UNIVERSITY OF SOUTHERN QUEENSLAND

ASSESSMENT OF ENERGY USAGE FOR COTTON GINS IN AUSTRALIA

A dissertation submitted by

Siti Amni Ismail, B Eng (Bio & Agric)

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ABSTRACT

Ginning is an energy intensive process. This project evaluates the energy usage inside the cotton gins in Australia. Benchmark electricity use is found to range between 44-66 kWh per bale, with national average being 52.3 kWh. The electricity consumption for different gins is nearly linearly correlated with bale numbers produced. The electricity network charge is a significant cost in cotton ginning operations. Maximum demand occupies 48-67% of total kW required to run all the energy-consuming equipment. All gins monitored had an overall power factor of higher than 0.85.

Drying temperature generally increases as module moisture increases. It is also found that the regulated drying temperature for the cotton dryer has a strong relationship with the incoming module moisture. Gas usage is strongly influenced by the amount of moisture removed from the incoming cotton as well as the regulated drying temperature. The drying process uses some 0.74 – 3.90 m^3 of natural gas or 2.27 – 5.61 litres of liquefied petroleum gas (LPG) per bale. Overall thermal efficiency of the drying process is lower than 15%. The cost of gas in producing one bale ranges between $0.98–3.39/bale. Overall, the gas and electricity usage comprises approximately 39% and 61% respectively of the total energy usage (GJ/bale) in the cotton ginning process. On average, the total “national benchmark” energy cost (both electricity and gas) is $ 10.70/ bale. 60.38 kg of CO_2 are emitted due to the energy use for processing each bale of cotton.

A method for the detailed monitoring of energy performance in cotton ginning is developed and described. Detailed monitoring and analysis were carried out at two gin sites. It is found that changes in trash content in the module, degree of moisture and lint quality produced do not have significant influence on electricity usage. However, the cotton variety is shown to affect the energy usage. The energy used within each ginning sub-process is quite different between the two gins monitored.

Overall, cotton handling is found to have the largest energy requirement and accounts for almost 50% of the total power usage in both gins. When combined, packaging and handling account for approximately 70% of the total power required. A significant proportion of motors inside the gins are found to operate at less than 40% loading. The low power factors of individual motors have been successfully corrected by the capacitor banks so that the overall power factor of the whole gin is satisfactory.

CERTIFICATION OF DISSERTATION

This is to certify that this dissertation is entirely my own effort, to the best of my knowledge and belief, it contains no material previously published or written by another person, except where acknowledgment and reference is made. I also certify that this work is original and has not been submitted for any other award, except where otherwise acknowledged.

CANDIDATE

Siti Amni Ismail	Date

ENDORSEMENT

SUPERVISOR

Dr Guangnan Chen	Date

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GLOSSARY

This glossary clarifies the use of specific terms within the thesis

Cotton

Bale

Unit of ginned cotton weighing 227 kilograms of lint

Ginning

The separation of picked cotton into seed and lint

Lint

Cotton fibre

Linters

Shorter, furry fibres separated from the seed after ginning.

Module

A large, tightly packed ‘brick’ of seed cotton that is transported from the farm to the gin

Motes

Low-grade cotton fiber, mainly because of their short fibers and off-color appearance

Seed cotton

A term used to describe cotton before it has been ginned (e.g. it contains the seed and lint which is attached to the seed)

Trash

Any unwanted material such as dirt, seed coat, bark, leaves and twigs that might become caught up in the cotton.

Energy and Energy management

Capacity Charge

A unit rate of charge per kVa (or kWh) of demand made available to a customer. This is also known as the availability charge. This charge is often associated with providing the local distribution network to the consumer.

Demand charge

That portion of the consumer's bill for electric service based on the consumer's maximum electric capacity usage and calculated based on the billing demand charges under the applicable rate schedule. It is typically recorded every 15 minutes. This charge reflects the seasonal incidence of the customer.

Energy

The capability of doing work; different forms of energy can be converted into other forms but the total amount of energy remains the same.

Energy Audit

A survey that shows how much energy is used in a facility and that helps identify ways to use less energy.

Greenhouse Gases

Greenhouse gases contribute to global warming by absorbing solar radiation. The main ones are carbon dioxide, methane, nitrous oxide and water vapor.

Load factor

The average percentage of capacity of a utility that is used over a given period of time such as a month or year. Deregulated electricity sellers prefer clients with high load factors (e.g., stable and predictable loads) and sometimes offer them preferred rates.

Power Factor (PF)

The ratio of power actually being used in an electric circuit, expressed in kW, to the power that is apparently being drawn from the power source, expressed in kilovolt-amperes (kVA).

Tariff

A schedule of prices or fees. Typically approved by regulators, tariffs specify cost structures and terms of service for utility customers.

Time-Of-Use (TOU) rate

Pricing of electricity based on several time blocks per 24-hour period (e.g., on-peak, mid-peak, off-peak, etc.) and on seasons of the year (e.g., summer and winter).

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CHAPTER 1

Introduction

1.1 Project background

All primary industries use energy and other resources throughout their production chains. Energy efficiency of farming operations and agricultural processing is now becoming increasingly important in the context of both rising energy costs and concern over greenhouse gas (GHG) emissions. Within highly mechanised production systems, such as those used within the Australian cotton industry, energy inputs present a major cost to growers and processors. Rational and efficient use of energy consumption is essential for sustainable development in agriculture.

Ginning is an important operation within the overall cotton production system. It was reported that ginning represents approximately 38% of cotton processing cost in the US (Cleveland and Mayfield, 1994). In addition to the significant energy costs involved, ginning can also have a major impact on the value and the quality (e.g., spinning characteristics) of cotton fibres. It is therefore critical that the gin is operated and managed efficiently.

1.2 Cotton ginning

Cotton ginning is a process where cotton seed and foreign matter (trash) are removed from the lint. Generally, the process involves drying the cotton, removal of leaf trash and dirt, and separating the lint from the seed. The four major ginning processes are:

- Drying - cotton is dried to remove excess moisture
- Cleaning - leaves, sticks, twigs and dirt are removed
- Gin stand - seed is removed
- Baling machine - clean cotton fibre is pressed into bales

Before ginning, cotton typically contains approximately 35% of lint, 55% of seed, and 10% of trash. At the end of ginning, cotton lint is compressed into a standard 227 kg (500lb) bale which is sent out to the spinning factories. Ginning is normally carried out in cotton gins, which are usually located in cotton-growing regions, in order to reduce the transport costs.

