UNIVERSITI PUTRA MALAYSIA

A FRAMEWORK FOR EFFECTIVE ENERGY MANAGEMENT IN A CHEMICAL COMPOUND PLANT

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By

JAYASEELAN NADARAJAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfillment of the Requirements for the Degree of Doctor of Engineering

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DEDICATION

Dedicated to… ***My parents***

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Engineering

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By

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February 2017

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The electrical energy requirements by industry has increased tremendously as reported by the Malaysian electrical energy utility company, Tenaga Nasional Berhad. This increase has forced engineers to devise initiatives to overcome the possible shortages. Emphasis should thus be given to alter the consumption patterns. The impact to the environment and the conservation of energy should also be addressed. Effective energy management reduces operating costs of industries. In Malaysia, industries have already been advised, some two decades ago to perform energy saving measures. This exercise should be performed with the intention of becoming more competitive, apart from lowering operating costs and conserving the environment. This is very important for economic growth in a country. Resources utilizing low cost options are being utilized to ensure adequate electrical energy supplies. Awareness programs are being implemented in industry to discourage wastage, but to encourage efficient and cost effective operations. This research also discovered that currently the chemical compound industry lacked a well-structured and a systematic method for analysis of energy consumption. The demand for energy in this industry continues to grow at a staggering 7% per annum, according to the Ministry of International Trade and Industry of Malaysia. This is notwithstanding the expected increase in tariff, by approximately 10% before the year 2020. Moreover, the current ISO 50001 Standards on Energy Management were deemed as only a guide but not a complete reference for the said industry. Therefore, this research embarked to rank the parameters that contributed to energy efficiency in industry and subsequently to develop a framework and to validate it upon implementation in industry. The methodology used in this research involved data collection and analysis, which utilized graphical methods, tables and charts and a questionnaire design. The major findings of this research are, amongst others, the said industry's acceptance of the proposed framework and the reduction of electrical energy consumption, and hence greenhouse gas (GHG) emission upon implementation of the recommended projects. The results of this research also

indicate very clearly that the integration between maintenance, human resources and production. are vital for improved and optimized consumption of energy. This research will encourage industrialists to consider the various opportunities available to manage energy in industry utilizing a well-structured and engineered methodology and to consider energy management initiatives seriously.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Kejuruteraan

RANGKA KERJA UNTUK PENGURUSAN TENAGA BERKESAN UNTUK INDUSTRI CAMPURAN KIMIA

Oleh

JAYASEELAN NADARAJAH

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Keperluan tenaga elektrik dalam industri telah meningkat dengan ketara seperti yang dilapurkan oleh syarikat utility tenaga elektrik Malaysia, Tenaga Nasional Berhad. Peningkatan ini telah memaksa jurutera untuk merangka inisiatif untuk mengatasi kebarangkalian pengurangan tenaga. Penekanan itu perlu diberikan untuk mengubah corak penggunaan. Kesan kepada alam sekitar dan pemeliharaan tenaga juga perlu diberi perhatian. Pengurusan tenaga yang berkesan dapat mengurangkan kos operasi industri. Di Malaysia, industri telah disarankan kira-kira dua dekad yang lalu, untuk melaksanakan langkah-langkah penjimatan tenaga. Ini perlu dilakukan agar menjadi lebih berdaya saing, selain mengurangkan kos operasi dan pemeliharaan alam sekitar. Ini amat penting bagi pertumbuhan ekonomi negara. Pilihan menggunakan sumber kos rendah ini adalah untuk memastikan bekalan tenaga elektrik yang mencukupi. Program kesedaran dilaksanakan dalam industri untuk mengelakkan pembaziran dan menggalakkan penggunaan kos operasi yang cekap dan efektif. Kajian ini juga mendapati bahawa kini industri pemprosesan sebatian kimia masa ini tidak mempunyai kaedah yang berstruktur, sistematik dan inovatif untuk mengkaji penggunaan tenaga. Menurut Kementerian Perdagangan Antarabangsa dan Industri Malaysia, permintaan tenaga dalam industri ini terus meningkat 7% setahun. Ini adalah jangkaan peningkatan tarif kira-kira 10% sebelum tahun 2020. Piawaian ISO 50001 semasa mengenai Pengurusan Tenaga dianggap sebagai satu-satunya panduan tetapi bukan rujukan lengkap untuk industri tersebut. Oleh itu, kajian ini telah dimulakan untuk merumuskan kaedah yang sistematik dan inovatif untuk proses mengkaji dan seterusnya untuk membangunkan rangka kerja dan untuk mengesahkannya apabila dilaksanakan dalam industri. Kaedah yang digunakan dalam kajian ini melibatkan pengumpulan data dan analisa, kaedah grafik, jadual dan carta serta reka bentuk soal selidik. Penemuan utama kajian ini adalah antara lain, penerimaan industri tersebut, rangka kerja yang dicadangkan dan pengurangan penggunaan tenaga elektrik, dan dengan itu gas rumah hijau (GHG) kepada pelaksanaan projek-projek yang dicadangkan. Hasil kajian ini juga menunjukkan

