DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

NABR Wijayawardhana

Date: 28th January 2010

We endorse the declaration by the candidate.

Eng. WDAS Wijayapala

Senior Lecturer

University of Moratuwa

Eng. DG Rienzie Fernando

Managing Director

Amithi Power Consultants (Pvt) Ltd

D. G. RIENZIE FERNANDO
B.Sc. Eng. (Hons), C. Eng., MIE (SL)

ACKNOWLEDGEMENTS

This work has been carried out at the Department of Electrical Engineering, University of Moratuwa.

Foremost, I would like to express my sincere gratitude to my advisor Eng. WDAS Wijayapala, Senior Lecturer, University of Moratuwa for the continuous support of my M.Sc. study and research, for his patience, comments and immense knowledge. His guidance helped me in all the time of research and writing of this dissertation. I could not have imagined having a better advisor and a mentor for my M.Sc. study.

I take this opportunity to extend my earnest thanks to Eng. DG Rienzie Fernando, Managing Director, Amithi Power Consultants (Pvt) Ltd, who enlightened me the first glance of research and motivated me, whenever I discussed technical issues encouraging me to carry out this project successfully.

My sincere thanks also go to Eng. S Bogahawatte, Project Director, Lighting Sri Lanka Hambantota Project, Ceylon Electricity Board for his encouragement and leading me working on diverse exciting project works.

I thank my fellow colleague Roshan for the sleepless nights we were working together before deadlines, and for all the fun we had in the last two years. Also I thank my friends Prasanna, Dinesh and Sarath.

And I like to remind my brothers, Chathura and Sachintha. In particular, I am grateful to my fiancée Sashi for her love and continuous encouragement.

Last but not the least, I would like to thank my family: my parents Wijayawardhana and Ariyawathie, for bringing me up and supporting me spiritually throughout my life.

CONTENTS

Declaration		i
Abstract		ii
Acknowledgement		iii
Contents		iv
List of Figures		vi
List of Tables		vii
List of Abbreviations		viii
1	**Introduction**	**1**
1.1	Background	1
1.2	Objective	2
1.3	Scope of work	2
2	**Problem Statement**	3
3	**Technology**	**5**
3.1	Solar Thermal Power	5
	3.1.1 Power Towers	6
	3.1.2 Parabolic Troughs	7
	3.1.3 Dish /Engine Systems	8
4	**Site Selection**	**09**
4.1	Availability of Solar Resources	09
4.2	Availability of suitable Lands (Topography)	11
4.3	Availability of Water	12
4.4	Proximity to Available Transmission	12
4.5	Impact on Environment	13
4.6	Other Considerations	13
5	**Conceptual Design of the Plant**	**14**
5.1	Determination of the Size of the Plant	14
5.2	The Methodology of Conceptual Design	15
5.3	Design Calculations	15
	5.3.1. Design of Heliostats Field	17

5.3.2. Design of the Heliostat Field Layout 18
5.3.2.1. Cosine Effect 18
5.3.2.2. Shadowing & Blocking 21
5.3.2.3. Reflectance 22
5.3.2.4. Atmospheric transmittance 22
5.3.2.5. Field Layout 23
5.3.2.6. Tower Height 27
5.3.2.7. Atmospheric Transmittance in Tanamalwila Site 28
5.3.3 Design of the Receiver 29
5.3.4 Design of the Storage 30
5.3.5 Thermal Performance 31

6 Environmental Impacts 33
6.1 Impact on Environment in General 33
6.2 Minimization of Land Use Impacts 34
6.3 Displacement of CO_2, NO_x and SO_2 Emissions 35

7 Economic Evaluation 36
7.1 Cost Estimation 36
7.2 Estimation of Annual Energy Output 38
7.3 Evaluation of Economic Feasibility 39
7.4 Sensitivity Analysis 42

8 Conclusion 45
References 46
Appendix A 48
Appendix B 51
Appendix C 52
Appendix D 55

List of Figures

Figure		Page
Chapter 3		
Figure 3.1	A schematic diagram of solar thermal power plant.....	6
Figure 3.2	A simple diagram of a power tower	7
Chapter 4		
Figure 4.1	A pyrheliometer in a site	09
Figure 4.2	Monthly average DNI at Hambantota	10
Figure 4.3	The area having annual DNI 4.5~5 kWh/m2/day and the selected site	12
Chapter 5		
Figure 5.1	A simple schematic diagram of a power tower	16
Figure 5.2	Cosine effect.....	19
Figure 5.3	Azimuth Angle A and Altitude α	20
Figure 5.4	Cosine efficiency at Tanamalwila site.....	21
Figure 5.5	Average monthly visibility at Hambantota	23
Figure 5.6	Radial Stagger pattern	24
Figure 5.7	Radial and azimuthal spacing Vs. Distance	26
Figure 5.8	Local heliostat field density	26
Figure 5.9	DNI Profile of April of Hambantota in Wh/m2	27
Figure 5.10	Range of optimum receiver tower heights for systems with different power levels	28
Figure 5.11	Atmospheric Transmittance at Tanamalwila.....	29
Chapter 6		
Figure 6.1	A Space for Cultivations	34
Chapter 7		
Figure 7.1	Power Tower Costs in Percentages for long term estimation	38

List of Tables

Table		Page
Chapter 5		
Table 5.1	Heliostats layout design results for tower height of 180m....	25
Table 5.2	Distance to furthest line of heliostats	27
Table 5.3	*The ratio between Peak DNI of a day to Average DNI of a day*	*27*
Chapter 7		
Table 7.1	Midterm Cost Estimations of Tanamalwila 50 MW Power Tower	36
Table 7.2	Long term Cost Estimations of Tanamalwila 50 MW Power Tower	37
Table 7.3	Input Parameters for Economic Evaluation.....	39
Table 7.4	Final Results of Economic Evaluation	41
Table 7.5	After Tax Net Equity Cash Flow.....	42
Table 7.6	LCOE vs. Capacity Factor.....	42
Table 7.7	LCOE vs. Real Discount Rate.....	43
Table 7.8	LCOE vs. Minimum Required IRR.....	43
Table 7.9	LCOE vs. Availability of Carbon Credit.....	43
Table 7.10	LCOE vs. Loan Term	44
Table 7.11	LCOE vs. Availability of BOI state	44
Table 7.12	LCOE vs. PPA escalation rate.....	44

List of Abbreviations

Term	Definition or Clarification
ADB	Asian Development Bank
BOI	Board of Investment
CPV	Concentrating Photovoltaic
CSP	Concentrating Solar Power
CST	Concentrating Solar Thermal
DNI	Direct Normal Irradiance
GEF	Global Environmental Fund
HTF	Heat Transfer Fluid
IPP	Independent Power Producer
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
kJ	Kilo Jules
kWe	Kilo Watts (electrical energy)
kWh	Kilo Watt Hours
kWt	Kilo Watts (thermal energy)
LCOE	Levelized Cost of Energy
LFR	Linear Fresnel Reflector
m	meters
MJ	Mega Joules
MVA	Mega Volt Amperes
MWh	Mega Watt Hours
NREL	National Renewable Energy Laboratory
PPA	Power Purchase Agreement
PV	Photovoltaic
USD	United States Dollars
° C	Celsius