Ginning is also an energy intensive process. The movement of the cotton from each process is handled by pneumatic systems powered by push (blown air) and pulling (suction) fans. Inside modern ginning plants, electrical power is required to run all the motors in the ginning processes, except for drying where the gas is used.

1.3 Ginning energy costs

Ginning is a seasonal process where it is only operated 3-4 months a year. Like any other business, the cost of ginning can be divided into the fixed costs and numerous variable costs. The fixed costs exist regardless of the quantity of bales produced or even if the gin is operated at all or outside of the normal ginning season. These costs include the (amortised) cost of the equipment, annual and monthly fixed costs such as property insurance, property taxes, the cost of gin maintenance, and network charges applied by the electricity company etc.

Unlike the fixed costs, the variable costs are dependent upon the number of bales of cotton ginned. Typical primary variable cost items are: seasonal and temporary labour, electrical energy (associated with the ginning process), fuel energy (e.g., LPG for drying etc.), bagging and ties, and repair (e.g., breakdown maintenance) etc. (Cleveland and Mayfield, 1994).

In Australia, ginners usually have pay in the range of $68,000 – $400,000 per year just to cover the energy costs alone.

1.4 Project aims

Currently, there is little research or data available for the optimisation of ginning operations, particularly from the perspective of energy usage. This lack of available information warrants the study to firstly evaluate the energy usage inside the cotton gin, and secondly to identify any opportunities of energy saving that may exist. The aim of this project is therefore to determine the energy usage patterns in Australian cotton ginning and specifically to determine where energy is utilised inside the cotton gin. This project also aims to show how the electricity and gas usage is affected by the condition of incoming cotton, including the ginner's decision in regulating the dryer temperature, and other operational decisions such as determining the sequences of machine operations (e.g., removing and re-introducing machines into the ginning process). This thesis will therefore provide a basis for informed decision-making in order to increase the energy usage efficiency in cotton gins.

The specific objectives of this research are:

1. Review the operation of the cotton ginning process,
2. Identify data availability,
3. Identify suitable methods for energy monitoring,
4. Quantify the total energy use and GHG emissions associated with cotton ginning,
5. Investigate factors contributing to the energy usage requirements of cotton ginning,
6. Link the energy input and production costs to the operation and product quality; and
7. Identify and report the areas of activity with the greatest potential for energy (and monetary) saving.

1.5 Project methodology

This research will be conducted based on real practices in Australia. The energy data collection will be divided into two levels, namely:

1. Basic level, and
2. Advanced level.

The purpose of the basic level is to survey cotton ginners and to evaluate energy usage for the whole gin plant based on historical data. For the advanced level, the main objective is to calculate the energy use breakdown for each of the ginning sub-processes including handling, cleaning, gin stand (seed removal from the lint) and packaging, and to investigate the electricity usage patterns based upon the varying condition of incoming cotton (e.g., moisture, trash and cotton variety), and production volume. Energy monitoring of individual motors inside the gin will also be carried out as part of the advanced level investigations.

In order to evaluate the ginning energy usage requirements and look for the any opportunities for energy savings, the concept of the "energy audit" (Joint Technical Committee, 2000) is adopted in this research. Accordingly, the basic level is essentially corresponding to the energy audit Level 1 while the advanced level covers an energy audit at Level 2 and 3 (Figure 1.1).

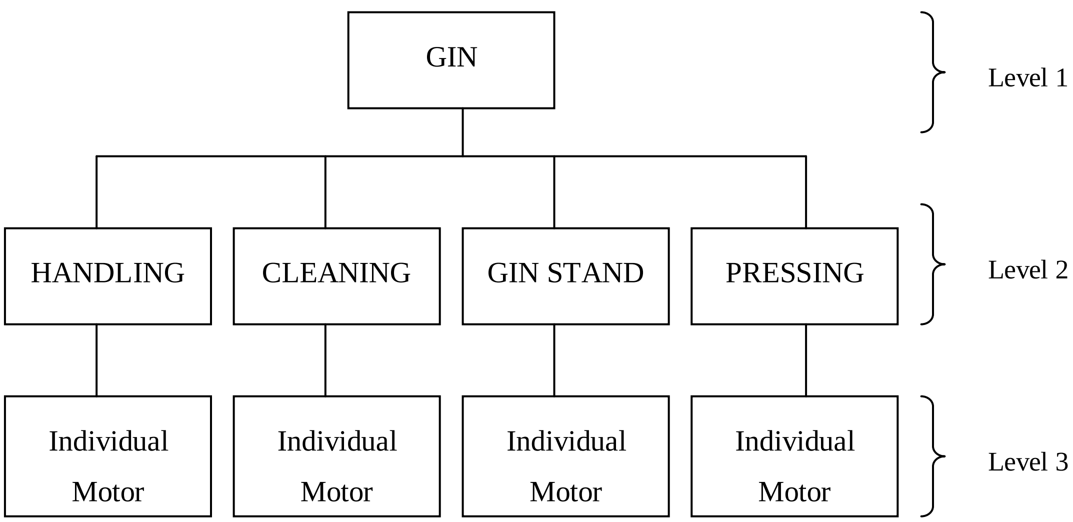


Figure 1.1: Energy audit level

The study will first involve the surveys with cotton ginners. This is then followed by collecting the historical records, and in-situ site monitoring.

Surveys with cotton ginners

This project has been conducted with the support of the Cotton Research and Development Corporation (CRDC), and the Australian Cotton Ginners Association (ACGA). An email was first sent to all members of the Australian Cotton Ginners Association to invite them to contribute to this project. Research started by inspecting the selected cotton gins to identify and compare any differing ginning practices between the different ginning plants, and to identify historical data availability and discuss the possibility of access to the historical energy and production data. While the inspection was conducted, a questionnaire (Appendix 1.1) was designed to gather the necessary information about the specific ginning operation. The possible methods and requirement for installing monitoring equipment in the gin plants was also evaluated.