dengan jelas bahawa integrasi antara penyelenggaraan, sumber manusia dan pengeluaran adalah penting untuk memastikan penggunaan tenaga yang lebih baik dan memaksimumkan penggunaan tenaga. Kajian ini akan menggalakkan jurutera di dalam industri untuk menilai, menyiasat, menemui dan membincangkan pelbagai peluang yang ada untuk menguruskan tenaga dalam industri menggunakan kaedah yang berstruktur dan kejuruteraan dan mempertimbangkan inisiatif pengurusan tenaga dengan serius.

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I would like to dedicate this work to my beloved late mother.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia, and has been accepted as fulfillment of the requirement for the Degree of Doctor of Engineering. The members of the Supervisory Committee are as follows:

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
BAS	Building Automation System
BEE	Bureau of Energy Efficiency
BRECSU	Building Research Energy Conservation Support Unit
CSB	Central Statistical Bureau of Latvia
CECIC	China Energy Conservation Investment Corporation
CMMS	Computerized Maintenance Management System
CO_2	Carbon Dioxide
DOE	Department of Energy
EC	Energy Commission
EC	European Commission
EEO	Energy Efficiency Office
EMCO	Energy Management Company
EMS	Energy Management Software's
EnMS	Energy Management System
ENPIs	Energy Performance Indicators
ESCO	Energy Service Company
EU	European Union
£	British pounds sterling
GDP	Gross Domestic Product
GEF	Global Economic Forum
GHG	Greenhouse Gas
GJ	Giga Joules
GTOE	Giga Tons of Oil Equivalent

GTZ	German Technical Cooperation
HK$	Hong Kong Dollars
HVAC	Heating, Ventilating and Air Conditioning
IEA	International Energy Agency
IIP	Institute of Industrial Productivity
KTOE	Kilo Tons of Oil Equivalent
LCOE	Levelized Cost of Energy
MTOE	Metric Tons of Oil Equivalent
NGO	Non-Governmental Organizations
NPV	Net Present Value
O&M	Operations and Maintenance
PCC	Precipitated Calcium Carbonate
P3M	Productive Planned Preventive Maintenance
PJ	Peta Joules
RAF	Royal Air Force
RAM	Responsibility Assignment Matrix
REDA	Renewable Energy Development Authority
ST	Suruhanjaya Tenaga
SEUs	Significant Energy Users
TCE	Tons of Coal Equivalent
TLCC	Total Life Cycle Cost
TNB	Tenaga Nasional Berhad
TQM	Total Quality Management
USAID	United States Agency for International Development
U.S.	United States of America
US$/t	United States of America Dollars per ton

WB	World Bank
WEA	World Energy Assessment
WEC	World Energy Council

CHAPTER 1

INTRODUCTION

1.1 Introduction

The energy policy of Malaysia is determined by the Malaysian Government, which addresses issues of energy production, distribution, and consumption. The Energy Commission acts as the regulator while other players in the energy sector include energy supply and service companies, research and development institutions and consumers. Government-linked companies, Petronas and Tenaga Nasional Berhad are major players in Malaysia's energy sector. Governmental agencies that contribute to the policy are the Ministry of Energy, Green Technology and Water, the Energy Commission (Suruhanjaya Tenaga), and the Malaysia Energy Centre (Pusat Tenaga Malaysia). Among the documents that the policy is based on are the 1974 Petroleum Development Act, 1975 National Petroleum Policy, 1980 National Depletion Policy, 1990 Electricity Supply Act, 1993 Gas Supply Acts, 1994 Electricity Regulations, 1997 Gas Supply Regulations and the 2001 Energy Commission Act ("National Energy Policy"; Ministry of Energy, Green Technology and Water, 2013).

