321340	263099	30.75	21.77	25.44	25.7	28.62	34.73	795033	25334	1545	6775	5173	1493	4345	91.44	710.6	31.55	742.1	161.6	1.993	3.207	63238	731772	39.82	48.07	44.24	1654065.6
08:51:03	1043.7	1032.5	96.0	84747.0	241.4	219387	321374	263114	30.59	21.66	25.44	25.7	28.63	34.72	795033	25322	1545	6775	5172	1492	4345	91.42	710.5	31.54	741.9	161.5	1.993	3.189	63224	731786	39.83	48.08	44.25	1653771.9
08:56:03	1049.3	1038.8	95.9	85263.0	242.9	219341	321406	263128	30.31	21.56	25.45	25.71	28.63	34.71	795033	25310	1545	6775	5171	1492	4344	91.4	710.3	31.53	741.8	161.5	1.992	3.174	63211	731799	39.83	48.08	44.26	1653391.8
09:01:03	1053.2	1044.4	95.9	85724.0	244.8	219300	321435	263141	30.31	21.47	25.46	25.71	28.63	34.71	795033	25300	1546	6775	5170	1492	4343	91.38	710.2	31.53	741.6	161.5	1.992	3.163	63199	731811	39.84	48.09	44.27	1653105.3
09:06:03	1059.2	1051.3	95.9	86295.0	245.8	219250	321464	263156	30.15	21.36	25.47	25.71	28.63	34.71	795033	25288	1546	6775	5169	1491	4343	91.36	710.1	31.52	741.5	161.4	1.992	3.142	63184	731825	39.85	48.1	44.28	1652505.6
09:11:03	1063.7	1056.3	95.9	86704.0	247.0	219213	321495	263167	30.04	21.28	25.48	25.71	28.64	34.7	795033	25279	1546	6775	5168	1491	4341	91.35	710	31.52	741.4	161.4	1.991	3.13	63174	731835	39.86	48.11	44.29	1652496.4
09:16:03	1069.6	1061.4	95.9	87121.0	248.2	219176	321521	263178	29.92	21.2	25.49	25.71	28.64	34.7	795033	25270	1547	6775	5167	1491	4341	91.33	709.8	31.51	741.3	161.4	1.991	3.117	63163	731846	39.86	48.12	44.29	1652327
09:21:03	1072.7	1066.3	95.8	87520.0	249.3	219141	321546	263189	29.8	21.12	25.49	25.71	28.64	34.7	795033	25261	1547	6775	5166	1491	4340	91.32	709.7	31.51	741.3	161.4	1.991	3.105	63153	731856	39.87	48.13	44.3	1651989
09:26:03	1073.4	1069.8	95.8	87813.0	250.2	219115	321564	263197	29.72	21.06	25.49	25.72	28.64	34.69	795033	25251	1547	6775	5165	1490	4339	91.3	709.6	31.5	741	161.3	1.99	3.09	63140	731869	39.88	48.13	44.31	1651673.7
09:31:03	1074.1	1072.5	95.8	88028.0	250.8	219086	321582	263205	29.64	21	25.5	25.72	28.64	34.69	795033	25249	1547	6775	5165	1490	4339	91.3	709.6	31.5	741	161.3	1.99	3.087	63138	731871	39.88	48.14	44.31	1651622
09:36:03	1073.1	1073.3	95.8	88099.0	251.0	219089	321582	263205	29.64	21	25.5	25.72	28.64	34.69	795033	25249	1547	6775	5165	1490	4339	91.3	709.6	31.5	741	161.3	1.99	3.086	63137	731872	39.88	48.14	44.31	1651604
09:41:51	1073.3	1073.5	95.8	88111.0	251.0	219089	321582	263205	29.64	21	25.5	25.72	28.64	34.69	795033	25249	1547	6775	5165	1490	4339	91.3	709.6	31.5	741	161.3	1.99	3.086	63137	731872	39.88	48.14	44.31	1651604
09:46:51	1070.2	1072.7	95.8	88045.0	250.9	219094	321578	263203	29.66	21.01	25.5	25.72	28.64	34.69	795033	25249	1547	6775	5165	1490	4339	91.3	709.6	31.5	741	161.3	1.99	3.086	63137	731872	39.88	48.14	44.31	1651604
09:51:51	1078.8	1073.8	95.8	88140.0	251.1	219086	321584	263206	29.63	20.99	25.5	25.72	28.64	34.69	795033	25248	1547	6775	5164	1490	4338	91.28	709.5	31.49	740.9	161.3	1.99	3.074	63127	731882	39.89	48.15	44.32	1651343.6
09:56:51	1093.5	1078.9	95.8	88559.0	252.3	219049	321610	263217	29.51	20.91	25.5	25.72	28.65	34.68	795033	25219	1547	6775	5163	1490	4337	91.25	709.2	31.48	740.6	161.2	1.989	3.046	63104	731905	39.9	48.16	44.34	1650783.1
10:01:43	1089.8	1083.1	95.8	88899.0	253.3	219019	321631	263226	29.42	20.84	25.51	25.72	28.65	34.67	795033	25212	1548	6775	5162	1489	4336	91.24	709.1	31.48	740.5	161.2	1.989	3.036	63095	731914	39.91	48.17	44.34	1650565.8
10:06:43	1097.6	1089.9	95.7	89462.0	254.9	218969	321665	263241	29.26	20.73	25.52	25.72	28.65	34.67	795033	25209	1548	6775	5162	1489	4336	91.24	709.1	31.48	740.5	161.2	1.989	3.032	63092	731917	39.91	48.17	44.35	1650487
10:11:43	1095.8	1094.2	95.7	89811.0	255.9	218937	321687	263251	29.16	20.64	25.52	25.72	28.65	34.67	795033	25209	1548	6775	5162	1489	4336	91.24	709.1	31.48	740.5	161.2	1.989	3.032	63092	731917	39.91	48.17	44.35	1650487
10:16:43	1095.7	1095.7	95.7	89838.0	256.3	218917	321695	263254	29.12	20.67	25.52	25.72	28.65	34.67	795033	25209	1548	6775	5163	1490	4338	91.27	709.3	31.49	740.7	161.3	1.99	3.06	63115	731893	39.9	48.15	44.33	1651068.5
10:21:43	1065.3	1089.6	95.7	89435.0	254.8	218971	321664	263241	29.26	20.74	25.52	25.72	28.65	34.68	795033	25220	1547	6775	5163	1490	4338	91.27	709.3	31.49	740.7	161.3	1.99	3.06	63115	731893	39.9	48.15	44.33	1651068.5
10:26:43	1076.5	1084.3	95.8	89002.0	253.6	219010	321637	263239	29.39	20.82	25.51	25.72	28.65	34.68	795033	25229	1547	6775	5167	1491	4340	91.33	709.8	31.51	741.2	161.4	1.991	3.109	63157	731853	39.87	48.12	44.3	1652072.2
10:31:33	1071.7	1064.6	95.8	87986.0	249.0	219153	321577	263186	30.91	21.14	25.49	25.71	28.62	34.7	795033	25362	1545	6775	5174	1493	4347	91.46	710.9	31.56	742.3	161.6	1.994	3.232	63260	731750	39.8	48.05	44.23	1654591.3
10:41:33	1077.9	1018.4	96.0	83595.0	238.1	219489	321303	263083	30.91	21.89	25.43	25.7	28.62	34.73	795033	25342	1545	6775	5174	1493	4346	91.45	710.7	31.55	742.2	161.6	1.994	3.217	63248	731763	39.81	48.06	44.23	1654290.8
10:46:33	1087.5	1021.2	96.0	83417.0	238.7	219469	321317	263089	30.85	21.85	25.43	25.7	28.62	34.73	795033	25342	1545	6775	5170	1492	4343	91.39	710.3	31.53	741.7	161.5	1.992	3.167	63204	731804	39.84	48.09	44.26	1653263.2
10:51:33	1097.6	1041.3	95.9	85470.0	243.5	219373	321419	263134	30.38	21.52	25.46	25.7	28.63	34.72	795033	25306	1546	6775	5170	1492	4343	91.39	710.3	31.53	741.7	161.5	1.992	3.167	63204	731804	39.84	48.09	44.26	1653263.2
10:56:33	1095.6	1089.7	95.7	89439.0	243.5	219373	321419	263134	30.38	21.52	25.46	25.7	28.63	34.72	795033	25306	1546	6775	5170	1492	4343	91.39	710.3	31.53	741.7	161.5	1.992	3.167	63204	731804	39.84	48.09	44.26	1653263.2
11:01:23	1109.3	1097.5	95.7	90083.0	256.7	218914	321704	263258	29.08	20.61	25.53	25.72	28.65	34.67	795033	25206	1548	6775	5161	1489	4335	91.22	709	31.47	740.4	161.2	1.989	3.02	63081	731927	39.92	48.18	44.35	1650337.7
11:06:23	1100.3	1100.7	95.7	90346.0	257.5	218891	321720	263265	29.01	20.56	25.53	25.73	28.65	34.67	795033	25200	1548	6775	5161	1489	4335	91.22	709	31.47	740.4	161.2	1.989	3.02	63081	731927	39.92	48.18	44.35	1650337.7
11:11:23	345.0	912.6	96.4	74902.0	213.1	220260	320768	262847	39.37	23.6	25.29	25.66	28.58	34.82	795033	25537	1541	6775	5191	1498	4361	91.75	713.1	31.66	744.7	162.1	2	3.487	63476	731557	39.67	47.9	44.07	1659837.9
11:16:23	124.0																																	

Time	DNI	DNI Avr	Solar Field Power [kWt]	MCR [%]	HPH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWt]	BFP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	FDF Power [kWt]	PAF Power [kWt]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWt]	Net Power [kWt]	n _O [%]	n _G [%]	n _N [%]	Heat_in [kWt]	
12:41:03	0.0	382.5	98.5	31396.0	89.0	224141	318105	261629	45.79	32.17	24.59	25.49	28.36	35.22	795033	26508	1521	6775	5276	1522	4432	93.26	724.8	32.17	756.9	164.8	2.033	4.737	64634	730411	38.97	47.13	43.3	1687033.6	
12:46:03	0.0	139.0	99.5	11409.0	32.3	225936	316890	261050	51.56	36.12	24.26	25.42	28.26	35.39	795033	26967	1512	6775	5315	1534	4465	93.95	730.2	32.41	762.5	166	2.048	5.394	65149	729881	38.65	46.78	42.94	1699595.3	
12:51:03	0.0	31.0	99.9	2544.0	7.2	22735	316353	260788	54.13	37.86	24.11	25.38	28.21	35.47	795033	27173	1508	6775	5333	1539	4480	94.26	732.6	32.52	765	166.6	2.055	5.658	65389	729643	38.51	46.62	42.94	1705180.1	
12:56:03	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6	
13:01:03	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6	
13:06:03	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6	
13:11:03	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6	
13:16:03	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6	
13:21:03	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6	
13:26:03	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6	
13:31:03	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6	
13:36:03	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6	
13:41:03	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6	
13:46:03	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6	
13:51:03	0.0	0.0	99.6	8208.0	11.6	226594	316447	260835	53.68	37.56	24.14	25.39	28.22	35.46	795033	27337	1509	6775	5322	1536	4470	94.06	731.1	32.45	763.4	166.2	2.051	5.49	65236	729795	38.6	46.72	42.89	1701971.1	
13:56:03	0.0	1101.7	275.4	98.9	22608.0	23.2	226924	316696	52.49	36.75	24.21	25.4	28.24	35.42	795033	27041	1511	6775	5293	1527	4447	93.56	727.2	32.28	759.3	165.3	2.04	5.06	64848	730179	38.83	46.97	43.14	1692551.8	
14:01:03	0.0	1089.3	821.0	96.8	67389.0	191.6	218964	321667	263242	29.15	20.66	25.53	25.72	28.65	34.67	795033	25211	1548	6775	5162	1489	4336	91.24	709.1	31.48	740.5	161.2	1.989	3.034	63094	731915	39.91	48.17	44.34	1650535
14:06:03	1095.1	1094.8	95.7	89367.0	254.6	218977	321659	263249	29.28	20.75	25.52	25.72	28.65	34.67	795033	25211	1547	6775	5162	1489	4336	91.24	709.1	31.48	740.5	161.2	1.989	3.034	63094	731915	39.91	48.17	44.34	1650535	
14:11:03	1083.9	1089.3	95.7	89496.0	255.0	218970	321664	263241	29.26	20.74	25.52	25.72	28.65	34.68	795033	25220	1547	6775	5163	1490	4337	91.25	709.2	31.48	740.6	161.2	1.989	3.034	63094	731915	39.91	48.17	44.34	1650793.1	
14:16:03	1086.7	1088.8	95.7	89367.0	254.6	218977	321659	263249	29.28	20.75	25.52	25.72	28.65	34.67	795033	25211	1547	6775	5162	1489	4336	91.24	709.1	31.48	740.5	161.2	1.989	3.034	63094	731915	39.91	48.17	44.34	1650793.1	
14:21:03	1093.2	1089.7	95.7	89496.0	255.0	218970	321664	263241	29.26	20.74	25.52	25.72	28.65	34.68	795033	25220	1547	6775	5163	1490	4337	91.25	709.2	31.48	740.6	161.2	1.989	3.034	63094	731915	39.91	48.17	44.34	1650793.1	
14:26:03	1099.2	1099.8	95.7	89529.0	254.9	218963	321669	263243	29.24	20.72	25.52	25.72	28.65	34.68	795033	25208	1548	6775	5161	1489	4335	91.23	708.9	31.47	740.4	161.2	1.989	3.034	63094	731915	39.91	48.17	44.34	1650793.1	
14:31:03	1112.2	1097.8	95.7	90110.0	256.8	218912	321705	263259	29.07	20.61	25.53	25.72	28.65	34.67	795033	25215	1548	6775	5161	1489	4335	91.22	708.9	31.47	740.4	161.2	1.989	3.034	63094	731915	39.91	48.17	44.34	1650793.1	
14:36:03	1105.0	1102.4	95.7	90484.0	257.9	218879	321728	263269	28.97	20.53	25.54	25.72	28.65	34.67	795033	25213	1548	6775	5161	1489	4335	91.22	708.9	31.47	740.4	161.2	1.989	3.034	63094	731915	39.91	48.17	44.34	1650793.1	
14:41:03	1097.5	1103.5	95.7	90319.0	258.1	218871	321734	263271	28.94	20.52	25.54	25.72	28.65	34.67	795033	25213	1548	6775	5161	1489	4335	91.22	708.9	31.47	740.4	161.2	1.989	3.034	63094	731915	39.91	48.17	44.34	1650793.1	
14:46:03	1084.7	1093.5	95.7	89754.0	255.8	218843	321683	263249	29.01	20.67	25.52	25.72	28.65	34.67	795033	25213	1548	6775	5161	1489	4335	91.22	708.9	31.47	740.4	161.2	1.989	3.034	63094	731915	39.91	48.17	44.34	1650793.1	
14:51:03	1075.2	1086.2	95.8	89153.0	254.0	218996	321646	263233	29.34	20.79	25.51	25.72	28.65	34.69	795033	25240	1547	6775	5163	1490	4338	91.26	709.3	31.49	740.9	161.3	1.99	3.056	63112	731886	39.89	48.15	44.32	1651259.8	
14:56:03	1075.2	1086.2	95.8	89153.0	254.0	218996	321646	263233	29.34	20.79	25.51	25.72	28.65	34.69	795033	25240	1547	6775	5163	1490	4338	91.26	709.3	31.49	740.9	161.3	1.99	3.056	63112	731886	39.89	48.15	44.32	1651259.8	
15:01:03	1075.2	1086.2	95.8	89153.0	254.0	218996	321646	263233	29.34	20.79	25.51	25.72	28.65	34.69	795033	25240	1547	6775	5163	1490	4338	91.26	709.3	31.49	740.9	161.3	1.99	3.056	63112	731886	39.89	48.15	44.32	1651259.8	
15:06:03	1066.1	1075.9	95.8	88312.0	251.6	219071	321594	263210	29.58	20.96	25.5	25.72	28.64	34.7	795033	25262	1546	6775	5165	1490	4339	91.29	709.5	31.5	740.9	161.3	1.99	3.088	63139	731876	39.88	48.14	44.32	1651374.7	
15:11:03	1081.5	1078.3	95.8	88089.0	251.0	219091	321581	263204	29.64	21	25.5	25.72	28.64	34.7	795033	25262	1546	6775	5165	1490	4339	91.29	709.5	31.5	740.9	161.3	1.99	3.088	63139	731876	39.88	48.14	44.32	1651374.7	
15:16:03	1084.3	1073.2	95.8	88089.0	251.0	219091	321581	263204	29.64	21	25.5	25.72	28.64	34.7	795033	25262	1546	6775	5165	1490	4339	91.29	709.5	31.5	740.9	161.3	1.99	3.088	63139	731876	39.88	48.14	44.32	1651374.7	
15:21:03	1084.3	1073.2	95.8	88089.0	251.0	219091	321581	263204	29.64	21	25.5	25.72	28.64	34.7	795033	25262	1546	6775	5165	1490	4339	91.29	709.5	31.5	740.9	161.3	1.99	3.088	63139	731876	39.88	48.14	44.32		

Time	DNI	DNI Avr	MCR [%]	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWt]	IPT Power [kWt]	LPT Power [kWt]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWt]	BFP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	FDF Power [kWt]	PAF Power [kWt]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWt]	Net Power [kWt]	n _O [%]	n _G [%]	n _N [%]	Heat_In [kWt]
16:56:03	316.0	79.0	99.7	6484.0	18.3	226380	316591	260905	52.99	37.09	24.18	25.4	28.23	35.44	795033	27081	1510	6775	5325	1536	4473	94.12	731.5	32.47	763.9	166.3	2.052	5.541	65282	729749	38.57	46.69	42.86	1707686.9
17:01:03	199.6	128.9	99.5	10581.0	25.9	226011	316840	261025	51.8	36.28	24.25	25.41	28.25	35.4	795033	26986	1512	6775	5317	1534	4467	93.98	730.4	32.42	762.7	166.1	2.049	5.419	65172	729859	38.54	46.76	42.93	1700116.6
17:06:03	578.2	273.5	98.9	22445.0	63.6	224944	317560	261371	48.37	33.94	24.44	25.46	28.31	35.3	795033	26713	1517	6775	5294	1527	4447	93.57	727.2	32.28	759.4	165.3	2.04	5.063	64853	730174	38.82	46.97	43.14	1692639.9
17:11:03	569.8	415.9	98.4	24137.0	96.8	223896	318272	261708	45.31	31.63	24.63	25.5	28.37	35.19	795033	26446	1522	6775	5271	1521	4428	93.16	724.1	32.14	756.9	164.8	2.031	4.715	64614	730483	39.07	47.17	43.34	1685314.1
17:16:03	181.3	382.2	98.5	31374.0	88.9	224143	318104	261629	45.8	32.18	24.59	25.49	28.36	35.22	795033	26509	1521	6775	5276	1522	4432	93.26	724.8	32.17	756.9	164.8	2.033	4.798	64614	730410	38.97	47.13	43.32	1687047.4
17:21:03	534.3	465.9	98.2	38242.0	108.4	223528	318522	261825	43.83	30.82	24.7	25.52	28.39	35.16	795033	26353	1524	6775	5263	1518	4421	93.02	722.9	32.09	754.9	164.4	2.028	4.592	64432	730590	39.08	47.25	43.42	1687740.7
17:26:03	753.9	509.8	98.0	41848.0	128.7	223206	318743	261927	42.79	30.11	24.76	25.53	28.41	35.12	795033	26272	1526	6775	5255	1516	4415	92.9	722	32.05	753.9	164.1	2.025	4.484	64237	730685	39.13	47.31	43.48	1680482.5
17:30:03	742.6	553.0	97.8	45394.0	143.8	222889	318959	262028	41.78	29.42	24.81	25.55	28.43	35.09	795033	26192	1527	6775	5248	1514	4409	92.79	718.1	31.88	749.8	163.2	2.021	4.404	63955	731063	39.17	47.37	43.54	1678261.2
17:35:03	719.1	687.5	97.3	56428.0	160.3	221904	319634	262337	38.63	27.24	24.99	25.59	28.48	34.99	795033	25945	1532	6775	5227	1508	4386	92.39	717.3	31.84	749.8	163.1	2.012	4.355	63877	731440	39.41	47.62	43.79	1669486.1
17:40:03	680.5	724.0	97.2	59426.0	168.1	221637	319818	262421	37.77	26.65	25.04	25.6	28.5	34.96	795033	25878	1534	6775	5226	1508	4380	92.37	717.9	31.87	749.7	163.2	2.014	4.026	63938	731080	39.38	47.58	43.75	1670957.8
17:45:03	639.3	695.3	97.3	57074.0	162.1	221846	319674	262355	38.44	27.11	25	25.59	28.49	34.98	795033	25950	1533	6775	5232	1510	4395	92.48	718.7	31.9	750.5	163.4	2.016	4.118	64018	731000	39.33	47.52	43.7	1672797.1
17:50:03	592.7	657.9	97.4	53999.0	153.4	222121	319485	262270	39.34	27.72	24.95	25.58	28.47	35.01	795033	25999	1531	6775	5232	1510	4395	92.48	718.7	31.9	750.5	163.4	2.016	4.118	64018	731000	39.33	47.52	43.7	1672797.1
17:55:03	556.0	617.1	97.6	50653.0	143.8	222419	319281	262166	40.28	28.38	24.9	25.57	28.45	35.04	795033	26074	1530	6775	5238	1511	4400	92.59	719.6	31.94	751.5	163.6	2.018	4.219	64106	730914	39.27	47.47	43.64	1674970.9
18:00:03	521.0	577.5	97.7	47401.0	128.7	222710	319082	262198	41.2	29.66	24.85	25.56	28.44	35.07	795033	26147	1528	6775	5245	1513	4406	92.7	720.5	31.98	752.4	163.8	2.021	4.317	64191	730829	39.22	47.41	43.58	1677005.2
18:05:03	481.6	538.1	97.8	44165.0	134.5	222999	318884	261993	42.13	29.66	24.8	25.54	28.42	35.1	795033	26219	1527	6775	5251	1515	4411	92.82	721.4	32.02	753.1	164	2.026	4.504	64276	730745	39.17	47.35	43.52	1679030.7
18:10:03	447.1	501.7	98.0	41176.0	116.8	223666	318701	261908	42.99	30.25	24.75	25.53	28.41	35.13	795033	26287	1525	6775	5257	1517	4416	92.92	722.2	32.06	755.1	164.2	2.028	4.594	64434	730589	39.07	47.25	43.42	1682781.5
18:15:03	409.8	465.1	98.2	38177.0	108.3	223534	318518	261823	43.85	30.84	24.7	25.52	28.39	35.16	795033	26355	1524	6775	5263	1519	4421	93.02	723	32.09	755	164.4	2.03	4.686	64516	730508	38.91	47.13	43.36	1684713.1
18:20:03	371.8	427.6	98.3	35095.0	99.5	223810	318390	261795	44.73	31.45	24.65	25.51	28.37	35.18	795033	26424	1523	6775	5269	1520	4432	93.25	723.8	32.13	755.8	164.6	2.036	4.905	64710	730315	38.97	47.13	43.3	1686830.2
18:25:03	317.1	386.5	98.5	31720.0	89.9	224112	318125	261639	45.7	32.11	24.59	25.49	28.36	35.21	795033	26501	1521	6775	5283	1524	4438	93.38	725.8	32.22	759.1	165	2.039	5.034	64825	730201	38.84	46.99	43.16	1692011.7
18:30:03	254.8	338.4	98.7	27774.0	78.7	224466	317884	261525	48.84	32.89	24.53	25.48	28.34	35.25	795033	26591	1519	6775	5291	1527	4445	93.53	726.9	32.27	759.1	165.3	2.039	5.034	64825	730201	38.84	46.99	43.16	1692011.7
18:35:03	200.7	285.9	98.9	23467.0	66.5	224853	317622	261401	49.36	33.74	24.46	25.46	28.32	35.29	795033	26689	1517	6775	5300	1529	4453	93.69	728.1	32.32	760.4	165.5	2.042	5.167	64945	730083	38.77	46.91	43.08	1694811.5
18:40:03	154.7	231.6	99.1	19012.0	53.8	225253	317351	261272	49.36	34.62	24.39	25.43	28.27	35.36	795033	26792	1515	6775	5308	1532	4459	93.83	729.3	32.37	761.5	165.8	2.045	5.291	65056	729973	38.7	46.84	43.01	1697436.1
18:45:03	115.5	181.2	99.3	14875.0	42.1	226361	317100	261151	50.56	35.43	24.32	25.43	28.27	35.39	795033	26887	1514	6775	5317	1534	4466	93.98	730.4	32.42	762.7	166.1	2.049	5.416	65169	729861	38.64	46.76	42.93	1700061.2
18:50:03	49.8	130.0	99.5	10669.0	30.2	226003	316845	261028	51.77	36.26	24.25	25.41	28.25	35.4	795033	26984	1512	6775	5317	1534	4466	93.98	730.4	32.42	762.7	166.1	2.052	5.536	65278	729753	38.58	46.7	42.86	1702593.6
18:55:03	5.1	81.6	99.7	6648.0	18.8	226361	316601	260910	52.94	37.05	24.18	25.4	28.23	35.44	795033	27078	1510	6775	5325	1536	4473	94.12	731.5	32.47	763.8	166.3	2.052	5.536	65278	729753	38.58	46.7	42.86	1702593.6
19:00:03	4.0	43.6	99.8	3579.0	10.1	226641	316415	260819	53.83	37.66	24.13	25.38	28.2	35.46	795033	27149	1508	6775	5331	1538	4478	94.22	732.3	32.51	764.7	166.5	2.054	5.628	65361	729671	38.53	46.64	42.81	1704528.2
19:05:03	2.8	4.1	158.9	1293.0	3.7	226847	316277	260723	54.77	38.3	24.08	25.37	28.2	35.49	795033	27226	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.724	65449	729583	38.48	46.59	42.75	1706597.8
19:10:03	2.5	3.6	100.0	296.4	0.8	226937	316216	260722	54.8	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.724	65453	729580	38.47	46.58	42.75	1706652.6
19:15:03	2.5	3.6	100.0	296.4	0.8	226937	316216	260722	54.8	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.724	65453	729580	38.47	46.58	42.75	1706652.6
19:20:03	2.5	3.6	100.0	296.4	0.8	226937	316216	260722	54.8	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.724	65453	729580	38.47	46.58	42.75	1706652.6
19:25:03	2.5	3.6	100.0	296.4	0.8	226937	316216	260722	54.8	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.724	65453	729580	38.47	46.58	42.75	1706652.6
19:30:03	2.5	3.6	100.0	296.4	0.8	226937	316216	260722	54.8	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.724	65453	729580	38.47	46.58	42.75	1706652.6
19:35:03	2.5	3.6	100.0	296.4	0.8	226937	316216	260722	54.8	38.33	24.08	25.37	28.2	35.49	795033	27228	1507	6775	5337	1540	4483	94.34	733.2	32.55	765.6	166.7	2.057	5.724	65453	729580	38.47	46.58	42.75	1706652.6
19:40:03	2.5	3.6	100.0	296.4	0.8	226937	316216	260722	5																									

Time	DNI	DNI Avr	Solar Field Power [kWg]	HPH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWm]	BFP Power [kWm]	CEP Power [kWm]	ACC Power [kWm]	IDF Power [kWm]	FDF Power [kWm]	PAF Power [kWm]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWm]	Net Power [kWm]	n _O [%]	n _G [%]	n _N [%]	Heat_In [kWt]	
21:10:02	0.0	0.6	100.0	0.0	0.1	226960	316201	260714	54.86	38.36	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65457	729576	38.47	46.58	42.75	1706755.4
21:15:02	0.0	0.7	100.0	0.0	0.1	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:20:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:25:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:30:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:35:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:40:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:45:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:50:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:55:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:00:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:05:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:10:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:15:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:20:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:25:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:30:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:35:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:40:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:45:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:50:02	0.0	0.0	100.0	0.0	0.0	221216	308162	254276	52.41	37	23.28	24.52	27.29	34.42	775033	25795	1469	6775	5212	1504	4378	92.12	716	31.78	747.7	162.8	2.008	7.041	63372	711661	38.43	46.51	42.7	1666537
22:55:02	0.0	0.0	93.9	0.0	0.0	215470	300136	247824	50.03	35.66	22.5	23.68	26.4	33.35	755033	24415	1431	6775	5086	1467	4272	89.9	698.7	31.01	729.6	158.8	1.96	8.225	61344	693689	38.39	46.43	42.66	1626218.3
23:00:02	0.0	0.0	90.9	0.0	0.0	209728	292124	241357	47.72	34.34	21.73	22.85	25.51	32.28	755033	23091	1394	6775	4959	1431	4166	87.66	681.3	30.24	711.5	154.9	1.911	9.294	59371	675562	38.35	46.35	42.61	1585830.3
23:05:02	0.0	0.0	88.0	0.0	0.0	209989	284123	234874	45.5	33.05	20.97	22.03	24.64	31.22	715033	21821	1356	6775	4833	1395	4060	85.43	663.9	29.47	693.3	150.9	1.862	10.25	57451	657582	38.3	46.27	42.55	1545370.6
23:10:02	0.0	0.0	85.1	0.0	0.0	198253	276195	228376	43.34	31.77	20.21	21.22	23.77	30.16	695033	20602	1319	6775	4706	1358	3953	83.19	646.5	28.7	675.1	147	1.813	11.11	54332	640701	38.32	46.19	42.58	1504838.6
23:15:02	0.0	0.0	82.2	0.0	0.0	192521	268158	221862	41.25	30.52	19.47	20.43	21.92	29.11	675033	19432	1281	6775	4552	1285	3740	78.69	611.6	27.15	638.7	139	1.715	12.53	50740	604293	38.2	46.01	42.45	1423551.6
23:20:02	0.0	0.0	79.4	0.0	0.0	186792	260193	215333	39.23	29.29	18.73	19.64	22.08	28.06	655033	18310	1244	6775	4434	1248	3633	76.44	594.1	26.37	620.4	135.1	1.666	13.1	49013	586020	38.14	45.92	42.38	1382793
23:25:02	0.0	0.0	76.6	0.0	0.0	181068	252240	208788	37.27	28.08	18	18.87	21.24	27.01	635033	17233	1206	6775	4324	1211	3526	74.18	576.5	25.59	602.1	131.1	1.617	13.58	47329	567704	38.07	45.83	42.3	1341954.2
23:30:02	0.0	0.0	73.8	0.0	0.0	175347	244297	202229	35.38	26.89	17.29	18.11	20.42	25.97	615033	16201	1169	6775	4197	1211	3310	69.65	541.3	24.81	583.7	127.1	1.568	13.99	45687	549346	38	45.74	42.22	1301034
23:35:02	0.0	0.0	71.1	0.0	0.0	169631	236366	195655	33.54	25.72	16.58	17.36	19.61	24.93	595033	15211	1131	6775	4069	1174	3418	71.92	559	24.81	583.7	127.1	1.568	13.99	45687	549346	38	45.74	42.22	1301034
23:40:02	0.0	0.0	68.4	0.0	0.0	163918	228445	189065	31.76	24.58	15.88	16.62	18.8	23.9	575033	14263	1094	6775	3941	1137	3310	69.65	541.3	24.81	583.7	127.1	1.568	13.99	45687	549346	38	45.74	42.22	1301034
23:45:02	0.0	0.0	65.7	0.0	0.0	158210	220534	182462	30.03	23.45	15.19	15.9	18.01	22.87	555033	13354	1057	6775	3812	1100	3202	67.38	523.7	23.25	546.9	119.1	1.469	14.57	44254	512509	37.84	45.53	42.05	1218937.6
23:50:02	0.0	0.0	63.1	0.0	0.0	152506	212633	175844	28.36	22.34	14.5	15.18	17.23	21.85	535033	12483	1020	6775	3683	1063	3094	65.11	506	22.46	528.4	115	1.419	14.75	41000	494033	37.75	45.43	41.95	117754.7
23:55:02	0.0	0.0	60.5	0.0	0.0	146807	204741	169214	26.74	21.25	13.83	14.47	16.45	20.84	515033	11649	982.5	6775	3554	1026	2986	62.82	488.3	21.67	509.9	111	1.37	14.87	39512	475521	37.66	45.32	41.84	1136476.9