Energy data collection - Basic level

The basic level of energy data collection is aimed to establish an energy usage benchmark for a typical gin within the Australian cotton ginning industry. This will be achieved by collecting the historical data of the last 24 months of energy consumption (electricity and gas) bills, the monthly production volume (number of bales produced) and (if available) the records of incoming moisture content and trash levels. This data will then be analysed to establish a nation-wide energy performance benchmark where the individual company can compare their performance with the benchmark to gauge their own performance. Besides evaluating the specific energy usage for the ginning processes, an energy profile for the whole gin will be produced. All cotton gins in Australia were invited to participate, but only 8 gins have taken up the opportunity. Six gins were able to provide all the needed historical data.

Energy data collection - Advanced level

The aim for this level of data collection is to calculate the energy usage breakdown between the different ginning sub-processes (drying, cleaning, gin stand and baling) and to determine where the energy is consumed inside the cotton gins. For this level, detailed monitoring of the cotton ginning operation has been undertaken at two ginning sites. The monitoring involved the measurement of power and energy consumption for each individual motor. The process began by analysing the plant layout and motor ratings. The motors that operated under one line of the ginning process were then selected and monitored.

After selecting the motors, an inspection of the two ginning plants were undertaken to identify the location of each motor's connection and to identify an issues with the connection of the monitoring equipment; a monitoring schedule was prepared from this information. At the time of monitoring, the energy usage of each meter inside the gin was also recorded by the electricity company. Each of these meters measures the energy usage for a group of motors inside the gin in each sub board. A form (to be completed by the ginner) to collect relevant information about the incoming cotton (e.g. moisture content, variety, lint quality and trash level) was developed.

The collected energy usage data will then be correlated with the conditions of incoming cotton, lint quality and quantity of bales produced to find the most affected process by the incoming cotton and to determine where energy is spent inside the cotton gin. The energy usage for each sub-process in producing one bale also will be calculated. Also, the average power usage for each motor will be analysed and compared with their specification.

After evaluating all the energy usage inside the gin, opportunities for the improvement of energy efficiency will then be identified so that gin managers can use this information to assist their decision-making of bypassing certain operations or upgrading/downgrading certain motors or installing such equipment as variable speed drivers etc.

1.6 Structure of the dissertation

This dissertation consists of eight chapters. A brief outline for each chapter is given below:

Chapter 1

This chapter provides the background of the research, the statement of the problem for this research, the research aims and project methodology.

Chapter 2

This chapter provides an overview of the cotton and ginning industry in Australia and also includes a discussion of the various energy sources and energy supply issues for cotton ginning.

Chapter 3

This chapter reviews the available literature on ginning processes and energy management practices for cotton ginning. The major ginning processes and its effect on cotton ginning quality and energy consumption are also discussed.

Chapter 4

This chapter discusses electricity consumption and the electricity profile at the whole plant level. The process of developing an energy usage benchmark for cotton ginning is outlined and the relationship between electricity consumption and ginning production (bales) is also discussed.

Chapter 5

This chapter discusses gas consumption in the ginning process and discusses the ginners' practice of regulating the dryer temperature based on the incoming cotton moisture. The relationship between gas usage versus drying temperature, the reduction in cotton moisture and bale production is also discussed.

Chapter 6

This chapter discusses the procedures for the detailed monitoring undertaken. This will describe the methods of data collection; including the objectives of monitoring, the parameters measured and the equipment used.

Chapter 7

This chapter discusses the results of detailed monitoring. The relationship between electricity consumption (kWh) and production (bales) and condition of incoming modules will be evaluated. The energy costs will also be broken down into the four major processes of handling, cleaning, gin stand and bale pressing. Opportunities for the improvement of energy efficiency will also be identified.

Chapter 8

The major conclusion from this research will be discussed in this chapter.

CHAPTER 2

Overview of the Cotton and Ginning Industry in Australia

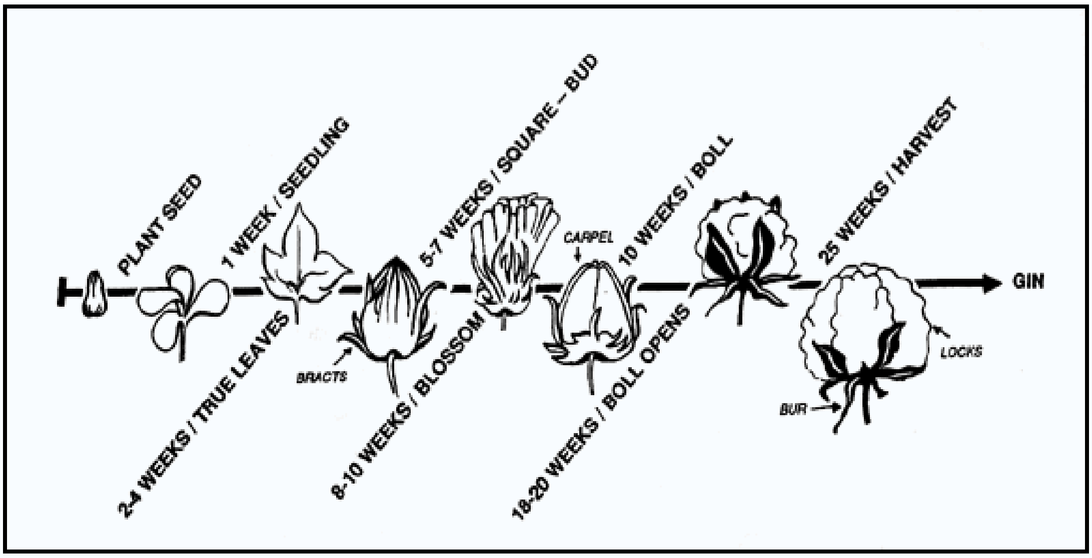
This chapter provides an overview of the cotton and ginning industry in Australia and also includes a discussion of the energy supply for cotton ginning.

