ENERGY EFFICIENCY ASSESSMENT IN PRODUCTION LINE: A SUSTAINABLE MANUFACTURING APPROACH

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Submitted to the Department of Industrial Engineering in Partial Fulfillment of the Requirements for the Degree of Bachelor of Engineering from Universitas Islam Indonesia

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DEDICATION

This thesis is dedicated for my beloved mother and father, who always encourage and provide endless supports mentally, materially, and spiritually for me until I have reached this final point. I would also express my gratitude for all families and friends.

MOTTO

"For indeed, with hardship (will be) ease. Indeed, with hardship (will be) ease. So when you have finished (your duties), then stand up (for worship)"

(QS. Al – Inshirah (94): 5 – 7)

PREFACE

Assalamuallaikum Wr. Wb.

All praises are to Allah SWT for giving His gracious mercy and guidance to the Author during the time of finishing this undergraduate thesis. The Author would also like to express the gratitude and the highest appreciation to those who have supported and motivated the Author in completing this piece of work. The Author would like to say thanks to:

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ABSTRACT

An increasing demands of the energy which causes a quick depletion of the natural energy reserves within the earth has become a critical concern by the human society. Additionally, anthropogenic activities which generate carbon emissions is indicated as the primary cause of many environmental adverse impacts and the climate change. Industrial sector is concerned to be the largest energy consumer compared to other sectors. Manufacturing enterprises majorly expend energy intensively within the production lines. Thus, an energy efficiency improvement tends to be a proper solution to addressing this problem. This work aims to analyze a prospect energy efficiency improvement within a production line. A discrete-event simulation (DES) was used to investigate the energy saving potential and a case study was conducted in a crumb rubber company. Three parameters were taken into consideration to calculate the energy consumption, i.e. processing time, material flow, and machine states. An initial model which represents an actual condition of the manufacturing production line was developed. From the analysis of the initial model result, a recommendation scenario was built. It was shown that a reduction of 8.22% in the energy consumption is achievable by implementing the suggested scenario.

Keywords: *Anthropogenic activities; carbon emissions; climate change; energy efficiency; discrete-event simulation (DES).*

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CHAPTER 1

INTRODUCTION

This chapter gives a brief introduction of the research background and motivation on a particular issue, in which this thesis would address. From the research background, research questions are proposed which become the points of investigation. Additionally, several scopes of the research problem, research objective, and research benefit are also included in this chapter.

1.1 Introduction and Background

Global demands over energy in the manufacturing sector continue to increase. However, the abundance of natural resources within the earth is limited and recently is facing a great slump due to the continuous exploitation for human utilities. According to a report by EIA (2018), industrial sector is considered to be the largest and also the most growth consumer of natural gas in the globe. It accounts for 35% of the total natural gas consumption compared to other sectors (e.g. transportation, commercial, residential). Additionally, the demands are projected to rise for approximately 3% by 2050. Natural gas is used for heating and power within the industrial sector. Apart from that, manufacturing companies also consume a great amount of other resources for the feedstock of production activities. Thus, this induces the sector to be one of the key factors affecting the quick depletion of the natural resources in the earth. Additionally, greenhouse gas (GHG) emissions from fossil fuels combustion in manufacturing processes are considered as the prime cause towards the climate change and the global warming. These problems have been becoming serious issues faced by the human society for the last few decades, thus serious commitment to recover the vulnerable earth becomes imperative.

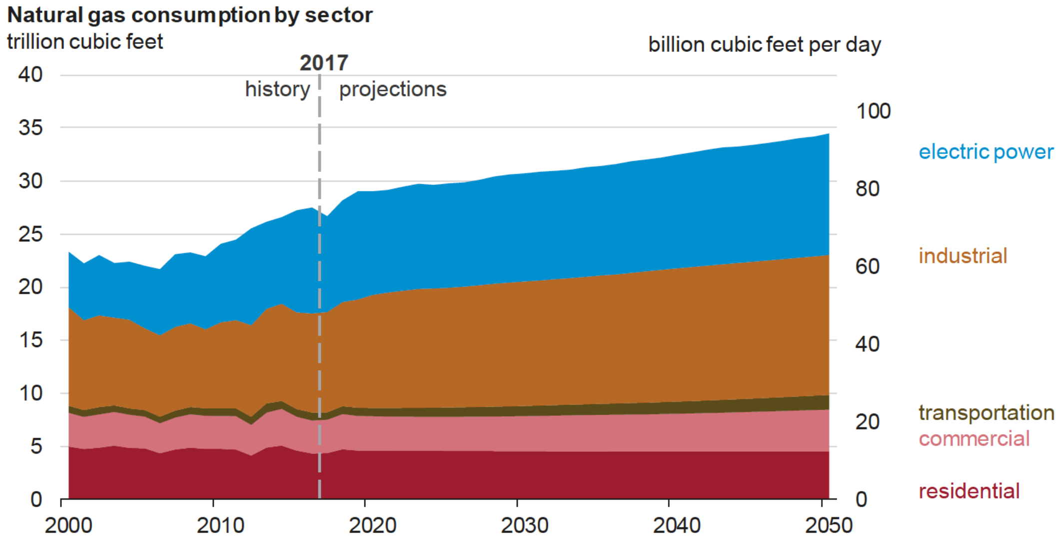


Figure 1.1 – **A distribution of energy consumption by sector**

Source: EIA (2018)

Several suggestions have been addressed to target the rising of the global temperature to well below 2 °C (IEA, 2017). A promising action to attain this goal is by improving the energy efficiency in manufacturing enterprises. (Sobottka et al., 2018). The interest of academics and practitioners to find solutions to improve the energy efficiency and to reduce the environmental impacts on manufacturing systems shows a significant upsurge.

Various previous studies have been conducted to evaluate the energy efficiency at different levels, ranging from the product level (A. Huang & Badurdeen, 2018; Jeon et al., 2014), machine level (Mousavi et al., 2016), production line level, process level, and factory level. Investigations upon the energy efficiency improvement in machining processes, especially which occur in CNC machining, such as the cutting process (Ahn et al., 2016; D. Liu et al., 2017), the drilling process (Apostolos et al., 2012), and the milling process (C. Li et al., 2017; Shin et al., 2017) were among the dominant issues of the manufacturing's energy efficiency research. However, the developed energy consumption models are typically valid solely for specific work materials, cutters, machinery and even certain operators (D. Liu et al., 2017). Analysis and implementation effort through a wider scope which considers other aspects within the manufacturing system should be carried out. This means is very potential to provide a more realistic picture of the energy saving prospect in the manufacturing systems.

Production line is considered to be the foremost intensive energy consumer in a manufacturing system. In general, the production system is divided into two main areas, i.e. manufacturing line and assembly line, where each of those consists of production machinery and facilities (Kohl et al., 2014). Each machine is operated differently and consume energy unequally subject to different products being manufactured, processing time, machine states, etc. This complexity shows that the manufacturing sector in the real condition is a highly dynamic system. Thus, in order to investigate the energy consumption and the potential energy saving of a stochastic and a dynamic system, a simulation approach needs to be used (Perez-Acle et al., 2017).

This research aims to present an evaluation towards energy efficiency in the production line of the manufacturing industry by using a discrete-event simulation (DES) approach. A development of an initial model which represents the real condition of the addressed system is the first step of the evaluation. Afterwards an alternative recommendation modification is proposed subject to the initial simulation result which shows some indications for the future improvement. The energy saving potential can be obtained by comparing the result of the initial and the alternative recommendation model.

1.2 Research Question

Against the aforementioned problems and the research background, several research questions are proposed as follows:

1. How to analyze the impact of a production process upon the energy efficiency?
2. What is the impact of the adjustment of certain parameter(s) on the improvement of the energy efficiency?
3. How significance the energy efficiency can be improved by applying certain alternative improvement on the system?

1.3 Research Scope

Based on the research question, certain boundaries and research scopes are defined as follows:

1. The data collection is done at a crumb rubber processing company.

2. The measurement of the energy consumption is conducted solely in the production line, which includes production stations and the material flows,
3. The investigated energy is based solely on the energy flows within the production line, however the energy consumption from HVAC (heating, ventilation, and air conditioning) system, and TBS (Technical building services) are not taken into account.
4. The research only investigates the electrical energy, other forms of energy such as water, and compressed air are disregarded.

1.4 Research Objective

Based on the research questions and the problem boundaries, the following research objectives can be expected:

1. Improving the understanding of the analysis of the energy efficiency potential in the production process.
2. Perceiving the impact of the adjustment of certain parameter(s) on the improvement of the energy efficiency.
3. Perceiving the significant amount of the energy efficiency that can be improved by applying certain alternative improvement on the system?

1.5 Research Benefit

Here are several benefits that can be achieved from this study.

1. Improving the energy saving of the manufacturing industry.
2. Improving the understanding upon the energy efficiency potential in the production process.
3. Enhancing the contribution of the discussion in the issues revolving around the sustainable manufacturing.

CHAPTER 2

LITERATURE REVIEW

This chapter provides inductive and deductive reviews of previous studies which correlate with the topic of this research. The inductive review is information being referenced from previous works which are obtained from indexed and reputable published academic papers. This sort of works is required in order to avoid duplication of previous researches, as well as the results, and to find the state of the art of the research being conducted. The deductive review is information being referenced from textbooks and other sources which contain supported theories upon the research. These reviews will present a gap corresponding to the questions of the research.

2.1 Literature Review on Previous Researches

Global warming is an indication of the environmental change that becomes a big challenge faced by human society in these last few decades. Anthropogenic activities are considered to be the dominant factor of this adverse environmental impact (Sachs, 2015). The combustion of fossil fuels generates and releases greenhouse gas (GHG) emissions which predominantly composed by CO_2 to the atmosphere as the by-product of the energy use. Industrial sector plays a vital role of the occurred global environmental changes, since it contributes to around a half of the total share of the global energy consumptions (BP, 2018). Moreover, it is additionally projected that the trends of energy consumption in this particular sector will exhibit a significant grow to up to 38% between 2017 – 2050 (EIA, 2018).

Responding to such associate environmental drawback which doubtlessly may harm the ecosystem and the life in the future, thus converting the manufacturing industry to be more sustainable is becoming an imperative resolution (Meo et al., 2017). Accordingly, a number of endeavors towards sustainable manufacturing have been brought to the global forefront by some experts and researchers. The main target of the sustainable manufacturing is developing metrics and tools for evaluating environmental performances in varied levels of the manufacturing system throughout three-dimensional aspects (i.e. technology, energy, and material) (AlGeddawy & ElMaraghy, 2016). Thus, a transformation from the prevailing production ways to resource-efficient production schemes becomes one of the main goals. Pursuing the sustainability within the manufacturing systems is not going to be solely beneficial to the environment, nonetheless would also boost the enterprises to become economically sound (Cataldo et al., 2015; Singh et al., 2018; Zeng et al., 2018). In recent published literature, discussions on sustainable manufacturing brought a broad range of topics including analysis of GHG emissions (B. Huang et al., 2017; Saleh et al., 2015; Saleh et al., 2016; Zhang et al., 2016), resource efficiency enhancement (S. Thiede et al., 2013), and methods for data collection, monitoring and forecasting of energy consumption (Bornschlegl et al., 2016; Reimann et al., 2018; Tan et al., 2017). For resource efficiency matters, several studies have been conducted to improve the efficiency of the production resources, such as water, energy, and materials (Azevedo et al., 2018; Gould et al., 2016; Mousavi et al., 2016; Sebastian Thiede et al., 2016). However, material or water efficiency is not straightforward in case of reducing the carbon footprints intensity. Hence, one of the foremost appropriate measures that would directly control and offer a promising expectancy in reducing carbon emissions towards the realization of sustainable manufacturing is by improving the energy efficiency (Guo et al., 2018; Song et al., 2018). According to existing literature (Fysikopoulos et al., 2014; A. Huang & Badurdeen, 2018), researches whose main concerns are regarding to energy consumption and environmental related performances are mainly divided into five general levels : (1) product level, (2) machining level, (3) production line level, (4) process level, and (5) factory level.

At the product level, the focus is majorly involved to the assessment of the potential environmental impacts and the quantification of the resource stocks caused by products manufacturing through the implementation of Life Cycle Assessment (LCA) (Luz et al., 2018). However, improving the energy efficiency for products could also be achieved by designing the products with energy efficiency-oriented (L. Li et al., 2018; Seow et al., 2013). A study conducted by Seow et al. (2016) is an example. They proposed a design methodology that takes energy into consideration during a number of design phases. According to Nishijima (2016), changing in the product lifetime may additionally be attainable to improve the energy efficiency and reducing the CO_2 emissions. To date, discussions associated with the energy measurement, monitoring, modeling, and optimization in machining facilities are significantly high (W. Cai et al., 2017). Liu et al. (2018) suggested that in order to boost the energy efficiency in the manufacturing system, a possible solution is by purchasing highly efficient machining tools. Consequently, the experiments conducted in this level are mainly targeted on the improvement of machining processes such as grinding (Salonitis, 2015), cutting (Suwa & Samukawa, 2016), and milling (Y. Cai et al., 2018). Nevertheless, researches corresponding to the machining-related energy also extend outward from this scope. For instance, Jirasuwankul (2017) conducted a research on improving energy efficiency use in induction motor drive system using fuzzy logic. Liu et al. (2017) proposed an approach for acquiring the real-time energy efficiency (REE) of machining tools. De Carvalho & De Oliveira Gomes (2015) investigated the reduction of electrical energy consumption during standby mode. An exploration of possible improvement of the energy consumption through visualization of manufactured parts in the machining systems is provided by (Tuo et al., 2018). However, analysis specifically on the products or machining tools do not adequately represent the manufacturing system as an entire. Thus, a more holistic view would be required.

There are abundantly lots of well-developed ideas and approaches regarding the sustainability issues at the system level, starting from the issues concerning to the industrial ecology, green supply chain management, as well as sustainable regulation and policy (Despeisse et al., 2013). Researches focused on plant-level were conjointly done. An investigation of the energy efficiency in the manufacturing facilities has been provided by (Jeong & Kim, 2016). A comprehensive evaluation of the energy footprint through modeling across multi levels manufacturing system was also conducted by (Jeon et al., 2014). The method begins by parameterizing product-level energy factors, linking the parameters as input data in the machining-level. Machine states, processing power and processing times are the designed parameters of the modeling. Afterward, the simulation model at the machining level is then used to identify any significant factors of the energy footprint in the plant-level. Although observing energy consumption in the factory or system level could be one amongst of the most effective solutions to investigate the conditions of energy transformation in a manufacturing system, it needs an excessive effort for collecting the supporting information for the analysis. Thus, investigation of the energy efficiency within the production system is likely going to be the foremost feasible alternative measures. Moreover, operations within the production line are considered to be the most extensive energy consumer in the manufacturing enterprises (Lee et al., 2012).

A production system is generally divided into two main areas: manufacturing line and assembly line (Kohl et al., 2014). In the manufacturing line or shop floor the total energy consumptions are majorly expended in the heating, ventilation, and air conditioning (HVAC) systems (Katchasuwanmanee et al., 2017; Sun et al., 2016), process-related activities (Estrada et al., 2018), and the technical building services (TBS) (Posselt et al., 2014). Numerous methods have been proposed to improve the energy efficiency in the production line. See (Olanrewaju & Jimoh, 2014) for a comprehensive review of the various existing efficient industrial energy models. According to Kohl et al. (2014), material flow simulation is very counseled to measure the energy consumption within the production line. This method is able to address the complexity occurred within the system, in terms of distinct variables, dynamic energy consumption, and the interaction among processes (Mousavi et al., 2015). Therefore it can be used as a baseline for enhancing the energy efficiency. Ghadimi et al. (2014) proposed a method for the improvement of energy efficiency by integrating material and energy flow analysis. Flick et al. (2017), have shown internal and external influencing factors of the energy expenditure within the shop floor: product size, shop area, and utilization are the most influencing factors relating to the energy performance indicator (EnPI).