9.7 Appendix C-5: Cloudless day parametric table data

Time	DNI	DNI Avr	Solar Power [kWt]	APH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	IPH 3 Bleed [kg/s]	IPH 2 Bleed [kg/s]	IPH 1 Bleed [kg/s]	Gross Power [kWw]	BFP Power [kWw]	CEP Power [kWw]	ACC Power [kWw]	IDF Power [kWw]	PDF Power [kWw]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWw]	Net Power [kWw]	n _O [%]	n _G [%]	n _N [%]	Heat _{In} [kWw]	
04:05:52	0.0	0.0	60.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:14:52	0.0	0.0	60.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:19:52	0.0	0.0	60.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:24:52	0.0	0.0	60.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:29:52	0.0	0.0	60.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:34:52	0.0	0.0	60.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:39:52	0.0	0.0	60.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:44:52	0.0	0.0	60.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:49:52	0.0	0.0	60.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:54:52	0.0	0.0	60.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
04:59:52	0.0	0.0	60.0	0.0	145798	203344	168038	26.46	21.06	13.71	14.35	16.32	20.66	511492	11505	975.9	6775	3531	1019	2966	62.42	485.1	21.53	506.6	110.3	1.361	14.88	39252	472240	37.64	45.3	41.82	1129158.5
05:04:52	0.0	0.0	65.2	0.0	151497	217335	174671	28.07	22.14	14.38	15.05	17.09	21.67	531492	12333	1013	6775	3660	1056	3075	64.7	502.9	22.32	525.1	114.3	1.41	14.78	40734	490758	37.74	45.41	41.93	1170453.3
05:09:52	0.0	0.0	67.9	0.0	162907	227044	187897	31.45	24.37	15.75	16.49	18.66	23.72	571492	14099	1088	6775	3789	1093	3183	66.98	520.6	23.11	543.6	118.3	1.46	14.61	42251	509241	37.83	45.52	42.03	1211652.8
05:14:52	0.0	0.0	70.6	0.0	166619	234963	194489	33.22	25.52	16.45	17.23	19.46	24.75	591492	15041	1125	6775	4046	1167	3399	71.52	555.8	24.67	580.4	126.4	1.559	14.05	45401	546091	37.99	45.72	42.21	1252780.6
05:19:52	0.0	0.0	73.3	0.0	174935	242892	201066	35.05	26.68	17.87	17.88	18.74	21.1	6283	16023	1162	6775	4302	1241	3614	76.04	591	26.23	617.1	134.4	1.658	13.19	46711	582781	38.13	45.91	42.37	1375568.4
05:24:52	0.0	0.0	76.1	0.0	180055	250833	207628	36.93	27.87	17.88	18.74	21.1	26.83	631492	17048	1200	6775	4557	1315	3828	80.54	626	27.79	653.7	142.3	1.756	11.99	52195	619287	38.25	46.09	42.5	1457035.7
05:29:52	0.0	0.0	78.9	0.0	185779	258784	214375	38.88	29.08	18.6	19.51	21.93	27.87	651492	18116	1237	6775	4684	1351	3935	82.79	643.4	28.56	670.1	146.3	1.805	11.25	54007	637485	38.31	46.17	42.57	1497654.6
05:34:52	0.0	0.0	81.7	0.0	191506	266747	220707	40.89	30.3	19.34	20.29	22.77	28.92	671492	19230	1275	6775	4810	1388	4041	85.03	660.9	29.34	690.1	150.2	1.854	10.41	57886	672604	38.43	46.44	42.71	1574899.8
05:39:52	0.0	0.0	84.6	0.0	197326	274722	227724	42.97	31.55	20.08	21.08	23.62	29.97	691492	20391	1312	6775	4926	1421	4138	87.06	676.7	30.04	706.6	153.8	1.898	9.299	58886	672604	38.43	46.44	42.71	1574899.8
05:44:52	0.0	0.0	87.5	0.0	202973	282708	237725	45.11	32.82	20.83	21.88	24.48	31.03	711492	21601	1350	6775	5039	1454	4233	89.07	692.2	30.73	722.9	157.4	1.942	8.039	60679	690809	38.59	46.64	42.87	1611234.4
05:49:52	150.0	55.0	92.8	1232.0	35.3	313338	299451	46.13	33	22.56	23.58	26.3	33.06	751492	23913	1430	6775	5138	1483	4317	90.83	705.9	31.33	737.1	160.5	1.98	6.468	62338	709147	38.84	46.96	43.16	1643039
05:54:52	315.0	133.8	95.2	25955.0	73.8	317865	308295	47.81	34.67	23.56	24.47	27.26	34.01	771492	24975	1474	6775	5259	1513	4418	92.95	722.4	32.07	754.4	164.2	2.026	5.111	64313	727171	39.02	47.07	43.37	1681520.2
05:59:52	465.0	390.8	98.2	38167.0	108.2	323535	318533	48.75	36.84	24.65	25.51	28.38	35.18	795033	26416	1523	6775	5268	1520	4425	93.12	723.7	32.13	755.7	164.5	2.03	4.675	64506	730517	39.03	47.2	43.48	1684825.5
06:04:52	601.0	502.5	97.6	49380.0	140.0	322537	319200	48.65	38.64	24.88	25.56	28.45	35.05	795033	26103	1529	6775	5241	1512	4403	92.64	720	31.96	745.1	163.7	2.019	4.259	64404	730879	39.14	47.31	43.48	1680370.7
06:09:52	644.0	555.5	97.5	52860.0	150.1	322222	319416	48.65	38.64	24.94	25.58	28.46	35.02	795033	26024	1531	6775	5234	1507	4397	92.51	719	31.92	750.8	163.5	2.017	4.152	64404	730879	39.14	47.31	43.48	1680370.7
06:14:52	680.0	609.3	97.1	55814.0	158.5	321959	319597	48.65	38.64	24.98	25.59	28.48	34.99	795033	25959	1532	6775	5228	1509	4392	92.41	718.2	31.88	750	163.3	2.015	4.064	63971	731047	39.31	47.45	43.68	1673591.2
06:19:52	713.0	659.5	97.2	58523.0	168.3	321717	319763	48.65	38.64	25.03	25.6	28.49	34.97	795033	25898	1533	6775	5223	1507	4388	92.32	717.5	31.85	749.3	163.1	2.013	3.982	63900	731117	39.4	47.61	43.78	1670052.7
06:24:52	750.0	723.3	97.0	62791.0	171.4	321556	319873	48.65	38.64	25.06	25.61	28.5	34.95	795033	25858	1534	6775	5214	1505	4381	92.17	716.4	31.83	748.7	163	2.011	3.927	63857	731164	39.43	47.64	43.81	1668925.1
06:29:52	785.0	750.8	96.9	64843.0	184.3	321154	320024	48.65	38.64	25.09	25.62	28.51	34.93	795033	25804	1535	6775	5209	1503	4376	92.07	715.6	31.76	747.2	162.7	2.007	3.764	63713	731303	39.52	47.73	43.89	1666107.8
06:34:52	801.0	772.8	96.9	65746.0	186.9	321074	320206	48.65	38.64	25.14	25.63	28.53	34.91	795033	25738	1536	6775	5206	1502	4373	92.01	715.1	31.74	746.8	162.6	2.006	3.715	63670	731343	39.54	47.76	43.94	1664572
06:39:52	820.0	794.0	96.8	67308.0	191.6	320928	320306	48.65	38.64	25.17	25.63	28.54	34.89	795033	25704	1537	6775	5206	1502	4373	92.01	715.1	31.74	746.8	162.6	2.006	3.715	63670	731343	39.54	47.76	43.94	1664572
06:44:52	835.0	819.3	96.7	68537.0	194.9	320826	320377	48.65	38.64	25.18	25.63	28.54	34.89	795033	25677	1538	6775	5206	1502	4373	92.01	715.1	31.74	746.8	162.6	2.006	3.715	63670	731343	39.54	47.76	43.94	1664572
06:49:52	850.0	835.3	96.6	70999.0	202.0	320607	320528	48.65	38.64	25.23	25.65	28.56	34.87	795033	25622	1539	6775	5203	1501	4371	91.97	714.8	31.73	745.4	162.5	2.005	3.686	63640	731374	39.56	47.78	43.96	1663804.1
06:54:52	865.0	851.8	96.5	72723.0	206.9	320454	320634	48.65	38.64	25.26	25.66	28.57	34.84	795033	25584	1540	6775	5198	1500	4367	91.89	714.2	31.7	744.6	162.5	2.003	3.605	63577	731437	39.6	47.83	44	1662269.4
06:59:52	880.0	871.0	96.4	75103.0	213.7	320266																											

Time	DNI	DNI Avr	Solar Field Power [kWt]	HPH By-pass [kWt]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	IPH 3 Bleed [kg/s]	IPH 2 Bleed [kg/s]	IPH 1 Bleed [kg/s]	Gross Power [kWt]	BFP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	PDF Power [kWt]	PAF Power [kWt]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWt]	Net Power [kWt]	n _O [%]	n _G [%]	n _N [%]	Heat_In [kWt]	
08:26:03	1006.0	994.5	96.1	82572.0	235.1	219579	321240	263056	31.2	22.09	25.41	25.69	28.61	34.74	795033	25369	1544	6775	5176	1494	4348	91.49	711.1	31.56	742.5	161.7	1.994	3.255	63279	731731	39.79	48.04	44.21	1650564.7
08:31:03	1013.0	1003.8	96.0	83557.0	238.0	219492	321301	263082	30.92	21.9	25.43	25.7	28.62	34.73	795033	25347	1545	6775	5174	1493	4347	91.46	710.8	31.55	742.3	161.6	1.994	3.225	63254	731756	39.81	48.05	44.23	1654452.2
08:36:03	1030.0	1013.8	96.0	84542.0	240.8	219405	321362	263109	30.65	21.7	25.44	25.7	28.62	34.72	795033	25326	1545	6775	5172	1492	4345	91.42	710.5	31.54	742	161.5	1.993	3.196	63229	731781	39.82	48.07	44.25	1653893.8
08:41:03	1028.0	1027.5	96.0	84378.0	240.3	219419	321352	263104	30.69	21.74	25.44	25.7	28.62	34.72	795033	25330	1545	6775	5172	1492	4345	91.43	710.6	31.54	742	161.5	1.993	3.201	63233	731777	39.83	48.07	44.24	1653941.9
08:46:03	1035.0	1027.8	96.0	84953.0	242.0	219368	321387	263130	30.53	21.62	25.45	25.7	28.63	34.73	795033	25337	1545	6775	5171	1492	4344	91.41	710.4	31.54	741.9	161.5	1.993	3.183	63219	731791	39.83	48.08	44.25	1653584.7
08:51:03	1037.0	1032.5	95.9	85117.0	242.4	219354	321397	263124	30.48	21.59	25.45	25.7	28.63	34.72	795033	25334	1545	6775	5171	1492	4344	91.4	710.4	31.53	741.8	161.5	1.993	3.178	63214	731795	39.83	48.08	44.26	1653482.7
08:56:03	1041.0	1035.3	95.9	85445.0	243.4	219325	321418	263133	30.39	21.51	25.46	25.71	28.63	34.72	795033	25306	1546	6775	5170	1492	4343	91.39	710.3	31.53	741.7	161.5	1.992	3.168	63206	731804	39.84	48.09	44.26	1653278.6
09:01:03	1048.0	1040.3	95.9	86020.0	245.0	219274	321453	263149	30.23	21.41	25.46	25.71	28.63	34.71	795033	25284	1546	6775	5169	1492	4343	91.37	710.1	31.52	741.6	161.4	1.992	3.151	63191	731818	39.85	48.1	44.27	1652921.5
09:06:03	1053.0	1044.8	95.9	86430.0	246.2	219238	321478	263160	30.11	21.33	25.47	25.71	28.63	34.71	795033	25285	1546	6775	5169	1492	4343	91.39	710.3	31.53	741.7	161.5	1.992	3.151	63191	731818	39.85	48.1	44.27	1652921.5
09:11:03	1065.0	1051.8	95.8	87415.0	249.0	219150	321539	263186	29.83	21.14	25.49	25.71	28.63	34.71	795033	25284	1546	6775	5168	1491	4342	91.36	710	31.52	741.4	161.4	1.992	3.138	63181	731829	39.85	48.11	44.28	1652666.7
09:16:03	1071.0	1059.3	95.8	87908.0	250.5	219107	321569	263200	29.7	21.09	25.5	25.72	28.64	34.69	795033	25248	1547	6775	5166	1491	4340	91.32	709.8	31.51	741.2	161.4	1.991	3.108	63156	731853	39.87	48.12	44.3	1652054.6
09:21:03	1074.0	1065.8	95.8	88154.0	251.2	219085	321585	263206	29.63	20.99	25.5	25.72	28.64	34.69	795033	25248	1547	6775	5165	1490	4339	91.3	709.6	31.5	741	161.3	1.99	3.093	63143	731866	39.88	48.13	44.31	1651748.4
09:26:03	1075.0	1071.3	95.8	88236.0	251.4	219078	321590	263208	29.6	20.98	25.5	25.72	28.64	34.69	795033	25248	1547	6775	5165	1490	4339	91.3	709.6	31.5	741	161.3	1.99	3.086	63137	731872	39.88	48.14	44.31	1651595.4
09:31:03	1078.0	1074.5	95.8	88482.0	252.1	219056	321605	263215	29.53	20.93	25.5	25.72	28.64	34.69	795033	25240	1547	6775	5164	1490	4338	91.29	709.5	31.49	740.9	161.3	1.99	3.076	63129	731880	39.89	48.14	44.32	1651391.4
09:36:03	1081.0	1077.0	95.8	88728.0	252.8	219034	321620	263222	29.46	20.88	25.51	25.72	28.65	34.68	795033	25235	1547	6775	5164	1490	4338	91.28	709.4	31.49	740.8	161.3	1.99	3.069	63122	731887	39.89	48.15	44.32	1651238.4
09:41:03	1081.0	1081.3	95.8	88728.0	252.8	219034	321620	263222	29.46	20.88	25.51	25.72	28.65	34.68	795033	25235	1547	6775	5163	1490	4337	91.26	709.3	31.48	740.6	161.2	1.989	3.044	63108	731891	39.9	48.16	44.33	1650881.6
09:46:03	1083.0	1080.5	95.8	88893.0	253.3	219019	321630	263226	29.42	20.85	25.51	25.72	28.65	34.68	795033	25235	1547	6775	5163	1490	4337	91.26	709.3	31.48	740.6	161.2	1.989	3.044	63108	731891	39.9	48.16	44.33	1650728.6
09:51:03	1081.0	1081.3	95.8	88728.0	252.8	219034	321620	263222	29.46	20.88	25.51	25.72	28.65	34.68	795033	25235	1547	6775	5163	1490	4337	91.26	709.3	31.48	740.6	161.2	1.989	3.044	63108	731891	39.9	48.16	44.33	1650728.6
09:56:03	1088.0	1083.0	95.8	89403.0	254.5	218983	321656	263237	29.3	20.77	25.52	25.72	28.65	34.68	795033	25217	1548	6775	5161	1489	4336	91.23	709	31.47	740.3	161.2	1.988	3.011	63074	731934	39.92	48.18	44.36	1650006.6
10:01:03	1091.0	1085.8	95.7	89549.0	255.2	218961	321671	263244	29.23	20.72	25.52	25.72	28.65	34.67	795033	25198	1548	6775	5161	1489	4335	91.22	709	31.47	740.3	161.2	1.989	3.016	63079	731930	39.92	48.18	44.35	1650167.9
10:06:03	1098.0	1089.5	95.7	90124.0	256.8	218910	321706	263259	29.07	20.6	25.53	25.72	28.65	34.67	795033	25205	1548	6775	5161	1489	4336	91.23	709	31.47	740.4	161.2	1.989	3.024	63085	731923	39.92	48.17	44.35	1650329.5
10:11:03	1101.0	1097.5	95.7	90370.0	257.5	218889	321721	263266	29	20.56	25.53	25.73	28.65	34.67	795033	25201	1548	6775	5161	1489	4335	91.22	709	31.47	740.4	161.2	1.989	3.021	63083	731926	39.92	48.18	44.35	1650269.8
10:16:03	1100.0	1094.5	95.7	90288.0	257.3	218886	321716	263263	29.02	20.57	25.53	25.72	28.65	34.67	795033	25198	1548	6775	5161	1489	4335	91.22	709	31.47	740.4	161.2	1.989	3.016	63079	731930	39.92	48.18	44.35	1650167.9
10:21:03	1102.0	1100.3	95.7	90452.0	257.8	218881	321726	263268	28.98	20.54	25.53	25.73	28.65	34.67	795033	25198	1548	6775	5161	1489	4335	91.22	709	31.47	740.4	161.2	1.989	3.016	63079	731930	39.92	48.18	44.35	1650167.9
10:26:03	1104.0	1101.8	95.7	90616.0	258.2	218867	321737	263272	28.93	20.51	25.54	25.73	28.66	34.67	795033	25194	1548	6775	5160	1489	4335	91.21	708.9	31.47	740.3	161.2	1.988	3.011	63074	731934	39.92	48.18	44.36	1650006.6
10:31:03	1102.0	1101.8	95.7	90452.0	257.8	218881	321726	263268	28.98	20.54	25.53	25.73	28.65	34.67	795033	25201	1548	6775	5161	1489	4335	91.22	709	31.47	740.4	161.2	1.989	3.021	63083	731926	39.92	48.18	44.35	1650269.8
10:36:03	1099.0	1101.8	95.7	90206.0	257.8	218893	321701	263261	29.05	20.59	25.53	25.72	28.65	34.67	795033	25207	1548	6775	5161	1489	4336	91.23	709	31.47	740.4	161.2	1.989	3.024	63085	731923	39.92	48.17	44.35	1650329.5
10:41:03	1097.0	1100.5	95.7	90042.0	256.6	218918	321701	263257	29.09	20.62	25.53	25.72	28.65	34.67	795033	25203	1548	6775	5161	1489	4336	91.23	709	31.47	740.4	161.2	1.989	3.021	63083	731926	39.92	48.18	44.35	1650269.8
10:46:03	1098.8	1099.2	95.7	90192.0	257.0	218904	321710	263261	29.05	20.59	25.53	25.72	28.65	34.67	795033	25203	1548	6775	5161	1489	4336	91.23	709	31.47	740.4	161.2	1.989	3.024	63085	731923	39.92	48.17	44.35	1650329.5
10:51:03	1092.3	1096.8	95.7	89657.0	255.5	218952	321677	263247	29.2	20.7	25.52	25.72	28.65	34.68	795033	25215	1547	6775	5162	1490	4337	91.22	709	31.47	740.3	161.2	1.989	3.018	63080	731929	39.92	48.16	44.35	1650197.3
11:01:03	1086.7	1094.8	95.8	89197.0	254.2	218992	321649	263234	29.33	20.79	25.51	25.72	28.65	34.68	795033	25225	1547	6775	5163	1490	4337	91.26	709.3	31.49	740.7	161.3	1.989	3.054	63110	731898	39.9	48.16	44.33	1650947.3
11:06:03	1098.4	1094.7	95.7	90155.0	256.9	218908	321708	263260	29.06	20.6	25.53	25.72	28.65	34.67	795033	25204	1548	6775	5161	1489	4336	91.23	709	31.47	740.4	161.2	1.989	3.025	63086	731922	39.91	48.17	44.35	1650352.5
11:11:03	1100.2	1096.7	95.7	90304.0	257.3	218895	321717	263264	29.02	20.57	25.53	25.72	28.65	34.67	795033	25201	1548	6775	5161	1489	4336	91.23</												

Time	DNI	DNI Avr	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWm]	IPT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	UPH 3 Bleed [kg/s]	UPH 2 Bleed [kg/s]	UPH 1 Bleed [kg/s]	Gross Power [kWt]	BFP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	PDF Power [kWt]	PAF Power [kWt]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FS} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWt]	Net Power [kWt]	n _O [%]	n _G [%]	n _N [%]	Heat_In [kWt]	
12:41:03	1130.0	1118.5	95.6	92750.0	264.4	218678	321868	263329	28.33	20.09	25.57	25.73	28.67	34.65	795033	25148	1549	6775	5156	1488	4332	91.14	708.3	31.44	739.7	161	1.987	2.947	63021	731988	39.96	48.22	44.4	1648741
12:46:03	1125.0	1121.0	95.6	92340.0	263.2	218714	321843	263318	28.44	20.17	25.56	25.73	28.66	34.65	795033	25157	1549	6775	5157	1488	4332	91.16	708.5	31.45	739.8	161.1	1.987	2.959	63031	731977	39.95	48.21	44.39	1648995.7
12:51:03	1124.0	1122.8	95.6	92258.0	263.0	218722	321838	263316	28.47	20.18	25.56	25.73	28.66	34.65	795033	25159	1549	6775	5157	1488	4332	91.16	708.5	31.45	739.8	161.1	1.987	2.961	63033	731975	39.95	48.21	44.39	1649046.7
12:56:03	1120.0	1124.8	95.6	92150.0	262.0	218751	321818	263307	28.56	20.25	25.56	25.73	28.66	34.65	795033	25166	1549	6775	5158	1488	4333	91.17	708.6	31.45	739.9	161.1	1.987	2.971	63041	731967	39.94	48.21	44.38	1649250.4
13:01:03	1121.0	1122.5	95.6	92012.0	262.3	218743	321823	263310	28.54	20.23	25.56	25.73	28.66	34.65	795033	25164	1549	6775	5158	1488	4333	91.17	708.5	31.45	739.9	161.1	1.987	2.969	63039	731969	39.94	48.21	44.38	1649199.6
13:06:03	1115.0	1120.0	95.6	91519.0	260.8	218787	321792	263296	28.68	20.33	25.55	25.73	28.66	34.66	795033	25175	1548	6775	5159	1488	4334	91.18	708.7	31.46	740.0	161.1	1.988	2.984	63051	731957	39.94	48.2	44.37	1649505.3
13:11:03	1104.9	1115.2	95.7	90667.0	258.5	218860	321741	263274	28.91	20.49	25.54	25.73	28.66	34.67	795033	25193	1548	6775	5160	1489	4335	91.21	708.9	31.47	740.3	161.2	1.988	3.009	63073	731936	39.92	48.18	44.36	1650020.3
13:16:03	1103.4	1111.4	95.7	90667.0	258.1	218871	321734	263271	28.94	20.52	25.54	25.73	28.66	34.67	795033	25193	1548	6775	5160	1489	4335	91.21	708.9	31.47	740.3	161.2	1.988	3.013	63076	731933	39.92	48.18	44.36	1650096.5
13:21:03	1104.6	1107.0	95.7	90667.0	258.4	218862	321740	263274	28.92	20.5	25.54	25.73	28.66	34.67	795033	25193	1548	6775	5160	1489	4335	91.21	708.9	31.47	740.3	161.2	1.988	3.013	63076	731933	39.92	48.18	44.36	1650096.5
13:26:03	1105.9	1104.7	95.7	90774.0	258.7	218853	321746	263276	28.89	20.48	25.54	25.73	28.66	34.66	795033	25193	1548	6775	5160	1489	4335	91.21	708.9	31.47	740.3	161.2	1.988	3.013	63076	731933	39.92	48.18	44.36	1650096.5
13:31:03	1112.0	1108.5	95.7	91274.0	260.1	218809	321777	263299	28.75	20.36	25.53	25.73	28.66	34.66	795033	25191	1548	6775	5160	1489	4335	91.21	708.9	31.47	740.3	161.2	1.988	3.013	63076	731933	39.92	48.18	44.36	1650096.5
13:36:03	1100.6	1105.8	95.7	90341.0	257.4	218891	321720	263265	29.01	20.58	25.53	25.73	28.66	34.66	795033	25190	1548	6775	5159	1489	4335	91.21	708.9	31.47	740.3	161.2	1.988	3.013	63076	731933	39.92	48.18	44.36	1650096.5
13:41:03	1089.9	1102.1	95.7	89463.0	254.9	218969	321665	263241	29.26	20.73	25.52	25.73	28.65	34.67	795033	25200	1548	6775	5161	1489	4335	91.21	708.9	31.47	740.3	161.2	1.988	3.013	63076	731933	39.92	48.18	44.36	1650096.5
13:46:03	1096.4	1099.7	95.7	89993.0	256.4	218922	321698	263255	29.11	20.63	25.53	25.73	28.65	34.68	795033	25219	1547	6775	5161	1489	4335	91.21	708.9	31.47	740.3	161.2	1.988	3.013	63076	731933	39.92	48.18	44.36	1650096.5
13:51:03	1092.4	1094.9	95.7	89667.0	255.5	218951	321678	263247	29.2	20.69	25.52	25.73	28.65	34.67	795033	25208	1548	6775	5162	1489	4336	91.24	709.1	31.48	740.5	161.2	1.989	3.042	63100	731907	39.9	48.16	44.34	1650773.1
13:56:03	1091.5	1096.8	95.7	89589.0	255.3	218958	321678	263245	29.22	20.71	25.52	25.73	28.65	34.68	795033	25215	1547	6775	5162	1490	4337	91.25	709.2	31.48	740.6	161.2	1.989	3.044	63101	731907	39.9	48.16	44.34	1650773.1
14:01:03	1091.1	1092.8	95.7	89555.0	255.2	218961	321671	263244	29.23	20.72	25.52	25.73	28.65	34.67	795033	25215	1547	6775	5162	1490	4337	91.25	709.2	31.48	740.6	161.2	1.989	3.044	63101	731907	39.9	48.16	44.34	1650773.1
14:06:03	1104.2	1094.8	95.7	90631.0	258.3	218866	321738	263273	28.93	20.5	25.54	25.73	28.66	34.67	795033	25204	1548	6775	5160	1489	4335	91.21	708.9	31.47	740.3	161.2	1.988	3.011	63074	731934	39.92	48.18	44.36	1650506.9
14:11:03	1101.0	1096.9	95.7	90368.0	257.5	218889	321721	263266	29	20.56	25.53	25.73	28.65	34.67	795033	25200	1548	6775	5161	1489	4335	91.21	708.9	31.47	740.3	161.2	1.988	3.011	63074	731934	39.92	48.18	44.36	1650506.9
14:16:03	1091.0	1096.8	95.7	89550.0	257.2	218891	321671	263244	29.23	20.72	25.52	25.73	28.65	34.68	795033	25217	1547	6775	5162	1490	4337	91.25	709.2	31.48	740.6	161.2	1.989	3.044	63101	731907	39.9	48.16	44.34	1650773.1
14:21:03	1095.3	1097.9	95.7	89805.0	256.2	218930	321693	263253	29.13	20.65	25.53	25.73	28.65	34.67	795033	25210	1548	6775	5162	1489	4336	91.24	709.1	31.48	740.5	161.2	1.989	3.033	63092	731916	39.91	48.17	44.34	1650508
14:26:03	1092.6	1095.8	95.7	89673.0	255.5	218950	321678	263247	29.2	20.69	25.52	25.73	28.65	34.68	795033	25215	1547	6775	5162	1490	4337	91.25	709.2	31.48	740.5	161.2	1.989	3.04	63098	731910	39.91	48.16	44.34	1650648.5
14:31:03	1092.4	1092.8	95.7	89663.0	255.5	218951	321678	263247	29.2	20.69	25.52	25.73	28.65	34.68	795033	25215	1547	6775	5162	1490	4337	91.25	709.2	31.48	740.5	161.2	1.989	3.04	63098	731910	39.91	48.16	44.34	1650648.5
14:36:03	1085.2	1091.4	95.8	89077.0	253.8	219003	321642	263231	29.37	20.81	25.51	25.73	28.65	34.68	795033	25228	1547	6775	5163	1490	4338	91.27	709.3	31.49	740.6	161.3	1.99	3.058	63114	731895	39.9	48.15	44.33	1651021.6
14:41:03	1076.3	1086.6	95.8	88346.0	251.7	219068	321596	263211	29.57	20.95	25.5	25.73	28.64	34.69	795033	25248	1547	6775	5165	1490	4339	91.29	709.5	31.5	740.9	161.3	1.991	3.101	63149	731860	39.87	48.13	44.3	1651896.1
14:46:03	1068.1	1080.5	95.8	87670.0	249.8	219180	321518	263177	29.76	21.09	25.49	25.71	28.64	34.7	795033	25271	1546	6775	5167	1491	4341	91.32	709.7	31.51	741.1	161.3	1.991	3.119	63149	731860	39.87	48.13	44.3	1651896.1
14:51:03	1060.9	1072.6	95.9	87078.0	248.1	219180	321518	263177	29.76	21.09	25.49	25.71	28.64	34.7	795033	25271	1546	6775	5167	1491	4341	91.32	709.7	31.51	741.1	161.3	1.991	3.119	63149	731860	39.87	48.13	44.3	1651896.1
14:56:03	1054.7	1065.0	95.9	86573.0	246.6	219225	321487	263164	30.07	21.3	25.47	25.71	28.63	34.71	795033	25282	1546	6775	5168	1491	4342	91.35	710	31.52	741.4	161.4	1.991	3.134	63177	731845	39.86	48.12	44.29	1652164
15:01:03	1050.0	1058.4	95.9	86184.0	245.5	219259	321463	263153	30.18	21.38	25.47	25.71	28.63	34.71	795033	25290	1546	6775	5169	1491	4342	91.37	710.1	31.52	741.5	161.4	1.992	3.146	63187	731822	39.85	48.1	44.28	1652871.5
15:06:03	1048.0	1053.4	95.9	86020.0	245.0	219274	321453	263149	30.31	21.41	25.46	25.71	28.63	34.71	795033	25294	1546	6775	5169	1492	4343	91.37	710.1	31.52	741.6	161.4	1.992	3.151	63191	731818	39.85	48.1	44.27	1652921.5
15:11:03	1044.5	1049.3	95.9	85737.0	244.2	219299	321435	263141	30.31	21.47	25.46	25.71	28.63	34.71	795033	25300	1546	6775	5170	1492	4343	91.38	710.2	31.53	741.6	161.5	1.992	3.159	63199	731811	39.84	48.09	44.27	1653097.3
15:16:03	1035.0	1044.4	96.0	84953.0	242.0	219368	321387	263120	30.53	21.62	25.45	25.7	28.63	34.72	795033	25317	1545	6775	5171	1492	4344	91.41	710.4	31.54	741.9	161.5	1.993	3.169	63219	731791	39.83	48.08	44.25	1653584.7
15:21:03	1029.4	1039.2	96.0	84496.0	240.7	219409	321359	263108	30.66	21.71	25.44	25.7	28.62	34.72	795033	25327	1545	6775																

