

**POTENTIAL OF GENERATING POWER OUT OF RICE HUSK
AND
ITS FINANCIAL VIABILITY**

P.I.A.S. Perera



University (09/8554) tuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Degree of Master of Science

Department of Electrical Engineering

**University of Moratuwa
Sri Lanka**

March 2013

DECLARATION

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

It has not been accepted for any degree, and is not concurrently submitted in candidature of any other degree.

P.I.A.S. Perera

Date: 6 January 2015



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

I endorse the declaration made by the candidate.

Dr. Asanka Rodrigo

Senior Lecturer

University of Moratuwa

ABSTRACT

Due to intense fossil fuel dependency on energy generation in the world, cost of energy has a greater bearing on the price of fossil fuels. Most of the countries in the world are suffering due to this and Sri Lanka is no exception. It is in this context, promotion of biomass as a renewable source is so vital to the country. Even though biomass plays a greater role as a source of primary energy in the country, its contribution towards power generation is negligible. Rice being the staple food of the country as well as the crop with highest land area under cultivation, rice husk produced in paddy processing was found to have a significant potential in power generation. Currently, rice husk has not been identified as promising source of energy for electricity production in the country. Hence, the purpose of this research was to investigate the possibility of using rice husk as a viable source of power generation in the country thereby releasing part of the burden on country's fuel bill.

Annual paddy production of the country remains slightly above 4 million metric tons with 800,000 metric tons of rice husk being produced as a byproduct in paddy processing. If assumed total rice husk production is tapped for energy generation, total energy potential comes to around 2,176 pJ per annum at the conversion rate of 20%. Since significant portion of this energy is currently being harnessed for thermal applications, potential for electricity generation out of rice husk is restricted somewhat. However, the findings of this research shows that still 30% of rice husk produced in the country is available for exploitation in power generation with a potential of about 180GWh per annum. Greater portion of this electrical energy can be tapped in the districts of Ampara, Polonnaruwa, Anuradhapura and Kurunegala because of higher paddy production and milling capacities in these districts. However, the scale of power generation is limited to 1MW to 2MW maximum plant capacities for above districts while small scale plants of the order of 40kW showing better financial viability under *Net Metering Scheme* currently in force.

ACKNOWLEDGEMENTS

This thesis was prepared as a part of my MSc program offered by the University of Moratuwa, Sri Lanka. During the course of this research there were many individuals who supported me in various ways to complete this work successfully. In the first place, I would like to express my sincere gratitude to the Ministry of New and Renewable Energy (MNRE), India for making me to conceive this project idea during the training offered by them in the field of Renewable Energy in October 2010. (I witnessed India's efforts and success in promoting rice husk as a source of electricity in India during this training and that inspired me to pick this as my research project.)

However, this thesis would not have been possible unless continuous guidance, expertise and comments of my supervisor, Dr. Asanka Rodrigo, Senior Lecturer of University of Moratuwa. From the day I conceived this research idea, he made sure that this work moved gradually towards the culmination smoothly.



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.tb.mru.ac.lk

Most difficult part of this exercise was the collection of data related to rice mills and rice husk produced in the district of Polonnaruwa. My special thanks in this regard should go to Miss. Hemali Amaradiwakara, Area Engineer, CEB, Minneriya and her meter readers for collecting above data while executing their duties in meter reading. In this endeavour, the role of rice millers cannot be forgotten as their information was very valuable in this research.

The biggest challenge I faced during this research was to find time for this and meeting targets. I am sure if not for my wife, Hemani Gunathilake, my children Upulith and Upethma and my mother R.A.N Hemalatha, I could not have completed this research on time. Hence, my gratitude should go to my beloved family members for the sacrifices they made during this research.

CONTENTS

Declaration.....	i
Abstract.....	ii
Acknowledgement.....	iii
Contents.....	iv
List of Figures.....	vii
List of Tables.....	ix
List of Abreviations.....	x
List of Appendices.....	xi
1 Introduction.....	1
1.1 Background.....	1
1.1.1 Current energy and electricity situation of the country.....	1
1.1.2 Rice husk as a source of non-conventional renewable energy.....	4
1.2 Objective of the Research.....	6
1.3 Methodology.....	6
2 Problem Statement.....	7
3 Energy from Rice Husk.....	9
3.1 Rice Plant and Paddy.....	9
3.2 Paddy Cultivation in Sri Lanka.....	10
3.3 Rice Husk and Its Properties.....	11
3.4 Uses of Rice Husk in Sri Lanka.....	13
4 Availability of Rice Husk and its Potential.....	16
4.1 Paddy Production.....	16
4.2 Availability of Rice Husk.....	19
4.3 Potential of Power Generation from Rice Husk.....	19
4.4 Area wise Paddy Production and Rice Husk Potential.....	22
5 Conversion Technologies.....	25
5.1 Introduction.....	25
5.2 Biomass Direct Combustion and Co-firing.....	26
5.3 Gasification.....	31