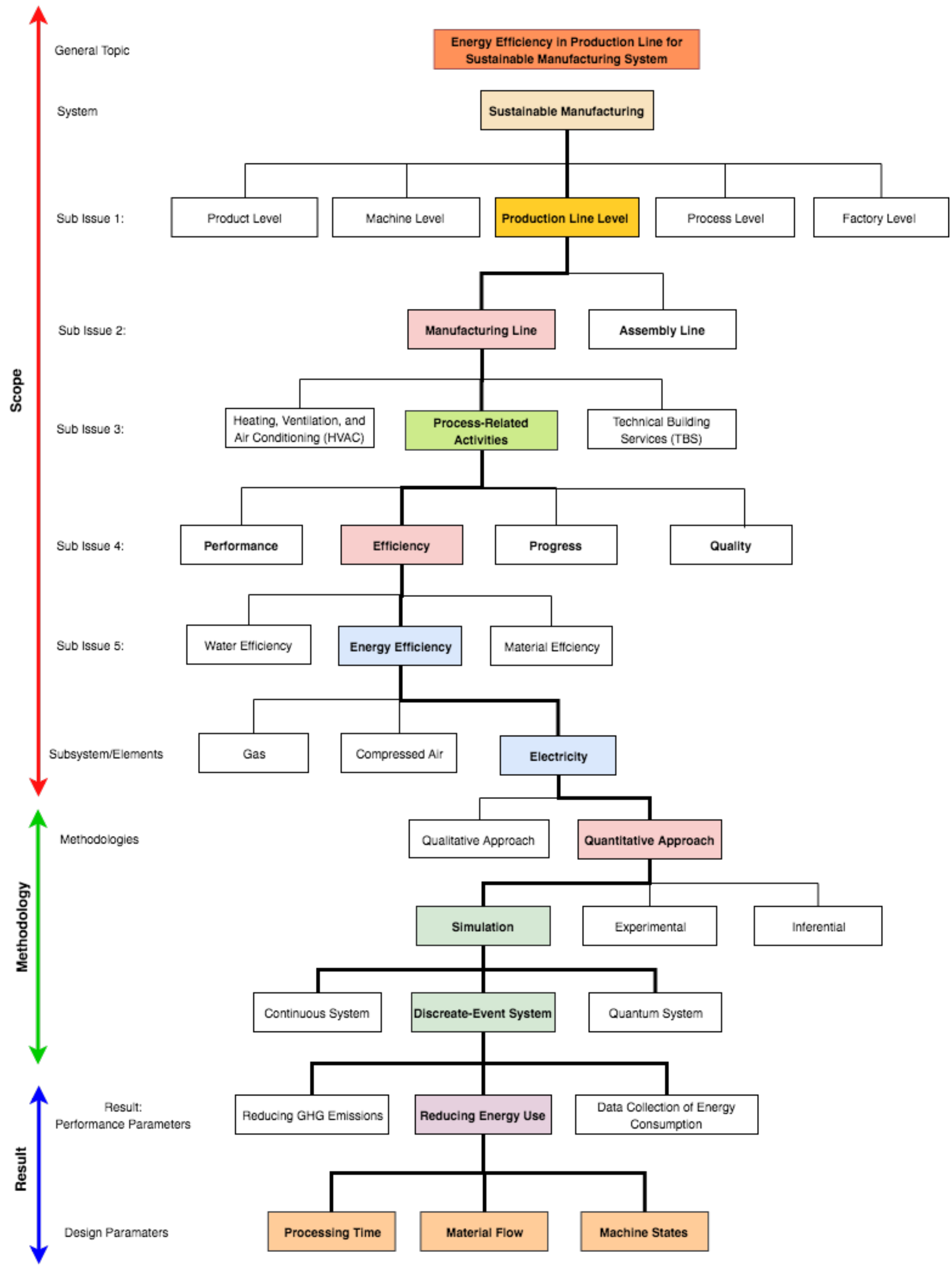


Figure 2.1 – **K-Chart**

From the literature reviews above, multiple issues revolving around sustainable manufacturing have been introduced, significantly within the context of energy efficiency. The information given is used as a knowledge domain to seek out the research question(s) for this thesis. Thus, a K-chart as depicted in figure 2.1 is designed as a tool to assist to find the question research. The chart provides a summary of the issues associated with the energy efficiency in the manufacturing systems, or more specifically in the production line. It shows an explicit potential methodology to resolve the stated problem, along with its performances and design parameters.

This thesis aims to investigate the attainable energy efficiency improvement during a manufacturing process. The analysis is going to be done by simulating the production process within a shop floor by employing a discrete-event simulation approach. This approach is a promising technique to measure the energy consumption and to evaluate its inherent energy efficiency.

2.2 Definition and Scope of Sustainable Manufacturing

2.2.1 Definition of Sustainable Manufacturing

A clear definition of sustainable manufacturing that universally accepted does not exist. However, stakeholders collectively agree with the concept of sustainable manufacturing in which has a close correlation to the concept of sustainable development. According to World Commission on Environment and Development (WCED) (1987), they defined sustainable development as: "Development that meets the needs of the present without compromising the ability of the future generations to meet their own needs". This suggests an associate urge to conserve the resources from the scarceness and extinction to realize the prosperity of the future generations. The manufacturing sector is chargeable for the soundness and the sustainability of the environment and natural resources due to its excessive exploitation associated with the production purposes which causing an extreme depletion of the nature reserve resources.

Several researchers and institutions who involve in studying sustainable manufacturing have tried to provide a definition of sustainable manufacturing. For example, The International Trade Administration, U.S. Department of Commerce (2011) defined sustainable manufacturing as the activity of manufacturing products that which is able to minimize negative impacts on the environment; conservation of energy and natural resources; safe for employees, society and consumers; and economically sound in a business perspective. Garetti & Taisch (2011) defined sustainable manufacturing as the ability to utilize natural resources for manufacturing purposes intelligently; able to preserve the nature whereas able to boost the standard of life. The American Society of Mechanical Engineering (ASME) (2014) defined sustainable manufacturing as the ability to develop a product that is able to utilize energy sources and sources of raw materials to a minimum; give a negative impact that is minimal on the environment; support the development of sustainability in processes, production systems and supply chains; economical and able to meet the needs of various parties.

From the various definitions proposed above, it can be concluded that sustainable manufacturing is a system whose purpose is to produce goods which is not solely intended to satisfy the consumer desires and is profitable from the economics viewpoint, however must additionally be able to develop or design a product, process, and system that may minimize the consumption of materials and energy resources, hence the preservation of the nature is maintained, is able to reduce the adverse impacts on the environment, as well as safe for employees, society and consumers.

2.2.2 The Scope of Sustainable Manufacturing

Sustainability is a complex issue. There are several dimensions that may be accounted for issues revolving around sustainability studies. However, the idea of sustainability is generally administered a triple bottom line (TBL), which is also being referred for the scope of sustainable manufacturing (i.e. environmental, economic and social) (Elkington, 1994).

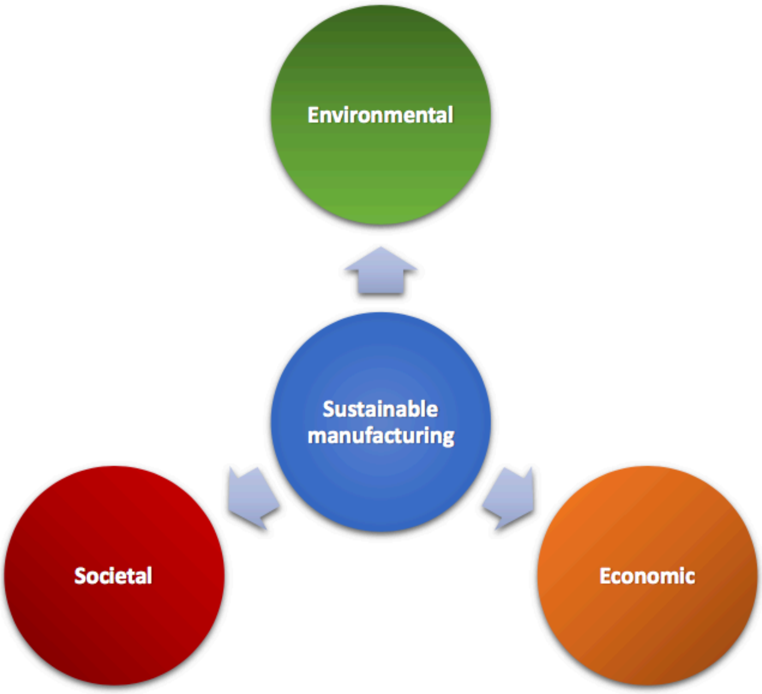


Figure 2.2 – **Tripple bottom line of sustainable manufacturing**

Source: Apostolos, 2014

According to Bonvoisin et al. (2017), research areas upon sustainable manufacturing can be classified into 4 different themes as follows:

1. Manufacturing technologies: researches focus on the production processes. The objective of the research in this field includes processes and equipment, such as machinery and facilities. Example of themes in this area include the development of new manufacturing processes, prediction on production tools maintenance, assessment of resource consumption during manufacturing, process chain simulation, and energy efficiency on facility building.
2. Product lifecycles: researches deal with product development. Main themes embrace lifecycle and product management, intelligent product development, and simplification of sustainable products assessments.
3. Value creation networks: researches specialize in the organizational context within the production system, such as resource efficient supply chain planning, and industrial ecology.

4. Global manufacturing impact: researches specialize in the transition mechanism from conventional manufacturing systems towards sustainable manufacturing systems. Key themes within this area include the development of sustainability assessment methods, sustainability standards, and sustainability education.

2.3 The Concept of Energy Efficiency

Energy efficiency is the main key to reducing carbon emissions which is one of the factors of global warming and climate change. Energy efficiency is defined as the ratio or comparison between the output produced by an associate instrumentality or P process, with the quantity of energy consumed in the process E (Blok & Nieuwlaar, 2017). Therefore, energy efficiency η can be formulated as follows:

$$\eta = P / E \tag{2.1}$$

In the context of energy efficiency, increasing the activity per unit of energy consumption or by way of explanation, efforts to maintain the production systems to do more activities with less energy consumption is the main objective. Improving the energy efficiency does not necessitate to limit the daily production activities which consequently reduce the energy consumption. However, it can be done through some modifications at the activity level which would reduce the unit energy consumption. Thus, the amount of energy use can be scaled down without compromising the production yields or the throughputs.

The energy management system has to be applied to the manufacturing industry to support the creation of energy efficiency and to bring the enterprises towards the sustainable direction. The most commonplace directive for the energy management is the ISO 50001 (ISO, 2016). This standard provides a series of guidelines for companies to develop efficient energy use policies, set targets, and objectives that are in line with the policy, do documentation and reporting, and to implement designs and efforts to equipment, systems, and processes that may contribute to achieving the sustainability and the energy efficiency.

2.4 Energy Analysis Methods

2.4.1 Energy Value Stream Mapping (EVSM)

Energy value stream mapping (EVSM) is a modification method developed from traditional value stream mapping (VSM), which take energy components into account (Verma & Sharma, 2016). The VSM method was developed to support the creation of lean manufacturing whose main purpose is to scale down waste and to increase the material flows within the manufacturing system (King & King, 2015). Researchers such as León & Calvo-Amodio (2017) and Mostafa & Dumrak (2015) have verified that the lean approach is able to support sustainability in a manufacturing system. Verma & Sharma (2016) declared that the EVSM is an effective method to be applied to support a manufacturing system in which orientation is to achieve the sustainability. The EVSM method is able to spot the extent of energy use and waste at every stage within the product life cycle, hence it can be used as a basic knowledge to develop energy efficiency scenarios through simulation.

2.4.2 Material and Energy Flow Analysis (MEFA)

Material and energy flow analysis (MEFA) is a systematic approach for estimating the flow of energy and materials in a system (Brunner & Rechberger, 2005). This approach focuses on the link of the input/output processes with the associated systems based on the mass conservation law (W. Li et al., 2017). MEFA is used as a tool for tracking the material and energy usage from the extraction processes to the manufacturing process, from the end use to the emissions and waste disposal (Taulo & Sebitosi, 2016). The MEFA method has been widely applied within the industrial world in a variety of variations. Sendra et al. (2007) applied a material flow analysis (MFA) approach to an industrial area where there are several factories in it. Lambrecht & Schmidt (2010) created a prototype based material optimization tool by integrating the material flow network (MFN) approach with the operational research. Taulo & Sebitos (2016) used the MEFA method to analyze and monitor the flow of energy and materials within a tea industry.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter introduces a research methodology which comprises of a research flow and a conceptual model to be carried out. The model is presented in an exceedingly detailed and comprehensive manner to facilitate understanding of the energy consumption structure within the production process. Bound parameters to investigate the potential energy efficiency improvement throughout the process is additionally introduced. Furthermore, the focus and object of the study together with the data collection method and also the energy analysis are comprehensively described.

3.1 Research Framework

Prior to discussing in details concerning a way to measure the energy consumption and determine the energy efficiency improvement, a comprehensive research framework as depicted in figure 3.1 is necessary to introduce. The research framework presented here is an adaptation of a proposed steps in a simulation study by (Banks et al., 2014).

The initial step of the simulation study is by defining the problem formulation and setting of objectives. See section 3.2 for a detailed discussion of the problem formulation and objectives setting. The next step is continued to establish a conceptualized simulation model, and the collection of the supported data. The simulation model conceptualization has a strong interplay with the data collection as the complexity of the model changes, it directly changes and affects the required data elements. The fifth step is the translation of the real-world system into a computer-recognizable format or the artificial environment.

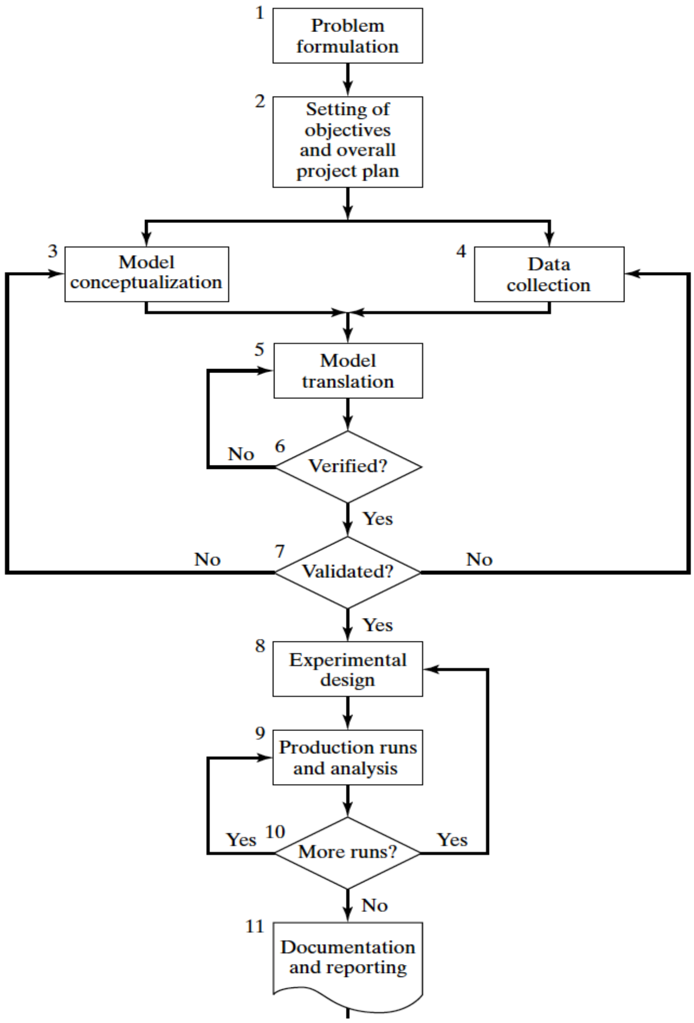


Figure 0.1 – **Reasearch framework**

Source: Banks, Carson II, Nelson, & Nicol (2014)

This model translation would be executed in a simulation software, namely Tecnomatix Plant Simulation®. The next step is the verification and the model validation to ensure the simulation model behaves as how it was intended and can accurately represent the actual system condition. If the input parameters and logical structure of the simulation model are perfectly represented in the computer simulation and the model accuracy is judged acceptable, thus the verification and validation have been completed.

In order to investigate the determined goal which in this case is the energy efficiency improvement, the experimental design of alternatives condition should also be developed. The alternatives experimental design is required for the decision making support which the result is compared with the initial system condition. Subsequently, the alternative model is executed. The result of the initial and the recommendation models should be evaluation. The evaluation is used to estimate the improvement of the energy efficiency potential. Finally, the models and the associated results should be documented and reported.

3.2 Focus and Object of the Research

The goal of this work is to investigate the energy efficiency improvement within a producing system. In general, the production system is split into two main categories: shop floor and assembly line, where every section consists of various machines and instrumentations (Kohl et al., 2014). Figure 3.2 illustrates the hierarchical division of a manufacturing factory. According to previous literature, researches over the energy efficiency analysis of the manufacturing system are mainly conducted at three main areas, such as HVAC (heating, ventilation, and air conditioning) system (Katchasuwanmanee et al., 2017; Sun et al., 2016); process-related energy (Estrada et al., 2018), and technical building services (TBS) system (Posselt et al., 2014). This particular work solely focuses on the analysis of process-related energy efficiency in the shop floor and will be using a simulation model to resolve the problem. The research was conducted at PT Sampit International, a company that produces technically specified rubbers (TSR) which is also referred to as crumb rubbers.

