

**A METHOD TO ASSESS FEASIBILITY OF  
ELECTRICITY GENERATION USING MUNICIPAL  
SOLID WASTE**

G.A.G. Pathirana

(08/8608)



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
www.theses.moratuwa.lk  
Degree of Master of Engineering

Department of Mechanical Engineering

University of Moratuwa

Sri Lanka

May 2013

## DECLARATION OF THE CANDIDATE AND SUPERVISOR

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature:  University of Moratuwa, Sri Lanka  
Electronic Theses & Dissertations  
www.lib.mrt.ac.lk

Date:

The above candidate has carried out research for the Masters under my supervision.

Signature of the supervisor:

Date

## ABSTRACT

Management of municipal solid waste is a severe issue locally and globally too, since its generation is increasing day by day. Many social, health and environmental problems occur around the Municipal solid waste dump yards. To overcome this problem there are many methods practicing around the world. But this issue is site specific, area specific & country specific.

Electricity requirement in Sri Lanka is increasing exceedingly in past few years. In 2012, 71% of electricity generation is based on thermal generating plants mainly by using diesel, heavy fuel or coal. The balance 28% is based on Hydro power generation which is mainly depend on rain. Only 1% of total generation was done by Non-Conventional Renewable Energy sources.

Electricity generation by municipal solid waste is one method to address the above issues. This method is practicing some countries with great success but fails in some countries.

Generation of solid waste in the country is very much higher than that count. The total collection of MSW was estimated as 7000 Ton/day. In Colombo district, the amount of solid waste collection was 1250Ton/day and the collection under CMC areas was nearly 700 Ton/day. This amount is almost 10% of the MSW collection throughout the country and it is reasonable to focus the study to the waste collection under CMC areas.

For this study, generation of electricity by using MSW combustion, 10MW Steam turbine was selected since this size & technology was proven and using in many countries, all over the world.

The amount of energy grabbed in the collected MSW was calculated and verified that it was quite enough for the plant that selected for electricity generation by MSW.

To get the financial feasibility of this project, the financial tool that using for the similar studies around the world, Net Present Value, was selected. The NPV scenario is that if the NPV is negative, that shows the project is financially not feasible, if the NPV is zero then the project reached its break-even point and if the NPV is positive the project is financially feasible. The break-even point shows the simple payback period of the project.

Finally, the variation of simple pay-back period of the project was observed with the changes of major factors that influence greatly to the project.

## DEDICATION

I lovingly dedicate this thesis to my wife and children who supported me in each & every way to make this effort a success.



University of Moratuwa, Sri Lanka.

Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## ACKNOWLEDGEMENT

I take this opportunity to express my sincere thanks to Prof. Rahula A. Attalage, Deputy Vice Chancellor of University of Moratuwa, Sri Lanka as my supervisor, for the encouragement and guidance given to fulfillment of this achievement. I would also like to express my sincere thanks to Dr. A.G.T Sugathapala, Course coordinator of MEng/PG Diploma in Energy Technology (2008), Dept. of Mechanical engineering, University of Moratuwa, for his great contribution to select this topic for the research project and guidance for finding data.

I also thank Mr. Nalin Mannapperuma, Deputy Director, Waste management Authority, Western province, Sri Lanka, and Mr. Hafeeze, Deputy Director, Solid waste management division of Colombo Municipal Council, Sri Lanka, for their fullest support shown me to collect data from their data base and guidance given me to get details from relevant authorities.

I would also like to thank my friends and colleagues specially Eng. H.M. Senevirathna, for their enormous encouragement, knowledge and help given me to make this task a success.

At last, but not least, I would like to thank my loving wife, children and parents for their tireless support and encouragement during the course of my academic career.