Time	DNI	DNI Avr	MCR [%]	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWt]	IPT Power [kWt]	LPT Power [kWt]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	IPH 3 Bleed [kg/s]	IPH 2 Bleed [kg/s]	IPH 1 Bleed [kg/s]	Gross Power [kWt]	BFP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	PAF Power [kWt]	m _{Coal} [kg/s]	m _{Air} [kg/s]	m _{Ash} [kg/s]	m _{FG} [kg/s]	m _{CO2} [kg/s]	m _{SO2} [kg/s]	m _{Spray} [kg/s]	Aux Power [kWt]	Net Power [kWt]	n _O [%]	n _G [%]	n _N [%]	Heat_In [kWt]		
16:56:03	761.0	774.5	97.0	62463.0	177.5	221366	320004	262505	36.91	26.05	25.09	25.62	28.51	34.93	34.93	795033	25811	1535	6775	5215	1505	4381	92.18	716.4	31.8	748.1	162.9	2.01	3.863	63798	731218	39.46	47.68	43.85	1667592.8
17:01:03	724.0	754.8	97.2	59426.0	168.9	221637	319818	262421	37.77	26.65	25.04	25.6	28.5	34.96	34.96	795033	25878	1534	6775	5221	1507	4386	92.29	717.3	31.84	749.1	163.1	2.012	3.955	63877	731140	39.41	47.62	43.79	1669488.7
17:06:03	719.0	742.0	97.2	59016.0	167.7	221673	319793	262421	37.89	26.73	25.03	25.6	28.5	34.96	34.96	795033	25887	1534	6775	5222	1507	4387	92.3	717.4	31.84	749.1	163.1	2.012	3.967	63887	731130	39.41	47.61	43.79	1669744.9
17:11:03	709.0	728.3	97.2	58195.0	165.3	221746	319742	262387	38.12	26.89	25.02	25.6	28.49	34.97	34.97	795033	25906	1533	6775	5223	1507	4388	92.33	717.6	31.85	749.3	163.1	2.013	3.992	63909	731109	39.39	47.6	43.77	1670257.4
17:16:03	701.0	713.3	97.2	57538.0	163.5	221805	319702	262368	38.31	27.02	25.01	25.6	28.49	34.98	34.98	795033	25920	1533	6775	5225	1508	4389	92.36	717.8	31.86	749.6	163.2	2.013	4.012	63926	731092	39.38	47.59	43.76	1670667.7
17:21:03	698.0	706.8	97.3	57292.0	162.8	221827	319687	262362	38.38	27.07	25.01	25.6	28.49	34.98	34.98	795033	25926	1533	6775	5225	1508	4390	92.36	717.8	31.86	749.6	163.2	2.013	4.019	63932	731085	39.38	47.58	43.76	1670821.5
17:26:03	680.4	697.1	97.3	55844.0	158.6	221956	319598	262321	38.79	27.34	24.98	25.58	28.48	34.99	34.99	795033	25958	1532	6775	5228	1509	4392	92.41	718.2	31.88	750.1	163.5	2.015	4.063	63970	731048	39.36	47.56	43.73	1671726
17:30:03	644.2	680.9	97.5	52880.0	150.2	222220	319471	262238	39.64	27.96	24.94	25.58	28.46	35.02	35.02	795033	26024	1531	6775	5234	1510	4397	92.61	719.1	31.92	750.8	163.5	2.017	4.152	64047	730971	39.31	47.5	43.68	1673578.4
17:35:03	608.1	657.7	97.6	49916.0	141.7	222485	319236	262072	41.33	29.11	24.84	25.55	28.43	35.08	35.08	795033	26157	1528	6775	5245	1514	4407	92.72	720.6	31.99	752.5	163.8	2.021	4.33	64203	730818	39.21	47.4	43.57	1677286
17:40:03	572.0	626.2	97.7	46952.0	133.3	222750	319054	262072	41.33	29.11	24.84	25.55	28.43	35.08	35.08	795033	26157	1528	6775	5245	1514	4407	92.72	720.6	31.99	752.5	163.8	2.021	4.33	64203	730818	39.21	47.4	43.57	1677286
17:45:03	535.9	590.1	97.9	43988.0	124.8	223014	318873	261988	42.18	30.28	24.79	25.54	28.42	35.13	35.13	795033	26231	1525	6775	5251	1517	4416	92.82	722.2	32.06	754.2	164.2	2.026	4.508	64359	730663	39.12	47.3	43.47	1680997.3
17:50:03	499.8	554.0	98.0	41024.0	116.4	223791	318652	261904	43.03	30.68	24.74	25.53	28.41	35.13	35.13	795033	26351	1524	6775	5262	1518	4421	93.02	722.9	32.09	754.9	164.4	2.028	4.589	64430	730592	39.08	47.25	43.42	1682692.4
18:00:03	466.8	496.9	98.2	39809.0	112.9	223888	318618	261870	43.38	30.52	24.72	25.53	28.4	35.14	35.14	795033	26318	1525	6775	5259	1518	4418	92.97	722.5	32.07	754.5	164.3	2.027	4.545	64391	730631	39.1	47.27	43.44	1681758.7
18:05:03	370.0	455.4	98.5	30370.0	86.9	224233	318042	261600	46.09	32.38	24.57	25.49	28.35	35.23	35.23	795033	26532	1521	6775	5278	1523	4434	93.29	725.1	32.19	757.2	164.8	2.034	4.828	64641	730384	38.95	47.11	43.28	1687677.6
18:10:03	365.0	421.7	98.6	29959.0	84.9	224270	318017	261588	46.21	32.46	24.56	25.49	28.35	35.23	35.23	795033	26541	1520	6775	5279	1523	4435	93.31	725.2	32.19	757.3	164.9	2.034	4.84	64652	730373	38.94	47.1	43.27	1687935.3
18:15:03	352.6	388.6	98.6	28940.0	82.0	224362	317955	261559	46.5	32.66	24.55	25.48	28.34	35.24	35.24	795033	26564	1520	6775	5281	1524	4436	93.34	725.5	32.2	757.6	164.9	2.035	4.871	64679	730346	38.93	47.08	43.25	1688575.1
18:20:03	317.2	351.2	98.7	26032.0	73.7	224622	317778	261475	47.34	33.23	24.5	25.47	28.33	35.27	35.27	795033	26697	1519	6775	5286	1525	4441	93.44	726.2	32.24	758.4	165.1	2.037	4.958	64757	730269	38.88	47.03	43.2	1692262.2
18:25:03	281.8	329.1	98.9	23126.0	65.5	224883	317602	261391	48.18	33.8	24.45	25.46	28.31	35.29	35.29	795033	26867	1517	6775	5292	1527	4446	93.54	727.3	32.27	759.2	165.3	2.039	5.044	64834	730192	38.83	46.98	43.15	1694052.8
18:30:03	246.3	299.5	99.0	20220.0	57.2	225144	317425	261307	49.01	34.41	24.45	25.44	28.28	35.32	35.32	795033	26764	1516	6775	5298	1529	4451	93.65	727.8	32.31	760.1	165.5	2.041	5.131	64912	730115	38.79	46.93	43.1	1694052.8
18:35:03	201.2	261.6	99.2	16511.0	46.7	225477	317199	261199	50.09	35.11	24.34	25.44	28.28	35.35	35.35	795033	26849	1514	6775	5305	1531	4457	93.77	728.8	32.35	761.1	165.7	2.044	5.242	65012	730017	38.73	46.87	43.03	1696384.6
18:40:03	192.3	230.4	99.2	15780.0	44.7	225543	317155	261177	50.3	35.25	24.33	25.43	28.28	35.36	35.36	795033	26866	1514	6775	5307	1531	4458	93.8	729	32.36	761.3	165.7	2.045	5.264	65031	729997	38.72	46.85	43.02	1696844.7
18:45:03	139.0	194.7	99.5	11407.0	32.3	225936	316890	261049	51.56	36.12	24.26	25.42	28.26	35.39	35.39	795033	26967	1512	6775	5315	1534	4465	93.95	730.2	32.41	762.5	166.2	2.048	5.394	65149	729881	38.65	46.78	42.94	1699596.3
18:50:03	98.5	157.7	99.6	8082.0	22.9	226236	316688	260952	52.52	36.77	24.21	25.4	28.24	35.42	35.42	795033	27044	1511	6775	5322	1536	4471	94.17	731.3	32.45	763.4	166.2	2.051	5.493	65239	729792	38.6	46.72	42.89	1701690.7
18:55:03	67.0	124.2	99.7	5503.0	15.6	226468	316532	260876	53.27	37.28	24.16	25.39	28.23	35.45	35.45	795033	27104	1509	6775	5327	1537	4475	94.16	731.8	32.48	764.2	166.4	2.053	5.57	65309	729723	38.56	46.68	42.84	1703315.5
19:00:03	36.5	85.2	99.9	2997.0	8.5	226694	316380	260802	54	37.78	24.12	25.38	28.21	35.47	35.47	795033	27163	1508	6775	5332	1538	4479	94.16	732.3	32.51	764.9	166.5	2.056	5.645	65377	729655	38.52	46.63	42.8	1704894.7
19:05:03	5.3	51.8	100.0	435.8	1.2	226925	316235	260726	54.74	38.31	24.08	25.37	28.2	35.49	35.49	795033	27222	1507	6775	5337	1540	4483	94.33	733.2	32.55	765.6	166.7	2.056	5.721	65447	729585	38.47	46.58	42.75	1706509.7
19:10:03	3.2	28.2	100.0	264.3	0.7	226940	316209	260719	54.82	38.33	24.08	25.37	28.2	35.49	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706655.2
19:15:03	2.2	11.8	100.0	183.0	0.5	226948	316209	260719	54.81	38.33	24.08	25.37	28.2	35.49	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706655.2
19:20:03	2.4	3.3	100.0	194.5	0.5	226946	316211	260719	54.81	38.33	24.08	25.37	28.2	35.49	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706655.2
19:25:03	2.5	2.6	100.0	205.2	0.6	226946	316211	260719	54.81	38.33	24.08	25.37	28.2	35.49	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706655.2
19:30:03	2.3	2.4	100.0	192.1	0.5	226947	316210	260719	54.81	38.33	24.08	25.37	28.2	35.49	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706655.2
19:35:03	2.2	2.4	100.0	180.6	0.5	226948	316209	260718	54.82	38.33	24.08	25.37	28.2	35.49	35.49	795033	27228	1507	6775	5337	1540	4484	94.34	733.2	32.55	765.7	166.7	2.057	5.728	65453	729580	38.47	46.58	42.75	1706655.2
19:40:03	2.5	2.4																																	

Time	DNI	DNI Avr	MCR [%]	Solar Field Power [kWt]	HPH Bypass [kg/s]	HPT Power [kWm]	PT Power [kWm]	LPT Power [kWm]	HPH 6 Bleed [kg/s]	HPH 5 Bleed [kg/s]	DST Bleed [kg/s]	LPH 3 Bleed [kg/s]	LPH 2 Bleed [kg/s]	LPH 1 Bleed [kg/s]	Gross Power [kWt]	BFP Power [kWt]	CEP Power [kWt]	ACC Power [kWt]	IDF Power [kWt]	FDF Power [kWt]	PAF Power [kWt]	m_ Coal [kg/s]	m_ Air [kg/s]	m_ Ash [kg/s]	m_ FG [kg/s]	m_ CO2 [kg/s]	m_ SO2 [kg/s]	m_ Spray [kg/s]	Aux Power [kWt]	Net Power [kWt]	n_O [%]	n_G [%]	n_N [%]	Heat_In [kWt]	
21:10:02	0.0	1.2	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:15:02	0.0	0.6	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:20:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:25:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:30:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:35:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:40:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:45:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:50:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
21:55:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:00:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:05:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:10:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:15:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:20:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:25:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:30:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:35:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:40:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:45:02	0.0	0.0	100.0	0.0	0.0	226964	316198	260713	54.87	38.37	24.07	25.37	28.2	35.49	795033	27232	1507	6775	5338	1540	4484	4848	94.35	733.3	32.55	765.7	166.7	2.057	5.734	65458	729575	38.47	46.58	42.75	1706784.6
22:50:02	0.0	0.0	96.9	0.0	0.0	221216	308162	254276	52.41	37	23.28	24.52	27.29	34.42	775033	25795	1469	6775	5212	1504	4378	92.12	716	31.78	747.7	162.8	2.008	7.041	63372	711661	38.43	46.51	42.7	1666537	
22:55:02	0.0	0.0	93.9	0.0	0.0	215470	300136	247824	50.03	35.66	22.5	23.68	26.4	33.35	755033	24415	1431	6775	5086	1467	4166	87.66	681.3	30.24	711.5	154.9	1.911	9.294	59371	675662	38.39	46.43	42.66	1626218.3	
23:00:02	0.0	0.0	90.9	0.0	0.0	209728	292124	241357	47.72	34.34	21.73	22.85	25.51	32.28	75033	23091	1394	6775	4959	1431	4060	85.43	663.9	29.47	693.3	150.9	1.862	10.25	57451	657582	38.35	46.35	42.61	1583830.1	
23:05:02	0.0	0.0	88.0	0.0	0.0	203969	284123	234874	45.5	33.05	20.97	21.08	24.64	31.22	715033	21821	1356	6775	4833	1395	3953	83.19	646.5	28.7	675.1	147	1.813	11.11	54332	640701	38.32	46.19	42.58	1545370.8	
23:10:02	0.0	0.0	85.1	0.0	0.0	198253	276135	228376	43.34	31.77	20.21	21.22	23.77	30.16	695033	20602	1319	6775	4706	1358	3953	83.19	646.5	28.7	675.1	147	1.813	11.11	54332	640701	38.32	46.19	42.58	1504838.6	
23:15:02	0.0	0.0	82.2	0.0	0.0	192521	268158	221862	41.25	30.52	19.47	20.43	22.92	29.11	675033	19432	1281	6775	4579	1321	3847	80.94	629.1	27.92	656.9	143	1.764	11.86	52513	622520	38.26	46.1	42.52	1464233	
23:20:02	0.0	0.0	79.4	0.0	0.0	186792	260193	215333	39.23	29.29	18.73	19.64	22.08	28.06	655033	18310	1244	6775	4452	1285	3740	78.69	611.6	27.15	638.7	139	1.715	12.53	50740	604293	38.2	46.01	42.45	1423551.5	
23:25:02	0.0	0.0	76.6	0.0	0.0	181068	252240	208788	37.27	28.08	18	18.87	21.24	27.01	635033	17233	1206	6775	4324	1248	3633	76.44	594.1	26.37	620.4	135.1	1.666	13.1	49013	586020	38.14	45.92	42.38	1382793.1	
23:30:02	0.0	0.0	73.8	0.0	0.0	175347	244297	202229	35.38	26.89	17.29	18.11	20.42	25.97	615033	16201	1169	6775	4197	1211	3526	74.18	576.5	25.59	602.1	131.1	1.617	13.58	47329	567704	38.07	45.83	42.3	1341954	
23:35:02	0.0	0.0	71.1	0.0	0.0	169631	236366	195655	33.54	25.72	16.58	17.36	19.61	24.93	595033	15211	1131	6775	4069	1174	3418	71.92	559	24.81	583.7	127.1	1.568	13.99	45687	549346	38	45.74	42.22	1301034	
23:40:02	0.0	0.0	68.4	0.0	0.0	163918	228445	189065	31.76	24.58	15.88	16.62	18.8	23.9	575033	14263	1094	6775	3941	1137	3310	69.65	541.3	24.03	565.3	123.1	1.518	14.32	44086	530947	37.92	45.64	42.14	1260029.5	
23:45:02	0.0	0.0	65.7	0.0	0.0	158210	220534	182462	30.03	23.45	15.19	15.9	18.01	22.87	555033	13354	1057	6775	3812	1100	3202	67.38	523.7	23.25	546.9	119.1	1.469	14.57	42524	512509	37.84	45.53	42.05	1218937.6	
23:50:02	0.0	0.0	63.1	0.0	0.0	152506	212633	175844	28.36	22.34	14.5	15.18	17.23	21.85	535033	12483	1020	6775	3683	1063	3094	65.11	506	22.46	528.4	115	1.419	14.75	41000	494033	37.75	45.43	41.95	1177754.6	
23:55:02	0.0	0.0	60.5	0.0	0.0	146807	204741	169214	26.74	2																									

9.8 Appendix D-1: Base-case LCOE calculation

Base Case LCOE Calculation				
Description	Year			
		0	1	2
		Construction	Construction	Construction
Capital Cost Coal-Fired Station [R]		R -711 400 000.00	R -2 561 040 000.00	R -4 979 800 000.00
Tax Benefit [R]				R -4 552 960 000.00
Total Capex after tax [R]		R -711 400 000.00	R -2 561 040 000.00	R -4 979 800 000.00
Discounted Capex [R]		R -711 400 000.00	R -2 425 227 272.73	R -4 465 643 652.43
Total Discounted Capex [R]	R -12 612 792 814.80			R -3 866 358 140.14
Fixed O&M Cost [R]				
Variable O&M Cost [R]				
Fuel Cost [R]				
Carbon Tax [R]				
TREC Income [R]				
Total Opex Real				
Tax Benefit				
Total OPEX after tax				
Discounted Opex				
Total Discounted Opex	R -35 814 787 046.31			
Total Discounted Expenses	R -48 427 579 861.11			
Electricity Production [kWh/year]				
Discounted Production				
Total Discounted Production [kWh]	68055476938.71			
LCOE [R/kWh]	R 0.711590			

Base Case LCOE Calculation						
Description	Year	4	5	6	7	
Capital Cost Coal-Fired Station [R]		Construction				
Tax Benefit [R]		R -1 422 800 000.00				
Total Capex after tax [R]			R 0.00	R 0.00	R 0.00	
Discounted Capex [R]		R -1 422 800 000.00	R 0.00	R 0.00	R 0.00	
Total Discounted Capex [R]		R -1 144 163 749.00	R 0.00			
		R -12 612 792 814.80				
Fixed O&M Cost [R]			R -364 000 000.00	R -364 000 000.00	R -364 000 000.00	
Variable O&M Cost [R]			R -258 084 162.59	R -258 084 162.59	R -258 084 162.59	
Fuel Cost [R]			R -764 539 907.73	R -764 539 907.73	R -764 539 907.73	
Carbon Tax [R]			R -230 420 937.60	R -230 420 937.60	R -230 420 937.60	
TREC Income [R]			R 0.00	R 0.00	R 0.00	
Total Opex Real			R -1 617 045 007.92	R -1 617 045 007.92	R -1 617 045 007.92	
Tax Benefit			R 452 772 602.22	R 452 772 602.22	R 452 772 602.22	
Total OPEX after tax			R -1 164 272 405.70	R -1 164 272 405.70	R -1 164 272 405.70	
Discounted Opex			R -886 614 875.23	R -1 164 272 405.70	R -1 164 272 405.70	
Total Discounted Opex			R -35 814 787 046.31			
Total Discounted Expenses		R -48 427 579 861.11				
Electricity Production [kWh/year]			5812706364.58	5812706364.58	5812706364.58	
Discounted Production			4426482928.70	4191745197.63	3969455679.57	
Total Discounted Production [kWh]			68055476938.71			
LCOE [R/kWh]						
		</				

Base Case LCOE Calculation					
Description	Year	8	9	10	11
Capital Cost Coal-Fired Station [R]					
Tax Benefit [R]					
Total Capex after tax [R]					
Discounted Capex [R]					
Total Discounted Capex [R]	R -12 612 792 814.80				
Fixed O&M Cost [R]					
Variable O&M Cost [R]					
Fuel Cost [R]					
Carbon Tax [R]					
TREC Income [R]		R 0.00	R 0.00	R 0.00	R 0.00
Total Opex Real					
Tax Benefit					
Total OPEX after tax					
Discounted Opex					
Total Discounted Opex	R -35 814 787 046.31				
Total Discounted Expenses	R -48 427 579 861.11				
Electricity Production [kWh/year]					
Discounted Production					
Total Discounted Production [kWh]	68055476938.71				
LCOE [R/kWh]	R 0.711590				

Base Case LCOE Calculation		Year	12	13	14	15
Description	Capital Cost Coal-Fired Station [R]					
	Tax Benefit [R]					
Total Capex after tax [R]	Discounted Capex [R]					
	Total Discounted Capex [R]	R -12 612 792 814.80				
Fixed O&M Cost [R]	Variable O&M Cost [R]		R -364 000 000.00	R -364 000 000.00	R -364 000 000.00	R -364 000 000.00
			R -258 084 162.59	R -258 084 162.59	R -258 084 162.59	R -258 084 162.59
Fuel Cost [R]			R -764 539 907.73	R -764 539 907.73	R -764 539 907.73	R -764 539 907.73
Carbon Tax [R]			R -230 420 937.60	R -230 420 937.60	R -230 420 937.60	R -230 420 937.60
TREC Income [R]			R 0.00	R 0.00	R 0.00	R 0.00
Total Opex Real	Tax Benefit		R -1 617 045 007.92	R -1 617 045 007.92	R -1 617 045 007.92	R -1 617 045 007.92
	Total OPEX after tax		R 452 772 602.22	R 452 772 602.22	R 452 772 602.22	R 452 772 602.22
Discounted Opex			R -1 164 272 405.70	R -1 164 272 405.70	R -1 164 272 405.70	R -1 164 272 405.70
			R -1 164 272 405.70	R -1 164 272 405.70	R -1 164 272 405.70	R -1 164 272 405.70
Total Discounted Opex			R -35 814 787 046.31			
	Total Discounted Expenses		R -48 427 579 861.11			
Electricity Production [kWh/year]	Discounted Production					
			5812706364.58	5812706364.58	5812706364.58	5812706364.58
Total Discounted Production [kWh]			3022813591.43	2862512870.67	2710712945.71	2566963016.77
LCOE [R/kWh]			R 0.711590			

Base Case LCOE Calculation					16	17	18	19
Description	Year							
Capital Cost Coal-Fired Station [R]								
Tax Benefit [R]								
Total Capex after tax [R]								
Discounted Capex [R]								
Total Discounted Capex [R]		R -12 612 792 814.80						
Fixed O&M Cost [R]								
Variable O&M Cost [R]								
Fuel Cost [R]								
Carbon Tax [R]								
TREC Income [R]								
Total Opex Real Tax Benefit								
Total OPEX after tax Discounted Opex								
Total Discounted Opex		R -35 814 787 046.31						
Total Discounted Expenses		R -48 427 579 861.11						
Electricity Production [kWh/year]								
Discounted Production								
Total Discounted Production [kWh]		68055476938.71						
LCOE [R/kWh]		R 0.711590						

Base Case LCOE Calculation						
Description	Year	20	21	22	23	
Capital Cost Coal-Fired Station [R]						
Tax Benefit [R]						
Total Capex after tax [R]						
Discounted Capex [R]						
Total Discounted Capex [R]	R -12 612 792 814.80					
Fixed O&M Cost [R]						
Variable O&M Cost [R]						
Fuel Cost [R]						
Carbon Tax [R]						
TREC Income [R]		R 0.00	R 0.00	R 0.00	R 0.00	
Total Opex Real						
Tax Benefit						
Total OPEX after tax						
Discounted Opex						
Total Discounted Opex	R -35 814 787 046.31					
Total Discounted Expenses	R -48 427 579 861.11					
Electricity Production [kWh/year]						
Discounted Production						
Total Discounted Production [kWh]	68055476938.71					
LCOE [R/kWh]						
	R 0.711590					

Base Case LCOE Calculation					
Description	Year	24	25	26	27
Capital Cost Coal-Fired Station [R]					
Tax Benefit [R]					
Total Capex after tax [R]					
Discounted Capex [R]					
Total Discounted Capex [R]	R -12 612 792 814.80				
Fixed O&M Cost [R]					
Variable O&M Cost [R]					
Fuel Cost [R]					
Carbon Tax [R]					
TREC Income [R]		R 0.00	R 0.00	R 0.00	R 0.00
Total Opex Real					
Tax Benefit					
Total OPEX after tax					
Discounted Opex					
Total Discounted Opex	R -35 814 787 046.31				
Total Discounted Expenses	R -48 427 579 861.11				
Electricity Production [kWh/year]					
Discounted Production					
Total Discounted Production [kWh]	68055476938.71				
LCOE [R/kWh]					

Base Case LCOE Calculation				
Description	Year	28	29	30
Capital Cost Coal-Fired Station [R]				
Tax Benefit [R]				
Total Capex after tax [R]				
Discounted Capex [R]				
Total Discounted Capex [R]	R -12 612 792 814.80			
Fixed O&M Cost [R]				
Variable O&M Cost [R]				
Fuel Cost [R]				
Carbon Tax [R]				
TREC Income [R]		R 0.00	R 0.00	R 0.00
Total Opex Real				
Tax Benefit				
Total OPEX after tax				
Discounted Opex				
Total Discounted Opex	R -35 814 787 046.31			
Total Discounted Expenses	R -48 427 579 861.11			
Electricity Production [kWh/year]				
Discounted Production				
Total Discounted Production [kWh]	68055476938.71			
LCOE [R/kWh]	R 0.711590			

R -364 000 000.00	R -364 000 000.00	R -364 000 000.00	R -364 000 000.00
R -258 084 162.59	R -258 084 162.59	R -258 084 162.59	R -258 084 162.59
R -764 539 907.73	R -764 539 907.73	R -764 539 907.73	R -764 539 907.73
R -230 420 937.60	R -230 420 937.60	R -230 420 937.60	R -230 420 937.60
R -1 617 045 007.92	R -1 617 045 007.92	R -1 617 045 007.92	R -1 617 045 007.92
R 452 772 602.22	R 452 772 602.22	R 452 772 602.22	R 452 772 602.22
R -1 164 272 405.70	R -1 164 272 405.70	R -1 164 272 405.70	R -1 164 272 405.70
R -1 164 272 405.70	R -1 164 272 405.70	R -1 164 272 405.70	R -1 164 272 405.70
5812706364.58	5812706364.58	5812706364.58	5812706364.58
1264121084.60	1197084360.41	1133602614.03	1073487323.89

Base Case LCOE Calculation				
Description	Year	32	33	34
Capital Cost Coal-Fired Station [R]				
Tax Benefit [R]				
Total Capex after tax [R]				
Discounted Capex [R]				
Total Discounted Capex [R]	R -12 612 792 814.80			
Fixed O&M Cost [R]				
Variable O&M Cost [R]				
Fuel Cost [R]				
Carbon Tax [R]				
TREC Income [R]		R 0.00	R 0.00	R 0.00
Total Opex Real				
Tax Benefit				
Total OPEX after tax				
Discounted Opex				
Total Discounted Opex	R -35 814 787 046.31			
Total Discounted Expenses	R -48 427 579 861.11			
Electricity Production [kWh/year]				
Discounted Production				
Total Discounted Production [kWh]	68055476938.71			
LCOE [R/kWh]	R 0.711590			

9.9 Appendix D-2: Solar augmentation LCOE calculation

Solar Augmentation LCOE Calculation				
Description	Year			
		0	1	2
		Construction	Construction	Construction
Capital Cost Coal-Fired Station [R]		R -711 400 000.00	R -2 561 040 000.00	R -4 979 800 000.00
Solar Field [R]				R -4 552 960 000.00
Tax Benefit [R]				R -268 141 680.00
Total Capex after tax [R]		R -711 400 000.00	R -2 561 040 000.00	R -4 979 800 000.00
Discounted Capex [R]		R -711 400 000.00	R -2 425 227 272.73	R -4 465 643 652.43
Total Discounted Capex [R]	R -13 026 231 622.07			R -4 094 063 142.94
Fixed O&M Cost [R]				
Variable O&M Cost [R]				
Solar Field O&M [R]				
Fuel Cost [R]				
Carbon Tax [R]				
TREC Income [R]				
Total Opex Real				
Tax Benefit				
Total OPEX after tax				
Discounted Opex				
Total Discounted Opex	R -35 670 339 828.82			
Total Discounted Expenses	R -48 696 571 450.89			
Electricity Production [kWh/year]				
Discounted Production				
Total Discounted Production [kWh]	68109659714.54			
LCOE [R/kWh]	R 0.71497			

Solar Augmentation LCOE Calculation

Description		Year	4	5	6	7
Capital Cost Coal-Fired Station [R]			Construction R -1 422 800 000.00 R -402 212 520.00			
Solar Field [R]						
Tax Benefit [R]						
Total Capex after tax [R]						
Discounted Capex [R]						
Total Discounted Capex [R]		R -13 026 231 622.07				
Fixed O&M Cost [R]						
Variable O&M Cost [R]						
Solar Field O&M [R]						
Fuel Cost [R]						
Carbon Tax [R]						
TREC Income [R]						
Total Opex Real Tax Benefit						
Total OPEX after tax						
Discounted Opex						
Total Discounted Opex						
Total Discounted Expenses						
Electricity Production [kWh/year]						
Discounted Production						
Total Discounted Production [kWh]		68109659714.54				
LCOE [R/kWh]						

Solar Augmentation LCOE Calculation				
Description	Year	8	9	10
Capital Cost Coal-Fired Station [R]				11
Solar Field [R]				
Tax Benefit [R]				
Total Capex after tax [R]				
Discounted Capex [R]				
Total Discounted Capex [R]	R -13 026 231 622.07			
Fixed O&M Cost [R]		R -364 000 000.00	R -364 000 000.00	R -364 000 000.00
Variable O&M Cost [R]		R -258 084 162.59	R -258 084 162.59	R -258 084 162.59
Solar Field O&M [R]		R -9 712 800.00	R -9 712 800.00	R -9 712 800.00
Fuel Cost [R]		R -758 350 165.92	R -758 350 165.92	R -758 350 165.92
Carbon Tax [R]		R -228 564 754.92	R -228 564 754.92	R -228 564 754.92
TREC Income [R]		R 8 188 697.12	R 8 188 697.12	R 8 188 697.12
Total Opex Real		R -1 610 523 186.31	R -1 610 523 186.31	R -1 610 523 186.31
Tax Benefit		R 450 946 492.17	R 450 946 492.17	R 450 946 492.17
Total OPEX after tax		R -1 159 576 694.15	R -1 159 576 694.15	R -1 159 576 694.15
Discounted Opex		R -1 159 576 694.15	R -1 159 576 694.15	R -1 159 576 694.15
Total Discounted Opex	R -35 670 339 828.82			
Total Discounted Expenses	R -48 696 571 450.89			
Electricity Production [kWh/year]		5817334185.59	5817334185.59	5817334185.59
Discounted Production		3761946955.97	3562449768.91	3194632555.05
Total Discounted Production [kWh]	68109659714.54			
LCOE [R/kWh]	R 0.71497			

Solar Augmentation LCOE Calculation					
Description	Year	12	13	14	15
Capital Cost Coal-Fired Station [R]					
Solar Field [R]					
Tax Benefit [R]					
Total Capex after tax [R]					
Discounted Capex [R]					
Total Discounted Capex [R]	R -13 026 231 622.07				
Fixed O&M Cost [R]					
Variable O&M Cost [R]					
Solar Field O&M [R]					
Fuel Cost [R]					
Carbon Tax [R]					
TREC Income [R]					
Total Opex Real					
Tax Benefit					
Total OPEX after tax					
Discounted Opex					
Total Discounted Opex	R -35 670 339 828.82				
Total Discounted Expenses	R -48 696 571 450.89				
Electricity Production [kWh/year]					
Discounted Production					
Total Discounted Production [kWh]	68109659714.54				
LCOE [R/kWh]	R 0.71497				