5.3.1.	Mechanism of gasification.....	33
5.3.2.	Gasification reactors	35
5.3.2.1.	Fixed bed gasifiers	35
5.3.2.2.	Fluidized bed gasifiers	38
5.3.3	Biomass integrated gasification combined cycle (IGCC) power generation.....	43
5.3.4	Selection of a technology for rice husk conversion.....	44
6	Case Study on Polonnaruwa District	46
6.1	Introduction.....	46
6.2	Paddy Production in Polonnaruwa District.....	47
6.3	Paddy Milling in Polonnaruwa District.....	48
6.4	Current Uses and Availability of Rice Husk in Polonnaruwa District	49
6.5	Availability of Rice Husk and its Distribution.....	50
6.6	Power Generation Potential of Rice Husk in the Polonnaruwa District..	52
6.7	Selection of Conversion Technology.....	53
6.8	Process Discription of the Selected Plant	54
6.9	Financial Analysis.....	56
6.9.1	Capital cost of the project.....	56
6.9.2	Fuel cost of the power plant	57
6.9.3	Operation and maintenance (O&M) cost of the power plant .	57
6.9.4	Debt /equity ratio of the capital investment.....	58
6.9.5	Finance cost and loan repayment period	58
6.9.6	Tax and incentives applicable	58
6.9.7	Returns of the project.....	58
6.9.8	Summary of the financial analysis.....	59
6.9.9	Sensitivity analysis.....	60
7	Results and Discussion.....	61
7.1	Potential of Rice Husk for Power Generation.....	61
7.2	Harnessing RH Potential in the Country.....	63
7.3	Promotion of RH Power Plants in the Country.....	68

References.....	70
Appendix I	73
Appendix II.....	74
Appendix III.....	82
Appendix IV.....	83



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

List of Figures

Figure		Page
Chapter 1		
Figure 1.1	Primary energy supply in TOE for year 2010	1
Figure 1.2	Hydro/Thermal/Non-conventional energy share in the National Grid	2
Figure 1.3	Gross (grid) electricity generation in GWh, 2010	2
Figure 1.4	Electricity generation mix (including off grid), 2005-2010	3
Chapter 3		
Figure 3.1	Cross section of a rice grain	9
Figure 3.2	Paddy cultivated areas and paddy production (2000/2001)	10
Figure 3.3	Electrification level of districts up to early 2011	14
Chapter 4		
Figure 4.1	Paddy production in <i>Maha</i> season from 1951 to 2011	16
Figure 4.2	Paddy production in <i>Yala</i> season from 1952 to 2010	17
Figure 4.3	Annual paddy production in thousand tons from 1990 to 2010	18
Figure 4.4	Area wise annual average paddy production (2001-2010)	23
Figure 4.5	Paddy production Vs milling capacity by district	24
Chapter 5		
Figure 5.1	Conventional steam cycle for power generating	27
Figure 5.2	Direct combustion technologies	28
Figure 5.3	Methods for co-firing biomass with pulverized coal	31
Figure 5.4	Basic steps of the process of a biomass gasification plant	33
Figure 5.5	Stages of gasification process	33
Figure 5.6	Fixed bed gasifier types	36
Figure 5.7	Fluidized bed gasifier	39
Figure 5.8	Circulating fluidized bed gasifier	42
Figure 5.9	Flow diagram of biomass IGCC power plant	43

Chapter 6

Figure 6.1	District map of Polonnaruwa	46
Figure 6.2	Annual paddy production of highest paddy producing districts in Sri Lanka.	48
Figure 6.3	Percentage use of RH for different applications	50
Figure 6.4	Paddy milling capacity in Polonnaruwa district by area	51
Figure 6.5	Rice husk production [in MT] of Polonnaruwa in 2010 by Area	51
Figure 6.6	Major paddy milling areas of Polonnaruwa district	52
Figure 6.7	Schematic diagram of the conceptual RH power plant	55



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

List of Tables

Table		Page
Chapter 3		
Table 3.1	Calorific values of different biomass fuels	12
Table 3.2	Composition of rice husk and its heating values	12
Chapter 4		
Table 4.1	Husk to paddy ratio values of some local varieties of paddy	20
Table 4.2	Forecast of energy potential from rice husk from 2011 to 2020	22
Table 4.3	Availability of mills and their capacities	24
Chapter 6		
Table 6.1	Rice mills in Polonnaruwa categorized according to capacity	49
Table 6.2	Key figures of financial analysis	59
Table 6.3	Summary of sensitivity analysis	60
Chapter 7		
Table 7.1	Assessment of surplus RH availability at country level	63
Table 7.2	Financial analysis of a 35kW RH power plant operated under Net Metering Scheme by a rice miller.	65

List of Abbreviations

CEB	: Ceylon Electricity Board
CHP	: Combine heat and power
CV	: Calorific value
EIRR	: Equity internal rate of return
FAO	: Food and Agriculture Organization
GHG	: Green house gases
HARTI	: Hector Kobbekaduwa Agrarian Research and Training Institute
HHV	: Higher heating value
HPR	: Husk to paddy ratio
IRR	: Internal rate of return
LHV	: Lower heating value
NCRE	: Non conventional renewable energy
NERD	: National Engineering Research and Development Centre
O&M	: Operation and maintenance
ORC	: Organic Rankine cycle
PIRR	: Project internal rate of return
PUCSL	: Public utilities commission of Sri Lanka
RH	: Rice husk
SPPA	: Standardized power purchase agreement
TOE	: Tons of oil equivalent



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

List of Appendices.

Appendix I : Data Sheet of Rice Mills	73
Appendix II: Paddy Milling Data Collected from Polonnaruwa District	74
Appendix III: Area Wise Paddy Production from 2001 to 2010	82
Appendix IV: Financial Analysis	83



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