2.1 Cotton and cotton growing cycle

Cotton is a soft, staple fibre that grows in a form known as a boll, around the seeds of the cotton plant; a shrub native to tropical and subtropical regions around the world. The fibre is spun into yarn or thread and used to make a soft, breathable textile, which is the most widely used natural fibre cloth in clothing today. In addition to the main purpose of providing fibre for the textile industry, cotton can also be used for many other purposes. For example, cotton seed is also crushed to make oil for cooking, while cotton seed meal is used for stock feed and composted for growing other plants. The lint may be used for making paper. On the farm, the stalks are often ploughed back into the earth for mulch to increase the soil nutrients. These by-products all add value to the cotton crop.

Cotton prefers long hours of sunshine. The higher the average temperature and amount of direct sunlight, the faster cotton will grow and develop. Thus, the longer and hotter the growing season, the higher the potential yield. Depending on the area under production, cotton can be grown either as a dry land (reliant on rainfall) crop or as irrigated cotton requiring a supplemental water supply. Dry land cotton is feasible only in selected areas, relying on stored subsoil moisture and moderate summer rainfall, while irrigated cotton is better suited to low rainfall areas.

Cotton growth takes about approximately 6 months from the day of planting until harvest (Figure 2.1). In Australia, soil preparation is started in August/September. It will be followed by cotton planting in spring during October and November. The main cotton growing season is between November and February. Within this period, the quality characteristics of the growing cotton are largely determined. Because of the local weather conditions, the level of nutrients and soil moisture can affect the cotton quality; the farmer therefore needs to check the soil condition regularly so that it will meet the optimum condition for cotton to produce good quality lint.



Source: (Cotton's journey)

Figure 2.1: Cotton growing cycle

Defoliation, cotton picking and transportation to the gin typically take place between March to May. Defoliation is the application of chemicals to cause the leaves of a plant to fall off, remove the leaves from the cotton plant before harvesting. When it is time for cotton picking, only the open bolls remain on the plant and the cotton can be picked cleanly without the leaves staining the lint.

Cotton can be harvested in two ways either using mechanised cotton pickers or cotton strippers. Cotton picker only picks the cotton from opened boll and leaves all unopened bolls. Cotton stripper strips fruit (opened and unopened bolls), branches, bark and any remaining leaves. The stripper harvest therein contains larger amounts of plant trash and contaminants that spindle harvested cotton.

In the field, harvested cotton is compacted in the form of a module by a compacting module builder that will compress about 13-14 tonnes of seed cotton. A module is usually 11-12m long, 2.5m wide and 2.5m high. Each module will then be transported to the gin for separating of lint from the cottonseed and trash. Each module can produce between 22-25 bales of lint. The lint is tightly pressed into bales at the end of the ginning process with each bale weighing 227 kg (500 lb) and is ready to be sent to spinning mills for further processing.

2.2 Australian cotton history

During the 1950s, cotton production in Australia was practically non-existent, even though the crop had been grown here since the time of the First Fleet. The modern cotton industry began in 1961 when two Californian growers planted a commercial crop at Wee Waa on the Namoi River, NSW, sparking the "first wave" of large scale cotton production in Australia. Prior to the 1980s, Australian cotton producers were completely dependent on American varieties (Cotton Australia, 2008).

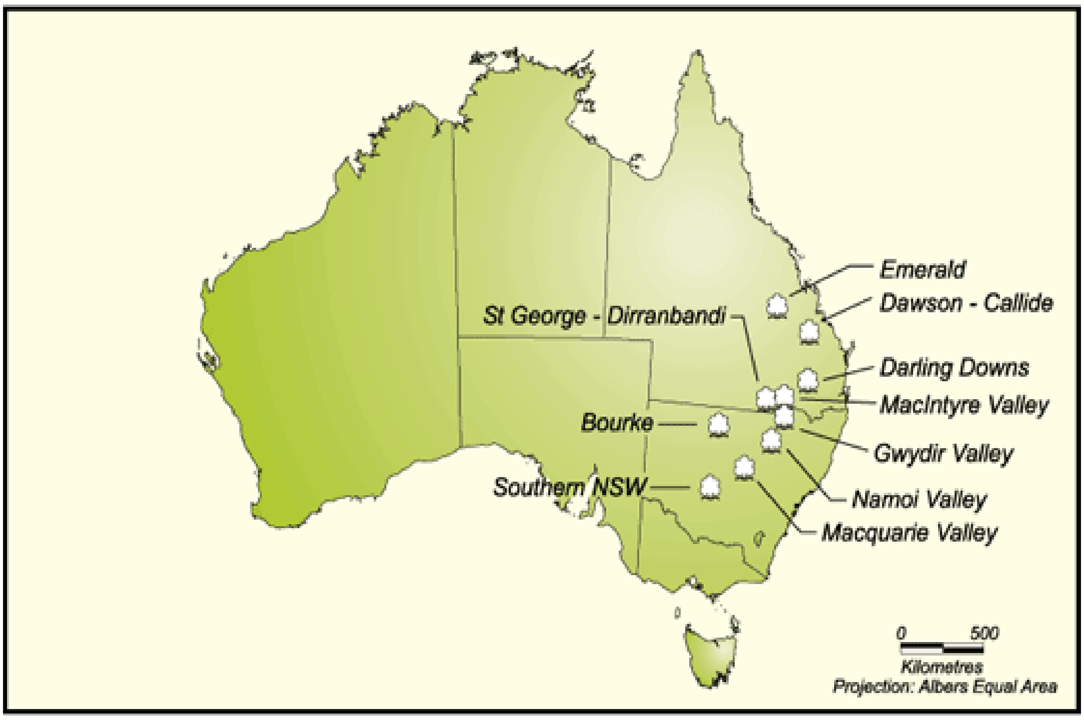
In 1990, the Australian Cotton Industry self-funded its First Environmental Audit that led to the introduction of Best Management Practices (BMPs) in Australia. The first Transgenic Insect Resistance Cotton (Ingard®) was introduced in 1996 after six years of field trials (Cotton Australia, 2008). By the 1990s, Australian varieties dominated the market and were delivering improved yields, higher fibre quality and better agronomic characteristics.