Solar Augmentation LCOE Calculation				
Description	Year	16	17	18
Capital Cost Coal-Fired Station [R]				19
Solar Field [R]				
Tax Benefit [R]				
Total Capex after tax [R]				
Discounted Capex [R]				
Total Discounted Capex [R]	R -13 026 231 622.07			
Fixed O&M Cost [R]				
Variable O&M Cost [R]				
Solar Field O&M [R]				
Fuel Cost [R]				
Carbon Tax [R]				
TREC Income [R]				
Total Opex Real				
Tax Benefit				
Total OPEX after tax				
Discounted Opex				
Total Discounted Opex	R -35 670 339 828.82			
Total Discounted Expenses	R -48 696 571 450.89			
Electricity Production [kWh/year]				
Discounted Production				
Total Discounted Production [kWh]	68109659714.54			
LCOE [R/kWh]	R 0.71497			

Solar Augmentation LCOE Calculation				
Description	Year	20	21	22
Capital Cost Coal-Fired Station [R]				23
Solar Field [R]				
Tax Benefit [R]				
Total Capex after tax [R]				
Discounted Capex [R]				
Total Discounted Capex [R]	R -13 026 231 622.07			
Fixed O&M Cost [R]				
Variable O&M Cost [R]				
Solar Field O&M [R]				
Fuel Cost [R]				
Carbon Tax [R]				
TREC Income [R]				
Total Opex Real				
Tax Benefit				
Total OPEX after tax				
Discounted Opex				
Total Discounted Opex	R -35 670 339 828.82			
Total Discounted Expenses	R -48 696 571 450.89			
Electricity Production [kWh/year]				
Discounted Production				
Total Discounted Production [kWh]	68109659714.54			
LCOE [R/kWh]	R 0.71497			

Solar Augmentation LCOE Calculation

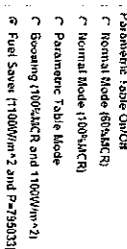
Description	Year	24	25	26	27
Capital Cost Coal-Fired Station [R]					
Solar Field [R]					
Tax Benefit [R]					
Total Capex after tax [R]					
Discounted Capex [R]					
Total Discounted Capex [R]	R -13 026 231 622.07				
Fixed O&M Cost [R]					
Variable O&M Cost [R]					
Solar Field O&M [R]					
Fuel Cost [R]					
Carbon Tax [R]					
TREC Income [R]					
Total Opex Real					
Tax Benefit					
Total OPEX after tax					
Discounted Opex					
Total Discounted Opex	R -35 670 339 828.82				
Total Discounted Expenses	R -48 696 571 450.89				
Electricity Production [kWh/year]					
Discounted Production					
Total Discounted Production [kWh]	68109659714.54				
LCOE [R/kWh]	R 0.71497				

Solar Augmentation LCOE Calculation				
Description	Year	28	29	30
Capital Cost Coal-Fired Station [R]				31
Solar Field [R]				
Tax Benefit [R]				
Total Capex after tax [R]				
Discounted Capex [R]				
Total Discounted Capex [R]	R -13 026 231 622.07			
Fixed O&M Cost [R]				
Variable O&M Cost [R]				
Solar Field O&M [R]				
Fuel Cost [R]				
Carbon Tax [R]				
TREC Income [R]				
Total Opex Real				
Tax Benefit				
Total OPEX after tax				
Discounted Opex				
Total Discounted Opex	R -35 670 339 828.82			
Total Discounted Expenses	R -48 696 571 450.89			
Electricity Production [kWh/year]				
Discounted Production				
Total Discounted Production [kWh]	68109659714.54			
LCOE [R/kWh]	R 0.71497			

Solar Augmentation LCOE Calculation				
Description	Year	32	33	34
Capital Cost Coal-Fired Station [R]				35
Solar Field [R]				
Tax Benefit [R]				
Total Capex after tax [R]				
Discounted Capex [R]				
Total Discounted Capex [R]	R -13 026 231 622.07			
Fixed O&M Cost [R]				
Variable O&M Cost [R]				
Solar Field O&M [R]				
Fuel Cost [R]				
Carbon Tax [R]				
TREC Income [R]				
Total Opex Real Tax Benefit				
Total OPEX after tax				
Discounted Opex				
Total Discounted Opex	R -35 670 339 828.82			
Total Discounted Expenses	R -48 696 571 450.89			
Electricity Production [kWh/year]				
Discounted Production				
Total Discounted Production [kWh]	68109659714.54			
LCOE [R/kWh]	R 0.71497			

9.10 Appendix E: Engineering equation solver model

- Diagram window
- Formatted equations
- Solutions
- Plots
 - o T-s diagram
 - o P-h diagram
 - o Temperature vs cycle position
 - o Pressure vs cycle position
 - o Mass flow vs cycle position



Totally yearly Electricity = 5817.7 (GWh)

Totality Party, Coe! = 2693.0 [KT

Totally yearly CO₂ = 4768.3 [kT]

Total yearly Green = 92.4 GWh

No Solar

Total Electricity, No Solar = 15925.2 (kWh/yr)

Total CO₂ Non-solar = 13152.2 [T]

Total Green Directivity, No Solar = 0 (TriVeo)

Mostly Cloudy Day

10th Electricity, Morby ■ 16925.4 [MWh]

Total CO₂ Mostly = 13150.7 [T]

 10th^{th} Grade Electricity, Magnetism = 3.1 (Average)

Energy Ctr.

Very Cloudy Day

Overlaid: 1374.20 [INVERTED]
Total: 7324.5 FT

TotalCO ₂ vary = 13074.4 [T]	TotalCO ₂ slightly = 13007.0 [T]

[illegible]

$\frac{d}{dt} \left(\frac{\partial L}{\partial \dot{x}} \right) = \frac{\partial L}{\partial x}$

Cloudless Day

One Electricity, Clouds = 10000.0 [unmarked]

TotalCO₂cloudless = 12937.8 [T]

1.044 Green Electricity, Cloud = 463.8 [MWh/mo]

[illegible]

Functions

Procedure **Eienskappe** (Temp, Pressure : sh, v)

$s := s [\text{Steam}, T = \text{Temp}, P = \text{Pressure}]$

$h := h [\text{Steam}, T = \text{Temp}, P = \text{Pressure}]$

$v := v [\text{Steam}, T = \text{Temp}, P = \text{Pressure}]$

End **Eienskappe**

Procedure **Pump** (P_{uit} , s_{uit} : h_{uit} , v_{uit} , t_{uit})

$h_{uit} := h [\text{Steam}, s = s_{uit}, P = P_{uit}]$

$t_{uit} := T [\text{Steam}, P = P_{uit}, s = s_{uit}]$

$v_{uit} := v [\text{Steam}, s = s_{uit}, P = P_{uit}]$

End **Pump**

Procedure **Rotating** (t , s , P : h , v)

$h := h [\text{Steam}, s = s, T = t]$

$v := v [\text{Steam}, s = s, P = P]$

End **Rotating**

Input Parameters

Main Steam

$T_{MS} = 560^\circ\text{C}$ $P_{MS} = 24100 \text{ kPa}$

$RS_{ratio} = 0.005299838 \text{ } [\%]$

$\dot{E}S = 0.3 \text{ } [\text{kg/s}]$

$RS_{IPT,ratio} = 0.792 \text{ } [\%]$

$\dot{R}S = \dot{s}s_{HPT} \cdot RS_{IPT,ratio}$

$SS_{IPT,ratio} = 0.000762046 \text{ } [\%]$

$MCR = 100\%$

$$m_{\text{total}} = 617 \cdot \frac{\text{MCR}}{100}$$

$$T_{\text{theo}} = 786 \cdot \frac{\text{MCR}}{100}$$

$$P_{\text{MS}} = [0.2847 \cdot T_{\text{theo}} + 17.47] \cdot 100$$

$$P_{\text{CR}} = P_{\text{MS}} \cdot 0.226828$$

Cold Reheat

$$\delta_{\text{CR}} = 5170.98 \quad [\%]$$

Reheated Steam

$$P_{\text{RH}} = 5.0 \cdot P_{\text{CR}} - P_{\text{CR}} \cdot 0.081$$

Isentropic Efficiencies

$$\eta_{\text{HPT},i} = 0.9875\% \quad \eta_{\text{IPT},i} = 0.9939\% \quad \eta_{\text{LPT},i} = 0.9943\% \quad \eta_{\text{IPT},i} = 0.9979\% \quad \eta_{\text{LPT},i} = 0.9903\% \quad \eta_{\text{LPT},i} = 0.9859\% \quad \eta_{\text{LPT},i} = 0.9962\%$$

$$\eta_{\text{CEP},i} = 0.8 \quad [\%] \quad \eta_{\text{CEP},i} = 0.83\%$$

Efficiencies

$$\eta_{\text{BFP}} = 0.94 \quad [\%] \quad \eta_{\text{bfp,motor}} = 0.95 \quad [\%] \quad \eta_{\text{HPT}} = 1 \quad [\%] \quad \eta_{\text{IPT}} = 1 \quad [\%]$$

$$\eta_{\text{LPT}} = 1 \quad [\%] \quad \eta_{\text{CEP}} = 0.95 \quad [\%] \quad \eta_{\text{CEP,motor}} = 0.94 \quad [\%]$$

$$\eta_{\text{LPH,pump}} = 0.8 \quad [\%] \quad \eta_{\text{LPH,pump,motor}} = 0.98 \quad [\%] \quad \eta_{\text{furnace}} = 0.9 \quad [\%]$$

Bleed Steam Pressures

$$P_{\text{IPT,Stage1}} = P_{\text{RH}} \cdot 0.543249 \quad P_{\text{IPT,Stage2}} = P_{\text{RH}} \cdot 0.2211175$$

$$P_{\text{IPT,Stage3}} = P_{\text{RH}} \cdot 0.11655 \quad P_{\text{LPT,Stage1}} = P_{\text{IPT,Stage3}} \cdot 0.4458$$

$$P_{\text{LPT,Stage2}} = P_{\text{IPT,Stage3}} \cdot 0.137355$$

$$\delta_{\text{IPT,Stage1}} = 0.9802 \quad [\%] \quad \delta_{\text{IPT,Stage2}} = 0.96047 \quad [\%] \quad \delta_{\text{IPT,Stage3}} = 0.95053 \quad [\%]$$

$$\delta_{\text{LPT,Stage1}} = 0.951743 \quad [\%] \quad \delta_{\text{LPT,Stage2}} = 0.957764 \quad [\%]$$

$$P_{\text{Heater,CR}} = P_{\text{CR}} \cdot \delta_{\text{CR}}$$

$$P_{\text{Heater,IPT,Stage1}} = P_{\text{IPT,Stage1}} \cdot \delta_{\text{IPT,Stage1}}$$

$$P_{\text{Heater,IPT,Stage2}} = P_{\text{IPT,Stage2}} \cdot \delta_{\text{IPT,Stage2}}$$

$$P_{\text{Heater,IPT,Stage3}} = P_{\text{IPT,Stage3}} \cdot \delta_{\text{IPT,Stage3}}$$

$$P_{\text{Heater,LPT,Stage1}} = P_{\text{LPT,Stage1}} \cdot \delta_{\text{LPT,Stage1}}$$

$$P_{\text{Heater,LPT,Stage2}} = P_{\text{LPT,Stage2}} \cdot \delta_{\text{LPT,Stage2}}$$

From HPT

$$s_{hpt,uit} = s_{ms}/\eta_{a,hpt,i}$$

$$T_{hpt,uit} = T[\text{Steam}, P = P_{CR}, s = s_{r,hpt,uit}]$$

$$T_{CR} = T_{hpt,uit}$$

Condenser Conditions

$$P_{CEP} = 2500 \text{ kPa}$$

$$P_{Condenser} = 13.2 \text{ kPa}$$

$$\delta T = 4.07 \text{ [C]}$$

From IPT

$$T_{IPT1} = T_{ipt1,uit}$$

Augment

$$\dot{m}_{solar} = 30$$

Deaerator Storage Tank exit conditions

$$T_1 = T_{sat}[\text{Steam}, P = P_{Heater,IPT,Stage2}]$$

$$p_1 = P_{Heater,IPT,Stage2} + 0.5$$

$$m_1 = m_{total} + m_{spray} \quad \text{Remove for Fuel Saver Mode}$$

$$\text{Call Eienskappe}[T_1, p_1 : s_1, h_1, v_1] \quad (T, P : s, h, v)$$

Additional Heat Exchanger Augmentation Scenario

$$A_{Collector} = 171000 \text{ [m}^2\text{]}$$

$$DNI = 1030 \text{ W/m}^2$$

$$\eta_{sr} = 60\%$$

$$P_{SC,hot} = 60000 \text{ kPa}$$

$$\eta_{CP} = 88 \text{ [%]}$$

$$dP_{AH} = 0.01 \text{ [%]}$$

$$dP_{SF} = 0.1 \text{ [%]}$$

$$P_{SC,cold} = P_{SC,hot} - P_{SC,hot} \cdot dP_{AH}$$

$$P_{\text{Radiation}} = \frac{A_{\text{Collector}} \cdot \text{DNI}}{1000}$$

$$P_{\text{Solarfield}} = P_{\text{Radiation}} \cdot \frac{\eta_{\text{ST}}}{100}$$

$$T_{\text{Hot}} = 350 \text{ C}$$

$$T_{\text{Cold}} = T_3$$

$$h_{\text{hot}} = h[\text{Steam}, T = T_{\text{hot}}, P = P_{\text{SC,hot}}]$$

$$h_{\text{cold}} = h[\text{Steam}, T = T_{\text{Cold}}, P = P_{\text{SC,cold}}]$$

$$h_{\text{cold,hp}} = h[\text{Steam}, T = T_{\text{Cold}}, P = P_{\text{SF,HP}}]$$

$$P_{\text{SF,HP}} = P_{\text{SC,hot}} + P_{\text{SC,hot}} \cdot dP_{\text{SF}}$$

$$\dot{m}_{\text{SC}} = \frac{P_{\text{Solarfield}}}{h_{\text{hot}} - h_{\text{cold}}}$$

$$m_{\text{bypass}} = 0 \text{ kg/s}$$

$$m_{\text{bypass}} = \frac{\dot{m}_{\text{SC}} \cdot [h_{\text{cold}} - h_{\text{hot}}]}{h_3 - h_{13}}$$

$$P_{\text{CP}} = \dot{m}_{\text{SC}} \cdot [h_{\text{cold,hp}} - h_{\text{cold}}] \cdot \frac{\eta_{\text{CP}}}{100}$$

$$T_{\text{Saturation}} = T_{\text{sat}}[\text{Steam}, P = P_{\text{SC,hot}}]$$

Boiler Feedwater Pumps

$$P_{\text{Losses}} = 6690 \text{ [kPa]}$$

$$P_{\text{Required}} = P_{\text{MS}} + P_{\text{Losses}}$$

$$P_{\text{Interstage}} = P_{\text{CR}} \text{ Reheater Spraywater}$$

Stage 1

$$P_2 = P_{\text{Interstage}}$$

$$t_{i1} = T_1$$

$$s_{i1} = s_1$$

$$h_{\text{pump1}} = h[\text{Steam}, s = s_{i1}, P = P_{\text{Interstage}}]$$

$$h_{\text{pump1,uit}} = \frac{h_{\text{pump1}} - h_1}{\frac{\eta_{\text{BFP1,i}}}{100}} + h_1$$

$$h_2 = h_{\text{pump1,uit}}$$

$$s_2 = s [\text{Steam}, h = h_2, P = P_2] \quad \text{Isentropic Process}$$

$$v_2 = v [\text{Steam}, s = s_2, P = P_2]$$

$$T_2 = T [\text{Steam}, P = P_2, s = s_2] \quad (P_{\text{in}}, P_{\text{uit}}, s_{\text{in}}, h_{\text{uit}}, v_{\text{uit}}, T_{\text{uit}})$$

$$m_2 = m_1 - m_{\text{spray}}$$

$$v_{\text{bfp,stage1}} = \frac{v_2 + v_1}{2}$$

$$P_{\text{bfp,stage1}} = \frac{m_1 \cdot [h_2 - h_1]}{\eta_{\text{BFP}}}$$

$$s_{i2} = s_{i1}$$

$$t_{i2} = T [\text{Steam}, P = P_2, s = s_{i2}]$$

Stage2

$$P_3 = P_{\text{Required}}$$

$$h_{\text{ipump2}} = h [\text{Steam}, s = s_{i2}, P = P_3]$$

$$h_{\text{pump2,uit}} = \frac{h_{\text{ipump2}} - h_2}{\frac{\eta_{\text{BFP1,i}}}{100}} + h_2$$

$$h_3 = h_{\text{pump2,uit}}$$

$$s_3 = s [\text{Steam}, h = h_3, P = P_3]$$

$$v_3 = v [\text{Steam}, s = s_3, P = P_3]$$

$$T_3 = T [\text{Steam}, P = P_3, s = s_3]$$

Isentropic Process

$$m_3 = m_2 - m_{\text{bypass}}$$

$$v_{\text{bfp,stage2}} = \frac{v_3 + v_2}{2}$$

$$P_{\text{bfp,stage2}} = \frac{m_2 \cdot [h_3 - h_2]}{\eta_{\text{BFP}}}$$

$$P_{\text{BFP,m}} = P_{\text{bfp,stage1}} + P_{\text{bfp,stage2}}$$

$$P_{\text{BFP,e}} = \frac{P_{\text{BFP,m}}}{\eta_{\text{bfp,motor}}}$$

$$s_{i3} = s_{i2}$$

$$t_{i3} = T [\text{Steam}, P = P_3, s = s_{i3}]$$

High Pressure Heaters

```

eta_hph5_subcooling=8
eta_hph5_desuperheating=-1
eta_hph6_subcooling=8
eta_hph6_desuperheating=1
eta_LPH1_heating=1.9
eta_LPH2_heating=2
eta_LPH3_heating=2
eta_LPH3_subcooling=5.9

```

$$T_{\text{sat,cr}} = T_{\text{sat}} [\text{Steam}, P = P_{\text{Heater,CR}}]$$

$$h_{\text{Heater,CR}} = h [\text{Steam}, T = T_{\text{CR}}, P = P_{\text{Heater,CR}} + 0.1]$$

$$T_{\text{HPH6,uit}} = T_{\text{sat,cr}} - \eta_{\text{hph6,desuperheating}}$$

$$h_{\text{hph6,uit}} = h [\text{Steam}, T = T_{\text{HPH6,uit}}, P = P_3]$$

$$T_{\text{sat,IPTs1}} = T_{\text{sat}} [\text{Steam}, P = P_{\text{Heater,IPT,Stage1}}]$$

$$T_{\text{HPH5,uit}} = T_{\text{sat,IPTs1}} - \eta_{\text{hph5,desuperheating}}$$

$$h_{\text{hph5,uit}} = h [\text{Steam}, T = T_{\text{HPH5,uit}}, P = P_3]$$

$$h_{\text{Heater,IPT,stage1}} = h [\text{Steam}, T = T_{\text{IPT1}}, P = P_{\text{Heater,IPT,Stage1}}]$$

$$s_{\text{MS}} = s [\text{Steam}, T = T_{\text{MS}}, P = P_{\text{MS}}]$$

$$T_{\text{tap,cr}} = \text{Temperature}(\text{Steam}, P = P_{\text{CR}}, s = s_{\text{hpt}})$$

$$T_{\text{cascade,hph6}} = T_{\text{HPH5,uit}} + \eta_{\text{hph6,subcooling}}$$

$$h_{\text{cascade,hph6}} = h [\text{Steam}, T = T_{\text{cascade,hph6}}, P = P_{\text{Heater,CR}}]$$

$$T_{\text{cascade,hph5}} = T_3 + \eta_{\text{hph5,subcooling}}$$

$$h_{\text{cascade,hph5}} = h [\text{Steam}, T = T_{\text{cascade,hph5}}, P = P_{\text{Heater,IPT,Stage1}}]$$

$$m_{\text{tap,cr}} = \frac{m_3 \cdot [h_{\text{hph5,uit}} - h_{\text{hph6,uit}}]}{h_{\text{cascade,hph6}} - h_{\text{Heater,CR}}}$$

$$m_{\text{tap,IPT1}} = \frac{m_3 \cdot [h_3 - h_{\text{hph5,uit}}] - m_{\text{tap,cr}} \cdot h_{\text{cascade,hph5}} + m_{\text{tap,cr}} \cdot h_{\text{cascade,hph6}}}{h_{\text{cascade,hph5}} - h_{\text{Heater,IPT,stage1}}}$$

$$T_{\text{sat,IPTs2}} = T_{\text{sat}} [\text{Steam}, P = P_{\text{Heater,IPT,Stage2}}]$$

$$T_{\text{sat,IPTs3}} = T_{\text{sat}} [\text{Steam}, P = P_{\text{Heater,IPT,Stage3}}]$$

$$T_{\text{LPH3,uit}} = T_{\text{sat,IPTs3}} - \eta_{\text{LPH3,heating}}$$

$$h_{\text{LPH3,uit}} = h [\text{Steam}, T = T_{\text{LPH3,uit}}, P = P_{\text{CEP}}]$$

$$T_{\text{sat,LPHs1}} = T_{\text{sat}} [\text{Steam}, P = P_{\text{Heater,LPT,Stage1}}]$$

$$T_{LPH2,uit} = T_{sat,LPHs1} - \eta_{LPH2,heating}$$

$$h_{LPH2,uit} = h[\text{Steam}, T = T_{LPH2,uit}, P = P_{CEP}]$$

$$v_{cascade,lph2} = v[\text{Steam}, T = T_{sat,LPHs1}, P = P_{Heater,LPT,Stage1} + 0.1]$$

$$T_{cascade,LPH3} = T_{LPH2,uit} + \eta_{LPH3,subcooling}$$

$$h_{cascade,lph3} = h[\text{Steam}, T = T_{cascade,LPH3}, P = P_{Heater,IPT,Stage3}]$$

$$T_{sat,LPHs2} = T_{sat}[\text{Steam}, P = P_{Heater,LPT,Stage2}]$$

$$T_{LPH1,uit} = T_{sat,LPHs2} - \eta_{LPH1,heating}$$

$$h_{LPH1,uit} = h[\text{Steam}, T = T_{LPH1,uit}, P = P_{CEP}]$$

$$t_{cascade,lph1} = T_{sat,LPHs2}$$

$$h_{cascade,lph1} = h[\text{Steam}, T = t_{cascade,lph1}, x = 0]$$

$$T_{sat,LPTs3} = T_{sat}[\text{Steam}, P = P_{condenser}]$$

Flashbox

$$x = x[\text{Steam}, P = P_{condenser}, h = h_{cascade,lph1}]$$

$$h_{\text{Steam}} = h[\text{Steam}, P = P_{condenser}, x = 1]$$

$$h_{\text{water}} = h[\text{Steam}, P = P_{condenser}, x = 0]$$

$$v_{\text{steam}} = v[\text{Steam}, h = h_{cascade,lph1}, P = P_{condenser}]$$

High Pressure Heater 5

$$Itt_{hph5} = 5$$

$$\text{Fraction}_{HPH5} = \frac{T_{HPH5,uit} - T_3}{Itt_{hph5}}$$

$$t_i = t_{i-1} + \text{Fraction}_{HPH5} \quad \text{for } i = 4 \text{ to } (3+Itt_{hph5})$$

$$p_i = p_{i-1} \quad \text{for } i = 4 \text{ to } (3+Itt_{hph5})$$

$$m_i = m_3 \quad \text{for } i = 4 \text{ to } (3+Itt_{hph5})$$

(Temp,Pressure:s,h,v)

$$\text{Call Eienskappe}[t_i, p_i : s_4, h_4, v_i] \quad \text{for } i = 4 \text{ to } (3+Itt_{hph5})$$

$$\text{count}_{hph5} = 3 + Itt_{hph5}$$

$$Q_{HPH5} = m_8 \cdot [h_{hph5,uit} - h_3]$$

High Pressure Heater 5

$$Itt_{hph5} = 5$$

$$\text{Fraction}_{\text{HPH6}} = \frac{T_{\text{HPH6,uit}} - T_8}{\text{Itt}_{\text{hph6}}}$$

$$t_i = t_{i-1} + \text{Fraction}_{\text{HPH6}} \quad \text{for } i = (\text{count}_{\text{hph5}}+1) \text{ to } (\text{count}_{\text{hph5}}+\text{itt}_{\text{hph6}})$$

$$p_i = p_{i-1} \quad \text{for } i = (\text{count}_{\text{hph5}}+1) \text{ to } (\text{count}_{\text{hph5}}+\text{itt}_{\text{hph6}})$$

$$m_i = m_{i-1} \quad \text{for } i = (\text{count}_{\text{hph5}}+1) \text{ to } (\text{count}_{\text{hph5}}+\text{itt}_{\text{hph6}})$$

(Temp,Pressure:s,h,v)

$$\text{Call Eienskappe}[t_i, p_i : s_9, h_9, v_i] \quad \text{for } i = (\text{count}_{\text{hph5}}+1) \text{ to } (\text{count}_{\text{hph5}}+\text{itt}_{\text{hph6}})$$

$$\text{Count}_{\text{hph6}} = \text{count}_{\text{hph5}} + \text{Itt}_{\text{hph6}}$$

$$Q_{\text{HPH6}} = m_{13} \cdot [h_{13} - h_8]$$

Boiler & Superheaters

$$\text{Itt}_{\text{boiler}} = 30$$

$$\text{fraction}_{\text{boiler}} = \frac{T_{\text{MS}} - T_{13}}{\text{Itt}_{\text{boiler}}}$$

$$\text{fraction}_{\text{boiler,p}} = \frac{P_{13} - P_{\text{MS}}}{\text{Itt}_{\text{boiler}}}$$

$$t_i = t_{i-1} + \text{fraction}_{\text{boiler}} \quad \text{for } i = (\text{count}_{\text{hph6}}+1) \text{ to } (\text{count}_{\text{hph6}}+\text{Itt}_{\text{boiler}})$$

$$p_i = p_{i-1} - \text{fraction}_{\text{boiler,p}} \quad \text{for } i = (\text{count}_{\text{hph6}}+1) \text{ to } (\text{count}_{\text{hph6}}+\text{Itt}_{\text{boiler}})$$

(Temp,Pressure:s,h,v)

$$\text{Call Eienskappe}[t_i, p_i : s_{14}, h_{14}, v_i] \quad \text{for } i = (\text{count}_{\text{hph6}}+1) \text{ to } (\text{count}_{\text{hph6}}+\text{Itt}_{\text{boiler}})$$

$$m_i = m_{\text{Count,hph6}} + m_{\text{bypass}} \quad \text{for } i = (\text{count}_{\text{hph6}}+1) \text{ to } (\text{count}_{\text{hph6}}+\text{Itt}_{\text{boiler}})$$

$$\text{Count}_{\text{boiler}} = \text{Count}_{\text{hph6}} + \text{Itt}_{\text{boiler}}$$

$$Q_{\text{boiler1}} = m_{43} \cdot [h_{43} - h_{13}]$$

High Pressure Turbine

$$\text{Itt}_{\text{hpt}} = 20$$

$$\dot{s}s_{\text{HPT}} = m_{43} \cdot \text{RS}_{\text{ratio}}$$

$$T_{\text{hpt,uit}} = T[\text{Steam}, P=P_{\text{CR}}, s=s_{\text{MS}}]$$

$$h_{i_{hpt,uit}} = h[\text{Steam}, s = s_{MS}, P = P_{CR}]$$

$$h_{HPT,uit} = \left[(h_{43} - h_{i_{hpt,uit}}) \cdot \frac{\eta_{hpt,i}}{100} - h_{43} \right] \cdot -1$$

$$s_{f_{hpt,uit}} = s[\text{Steam}, h = h_{HPT,uit}, P = P_{CR}]$$

$$\text{Fraction}_{HPT,sr} = \frac{s_{f_{hpt,uit}} - s_{43}}{itt_{hpt}}$$

$$\text{Fraction}_{hpt,ti} = \frac{T_{43} - T_{i_{hpt,uit}}}{itt_{hpt}}$$

$$ti_{43} = T_{43}$$

$$si_{43} = s_{43}$$

$$\text{Fraction}_{hpt,t} = \frac{T_{43} - T_{hpt,uit}}{itt_{hpt}}$$

$$\text{Fraction}_{hpt,s} = (s_{f_{hpt,uit}} - s_{count\_boiler}) / itt_{hpt}$$

$$\text{fraction}_{hpt,p} = \frac{P_{43} - P_{CR}}{itt_{hpt}}$$

$$Ti_i = ti_{i-1} - \text{Fraction}_{hpt,ti} \quad \text{for } i = (\text{count}_{boiler}+1) \text{ to } (\text{count}_{boiler}+itt_{hpt})$$

$$si_i = s_{count\_boiler} \quad \text{for } i = (\text{count}_{boiler}+1) \text{ to } (\text{count}_{boiler}+itt_{hpt})$$

$$p_i = p_{i-1} - \text{fraction}_{hpt,p} \quad \text{for } i = (\text{count}_{boiler}+1) \text{ to } (\text{count}_{boiler}+itt_{hpt})$$

$$s_i = s_{i-1} + \text{Fraction}_{HPT,sr} \quad \text{for } i = (\text{count}_{boiler}+1) \text{ to } (\text{count}_{boiler}+itt_{hpt})$$

$$t_i = T[\text{Steam}, P = p_i, s = s_i] \quad \text{for } i = (\text{count}_{boiler}+1) \text{ to } (\text{count}_{boiler}+itt_{hpt})$$

$$h_i = h[\text{Steam}, T = t_i, P = p_i] \quad \text{for } i = (\text{count}_{boiler}+1) \text{ to } (\text{count}_{boiler}+itt_{hpt})$$

$$v_i = v[\text{Steam}, T = t_i, P = p_i] \quad \text{for } i = (\text{count}_{boiler}+1) \text{ to } (\text{count}_{boiler}+itt_{hpt})$$

$$(t,s,P,h,v)$$

$$m_i = m_{count\_boiler} - m_{count\_boiler} \cdot \text{RS}_{ratio} \quad \text{for } i = (\text{count}_{boiler}+1) \text{ to } (\text{count}_{boiler}+itt_{hpt})$$

$$P_{64} = P_{63}$$

$$T_{64} = T_{63}$$

$$s_{64} = s_{63}$$

$$h_{64} = h_{63}$$

$$v_{64} = v_{63}$$

$$m_{64} = m_{63}$$

$$\text{Count}_{hpt} = \text{Count}_{boiler} + itt_{hpt} + 1$$

$$P_{HPT} = m_{43} \cdot [h_{43} - h_{64}] \cdot \eta_{HPT}$$

Steam Injection

$$\text{Count}_{\text{Inject}} = \text{Count}_{\text{hpt}} + 1$$

$$P_{65} = P_{64}$$

$$m_{65} = m_{64} - \dot{E}S - m_{\text{tap,cr}} \quad \text{Ejector Steam \& CSP Steam}$$

$$h_{65} = h_{64}$$

$$t_{65} = T_{64}$$

$$v_{65} = v_{64}$$

$$s_{65} = s_{64}$$

Reheater

Stage 1

$$\text{Itt}_{\text{RH}} = 10$$

$$\eta_{\text{heating}} = 0.2521 \quad 0.252182536 \quad \text{Percentage of first pass boiler heat}$$

$$Q_{\text{RH}} = Q_{\text{boiler1}} \cdot \eta_{\text{heating}}$$

$$h_{\text{overheat}} = \frac{Q_{\text{RH}} + h_{65} \cdot m_{65}}{m_{65}}$$

$$P_{\text{overheat}} = P_{65} - P_{65} \cdot \delta P_{\text{RH}}$$

$$T_{\text{overheat}} = T[\text{Steam}, P = P_{\text{overheat}}, h = h_{\text{overheat}}]$$

$$\Delta T = 50$$

$$\text{Overtemp} = 700$$

$$\text{fraction}_{\text{RH}} = \frac{T_{\text{overheat}} - t_{65}}{\text{Itt}_{\text{RH}}}$$

$$p_i = P_{\text{Count,Inject}} - P_{\text{Count,Inject}} \cdot \delta P_{\text{RH}} \quad \text{for } i = (\text{Count}_{\text{Inject}}+1) \text{ to } (\text{Count}_{\text{Inject}}+\text{Itt}_{\text{RH}})$$

$$t_i = t_{i-1} + \text{fraction}_{\text{RH}} \quad \text{for } i = (\text{Count}_{\text{Inject}}+1) \text{ to } (\text{Count}_{\text{Inject}}+\text{Itt}_{\text{RH}})$$