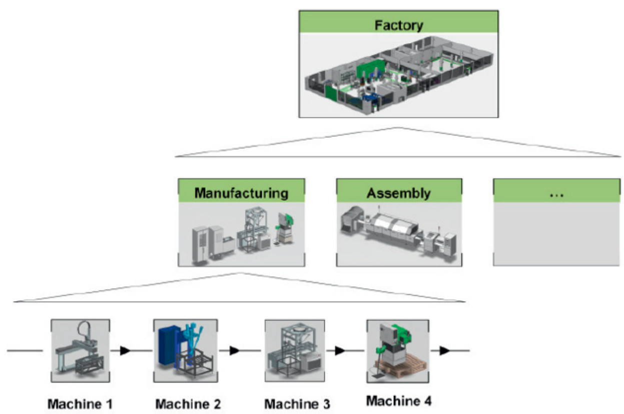


Figure 3.2 – **A hierarchical division of a factory in networks**

Source: Kohl et al. 2014

3.3 Conceptual Simulation Model

A conceptual simulation model is designed to abstract the essential features of the problem. Certain bound parameters are considered in order to analyze the energy efficiency throughout the production process. The model takes into consideration three parameters which represent the dynamic characteristic of the production system in terms of energy consumption: processing time, material flow, and machine states (e.g. idle, setting up, stand-by, operational, production, and breakdown). Figure 3.3 depicts a causal loop diagram which illustrates the dynamic condition of energy consumption in production activities.

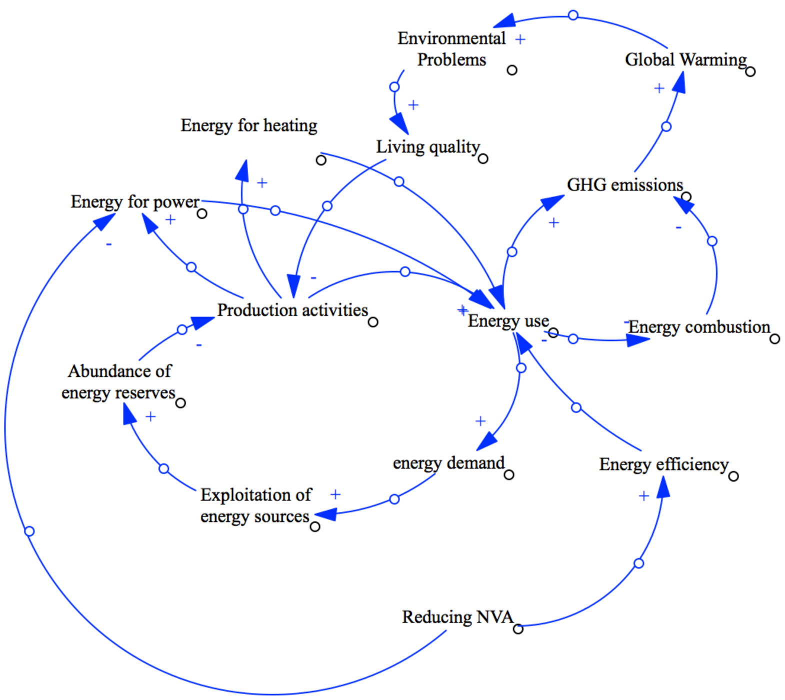


Figure 3.3 – **Causal loop diagram of energy consumption in production line**

According to (Mousavi et al., 2015), three alternatives are often considered to set up the duration and power for each operational or machine state: a constant value, a predetermined probability distribution function, and a mathematical equation of the existing empirical models of the unit process. A few operational states possess relatively constant trends such as standby, idle, rump up, etc. Hence, the first two options are sufficient to configure the aforementioned conditions in the simulation. The last option is regarded to be the foremost adequate to characterize the energy consumption and process parameters which featuring dynamics behavior. In order to realize the target and to facilitate a much better understanding upon the proposed methodology, this conceptual model is divided into sections to introduce the interlinked relationships of the mentioned parameters with the quantity of energy consumption.

3.3.1 Production energy consumption

The process-related energy consumption is subject to dissimilar states of each machine. Numerous parameters associated with the machine state would directly specify the performance of machine tools in terms of energy consumption. The production line produces energy profiles dynamically over time that consists of many intense energy consuming components depending on the process parameters and the actual states of the machine (S. Thiede et al., 2013). According to Kobayashi et al. (2017), the energy consumption at a facility can be formulated with the subsequent equation:

$$E^k = e_r^k T_r^k + e_s^k T_s^k + e_b^k T_b^k + e_i^k T_i^k \qquad (3.1)$$

if a company has *n* facilities, the sum of energy consumption would follow the following equation:

$$E = \sum_{k=1}^{n} E^k \qquad (3.2)$$

Where:

E = Total energy consumption

E^k = Total energy consumption in facility *k,*

e_r^k = Energy consumption per unit time during run state in facility *k,*

e_s^k = Energy consumption per unit time during setup state in facility *k,*

e_b^k = Energy consumption per unit time during breakdown state in facility *k,*

e_i^k = Energy consumption per unit time during idle state in facility *k,*

T_r^k = Run state time in facility *k,*

T_s^k = Setup state time in facility *k,*

T_b^k = Breakdown state time in facility *k,*

T_i^k = Idle state time in facility *k*

3.3.2 Machine states

Every production activity that employs machinery habitually experiences several conditions. Each condition consumes a totally different quantity of energy due to undertaken at different processing times. There are at least five operational states exist during the production period and are defined as follows:

1. Setting up: refers to the period of time which correlates with the adjustment for production product changing.
2. Production: refers to the state or condition when the machine is performing work to produce desirable products, it is typically associated with the value-adding condition.
3. Stand-by: refers to the state or condition when the machine remains activated at the operational readiness for performing tasks.
4. Idle: refers to the condition or the state when the machine is not doing any useful work or no material order to be processed, however certain necessary components remain activated (e.g. control panel).
5. Breakdown: refers to the condition or the state when the machine fails to produce products and should be deactivated for maintenance due to experiencing certain troubles.

3.4 Data Collection Method

With the research boundary in mind, this work investigates solely the energy efficiency improvement in the production line of the company. The energy to be calculated is the electrical power consumption. As described in the section 3.2.1, the required data as the input data of the simulation are facilities electrical power consumption (in kWh). The electrical power consumption for each facility can be obtained by a self-measuring by using power metering devices. However, owing to the absence of the devices, this particular research will measure the associated input data by calculating the current, voltage, and also the power factor of each facility appeared on the electrical panel in the electrical room. In addition, the electrical power recording obtained from the company's electrical department is also collected. This data will be used to compare the simulation and the actual power consumption to ensure the validation of the simulation result.

Another information needed to accomplish the simulation is the production shift schedule.

3.5 Validation and Verification

Validation and verification are of the most important steps in the simulation study. The goal is to create a model that represents a close condition with the true system characteristic as a substitute for the actual system for the aim of experimenting of the system, analyzing system behavior, and predicting system performance. Besides that, it increases the credibility of the model to an acceptable level, so that it will be considered by the decision makers.

Validation is not an isolated set of procedures that follows model development, but rather as an integral part of the model development. Conceptually, the verification and validation process consists of the following components:

1. Verification is concerned with building the model correctly. It proceeds by the comparison of the conceptual model to the computer representation that implements that conception.
2. Validation is concerned with building the correct model. It attempts to confirm that a model is an accurate representation of the real system. Validation is usually achieved through the calibration of the model, an iterative process of comparing the model to actual system behavior and using the discrepancies between the two, and the insights gained, to improve the model. This process is repeated until model accuracy is judged to be acceptable.

3.6 Simulation Run and Analysis

Energy analysis is the final step of the research process. This study employs a discrete-event simulation (DES) approach in order to analyze and determine the potential energy efficiency. The DES is chosen by the reason of its ability to analyze problems in the dynamic condition, which is the nature of the manufacturing system in real terms.

Simulation is carried out by using Tecnomatix Plant Simulation® software. Through this software, a DES model is created and executed. In this research, several models are created: (1) a model of current condition; and (2) alternative conditions for improvement. The result of the simulations is compared to determine which condition has a promising higher energy efficiency.

CHAPTER 4

DATA COLLECTION AND DATA PROCESSING

This chapter consists of the data collection and the data processing, which were accomplished by running a simulation model. The information required for this research was the production data which consists of the process flow, processing time, and working shift, and the energy data. The data processing consists of the establishment of an initial simulation model which represents the actual condition of the system being investigated, model validation and verification was also conducted. Ultimately, an alternative scenario was developed by evaluating the initial simulation result to enhance the energy saving potential.

4.1 Data Collection

4.1.1 Process flow data

In order to manufacture products, a shop floor typically consists of a series of production machines and operation processes which are designed deliberately to complete production objectives (Mousavi et al., 2016). These typical features create dynamic energy profiles within the production line. Three parameters can be considered as dependent factors, which dynamic energy profiles rely to, i.e. processing time (Seow et al., 2013), process flow (Mousavi et al., 2015), and machine states, such as idle, change over, ramp up, stand-by, and breakdown (Jeon et al., 2014).

The manufactured product (i.e. technically specified rubber) is carried out through two main processes, namely the wet rubber process, and the dry rubber process. Each process is performed on a different production floor. Figure 4.1 depicts a series of production process flow in the manufacturing of the technically specified rubbers.

Figure 4.1 – **Production process flows**

The first stage of the technically specified rubbers production process is performed through a wet process, where the raw materials are crumbled in hammermill facilities. This process is done for three times using through two different hammermill machines: hammermill machine 1, hammermill machine 2, and hammermill machine 3. The process within the first machine forming the raw rubbers into coarse rubber lumps. The products are subsequently processed in the second and third machines to make the rubber clumps into smaller crumbs. During this process, rubber crumbs are washed in large ponds to filter out the contained impurities.

The second stage is the extrusion process using mangal machines. The extrusion process is performed for six times consecutively through six different mangal machines. The extrusion process forms crumb rubber into rubber sheets that are ready for further processing, i.e. the drying process in a dry rubber production room. However, before the drying process is undertake, all rubber sheets are air-dried in the hanging room for about two weeks depending on the weather conditions.

After passing the air-drying period, the rubber sheets enter the dryer machine. The company utilize two dryers, namely apron dryer and oven dryer. Each of those dyers have identical operation function, however their use is done alternately. The distinction between the two dryers solely lies within the length of the drying duration. The apron dryer requires two and a half hours for completing the task of each batch, whereas the oven dryer takes four and a half hours. The employment of the dyers is absolutely dependent with the consumer demands, due to each consumer desires different levels of crumb rubber maturity. The drying process is the final process in making the technically specified rubber products. Subsequent to the drying process, crumb rubber products are packaged and stored in the warehouse to prepare for shipping worldwide to the consumers.

4.1.2 Processing time

Processing time is one of the parameters which influences the energy profiles within the production process in a manufacturing company. The wet process, which consists of mangal station and hammermill station, undertake the production process continuously rather than produce a specific unit of product. This particular condition happens due to the process produces uncountable or non-discrete goods. Thus, an assumption is necessary to be made in order to set up the processing time in the simulation. The processing time are assumed to be 10 minutes and 5 minutes for hammermill station and mangal station respectively. This assumption was made based on the production manager assumption.

An identical problem also occurs within the drying process. Although it yields discrete products, which allowing to measure the processing time of each production batch. For instance, the apron dryer requires 3.5 hours for a production batch passes through it from the entrance side to the exit side of the machine, whereas the oven dryer takes a longer time of around 4.5 hours per production batch. However, it is challenging to estimate the processing time of each batch or each unit product during this particular process. The dryer machines employed by the company are long vacuum rooms with an embedded low speed conveyor. This physical and dimensional feature allows a batch to undertake a considerably long period of time to be dried, as well as enable several batch to enter the machine concurrently whilst other batches are being processed within the dryer. This occurrence assuming the dryers to perform work continuously rather than processed separate single batches in cyclical. This condition raises an impediment to estimate the cycle time of each production batch. Thus, an assumption is also made. The processing time for both dryers are assumed to be constant with the value of 7 hours by neglecting the cycle time of the unit production. Besides that, certain assumptions for the period of idle, standby, failure, and repair times are also taken into account in the simulation which represents the actual condition of the production processes. These assumptions are made based on the production manager opinion.

4.1.3 Working shift

The company running production differently between the wet process and the dry process. Table 4.1 and Table 4.2 below illustrate the working shift of the dry process and wet process, respectively.

Table 4. 1 Drying Process Working Shift

Shift	From	To	Break	Day
Shift1	06.00	14.00	11:00 - 12:00	Mon - Sat
Shift2	14.00	22.00	18:00 - 19:00	Mon - Sat
Shift3	22.00	06.00	04:00 - 05:00	Mon - Sat

Table 4. 2 Wet Process Working Shift

Shift	From	To	Break	Day
Shift1	06.00	14.00	11:00 - 12:00	Mon - Fri
Shift2	16.00	00.00	18:00 - 19:00	Mon - Fri

4.1.4 Energy Data

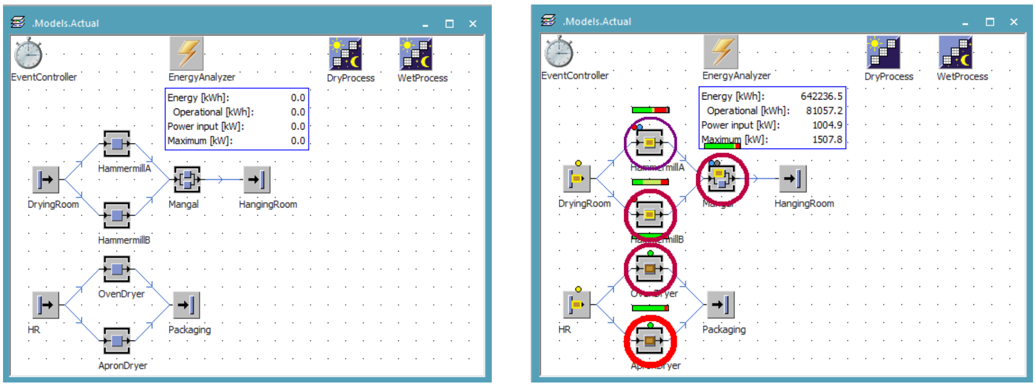
Table 4. 3 Power Calculation

Facility	Power Factor	Current (A)	Voltase (V)	Power (kW)
Oven Dryer	0.8	238	380	125.31
Apron Dryer	0.8	650	380	342.24
Mangal	0.8	900	380	473.88
Hammermill Facility A	0.8	400	380	210.61
Hammermill Facility B	0.8	480	380	252.73

4.2 Data Processing

4.2.1 Initial Simulation Model Development

A discrete-event model simulation is employed to experiment and analyze the energy consumption as well as the energy saving potential of the production line in manufacturing system. The simulation was developed by using Tecnomatix® simulation software. To represent the actual condition of the company's production line, an initial simulation model is developed. Several variables and parameters, such as processing time, working shift schedule, and energy input if machine states have been defined as the input data for the simulation. Figure 4.2 (a) and (b) below depict the layout design of the facilities and the hotspot plotting of the simulation running result indicating which facilities possess larger energy consumption. Working shifts of the wet and dry processes were set up to control the working period of the production line.



(a) (b)

Figure 4.2 – **(a) Initial production line simulation model; (b) hotspot plotting**

Besides hotspot plotting, the simulation running of the initial model also showed a distribution of the energy consumption in each facility according to the machine states as depicted in figure 4.3 below.