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## TABLE OF CONTENTS

Declaration of the candidate and supervisor	i
Abstract	ii
Dedication	iii
Acknowledgement	iv
List of figures	viii
List of table	ix
List of abbreviations	xi
List of appendices	xii
1. Introduction	1
1.1. Background	1
1.2. Objective	3
2. MSW at a glance and electricity generating methods	5
2.1. Introduction	5
2.2. What is waste	5
2.2.1. Definition of Waste	5
2.2.2. Examples of Waste	5
2.3. Categorization of Waste	6
2.3.1. Solid, Liquid, Gas	6
2.3.2. Organic, Inorganic	6
2.3.3. Industrial, Commercial, Institutional	7
2.3.4. Domestic/Household waste	7
2.3.5. Hazardous waste	7
2.4. Categorization of Solid Waste	8
2.5. Characteristics of Solid Waste	8
2.5.1 Factors affecting the composition	8
2.6. Municipal Solid Waste (MSW)	9
2.6.1. Generation of MSW	9
2.6.2. Properties of MSW	13
2.6.3. Present processes of MSW conversion	14
2.6.4. Mass Burn Technology	15
2.6.5. Refuse-Derived Fuel	17
2.6.6. Pyrolysis/ Thermal gasification	17
2.6.7. Permitting Issues for Pyrolysis/Thermal Gasification Facilities	17
2.7. Electricity Generation by MSW	18
2.7.1. Steam Turbine Technology	18
2.7.2. Gasification Technology	21
2.7.3. Gasification of Municipal Solid Waste	23
2.7.4. Type of Gasifires for MSW treatment	23
2.7.5. Advantages and Disadvantages of Gasification	25

3.	Availability and Capacity of collection of MSW at areas under CMC	27
3.1.	MSW collection by CMC	27
3.2.	Estimation of generation of municipal solid waste in areas under CMC	31
3.2.1.	Qion et al Method	31
3.2.2.	Survey Sampling Method	32
3.2.3.	Method using the available statistical data	33
4.	Implementation of electricity generating plant by MSW	36
4.1.	Site Selection	36
4.2.	Plant requirement	37
4.2.1.	Preparation & fuel handling	39
4.2.2.	Inlet air filtration/ supply system	40
4.2.3.	Combustor/ Boiler system	40
4.2.4.	Steam Turbine	41
4.2.5.	Balance of Plant (BOP)	44
4.2.6.	Electrical system	45
4.3.	Some important definitions, estimations and assumptions made to development of the power plant	48
4.4.	Steam power cycle	51
4.4.1.	Isentropic efficiency of Turbine	53
4.4.2.	Boiler efficiency	53
4.4.3.	Heat Rate	54
5.	Assessment of the energy availability of MSW	55
5.1.	Energy potential in MSW at the area under CMC	55
6.	Economic assessment of the plant	61
6.1.	Introduction	61
6.1.1.	Net Present Value	61
6.1.2.	Internal rate of return	62
6.2.	National Energy Policy & Strategies of Sri Lanka	62
6.3.	Tariff system for NCRE of Sri Lanka	63
6.4.	Cost involvement of development of the plant	65
6.5.	Financial Assessment	69
6.6.	Factors that affects to project feasibility	73
6.6.1.	Load factor consideration	74
6.6.2.	Financial Subsidiary for the project (for Capital cost)	74
6.6.3.	Selling price	75
6.6.4.	Financial Grant for effective handling of MSW	76
6.6.5.	Tax benefits	77
6.7.	Issues related to the plant	77
7.	Conclusion and Recommendations	79

Reference List	83
Bibliography	85
Appendix A: Gazette Notification on 10.06.2008	86
Appendix B: Tariff announcement for Non-Conventional Renewable Energy	87



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)