(Temp, Pressure s,h,v)

$$\text{Call Eienskappe}[t_i, p_i : s_{66}, h_{66}, v_i] \quad \text{for } i = (\text{Count}_{\text{Inject}}+1) \text{ to } (\text{Count}_{\text{Inject}}+\text{Itt}_{\text{RH}})$$

$$m_i = m_{\text{Count,Inject}} \quad \text{for } i = (\text{Count}_{\text{Inject}}+1) \text{ to } (\text{Count}_{\text{Inject}}+\text{Itt}_{\text{RH}})$$

$$\text{Count}_{\text{RH1}} = \text{Count}_{\text{Inject}} + \text{Itt}_{\text{RH}}$$

Spray Water

$$\dot{s}_{\text{ipt}} = \text{SS}_{\text{IPT, ratio}} \cdot m_{85}$$

$$\Delta P_{\text{RH}} = 0.0810\%$$

$$m_{\text{spray}} = 5$$

$$\text{Fraction}_{\text{RH2}} = \frac{T_{\text{overheat}} - T_{\text{RH}}}{\text{Itt}_{\text{RH}}}$$

$$p_i = p_{i-1} \quad \text{for } i = (\text{Count}_{\text{rh1}}+1) \text{ to } (\text{Count}_{\text{rh1}}+\text{Itt}_{\text{RH}})$$

$$t_i = t_{i-1} - \text{Fraction}_{\text{RH2}} \quad \text{for } i = (\text{Count}_{\text{rh1}}+1) \text{ to } (\text{Count}_{\text{rh1}}+\text{Itt}_{\text{RH}})$$

(Temp, Pressure s, h, v)

$$\text{Call Eienskappe} [t_i, p_i : s_{76}, h_{76}, v_i] \quad \text{for } i = (\text{Count}_{\text{rh1}}+1) \text{ to } (\text{Count}_{\text{rh1}}+\text{Itt}_{\text{RH}})$$

$$\text{Count}_{\text{RH2}} = \text{Count}_{\text{RH1}} + \text{Itt}_{\text{RH}}$$

$$m_{\text{spray}} = \frac{m_{75} \cdot [h_{75} - h_{85}]}{h_{75} - h_2}$$

$$m_i = m_{\text{count, rh1}} + m_{\text{spray}} - \dot{s}_{\text{ipt}} \quad \text{for } i = (\text{Count}_{\text{rh1}}+1) \text{ to } (\text{Count}_{\text{rh1}}+\text{Itt}_{\text{RH}})$$

$$Q_{\text{RH2}} = [h_{85} - h_{75}] \cdot m_{85}$$

$$Q_{\text{In}} = Q_{\text{boiler1}} + Q_{\text{RH}}$$

Intermediate Pressure Turbine

Stage 1

$$\text{Itt}_{\text{IPT}} = 20$$

$$T_{\text{ipt1, uit}} = T [\text{Steam}, P = P_{\text{IPT, Stage1}}, s = s_{85}]$$

$$\text{fraction}_{\text{ipt1, ti}} = \frac{T_{85} - T_{\text{ipt1, uit}}}{\text{Itt}_{\text{IPT}}}$$

$$h_{\text{ipt1}} = h [\text{Steam}, s = s_{85}, P = P_{\text{IPT, Stage1}}]$$

$$h_{\text{IPT1, uit, real}} = \left[(h_{85} - h_{\text{ipt1}}) \cdot \frac{\eta_{\text{IPT, I}}}{100} - h_{85} \right] \cdot -1$$

$$t_{i85} = T_{85}$$

$$s_{i85} = s_{85}$$

$$s_{\text{ipt1, uit}} = s [\text{Steam}, h = h_{\text{IPT1, uit, real}}, P = P_{\text{IPT, Stage1}}]$$

$$T_{ipt1,uit} = T \left[\text{Steam}, P = P_{IPT,Stage1}, s = s_{ipt1,uit} \right]$$

$$\text{fraction}_{ipt1,s} = \frac{s_{ipt1,uit} - s_{85}}{l_{tt_{IPT}}}$$

$$\text{Fraction}_{ipt1,t} = \frac{T_{85} - T_{ipt1,uit}}{l_{tt_{IPT}}}$$

$$\text{fraction}_{ipt1,p} = \frac{p_{85} - P_{IPT,Stage1}}{l_{tt_{IPT}}}$$

$$s_i = s_{i-1} \quad \text{for } i = (\text{Count}_{RH2}+1) \text{ to } (\text{Count}_{RH2}+itt_{ipt})$$

$$T_i = t_{i-1} - \text{fraction}_{ipt1,ti} \quad \text{for } i = (\text{Count}_{RH2}+1) \text{ to } (\text{Count}_{RH2}+itt_{ipt})$$

$$m_i = m_{i-1} \quad \text{for } i = (\text{Count}_{RH2}+1) \text{ to } (\text{Count}_{RH2}+itt_{ipt})$$

$$s_i = s_{i-1} + \text{fraction}_{ipt1,s} \quad \text{for } i = (\text{Count}_{RH2}+1) \text{ to } (\text{Count}_{RH2}+itt_{ipt})$$

$$p_i = p_{i-1} - \text{fraction}_{ipt1,p} \quad \text{for } i = (\text{Count}_{RH2}+1) \text{ to } (\text{Count}_{RH2}+itt_{ipt})$$

$$t_i = T \left[\text{Steam}, P = p_i, s = s_i \right] \quad \text{for } i = (\text{Count}_{RH2}+1) \text{ to } (\text{Count}_{RH2}+itt_{ipt})$$

$$h_i = h \left[\text{Steam}, T = t_i, P = p_i \right] \quad \text{for } i = (\text{Count}_{RH2}+1) \text{ to } (\text{Count}_{RH2}+itt_{ipt})$$

$$v_i = v \left[\text{Steam}, T = t_i, P = p_i \right] \quad \text{for } i = (\text{Count}_{RH2}+1) \text{ to } (\text{Count}_{RH2}+itt_{ipt})$$

call rotating (t_i, s_i, P_i, h_i, v_i)

(t, s, P, h, v)

$$\text{Count}_{IPT1} = \text{Count}_{RH2} + l_{tt_{IPT}}$$

$$P_{IPT1} = m_{105} \cdot [h_{85} - h_{105}] \cdot \eta_{IPT}$$

Stage2

$$T_{ipt2,uit} = T \left[\text{Steam}, P = P_{IPT,Stage2}, s = s_{105} \right]$$

$$\text{fraction}_{ipt2,ti} = \frac{T_{105} - T_{ipt2,uit}}{l_{tt_{IPT}}}$$

$$h_{ipt2} = h \left[\text{Steam}, s = s_{105}, P = P_{IPT,Stage2} \right]$$

$$h_{IPT2,uit,real} = \left[(h_{105} - h_{ipt2}) \cdot \frac{\eta_{IPT2,i}}{100} - h_{105} \right] \cdot -1$$

$$s_{ipt2,uit} = s \left[\text{Steam}, h = h_{IPT2,uit,real}, P = P_{IPT,Stage2} \right]$$

$$T_{ipt2,uit} = T \left[\text{Steam}, P = P_{IPT,Stage2}, s = s_{ipt2,uit} \right]$$

$$\text{fraction}_{ipt2,s} = \frac{s_{ipt2,uit} - s_{105}}{l_{tt_{IPT}}}$$

$$\text{Fraction}_{ipt2,t} = \frac{T_{105} - T_{ipt2,uit}}{l_{tt_{IPT}}}$$

$$\text{fraction}_{ipt2,p} = \frac{P_{105} - P_{IPT,Stage2}}{l_{tt_{IPT}}}$$

$$s_i = s_{i-1} \quad \text{for } i = (\text{Count}_{ipt1}+1) \text{ to } (\text{Count}_{ipt1}+\text{itt}_{ipt})$$

$$T_i = t_{i-1} - \text{fraction}_{ipt2,i} \quad \text{for } i = (\text{Count}_{ipt1}+1) \text{ to } (\text{Count}_{ipt1}+\text{itt}_{ipt})$$

$$m_i = m_{\text{count},ipt1} - m_{\text{tap},IPT1} \quad \text{for } i = (\text{Count}_{ipt1}+1) \text{ to } (\text{Count}_{ipt1}+\text{itt}_{ipt})$$

$$s_i = s_{i-1} + \text{fraction}_{ipt2,s} \quad \text{for } i = (\text{Count}_{ipt1}+1) \text{ to } (\text{Count}_{ipt1}+\text{itt}_{ipt})$$

$$p_i = p_{i-1} - \text{fraction}_{ipt2,p} \quad \text{for } i = (\text{Count}_{ipt1}+1) \text{ to } (\text{Count}_{ipt1}+\text{itt}_{ipt})$$

$$t_i = T[\text{Steam}, P=p_i, s=s_i] \quad \text{for } i = (\text{Count}_{ipt1}+1) \text{ to } (\text{Count}_{ipt1}+\text{itt}_{ipt})$$

$$h_i = h[\text{Steam}, T=t_i, P=p_i] \quad \text{for } i = (\text{Count}_{ipt1}+1) \text{ to } (\text{Count}_{ipt1}+\text{itt}_{ipt})$$

$$v_i = v[\text{Steam}, T=t_i, P=p_i] \quad \text{for } i = (\text{Count}_{ipt1}+1) \text{ to } (\text{Count}_{ipt1}+\text{itt}_{ipt})$$

call rotating (t_i, s_i, P_i, h_i, v_i)

(t, s, P, h, v)

$$\text{Count}_{IPT2} = \text{Count}_{IPT1} + \text{Itt}_{IPT}$$

$$P_{IPT2} = m_{125} \cdot [h_{105} - h_{125}] \cdot \eta_{IPT}$$

$$m_{IPT2,tap} = \frac{m_1 \cdot [h_1 - h_{LPH3,uit}] - [(m_{tap,IPT1} + m_{tap,cr}) \cdot (h_{cascade,hph5} - h_{LPH3,uit})]}{h_{125} - h_{LPH3,uit}}$$

Stage3

$$T_{ipt3,uit} = T[\text{Steam}, P=P_{IPT,Stage3}, s=s_{125}]$$

$$\text{fraction}_{ipt3,i} = \frac{T_{125} - T_{ipt3,uit}}{\text{Itt}_{IPT}}$$

$$h_{ipt3} = h[\text{Steam}, s=s_{125}, P=P_{IPT,Stage3}]$$

$$h_{IPT3,uit,real} = \left[(h_{125} - h_{ipt3}) \cdot \frac{\eta_{IPT3,i}}{100} - h_{125} \right] \cdot -1$$

$$s_{ipt3,uit} = s[\text{Steam}, h=h_{IPT3,uit,real}, P=P_{IPT,Stage3}]$$

$$T_{ipt3,uit} = T[\text{Steam}, P=P_{IPT,Stage3}, s=s_{ipt3,uit}]$$

$$\text{fraction}_{ipt3,s} = \frac{s_{ipt3,uit} - s_{125}}{\text{Itt}_{IPT}}$$

$$\text{Fraction}_{ipt3,t} = \frac{T_{125} - T_{ipt3,uit}}{\text{Itt}_{IPT}}$$

$$\text{fraction}_{ipt3,p} = \frac{P_{125} - P_{IPT,Stage3}}{\text{Itt}_{IPT}}$$

$$s_i = s_{i-1} \quad \text{for } i = (\text{Count}_{IPT2}+1) \text{ to } (\text{Count}_{IPT2}+\text{itt}_{ipt})$$

$$T_i = t_{i-1} - \text{fraction}_{ipt3,i} \quad \text{for } i = (\text{Count}_{IPT2}+1) \text{ to } (\text{Count}_{IPT2}+\text{itt}_{ipt})$$

$$m_i = m_{\text{count},ipt2} - m_{IPT2,tap} + RS \quad \text{for } i = (\text{Count}_{IPT2}+1) \text{ to } (\text{Count}_{IPT2}+\text{itt}_{ipt})$$

HP gland relief steam
bleed steam

$$s_i = s_{i-1} + \text{fraction}_{ipt3,s} \quad \text{for } i = (\text{Count}_{IPT2}+1) \text{ to } (\text{Count}_{IPT2}+\text{itt}_{ipt})$$

$$p_i = p_{i-1} - \text{fraction}_{ipt3,p} \quad \text{for } i = (\text{Count}_{IPT2}+1) \text{ to } (\text{Count}_{IPT2}+\text{itt}_{ipt})$$

$$t_i = T[\text{Steam}, P=p_i, s=s_i] \quad \text{for } i = (\text{Count}_{IPT2}+1) \text{ to } (\text{Count}_{IPT2}+\text{itt}_{ipt})$$

$$h_i = h[\text{Steam}, T=t_i, P=p_i] \quad \text{for } i = (\text{Count}_{IPT2}+1) \text{ to } (\text{Count}_{IPT2}+\text{itt}_{ipt})$$

$$v_i = v[\text{Steam}, T=t_i, P=p_i] \quad \text{for } i = (\text{Count}_{IPT2}+1) \text{ to } (\text{Count}_{IPT2}+\text{itt}_{ipt})$$

$$\text{Count}_{IPT3} = \text{Count}_{IPT2} + \text{itt}_{IPT}$$

$$P_{IPT3} = m_{145} \cdot [h_{125} - h_{145}] \cdot \eta_{IPT}$$

$$P_{IPT} = P_{IPT1} + P_{IPT2} + P_{IPT3}$$

$$m_{LPH3,uit} = m_1 - m_{IPT2,tap} - m_{tap,cr} - m_{tap,IPT1}$$

$$m_{IPT3,tap} = \frac{m_{LPH3,uit} \cdot [h_{LPH2,uit} - h_{LPH3,uit}]}{h_{cascade,iph3} - h_{145}}$$

Exit

$$\text{count}_{LPT,in} = \text{Count}_{IPT3} + 1$$

$$m_{146} = m_{145} - m_{IPT3,tap}$$

$$T_{146} = T_{145}$$

$$s_{146} = s_{145}$$

$$P_{146} = P_{145}$$

$$h_{146} = h_{145}$$

$$v_{146} = v_{145}$$

Low Pressure Turbine

Stage 1

$$\text{itt}_{LPT} = 20$$

$$T_{LPT1,uit} = T[\text{Steam}, P=P_{LPT,Stage1}, s=s_{146}]$$

$$\text{fraction}_{Lpt1,ti} = \frac{T_{146} - T_{LPT1,uit}}{\text{itt}_{LPT}}$$

$$h_{Lpt1} = h[\text{Steam}, s=s_{146}, P=P_{LPT,Stage1}]$$

$$h_{LPT1,uit,real} = \left[(h_{146} - h_{Lpt1}) \cdot \frac{\eta_{LPT1,i}}{100} - h_{146} \right] \cdot -1$$

$$ti_{146} = T_{146}$$

$$si_{146} = s_{146}$$

$$s_{Lpt1,uit} = s \left[\text{Steam}, h = h_{LPT1,uit,real}, P = P_{LPT,Stage1} \right]$$

$$T_{LPT1,uit} = T \left[\text{Steam}, P = P_{LPT,Stage1}, s = s_{Lpt1,uit} \right]$$

$$\text{fraction}_{Lpt1,s} = \frac{s_{Lpt1,uit} - s_{146}}{Itt_{LPT}}$$

$$\text{Fraction}_{Lpt1,t} = \frac{T_{146} - T_{LPT1,uit}}{Itt_{LPT}}$$

$$\text{fraction}_{Lpt1,p} = \frac{P_{146} - P_{LPT,Stage1}}{Itt_{LPT}}$$

$$si_i = si_{i-1} \quad \text{for } i = (\text{count}_{LPT,in}+1) \text{ to } (\text{count}_{LPT,in}+itt_{Lpt})$$

$$Ti_i = ti_{i-1} - \text{fraction}_{Lpt1,t} \quad \text{for } i = (\text{count}_{LPT,in}+1) \text{ to } (\text{count}_{LPT,in}+itt_{Lpt})$$

$$mi_i = mi_{i-1} \quad \text{for } i = (\text{count}_{LPT,in}+1) \text{ to } (\text{count}_{LPT,in}+itt_{Lpt})$$

$$si_i = si_{i-1} + \text{fraction}_{Lpt1,s} \quad \text{for } i = (\text{count}_{LPT,in}+1) \text{ to } (\text{count}_{LPT,in}+itt_{Lpt})$$

$$pi_i = pi_{i-1} - \text{fraction}_{Lpt1,p} \quad \text{for } i = (\text{count}_{LPT,in}+1) \text{ to } (\text{count}_{LPT,in}+itt_{Lpt})$$

$$ti_i = T \left[\text{Steam}, P = pi_i, s = si_i \right] \quad \text{for } i = (\text{count}_{LPT,in}+1) \text{ to } (\text{count}_{LPT,in}+itt_{Lpt})$$

$$hi_i = h \left[\text{Steam}, T = ti_i, P = pi_i \right] \quad \text{for } i = (\text{count}_{LPT,in}+1) \text{ to } (\text{count}_{LPT,in}+itt_{Lpt})$$

$$vi_i = v \left[\text{Steam}, T = ti_i, P = pi_i \right] \quad \text{for } i = (\text{count}_{LPT,in}+1) \text{ to } (\text{count}_{LPT,in}+itt_{Lpt})$$

$$\text{Count}_{LPT1} = \text{count}_{LPT,in} + Itt_{LPT}$$

$$P_{LPT1} = m_{166} \cdot [h_{146} - h_{166}] \cdot \eta_{LPT}$$

$$m_{LPT1,lap} = \frac{m_{LPH3,uit} \cdot [h_{LPH1,uit} - h_{LPH2,uit}] - m_{IPT3,tap} \cdot h_{LPH1,uit} + m_{IPT3,tap} \cdot h_{cascade,lph3}}{h_{LPH1,uit} - h_{166}}$$

Stage 2

$$\dot{G}E = \dot{s}s_{HPT} - \dot{R}S$$

$$Ti_{LPT2,uit} = T \left[\text{Steam}, P = P_{LPT,Stage2}, s = s_{166} \right]$$

$$\text{fraction}_{Lpt2,t} = \frac{T_{166} - Ti_{LPT2,uit}}{Itt_{LPT}}$$

$$hi_{Lpt2} = h \left[\text{Steam}, s = s_{166}, P = P_{LPT,Stage2} \right]$$

$$h_{LPT2,uit,real} = \left[(h_{166} - hi_{Lpt2}) \cdot \frac{\eta_{LPT2,i}}{100} - h_{166} \right] \cdot -1$$

$$s_{Lpt2,uit} = s \left[\text{Steam}, h = h_{LPT2,uit,real}, P = P_{LPT,Stage2} \right]$$

$$T_{LPT2,uit} = T \left[\text{Steam}, P = P_{LPT,Stage2}, s = s_{Lpt2,uit} \right]$$

$$\text{fraction}_{Lpt2,s} = \frac{S_{Lpt2,uit} - S_{166}}{Itt_{LPT}}$$

$$\text{Fraction}_{Lpt2,t} = \frac{T_{166} - T_{LPT2,uit}}{Itt_{LPT}}$$

$$\text{fraction}_{Lpt2,p} = \frac{P_{166} - P_{LPT,Stage2}}{Itt_{LPT}}$$

$$s_i = s_{i-1} \quad \text{for } i = (\text{Count}_{LPT1}+1) \text{ to } (\text{Count}_{LPT1}+itt_{Lpt})$$

$$T_i = t_{i-1} - \text{fraction}_{Lpt2,ti} \quad \text{for } i = (\text{Count}_{LPT1}+1) \text{ to } (\text{Count}_{LPT1}+itt_{Lpt})$$

$$m_i = m_{\text{count},lpt1} - m_{LPT1,tap} \quad \text{for } i = (\text{Count}_{LPT1}+1) \text{ to } (\text{Count}_{LPT1}+itt_{Lpt})$$

$$s_i = s_{i-1} + \text{fraction}_{Lpt2,s} \quad \text{for } i = (\text{Count}_{LPT1}+1) \text{ to } (\text{Count}_{LPT1}+itt_{Lpt})$$

$$p_i = p_{i-1} - \text{fraction}_{Lpt2,p} \quad \text{for } i = (\text{Count}_{LPT1}+1) \text{ to } (\text{Count}_{LPT1}+itt_{Lpt})$$

$$t_i = T[\text{Steam}, P=p_i, s=s_i] \quad \text{for } i = (\text{Count}_{LPT1}+1) \text{ to } (\text{Count}_{LPT1}+itt_{Lpt})$$

$$h_i = h[\text{Steam}, T=t_i, s=s_i] \quad \text{for } i = (\text{Count}_{LPT1}+1) \text{ to } (\text{Count}_{LPT1}+itt_{Lpt})$$

$$v_i = v[\text{Steam}, T=t_i, s=s_i] \quad \text{for } i = (\text{Count}_{LPT1}+1) \text{ to } (\text{Count}_{LPT1}+itt_{Lpt})$$

$$\text{Count}_{LPT2} = \text{Count}_{LPT1} + Itt_{LPT}$$

$$P_{LPT2} = m_{166} \cdot [h_{166} - h_{166}] \cdot \eta_{LPT}$$

$$m_{LPH1,uit} = m_{LPH3,uit} - m_{LPT1,tap} - m_{IPT3,tap}$$

Stage 3

$$T_{LPT3,uit} = T[\text{Steam}, P=P_{\text{condenser}}, s=s_{166}]$$

$$\text{fraction}_{Lpt3,ti} = \frac{T_{166} - T_{LPT3,uit}}{Itt_{LPT}}$$

$$h_{Lpt3} = h[\text{Steam}, s=s_{166}, P=P_{\text{condenser}}]$$

$$h_{LPT3,uit,real} = \left[(h_{166} - h_{Lpt3}) \cdot \frac{\eta_{LPT3,i}}{100} - h_{166} \right] \cdot -1$$

$$s_{Lpt3,uit} = s[\text{Steam}, h=h_{LPT3,uit,real}, P=P_{\text{condenser}}]$$

$$T_{LPT3,uit} = T[\text{Steam}, P=P_{\text{condenser}}, s=s_{Lpt3,uit}]$$

$$\text{fraction}_{Lpt3,s} = \frac{S_{Lpt3,uit} - S_{166}}{Itt_{LPT}}$$

$$\text{Fraction}_{Lpt3,t} = \frac{T_{166} - T_{LPT3,uit}}{Itt_{LPT}}$$

$$\text{fraction}_{Lpt3,p} = \frac{P_{166} - P_{\text{condenser}}}{Itt_{LPT}}$$

$$\text{Fraction}_{Lpt3,h} = \frac{h_{166} - h_{LPT3,uit,real}}{Itt_{LPT}}$$

$$s_i = s_{i-1} \quad \text{for } i = (\text{Count}_{\text{LPT2}}+1) \text{ to } (\text{Count}_{\text{LPT2}}+\text{itt}_{\text{Lpt}})$$

$$T_i = t_{i-1} - \text{fraction}_{\text{Lpt3,li}} \quad \text{for } i = (\text{Count}_{\text{LPT2}}+1) \text{ to } (\text{Count}_{\text{LPT2}}+\text{itt}_{\text{Lpt}})$$

$$m_i = m_{\text{count,LPT2}} - m_{\text{LPT2,tap}} \quad \text{for } i = (\text{Count}_{\text{LPT2}}+1) \text{ to } (\text{Count}_{\text{LPT2}}+\text{itt}_{\text{Lpt}})$$

$$s_i = s_{i-1} + \text{fraction}_{\text{Lpt3,s}} \quad \text{for } i = (\text{Count}_{\text{LPT2}}+1) \text{ to } (\text{Count}_{\text{LPT2}}+\text{itt}_{\text{Lpt}})$$

$$p_i = p_{i-1} - \text{fraction}_{\text{Lpt3,p}} \quad \text{for } i = (\text{Count}_{\text{LPT2}}+1) \text{ to } (\text{Count}_{\text{LPT2}}+\text{itt}_{\text{Lpt}})$$

$$t_i = T[\text{Steam}, P=p_i, s=s_i] \quad \text{for } i = (\text{Count}_{\text{LPT2}}+1) \text{ to } (\text{Count}_{\text{LPT2}}+\text{itt}_{\text{Lpt}})$$

$$h_i = h[\text{Steam}, T=t_i, s=s_i] \quad \text{for } i = (\text{Count}_{\text{LPT2}}+1) \text{ to } (\text{Count}_{\text{LPT2}}+\text{itt}_{\text{Lpt}})$$

$$v_i = v[\text{Steam}, T=t_i, s=s_i] \quad \text{for } i = (\text{Count}_{\text{LPT2}}+1) \text{ to } (\text{Count}_{\text{LPT2}}+\text{itt}_{\text{Lpt}})$$

$$\text{Count}_{\text{LPT3}} = \text{Count}_{\text{LPT2}} + \text{itt}_{\text{LPT}}$$

$$x_{206} = x[\text{Steam}, T=T_{206}, h=h_{206}]$$

$$m_{\text{LPT2,tap}} = \frac{m_{\text{LPH1,uit}} \cdot [h_{\text{LPH1,uit}} - h_{\text{LPH1,in}}]}{h_{186} - h_{\text{cascade,lph1}}}$$

$$P_{\text{LPT3}} = m_{206} \cdot [h_{186} - h_{206}] \cdot \eta_{\text{LPT}}$$

$$P_{\text{LPT}} = P_{\text{LPT1}} + P_{\text{LPT2}} + P_{\text{LPT3}}$$

$$P_{\text{Shaft}} = P_{\text{HPT}} + P_{\text{IPT}} + P_{\text{LPT}}$$

$$P_{\text{generator}} = P_{\text{Shaft}} \cdot \frac{\eta_{\text{generator}}}{100}$$

Flashbox

$$m_{\text{steam}} = m_{\text{LPT2,tap}} \cdot x$$

$$m_{\text{water}} = m_{\text{LPT2,tap}} \cdot [1 - x]$$

Condenser

$$\text{itt}_{\text{condenser}} = 10$$

$$\text{Condenser}_{\text{sub}} = T_{206} - \delta T$$

$$h_{\text{condenser,sub}} = h[\text{Steam}, T=\text{Condenser}_{\text{sub}}, P=P_{206}]$$

$$\text{fraction}_{\text{condenser}} = \frac{x_{206}}{\text{itt}_{\text{condenser}}}$$

$$\text{fraction}_{\text{condenser}} = \frac{h_{206} - h_{\text{Condenser,subcooling}}}{\text{itt}_{\text{condenser}}}$$

$$x_i = x_{i-1} - \text{fraction}_{\text{condenser}} \quad \text{for } i = (\text{Count}_{\text{LPT3}}+1) \text{ to } (\text{Count}_{\text{LPT3}}+\text{itt}_{\text{condenser}})$$

$$p_i = p_{i-1} \quad \text{for } i = (\text{Count}_{\text{LPT3}}+1) \text{ to } (\text{Count}_{\text{LPT3}}+\text{itt}_{\text{condenser}})$$

$$h_i = h[\text{Steam}, x=x_i, P=p_i] \quad \text{for } i = (\text{Count}_{\text{LPT3}}+1) \text{ to } (\text{Count}_{\text{LPT3}}+\text{itt}_{\text{condenser}})$$

$$t_i = T[\text{Steam}, P=p_i, x=x_i] \quad \text{for } i = (\text{Count}_{\text{LPT3}}+1) \text{ to } (\text{Count}_{\text{LPT3}}+\text{itt}_{\text{condenser}})$$

$$s_i = s[\text{Steam}, x=x_i, P=p_i] \quad \text{for } i = (\text{Count}_{\text{LPT3}}+1) \text{ to } (\text{Count}_{\text{LPT3}}+\text{itt}_{\text{condenser}})$$

$$v_i = v[\text{Steam}, x=x_i, P=p_i] \quad \text{for } i = (\text{Count}_{\text{LPT3}}+1) \text{ to } (\text{Count}_{\text{LPT3}}+\text{itt}_{\text{condenser}})$$

$$m_i = m_{\text{count\_lpt3}} + m_{\text{steam}} + \dot{s}s_{\text{ipt}} \quad \text{for } i = (\text{Count}_{\text{LPT3}}+1) \text{ to } (\text{Count}_{\text{LPT3}}+\text{itt}_{\text{condenser}})$$

$$\text{Count}_{\text{condenser}} = \text{Count}_{\text{LPT3}} + \text{itt}_{\text{condenser}}$$

$$\text{Fraction}_{\text{condenser,sub}} = \frac{h_{216} - h_{\text{condenser,sub}}}{\text{itt}_{\text{condenser}}}$$

$$p_i = p_{i-1} \quad \text{for } i = (\text{Count}_{\text{condenser}}+1) \text{ to } (\text{Count}_{\text{condenser}}+\text{itt}_{\text{condenser}})$$

$$h_i = h_{i-1} - \text{Fraction}_{\text{condenser,sub}} \quad \text{for } i = (\text{Count}_{\text{condenser}}+1) \text{ to } (\text{Count}_{\text{condenser}}+\text{itt}_{\text{condenser}})$$

$$t_i = T[\text{Steam}, P=p_i, h=h_i] \quad \text{for } i = (\text{Count}_{\text{condenser}}+1) \text{ to } (\text{Count}_{\text{condenser}}+\text{itt}_{\text{condenser}})$$

$$s_i = s[\text{Steam}, h=h_i, P=p_i] \quad \text{for } i = (\text{Count}_{\text{condenser}}+1) \text{ to } (\text{Count}_{\text{condenser}}+\text{itt}_{\text{condenser}})$$

$$v_i = v[\text{Steam}, h=h_i, P=p_i] \quad \text{for } i = (\text{Count}_{\text{condenser}}+1) \text{ to } (\text{Count}_{\text{condenser}}+\text{itt}_{\text{condenser}})$$

$$m_i = m_{i-1} \quad \text{for } i = (\text{Count}_{\text{condenser}}+1) \text{ to } (\text{Count}_{\text{condenser}}+\text{itt}_{\text{condenser}})$$

$$\text{count}_{\text{condenser2}} = \text{Count}_{\text{condenser}} + \text{itt}_{\text{condenser}}$$

$$Q_{\text{reject}} = m_{226} \cdot [h_{206} - h_{226}]$$

$$\text{Exponent} = 0.0014 \cdot \frac{Q_{\text{reject}}}{1000}$$

$$P_{\text{Cond}} = 3.7365 \cdot \exp[\text{Exponent}] \quad 3.7365 * (\text{EXP}(0.0014 * Q_{\text{reject}}))$$

$$P_{\text{condenser}} = P_{\text{Cond}}$$

$$P_{\text{ACC,e}} = 6775 \text{ [kW]} \cdot Q_{\text{reject}}^{0.007330314}$$

Condensate Storage Tank

$$\text{itt}_{\text{storage}} = 10$$

$$h_{\text{storage,uit}} = \frac{m_{226} \cdot h_{226} + m_{\text{water}} \cdot h_{\text{water}}}{m_{226} + m_{\text{water}}}$$