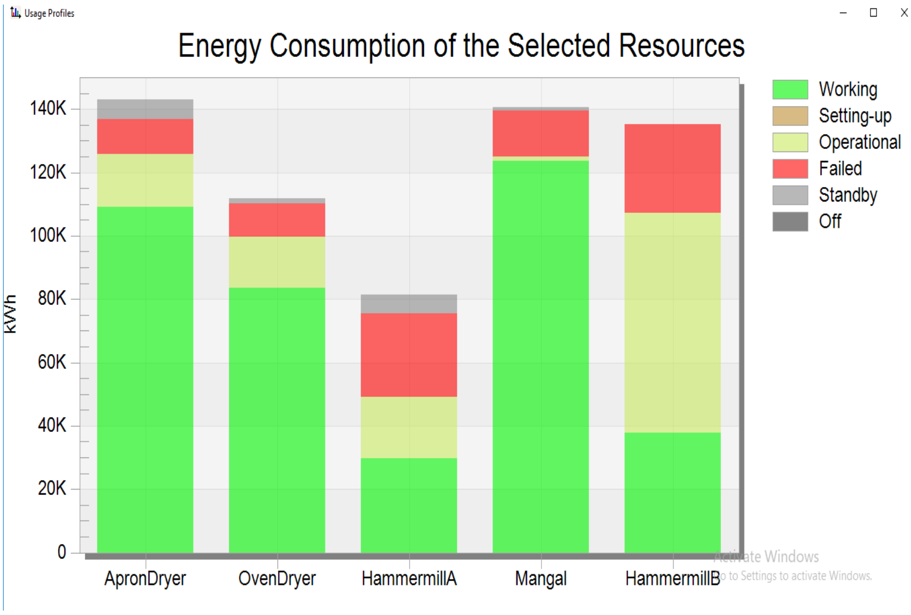


Figure 4.3 – **Energy consumption at facilities based on machine states**

4.2.2 Model Verification

A simulation model should run accurately as it was intended. Simulation as a representation of the actual or real-world condition quite often comprises abstraction, assumption, and simplification in the modeling system. Thus, to ensure the behavior of a simulation system to work perfectly, a model verification is required to conduct. According to (Banks et al., 2014), several suggestions can be used for the verification process. First, let the model be checked by someone other than the developer, for example a simulation software expert. Examining the model output for reasonableness under certain variety of parameters setting can also be used for the model verification purpose. The model should be able to display the output statistics if this means is going to be employed. Another way is by implementing graphical interfaces in the simulation.

This particular research employed graphical interfaces and the evaluation of the model output under certain variety of parameters setting to verify the model. As discussed earlier in previous chapters, this research takes into consideration of three parameters as the driving factors of the energy profiles within the production processes. The output statistics was able to be displayed after the simulation stopped running. Owing to the research purpose which solely investigate the energy efficiency matter as the performance parameter, thus the energy-related statistics was only displayed. Figure 4.4 below depicts the energy statistics of a selected production machine.

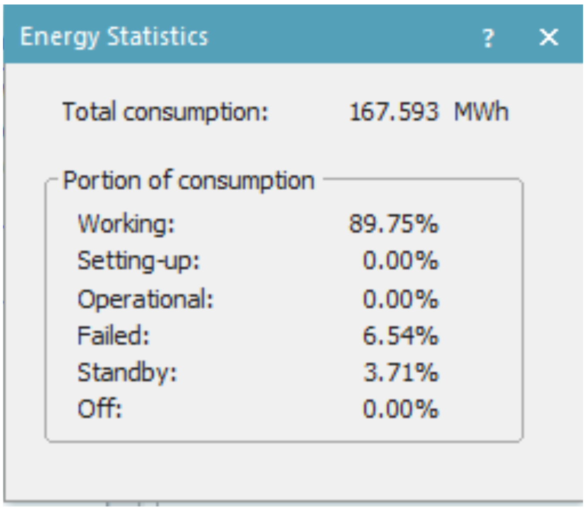


Figure 4.4 – **A display of energy statistics of a selected machine**

Certain graphical interfaces ware displayed to illustrate the condition of the simulation result from the processing of the input data. Selected graphical interfaces displayed in the simulation were a diagram of a power input plotter as illustrated in figure 4.5, and a chart of the energy consumption distribution based on machine states as depicted in figure 4.3.

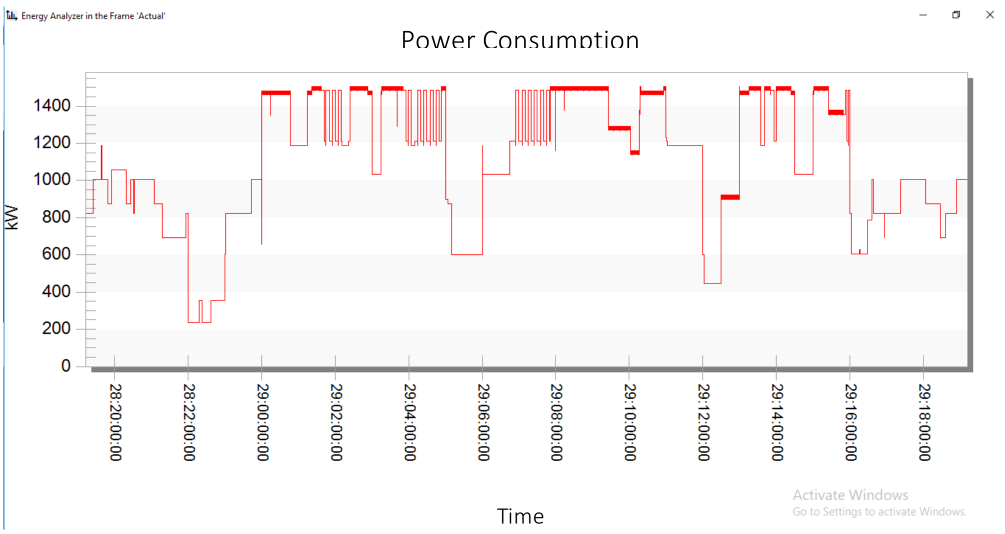


Figure 4.5 – **A display of power consumption plotter**

4.2.3 Model Validation

Model verification is the process of comparing the model with the realistic system. It is intended to ensure the model to behave as close as possible with the real-world system. A simulation model is only an approximation of the realistic system, thus it will never be absolutely identical to the actual system. However, the goal of the model validation is to examine the accuracy of the model with certain degree of confidence, so that the model can assure for the decision making purposes.

The model validation in this research was used input-output validation technique. This research was used sample data collected from the company's historical documentations. The available provided data from the company was hourly power documentations in February 2018. The total actual energy consumed within the production line is compared with the energy consumption resulted from simulation. The confidence interval is set to 95% for the simulation.

The simulation model has been set to run for a month. The total monthly energy consumed from the simulation result is 611864.10 kWh, while the actual energy consumption is 633984.20 kWh. Table 4.4 shows the comparison of the simulation result and the actual data.

Table 4. 4 Comparison of the simulated result and the actual data

	Actual	Simulation	Difference (Simulation – Actual)	Percentage Error
Energy Consumption (kWh)	633984.20	642235.50	8251.30	1.30%

From the table above it can be seen that the percentage error of the simulation result and the actual data is 1.30%. Thus, the simulation result is considered valid since it is within the targeted percentage error.

CHAPTER 5

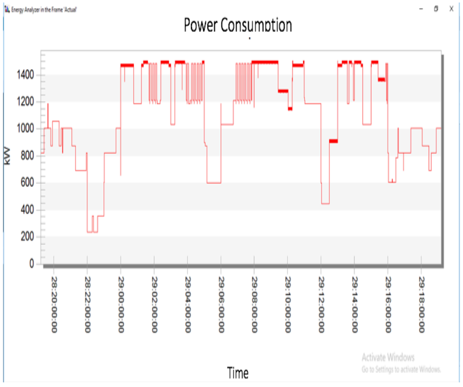
DISCUSSION

This chapter will discuss the result of the simulation into details. The result consists of the energy consumption estimation and its distribution according to the machine state, which is a parameter that influences the fluctuation of the energy consumption of a facility. The energy efficiency saving potential from the comparison of the initial and the alternative model is also explained.

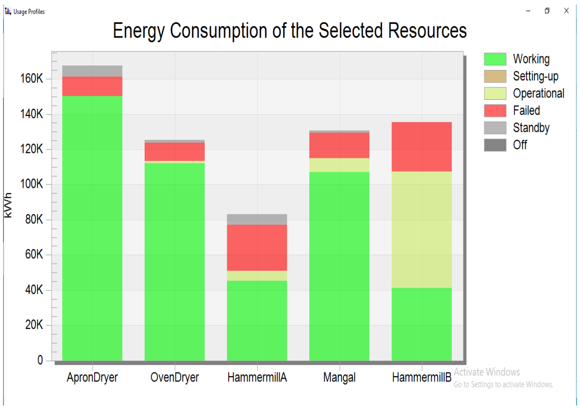
5.1 Initial Simulation Result

A simulation approach is conducted to estimate the energy consumption of the production line in the manufacturing company. From the simulation result of the case study, it shows that the energy expended in the production line behaves dynamically depending on certain factors as illustrated in figure 5.1 (a). Energy input, processing times, working schedule, and machine state are among the driving factors of the fluctuation of the energy consumption. Figure 5.1 (b) shows the allocation of the energy consumption distribution based on the machine states of the production facilities.

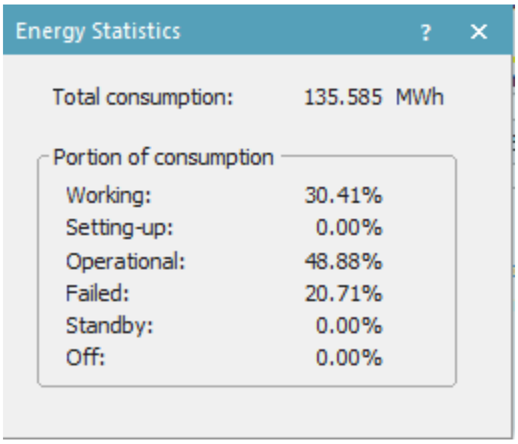
From the diagram, it can be seen that the energy was mainly expended during the working, operational, and failed states. An insignificant amount of energy was expended on the stand-by state. Energy expenditure can be classified into two main categories, namely value added energy and non-value added energy. The value added energy is defined as the energy consumed when a machine is running due to the existence of a material being processed. Energy consumed during the working state is considered to be a value-added energy, while on the other hand, the other states are considered to be the non-value added energy since they do not directly correspond to the material processing activities.



(a)



(b)



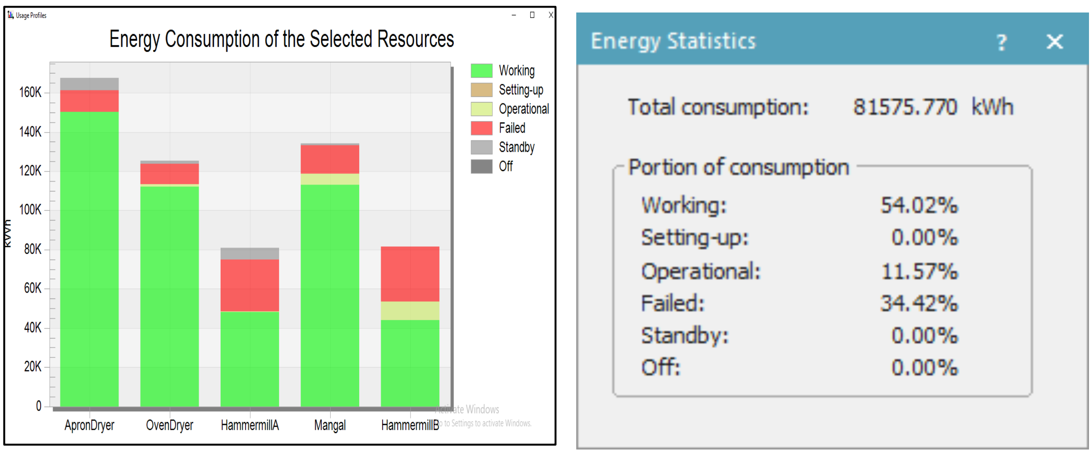
(c)

Figure 5.1 – **(a) Energy plotter; (b) Energy distributan chart of initial model; (c) Initial hammermill B energy statistics**

Apron dryer, mangal machine, and hammermill B machine were the major consumers of the energy in the production line. However, the mangal machine and the apron dryer consumed energy majorly for the value added purposes, whilst the energy in the hammermill B machine was much more expended for the non-value added one in terms of operational or idle time. Figure 5.1 (c) depicts the energy statistics of the initial condition of hammermill B machine.

5.2 Alternative Scenario Simulation Result

The energy efficiency can be attained by reducing the non-added energy expenditures. In the alternative scenario a modification of the parameter setting was done for the hammermill B machine due to it consumed larger energy for non-value added activities as indicated in the initial simulation result. The hammermill B consumed the largest portion of the non-value added energy, in the form of operational or idle time. In the actual condition, the hammermill station which consists of two machines, namely hammermill A and hammermill B are utilized interchangeable in random scheduling during the production process. However, both machines are still kept active, even though only one machine is undertaking the production activity. This operational configuration is applied to minimize the pre-production time during a sudden breakdown which occurs quite often of either machine being operated. Besides that, several peripheral elements such as a water pump, which is integrated with both machine is activated while one of the machines is turned on. This led to high energy consumption of unfortunately associated with the non-added energy value, which is considered as waste. Thus, a suggestion proposed to improve the energy efficiency in the simulation is by changing the associated operational state condition. It is assumed if both machines have separate water pump installation in each machine, so that when one machine is turned off, the non-value added energy in the form of operational energy can be lowered.

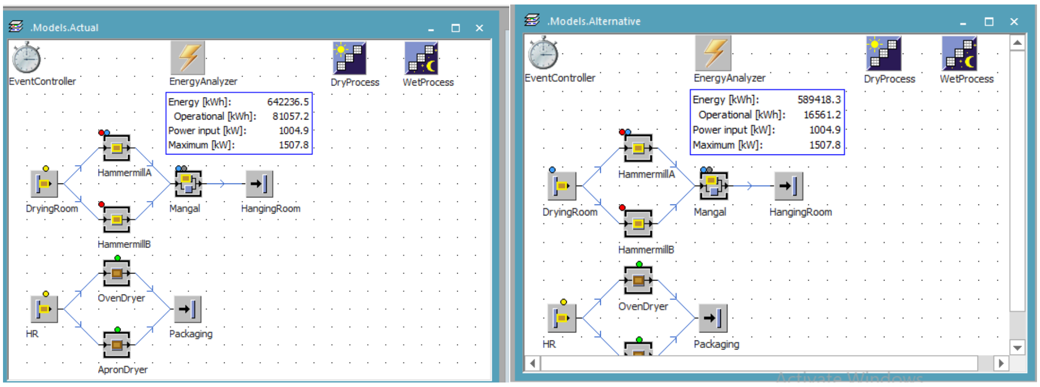


(a) **(b)**

Figure 5.2 – **(a) Energy consumption of the alternative scenario model; (b) Alternative Scenario hammermill B energy statistics**

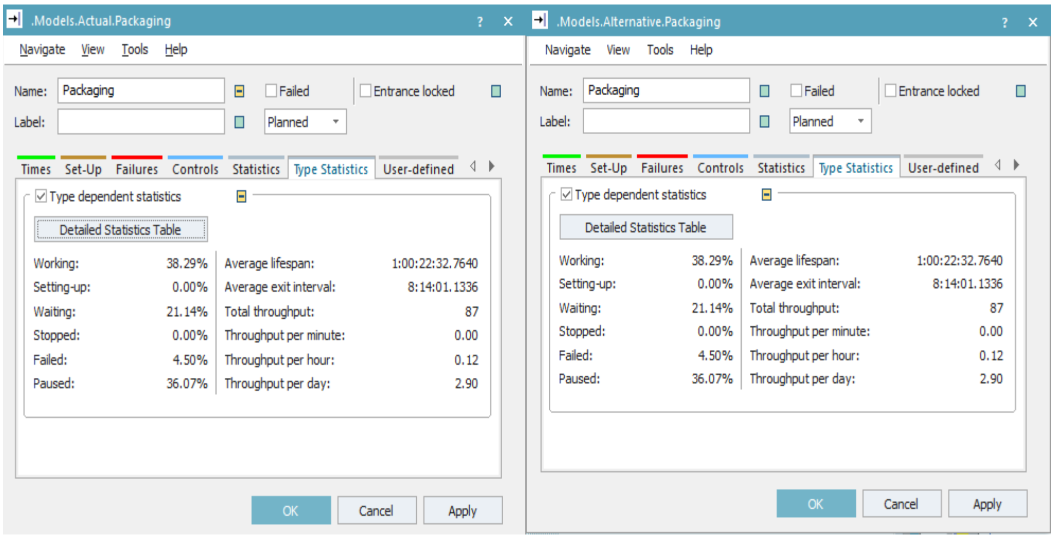
5.3 Energy Efficiency Evaluation

The simulation of the initial model resulted certain factors which influence the energy consumption within the production system. A proposed improvement scenario which can be done to minimize the energy expenditure is by implementing a reduction of non-value added energy, or in this case is by modifying the operational state condition. The implementation has been made within the hammermill B machine. After the suggested scenario executed by using the simulation, a promising energy efficiency improvement has been achieved without affecting the production throughput as depicted in figure 5.4. The initial simulation model generates energy of around 642,236.5 kWh a month, whilst after the alternative scenario has been implemented, the system only consumes 589,418.3 kWh a month. Thus, the energy efficiency can be improved for around 8.22%. This also means Rp. 77.959.663 of cost reduction in terms of electricity cost is achievable.



