UNIVERSITI MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: MOHAMED BASHIR ALI BASHIR (I.C/Passport No: B0638914)

Registration/Matric No: KGH 080026

Name of Degree: Master of Mechanical Engineering

Title of Project Paper/Research Report/Dissertation/Thesis ("this Work"):

Energy Analysis for Food Industries in Malaysia

Field of Study: Energy

I do solemnly and sincerely declare that:

(1) I am the sole author/writer of this Work;
(2) This Work is original;
(3) Any use of any work in which copyright exists was done by way of fair dealing and for permitted purposes and any excerpt or extract from, or reference to or reproduction of any copyright work has been disclosed expressly and sufficiently and the title of the Work and its authorship have been acknowledged in this Work;
(4) I do not have any actual knowledge nor do I ought reasonably to know that the making of this work constitutes an infringement of any copyright work;
(5) I hereby assign all and every rights in the copyright to this Work to the University of Malaya ("UM"), who henceforth shall be owner of the copyright in this Work and that any reproduction or use in any form or by any means whatsoever is prohibited without the written consent of UM having been first had and obtained;
(6) I am fully aware that if in the course of making this Work I have infringed any copyright whether intentionally or otherwise, I may be subject to legal action or any other action as may be determined by UM.

Candidate's Signature Date November 08,2010

Subscribed and solemnly declared before,

Witness's Signature Date

Name:
Designation:

ABSTRACT

The industrial sector is the largest consumer of energy in Malaysia. Malaysian food industries consume a significant amount of energy, about 14% of total manufacturing energy consumption. Therefore, the recent increase in energy cost has created has an essential consequence for developing alternative energy efficient technologies. In this case, energy efficiency means reduction of environmental degradation, increase of sustainability and cost savings. This dissertation focuses on the energy savings, economic benefits and emission reductions. These objective could be achieved by installation of variable speed drives, high efficiency motors, waste heat recovery unit of the boiler, new efficiency lamp (T5) for lighting and repairing, purpose of critical equipment in Malaysian food industries. It has been estimated that the total amount of 1,428, 2,129 and 2,466 MWh energy savings can be achieved annually by utilizing high efficiency motors for 50%, 75% and 100% motor loads respectively. It was also found that for different motor loads, an estimated US$91,385, US$136,252 and US$157,832 could be saved in anticipated energy costs and subsequently 843, 1,257 and 1,456 tons of CO_2 emission reductions could be obtained at 50%, 75% and 100% motor loads respectively. It was also found that, the average of payback period associated with energy savings are about 2.01, 1.61 and 1.40 years for 50%, 75% and 100% motor loads respectively. Similarly, sizeable amount of energy can be saved using VSDs, waste heat recovery, new efficiency lamps (T5) and repairing leakages, resulting to curb energy costs. Furthermore, a considerable reduction in the amount of emissions can be obtained together with the associated energy savings for different energy savings strategies. In addition, the payback period for different energy savings strategies has been firmly established.

ACKNOWLEDGMENTS

First of all, I would like to thank Allah, the Almighty, for giving me the strength and courage to endlessly acquire knowledge.

I would like to express my great appreciation and deep thanks to my supervisor Assoc. Prof. Dr. Saidur Rhman, for his kind assistance, support and important advice during this research and dissertation work.

I would also like to express my special thanks and gratitude to my parents for their support and encouragement during my study.

Last but not the least, I would like to extend my appreciation to those who have been involved directly or indirectly in completing this dissertation.