The Energy Commission was created under the Energy Commission Act 2001 as a new regulator for the energy industry in Peninsular Malaysia and Sabah. The Commission was established to ensure that the energy industry is developed in an efficient manner so that Malaysia will be ready to meet the new challenges of globalization and liberalization, particularly in the energy supply industry. The commission regulates and promotes all matters relating to the electricity and gas supply industry within the scope of applicable legislation namely the Electricity Supply Act 1990, License Supply Regulation 1990, Gas Supply Act 1993, Electricity Regulation 1994, and Gas Supply Regulation 1997. In performing its role the commission takes the self-regulation approach (The Energy Commission of Malaysia, 2009).

The electrical energy consumption in Malaysia has increased sharply in the past few years, and modern energy efficient technologies are desperately needed for the national energy policy to increase public awareness. Figure 1.1 indicates the energy consumption by fuel type in Malaysia. It is very clear that electrical energy consumption is the highest and the increase during the 35 year period (1978-2013) is about ten times (increasing from about 5,000 KTOE (Kilo Tons of Oil Equivalent) to about 50,000 KTOE). Notwithstanding this, Figure 1.2 indicates the world energy consumption by fuel type. It is very clear that electrical energy consumption has increased during the 40 year period (1971-2014) by more than two fold, i.e. from about 4,000 GTOE (Giga Tons of Oil Equivalent) to about 9,000 GTOE. Surveys are continuously being performed to assess the consumption pattern and the existing techniques for energy efficiency. Based on past surveys, the extent of the feasibility of improving the available systems and adopting new programs in different sectors

was not investigated in depth. Studies reveals the fact that the energy conservation policy of Malaysia has been fairly improved in the last ten years. However the country has to pay more attention to this area and make urgent measures to adopt more energy efficient technologies in various sectors (Anwar, 2009).

Response to the increase in energy consumption significantly amongst the various industries has been tremendous because the increase in production did not keep up

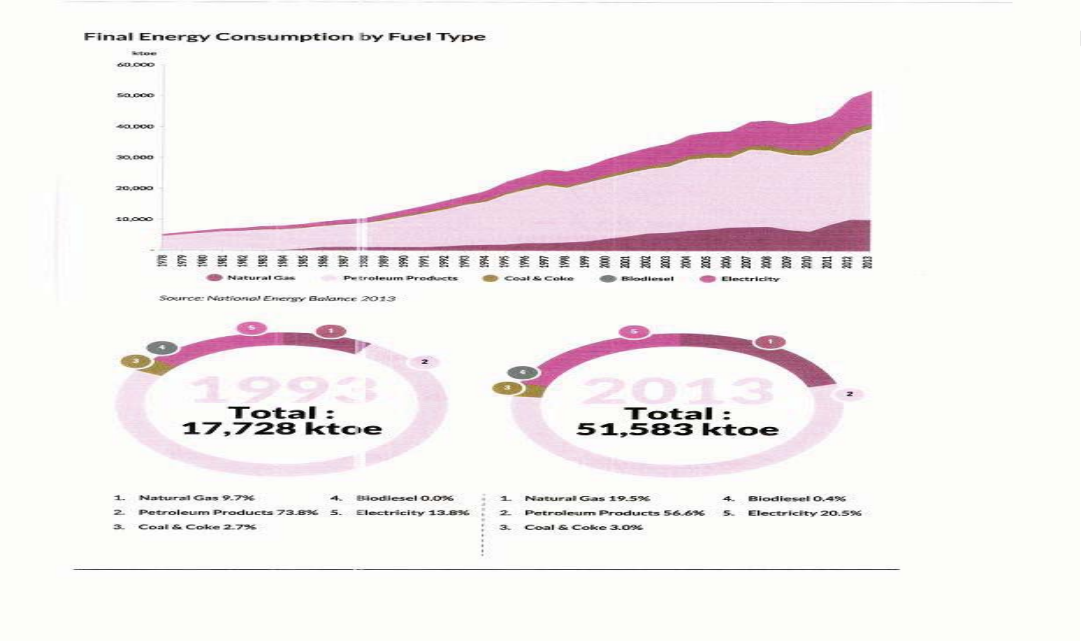

Figure 1.1 : Energy Consumption by Fuel Type in Malaysia
(Source:- Annual Report, Tenaga Nasional Berhad, 2013)