(a) (b)

Figure 5.3 – **(a) Initial model energy consumption; (b) Proposed scenario energy consumption**



(a) (b)

Figure 5.4 – **(a) Initial statistics report; (b) Alternative scenario statistics report**

CHAPTER 6

CONCLUSION

6.1 Conclusion

Production line is considered to be the most intensive energy consumer within a manufacturing system. An investigation should be conducted to achieve a potential reduction of the consumed energy. This research aims to present an analysis of the energy efficiency improvement within the production line.

Discrete-event simulation (DES) approach was used to analyze the promising improvement in terms of the electrical energy within the production line. Initially, a model which represents the actual condition was established, afterwards the simulation was run and analyzed. From the analysis of the initial simulation result, an improvement scenario can be developed. Certain parameters, such as processing time, working shift schedule, and machine states was taken into account to see the significant impact of the expended energy quantity. A measure that can be done to minimize the energy expenditure is by reducing the non-value added energy within the production system. In the case study, the hammermill B machine was the major consumer of the non-value added energy, in the form of idle time. Thus, a suggestion proposed to improve the energy efficiency is by separating water pump installation in each machine, so that when one machine is turned off, the operational energy can be lowered. This modification is directly related to an adjustment of the machine states, which is one of the parameters included in the study. By implementing the suggested scenario, 8.22% of the energy consumption reduction can be achieved.

6.2 Future Work

This study was solely conducted to investigate the electrical energy efficiency within a production system, without considering any relevant environmental impacts evaluation. Thus, involving the environmental analysis into evaluation is highly recommended to be done in the future. Furthermore, beside energy intensive, crumb rubber manufacturing is also water intensive. An effort to manage the water consumption would be beneficial to pursue the sustainability within the crumb rubber manufacturing.

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APPENDIX A

SYSTEMATIC LITERATURE REVIEW (SLR) TABLE

Article	Author	Methodology	Result	Further Research
Energy and material efficiency of steel powder metallurgy	José M. C. Azevedo, André Cabrera Serrenho, Julian M. Allwood	*Production chain mapping*	The results show that there are opportunities to reduce energy and material requirements, which are offered through five efforts, namely: reducing heat release in the annealing and sintering powder process, reducing raw material requirements in the consolidation process; increase production of single fluid metal powder (single fluid metal powder); Avoid using lasers to produce heat in additive manufacturing; avoid powder bed in additive manufacturing.	Research can be developed by taking into account the phase of use and end of life of products made from metallurgical powder.
Optimization of energy efficiency of a production site: a method to support data acquisition for effective action plans	Ivan Meo, Alessandra Papetti, Fabio Gregori, Michele Germani	*Energy plant assesment framework*	The framework offered has been applied to case studies in real terms, and confirms the effectiveness of the method.	Future development is expected to focus on automating data management through implementing on-board sensors and developing tools or tools to support data collection and elaboration.

Article	Author	Methodology	Result	Further Research
Integrating process optimization with energy-efficiency scheduling to save energy for paper mills	Zhiqiang Zeng , Mengna Hong, Jigeng Li, Yi Man, Huanbin Liu, Zeeman Li, Huanhuan Zhang	*particle swarm optimization (PSO)* dan *non-dominated sorting genetic algorithm II (NSGA-II)*	The experimental result shows that there is a large potential energy efficiency in the drying process, reaching 12.53% of the total energy consumption.	Further research is expected to focus on improving optimization algorithms for process optimization and scheduling.
A hierarchical framework for concurrent assessment of energy and water efficiency in manufacturing systems	Smaeil Mousavi, Sami Kara, Bernard Kornfeld	*Hierarchical assesment framework*	The experimental result shows a reduction of 6.42% and 1.97% of energy consumption and total water per liter of product can be achieved based on the selection of different production parameters.	Future research will attempt to assess the efficiency potential of indirect water on water consumption.
Review of energy models to the development of an efficient industrial energy model	O.A Olanrewaju, A.A Jimoh	*New hybrid energy model*	The new hybrid model offered successfully identified more energy efficiency potentials based on other models compared.	
Analysis of energy efficiency in PCB manufacturing process	Gyu-Bong Lee, Min-Jae Ko, and Tae-Jun Ku	*Energy Resource Management (ERM)*	The experimental result proves that the ERM method offered can be used as a guideline for managing and improving energy efficiency in the manufacturing process.	Further research could be conducted to develop the ERM method is to involve aspects of production planning.

Article	Author	Methodology	Result	Further Research
An Energy Efficiency Evaluation Scheme for Manufacturing Facility	Sangjin Jeong, Yong-Woon Kim	*Weighted spider web chart*	Research has successfully proven that the method offered is able to meet the needs of evaluating the energy efficiency of manufacturing facilities holistically.	
On a generalized approach to manufacturing energy efficiency	Apostolos Fysikopoulos, Georgios Pastras, Theocharis Alexopoulos, George Chryssolouris	*Generelized approch of manufacturing energy efficiency*	Experimental results through case studies show that many difficulties in optimizing energy efficiency can be handled through this approach.	
SME appropriate concept for continuously improving the energy and resource efficiency in manufacturing companies	S. Thiede, G. Posselt, C. Herrmann	*Systematic and continuous improvement of the energy and resource efficiency*	The method offered has been implemented in various case studies and successfully verified the applicability and benefits. The main focus in case studies is devoted to electrical energy as an important career energy in manufacturing systems, but this concept is also easily applied to other types of energy.	Further research will focus on integrating more emphasis on automation in different application interactions and developing further concepts on commercial solutions.
An integrated approach for improving energy efficiency of manuf acturing process chains	Smaeil Mousavia, Sebastian Thiede, Wen Li, Sami Kara, and Christoph Herrmann	*Integrated conceptual framework*	Research shows that the methods offered are able to study and investigate the potential for energy efficiency in production systems through machine selection, defining process parameters, and production planning.	Further research is to apply the method offered by considering the interaction between the unit process and the technical building system (TBS).

Article	Author	Methodology	Result	Further Research
An Integrated approach to energy efficienc y in automotive manufa cturing systems: quantitative analysis and optimisation	Kanet Katchasuwanman ee, Richard Bateman, Kai Cheng	*Energy-smart production management (e-ProMan)*	The method offered has been tested in a case study through implementing the HVAC system and contributing to weather forecasting data. The results of the study show that there is a reduction in energy consumption in manufacturing systems in terms of temperature or temperature control.	Further research will focus on work flow in the manufacturing process.
Modelling and analysis of energy footprint of manufacturing s ystems	Hyun Woo Jeon, Marco Taisch & Vittaldas V. Prabhu	*Energy footprint simulation*	The result of the research shows that energy in manufacturing systems can be estimated based on factors at different levels, so that the potential for energy efficiency can be analyzed.	The method offered is proven to be able to be used as a tool that can measure manufacturing energy use, but its implementation takes a long time, so further development to further simplify the model will be the focus of further research.
Energy efficiency evaluation of manufacturing systems by considering relevant influencing factors	Dominik Flick, Li Ji, Patrick Dehning, Sebastian Thiede, Christoph Herrmann	*Regression model for energy evaluation*	The result of the study shows that the method offered was successfully implemented using principles component analysis and regression models to overcome large amounts of colinearity in independent variables. Performance evaluation is based on a comparison of energy performance indicators (EnPI) between real EnPI and EnPI models.	Further research can be carried out by developing a principal components regression (PCR) per work area and evaluating EnPI that are different from general influence factors.

Article	Author	Methodology	Result	Further Research
Method for Increasing Energy Efficiency in Flexible Manufacturing Systems: A Case Study	Hugo M.B. de Carvalho, Jefferson de Oliveira Gomes	*Energy efficiency method*	The method has been tested on CNC machining and proven to be able to improve energy efficiency. The result shows a reduction on the consumption of electrical energy on conveyors, washing machines, center filters by 83%, 12.5%, and 1% respectively.	
Hybrid simulation-based optimization of discrete parts manufacturing to increase energy efficiency and productivity	Thomas Sobottka, Felix Kamhuber, Matthias Rössler, Wilfried Sihn	*Hybrid simulation-based optimization approach*	The research presented has been able to show that the method developed can be applied to planning a real production system. The result shows a significant overall optimization potential of up to 50% of the objective function value, including a ~ 30% reduction in energy consumption.	Future research will include more advanced planning for the technical building system or FFB from the production system. This case will include the actuating variables for TBS, such as prioritizing several devices in a supply network - namely cooling - or setting the target temperature in a heat reservoir and circuit.
Energy gap method (EGM) to increase energy efficiency in industrial processes: Successful cases in polymer processing	Omar Estrada, Iván D. López, Alexander Hernández, Juan C. Ortíz	*Energy gap method (EGM)*	The implementation of EGM in polymer processing plants allowed a significant increase of energy efficiency in polymer extrusion blow molding and polymer injection molding processes, increasing the productivity, reducing non-compliant production, and reducing the carbon foot print of the process.	

Article	Author	Methodology	Result	Further Research
Energy efficiency optimization of air supply system in a water bottle manufacturing system	Vukica Jovanovic, Branislav Stevanov, Dragan Šešlija, Slobodan Dudić, Zdravko Tešić	*Green manufacturing methods* dan *discrete event simulation (DES)*	The obtained results clearly indicate an increase in energy efficiency of 4.44% by simply connecting the compressors to a joint reservoir, energy efficiency is improved, along with an increase in reliability.	Future work will be focused on applying this optimization method to another industrial application.
A novel method for energy efficiency evaluation to support efficient machine tool selection	Peiji Liu, Junbo Tuo, Fei Liu, Congbo Li , Xicheng Zhang	*Potential efficiency (PE) method*	This research provides satisfactory results. The application of the proposed method is illustrated by an example of gear selection, with a reduction in energy consumption of 2.88Eþ06 kJ per engine chosen per year achieved, indicating that the proposed PE method is able to provide decision support for producers to choose an efficient machine. Comparison with other methods shows that this method has a higher level of accuracy than component-based methods and the experience rules used in the procurement stage have a higher level of practicality than experimental-based methods.	Further studies will consist of two aspects. First, supporting tools for decision making in the procurement stage, which integrate energy performance into other important objectives (eg flexibility, cost, productivity) to choose high-efficiency machinery for the construction of energy-efficient manufacturing systems. Second, the engineered design method for the purpose of maximizing energy efficiency will be investigated in the next step.

Article	Author	Methodology	Result	Further Research
Methodology and model for predicting energy consumption in manufacturing at multiple scales	Jan Reimann, Ken Wenzel, Marko Friedemann, Matthias Putz	*General approach and a normalized data format*	The proposed approach has been tested and has successfully predicted energy consumption in an extraction process in a casting machine.	Further research will apply the format for special importers that are most often used in production or which have proven effective.
Methods for evaluation of energy efficienc y of machine tools	Timo Schudeleit, Simon Züst, Konrad Wegener	*Analytic Hierarchy Process (AHP)*	Consistency evaluation proves the validity of research results. This study led to significant differences in globalized global priorities and ranking differences in different test methods.	In further research, research findings will be integrated into the ISO 14995 series.
Methods-Energy Measurement – An approach for sustainable energy planning of manufacturing technologies	Martin Bornschlegl, Mar kus Bregulla, Jörg Franke	*Method-Energy Measurement*	In this study compared energy forecasting using the MEM approach with real energy consumption, then the standard deviation was calculated. The results showed that the deviation was within the tolerance range of below 5%.	Further research that will be carried out is to integrate the energy chain management (ECM) method with the MEM method.

Article	Author	Methodology	Result	Further Research
A ‘Design for Energy Minimization’ approach to reduce energy consumption during the manufacturing phase	Yingying Seow, Nicholas Goffin, Shahin Rahimifard, Elliot Woolley	*Design for Energy Minimization (DfEM)*	In this study, the DfEM methodology has been proven to be applicable to three stages of the design and production process: Concept Design, Design and Production Detail. In concept design, an efficient life cycle assessment is needed to provide a general prediction of manufacturing energy use. Furthermore, at the detailed design stage using an energy simulation model, which consists of an energy database, a simulation engine that assesses the manufacturing process with data from a database and a houe of qualit-based tools, using simulation results to determine specific design features. During the production phase, the process is monitored by an energy measurement system which then provides feedback on empirical data on energy use at the plant, while this validates the results of the methodology and provides empirical data for further improvement.	In future research, this approach can be integrated with other life cycle management approaches to evaluate the overall life cycle impact of the product, and to ensure that absolute environmental impacts are reduced and not increased.

Article	Author	Methodology	Result	Further Research
Integrated Material and Energy Flow Analysis towards Energy Efficient Manufacturing	Pouya Ghadimi, Wen Lia, Sami Kara, Christoph Herrmann	*Material and Energy Flow Analysis (MEFA)*	The final result of this study illustrates the importance of integrated material and energy flows to ensure the achievement of the main production objectives in addition to maximizing the potential for energy savings.	In future research, approaches that seek to improve further sustainability such as integrated process and material control and optimization of energy flows must be studied in more detail.
A New Framework of Energy-efficient Manufacturing Systems Based on Energy Load Profiles	Haruhiko Suwa, Tetsuo Samukawa	*Energy Load Profile*	In the study, the result indicates that high-speed machines and tool path flexibility can produce more energy efficient processing modes through several cutting experiments at the machining center.	Further research will build an energy consumption prediction model from theoretical aspects that can be directly used as a processing mode.
A tool for assessing the energy demand and efficiency of machining systems: Energy benchmarking	Wei Cai, Fei Liu, Jun Xie, Peiji Liu, Junbo Tuo	*Energy Benchmarking Frameworks for Machining Systems*	In this study, the proposed approach has been applied to a case study and the results of the study show that the proposed method is feasible to be an energy comparator for workpieces in the machining system and can play an important role in improving energy management and improving energy efficiency.	Further studies will focus on two aspects of energy benchmarking: first, energy evaluation standards and the certification process for machining systems will be considered using the energy benchmarking process. Second, the acquisition of data to build more basic databases will be further developed.

Article	Author	Methodology	Result	Further Research
Discrete Event Simulation of Individual Energy Consumption for Product-varieties	Johannes Kohl, Simon Spreng, Jörg Franke	*Discrete Event Simulation (DES)*	The result of this study indicates that this procedure allows predicting energy in the production line or even all factories within the scope of load management. In addition, this approach is able to quantify variable energy costs for each product variation that is simulated so as to provide more transparency in energy-related cost accounting.	Further studies will include the application of advanced modules that allow energy modules to communicate with dynamically defined attributes such as the simulation temperature of a product.
Concepts for dynamic modelling of energy-related flows in manufacturing	A. J. Wright, M. R. Oates, R. Greenough	*THrough-life Energy and Resource Modelling (THERM)*	The result shows that this model is fully feasible and has potential use value, although to develop a tool that can comprehensively model energy flow and manufacturing is a considerable effort.	
Simulation of energy consumption in the manufacture of a product	Yingying Seow, Shahin Rahimifard, Elliot Woolley	*Energy Simulation Model (ESM)*	This study has shown the effectiveness of the ESM approach to provide greater transparency of energy consumption during the production phase of a product. In addition, the flexibility offered by the ESM enables a wider range of results tailored to the specific needs of various potential users in manufacturing facilities (eg operators, shop floor planners, maintenance and design designers) to be produced.	Further research will highlight two aspects: first, exploration of 'what-if' scenarios to see how changes in production processes and operations can affect energy consumption. Second, using details of energy flow and modeling output as a supporting tool to improve product design.

Article	Author	Methodology	Result	Further Research
Sustainable manufacturing tactics and cross-functional factory modelling	Mélanie Despeisse, Michael R. Oates, Peter D. Ball	*Cross-Functional Factory Modelling*	The result of the research shows that there is a possibility to identify opportunities for sustainable manufacturing system improvement in a structured and systematic way using manufacturing system modeling.	Further research will be repositioning research activities as a result of developing tools or tools for integrated resource flow modeling to identify sustainable manufacturing system improvement opportunities through a combined analysis of manufacturing operations, support systems of production facilities and buildings, and integration of best practices available from producer.
A simple energy usage toolkit from manufacturing simulation data	Joel Wilson, Alan Arokiam, Hafid Belaidi, John Ladbrook	*Discrete Event Simulation (DES)*	Based on the results of research and simulation, there was a decrease in energy consumption by 23% from the comparison between the simulation of the production process in real conditions with an alternative production process, namely engineering in a production process that aims to reduce energy consumption.	Further research will expand the use of toolkits or post-processing tool devices to incorporate existing environmental considerations as a direct result of the manufacturing line being operated.