Between 2000 - 2007, the second edition of the BMP manual was released and Cotton Industries undertook a Second Environmental Audit. Besides that, cotton traits namely Bollgard II®, Roundup Ready®, Roundup Ready Flex® and Liberty Link® were introduced to Australian cotton varieties (germplasm), which are then termed transgenic varieties. By 2007, over 95% of Australian cotton growers planted transgenic varieties, accounting for over 80% of the total crop (Cotton Australia, 2008).

2.3 Australian cotton industry

2.3.1 Area of cotton grown

Figure 2.2 shows the location of the main cotton planting areas in Australia. Approximately 70 per cent of the total Australian cotton plantings are within New South Wales, with the remaining approximate 30% being grown in Queensland.



Source: (ANRA, 2009)

Figure 2.2: Location of cotton planting area in Australia

In New South Wales, cotton growing stretches down from the MacIntyre Valley to the Macquarie Valley. In Queensland, cotton is generally restricted to inland southern/central areas such as St. George, Darling Downs, Dawson and Emerald. The total growing area for Australia for the 2006/07 season was 157,000 hectares. Of this, 115,000 hectares were grown in NSW and 42,000 hectares grown in Queensland. The amount of cotton planted every year varies depending on the weather, world cotton prices and the availability of water. Most Australian cotton farms are typically around 500 to 2000 hectares and managed by family farmers. There is about 800 growers spreading across the Australian states of Queensland

(~30%) and New South Wales (~70%). Australian farms are highly mechanised, capital intensive and technologically sophisticated (CRDC, 2009).

2.3.2 Yields

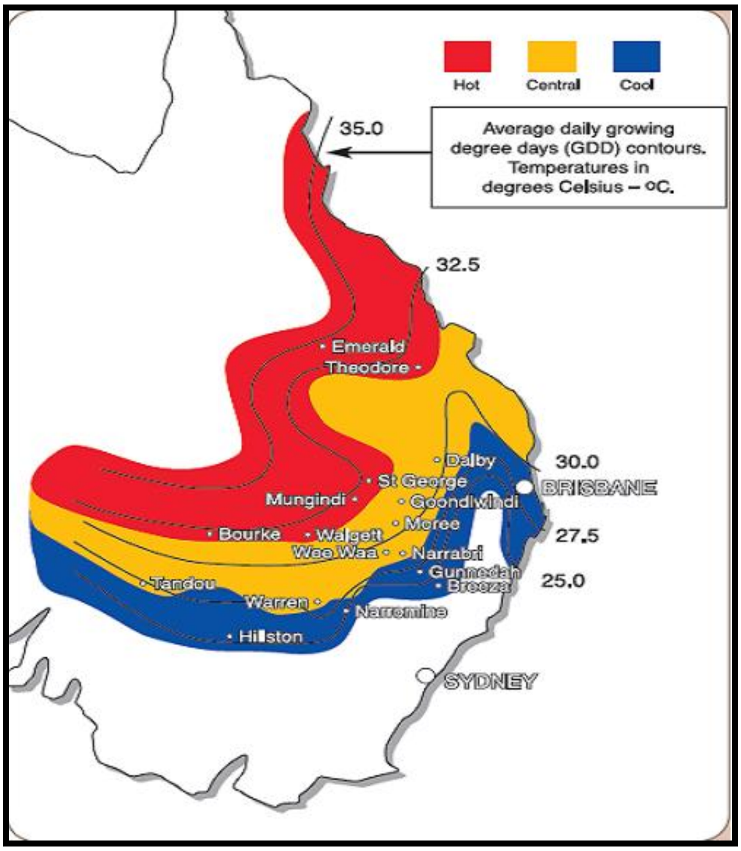
In 2005/2006, 84% of the Australian cotton crop was grown under irrigation (Cotton Australia, 2006). One hectare of irrigated cotton, on average, can produce 8 bales of cotton whereas dry land produces approximately 2.6 bales. In terms of production, irrigated cotton has contributed about 93% of cotton produced in Australia while an approximate 7% is produced by dry land production.

In 2006/07, Australia yielded an average 1,792 kg/ha (7.89 cotton bales per hectare). This figure was almost two and a half times the world average of 747 kg/ha (Cotton Australia, 2008). Furthermore, Australia has a reputation on the world market as a reliable supplier of high quality cotton. In a typical non-drought year, Australia's cotton industry is worth approximately $1 billion and produces around 3 million bales (Turco, 2003). This makes the cotton is one of Australia's largest rural export earners and helps underpin the viability of many rural communities (Cotton Australia, 2008).

2.3.3 Cotton variety

Most cotton fibre quality characteristics are determined by its variety. In Australia, over 95% of cotton growers plant transgenic varieties (Cotton Australia, 2008). Transgenic cotton that has been genetically modified (GM) is resistance to insect and herbicide. Common insect and herbicide resistance transgenic cotton were developed from the insertion of genes (Ingard® / Bollgard II® / Roundup Ready®/ Roundup Ready Flex® / Liberty Link®) to Australian cotton varieties (germplasm). The combination of these traits and Australian cotton varieties were then termed as transgenic varieties. All the GM cottonseeds have been developed by overseas companies that entered the GM cotton market in Australia. All the varieties mentioned except Liberty Link® have been developed by Monsanto while Liberty Link® is developed by Bayer Crop Science (AFAA, 2003). GM cotton was introduced for maintaining and preserving the quality of cotton while lowering the cost of farm maintenance (pesticide and herbicide application).

The CSIRO (The Commonwealth Scientific and Industrial Research Organisation) of Australia continues breeding new varieties (transgenic and conventional) to improve both crop and post harvest performance. The varieties developed are also tailored to the specific conditions of the region where the intended cotton is planted (Figure 2.3). Sicot, Siokra, Sicala, Sipima are some of the results of a research program conducted by CSIRO. The varieties for the 2008 planting and their suitable regions are shown in Table 2.1.