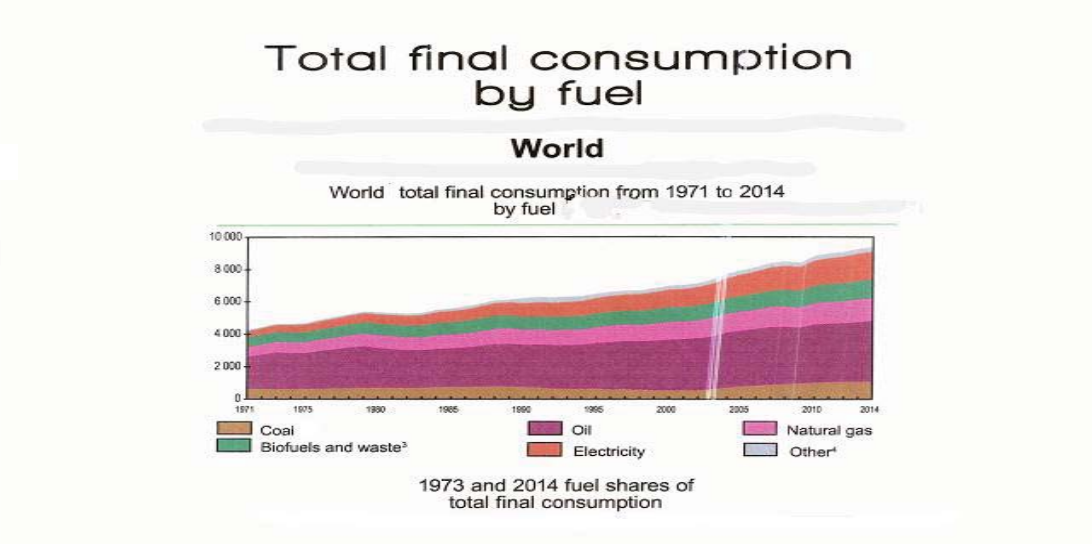

Figure 1.2 : World Energy Consumption by Fuel Type
(Source:-WEC, Energy Efficiency: A Worldwide Report Indicators, Policies, Evaluation, World Energy Council, London, 2014)

with the increase in consumption and the production/consumption ratios differ (National Energy Policy, 2013).

Energy efficiency improvements can always be performed in large, medium and small industries. A range of energy conservation methodologies have already and are still being developed for industrial applications throughout industry. Effective systems have been devised and energy conservation measures have been implemented successfully (Tanaka, 2011; World Energy Council WEC, 2008).

In Malaysia, industries have already been advised, some 2 decades ago to perform energy saving measures. This exercise should be performed with the intention of becoming more competitive, apart from lowering operating costs and conserving the environment. This is very important for economic growth in a country (Zhao, 2011; Bassi et al., 2009; Demailly and Quirion, 2008). Of course, it is agreed that different countries will have a different approach but all with a single goal. It is also accepted that the measures will depend on a variety of factors inter-alia, barriers, availability of funds and technology etc. Engineers have thus become aware and critical of operations for an extremely competitive manufacturing fraternity. Energy, like manpower, is being treated as a resource which can be altered to maintain product quality and to ensure competitive product costs. It is therefore essential that information on which monitoring methodology is based is of relevance and conveniently processed. An example of an energy intensive chemical processing industry is that of the calcium compound processing industry. The chain of production of these processes are thus derived from many individual process routes, using a combination of energy sources. The typical process route for the industry is superimposed by the range of specific energy consumptions for the various sections. Energy is largely used for operating their kilns, hydration, precipitated calcium carbonate (PCC) and waste-water treatment plants. The energy cost is about 20 to 35 per cent of the total production cost, and therefore prices and availability of the various energy sources are important to maintain a very competitive edge. Energy sources used within this industry are of course, electricity, natural gas and water.

This research evaluated the current energy management system (EnMS) in the chemical compound processing industry. It indicates the success of the measures taken so far and also the how the steps and policy will affect the energy efficiency improvements in industry.

1.2 Problem Statement

The demand for energy in this chemical compound processing industry continues to grow at a staggering 7% per annum, according to the Ministry of International Trade and Industry of Malaysia (IMP3, 2012). This is notwithstanding the expected increase in tariff, by approximately 10% before the year 2020, according to the Malaysian electricity utility company, Tenaga Nasional Berhad (TNB, 2013). This

expected demand has resulted in several initiatives aimed at overcoming potential shortages**.** Influencing the energy consumption patterns is of prime importance in this industry especially during peak times when energy supplies are strained. Moreover, industries are more sensitive to the impact on the environment. The current problems faced by the said industry are numerous, as far as managing energy is concerned. Optimizing maintenance programs and manufacturing plans are not easy because of the number of possibilities to assess. The investigated problem comprised two important fields of concern-preventive maintenance scheduling and manufacturing planning.