TABLE OF CONTENTS

Page

DECLARATION……...……i

ABSTRACT……...……ii

ACKNOWLEDGMENTS…….…….…….……iii

TABLE OF CONTENTS……..……...……iv

LIST OF FIGURES……..……...……...….ix

LIST OF TABLES…….……...…….….…xii

NOMENCLATURES…….…….……...…xiv

CHAPTERS **Page**

CHAPTER ONE: INTRODUCTION……1

1.1 Energy efficiency……..……,……1

1.2 Worldwide energy consumption in food industry ….……...……..….3

1.3 Objectives of the study……..……..4

1.4 Scope of the study…….……5

1.5 Organization of dissertation……..……6

CHAPTER TWO: LITERATURE REVIEW…….……..8

2.1 Introduction……..…….…….……8

2.2 Energy demand trend in Malaysia……...8

2.3 Motor……..……..……..11

2.3.1 High efficiency motors…….……..……13

2.3.1.1 Energy savings through high efficiency motors……15

2.3.1.2 Benefits of high efficiency motors...……...……..……17

2.3.2 Variable speed drives…….……...…..……18

2.3.2.1 Variable speed drives systems…..…….……..…….19

2.3.2.2 Energy savings through VSDs…….…….……20

2.3.2.3 Benefits of variable speed drives……..……...……..…….22

2.4 Boiler…….…….23

2.4.1 Heat recovery systems (economizer)……..……..……...……24

2.4.2 Energy savings through heat recovery systems (economizer)…….……..…..25

2.4.3 Benefits of heat recovery systems (economizer)……...…….……...…….26

2.5 Lighting …….…….27

2.5.1 Types of electrical lighting…….…….……29

2.5.1.1 Incandescent lamp……...…….…….…….29

2.5.1.2 Linear fluorescent lamp……..…….……..…….……30

2.5.1.3 Compact fluorescent lamp……..…….…….…….……30

2.5.1.4 High intensity discharge lamp …...…..…….…….…….……31

2.5.2 Energy savings through replacing T12 and T8 lamps with T5 lamp…….……...…..32

2.5.3 Benefits of replacing T12 and T8 lamps with T5 lamp…....…….……..33

2.6 Air compressor systems...……..……..……33

2.6.1 Leakage of air compressor systems……..……35

2.6.2 Leak detection ……..……37

2.6.3 Fixing the leakage……..……37

2.6.4 Energy savings through repairing leakage of air compressor systems..……..…….38

2.6.5 Benefits of fixing leaks of air compressor systems.……..……39

CHAPTER THREE: METHODOLOGY……40

3.1 Introduction……40

3.2 High efficiency motors…….……..……...……...……..……..40

3.2.1 Targeted manufacturing factories and audit data collection……..……...…..40

3.2.2 Energy consumption of motors……..……..40

3.2.3 Estimate energy savings using HEMs ……..……..……..….41

3.2.4 Cost benefit analysis when using HEMs……...….…….……..41

3.2.5 Emission reduction when using HEMs……..……..41

3.2.6 Payback period when using HEMs……..……..42

3.3 Variable speed drives ……...……..……..…..42

3.3.1 Targeted manufacturing factories and audit data collection……..……...….42

3.3.2 Energy savings when using VSDs ……..……..42

3.3.3 Cost benefit analysis when using VSDs……..……..…….42

3.3.4 Emissions reduction when using VSDs……..……..43

3.3.5 Payback period when using VSDs……..…..…….43

3.4 Heat recovery system using economizer……43

3.4.1 Targeted manufacturing factories and audit data collection……..……...….43

3.4.2 Energy savings when using heat recovery systems (economizer) …….…….…….44

3.4.3 Cost benefit analysis when using heat recovery systems (economizer) ….…….44

3.4.4 Emissions reduction when using heat recovery systems (economizer) ….…….…..44

3.4.5 Payback period when installing economizer systems….……..……..….45

3.5 Energy conservation for lighting system……..……..…….45

3.5.1 Targeted manufacturing factories and audit data collection …….……..…….45

3.5.2 Energy savings when replacing T12 and T8 lamps with T5 lamps…...……..…….45

3.5.3 Cost benefit analysis ……...…….46

3.5.4 Emissions reduction…….……..……...46

3.6 Energy conservation when repairing leakage of air compressor systems….……..47

3.6.1 Targeted manufacturing factories and Audit data collection……47

3.6.2 Energy savings by repairing leakage…….47