Source: (CSD, 2008)

Figure 2.3: Growing degree days at cotton planting area

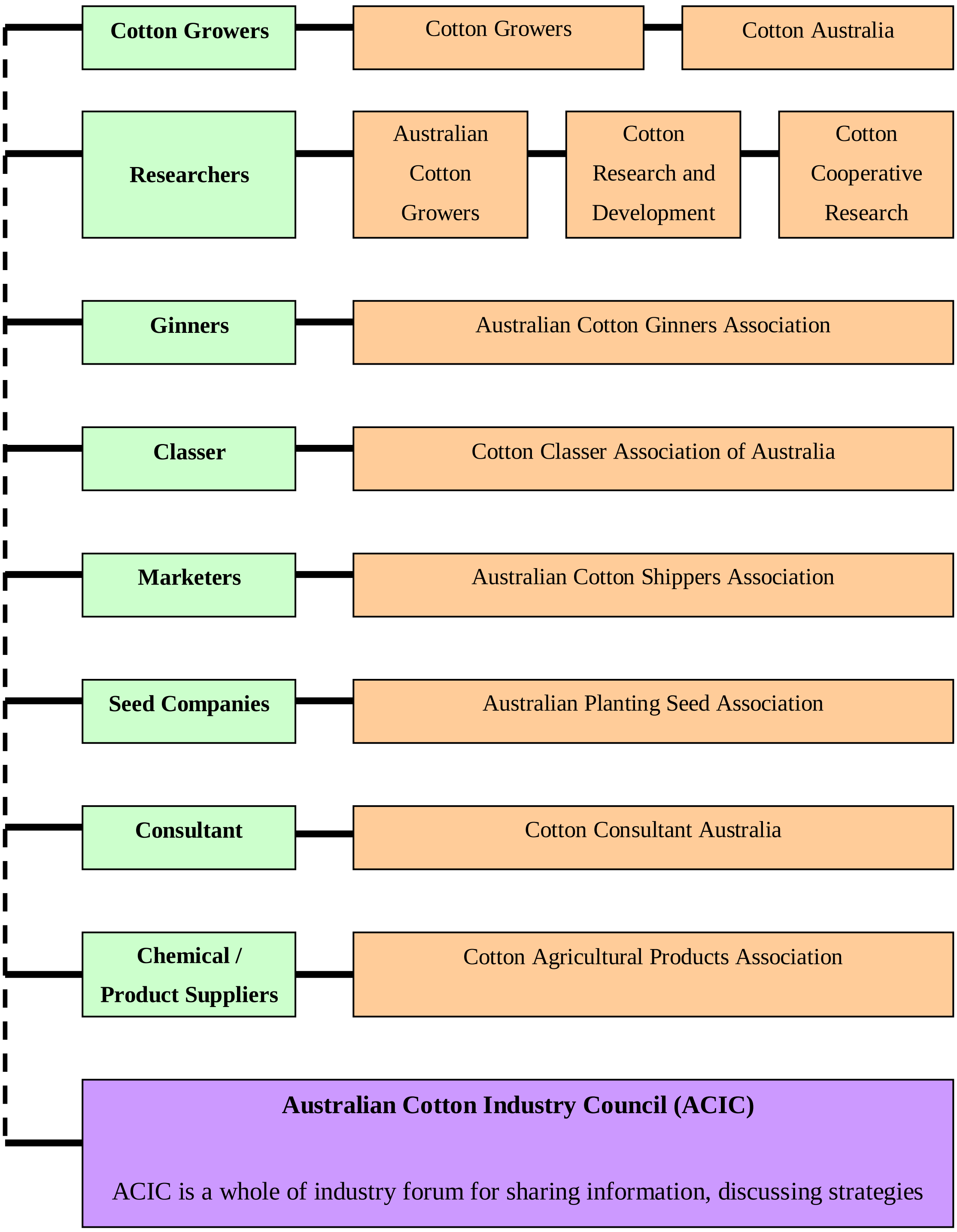
Table 2.1: Varieties for the 2008 planting and suitable region

	Varieties	**Region**
Combination of Bollgard II® and Roundup Ready Flex®	Sicot 80BRF	Central Hot Dryland
	Sicot 43BRF	Central Cool
	Siokra V-18BRF	Central Cool Dryland
	Sicala 60BRF	Central Cool
	Sicot 70BRF	Central Hot Cool
	Sicot 71BRF	Central Hot Cool
Combination of Bollgard II® and Roundup Ready®	Sicot 71BR	Central Hot Cool
	Siokra V-16BR	Dryland
Bollgard II®	Sicot 71B	Central Hot Cool
	Sicot 80B	Central Hot Dryland
	Siokra 24B	Hot Dryland
	Sicala 350B	Central Hot Dryland
	Sicala 45B	Central Cool
Roundup Ready Flex®	Sicot 80RRF	Central Hot Dryland
	Sicot 43RRF	Central Cool
	Sicot 71RRF	Central Cool Dryland
Roundup Ready®	Sicot 71RR	Central Hot Cool
	Siokra V-16RR	Central Hot Dryland
Liberty Link®	Sicot 80L	Central Hot Dryland
	Sicot 43L	Central Cool
Conventional	Sicot 75	Central Hot
	Sicot 71	Central Hot Cool
	Sicot 81	Central Hot Dryland
	Siokra 24	Hot Dryland
	Sipima 280	Western Hot
	Pima A8	Western Central

Source: (CSD, 2008)

2.3.4 Australian cotton industry structure

The Australian cotton industry is supported by several large cotton companies who play a significant role in industry organisations and matters. These companies are made up of a mix of local and US companies, and include: Namoi Cotton Co-operative Ltd, Queensland Cotton Ltd., Dunavant Enterprises Ltd., and Auscott Ltd. Among the listed companies, Auscott Ltd is the only company that involved in the vertically integrated agribusinesses of producing, ginning, classing, marketing and shipping for both its own production and that of other Australian cotton growers. The other companies do not grow any cotton and are only as integrated ginners/ warehousing/ shippers. These companies play an important role in assisting growers to improve fibre quality and to ensure the cotton product meets the specifications required by the spinner. The whole cotton industry is represented by the Australian Cotton Industry Council (ACIC) which serves as an industry forum to share information, discuss strategies and promote cooperation between industry bodies. The structure of the Australian cotton industry is shown in the Figure 2.4.