Article	Author	Methodology	Result	Further Research
A simulation based approach to realize green factory from unit green manufacturing processes	Amandeep Singh, Deepu Philip, J. Ramkumar, Mainak Da	*Artificial Bee Colony algorithm (ABC)* dan *Discrete Event Simulation (DES)*	The process of milling, drilling, grinding, and μ-WEDG operating in the setting of green parameters shows 29%, 16%, 31%, and 42% energy savings respectively; The results show a total savings of 28% in the variable energy of the entire plant. Also, the results show an approximately 92% reduction in the use of cutting fluids.	Further studies will work to apply the findings on the floor of machining work to realistically measure the increase in greenness of existing facilities.
Multi-level simulation in manufacturing companies: The water-energy nexus case	Sebastian Thiede, Malte Schönemann, Denis Kurle, Christoph Herrmann	*Multu-level Simulation*	The results of research on case studies show that the multi-level approach allows a more in-depth analysis of interdependencies between actions or scenarios.	Further work will focus on model details, integrating further models (eg buildings) and applications to other domains (eg battery production).

Article	Author	Methodology	Result	Further Research
Extending Energy Value Stream Models by the TBS Dimension – Applied on a Multi Product Process Chain in the Railway Industry	G. Posselt, J. Fischer, T. Heinemann, S. Thiede, S. Alvandi, N. Weinert, S. Kara, C. Herrmann	*Extended Energy Value Stream Models*	As a result the study allows the comparison of the overall activity between value-added activities and non-value-added activities that are decomposed into processes and products. In this case, high potential increases can be identified in non-value-added activities, which make up about 60% of total demand. Therefore, to improve the energy efficiency of the peripheral system is focused on the first level. The first identifiable way to reduce demand is for example by using a local exhaust system for welding applications because this will reduce the time to use a central intensive energy disposal system that is controlled by an air quality sensor. In addition, this methodology highlights the relevance of reducing processing time, because processes with the highest duration tend to consume the highest intensity of energy.	Subsequent studies will strive to achieve improved pragmatic solutions that can be applied to adapt to the continuous improvement process within the ISO 50001. energy management framework. In addition, further research that can be done is to expand the methodology into the perspective of environmental evaluation, also consider additional auxiliary materials (eg cutters liquid) and the environmental impact of the material and form of energy used for further consideration.

Article	Author	Methodology	Result	Further Research
Energy Consumption Modeling and Analyses in Automotive Manufacturing Plant	Lujia Feng, Laine Mears	*Hierarchical Modelling Method*	The results of the study indicate that the proposed approach can efficiently identify important energy components in the plant and be able to provide useful improvement suggestions.	Subsequent research will further analyze the paint spray booth environmental control system, energy models can be formed in two aspects: first, energy supply from hot and cold water, and second is energy demand from changes in air status.
Evaluation of Process Chains for an Overall Optimization of Manufacturing Energy Efficiency	Christian Mose, Nils Weinert	*EnergyBlocks-Method*	The results of the research provide a basis for improving the energy efficiency of the plant, as well as calculating the energy contained in a product, and also encourage energy optimization from the side of the manufacturing process.	In further research to improve sustainability, energy efficiency activities combined with further approaches, for example, the establishment of extensive renewable energy sources is a way that can be done. Innovative concepts such as developing CO2 from hazardous substances into valuable raw materials such as what has been introduced as a Green Cycle economy must also be developed intensively.

Article	Author	Methodology	Result	Further Research
Interdisciplinary multi-criteria optimization using hybrid simulation to pursue energy efficiency through production planning	Wilfried Sihn, Thomas Sobottka, Bernhard Heinzl, Felix Kamhuber	*hyPDEVS*	This approach has been applied and evaluated in a case study in the food industry, the simulation results show the potential for energy efficiency gains of up to 30%.	There are two obstacles that are still found in this method, so it requires further study to develop this method: First, the development of the model still requires significant effort and expert domain knowledge because choosing adequate model details is a must. Second, the performance of calculations is very important - the number of simulation evaluations that are "affordable" near the minimum for a GA works well - so it is necessary to include empirical knowledge about the production system into the optimization algorithm.
Simulation of Energy Efficiency Improvement in Induction Motor Drive by Fuzzy Logic Based Temperature Compensation	N. Jirasuwankul	*Fuzzy Logic*	Simulation results show that the system model can operate and maintain drive performance while achieving energy efficiency in high temperature conditions.	To confirm the effectiveness of the proposed approach, experimental tests with implementation on real machines and drive systems, namely field-oriented controls, can be carried out, and this will be a follow-up study in the future.

Article	Author	Methodology	Result	Further Research
Energy use analysis and local benchmarking of manufacturing lines	Hoda A. ElMaraghy, Ayman M. A.Youssef, Ahmed M. Marzoukc, Waguih H. ElMaraghy	*Energy Use and Local Benchmarking Method*	The results of a detailed analysis of energy consumption in the cycle of CNC machines shows that the machines that are running consume almost the same amount of energy whether they are working productively or not. So, optimizing the use of material handling equipment will reduce energy consumption per unit of production. Meanwhile, the results of the benchmarking analysis show the percentage of energy waste in several different categories and highlight the lost production that occurs based on time, and displays the effectiveness of the equipment as a whole.	Further research will consider different operational conditions and technology enablers in addressing global benchmarking problems in equipment and production floors used in discrete industrial products.
Energy efficiency a ssessment of grinding strategy	Konstantinos Salonitis	*Energy Efficiency Assessment Framework*	The results showed that the effects of the milling process parameters on energy consumption were not too significant. However, on the other hand, the subsystem of the machinery equipment consumes a significant portion of total energy demand.	This experimental method will be associated with the design of experiments in future research.

Article	Author	Methodology	Result	Further Research
Design of energy efficient RAL system using evolutionary algorithms	Mukund J. Nilakantan, S. G. Ponnambalam, N. Jawahar	*Particle Swarm Optimization (PSO) Algorithm dan Differential Evolution (DE) Algorithm.*	From the results obtained through this approach it can be observed that DE-based algorithms can obtain better path efficiency than PSO-based algorithms. Energy consumption and cycle times, as well as other problems are also reported. In addition, it can be observed that DE-based models can produce solutions at a lower computing time than PSO for large datasets. But in the case of large datasets, PSO performs faster than DE. This may be due to repeated fitness evaluations during the selection process.	In future research, algorithms can be tested by considering a certain time span, where factors such as maintenance operations and the effects of resource failures in the system can be included. Another evolutionary algorithm, as an alternative to PSO and DE, can be tried to solve the same problem.
From energy targets setting to energy-aware operations control and back: An advanced methodology for energy efficient manufacturing	Miriam Benedetti, Vittorio Cesarotti, Vito Introna	*Energy Performance Indicator (EnPI)*	The results show that the proposed methodology allows direct identification of manufacturing plant energy performance deviations through monitoring of Energy Performance Indicators over time, and the relationship of causes and responsibilities for these deviations, to enable companies to react quickly to define action plans and rearrange targets if necessary ; Research has also been validated through industry case studies.	The method developed still needs to be tested in more case studies in order to further validate and improve the usability of the methods offered, especially in companies with different production schemes and characterized by different dimensions.

Article	Author	Methodology	Result	Further Research
A novel approach for acquiring the real-time energy efficiency of machine tools	Peiji Liu, Fei Liu, Hang Qiu	*Real Time Energy Efficiency (REE)*	This method has been tested and validated on commonly used machinery, and the results show practicality with high accuracy to obtain energy efficiency data in real time. This approach can be applied to assess the energy efficiency of machinery equipment, supporting designers to design machinery and high-efficiency uses, and to improve the energy efficiency of the manufacturing process.	In the future, the proposed approaches and models will be further developed to provide energy savings advice automatically and acceptable.
Design for energy sustainability in manufacturing systems	Tarek AlGeddawy, Hoda ElMaraghy	*Manufacturing Systems Design for Energy Minimization (MSDEM)*	The results show that the energy consumption of manufacturing systems can be minimized in production planning by system design. Manufacturing system design for energy sustainability complements other energy use reduction methods.	
An energy consumption evaluation methodology for a manufacturing plant	A. Cataldoa, R. Scattolini, T. Tolio	*aCtuatorS Metodologi (CSM)*	The results showed that the system behavior predicted by CSM and measured data did not have much difference.	Future research will test CSM in different case studies. In addition, the characteristics of CSM will be generalized to allow application to a wider manufacturing system. For this purpose, the standard library of simulation process equipment will be developed in factory design activities.

Article	Author	Methodology	Result	Further Research
Energy efficiency evaluation for machining systems through virtual part	Junbo Tuo, Fei Liu, Peiji Liu, Hua Zhang, Wei Cai	*Virtual Part Method*	The results of the research through the application of the proposed method in machining equipment show that the proposed method is more accurate than the existing method and contributes to the effort to save energy including the development of energy efficiency standards, the design of energy-efficient machinery systems, and the reform of the old machining system.	Future research will try to use feedback data through computer science concepts, such as the internet of things and artificial intelligence.
An energy efficiency focused semantic information model for manufactured assemblies	Milton Borsato	*Semantic Information Models*	The results show that it is feasible to correlate all the data required through semantic relations in estimating energy efficiency indicators before making physical prototypes, or comparing various alternatives in the manufacturing process regarding energy efficiency.	

Article	Author	Methodology	Result	Further Research
Internet-of-Things Enabled Real-time Monitoring of Energy Efficiency on Manufacturing Shop Floors	Yee Shee Tan, Yen Ting Ng, Jonathan Sze Choong Low	*Internet of Things*	The results of the study yield valuable benefits, namely: 1) enabling real-time monitoring while capturing abnormal energy efficiency events and measuring through comparing potential increase in real time, and 2) helping energy managers to instill the best energy management practices in daily operations and achieving better energy efficiency by eliminating the possibility of energy waste in manufacturing operations.	Further research will be conducted on case studies involving more variation in product types and operating parameters.
Data-driven Approach for Discovery of Energy Saving Potentials in Manufacturing Factory	Bin Song, Yintai Ao, Li Xiang, K. Y. Ng Lionel	*Data Analytics Approach*	The proposed method has been applied to the chiller system. The results showed that the output chiller (RT) was significantly correlated with power consumption (kw), and was influenced by cold water inlet temperature (℃) and condenser water inlet temperature (℃). If the chiller can operate at the best energy efficiency achieved, 8.6% of chiller energy consumption can be stored.	Further research will examine the proposed approach to factory-level data where parameter data from energy production and production machines will be analyzed to reveal the level of correlation between the machine, correlated engine energy efficiency limits, and energy saving potential.

Article	Author	Methodology	Result	Further Research
A life cycle energy analysis integrated process planning approach to foster the sustainability of discrete part manufacturing	Yansong Guo, Joost R. Duflou, Yelin Deng, Bert Lauwers	*Life Cycle Energy Analysis Integrated Process Planning (LCEA-PP)*	The results showed that the application of near-net shape (NNS) strategies resulted in energy mitigation of more than 40% compared to conventional form (CS) strategies. However, further analysis shows that CS strategy can be more energy efficient under certain manufacturing arrangements.	In further research, the development of an approach is needed to support industrial producers to adopt an energy-efficient process plan that will effectively help them to achieve a more sustainable manufacturing system.
Plant-level electricity demand response for combined manufacturing system and heating, venting, and air-conditioning (HVAC) system	Zeyi Sun, Lin Li, Fadwa Dababneh	*Electricity Demand Response Method*	The results of numerical case studies illustrate the effectiveness of the proposed integrated modeling methodology. Power demand results during peak periods, peak periods outside, and demand response events in scenario 2 which are baseline situations where manufacturing systems and HVAC systems are operated and controlled separately are slightly higher than the results in scenario 1 which is an implementation of the proposed method.	Further research will investigate the development of assumptions to be more complex than previous assumptions to make the model closer to real life. For example, modeling more complex factory buildings such as work areas, operator rest areas, office areas, etc., will be considered. Models of heat capacity for different areas can also be investigated to represent the heat capacity of the entire building. HVAC efficiency models can be explored to identify their relationship with the factors that influence them. In addition, application and testing methods in the winter can also. Decision making for the real-time integration of electricity demand

Article	Author	Methodology	Result	Further Research
				response systems, which can be used for emergency request response programs, will also be investigated.

APPENDIX B

COMPANY'S HOURLY POWER DOCUMENTATION

Thursday
1-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	200	108	600	324	400	216	400	216	900	486
7:00	50	390	300	162	700	378	400	216	300	162	900	486
8:00	50	390	200	108	700	378	400	216	400	216	900	486
9:00	50	390	200	108	600	324	400	216	300	162	900	486
10:00	50	390	300	162	700	378	400	216	300	162	700	378
11:00	50	390	200	108	600	324	400	216	400	216	900	486
12:00	50	390	300	162	600	324	400	216	300	162	800	432
13:00	50	390	200	108	700	378	400	216	400	216	800	432
14:00	50	390	200	108	700	378	400	216	400	216	800	432
15:00	50	390	400	216	700	378	400	216	400	216	900	486
16:00	50	390	400	216	600	324	0	0	0	0	0	0
17:00	50	390	400	216	600	324	0	0	0	0	0	0
18:00	50	390	300	162	600	324	0	0	0	0	0	0
19:00	50	390	300	162	600	324	0	0	0	0	0	0
20:00	50	390	300	162	600	324	300	162	300	162	800	432
21:00	50	390	300	162	600	324	400	216	400	216	800	432
22:00	50	390	200	108	600	324	400	216	400	216	900	486
23:00	50	390	200	108	600	324	400	216	400	216	900	486
0:00	50	390	200	108	600	324	400	216	400	216	800	432
1:00	50	390	200	108	600	324	400	216	400	216	800	432
2:00	50	390	200	108	600	324	400	216	400	216	800	432
3:00	50	390	200	108	600	324	400	216	400	216	800	432
4:00	50	390	200	108	500	270	400	216	400	216	800	432
5:00	50	390	200	108	500	270	400	216	400	216	800	432
Total				3,296		7,998		4,269		4,053		9,024

Friday
2-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
							B		A			
	Hz	Volt	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	400	216	200	108	400	216	400	216	600	324
7:00	50	390	600	324	200	108	400	216	300	162	900	486
8:00	50	390	600	324	0	0	400	216	400	216	900	486
9:00	50	390	500	270	0	0	400	216	300	162	700	378
10:00	50	390	600	324	0	0	400	216	300	162	800	432
11:00	50	390	0	0	0	0	0	0	0	0	0	0
12:00	50	390	0	0	0	0	0	0	0	0	0	0
13:00	50	390	500	270	0	0	400	216	400	216	900	486
14:00	50	390	500	270	0	0	400	216	300	162	900	486
15:00	50	390	500	270	0	0	400	216	200	108	900	486
16:00	50	390	0	0	0	0	0	0	0	0	0	0
17:00	50	390	0	0	0	0	0	0	0	0	0	0
18:00	50	390	0	0	0	0	0	0	0	0	0	0
19:00	50	390	0	0	0	0	0	0	0	0	0	0
20:00	50	390	0	0	0	0	0	0	0	0	0	0
21:00	50	390	0	0	0	0	0	0	0	0	0	0
22:00	50	390	300	162	600	324	400	216	400	216	900	486
23:00	50	390	300	162	600	324	400	216	400	216	900	486
0:00	50	390	400	216	600	324	400	216	400	216	900	486
1:00	50	390	300	162	600	324	400	216	400	216	800	432
2:00	50	390	400	216	600	324	400	216	400	216	800	432
3:00	50	390	400	216	600	324	400	216	400	216	800	432
4:00	50	390	300	162	600	324	400	216	400	216	800	432
5:00	50	390	200	108	600	324	400	216	300	162	800	432
Total				3,675		2,810		3,458		3,080		7,187