3.6.3 Cost benefit analysis ……...….47

3.6.4 Emissions reduction…….……..…….……..47

CHAPTER FOUR: RESULTS AND DISCUSSION……..…….49

4.1 Introduction…….49

4.2 Results of high efficiency motors...…….…….…..…..…….... 49

4.2.1 Energy savings when using high efficiency motors…….…….50

4.2.2 Cost benefit analysis when using HEMs…….……..……..52

4.2.3 Emission reduction when using HEMs…….53

4.2.4 Payback period when using HEMs…….……..…..……..54

4.3 Results of variable speed drives ……...…..…….……...….56

4.3.1 Energy savings when using variable speed drives……..…..…….56

4.3.2 Cost benefit analysis when using VSDs……...…….57

4.3.3 Emission reduction when using VSDs ……..……57

4.3.4 Payback period when using VSDs…….…….……..58

4.4 Heat recovery results ……..….60

4.4.1 Energy saving when using economizer ……...60

4.4.2 Cost benefit analysis when using economizer……..61

4.4.3 Emission reduction when using economizer……62

4.4.4 Payback period when using economizer……...63

4.5 Lighting results…….……..…….64

4.5.1 Energy savings of lighting ……..…….……..….65

4.5.2 Cost benefits analysis of lighting……..…….……..66

4.5.3 Emission reduction of lighting ……...……67

4.6 Results of air compressor systems …….……...……...…..….68

4.6.1 Energy savings of air compressor systems……..…….…….68

4.6.2 Cost benefits analysis when repairing leaks of air compressor systems…….…..69

4.6.3 Emissions reduction when repairing leaks of air compressor systems..…….…..70

CHAPTER FIVE: CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK.72

5.1 Conclusions..…….…….…….72

5.2 Suggestions for future work...…….……73

REFERENCES……...…….……..…….…….75

APPENDICES…...…...……..…….79

LIST OF FIGURES

Figure	Title	Page
Figure 2.1:	Energy demand in Malaysia	9
Figure 2.2:	Final energy demands	10
Figure 2.3:	Final energy uses in Malaysia	10
Figure 2.4:	End use energy breakdowns in Malaysian industrial sector	12
Figure 2.5:	Components of a variable speed drives	20
Figure 2.6:	Relationship between motor power reduction and rated speed	21
Figure 2.7:	A typical block diagram of economizer system	25
Figure 2.8:	Lighting cost comparison	27
Figure 2.9:	Incandescent lamp	29
Figure 2.10:	Different sizes of linear fluorescent lamps	30
Figure 2.11:	Compact fluorescent lamp	31
Figure 2.12:	High intensity discharge lamp	32
Figure 2.13:	Cost components in a typical compressed air system	34
Figure 2.14:	Compressed air system block diagrams	35
Figure 2.15:	Power losses as a function of leak through varied hole diameter at 600 kPa pressure	36

Figure 2.16: Cost of waste energy due to leak……37

Figure 2.17: Different options of compressed-air energy savings…..38

Figure 4.1: Energy consumption in Malaysian industrial sector…..49

Figure 4.2: Annual energy savings when installing HEMs..…..51

Figure 4.3: Bill savings when using HEMs…..52

Figure 4.4: Emissions reduction when installing HEMs..…..53

Figure 4.5: Payback period when using HEMs..…..54

Figure 4.6: Energy savings when using VSDs…..56

Figure 4.7: Bill savings when using VSDs…….57

Figure 4.8: Emissions reduction when installing VSDs.…..58

Figure 4.9: Payback period when using VSDs.…..59

Figure 4.10: Energy saving when economizer is used ….60

Figure 4.11: Bill savings when economizer is used ……61

Figure 4.12: Emissions reduction with installation economizer…….62

Figure 4.13: Payback period when economizer is used.....63

Figure 4.14: Energy savings by replacing lighting with T5…..…..65

Figure 4.15: Bill savings by replacing lighting with T5…….66

Figure 4.16: Emissions reduction by replacing Lighting with T-5 lamps…….67

Figure 4.17: Energy savings when repairing leaks of air compressor systems…….....69