## LIST OF FIGURES

	Page
Figure 1.1 : Electricity generation by Source	1
Figure 2.1 : Examples of domestic waste	6
Figure 2.2 : Population density in Sri Lanka	10
Figure 2.3 : Generation of MSW in Provincial level	12
Figure 2.4 : Combined Heat & Power (CHP) steam turbine by fuel type	18
Figure 2.5 : Technological Description	19
Figure 2.6 : Steam Turbine schematic diagram	20
Figure 2.7 : T-S Diagram for steam cycle	20
Figure 2.8 : Non-condensing steam turbine	21
Figure 2.9 : Extraction Steam turbine	21
Figure 2.10 : Gasification process	22
Figure 3.1 : Administrative district under CMC	28
Figure 4.1 : Fuel (MSW) handling system	39
Figure 4.2 : MSW mass burning	40
Figure 4.3 : Electrical system conceptual diagram	47
Figure 4.4 : Process and Component flow chart	47
Figure 4.5 : MSW Combustion plant arrangement	48
Figure 4.6 : Losses and auxiliary consumption between turbine and energy meter	49
Figure 4.7 : Stage losses of the steam turbine	47
Figure 4.8 : T-S Diagram and Schematic Diagram for reheat Rankine cycle	51
Figure 6.1 : The graph of NPV vs. Plant life	72
Figure 6.2 : The graph of NPV vs. Discount factor	73
Figure 6.3 : The graph of NPV vs. Plant life with different load factors	74
Figure 6.4 : The graph of NPV vs. Plant life with a subsidiary to capital cost	75
Figure 6.5 : The graph of NPV vs. Plant life with changing selling price	76

## LIST OF TABLES

	Page
Table 2.1 : Population by province	9
Table 2.2 : Sri Lanka's Major cities by population	10
Table 2.3 : Contribution for generation of waste by a person living in area	11
Table 2.4 : Collection of MSW in Provincial level	11
Table 2.5 : Important parameters in Sri Lanka	12
Table 2.6 : Important parameters in Western province	12
Table 2.7 : Composition of MSW generation with income level	13
Table 2.8 : Gasifire design vs. Fuel capacity	24
Table 3.1 : Useful details of districts under CMC	30
Table 4.1 : Losses between Turbine and Generator	50
Table 5.1 : Amount of MSW collection under CMC	55
Table 5.2 : Percentage of constituents of MSW	55
Table 5.3 : Collection of MSW in different constituent	56
Table 5.4 : Amount of Energy in different constituent	56
Table 5.5 : Available Energy of MSW constituent	57
Table 5.6 : Usage of energy per hour in the combustor	59
Table 5.7 : Annual production of energy per year	60
Table 6.1 : Tariffs for electricity produced using NCRE sources based on SPPAs; Option 1	63
Table 6.2 : Tariffs for electricity produced using NCRE sources based on SPPAs; Option 2	64
Table 6.3 : Percentage breakdown of contract price	66
Table 6.4 : Division of total project cost	66
Table 6.5 : Operation cost of the plant	67
Table 6.6 : Cost estimation for security and transport	67
Table 6.7 : Total annual operating cost	68
Table 6.8 : Worksheet for Net Present Value	71
Table 6.9 : Decrement of the payback period with load factor	74

Table 6.10	: Decrement of the payback period with a subsidiary to the capital cost	75
Table 6.11	: Decrement of the payback period with the increment of selling price	76



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## LIST OF ABBREVIATIONS

Abbreviation	Description
MSW	Municipal Solid Waste
CHP	Combined Heat & Power
PRV	Pressure reducing valve
CMC	Colombo Municipal Council
CEB	Ceylon Electricity Board
BOP	Balance of plant
HP	High pressure
IP	Intermediate pressure
LP	Low pressure
EOT	Electric Overhead Travelling
HVAC	Heat, Ventilation & Air Condition
PF	Power Factor
CT	Current Transformer
VT	Voltage Transformer
GSS	Grid Sub Stations
O&M	Operation and Maintenance
BTU	British thermal unit
NPV	Net Present Value
IRR	Internal Rate of Return
PUCSL	Public Utility Commission of Sri Lanka.
NCRE	Non-conventional Renewable Energy
SPPAs	Standardized Power Purchase Agreements
EPC	Engineering, procurement & construction
FAC	Fuel Adjustment Charges



University of Moratuwa, Sri Lanka.  
 E-Books & Dissertations  
 www.mart.mil.lk

## LIST OF APPENDICES

Appendix	Description
Appendix A	National Energy Policy & Strategies of Sri Lanka, Gazette Notification
Appendix B	Non-Conventional Renewable Energy Tariff Announcement



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)