Saturday
3-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	0	0	0	0	400	216	300	162	700	378
7:00	50	390	0	0	0	0	400	216	400	216	900	486
8:00	50	390	0	0	0	0	400	216	400	216	900	486
9:00	50	390	0	0	0	0	400	216	300	162	900	486
10:00	50	390	0	0	0	0	400	216	400	216	900	486
11:00	50	390	0	0	0	0	200	108	200	108	800	432
12:00	50	390	0	0	0	0	400	216	400	216	1,000	540
13:00	50	390	0	0	0	0	400	216	400	216	800	432
14:00	50	390	0	0	0	0	400	216	400	216	900	486
15:00	50	390	0	0	0	0	400	216	400	216	800	432
16:00	50	390	0	0	0	0	400	216	400	216	800	432
17:00	50	390	0	0	0	0	0	0	0	0	0	0
18:00	50	390	0	0	0	0	0	0	0	0	0	0
19:00	50	390	0	0	0	0	0	0	0	0	0	0
20:00	50	390	0	0	0	0	0	0	0	0	0	0
21:00	50	390	0	0	0	0	0	0	0	0	0	0
22:00	50	390	0	0	0	0	0	0	0	0	0	0
23:00	50	390	0	0	0	0	0	0	0	0	0	0
0:00	50	390	0	0	0	0	0	0	0	0	0	0
1:00	50	390	0	0	0	0	0	0	0	0	0	0
2:00	50	390	0	0	0	0	0	0	0	0	0	0
3:00	50	390	0	0	0	0	0	0	0	0	0	0
4:00	50	390	0	0	0	0	0	0	0	0	0	0
5:00	50	390	0	0	0	0	0	0	0	0	0	0
Total				0		0		2,270		2,162		5,080

Monday
5-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
							B		A			
	Hz	Volt	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	0	0	0	0	200	108	200	108	800	432
7:00	50	390	0	0	0	0	300	162	400	216	800	432
8:00	50	390	0	0	0	0	400	216	500	270	900	486
9:00	50	390	0	0	0	0	400	216	400	216	900	486
10:00	50	390	0	0	0	0	400	216	400	216	800	432
11:00	50	390	0	0	0	0	400	216	400	216	800	432
12:00	50	390	0	0	0	0	400	216	300	162	800	432
13:00	50	390	0	0	0	0	300	162	400	216	800	432
14:00	50	390	0	0	0	0	300	162	300	162	700	378
15:00	50	390	0	0	0	0	0	0	0	0	0	0
16:00	50	390	0	0	0	0	0	0	0	0	0	0
17:00	50	390	0	0	0	0	0	0	0	0	0	0
18:00	50	390	0	0	0	0	0	0	0	0	0	0
19:00	50	390	0	0	0	0	0	0	0	0	0	0
20:00	50	390	0	0	0	0	0	0	0	0	0	0
21:00	50	390	0	0	0	0	300	162	400	216	700	378
22:00	50	390	0	0	0	0	400	216	400	216	600	324
23:00	50	390	0	0	0	0	400	216	300	162	700	378
0:00	50	390	0	0	0	0	400	216	400	216	900	486
1:00	50	390	0	0	0	0	400	216	300	162	900	486
2:00	50	390	0	0	0	0	400	216	400	216	800	432
3:00	50	390	0	0	0	0	400	216	400	216	900	486
4:00	50	390	0	0	0	0	400	216	300	162	800	432
5:00	50	390	0	0	0	0	400	216	300	162	0	0
Total				0		0		3,567		3,512		7,349

Tuesday
6-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	400	216	200	108	200	108	200	108	800	432
7:00	50	390	400	216	200	108	400	216	400	216	800	432
8:00	50	390	200	108	700	378	400	216	400	216	800	432
9:00	50	390	200	108	700	378	400	216	400	216	900	486
10:00	50	390	400	216	700	378	400	216	400	216	900	486
11:00	50	390	300	162	700	378	400	216	400	216	800	432
12:00	50	390	300	162	700	378	400	216	400	216	800	432
13:00	50	390	400	216	700	378	400	216	400	216	800	432
14:00	50	390	300	162	700	378	400	216	400	216	900	486
15:00	50	390	400	216	600	324	0	0	0	0	0	0
16:00	50	390	400	216	700	378	0	0	0	0	0	0
17:00	50	390	400	216	700	378	0	0	0	0	0	0
18:00	50	390	400	216	600	324	0	0	0	0	0	0
19:00	50	390	300	162	600	324	0	0	0	0	0	0
20:00	50	390	300	162	600	324	0	0	0	0	0	0
21:00	50	390	300	162	600	324	400	216	400	216	900	486
22:00	50	390	300	162	600	324	400	216	0	0	400	216
23:00	50	390	300	162	700	378	400	216	0	0	700	378
0:00	50	390	300	162	700	378	400	216	0	0	600	324
1:00	50	390	200	108	600	324	200	108	0	0	0	0
2:00	50	390	300	162	600	324	0	0	0	0	0	0
3:00	50	390	200	108	700	378	0	0	0	0	0	0
4:00	50	390	200	108	700	378	0	0	0	0	0	0
5:00	50	390	300	162	400	216	0	0	0	0	0	0
Total				4,053		7,944		2,810		2,053		5,458

Wednesday
7-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
							B		A			
	Hz	Volt	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	400	216	700	378	0	0	0	0	500	270
7:00	50	390	400	216	700	378	0	0	400	216	400	216
8:00	50	390	400	216	700	378	0	0	400	216	500	270
9:00	50	390	200	108	600	324	400	216	400	216	800	432
10:00	50	390	200	108	600	324	400	216	400	216	800	432
11:00	50	390	300	162	600	324	400	216	400	216	800	432
12:00	50	390	200	108	700	378	400	216	400	216	800	432
13:00	50	390	200	108	700	378	400	216	400	216	900	486
14:00	50	390	200	108	700	378	400	216	400	216	400	216
15:00	50	390	200	108	680	367	0	0	0	0	0	0
16:00	50	390	200	108	680	367	0	0	0	0	0	0
17:00	50	390	200	108	680	367	0	0	0	0	0	0
18:00	50	390	200	108	680	367	0	0	0	0	0	0
19:00	50	390	200	108	680	367	0	0	0	0	0	0
20:00	50	390	200	108	680	367	0	0	0	0	400	216
21:00	50	390	200	108	680	367	400	216	400	216	800	432
22:00	50	390	200	108	600	324	400	216	300	162	900	486
23:00	50	390	300	162	600	324	400	216	400	216	800	432
0:00	50	390	200	108	700	378	400	216	300	162	900	486
1:00	50	390	200	108	700	378	400	216	400	216	800	432
2:00	50	390	300	162	600	324	400	216	300	162	700	378
3:00	50	390	200	108	600	324	400	216	400	216	700	378
4:00	50	390	300	162	700	378	400	216	400	216	800	432
5:00	50	390	200	108	600	324	400	216	300	162	400	216
Total				3,134		8,570		3,242		3,458		7,079

Thursday
8-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	300	162	700	378	400	216	400	216	800	432
7:00	50	390	300	162	700	378	200	108	200	108	800	432
8:00	50	390	400	216	700	378	400	216	400	216	800	432
9:00	50	390	300	162	600	324	200	108	300	162	400	216
10:00	50	390	400	216	600	324	400	216	400	216	800	432
11:00	50	390	200	108	600	324	400	216	300	162	800	432
12:00	50	390	400	216	600	324	200	108	200	108	400	216
13:00	50	390	200	108	700	378	400	216	400	216	400	216
14:00	50	390	300	162	680	367	0	0	0	0	0	0
15:00	50	390	300	162	700	378	0	0	0	0	0	0
16:00	50	390	300	162	700	378	0	0	0	0	0	0
17:00	50	390	300	162	700	378	0	0	0	0	0	0
18:00	50	390	300	162	680	367	0	0	0	0	0	0
19:00	50	390	300	162	680	367	0	0	0	0	0	0
20:00	50	390	300	162	680	367	0	0	0	0	0	0
21:00	50	390	300	162	680	367	200	108	200	108	500	270
22:00	50	390	200	108	600	324	400	216	400	216	700	378
23:00	50	390	300	162	600	324	400	216	300	162	900	486
0:00	50	390	200	108	700	378	400	216	300	162	800	432
1:00	50	390	200	108	600	324	400	216	400	216	800	432
2:00	50	390	200	108	600	324	400	216	300	162	800	432
3:00	50	390	200	108	600	324	400	216	400	216	800	432
4:00	50	390	300	162	700	378	400	216	400	216	800	432
5:00	50	390	200	108	600	324	400	216	300	162	800	432
Total				3,621		8,484		3,242		3,026		6,539

Friday
9-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	400	216	600	324	300	162	300	162	800	432
7:00	50	390	300	162	600	324	300	162	300	162	800	432
8:00	50	390		0		0		0		0	0	0
9:00	50	390	400	216	600	324	400	216	400	216	800	432
10:00	50	390	400	216	600	324	400	216	400	216	800	432
11:00	50	390	300	162	600	324	400	216	300	162	600	324
12:00	50	390		0		0		0		0	0	0
13:00	50	390	300	162	600	324	300	162	400	216	500	270
14:00	50	390	400	216	680	367	400	216	400	216	900	486
15:00	50	390	300	162	680	367	400	216	500	270	900	486
16:00	50	390	200	108	700	378	400	216	400	216	800	432
17:00	50	390	200	108	680	367		0		0	0	0
18:00	50	390		0	680	367		0		0	0	0
19:00	50	390		0	680	367		0		0	0	0
20:00	50	390		0	680	367		0		0	0	0
21:00	50	390		0		0		0		0	0	0
22:00	50	390	200	108	600	324	400	216	300	162	700	378
23:00	50	390	200	108	700	378	400	216	400	216	900	486
0:00	50	390	200	108	600	324	400	216	400	216	900	486
1:00	50	390	300	162	600	324	400	216	300	162	700	378
2:00	50	390	200	108	600	324	400	216	400	216	800	432
3:00	50	390	200	108	600	324	400	216	500	270	800	432
4:00	50	390	200	108	600	324	400	216	400	216	800	432
5:00	50	390		0		0	400	216	400	216	700	378
Total				2,540		6,852		3,512		3,512		7,133

Saturday
10-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
							B		A			
	Hz	Volt	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	300	162	700	378	300	162	300	162	900	486
7:00	50	390	400	216	700	378	400	216	400	216	800	432
8:00	50	390	200	108	700	378	400	216	400	216	800	432
9:00	50	390	300	162	700	378	400	216	400	216	800	432
10:00	50	390	300	162	600	324	400	216	400	216	900	486
11:00	50	390	300	162	700	378	400	216	400	216	800	432
12:00	50	390	300	162	600	324	400	216	400	216	800	432
13:00	50	390	300	162	600	324	400	216	400	216	800	432
14:00	50	390	300	162	600	324		0	500	270	900	486
15:00	50	390	300	162	600	324	300	162	400	216	500	270
16:00	50	390	300	162	600	324		0		0	0	0
17:00	50	390	300	162	600	324		0		0	0	0
18:00	50	390	300	162	600	324		0		0	0	0
19:00	50	390	300	162	600	324		0		0	0	0
20:00	50	390	200	108	600	324		0		0	0	0
21:00	50	390	300	162	700	378		0		0	0	0
22:00	50	390	200	108	600	324		0		0	0	0
23:00	50	390	200	108	600	324		0		0	0	0
0:00	50	390	200	108	600	324		0		0	0	0
1:00	50	390	300	162	600	324		0		0	0	0
2:00	50	390	200	108	400	216		0		0	0	0
3:00	50	390		0		0		0		0	0	0
4:00	50	390		0		0		0		0	0	0
5:00	50	390		0		0		0		0	0	0
Total				3,134		7,025		1,837		2,162		4,323

Monday

12-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
							B		A			
	Hz	Volt	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	200	108	400	216	200	108	200	108	400	216
7:00	50	390	300	162	600	324	400	216	400	216	800	432
8:00	50	390	200	108	700	378	400	216	400	216	1,000	540
9:00	50	390	300	162	680	367	400	216	400	216	880	476
10:00	50	390	300	162	680	367	400	216	400	216	900	486
11:00	50	390	200	108	680	367	400	216	400	216	880	476
12:00	50	390	200	108	680	367	400	216	400	216	900	486
13:00	50	390	300	162	600	324	400	216	400	216	880	476
14:00	50	390	200	108	600	324	400	216	300	162	800	432
15:00	50	390	300	162	700	378		0		0	0	0
16:00	50	390	200	108	600	324		0		0	0	0
17:00	50	390	300	162	600	324		0		0	0	0
18:00	50	390	200	108	600	324		0		0	0	0
19:00	50	390	200	108	700	378		0		0	0	0
20:00	50	390	300	162	600	324		0		0	0	0
21:00	50	390	200	108	600	324	400	216	400	216	700	378
22:00	50	390	200	108	600	324	400	216	400	216	700	378
23:00	50	390	300	162	700	378	400	216	400	216	800	432
0:00	50	390	200	108	700	378	400	216	400	216	900	486
1:00	50	390	200	108	700	378	400	216	400	216	900	486
2:00	50	390	300	162	600	324	400	216	400	216	800	432
3:00	50	390	300	162	700	378	400	216	400	216	800	432
4:00	50	390	400	216	700	378	400	216	400	216	800	432
5:00	50	390	400	216	700	378	400	216	400	216	800	432
Total				3,350		8,333		3,783		3,729		7,911

Tuesday
13-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
							B		A			
	Hz	Volt	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	200	108	600	324	200	108	200	108	800	432
7:00	50	390	300	162	600	324	400	216	400	216	900	486
8:00	50	390	300	162	600	324	400	216	400	216	900	486
9:00	50	390	300	162	600	324	400	216	400	216	1,000	540
10:00	50	390		0		0		0		0	0	0
11:00	50	390		0		0		0		0	0	0
12:00	50	390	300	162	600	324	400	216	400	216	1,000	540
13:00	50	390	300	162	700	378	300	162	400	216	900	486
14:00	50	390	300	162	600	324	400	216	300	162	900	486
15:00	50	390	300	162	700	378		0		0	0	0
16:00	50	390	200	108	600	324		0		0	0	0
17:00	50	390	200	108	600	324		0		0	0	0
18:00	50	390	300	162	700	378		0		0	0	0
19:00	50	390	300	162	600	324		0		0	0	0
20:00	50	390	200	108	600	324		0		0	0	0
21:00	50	390	300	162	700	378	400	216	400	216	900	486
22:00	50	390	400	216	600	324	400	216	400	216	800	432
23:00	50	390	400	216	700	378	400	216	200	108	800	432
0:00	50	390	400	216	700	378	400	216	400	216	800	432
1:00	50	390	300	162	700	378	400	216	500	270	800	432
2:00	50	390	300	162	600	324	300	162	500	270	800	432
3:00	50	390	300	162	700	378	400	216	400	216	800	432
4:00	50	390	200	108	600	324	400	216	400	216	800	432
5:00	50	390	300	162	600	324	400	216	400	216	800	432
Total				3,458		7,565		3,242		3,296		7,403

Wednesday
14-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	200	108	600	324	200	108	300	162	600	324
7:00	50	390	200	108	600	324	400	216	300	162	900	486
8:00	50	390	200	108	600	324	400	216	400	216	900	486
9:00	50	390	200	108	600	324	400	216	300	162	900	486
10:00	50	390	200	108	600	324	400	216	400	216	900	486
11:00	50	390	200	108	600	324	400	216	300	162	900	486
12:00	50	390	200	108	600	324	400	216	400	216	900	486
13:00	50	390	200	108	600	324	400	216	400	216	900	486
14:00	50	390	200	108	600	324	400	216	300	162	800	432
15:00	50	390	300	162	600	324		0		0	0	0
16:00	50	390	200	108	700	378		0		0	0	0
17:00	50	390	300	162	600	324		0		0	0	0
18:00	50	390	300	162	600	324		0		0	0	0
19:00	50	390	300	162	700	378		0		0	0	0
20:00	50	390	200	108	700	378		0		0	0	0
21:00	50	390	200	108	600	324		0		0	0	0
22:00	50	390	200	108	700	378	300	162	300	162	800	432
23:00	50	390	200	108	700	378	400	216	400	216	700	378
0:00	50	390	200	108	700	378	400	216	400	216	700	378
1:00	50	390	300	162	700	378	400	216	400	216	800	432
2:00	50	390	300	162	600	324	400	216	400	216	800	432
3:00	50	390	200	108	700	378	400	216	400	216	800	432
4:00	50	390	200	108	700	378	300	162	300	162	800	432
5:00	50	390	200	108	700	378	300	162	300	162	800	432
Total				2,918		8,322		3,404		3,242		7,511