(Source: Cotton Australia)

Figure 2.4: Australian cotton industry structure

2.4 Australian cotton ginning industry

2.4.1 Ginning industry profile

Ginning is a fundamental process in cotton production. Although cotton quality is largely dependant on the variety and farming practices while the cotton is planted, ginning best practice is required to maintain cotton lint quality otherwise the final product value will be diminished. Inefficient or inappropriate ginning of cotton can damage the lint, leading to a price discount. In Australia, there are about 40 cotton gins. Most are located in NSW and Queensland. The major companies that are involved in ginning include: Namoi Cotton, Queensland Cotton, Twynam Cotton, Dunavant and Auscott. In addition, the sector is also serviced by several smaller regional-focused operations such as North West Ginning and Carrington Ginning. The presence of smaller independent gins, while not a risk-free proposition in a potentially over supplied market, does provide another dimension of competition and generates a need for ongoing research and technological innovation for the sector (Turco, 2003).

The ginning industry in Australia is relatively modern, with high throughput compared with ginning industries in other countries, however, almost all Australian gins use machinery designed and manufactured in the US; and hence optimised for US conditions. The two major brands are: “Lummus” (headquartered in Georgia, US) and “Continental Eagle” (headquartered in Alabama, US). Because there are distinct differences between the grades and properties of US and Australian cotton, it is not clear that the US designed ginning machinery is optimised for Australian conditions, particularly as evidenced by the nep and high short fibre content in some Australian ginned lint (CRC, 2007).

Gin plants in Australia range in age from 15 – 37 years old with a capacity range enabling production of 35,000 – 200,000 bales per annum. A gin can typically process up to 250 modules per week, producing around 5,500 bales in a typical season. If there is sufficient demand, cotton gins can run for up to 100 days a year, 24 hours a day, seven days per week. The gins also typically employ temporary and casual staff during the ginning season.

In Australia, the ginning industry is represented by Australian Cotton Ginners Association (ACGA). The members in this body are comprised of the ginners who are from both the major and small ginning and cotton companies. The ACGA is responsible for the Australian cotton ginning industry and is the place for ginners to discuss ideas and strategies in order to boost cotton ginning performance.

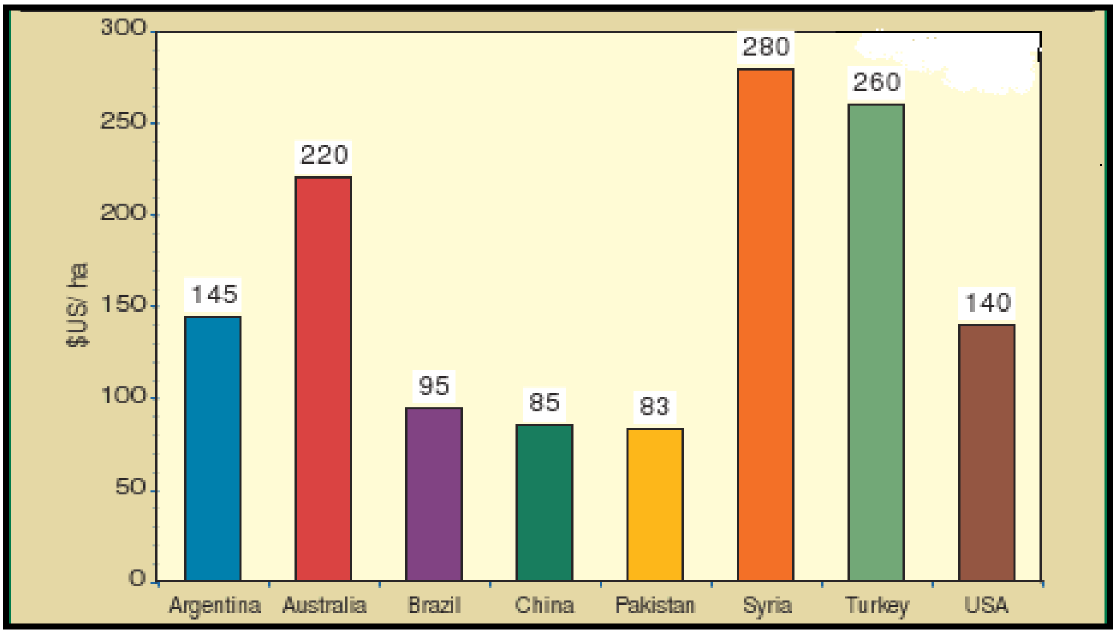
2.4.2 Research

Within the ginning industry, research in improving cotton quality is carried out by several research bodies. For example, CSIRO Materials Science and Engineering (CMSE), together with the Cotton CRC, are carrying out research on the ginning of Australian cotton to further enhance its cotton quality and industry profitability by reducing fibre and seed damage in the gin and by increasing ginning efficiency (e.g., improving gin turn-out).

The ACGA is also developing a Best Management Practices (BMPs) handbook for Australian ginning. The ACGA handbook is divided into several sections, including bale weight and moisture management, lint management, contamination management, bale management, sample management, and environment management. At the time of writing, an audit is still in progress to determine the compliance of the ginning sector with the Draft BMP handbook for ginning.

2.4.3 Ginning cost and its contributing factors

The Australian cotton ginning industry is cost competitive when placed against international producers. Figure 2.5 shows the data collected annually by the ICAC (Turco, 2003). From the chart, it can be seen that ginning costs vary considerably across different countries. By considering that 1 hectare of cotton farm can produce 5 to 6 bale, the ginning cost at Syria is at the extremes USD \$0.23/kg cotton (\$52.2/bale) while China at USD \$0.05/kg cotton (\$11.35/bale).



Source: (Turco, 2003)

Figure 2.5: A guide to the cost of ginning cotton in leading cotton producing nations in 2003. All costs are displayed in US Dollars. The Currency Rates at the time for each Nation (against the US Dollar) are not indicated.