$$\text{Fraction}_{\text{storage}} = \frac{h_{\text{storage,uit}} - h_{226}}{\text{itt}_{\text{storage}}}$$

$$m_i = m_{\text{count,condenser2}} + m_{\text{water}} \quad \text{for } i = (\text{count}_{\text{condenser2}}+1) \text{ to } (\text{count}_{\text{condenser2}}+\text{itt}_{\text{storage}})$$

$$p_i = p_{i-1} \quad \text{for } i = (\text{count}_{\text{condenser2}}+1) \text{ to } (\text{count}_{\text{condenser2}}+\text{itt}_{\text{storage}})$$

$$h_i = h_{i-1} + \text{Fraction}_{\text{storage}} \quad \text{for } i = (\text{count}_{\text{condenser2}}+1) \text{ to } (\text{count}_{\text{condenser2}}+\text{itt}_{\text{storage}})$$

$$t_i = T[\text{Steam}, P=p_i, h=h_i] \quad \text{for } i = (\text{count}_{\text{condenser2}}+1) \text{ to } (\text{count}_{\text{condenser2}}+\text{itt}_{\text{storage}})$$

$$s_i = s[\text{Steam}, h=h_i, P=p_i] \quad \text{for } i = (\text{count}_{\text{condenser2}}+1) \text{ to } (\text{count}_{\text{condenser2}}+\text{itt}_{\text{storage}})$$

$$v_i = v[\text{Steam}, h=h_i, P=p_i] \quad \text{for } i = (\text{count}_{\text{condenser2}}+1) \text{ to } (\text{count}_{\text{condenser2}}+\text{itt}_{\text{storage}})$$

$$\text{Count}_{\text{storage}} = \text{count}_{\text{condenser2}} + \text{itt}_{\text{storage}}$$

$$\text{itt}=205$$

$$h_{\text{LPH1,in}} = h_{\text{storage,uit}}$$

Condensate Extraction Pump

$$\text{Itt}_{\text{CEP}} = 10$$

$$\text{fraction}_{\text{CEP}} = \frac{P_{\text{CEP}} - P_{236}}{\text{Itt}_{\text{CEP}}}$$

$$T_{\text{CEP,uit}} = T[\text{Steam}, P=P_{\text{condenser}}, s=s_{236}]$$

$$\text{fraction}_{\text{cep,li}} = \frac{T_{\text{CEP,uit}} - T_{236}}{\text{Itt}_{\text{CEP}}}$$

$$h_{\text{CEP,uit}} = h[\text{Steam}, s=s_{236}, P=P_{\text{CEP}}]$$

$$h_{\text{CEP,uit}} = \frac{h_{\text{CEP,uit}} - h_{236}}{\eta_{\text{CEP,i}}} + h_{236}$$

$$t_{236} = T_{236}$$

$$s_{236} = s_{236}$$

$$s_{\text{CEP,uit}} = s[\text{Steam}, h=h_{\text{CEP,uit}}, P=P_{\text{CEP}}]$$

$$T_{\text{CEP,uit}} = T[\text{Steam}, P=P_{\text{CEP}}, s=s_{\text{CEP,uit}}]$$

$$\text{fraction}_{\text{cep,s}} = \frac{s_{\text{CEP,uit}} - s_{236}}{\text{Itt}_{\text{CEP}}}$$

$$\text{Fraction}_{\text{cep,t}} = \frac{T_{\text{CEP,uit}} - T_{236}}{\text{Itt}_{\text{CEP}}}$$

$$p_i = p_{i-1} + \text{fraction}_{\text{CEP}} \quad \text{for } i = (\text{Count}_{\text{storage}}+1) \text{ to } (\text{Count}_{\text{storage}}+\text{itt}_{\text{CEP}})$$

$$s_i = s_{i-1} \quad \text{for } i = (\text{Count}_{\text{storage}}+1) \text{ to } (\text{Count}_{\text{storage}}+\text{itt}_{\text{CEP}})$$

$$T_i = t_{i-1} + \text{fraction}_{\text{cep,li}} \quad \text{for } i = (\text{Count}_{\text{storage}}+1) \text{ to } (\text{Count}_{\text{storage}}+\text{itt}_{\text{CEP}})$$

$$m_i = m_{i-1} \quad \text{for } i = (\text{Count}_{\text{storage}}+1) \text{ to } (\text{Count}_{\text{storage}}+\text{itt}_{\text{CEP}})$$

$$t_i = t_{i-1} + \text{Fraction}_{\text{cep},t} \quad \text{for } i = (\text{Count}_{\text{storage}}+1) \text{ to } (\text{Count}_{\text{storage}}+\text{itt}_{\text{CEP}})$$

$$s_i = s_{i-1} + \text{fraction}_{\text{cep},s} \quad \text{for } i = (\text{Count}_{\text{storage}}+1) \text{ to } (\text{Count}_{\text{storage}}+\text{itt}_{\text{CEP}})$$

$$\text{Call Rotating} [t_i, s_i, p_i : h_{237}, v_i] \quad \text{for } i = (\text{Count}_{\text{storage}}+1) \text{ to } (\text{Count}_{\text{storage}}+\text{itt}_{\text{CEP}})$$

$$\text{Count}_{\text{CEP}} = \text{Count}_{\text{storage}} + \text{itt}_{\text{CEP}}$$

$$V_{\text{mean,CEP}} = \frac{V_{246} + V_{236}}{2}$$

$$P_{\text{CEP},m} = \frac{m_{246} \cdot [h_{246} - h_{236}]}{\eta_{\text{CEP}}}$$

$$P_{\text{CEP},a} = \frac{P_{\text{CEP},m}}{\eta_{\text{CEP},\text{motor}}}$$

 Low Pressure Heaters #1

$$\text{itt}_{\text{LPH}} = 20$$

$$\text{fraction}_{\text{LPH1}} = \frac{T_{\text{LPH1,uit}} - T_{246}}{\text{itt}_{\text{LPH}}}$$

$$m_i = m_{i-1} \quad \text{for } i = (\text{Count}_{\text{CEP}}+1) \text{ to } (\text{Count}_{\text{CEP}}+\text{itt}_{\text{LPH}})$$

$$p_i = p_{i-1} \quad \text{for } i = (\text{Count}_{\text{CEP}}+1) \text{ to } (\text{Count}_{\text{CEP}}+\text{itt}_{\text{LPH}})$$

$$t_i = t_{i-1} + \text{fraction}_{\text{LPH1}} \quad \text{for } i = (\text{Count}_{\text{CEP}}+1) \text{ to } (\text{Count}_{\text{CEP}}+\text{itt}_{\text{LPH}})$$

Eienskappe (Temp,Pressure,s,h,v)

$$\text{Call Eienskappe} [t_i, p_i : s_{247}, h_{247}, v_i] \quad \text{for } i = (\text{Count}_{\text{CEP}}+1) \text{ to } (\text{Count}_{\text{CEP}}+\text{itt}_{\text{LPH}})$$

$$\text{Count}_{\text{LPH1}} = \text{Count}_{\text{CEP}} + \text{itt}_{\text{LPH}}$$

 Low Pressure Heaters #2

$$\text{fraction}_{\text{LPH2}} = \frac{T_{\text{LPH2,uit}} - T_{266}}{\text{itt}_{\text{LPH}}}$$

$$m_i = m_{i-1} \quad \text{for } i = (\text{Count}_{\text{LPH1}}+1) \text{ to } (\text{Count}_{\text{LPH1}}+\text{itt}_{\text{LPH}})$$

$$p_i = p_{i-1} \quad \text{for } i = (\text{Count}_{\text{LPH1}}+1) \text{ to } (\text{Count}_{\text{LPH1}}+\text{itt}_{\text{LPH}})$$

$$t_i = t_{i-1} + \text{fraction}_{\text{LPH2}} \quad \text{for } i = (\text{Count}_{\text{LPH1}}+1) \text{ to } (\text{Count}_{\text{LPH1}}+\text{itt}_{\text{LPH}})$$

Eienskappe (Temp,Pressure,s,h,v)

Call **Eienskappe** $[t_i, p_i : s_{267}, h_{267}, v_i]$ for $i = (\text{Count}_{\text{iph1}}+1)$ to $(\text{Count}_{\text{iph1}}+\text{itt}_{\text{iph}})$

$$\text{Count}_{\text{LPH2}} = \text{Count}_{\text{LPH1}} + \text{itt}_{\text{LPH}}$$

$$m_{\text{cascade,iph2}} = m_{\text{LPT1,tap}} + m_{\text{IPT3,tap}}$$

$$v_{\text{mean,iph2p}} = \frac{v_{286} + v_{\text{cascade,iph2}}}{2}$$

$$P_{\text{LPH,pump,m}} = \frac{m_{\text{cascade,iph2}} \cdot v_{\text{mean,iph2p}} \cdot [P_{\text{CEP}} - P_{\text{Heater,LPT,Stage1}}]}{\eta_{\text{LPH,pump}}}$$

$$P_{\text{LPH,pump,e}} = \frac{P_{\text{LPH,pump,m}}}{\eta_{\text{LPH,pump,motor}}}$$

Low Pressure Heaters #3

$$\text{fraction}_{\text{LPH3}} = \frac{T_{\text{LPH3,uit}} - T_{286}}{\text{itt}_{\text{LPH}}}$$

$$m_i = m_{\text{count,iph2}} + m_{\text{cascade,iph2}} \quad \text{for } i = (\text{Count}_{\text{iph2}}+1) \text{ to } (\text{Count}_{\text{iph2}}+\text{itt}_{\text{iph}})$$

$$p_i = p_{i-1} \quad \text{for } i = (\text{Count}_{\text{iph2}}+1) \text{ to } (\text{Count}_{\text{iph2}}+\text{itt}_{\text{iph}})$$

$$t_i = t_{i-1} + \text{fraction}_{\text{LPH3}} \quad \text{for } i = (\text{Count}_{\text{iph2}}+1) \text{ to } (\text{Count}_{\text{iph2}}+\text{itt}_{\text{iph}})$$

Eienskappe (Temp,Pressure:s,h,v)

Call **Eienskappe** $[t_i, p_i : s_{287}, h_{287}, v_i]$ for $i = (\text{Count}_{\text{iph2}}+1)$ to $(\text{Count}_{\text{iph2}}+\text{itt}_{\text{iph}})$

$$\text{Count}_{\text{LPH3}} = \text{Count}_{\text{LPH2}} + \text{itt}_{\text{LPH}}$$

Deaerator

$$\text{itt}_{\text{DST}} = 10$$

$$\text{fraction}_{\text{dst}} = \frac{T_1 - T_{306}}{\text{itt}_{\text{DST}}}$$

$$m_i = m_{\text{count,iph3}} + m_{\text{tap,cr}} + m_{\text{tap,IPT1}} + m_{\text{IPT2,tap}} \quad \text{for } i = (\text{Count}_{\text{iph3}}+1) \text{ to } (\text{Count}_{\text{iph3}}+\text{itt}_{\text{dst}})$$

$$p_i = p_1 \quad \text{for } i = (\text{Count}_{\text{iph3}}+1) \text{ to } (\text{Count}_{\text{iph3}}+\text{itt}_{\text{dst}})$$

$$t_i = t_{i-1} + \text{fraction}_{\text{dst}} \quad \text{for } i = (\text{Count}_{\text{iph3}}+1) \text{ to } (\text{Count}_{\text{iph3}}+\text{itt}_{\text{dst}})$$

Eienskappe (Temp,Pressure:s,h,v)

Call **Eienskappe** $[t_i, p_i : s_{307}, h_{307}, v_i]$ for $i = (\text{Count}_{\text{iph3}}+1)$ to $(\text{Count}_{\text{iph3}}+\text{itt}_{\text{dst}})$

$$\text{Count}_{\text{dst}} = \text{Count}_{\text{LPH3}} + \text{Itt}_{\text{DST}}$$

 Bleed Steam

HPT

$$\text{itt}_{\text{bleed}} = 40$$

$$\text{Fraction}_{\text{hpt}} = \frac{h_{64} - h_1}{\text{itt}_{\text{bleed}}}$$

$$p_{\text{hpt},64} = P_{64}$$

$$h_{\text{hpt},64} = h_{64}$$

$$t_{\text{hpt},64} = T_{64}$$

$$s_{\text{hpt},64} = s_{64}$$

$$P_{\text{hpt},i} = p_{\text{hpt},i-1} \quad \text{for } i = (\text{count}_{\text{hpt}}+1) \text{ to } (\text{count}_{\text{hpt}}+\text{itt}_{\text{bleed}})$$

$$h_{\text{hpt},i} = h_{\text{hpt},i-1} - \text{Fraction}_{\text{hpt}} \quad \text{for } i = (\text{count}_{\text{hpt}}+1) \text{ to } (\text{count}_{\text{hpt}}+\text{itt}_{\text{bleed}})$$

$$t_{\text{hpt},i} = T[\text{Steam}, P=P_{\text{hpt},i}, h=h_{\text{hpt},i}] \quad \text{for } i = (\text{count}_{\text{hpt}}+1) \text{ to } (\text{count}_{\text{hpt}}+\text{itt}_{\text{bleed}})$$

$$s_{\text{hpt},i} = s[\text{Steam}, h=h_{\text{hpt},i}, P=P_{\text{hpt},i}] \quad \text{for } i = (\text{count}_{\text{hpt}}+1) \text{ to } (\text{count}_{\text{hpt}}+\text{itt}_{\text{bleed}})$$

IPT #1

$$\text{Fraction}_{\text{ipt1}} = \frac{h_{105} - h_1}{\text{itt}_{\text{bleed}}}$$

$$p_{\text{ipt1},105} = P_{105}$$

$$h_{\text{ipt1},105} = h_{105}$$

$$t_{\text{ipt1},105} = T_{105}$$

$$s_{\text{ipt1},105} = s_{105}$$

$$P_{\text{ipt1},i} = p_{\text{ipt1},i-1} \quad \text{for } i = (\text{count}_{\text{ipt1}}+1) \text{ to } (\text{count}_{\text{ipt1}}+\text{itt}_{\text{bleed}})$$

$$h_{\text{ipt1},i} = h_{\text{ipt1},i-1} - \text{Fraction}_{\text{ipt1}} \quad \text{for } i = (\text{count}_{\text{ipt1}}+1) \text{ to } (\text{count}_{\text{ipt1}}+\text{itt}_{\text{bleed}})$$

$$t_{\text{ipt1},i} = T[\text{Steam}, P=P_{\text{ipt1},i}, h=h_{\text{ipt1},i}] \quad \text{for } i = (\text{count}_{\text{ipt1}}+1) \text{ to } (\text{count}_{\text{ipt1}}+\text{itt}_{\text{bleed}})$$

$$s_{\text{ipt1},i} = s[\text{Steam}, h=h_{\text{ipt1},i}, P=P_{\text{ipt1},i}] \quad \text{for } i = (\text{count}_{\text{ipt1}}+1) \text{ to } (\text{count}_{\text{ipt1}}+\text{itt}_{\text{bleed}})$$

IPT #2

$$\text{Fraction}_{\text{ipt2}} = \frac{h_{125} - h_1}{\text{itt}_{\text{bleed}}}$$

$$p_{\text{ipt2},125} = P_{125}$$

$$h_{ipt2,125} = h_{125}$$

$$t_{ipt2,125} = T_{125}$$

$$s_{ipt2,125} = s_{125}$$

$$P_{ipt2,i} = p_{ipt2,i-1} \quad \text{for } i = (\text{count}_{ipt2}+1) \text{ to } (\text{count}_{ipt2}+\text{itt}_{bleed})$$

$$h_{ipt2,i} = h_{ipt2,i-1} - \text{Fraction}_{ipt2} \quad \text{for } i = (\text{count}_{ipt2}+1) \text{ to } (\text{count}_{ipt2}+\text{itt}_{bleed})$$

$$t_{ipt2,i} = T[\text{Steam}, P=P_{ipt2,i}, h=h_{ipt2,i}] \quad \text{for } i = (\text{count}_{ipt2}+1) \text{ to } (\text{count}_{ipt2}+\text{itt}_{bleed})$$

$$s_{ipt2,i} = s[\text{Steam}, h=h_{ipt2,i}, P=P_{ipt2,i}] \quad \text{for } i = (\text{count}_{ipt2}+1) \text{ to } (\text{count}_{ipt2}+\text{itt}_{bleed})$$

IPT #3

$$\text{Fraction}_{ipt3} = \frac{h_{145} - h_{286}}{\text{itt}_{bleed}}$$

$$p_{ipt3,145} = P_{145}$$

$$h_{ipt3,145} = h_{145}$$

$$t_{ipt3,145} = T_{145}$$

$$s_{ipt3,145} = s_{145}$$

$$P_{ipt3,i} = p_{ipt3,i-1} \quad \text{for } i = (\text{count}_{ipt3}+1) \text{ to } (\text{count}_{ipt3}+\text{itt}_{bleed})$$

$$h_{ipt3,i} = h_{ipt3,i-1} - \text{Fraction}_{ipt3} \quad \text{for } i = (\text{count}_{ipt3}+1) \text{ to } (\text{count}_{ipt3}+\text{itt}_{bleed})$$

$$t_{ipt3,i} = T[\text{Steam}, P=P_{ipt3,i}, h=h_{ipt3,i}] \quad \text{for } i = (\text{count}_{ipt3}+1) \text{ to } (\text{count}_{ipt3}+\text{itt}_{bleed})$$

$$s_{ipt3,i} = s[\text{Steam}, h=h_{ipt3,i}, P=P_{ipt3,i}] \quad \text{for } i = (\text{count}_{ipt3}+1) \text{ to } (\text{count}_{ipt3}+\text{itt}_{bleed})$$

LPT #1

$$\text{Fraction}_{Lpt1} = \frac{h_{166} - h_{286}}{\text{itt}_{bleed}}$$

$$p_{Lpt1,166} = P_{166}$$

$$h_{Lpt1,166} = h_{166}$$

$$t_{Lpt1,166} = T_{166}$$

$$s_{Lpt1,166} = s_{166}$$

$$P_{Lpt1,i} = p_{Lpt1,i-1} \quad \text{for } i = (\text{count}_{Lpt1}+1) \text{ to } (\text{count}_{Lpt1}+\text{itt}_{bleed})$$

$$h_{Lpt1,i} = h_{Lpt1,i-1} - \text{Fraction}_{Lpt1} \quad \text{for } i = (\text{count}_{Lpt1}+1) \text{ to } (\text{count}_{Lpt1}+\text{itt}_{bleed})$$

$$t_{Lpt1,i} = T[\text{Steam}, P=P_{Lpt1,i}, h=h_{Lpt1,i}] \quad \text{for } i = (\text{count}_{Lpt1}+1) \text{ to } (\text{count}_{Lpt1}+\text{itt}_{bleed})$$

$$s_{Lpt1,i} = s[\text{Steam}, h=h_{Lpt1,i}, P=P_{Lpt1,i}] \quad \text{for } i = (\text{count}_{Lpt1}+1) \text{ to } (\text{count}_{Lpt1}+\text{itt}_{bleed})$$

LPT #2

$$\text{Fraction}_{\text{Lpt2}} = \frac{h_{186} - h_{236}}{\text{itt}_{\text{bleed}}}$$

$$p_{\text{Lpt2},186} = P_{186}$$

$$h_{\text{Lpt2},186} = h_{186}$$

$$t_{\text{Lpt2},186} = T_{186}$$

$$s_{\text{Lpt2},186} = s_{186}$$

$$P_{\text{Lpt2},i} = p_{\text{Lpt2},i-1} \quad \text{for } i = (\text{count}_{\text{Lpt2}}+1) \text{ to } (\text{count}_{\text{Lpt2}}+\text{itt}_{\text{bleed}})$$

$$h_{\text{Lpt2},i} = h_{\text{Lpt2},i-1} - \text{Fraction}_{\text{Lpt2}} \quad \text{for } i = (\text{count}_{\text{Lpt2}}+1) \text{ to } (\text{count}_{\text{Lpt2}}+\text{itt}_{\text{bleed}})$$

$$t_{\text{Lpt2},i} = T[\text{Steam}, P=P_{\text{Lpt2},i}, h=h_{\text{Lpt2},i}] \quad \text{for } i = (\text{count}_{\text{Lpt2}}+1) \text{ to } (\text{count}_{\text{Lpt2}}+\text{itt}_{\text{bleed}})$$

$$s_{\text{Lpt2},i} = s[\text{Steam}, h=h_{\text{Lpt2},i}, P=P_{\text{Lpt2},i}] \quad \text{for } i = (\text{count}_{\text{Lpt2}}+1) \text{ to } (\text{count}_{\text{Lpt2}}+\text{itt}_{\text{bleed}})$$

Ontbranding

Chemical Constants

$$\text{O2}_{\text{air}} = 0.2315 \quad [\%] \quad \text{Gravimetries}$$

$$\text{N2}_{\text{air}} = 0.7685 \quad [\%]$$

$$\text{CO}_{\text{mm}} = \text{MolarMass}[\text{CarbonDioxide}]$$

$$\text{O}_{2,\text{mm}} = \text{MolarMass}[\text{Oxygen}]$$

$$\text{C}_{\text{mm}} = 12$$

$$\text{S}_{\text{mm}} = 32$$

$$\text{SO}_{2,\text{mm}} = \text{MolarMass}[\text{SulfurDioxide}]$$

$$\text{Water}_{\text{mm}} = \text{MolarMass}[\text{water}]$$

$$\text{H}_{\text{mm}} = \text{MolarMass}[\text{Hydrogen}]$$

Coal Composition

$$\text{Coal}_{\text{GCV}} = 25.35 \text{ MJ/kg}$$

$$\text{Sulphur} = 0.55\%$$

$$\text{Hydrogen} = 2.63\%$$

$$\text{Carbon} = 40.68\%$$

$$\text{Oxygen} = 8.93\%$$

$$\text{Nitrogen} = 0.92\%$$

$$\text{Ash} = 35.12\%$$

$$\text{Moisture} = 11.17\%$$

$$\text{C} + \text{O2} = \text{CO2}$$

$$\text{Oxygen}_{\text{C,required}} = \frac{\text{O}_{2,\text{mm}}}{\text{C}_{\text{mm}}} \cdot \text{Carbon}$$

$$\text{CO2}_{\text{formed}} = \text{Carbon} + \text{Oxygen}_{\text{C,required}}$$

$$S + O_2 = SO_2$$

$$Oxygen_{S,required} = \frac{O_{2,mm}}{S_{mm}} \cdot Sulphur$$

$$SO_{2,formed} = Sulphur + Oxygen_{S,required}$$

$$2H + O_2 = 2H_2O$$

$$Oxygen_{H,required} = \frac{O_{2,mm}}{H_{mm} \cdot 2} \cdot Hydrogen$$

$$H_2O_{formed} = Hydrogen + Oxygen_{H,required}$$

$$Oxygen_{Total,required} = Oxygen_{C,required} + Oxygen_{S,required} + Oxygen_{H,required} - Oxygen$$

$$Air_{Theoretical} = \frac{Oxygen_{Total,required}}{O_{2,air} \cdot 100}$$

$$Q_F = \frac{Q_{in}}{\eta_{furnace}}$$

$$\dot{m}_{coal} = \frac{Q_F}{coal_{GCV} \cdot 1000}$$

$$Air_{Excess} = 20\%$$

$$\dot{m}_{Air} = \dot{m}_{coal} \cdot Air_{Theoretical} + \dot{m}_{coal} \cdot Air_{Theoretical} \cdot \frac{Air_{Excess}}{100}$$

$$ASH$$

$$\delta_{ash} = 0 \quad [\%]$$

$$\dot{m}_{ash} = \dot{m}_{coal} \cdot \frac{Ash}{100}$$

$$\dot{m}_{flyash} = \dot{m}_{ash} \cdot \delta_{ash}$$

$$\dot{m}_{couseash} = \dot{m}_{ash} - \dot{m}_{flyash}$$

$$Counter$$

$$n_0 = 1$$

$$n_i = n_{i-1} + 1 \quad \text{for } i = 1 \text{ to } count_{dst}$$

$$\dot{m}_{CO_2} = \dot{m}_{coal} \cdot \frac{CO_{2,formed}}{100}$$

$$\dot{m}_{SO_2} = \dot{m}_{coal} \cdot \frac{SO_{2,formed}}{100}$$

$$\dot{m}_{H_2O} = \dot{m}_{coal} \cdot \left[\frac{H_2O_{formed} + Moisture}{100} \right]$$

$$\dot{m}_{N_2} = \dot{m}_{coal} \cdot \left[\frac{Nitrogen + m_{N,lug}}{100} \right]$$

$$\dot{M}_{\text{fluegas}} = \dot{m}_{\text{CO}_2} + \dot{m}_{\text{SO}_2} + \dot{m}_{\text{H}_2\text{O}} + \dot{m}_{\text{N}_2}$$

$$m_{\text{formed}} = \text{CO}_{2\text{formed}} + \text{SO}_{2\text{formed}} + \text{H}_2\text{O}_{\text{formed}} + \text{Moisture} + \text{Nitrogen}$$

$$m_{\text{N,lug}} = \frac{\dot{m}_{\text{Air}}}{\dot{m}_{\text{coal}}} \cdot 100 \cdot \text{N}_{2\text{air}}$$

$$\dot{m}_{\text{Fluegas}} = \dot{m}_{\text{coal}} \cdot \left[\frac{m_{\text{formed}} + m_{\text{N,lug}}}{100} \right] + \dot{m}_{\text{flyash}}$$

$$\dot{m}_{\text{fluegas,FFP}} = \dot{m}_{\text{Fluegas}} - \dot{m}_{\text{flyash}}$$

$$\text{H}_2\text{O}_{\text{out}} = \text{H}_2\text{O}_{\text{formed}} + \text{Moisture}$$

$$\eta_{\text{Cycle,Gross}} = \frac{P_{\text{generator}}}{Q_{\text{In}}} \cdot 100$$

$$\eta_{\text{Cycle,Net}} = \frac{P_{\text{Net,e}}}{Q_{\text{In}}} \cdot 100$$

$$\eta_{\text{Overall}} = \frac{P_{\text{Net,e}}}{Q_{\text{F}}} \cdot 100$$

$$\text{HEATRATE}_{\text{net}} = \frac{\dot{m}_{\text{coal}} \cdot \text{coal}_{\text{GCV}} \cdot 1000 \cdot 60 \cdot 60}{P_{\text{Net,e}}}$$

$$\text{HEATRATE}_{\text{gross}} = \frac{\dot{m}_{\text{coal}} \cdot \text{coal}_{\text{GCV}} \cdot 1000 \cdot 60 \cdot 60}{P_{\text{generator}}}$$

Flue gas desulphurisation

$$\text{H}_2\text{O}_{\text{required}} = \frac{10}{32} \cdot \dot{m}_{\text{SO}_2}$$

$$\text{H}_2\text{SO}_3_{\text{formed}} = \frac{42}{32} \cdot \dot{m}_{\text{SO}_2}$$

$$\text{CaCO}_3_{\text{required}} = \frac{50}{42} \cdot \text{H}_2\text{SO}_3_{\text{formed}}$$

$$\text{CaSO}_3_{\text{formed}} = \frac{60}{42} \cdot \text{H}_2\text{SO}_3_{\text{formed}}$$

$$\text{CO}_2_{\text{formed,fgd}} = \frac{24}{42} \cdot \text{H}_2\text{SO}_3_{\text{formed}}$$

$$\text{H}_2\text{O}_{\text{formed,fgd}} = \frac{8}{42} \cdot \text{H}_2\text{SO}_3_{\text{formed}}$$

$$\text{O}_2_{\text{required,fgd}} = \frac{8}{60} \cdot \text{CaSO}_3_{\text{formed}}$$

$$\text{CaSO}_4_{\text{formed}} = \frac{68}{60} \cdot \text{CaSO}_3_{\text{formed}}$$

$$\dot{m}_{\text{CO}_2,\text{ult}} = \dot{m}_{\text{CO}_2} + \text{CO}_{2\text{formed,fgd}}$$

Fans

$$\dot{m}_{PA} = \dot{m}_{Air} \cdot 0.25$$

$$\dot{m}_{SA} = \dot{m}_{Air} - \dot{m}_{PA}$$

$$P_{atm} = 90 \text{ [kPa]}$$

$$T_{atm} = 34 \text{ [C]}$$

$$\rho_{air} = \rho[\text{Air}_{ha}, T=T_{atm}, P=P_{atm}]$$

$$m_{Air} = \frac{\dot{m}_{Air}}{\rho_{air}}$$

$$m_{PA} = \frac{\dot{m}_{PA}}{\rho_{air}}$$

$$m_{SA} = \frac{\dot{m}_{SA}}{\rho_{air}}$$

$$T_{ID} = 90 \text{ [C]}$$

$$P_{ID} = 60 \text{ [kPa]}$$

$$\rho_{fluegas} = 1.326 \text{ [kg/m}^3\text{]}$$

$$m_{ID} = \frac{\dot{m}_{Fluegas}}{\rho_{fluegas}}$$

$$\eta_{fans} = 0.75$$

$$\delta_{FD} = 0.22_m$$

$$\delta_{PA} = 0.22_m$$

$$\delta_{ID} = 0.22_m$$

$$P_{FD,Mech} = m_{SA} \cdot \frac{9.81 \cdot 1000 \cdot \delta_{FD}}{\eta_{fans}}$$

$$P_{FD,Elec} = \frac{P_{FD,Mech}}{0.9 \cdot 1000}$$

$$P_{PA,Mech} = m_{PA} \cdot \frac{9.81 \cdot 1000 \cdot \delta_{PA}}{\eta_{fans}}$$

$$P_{PA,Elec} = \frac{P_{PA,Mech}}{0.9 \cdot 1000}$$

$$P_{ID,Mech} = m_{ID} \cdot \frac{9.81 \cdot 1000 \cdot \delta_{ID}}{\eta_{fans}}$$

$$P_{ID,Elec} = \frac{P_{ID,Mech}}{0.9 \cdot 1000}$$

Mills

$$P_{\text{Mill,required}} = 1250 \text{ [kW]}$$

$$\dot{m}_{\text{mill}} = 27.78 \text{ kg/s}$$

$$A_{\text{antal mills}} = \frac{\dot{m}_{\text{coal}}}{\dot{m}_{\text{mill}}}$$

$$\text{Mills}_{\text{required}} = \text{Ceil} [A_{\text{antal mills}}]$$

$$P_{\text{Mills,e}} = P_{\text{Mill,required}} \cdot \text{Mills}_{\text{required}}$$

$$A_{\text{ux other}} = P_{\text{generator}} \cdot 0.0168776$$

$$P_{\text{Net,e}} = P_{\text{generator}} - P_{\text{CEP,e}} - P_{\text{BFP,e}} - P_{\text{LPH,pump,e}} - P_{\text{ACC,e}} - P_{\text{FD,Elec}} - P_{\text{ID,Elec}} - P_{\text{PA,Elec}} - P_{\text{Mills,e}} - A_{\text{ux other}} - P_{\text{CP}}$$

$$P_{\text{Aux}} = P_{\text{CEP,e}} + P_{\text{BFP,e}} + P_{\text{LPH,pump,e}} + P_{\text{ACC,e}} + P_{\text{FD,Elec}} + P_{\text{ID,Elec}} + P_{\text{PA,Elec}} + P_{\text{Mills,e}} + A_{\text{ux other}} - P_{\text{CP}}$$