There are currently about 500 actively registered energy managers with the Energy Commission of Malaysia, who come from various industries and not necessarily from the chemical compound sector. It can therefore be concluded that a workable framework is required for an effective energy management system in industry.

The other pressing problems faced by industry also include, amongst others, to improve energy management significantly, to optimize their energy use and to introduce a framework of incremental energy management improvement to attain a much higher state of energy management maturity. The suggested model allows a formulation of other issues like, health, safety, environment, availability of staff and tools, as well as legal restrictions. The knowledge gap that needs to be filled will therefore be to develop a formal energy management model to provide a method to understand the energy management challenges in industry and then address them in a way that provides continuous improvement and allows for fine tuning and the ability to address new challenges.

The current ISO 50001 Standards on Energy Management Systems does not emphasize much on certain practical and application aspects, such as the Roles and Responsibilities of industries, trends, significant energy users, maintenance criteria, critical operating parameters, technical audits, training etc. These are deemed vital for systematic energy management in industry.

At the commencement of this research, energy management was not practiced at the designated plant. However, there will come a point in time when the plant may face difficulties in managing its business due to an increase in operating costs.

In order for industry to implement effective energy management, a comprehensive framework needs to be developed. At the moment there is no comprehensive framework in place which considers and ranks not only energy management, but also considers other areas, such as, maintenance, quality, human resource etc.

Therefore it is wise for industry to begin considering energy management when the current tariff is relatively lower and the overall maintenance program cost is also lower due to relatively new plant and equipment.

This research will encourage engineers to evaluate, investigate, discover and discuss the various opportunities available to manage energy, particularly in the chemical compound processing industry, utilizing a well-structured and engineered methodology and to consider energy management initiatives seriously.

1.3 Objectives

The objectives of this thesis are-:

1. To rank the parameters that contributed to energy efficiency at a chemical compound plant.
2. To develop a framework for total energy management system in industry
3. To validate the framework upon implementation in industry.

1.4 Scope of Studies

The author has selected a local calcium compound processing plant for the case study. The scope of the project is to, amongst others, to study the current energy management and energy conservation initiatives at the said industry, and to propose tailor made suggestions for improvement as far as energy management and energy conservation are concerned.

This will be followed by the development of a very comprehensive framework for the plant. The key factors involved in developing the framework, amongst others, will include data collection, data analysis, identifying and quantifying the SEUs, identification of the drivers, developing baselines and performance indicators, reviewing the operational control for all relevant SEUs, performing energy audits and finally identification of opportunities for improved performance, review and decision on action plans. However, these factors are common to most industries, and hence the framework can be adapted by them as well.

Upon completion on the development of this framework, it will be validated by practicing engineers from industry. This framework will then be dedicated to this specific industry.

The constraints encountered throughout this project amongst others, included, lack of manpower, time, and specialist measuring/logging equipment. Another limitation was that this research focused only on the manufacturing/processing plants PCC 1 and PCC 3 where there was a disparity in the electrical energy consumption.

Although this study met its aim and objectives, it had limitations as well. This study only managed to draw conclusions on the PCC 1 and PCC 3 plants due to the constraints stated above. This study, therefore, is considered a pilot project only and to obtain a general overview of the plant.
As a conclusion, this study, however, is suggested be used as a guide for future related works in other similar plants. Further analysis should be carried out in order to determine whether all the recommended elements are suitable for adoption.

1.5 Thesis Layout

The first chapter of the thesis introduces the objectives, scope and outline of the study. The second chapter presents an overview of the background literature for energy management in the chemical compound processing industry. Chapter three depicts the research methodology used in this work. It also explains various assumptions and criteria of the research.

Chapter four presents the results of the research by questionnaire survey, discusses the data gathered and provides analysis of the data. This chapter also discusses about developing the framework for implementing an energy management system in industry. It will assist policy makers, managers, designers, engineers and researchers to make decisions more easily and efficiently for energy management system implementation. Validation of the developed framework has also been argued in this chapter. Chapter five highlights the conclusions drawn from the questionnaire survey. The recommendations are made along with the limitations of the research and directions for future work.

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