Figure 4.18: Bill savings when repairing leaks of air compressor systems…….....70

Figure 4.19: Emissions reduction by repairing leaks of air compressor system.....71

LIST OF TABLES

Table	Title	Page
Table 2.1	Locations and number of factories in all Malaysian industrial sectors	11
Table 2.2	Results of industrial Malaysian energy audit	13
Table 2.3	Typical losses at different motor power 1800RPM	14
Table 2.4	Efficiency for standard and high efficiency motors at different loads	16
Table 2.5	potential of energy saving from VSD	21
Table 2.6	Results of the Malaysian food industrial energy audit	24
Table 2.7	Results of the Malaysian food industrial energy audit	28
Table 2.8	The comparison between T5, T8 and T12 lamps	33
Table 4.1	Results of food industrial Malaysian energy audit	50
Table 4.2	Emission factors form fossil fuel for a unit electricity generation	53
Table 4.3	Percentage of electricity generation based on fuel types	53
Table 4.4	Incremental costs of HEMs	55
Table 4.5	Incremental costs of VSDs	59
Table 4.6	Results of the lighting's of food industrial energy audit	64
Table 4.7	Results of air compressor system's food industrial energy audit	68

Table F.1 Diesel properties, prices of electricity, percentage of recoverable heat and efficiency of economizer……... ……...……98

Table F.2 Annual energy savings when installing HEMs…….……99

Table F.3 Bill savings when using HEMs……100

Table F.4 Emissions reduction when installing HEMs……..…….……101

Table F.5 Payback period when installing HEMs……..…….101

Table F.6 Energy savings when using VSDs……..…….102

Table F.7 Bill savings when using VSDs…….…103

Table F.8 Annual emission reduction when using VSDs at different speed reduction.104

Table F.9 payback period at different speed reduction when using (VSDs) ……...104

Table F.10 Energy savings when installing economizer systems.……..……105

Table F.11 Bill savings when installing economizer systems…….……..105

Table F.12 Emissions reduction when installing economizer……..……106

Table F.13 Energy savings when replacing lighting with T5……..……106

Table F.14 Bill savings when replacing lighting with T5…….……...……..107

Table F.15 Emissions reduction when replacing Lighting with T5…….……..……108

Table F.16 Energy savings when repairing leaks of air compressor systems……108

Table F.17 Bill savings when repairing leaks of air compressor systems…....…..….109

Table F.18 Emissions reduction when repairing leakage…….……..……..…….110

NOMENCLATURES

ABS Annual bill savings (US$)

ADC Annual diesel consumption (liter)

AEC Annual energy consumption (kWh)

AER Annual emission reduction in (kg)

AES Annual energy savings (kWh)

C Average energy cost (US$/kWh)

E_{ee} Efficiency rate of energy efficiency motor (%)

EF Emission factor (kg/kWh)

EHC Energy heat content of fuel (kJ/kg)

E_{std} Standard motor efficiency rating (%)

F Percentage of fuel (%)

FP Fuel price (US$)

H_{avg_usage} annual average usage hours (hours)

HEMs High efficiency motors

Hr Annual operating hours

IC Incremental cost (US$)

LF Load factor (percentage of full load) (%)

n Number of motors

P Power (HP)

PBP Payback period (years)

S_{SR} Percentage energy savings associated certain percentage of speed reduction (%)

VSDs Variable speed drives

ρ Density (kg/m^3)

$\%ES_{leak}$ Percentage of energy saving associated with repairing leakage (%)

$\%_{PRH}$ Percentage of recoverable heat (%)

$\%_{T\text{-}5}$ Percentage of energy saving by using T-5 lamp (%)

$\eta_{ECN\%}$ Economizer efficiency (%)

η_{th} Thermal efficiency (%)