Summary

Time = 13.00.00

No Solar

$$\text{Total Electricity, No Solar} = \frac{\text{SumParametric} ['\text{No Solar}', 'P_{\text{Net,e}}']}{1000} \cdot \frac{300}{3600}$$

$$\text{Total Coal, No Solar} = \text{SumParametric} ['\text{No Solar}', 'm_{\text{dot, coal}}'] \cdot \frac{300}{1000}$$

$$\text{Total CO}_2, \text{No Solar} = \text{SumParametric} ['\text{No Solar}', 'm_{\text{dot, CO}_2}'] \cdot \frac{300}{1000}$$

$$\text{Total Green Electricity, No Solar} = \frac{\text{SumParametric} ['\text{No Solar}', 'P_{\text{Solarfield}}']}{1000} \cdot \frac{300}{3600} \cdot \frac{\eta_{\text{Cycle, Gross}}}{100}$$

Mostly Cloudy

$$\text{Total Electricity, Mostly} = \frac{\text{SumParametric} ['\text{Mostly Cloudy Day}', 'P_{\text{Net,e}}']}{1000} \cdot \frac{300}{3600}$$

$$\text{Total Coal, Mostly} = \text{SumParametric} ['\text{Mostly Cloudy Day}', 'm_{\text{dot, coal}}'] \cdot \frac{300}{1000}$$

$$\text{Total CO}_2, \text{Mostly} = \text{SumParametric} ['\text{Mostly Cloudy Day}', 'm_{\text{dot, CO}_2}'] \cdot \frac{300}{1000}$$

$$\text{Total Green Electricity, Mostly} = \frac{\text{SumParametric} ['\text{Mostly Cloudy Day}', 'P_{\text{Solarfield}}']}{1000} \cdot \frac{300}{3600} \cdot \frac{\eta_{\text{Cycle, Gross}}}{100}$$

Very Cloudy Day

$$\text{Total}_{\text{Electricity,Very}} = \frac{\text{SumParametric} ['\text{Very Cloudy Day}', 'P_{\text{Net,e}}']}{1000} \cdot \frac{300}{3600}$$

$$\text{Total}_{\text{Coal,Very}} = \text{SumParametric} ['\text{Very Cloudy Day}', 'm_{\text{dot,coal}}'] \cdot \frac{300}{1000}$$

$$\text{Total}_{\text{CO}_2,\text{Very}} = \text{SumParametric} ['\text{Very Cloudy Day}', 'm_{\text{dot,CO}_2}'] \cdot \frac{300}{1000}$$

$$\text{Total}_{\text{GreenElectricity,Very}} = \frac{\text{SumParametric} ['\text{Very Cloudy Day}', 'P_{\text{Solarfield}}']}{1000} \cdot \frac{300}{3600} \cdot \frac{\eta_{\text{Cycle,Gross}}}{100}$$

Slightly Cloudy Day

$$\text{Total}_{\text{Electricity,Slightly}} = \frac{\text{SumParametric} ['\text{Slightly Cloudy Day}', 'P_{\text{Net,e}}']}{1000} \cdot \frac{300}{3600}$$

$$\text{Total}_{\text{Coal,Slightly}} = \text{SumParametric} ['\text{Slightly Cloudy Day}', 'm_{\text{dot,coal}}'] \cdot \frac{300}{1000}$$

$$\text{Total}_{\text{CO}_2,\text{Slightly}} = \text{SumParametric} ['\text{Slightly Cloudy Day}', 'm_{\text{dot,CO}_2}'] \cdot \frac{300}{1000}$$

$$\text{Total}_{\text{GreenElectricity,Slight}} = \frac{\text{SumParametric} ['\text{Slightly Cloudy Day}', 'P_{\text{Solarfield}}']}{1000} \cdot \frac{300}{3600} \cdot \frac{\eta_{\text{Cycle,Gross}}}{100}$$

Cloudless Cloudy Day

$$\text{Total}_{\text{Electricity,Cloudless}} = \frac{\text{SumParametric} ['\text{Cloudless Day}', 'P_{\text{Net,e}}']}{1000} \cdot \frac{300}{3600}$$

$$\text{Total}_{\text{Coal,Cloudless}} = \text{SumParametric} ['\text{Cloudless Day}', 'm_{\text{dot,coal}}'] \cdot \frac{300}{1000}$$

$$\text{Total}_{\text{CO}_2,\text{Cloudless}} = \text{SumParametric} ['\text{Cloudless Day}', 'm_{\text{dot,CO}_2}'] \cdot \frac{300}{1000}$$

$$\text{Total}_{\text{GreenElectricity,Cloud}} = \frac{\text{SumParametric} ['\text{Cloudless Day}', 'P_{\text{Solarfield}}']}{1000} \cdot \frac{300}{3600} \cdot \frac{\eta_{\text{Cycle,Gross}}}{100}$$

Yearly Data

$$\text{Total}_{\text{Yearly,Electricity}} = \left[\text{Total}_{\text{Electricity,Mostly}} \cdot \frac{\eta_{\text{mostly}}}{100} + \text{Total}_{\text{Electricity,Very}} \cdot \frac{\eta_{\text{Very}}}{100} + \text{Total}_{\text{Electricity,Slightly}} \cdot \frac{\eta_{\text{Slightly}}}{100} + \text{Total}_{\text{Electricity,Cloudless}} \cdot \frac{\eta_{\text{Cloudless}}}{100} \right] \cdot \frac{365}{1000}$$

$$\text{Total}_{\text{Yearly,Coal}} = \left[\text{Total}_{\text{Coal,Mostly}} \cdot \frac{\eta_{\text{mostly}}}{100} + \text{Total}_{\text{Coal,Very}} \cdot \frac{\eta_{\text{Very}}}{100} + \text{Total}_{\text{Coal,Slightly}} \cdot \frac{\eta_{\text{Slightly}}}{100} + \text{Total}_{\text{Coal,Cloudless}} \cdot \frac{\eta_{\text{Cloudless}}}{100} \right] \cdot \frac{365}{1000}$$

$$\text{Total}_{\text{Yearly,CO}_2} = \left[\text{Total}_{\text{CO}_2,\text{Mostly}} \cdot \frac{\eta_{\text{mostly}}}{100} + \text{Total}_{\text{CO}_2,\text{Very}} \cdot \frac{\eta_{\text{Very}}}{100} + \text{Total}_{\text{CO}_2,\text{Slightly}} \cdot \frac{\eta_{\text{Slightly}}}{100} + \text{Total}_{\text{CO}_2,\text{Cloudless}} \cdot \frac{\eta_{\text{Cloudless}}}{100} \right] \cdot \frac{365}{1000}$$

$$\text{Total}_{\text{Yearly,Green}} = \left[\text{Total}_{\text{GreenElectricity,Mostly}} \cdot \frac{\eta_{\text{mostly}}}{100} + \text{Total}_{\text{GreenElectricity,Very}} \cdot \frac{\eta_{\text{Very}}}{100} \right]$$

$$+ \text{Total}_{\text{GreenElectricity,Slight}} \cdot \frac{\eta_{\text{Slightly}}}{100} + \text{Total}_{\text{GreenElectricity,Cloud}} \cdot \frac{\eta_{\text{Cloudless}}}{100} \Bigg] \cdot \frac{365}{1000}$$

SOLUTION

Unit Settings: SI C kPa kJ mass deg

Aantal_{mills} = 3.284

Air_{Theoretical} = 6.477

Aux_{other} = 13418

CaCO_{3,required} = 3.107 [kg/s]

CaSO_{3,formed} = 3.729

CO_{2,formed} = 176.7

coal_{GCV} = 20.1 [MJ/kg]

Count_{boiler} = 43

Count_{condenser} = 216

Count_{dst} = 316

Count_{hph6} = 13

Count_{inject} = 65

Count_{IP2} = 125

Count_{LPH1} = 266

Count_{LPH3} = 306

Count_{LPT2} = 186

count_{LPT,in} = 146

Count_{RH2} = 85

CO_{mm} = 44.01

δP_{RH} = 0.081 [%]

δ_{CR} = 0.98 [%]

δ_{ID} = 0.636 [m]

δ_{IP2,Stage2} = 0.9605 [%]

δ_{LPT,Stage1} = 0.9517 [%]

δ_{PA} = 1.718 [m]

DNI = 1100 [W/m²]

dP_{SF} = 0.1 [%]

η_{BFP} = 0.94 [%]

η_{bfp,motor} = 0.95 [%]

η_{CEP,i} = 0.8 [%]

η_{Cloudless} = 5 [%]

η_{Cycle,Gross} = 48.13 [%]

η_{fans} = 0.75 [%]

η_{generator} = 98.9 [%]

η_{hph5,desuperheating} = -1

η_{hph6,desuperheating} = 1

η_{HPT} = 1 [%]

η_{IP2} = 1 [%]

η_{IP2,i} = 95 [%]

η_{LPH1,heating} = 1.9

η_{LPH3,heating} = 2

η_{LPH,pump} = 0.8 [%]

η_{LPT} = 1 [%]

η_{LPT2,i} = 82 [%]

η_{mostly} = 5 [%]

η_{Slightly} = 52 [%]

η_{Very} = 38 [%]

fraction_{boiler} = 9.839

fraction_{CEP} = 248.6

Fraction_{cep,t} = 0.0238

fraction_{condenser} = 0.09274

Air_{Excess} = 20 [%]

Ash = 34.5 [%]

A_{Collector} = 171000 [m²]

Carbon = 48.19 [%]

CaSO_{4,formed} = 4.226 [kg/s]

CO_{2,formed,fgd} = 1.492

Condenser_{sub} = 48.85

Count_{CEP} = 246

count_{condenser2} = 226

count_{hph5} = 8

Count_{hpt} = 64

Count_{IP1} = 105

Count_{IP3} = 145

Count_{LPH2} = 286

Count_{LPT1} = 166

Count_{LPT3} = 206

Count_{RH1} = 75

Count_{storage} = 236

C_{mm} = 12

δ_{ash} = 0 [%]

δ_{FD} = 0.1967 [m]

δ_{IP2,Stage1} = 0.9802 [%]

δ_{IP2,Stage3} = 0.9505 [%]

δ_{LPT,Stage2} = 0.9578 [%]

δ_T = 4.07 [C]

dP_{AH} = 0.01 [%]

ES = 0.3 [kg/s]

η_{BFP1,i} = 82 [%]

η_{CEP} = 1 [%]

η_{CEP,motor} = 0.94 [%]

η_{CP} = 88 [%]

η_{Cycle,Net} = 44.35 [%]

η_{furnace} = 0.9 [%]

η_{heating} = 0.2521000

η_{hph5,subcooling} = 8

η_{hph6,subcooling} = 8

η_{hpt,i} = 89 [%]

η_{IP2,i} = 91 [%]

η_{IP2,i} = 84.5 [%]

η_{LPH2,heating} = 2

η_{LPH3,subcooling} = 5.9

η_{LPH,pump,motor} = 0.98 [%]

η_{LPT1,i} = 82.5 [%]

η_{LPT3,i} = 97 [%]

η_{Overall} = 39.92 [%]

η_{ST} = 48 [%]

Exponent = 1.338

fraction_{boiler,p} = 223

fraction_{cep,s} = 0.0001949

fraction_{cep,li} = 0

Fraction_{condenser,sub} = 1.702

```

fractiondst = 2.858
FractionHPH6 = 7.666
fractionhpt,p = 895.4
Fractionhpt,t = 11.28
fractionipt1,p = 110.3
Fractionipt1,t = 4.524
Fractionipt2 = 59.89
fractionipt2,s = 0.002007
fractionipt2,li = 6.891
fractionipt3,p = 25.24
Fractionipt3,t = 4.1 [kg/s]
fractionLPH1 = 2.008
fractionLPH3 = 1.425
fractionLpt1,p = 15.59
FractionLpt1,t = 3.938
FractionLpt2 = 61.7
fractionLpt2,s = 0.005356
fractionLpt2,li = 5.002
fractionLpt3,p = 3.152
FractionLpt3,t = 2.229
fractionRH = 24.22
Fractionstorage = 0.1188
GE = 0.6509 [kg/s]
H2Oformed,fgd = 0.4972 [kg/s]
H2Orequired = 0.6215 [kg/s]
HEATRATEgross = 8303 [kJ/kWh]
hhpt,uit = 2972
hipt2 = 3138
hiLpt1 = 2821
hiLpt3 = 2416
hipump2 = 800
Hydrogen = 3.59 [%]
hcascade,hph6 = 1011 [kJ/kg]
hcascade,lph3 = 545.9 [kJ/kg]
hcold = 793.5
hcondenser,sub = 204.5
hHeater,CR = 3021
hhot = 2883
hhph6,uit = 1157
hIPT1,uit,real = 3415
hIPT3,uit,real = 3003
hLPH1,uit = 376.9
hLPH3,uit = 644
hLPT2,uit,real = 2674
Hmm = 2.016
hpump1,uit = 773.5
hSteam = 2596 [kJ/kg]
hwater = 221.5 [kJ/kg]
Ittboiler = 30
ittcondenser = 10
Itthph5 = 5
itthpt = 20
ittLPH = 20
IttRH = 10
MCR = 95.7 [%]
Moisture = 2.2 [%]
mbypass = 257.3 [kg/s]
mAir = 709 [kg/s]
FractionHPH5 = 8.036
Fractionhpt = 56.26
FractionHPT,sr = 0.003821
Fractionipt1 = 66.18
fractionipt1,s = 0.002253
fractionipt1,li = 5.276
fractionipt2,p = 77.77
Fractionipt2,t = 6.308
Fractionipt3 = 62.01
fractionipt3,s = 0.0007791
fractionipt3,li = 4.303
fractionLPH2 = 1.72
FractionLpt1 = 58.26
fractionLpt1,s = 0.003475
fractionLpt1,li = 4.716
fractionLpt2,p = 8.679
FractionLpt2,t = 4.756
FractionLpt3,h = 12.48
fractionLpt3,s = 0.001184
fractionLpt3,li = 2.229
FractionRH2 = 0.6643
Fractionhpt,li = 12.07
H2Oformed = 32.08
H2Oout = 34.28
H2SO3formed = 2.61
HEATRATEnet = 9019 [kJ/kWh]
hipt1 = 3382
hipt3 = 2994
hiLpt2 = 2635
hipump1 = 772.5
hsCEP,uit = 208.2
hcascade,hph5 = 827.3 [kJ/kg]
hcascade,lph1 = 383 [kJ/kg]
hCEP,uit = 208.8
hcold,hp = 793.8
hCondenser,subcooling = 2423
hHeater,IPT,stage1 = 3416
hhph5,uit = 981.6
hHPT,uit = 3018
hIPT2,uit,real = 3163
hLPH1,in = 205.7 [kJ/kg]
hLPH2,uit = 522.1
hLPT1,uit,real = 2853
hLPT3,uit,real = 2424
hoverheat = 3614
hpump2,uit = 805.8
hstorage,uit = 205.7
ittbleed = 40
IttCEP = 10
IttDST = 10
Itthph6 = 5
IttIPT = 20
IttLPT = 20
ittstorage = 10
Millsrequired = 4
mAir = 694.6 [m3/s]
mcascade,lph2 = 54.38
mash = 31.47 [kg/s]

```

```

m_CO2 = 161.2 [kg/s]
m_coal = 91.23 [kg/s]
m_Fluegas = 740.4 [kg/s]
m_flyash = 0
m_mill = 27.78 [kg/s]
m_PA = 177.2 [kg/s]
m_SC = 43.2 [kg/s]
m_formed = 214.3
m_IPT2,tap = 25.53 [kg/s]
m_LPH1,ult = 464
m_LPT1,tap = 28.65 [kg/s]
m_N,lug = 597.3
m_SA = 520.9
m_steam = 2.357 [kg/s]
m_tap,IPT1 = 20.57 [kg/s]
m_water = 32.31 [kg/s]
N2_air = 0.7685 [%]
O2_air = 0.2315 [%]
Oxygen = 8.15 [%]
Oxygen_H,required = 28.49
Oxygen_Total,required = 149.9
P_ACC,e = 6775 [kWe]
P_Aux = 63083 [kWe]
P_BFP,m = 23941 [kW/m]
P_bfp,stage2 = 20271 [kW/m]
P_CEP,e = 1548 [kWe]
P_Cond = 14.25
P_CP = 12.26 [kWe]
P_FD,Elec = 1489 [kWe]
P_generator = 795033 [kWe]
P_Heater,IPT,Stage1 = 2571
P_Heater,IPT,Stage3 = 534.9
P_Heater,LPT,Stage2 = 74.03
P_ID = 60 [kPa]
P_ID,Mech = 4.645E+06
P_IPT = 321716 [kW/m]
P_IPT2 = 136048
P_IPT,Stage1 = 2623 [kPa]
P_IPT,Stage3 = 562.7 [kPa]
P_LPH,pump,e = 166.9 [kWe]
P_LPT = 263263 [kW/m]
P_LPT2 = 82698
P_LPT,Stage1 = 250.9 [kPa]
P_Mills,e = 5000 [kWe]
P_MS = 23162 [kPa]
P_overheat = 4828
P_PA,Mech = 3.902E+06
P_Required = 29852
P_SC,cold = 5940 [kPa]
P_SF,HP = 6600
P_Solarfield = 90288 [kWt]
Q_F = 1833633.2 [kWt]
Q_HPH6 = 58327
Q_reject = 956017 [kWt]
Q_RH2 = -8620
rho_Fluegas = 1.326 [kg/m^3]
RS_IPT,ratio = 0.792 [%]
SO2_formed = 2.18
m_CO2,ult = 162.7 [kg/s]
m_couseash = 31.47
m_fuegas,FPP = 740.4
m_H2O = 31.27 [kg/s]
m_N2 = 545.9 [kg/s]
m_SA = 531.7 [kg/s]
m_SO2 = 1.989 [kg/s]
m_ID = 558.4 [m^3/s]
m_IPT3,tap = 25.72 [kg/s]
m_LPH3,ult = 518.4
m_LPT2,tap = 34.67 [kg/s]
m_PA = 173.6
m_spray = 3.021 [kg/s]
m_tap,cr = 29.02 [kg/s]
m_total = 590.5 [kg/s]
M_fuegas = 740.4
Nitrogen = 1.16 [%]
O2_required,fgd = 0.4972
Oxygen_C,required = 128.5
Oxygen_S,required = 1.09
O2,mm = 32
P_atm = 90 [kPa]
P_BFP,e = 25201 [kWe]
P_bfp,stage1 = 3670 [kW/m]
P_CEP = 2500 [kPa]
P_CEP,m = 1455 [kW/m]
P_condenser = 14.25 [kPa]
P_CR = 5254 [kPa]
P_FD,Mech = 1.340E+06
P_Heater,CR = 5149
P_Heater,IPT,Stage2 = 1025
P_Heater,LPT,Stage1 = 238.8
P_HPT = 218896 [kW/m]
P_ID,Elec = 5161 [kWe]
P_interstage = 5254
P_IPT1 = 102629
P_IPT3 = 83039
P_IPT,Stage2 = 1068 [kPa]
P_Losses = 6690 [kPa]
P_LPH,pump,m = 163.6 [kW/m]
P_LPT1 = 73708
P_LPT3 = 106857
P_LPT,Stage2 = 77.3 [kPa]
P_Mill,required = 1250 [kW]
P_Net,e = 731926 [kWe]
P_PA,Elec = 4336 [kWe]
P_Radiation = 188100 [kW]
P_RH = 4828 [kPa]
P_SC,hot = 6000 [kPa]
P_shaft = 803876 [kW/m]
Q_boiler1 = 1318001.63 [kWt]
Q_HPH5 = 58589 [kWt]
Q_P = 1650263.3 [kWt]
Q_RH = 332268
rho_air = 1.021
RS = 2.479 [kg/s]
RS_ratio = 0.0053 [%]
SO2,mm = 64.06

```

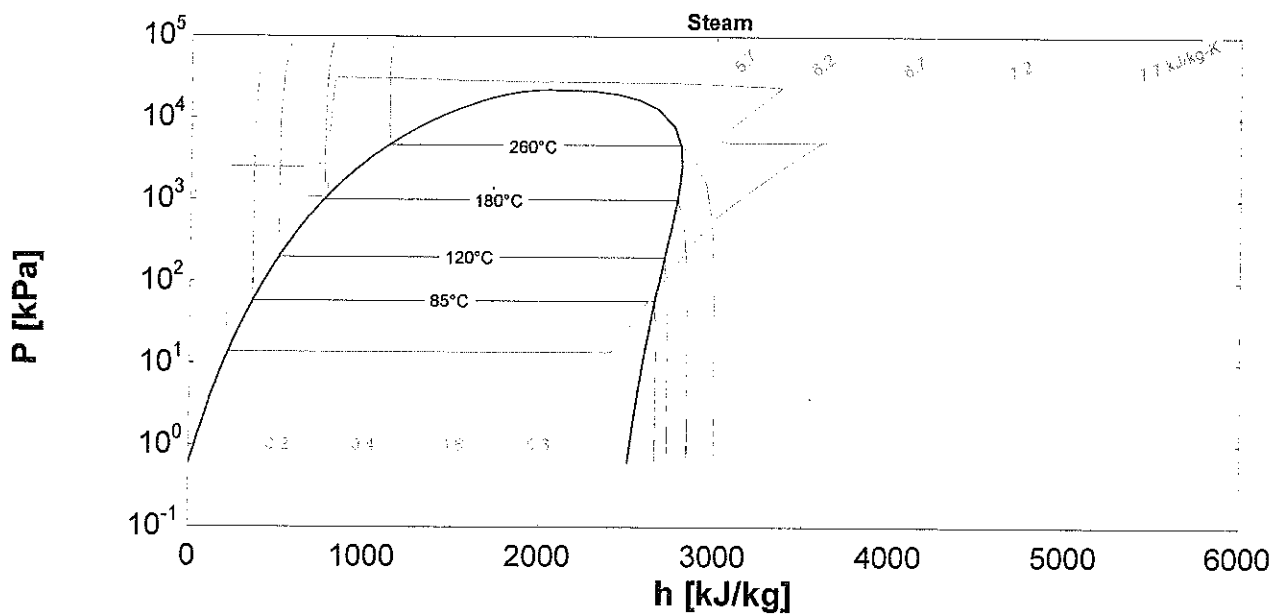
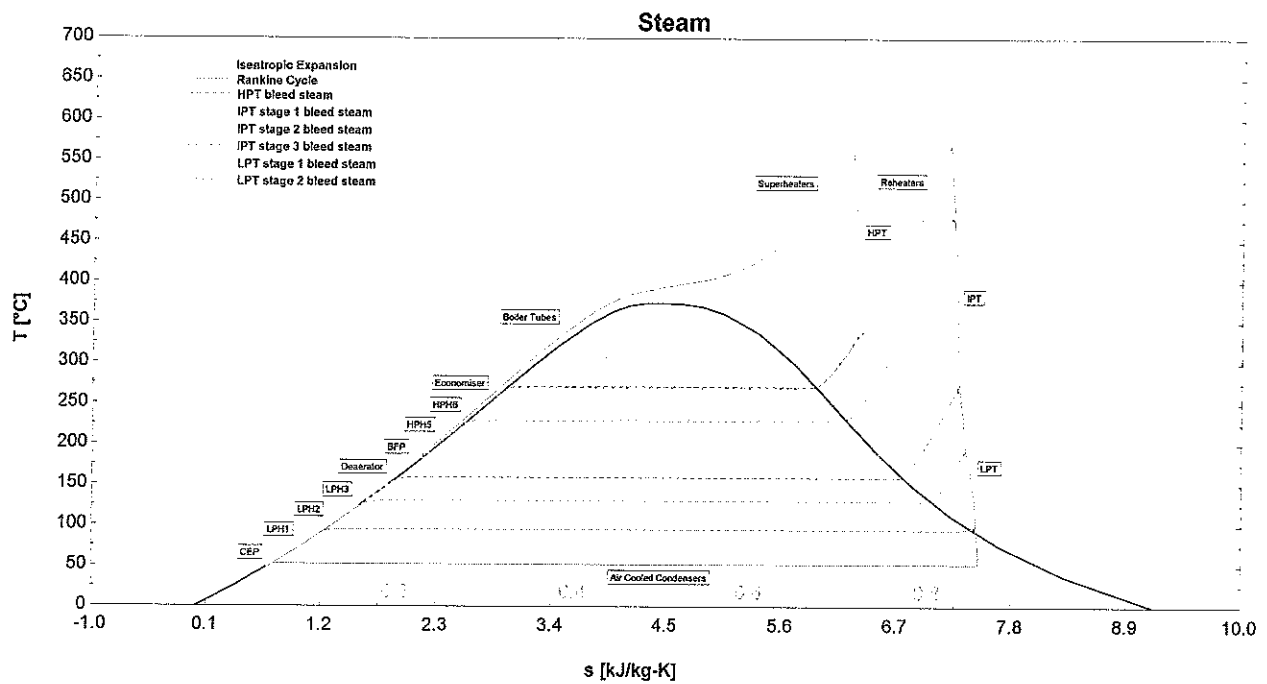
```

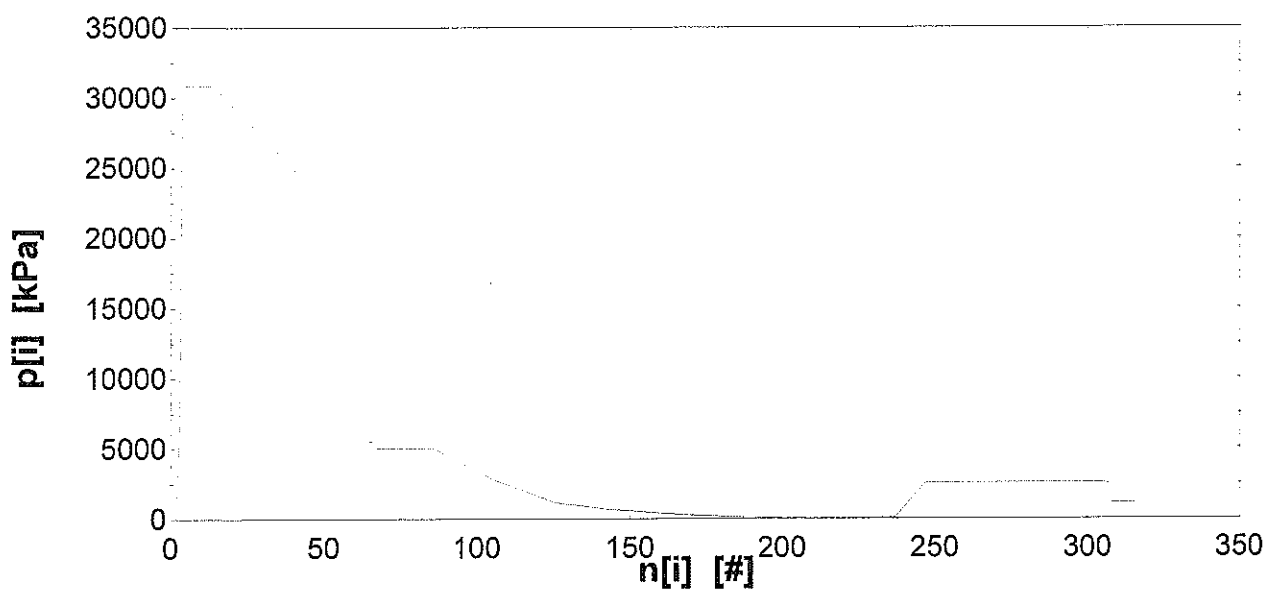
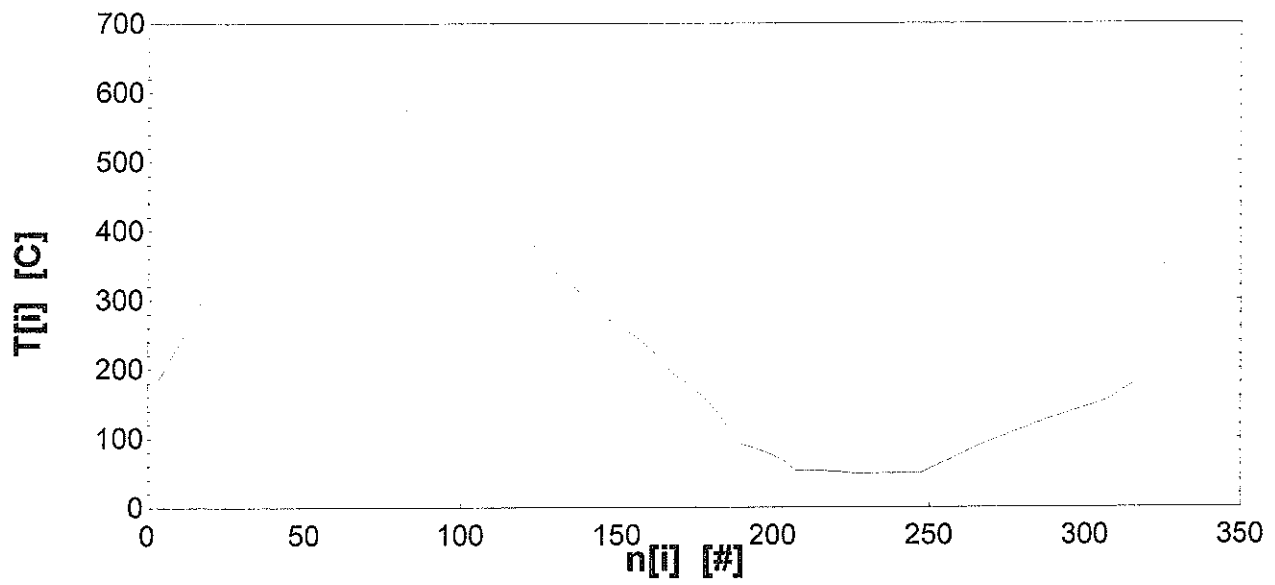
srhpt,uit = 6.347
SSipt = 0.4272 [kg/s]
Sulphur = 1.09 [%]
Sipt1,uit = 7.24
Sipt3,uit = 7.296
SLpt2,uit = 7.472
Smm = 32
TCEP,uit = 49.13
Tipt1,uit = 464.5
Tipt3,uit = 267.3
TLPT2,uit = 92.59
TotalCO2,Cloudless = 12937.8 [T]
TotalCO2,NoSolar = 13152.2 [T]
TotalCO2,Very = 13074.4 [T]
TotalCoal,Mostly = 7442.8 [T]
TotalCoal,Slightly = 7361.4 [T]
TotalElectricity,Cloudless = 15950.6 [MWhe]
TotalElectricity,NoSolar = 15925.2 [MWhe]
TotalElectricity,Very = 15934.5 [MWhe]
TotalGreenElectricity,Mostly = 3.1 [MWhe]
TotalGreenElectricity,Slight = 317.4 [MWhe]
TotalYearly,CO2 = 4758.3 [kT]
TotalYearly,Electricity = 5817.7 [GWhe]
Tatrn = 34 [C]
Tcascade,hph6 = 234.5 [C]
Tcascade,LPH3 = 129.8 [C]
TCold = 186.3 [C]
Thot = 300 [C]
THPH6,uit = 264.8
TID = 90 [C]
Tipt1,uit = 479.5
Tipt3,uit = 271.4
TLPH2,uit = 123.9
TLPT1,uit = 192.6
TLPT3,uit = 52.92
Toverheat = 576.6
TSaturation = 275.6 [C]
Tsat,IPTs1 = 225.5
Tsat,IPTs3 = 154.4
Tsat,LPHs2 = 91.44
Ttheo = 752.2
Vbfp,stage2 = 0.001119
Vmean,CEP = 0.001011
Vmean,lph2p = 0.001064
x = 0.06798 [%]

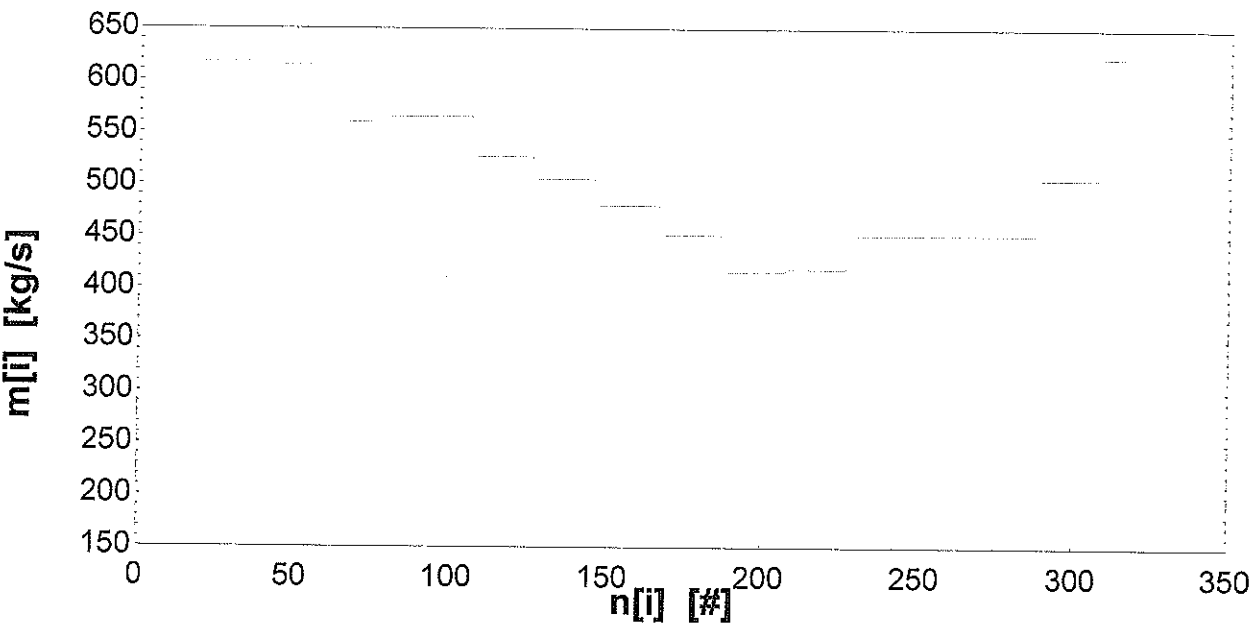
SSHPT = 3.129 [kg/s]
SSipt,ratio = 0.000762 [%]
SCEP,uit = 0.6945
Sipt2,uit = 7.28
SLpt1,uit = 7.365 [kg/s]
SLpt3,uit = 7.496
SMS = 6.271
Thpt,uit = 318.7
Tipt2,uit = 341.7
TLPT1,uit = 177
TLPT3,uit = 52.92
TotalCO2,Mostly = 13150.7 [T]
TotalCO2,Slightly = 13007.0 [T]
TotalCoal,Cloudless = 7322.3 [T]
TotalCoal,NoSolar = 7443.6 [T]
TotalCoal,Very = 7399.5 [T]
TotalElectricity,Mostly = 15925.4 [MWhe]
TotalElectricity,Slightly = 15942.5 [MWhe]
TotalGreenElectricity,Cloud = 468.8 [MWhe]
TotalGreenElectricity,NoSolar = 0 [MWhe]
TotalGreenElectricity,Very = 169.7 [MWhe]
TotalYearly,Coal = 2693.0 [kT]
TotalYearly,Green = 92.4 [GWhe]
Tcascade,hph5 = 194.3 [C]
tcascade,lph1 = 91.44 [C]
TCEP,uit = 49.37
TCR = 334.4 [C]
THPH5,uit = 226.5
Thpt,uit = 334.4
Tipt1 = 479.5 [C]
Tipt2,uit = 353.4
TLPH1,uit = 89.54
TLPH3,uit = 152.4
TLPT2,uit = 97.5
TMS = 560 [C]
TRH = 570 [C]
Tsat,cr = 265.8
Tsat,IPTs2 = 181
Tsat,LPHs1 = 125.9
Tsat,LPTs3 = 52.92
Vbfp,stage1 = 0.001127
Vcascade,lph2 = 0.0 [kW]
Vsteam = 0.716
Watermm = 18.02