Thursday
15-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	0	0	0	0	0	0	0	0	0	0
7:00	50	390	200	14	600	42	400	28	400	28	700	48
8:00	50	390	200	14	600	42	400	28	400	28	800	55
9:00	50	390	300	21	600	42	400	28	400	28	800	55
10:00	50	390	300	21	600	42	400	28	400	28	800	55
11:00	50	390	300	21	600	42	400	28	400	28	800	55
12:00	50	390	300	21	600	42	400	28	400	28	800	55
13:00	50	390	0	0	0	0	0	0	0	0	0	0
14:00	50	390	200	14	0	0	400	28	300	21	600	42
15:00	50	390	200	14	0	0	0	0	0	0	0	0
16:00	50	390	300	21	0	0	0	0	0	0	0	0
17:00	50	390	600	42	0	0	0	0	0	0	0	0
18:00	50	390	400	28	0	0	0	0	0	0	0	0
19:00	50	390	300	21	0	0	0	0	0	0	0	0
20:00	50	390	500	35	0	0	0	0	0	0	0	0
21:00	50	390	400	28	0	0	400	28	400	28	900	62
22:00	50	390	400	28	0	0	400	28	400	28	800	55
23:00	50	390	0	0	0	0	400	28	400	28	800	55
0:00	50	390	0	0	0	0	400	28	400	28	800	55
1:00	50	390	0	0	0	0	400	28	400	28	800	55
2:00	50	390	0	0	0	0	400	28	400	28	800	55
3:00	50	390	0	0	0	0	400	28	400	28	800	55
4:00	50	390	0	0	0	0	400	28	400	28	800	55
5:00	50	390	0	0	0	0	400	28	400	28	800	55
Total				339		249		443		436		873

Saturday
17-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
							B		A			
	Hz	Volt	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	400	216	0	0	400	216	400	216	800	432
7:00	50	390	500	270	0	0	400	216	300	162	800	432
8:00	50	390	600	324	0	0	350	189	300	162	800	432
9:00	50	390	600	324	0	0	400	216	400	216	800	432
10:00	50	390	600	324	0	0	400	216	4,000	2,162	800	432
11:00	50	390	600	324	0	0	400	216	400	216	800	432
12:00	50	390	600	324	0	0	400	216	400	216	800	432
13:00	50	390	0	0	0	0	0	0	0	0	0	0
14:00	50	390	600	324	0	0	400	216	300	162	800	432
15:00	50	390	600	324	0	0	400	216	400	216	800	432
16:00	50	390	600	324	0	0	0	0	0	0	0	0
17:00	50	390	500	270	0	0	0	0	0	0	0	0
18:00	50	390	600	324	0	0	0	0	0	0	0	0
19:00	50	390	500	270	0	0	0	0	0	0	0	0
20:00	50	390	0	0	0	0	0	0	0	0	0	0
21:00	50	390	0	0	0	0	0	0	0	0	0	0
22:00	50	390	400	216	0	0	0	0	0	0	0	0
23:00	50	390	600	324	0	0	0	0	0	0	0	0
0:00	50	390	600	324	0	0	0	0	0	0	0	0
1:00	50	390	600	324	0	0	0	0	0	0	0	0
2:00	50	390	600	324	0	0	0	0	0	0	0	0
3:00	50	390	0	0	0	0	0	0	0	0	0	0
4:00	50	390	0	0	0	0	0	0	0	0	0	0
5:00	50	390	0	0	0	0	0	0	0	0	0	0
Total				5,458		0		1,918		3,729		3,891

Moday
19-Feb-2018

Time	**Frq**	**Voltage**	**OVEN DRYER**		**APRON DRYER**		**HAMMERMILL**				**MANGAL**	
							B		**A**			
	Hz	**Volt**	**Amp**	**kWh**	**Amp**	**kWh**	**Amp**	**kWh**	**Amp**	**kWh**	**Amp**	**kWh**
6:00	50	390	500	270	0	0	400	216	300	162	700	378
7:00	50	390	600	324	0	0	400	216	400	216	900	486
8:00	50	390	600	324	0	0	400	216	400	216	700	378
9:00	50	390	500	270	0	0	400	216	300	162	900	486
10:00	50	390	600	324	0	0	400	216	400	216	900	486
11:00	50	390	600	324	0	0	400	216	400	216	700	378
12:00	50	390	500	270	0	0	400	216	300	162	700	378
13:00	50	390	600	324	0	0	400	216	400	216	900	486
14:00	50	390	400	216	0	0	400	216	400	216	900	486
15:00	50	390	500	270	0	0		0		0	0	0
16:00	50	390	500	270	0	0		0		0	0	0
17:00	50	390	500	270	0	0		0		0	0	0
18:00	50	390	500	270	0	0		0		0	0	0
19:00	50	390	500	270	0	0		0		0	0	0
20:00	50	390	500	270	0	0		0		0	0	0
21:00	50	390	500	270	0	0	400	216	400	216	800	432
22:00	50	390	500	270	0	0	400	216	400	216	700	378
23:00	50	390	500	270	0	0	400	216	400	216	700	378
0:00	50	390	500	270	0	0	400	216	400	216	800	432
1:00	50	390	500	270	0	0	400	216	400	216	800	432
2:00	50	390	500	270	0	0	400	216	400	216	800	432
3:00	50	390	500	270	0	0	400	216	400	216	800	432
4:00	50	390	500	270	0	0	400	216	400	216	800	432
5:00	50	390	500	270	0	0	400	216	400	216	800	432
Total				6,701		0		3,891		3,729		7,727

Tuesday
20-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	600	324	0	0	400	216	400	216	900	486
7:00	50	390	600	324	0	0	400	216	300	162	800	432
8:00	50	390	500	270	0	0	400	216	400	216	900	486
9:00	50	390	600	324	0	0	400	216	300	162	700	378
10:00	50	390	600	324	0	0	400	216	300	162	700	378
11:00	50	390	500	270	0	0	400	216	400	216	900	486
12:00	50	390	600	324	0	0	400	216	400	216	900	486
13:00	50	390	500	270	0	0	400	216	400	216	800	432
14:00	50	390	400	216	0	0	400	216	400	216	800	432
15:00	50	390	600	324	0	0	0	0	0	0	0	0
16:00	50	390	400	216	0	0	0	0	0	0	0	0
17:00	50	390	500	270	0	0	0	0	0	0	0	0
18:00	50	390	600	324	0	0	0	0	0	0	0	0
19:00	50	390	400	216	0	0	0	0	0	0	0	0
20:00	50	390	400	216	0	0	0	0	0	0	0	0
21:00	50	390	400	216	0	0	200	108	400	216	800	432
22:00	50	390	200	108	0	0	400	216	400	216	800	432
23:00	50	390	200	108	0	0	400	216	400	216	800	432
0:00	50	390	200	108	0	0	300	162	400	216	800	432
1:00	50	390	200	108	0	0	300	162	400	216	800	432
2:00	50	390	200	108	0	0	300	162	400	216	800	432
3:00	50	390	200	108	0	0	300	162	400	216	800	432
4:00	50	390	200	108	0	0	300	162	400	216	800	432
5:00	50	390	200	108	0	0	300	162	400	216	800	432
Total				5,296		0		3,458		3,729		7,890

Wednesday
21-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	200	108	500	270	400	216	300	162	800	432
7:00	50	390	200	108	600	324	400	216	400	216	900	486
8:00	50	390	300	162	600	324	400	216	400	216	900	486
9:00	50	390	200	108	700	378	400	216	300	162	900	486
10:00	50	390	300	162	700	378	400	216	500	270	800	432
11:00	50	390	200	108	600	324	400	216	300	162	700	378
12:00	50	390	300	162	600	324	400	216	400	216	800	432
13:00	50	390	200	108	600	324	400	216	500	270	900	486
14:00	50	390	400	216	700	378	400	216	400	216	800	432
15:00	50	390	400	216	700	378	400	216	400	216	800	432
16:00	50	390	400	216	700	378	0	0	0	0	0	0
17:00	50	390	400	216	700	378	0	0	0	0	0	0
18:00	50	390	300	162	700	378	0	0	0	0	0	0
19:00	50	390	400	216	700	378	0	0	0	0	0	0
20:00	50	390	300	162	600	324	0	0	0	0	0	0
21:00	50	390	400	216	600	324	400	216	400	216	800	432
22:00	50	390	200	108	600	324	300	162	400	216	800	432
23:00	50	390	200	108	700	378	300	162	400	216	800	432
0:00	50	390	200	108	700	378	300	162	400	216	800	432
1:00	50	390	200	108	700	378	300	162	400	216	800	432
2:00	50	390	200	108	700	378	300	162	400	216	800	432
3:00	50	390	200	108	700	378	300	162	400	216	800	432
4:00	50	390	200	108	600	324	300	162	400	216	800	432
5:00	50	390	200	108	600	324	300	162	400	216	800	432
Total				3,512		8,430		3,675		4,053		8,376

Thursday
22-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	200	108	600	324	400	216	300	162	700	378
7:00	50	390	200	108	700	378	400	216	400	216	900	486
8:00	50	390	300	162	700	378	400	216	400	216	900	486
9:00	50	390	200	108	600	324	400	216	300	162	800	432
10:00	50	390	300	162	650	351	400	216	400	216	900	486
11:00	50	390	200	108	700	378	400	216	350	189	700	378
12:00	50	390	300	162	600	324	400	216	400	216	900	486
13:00	50	390	300	162	600	324	400	216	400	216	700	378
14:00	50	390	300	162	700	378	400	216	400	216	800	432
15:00	50	390	300	162	700	378	0	0	0	0	0	0
16:00	50	390	300	162	700	378	0	0	0	0	0	0
17:00	50	390	300	162	700	378	0	0	0	0	0	0
18:00	50	390	300	162	700	378	0	0	0	0	0	0
19:00	50	390	300	162	600	324	0	0	0	0	0	0
20:00	50	390	300	162	700	378	0	0	0	0	0	0
21:00	50	390	400	216	600	324	200	108	200	108	600	324
22:00	50	390	300	162	600	324	400	216	300	162	800	432
23:00	50	390	280	151	700	378	400	216	300	162	800	432
0:00	50	390	200	108	700	378	300	162	300	162	800	432
1:00	50	390	200	108	700	378	400	216	300	162	800	432
2:00	50	390	200	108	700	378	400	216	300	162	800	432
3:00	50	390	200	108	700	378	400	216	300	162	800	432
4:00	50	390	200	108	700	378	300	162	300	162	800	432
5:00	50	390	200	108	700	378	300	162	300	162	800	432
Total				3,394		8,673		3,621		3,215		7,727

Friday
23-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	300	162	600	324	400	216	300	162	700	378
7:00	50	390	200	108	600	324	400	216	400	216	900	486
8:00	50	390	200	108	700	378	400	216	300	162	900	486
9:00	50	390	300	162	700	378	400	216	400	216	800	432
10:00	50	390	300	162	600	324	400	216	300	162	800	432
11:00	50	390	0	0	0	0	0	0	0	0	0	0
12:00	50	390	0	0	0	0	0	0	0	0	0	0
13:00	50	390	200	108	600	324	400	216	400	216	900	486
14:00	50	390	200	108	700	378	300	162	300	162	900	486
15:00	50	390	0	0	0	0	0	0	0	0	0	0
16:00	50	390	400	216	700	378	400	216	400	216	700	378
17:00	50	390	400	216	700	378	0	0	0	0	0	0
18:00	50	390	300	162	700	378	0	0	0	0	0	0
19:00	50	390	300	162	700	378	0	0	0	0	0	0
20:00	50	390	300	162	700	378	0	0	0	0	0	0
21:00	50	390	400	216	700	378	400	216	400	216	800	432
22:00	50	390	200	108	600	324	300	162	400	216	800	432
23:00	50	390	200	108	700	378	300	162	400	216	800	432
0:00	50	390	200	108	700	378	300	162	400	216	900	486
1:00	50	390	200	108	700	378	400	216	400	216	900	486
2:00	50	390	200	108	700	378	400	216	400	216	900	486
3:00	50	390	200	108	700	378	400	216	400	216	900	486
4:00	50	390	200	108	700	378	400	216	400	216	900	486
5:00	50	390	200	108	600	324	400	216	400	216	900	486
Total				2,918		7,619		3,458		3,458		7,782

Saturday
24-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
							B		A			
	Hz	Volt	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	300	162	600	324	400	216	300	162	700	378
7:00	50	390	200	108	600	324	400	216	400	216	900	486
8:00	50	390	200	108	500	270	400	216	300	162	800	432
9:00	50	390	300	162	600	324	400	216	400	216	900	486
10:00	50	390	200	108	600	324	400	216	300	162	900	486
11:00	50	390	300	162	700	378		0		0	0	0
12:00	50	390	200	108	600	324	400	216	300	162	800	432
13:00	50	390	200	108	400	216	400	216	300	162	800	432
14:00	50	390	400	216	700	378	300	162	300	162	800	432
15:00	50	390	400	216	700	378	300	162	400	216	800	432
16:00	50	390	300	162	700	378		0		0	0	0
17:00	50	390	400	216	700	378		0		0	0	0
18:00	50	390	300	162	600	324		0		0	0	0
19:00	50	390	300	162	700	378		0		0	0	0
20:00	50	390		0		0		0		0	0	0
21:00	50	390		0	0	0		0		0	0	0
22:00	50	390	200	108	700	378		0		0	0	0
23:00	50	390	200	108	700	378		0		0	0	0
0:00	50	390	200	108	700	378		0		0	0	0
1:00	50	390		0		0		0		0	0	0
2:00	50	390	200	108	600	324		0		0	0	0
3:00	50	390		0		0		0		0	0	0
4:00	50	390		0		0		0		0	0	0
5:00	50	390		0		0		0		0	0	0
Total				2,594		6,160		1,837		1,621		3,999

Tuesday
27-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390		0	200	108	400	216	400	216	1,000	540
7:00	50	390		0	200	108	400	216	400	216	900	486
8:00	50	390	300	162	600	324	400	216	400	216	700	378
9:00	50	390	300	162	600	324	400	216	400	216	800	432
10:00	50	390	300	162	600	324	400	216	400	216	800	432
11:00	50	390	400	216	700	378	400	216	300	162	700	378
12:00	50	390	300	162	700	378	400	216	400	216	700	378
13:00	50	390	300	162	700	378	400	216	400	216	900	486
14:00	50	390	200	108	700	378	400	216	400	216	900	486
15:00	50	390	200	108	700	378	400	216	400	216	900	486
16:00	50	390	200	108	700	378		0		0	0	0
17:00	50	390	200	108	700	378		0		0	0	0
18:00	50	390	200	108	700	378		0		0	0	0
19:00	50	390	200	108	700	378		0		0	0	0
20:00	50	390	200	108	700	378		0		0	0	0
21:00	50	390	200	108	600	324	400	216	400	216	900	486
22:00	50	390	200	108	400	216	400	216	300	162	800	432
23:00	50	390	200	108	400	216	400	216	400	216	1,000	540
0:00	50	390	300	162	600	324	400	216	300	162	800	432
1:00	50	390	200	108	700	378	400	216	400	216	1,000	540
2:00	50	390	200	108	600	324	400	216	400	216	5,500	2,972
3:00	50	390	200	108	600	324	400	216	300	162	800	432
4:00	50	390	300	162	700	378		0		0	0	0
5:00	50	390	200	108	600	324		0		0	0	0
Total				2,864		7,782		3,675		3,458		10,321

Wednesday
28-Feb-2018

Time	Frq	Voltage	OVEN DRYER		APRON DRYER		HAMMERMILL				MANGAL	
	Hz	Volt					B		A			
			Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh	Amp	kWh
6:00	50	390	200	108	600	324	400	216	400	216	800	432
7:00	50	390	300	162	700	378	400	216	400	216	800	432
8:00	50	390	300	162	700	378	400	216	400	216	800	432
9:00	50	390	300	162	700	378	400	216	400	216	800	432
10:00	50	390	300	162	700	378	400	216	400	216	800	432
11:00	50	390	300	162	700	378	400	216	400	216	800	432
12:00	50	390	300	162	600	324	400	216	400	216	900	486
13:00	50	390	400	216	600	324	400	216	400	216	900	486
14:00	50	390	400	216	600	324	400	216	400	216	900	486
15:00	50	390	300	162	600	324		0		0	0	0
16:00	50	390	300	162	600	324		0		0	0	0
17:00	50	390	300	162	600	324		0		0	0	0
18:00	50	390	300	162	600	324		0		0	0	0
19:00	50	390	300	162	600	324		0		0	0	0
20:00	50	390	300	162	600	324		0		0	0	0
21:00	50	390	300	162	600	324	400	216	400	216	800	432
22:00	50	390	200	108	600	324	400	216	400	216	800	432
23:00	50	390	200	108	600	324	400	216	400	216	800	432
0:00	50	390	200	108	600	324	400	216	400	216	800	432
1:00	50	390	300	162	600	324	400	216	400	216	800	432
2:00	50	390	200	108	600	324	400	216	400	216	800	432
3:00	50	390	200	108	600	324	400	216	400	216	800	432
4:00	50	390	200	108	600	324	400	216	400	216	800	432
5:00	50	390	200	108	600	324	400	216	400	216	800	432
Total				3,567		8,052		3,891		3,891		7,944