```

No unit problems were detected







9.11 Appendix F: Thermodynamic array table – No Solar Scenario

[illegible]

[illegible]

[illegible]

9.12 Appendix G - Thermodynamic array table – Solar Augmentation (1 100 W/m²)

Array	m[1]	m[2]	T[1]	h_Lo2[1]	h_Lo2[2]	h_Lo2[3]	h_Lo2[4]	h_Lo2[5]	h_Lo2[6]	h_Lo2[7]	h_Lo2[8]	h_Lo2[9]	h_Lo2[10]	p_Lo2[1]	p_Lo2[2]	p_Lo2[3]	p_Lo2[4]	p_Lo2[5]	s_Lo2[1]	s_Lo2[2]	s_Lo2[3]	s_Lo2[4]	s_Lo2[5]	s_Lo2[6]	s_Lo2[7]	s_Lo2[8]	s_Lo2[9]	s_Lo2[10]	s_Lo2[11]	s_Lo2[12]	s_Lo2[13]	s_Lo2[14]	s_Lo2[15]	s_Lo2[16]	s_Lo2[17]	s_Lo2[18]	s_Lo2[19]	s_Lo2[20]	s_Lo2[21]	s_Lo2[22]	s_Lo2[23]	s_Lo2[24]	s_Lo2[25]	s_Lo2[26]	s_Lo2[27]	s_Lo2[28]	s_Lo2[29]	s_Lo2[30]	s_Lo2[31]	s_Lo2[32]	s_Lo2[33]	s_Lo2[34]	s_Lo2[35]	s_Lo2[36]	s_Lo2[37]	s_Lo2[38]	s_Lo2[39]	s_Lo2[40]	s_Lo2[41]	s_Lo2[42]	s_Lo2[43]	s_Lo2[44]	s_Lo2[45]	s_Lo2[46]	s_Lo2[47]	s_Lo2[48]	s_Lo2[49]	s_Lo2[50]	s_Lo2[51]	s_Lo2[52]	s_Lo2[53]	s_Lo2[54]	s_Lo2[55]	s_Lo2[56]	s_Lo2[57]	s_Lo2[58]	s_Lo2[59]	s_Lo2[60]	s_Lo2[61]	s_Lo2[62]	s_Lo2[63]	s_Lo2[64]	s_Lo2[65]	s_Lo2[66]	s_Lo2[67]	s_Lo2[68]	s_Lo2[69]	s_Lo2[70]	s_Lo2[71]	s_Lo2[72]	s_Lo2[73]	s_Lo2[74]	s_Lo2[75]	s_Lo2[76]	s_Lo2[77]	s_Lo2[78]	s_Lo2[79]	s_Lo2[80]	s_Lo2[81]	s_Lo2[82]	s_Lo2[83]	s_Lo2[84]	s_Lo2[85]	s_Lo2[86]	s_Lo2[87]	s_Lo2[88]	s_Lo2[89]	s_Lo2[90]	s_Lo2[91]	s_Lo2[92]	s_Lo2[93]	s_Lo2[94]	s_Lo2[95]	s_Lo2[96]	s_Lo2[97]	s_Lo2[98]	s_Lo2[99]	s_Lo2[100]	s_Lo2[101]	s_Lo2[102]	s_Lo2[103]	s_Lo2[104]	s_Lo2[105]	s_Lo2[106]	s_Lo2[107]	s_Lo2[108]	s_Lo2[109]	s_Lo2[110]	s_Lo2[111]	s_Lo2[112]	s_Lo2[113]	s_Lo2[114]	s_Lo2[115]	s_Lo2[116]	s_Lo2[117]	s_Lo2[118]	s_Lo2[119]	s_Lo2[120]	s_Lo2[121]	s_Lo2[122]	s_Lo2[123]	s_Lo2[124]	s_Lo2[125]	s_Lo2[126]	s_Lo2[127]	s_Lo2[128]	s_Lo2[129]	s_Lo2[130]	s_Lo2[131]	s_Lo2[132]	s_Lo2[133]	s_Lo2[134]	s_Lo2[135]	s_Lo2[136]	s_Lo2[137]	s_Lo2[138]	s_Lo2[139]	s_Lo2[140]	s_Lo2[141]	s_Lo2[142]	s_Lo2[143]	s_Lo2[144]	s_Lo2[145]	s_Lo2[146]	s_Lo2[147]	s_Lo2[148]	s_Lo2[149]	s_Lo2[150]	s_Lo2[151]	s_Lo2[152]	s_Lo2[153]	s_Lo2[154]	s_Lo2[155]	s_Lo2[156]	s_Lo2[157]	s_Lo2[158]	s_Lo2[159]	s_Lo2[160]	s_Lo2[161]	s_Lo2[162]	s_Lo2[163]	s_Lo2[164]	s_Lo2[165]	s_Lo2[166]	s_Lo2[167]	s_Lo2[168]	s_Lo2[169]	s_Lo2[170]	s_Lo2[171]	s_Lo2[172]	s_Lo2[173]	s_Lo2[174]	s_Lo2[175]	s_Lo2[176]	s_Lo2[177]	s_Lo2[178]	s_Lo2[179]	s_Lo2[180]	s_Lo2[181]	s_Lo2[182]	s_Lo2[183]	s_Lo2[184]	s_Lo2[185]	s_Lo2[186]	s_Lo2[187]	s_Lo2[188]	s_Lo2[189]	s_Lo2[190]	s_Lo2[191]	s_Lo2[192]	s_Lo2[193]	s_Lo2[194]	s_Lo2[195]	s_Lo2[196]	s_Lo2[197]	s_Lo2[198]	s_Lo2[199]	s_Lo2[200]	s_Lo2[201]	s_Lo2[202]	s_Lo2[203]	s_Lo2[204]	s_Lo2[205]	s_Lo2[206]	s_Lo2[207]	s_Lo2[208]	s_Lo2[209]	s_Lo2[210]	s_Lo2[211]	s_Lo2[212]	s_Lo2[213]	s_Lo2[214]	s_Lo2[215]	s_Lo2[216]	s_Lo2[217]	s_Lo2[218]	s_Lo2[219]	s_Lo2[220]	s_Lo2[221]	s_Lo2[222]	s_Lo2[223]	s_Lo2[224]	s_Lo2[225]	s_Lo2[226]	s_Lo2[227]	s_Lo2[228]	s_Lo2[229]	s_Lo2[230]	s_Lo2[231]	s_Lo2[232]	s_Lo2[233]	s_Lo2[234]	s_Lo2[235]	s_Lo2[236]	s_Lo2[237]	s_Lo2[238]	s_Lo2[239]	s_Lo2[240]	s_Lo2[241]	s_Lo2[242]	s_Lo2[243]	s_Lo2[244]	s_Lo2[245]	s_Lo2[246]	s_Lo2[247]	s_Lo2[248]	s_Lo2[249]	s_Lo2[250]	s_Lo2[251]	s_Lo2[252]	s_Lo2[253]	s_Lo2[254]	s_Lo2[255]	s_Lo2[256]	s_Lo2[257]	s_Lo2[258]	s_Lo2[259]	s_Lo2[260]	s_Lo2[261]	s_Lo2[262]	s_Lo2[263]	s_Lo2[264]	s_Lo2[265]	s_Lo2[266]	s_Lo2[267]	s_Lo2[268]	s_Lo2[269]	s_Lo2[270]	s_Lo2[271]	s_Lo2[272]	s_Lo2[273]	s_Lo2[274]	s_Lo2[275]	s_Lo2[276]	s_Lo2[277]	s_Lo2[278]	s_Lo2[279]	s_Lo2[280]	s_Lo2[281]	s_Lo2[282]	s_Lo2[283]	s_Lo2[284]	s_Lo2[285]	s_Lo2[286]	s_Lo2[287]	s_Lo2[288]	s_Lo2[289]	s_Lo2[290]	s_Lo2[291]	s_Lo2[292]	s_Lo2[293]	s_Lo2[294]	s_Lo2[295]	s_Lo2[296]	s_Lo2[297]	s_Lo2[298]	s_Lo2[299]	s_Lo2[300]	s_Lo2[301]	s_Lo2[302]	s_Lo2[303]	s_Lo2[304]	s_Lo2[305]	s_Lo2[306]	s_Lo2[307]	s_Lo2[308]	s_Lo2[309]	s_Lo2[310]	s_Lo2[311]	s_Lo2[312]	s_Lo2[313]	s_Lo2[314]	s_Lo2[315]	s_Lo2[316]	s_Lo2[317]	s_Lo2[318]	s_Lo2[319]	s_Lo2[320]	s_Lo2[321]	s_Lo2[322]	s_Lo2[323]	s_Lo2[324]	s_Lo2[325]	s_Lo2[326]	s_Lo2[327]	s_Lo2[328]	s_Lo2[329]	s_Lo2[330]	s_Lo2[331]	s_Lo2[332]	s_Lo2[333]	s_Lo2[334]	s_Lo2[335]	s_Lo2[336]	s_Lo2[337]	s_Lo2[338]	s_Lo2[339]	s_Lo2[340]	s_Lo2[341]	s_Lo2[342]	s_Lo2[343]	s_Lo2[344]	s_Lo2[345]	s_Lo2[346]	s_Lo2[347]	s_Lo2[348]	s_Lo2[349]	s_Lo2[350]	s_Lo2[351]	s_Lo2[352]	s_Lo2[353]	s_Lo2[354]	s_Lo2[355]	s_Lo2[356]	s_Lo2[357]	s_Lo2[358]	s_Lo2[359]	s_Lo2[360]	s_Lo2[361]	s_Lo2[362]	s_Lo2[363]	s_Lo2[364]	s_Lo2[365]	s_Lo2[366]	s_Lo2[367]	s_Lo2[368]	s_Lo2[369]	s_Lo2[370]	s_Lo2[371]	s_Lo2[372]	s_Lo2[373]	s_Lo2[374]	s_Lo2[375]	s_Lo2[376]	s_Lo2[377]	s_Lo2[378]	s_Lo2[379]	s_Lo2[380]	s_Lo2[381]	s_Lo2[382]	s_Lo2[383]	s_Lo2[384]	s_Lo2[385]	s_Lo2[386]	s_Lo2[387]	s_Lo2[388]	s_Lo2[389]	s_Lo2[390]	s_Lo2[391]	s_Lo2[392]	s_Lo2[393]	s_Lo2[394]	s_Lo2[395]	s_Lo2[396]	s_Lo2[397]	s_Lo2[398]	s_Lo2[399]	s_Lo2[400]	s_Lo2[401]	s_Lo2[402]	s_Lo2[403]	s_Lo2[404]	s_Lo2[405]	s_Lo2[406]	s_Lo2[407]	s_Lo2[408]	s_Lo2[409]	s_Lo2[410]	s_Lo2[411]	s_Lo2[412]	s_Lo2[413]	s_Lo2[414]	s_Lo2[415]	s_Lo2[416]	s_Lo2[417]	s_Lo2[418]	s_Lo2[419]	s_Lo2[420]	s_Lo2[421]	s_Lo2[422]	s_Lo2[423]	s_Lo2[424]	s_Lo2[425]	s_Lo2[426]	s_Lo2[427]	s_Lo2[428]	s_Lo2[429]	s_Lo2[430]	s_Lo2[431]	s_Lo2[432]	s_Lo2[433]	s_Lo2[434]	s_Lo2[435]	s_Lo2[436]	s_Lo2[437]	s_Lo2[438]	s_Lo2[439]	s_Lo2[440]	s_Lo2[441]	s_Lo2[442]	s_Lo2[443]	s_Lo2[444]	s_Lo2[445]	s_Lo2[446]	s_Lo2[447]	s_Lo2[448]	s_Lo2[449]	s_Lo2[450]	s_Lo2[451]	s_Lo2[452]	s_Lo2[453]	s_Lo2[454]	s_Lo2[455]	s_Lo2[456]	s_Lo2[457]	s_Lo2[458]	s_Lo2[459]	s_Lo2[460]	s_Lo2[461]	s_Lo2[462]	s_Lo2[463]	s_Lo2[464]	s_Lo2[465]	s_Lo2[466]	s_Lo2[467]	s_Lo2[468]	s_Lo2[469]	s_Lo2[470]	s_Lo2[471]	s_Lo2[472]	s_Lo2[473]	s_Lo2[474]	s_Lo2[475]	s_Lo2[476]	s_Lo2[477]	s_Lo2[478]	s_Lo2[479]	s_Lo2[480]	s_Lo2[481]	s_Lo2[482]	s_Lo2[483]	s_Lo2[484]	s_Lo2[485]	s_Lo2[486]	s_Lo2[487]	s_Lo2[488]	s_Lo2[489]	s_Lo2[490]	s_Lo2[491]	s_Lo2[492]	s_Lo2[493]	s_Lo2[494]	s_Lo2[495]	s_Lo2[496]	s_Lo2[497]	s_Lo2[498]	s_Lo2[499]	s_Lo2[500]	s_Lo2[501]	s_Lo2[502]	s_Lo2[503]	s_Lo2[504]	s_Lo2[505]	s_Lo2[506]	s_Lo2[507]	s_Lo2[508]	s_Lo2[509]	s_Lo2[510]	s_Lo2[511]	s_Lo2[512]	s_Lo2[513]	s_Lo2[514]	s_Lo2[515]	s_Lo2[516]	s_Lo2[517]	s_Lo2[518]	s_Lo2[519]	s_Lo2[520]	s_Lo2[521]	s_Lo2[522]	s_Lo2[523]	s_Lo2[524]	s_Lo2[525]	s_Lo2[526]	s_Lo2[527]	s_Lo2[528]	s_Lo2[529]	s_Lo2[530]	s_Lo2[531]	s_Lo2[532]	s_Lo2[533]	s_Lo2[534]	s_Lo2[535]	s_Lo2[536]	s_Lo2[537]	s_Lo2[538]	s_Lo2[539]	s_Lo2[540]	s_Lo2[541]	s_Lo2[542]	s_Lo2[543]	s_Lo2[544]	s_Lo2[545]	s_Lo2[546]	s_Lo2[547]	s_Lo2[548]	s_Lo2[549]	s_Lo2[550]	s_Lo2[551]	s_Lo2[552]	s_Lo2[553]	s_Lo2[554]	s_Lo2[555]	s_Lo2[556]	s_Lo2[557]	s_Lo2[558]	s_Lo2[559]	s_Lo2[560]	s_Lo2[561]	s_Lo2[562]	s_Lo2[563]	s_Lo2[564]	s_Lo2[565]	s_Lo2[566]	s_Lo2[567]	s_Lo2[568]	s_Lo2[569]	s_Lo2[570]	s_Lo2[571]	s_Lo2[572]	s_Lo2[573]	s_Lo2[574]	s_Lo2[575]	s_Lo2[576]	s_Lo2[577]	s_Lo2[578]	s_Lo2[579]	s_Lo2[580]	s_Lo2[581]	s_Lo2[582]	s_Lo2[583]	s_Lo2[584]	s_Lo2[585]	s_Lo2[586]	s_Lo2[587]	s_Lo2[588]	s_Lo2[589]	s_Lo2[590]	s_Lo2[591]	s_Lo2[592]	s_Lo2[593]	s_Lo2[594]	s_Lo2[595]	s_Lo2[596]	s_Lo2[597]	s_Lo2[598]	s_Lo2[599]	s_Lo2[600]	s_Lo2[601]	s_Lo2[602]	s_Lo2[603]	s_Lo2[604]	s_Lo2[605]	s_Lo2[606]	s_Lo2[607]	s_Lo2[608]	s_Lo2[609]	s_Lo2[610]	s_Lo2[611]	s_Lo2[612]	s_Lo2[613]	s_Lo2[614]	s_Lo2[615]	s_Lo2[616]	s_Lo2[617]	s_Lo2[618]	s_Lo2[619]	s_Lo2[620]	s_Lo2[621]	s_Lo2[622]	s_Lo2[623]	s_Lo2[624]	s_Lo2[625]	s_Lo2[626]	s_Lo2[627]	s_Lo2[628]	s_Lo2[629]	s_Lo2[630]	s_Lo2[631]	s_Lo2[632]	s_Lo2[633]	s_Lo2[634]	s_Lo2[635]	s_Lo2[636]	s_Lo2[637]	s_Lo2[638]	s_Lo2[639]	s_Lo2[640]	s_Lo2[641]	s_Lo2[642]	s_Lo2[643]	s_Lo2[644]	s_Lo2[645]	s_Lo2[646]	s_Lo2[647]	s_Lo2[648]	s_Lo2[649]	s_Lo2[650]	s_Lo2[651]	s_Lo2[652]	s_Lo2[653]	s_Lo2[654]	s_Lo2[655]	s_Lo2[656]	s_Lo2[657]	s_Lo2[658]	s_Lo2[659]	s_Lo2[660]	s_Lo2[661]	s_Lo2[662]	s_Lo2[663]	s_Lo2[664]	s_Lo2[665]	s_Lo2[666]	s_Lo2[667]	s_Lo2[668]	s_Lo2[669]	s_Lo2[670]	s_Lo2[671]	s_Lo2[672]	s_Lo2[673]	s_Lo2[674]	s_Lo2[675]	s_Lo2[676]	s_Lo2[677]	s_Lo2[678]	s_Lo2[679]	s_Lo2[680]	s_Lo2[681]	s_Lo2[682]	s_Lo2[683]	s_Lo2[684]	s_Lo2[685]	s_Lo2[686]	s_Lo2[687]	s_Lo2[688]	s_Lo2[689]	s_Lo2[690]	s_Lo2[691]	s_Lo2[692]	s_Lo2[693]	s_Lo2[694]	s_Lo2[695]	s_Lo2[696]	s_Lo2[697]	s_Lo2[698]	s_Lo2[699]	s_Lo2[700]	s_Lo2[701]	s_Lo2[702]	s_Lo2[703]	s_Lo2[704]	s_Lo2[705]	s_Lo2[706]	s_Lo2[707]	s_Lo2[708]	s_Lo2[709]	s_Lo2[710]	s_Lo2[711]	s_Lo2[712]	s_Lo2[713]	s_Lo2[714]	s_Lo2[715]	s_Lo2[716]	s_Lo2[717]	s_Lo2[718]	s_Lo2[719]	s_Lo2[720]	s_Lo2[721]	s_Lo2[722]	s_Lo2[723]	s_Lo2[724]	s_Lo2[725]	s_Lo2[726]	s_Lo2[727]	s_Lo2[728]	s_Lo2[729]	s_Lo2[730]	s_Lo2[731]	s_Lo2[732]	s_Lo2[733]	s_Lo2[734]	s_Lo2[735]	s_Lo2[736]	s_Lo2[737]	s_Lo2[738]	s_Lo2[739]	s_Lo2[740]	s_Lo2[741]	s_Lo2[742]	s_Lo2[743]	s_Lo2[744]	s_Lo2[745]	s_Lo2[746]	s_Lo2[747]	s_Lo2[748]	s_Lo2[749]	s_Lo2[750]	s_Lo2[751]	s_Lo2[752]	s_Lo2[753]	s_Lo2[754]	s_Lo2[755]	s_Lo2[756]	s_Lo2[757]	s_Lo2[758]	s_Lo2[759]	s_Lo2[760]	s_Lo2[761]	s_Lo2[762]	s_Lo2[763]	s_Lo2[764]	s_Lo2[765]	s_Lo2[766]	s_Lo2[767]	s_Lo2[768]	s_Lo2[769]	s_Lo2[770]	s_Lo2[771]	s_Lo2[772]	s_Lo2[773]	s_Lo2[774]	s_Lo2[775]	s_Lo2[776]	s_Lo2[777]	s_Lo2[778]	s_Lo2[779]	s_Lo2[780]	s_Lo2[781]	s_Lo2[782]	s_Lo2[783]	s_Lo2[784]	s_Lo2[785]	s_Lo2[786]	s_Lo2[787]	s_Lo2[788]	s_Lo2[789]	s_Lo2[790]	s_Lo2[791]	s_Lo2[792]	s_Lo2[793]	s_Lo2[794]	s_Lo2[795]	s_Lo2[796]	s_Lo2[797]	s_Lo2[798]	s_Lo2[799]	s_Lo2[800]	s_Lo2[801]	s_Lo2[802]	s_Lo2[803]	s_Lo2[804]	s_Lo2[805]	s_Lo2[806]	s_Lo2[807]	s_Lo2[808]	s_Lo2[809]	s_Lo2[810]	s_Lo2[811]	s_Lo2[812]	s_Lo2[813]	s_Lo2[814]	s_Lo2[815]	s_Lo2[816]	s_Lo2[817]	s_Lo2[818]	s_Lo2[819]	s_Lo2[820]	s_Lo2[821]	s_Lo2[822]	s_Lo2[823]	s_Lo2[824]	s_Lo2[825]	s_Lo2[826]	s_Lo2[827]	s_Lo2[828]	s_Lo2[829]	s_Lo2[830]	s_Lo2[831]	s_Lo2[832]	s_Lo2[833]	s_Lo2[834]	s_Lo2[835]	s_Lo2[836]	s_Lo2[837]	s_Lo2[838]	s_Lo2[839]	s_Lo2[840]	s_Lo2[841]	s_Lo2[842]	s_Lo2[843]	s_Lo2[844]	s_Lo2[845]	s_Lo2[846]	s_Lo2[847]	s_Lo2[848]	s_Lo2[849]	s_Lo2[850]	s_Lo2[851]	s_Lo2[852]	s_Lo2[853]	s_Lo2[854]	s_Lo2[855]	s_Lo2[856]	s_Lo2[857]	s_Lo2[858]	s_Lo2[859]	s_Lo2[860]	s_Lo2[861]	s_Lo2[862]	s_Lo2[863]	s_Lo2[864]	s_Lo2[865]	s_Lo2[866]	s_Lo2[867]	s_Lo2[868]	s_Lo2[869]	s_Lo2[870]	s_Lo2[871]	s_Lo2[872]	s_Lo2[873]	s_Lo2[874]	s_Lo2[875]	s_Lo2[876]	s_Lo2[877]	s_Lo2[878]	s_Lo2[879]	s_Lo2[880]	s_Lo2[881]	s_Lo2[882]	s_Lo2[883]	s_Lo2[884]	s_Lo2[885]	s_Lo2[886]	s_Lo2[887]	s_Lo2[888]	s_Lo2[889]	s_Lo2[890]	s_Lo2[891]	s_Lo2[892]	s_Lo2[893]	s_Lo2[894]	s_Lo2[895]	s_Lo2[896]	s_Lo2[897]	s_Lo2[898]	s_Lo2[899]	s_Lo2[900]	s_Lo2[901]	s_Lo2[902]	s_Lo2[903]	s_Lo2[904]	s_Lo2[905]	s_Lo2[906]	s_Lo2[907]	s_Lo2[908]	s_Lo2[909]	s_Lo2[910]	s_Lo2[911]	s_Lo2[912]	s_Lo2[913]	s_Lo2[914]	s_Lo2[915]	s_Lo2[916]	s_Lo2[917]	s_Lo2[918]	s_Lo2[919]	s_Lo2[920]	s_Lo2[921]	s_Lo2[922]	s_Lo2[923]	s_Lo2[924]	s_Lo2[925]	s_Lo2[926]	s_Lo2[927]	s_Lo2[928]	s_Lo2[929]	s_Lo2[930]	s_Lo2[931]	s_Lo2[932]	s_Lo2[933]	s_Lo2[934]	s_Lo2[935]	s_Lo2[936]	s_Lo2[937]	s_Lo2[938]	s_Lo2[939]	s_Lo2[940]	s_Lo2[941]	s_Lo2[942]	s_Lo2[943]	s_Lo2[944]	s_Lo2[945]	s_Lo2[946]	s_Lo2[947]	s_Lo2[948]	s_Lo2[949]	s_Lo2[950]	s_Lo2[951]	s_Lo2[952]	s_Lo2[953]	s_Lo2[954]	s_Lo2[955]	s_Lo2[956]	s_Lo2[957]	s_Lo2[958]	s_Lo2[959]	s_Lo2[960]	s_Lo2[961]	s_Lo2[962]	s_Lo2[963]	s_Lo2[964]	s_Lo2[965]	s_Lo2[966]	s_Lo2[967]	s_Lo2[968]	s_Lo2[969]	s_Lo2[970]	s_Lo2[971]	s_Lo2[972]	s_Lo2[973]	s_Lo2[974]	s_Lo2[975]	s_Lo2[976]	s_Lo2[977]	s_Lo2[978]	s_Lo2[979]	s_Lo2[980]	s_Lo2[981]	s_Lo2[982]	s_Lo2[983]	s_Lo2[984]	s_Lo2[985]	s_Lo2[986]	s_Lo2[987]	s_Lo2[988]	s_Lo2[989]	s_Lo2[990]	s_Lo2[991]	s_Lo2[992]	s_Lo2[993]	s_Lo2[994]	s_Lo2[995]	s_Lo2[996]	s_Lo2[997]	s_Lo2[998]	s_Lo2[999]	s_Lo2[1000]	s_Lo2[1001]	s_Lo2[1002]	s_Lo2[1003]	s_Lo2[1004]	s_Lo2[1005]	s_Lo2[1006]	s_Lo2[1007]	s_Lo2[1008]	s_Lo2[1009]	s_Lo2[1010]	s_Lo2[1011]	s_Lo2[1012]	s_Lo2[1013]	s_Lo2[1014]	s_Lo2[1015]	s_Lo2[1016]	s_Lo2[1017]	s_Lo2[1018]	s_Lo2[1019]	s_Lo2[1020]	s_Lo2[1021]	s_Lo2[1022]	s_Lo2[1023]

[illegible]

3.15	3.16	3.17	3.18	3.19	3.20	3.21	3.22	3.23	3.24	3.25	3.26	3.27	3.28	3.29	3.30	3.31	3.32	3.33	3.34	3.35	3.36	3.37	3.38	3.39	3.40	3.41	3.42	3.43	3.44	3.45	3.46	3.47	3.48	3.49	3.50	3.51	3.52	3.53	3.54	3.55	3.56	3.57	3.58	3.59	3.60	3.61	3.62	3.63	3.64	3.65	3.66	3.67	3.68	3.69	3.70	3.71	3.72	3.73	3.74	3.75	3.76	3.77	3.78	3.79	3.80	3.81	3.82	3.83	3.84	3.85	3.86	3.87	3.88	3.89	3.90	3.91	3.92	3.93	3.94	3.95	3.96	3.97	3.98	3.99	4.00
3.15	3.16	3.17	3.18	3.19	3.20	3.21	3.22	3.23	3.24	3.25	3.26	3.27	3.28	3.29	3.30	3.31	3.32	3.33	3.34	3.35	3.36	3.37	3.38	3.39	3.40	3.41	3.42	3.43	3.44	3.45	3.46	3.47	3.48	3.49	3.50	3.51	3.52	3.53	3.54	3.55	3.56	3.57	3.58	3.59	3.60	3.61	3.62	3.63	3.64	3.65	3.66	3.67	3.68	3.69	3.70	3.71	3.72	3.73	3.74	3.75	3.76	3.77	3.78	3.79	3.80	3.81	3.82	3.83	3.84	3.85	3.86	3.87	3.88	3.89	3.90	3.91	3.92	3.93	3.94	3.95	3.96	3.97	3.98	3.99	4.00