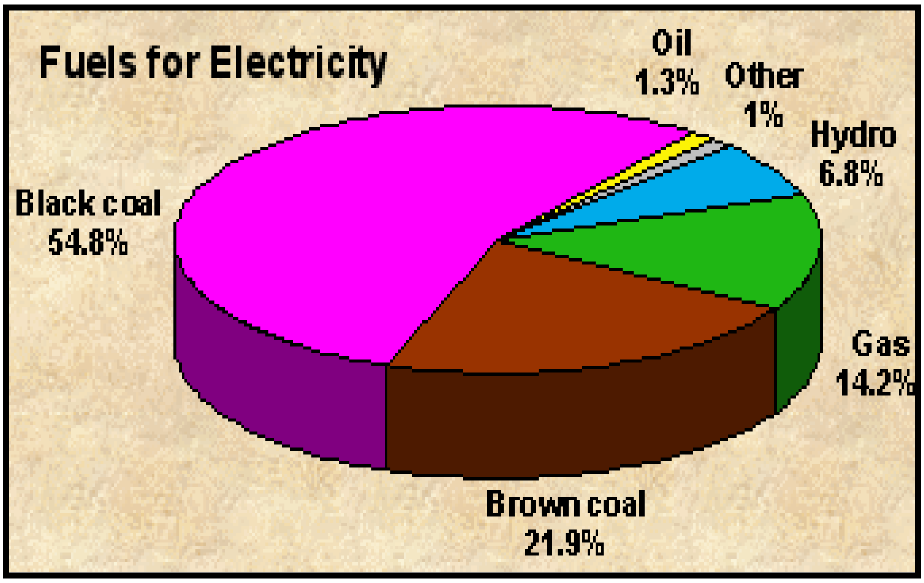
In 2001, a survey was conducted in the United States with 176 ginners there. It was found that the average variable cost was $19.59 per bale of cotton, with seasonal labour the largest single expense reported. Management cost was the second largest expense. Cost comparisons based on gin volume showed that larger annual volume could reduce per bale cost, primarily as a result of reduced labour cost. Based on the average variable cost and reasonable assumptions for gin plant fixed costs, total cost was estimated to be $40.67 per bale (Valco et al., 2003). In a similar survey undertaken in 2004 it has been found that the variable cost was about $20.22. However, the variable cost was increasing in 2007 to $21.58 per bale (Valco et al., 2009).

At present, based on the interview with the ginners, a flat fee of $55 per bale is typically charged to cotton farmers as a fee for cotton ginning in Australia. This represents approximately 16% of the total sale value of cotton bale which is currently around $350 (ABARE, 2009). This fee may change with the level of trash, but not with the incoming moisture content. The “estimated” ginning energy cost is “around $10 per bale”.

2.5 Australia's energy industry

In Australia, electricity is typically generated from fossil fuels (mostly coal). As shown in Figure 2.6, Australia is heavily dependent on coal in generating the electricity with approximately 75% of electricity produced in Australia being from coal and around 55% of coal generated electricity coming from highly-polluting black coal (WNA, 2009). In Australia, power generation now contributes 34.4% of the country's net greenhouse gas emissions (CO_2e) (198 out of 576 Mt/yr, an increase of 53% since 1990).

Since the early 1990s, the Australian electricity industry has been dramatically restructured with the breakup of previously wholly state-owned vertically integrated electricity monopolies. This restructuring has resulted in the development of a national electricity market. Electricity prices (for large customers) have since declined substantially, although some believe that present prices might not provide sufficient returns on investment for market participants. Consequently, future prices may increase and there may be some amalgamation in the industry to create better economies of scale.



Source: (WNA, 2009)

Figure 2.6: Fuel for electricity generation in Australia

2.5.1 Electricity tariff structures

An electricity tariff defines the policies and pricing mechanisms that are in use by regulated utilities. Electricity tariffs are based on the concept that the user will pay not only for the amount of energy consumed, but also for the use of the distribution and metering equipment that connects the load to the supply system (Joint Technical Committee EN/1, 2000).

Typically approved by regulators, tariffs specify cost structures and terms of service for utility customers. Since the energy market in Australia is complex and dynamic, prices can shift due to many variables and there are numerous regulatory and government requirements. Thus, tariffs and charges vary in almost every area of the country dependant on supplier, consumption profile, and the metering and control that has been set. Electricity pricing may also vary according to time of day, month or season and charge bands. Most tariffs are also 'stepped' which means there is a different rate for the first consumption bracket compared to subsequent brackets.

In general, the pricing of energy retail companies consists of the following three constituent elements:

Energy Costs

These are the cents per kWh rates for electricity supply. They include the generating costs plus the margin the retailer adds.

Network Costs

These are the charges the network companies charge for supplying electricity to the customer. Energy retail companies will pass these charges through to the customer without adding a margin.

Metering and Service Costs

These are the fees charged to the customer for meter reading, reconciliation and billing. Different tariffs may focus on different aspects and provide choices for different customers. A typical tariff analysis (maximum demand tariff) will look into following factors:

Availability charge

A unit rate of charge per kVA (or kWh) of demand made available to a customer. This is also called as capacity charge.

Demand charge

This portion of the consumer's bill for electric service is based on the consumer's maximum electric capacity usage and is calculated based on the billing demand charges under the applicable rate schedule. Demand peaks may influence "fixed" costs for a site.

Unit charge

'Time of Use' (TOU) metering allows the meter to differentiate between peak and off-peak consumption periods. This allows the customer to take advantage of cheaper off-peak electricity and benefit from lower electricity costs. TOU metering however carries higher service and rental charges. For example, a $350 installation charge may be applicable to all TOU meters installed. In many cases, off-peak electricity costs almost1/3 of the peak electricity cost.

Since ginning is a seasonal process where it is only operated 3-4 months in a year, selecting a suitable electricity tariff to match its consumption profile would have a significant impact of the energy costs of a ginner.

2.6 Conclusion

This chapter has reviewed the Australian cotton growing and cotton ginning industry. It has been shown that Australian cotton industry is currently dominated by several large companies which are involved in the vertically integrated agribusiness of producing, ginning, classing, marketing and shipping for both its own production and that of other Australian cotton growers. The Australian ginning industry is also quite cost competitive when compared with international producers. At present, a flat fee of $55 per bale is typically charged to cotton farmers as the fee for cotton ginning in Australia. This represents approximately 16% of the value of cotton bale. The energy supply industry and tariff structure in Australia has also been reviewed.

CHAPTER 3

Cotton Ginning Process and Energy Management

In this Chapter, the ginning operations and its impacts on cotton quality, energy use and costs will be reviewed. Significant research in cotton ginning has been undertaken in Australia and overseas, particularly in the Cotton Ginning Laboratories of the U.S Department of Agriculture (USDA).

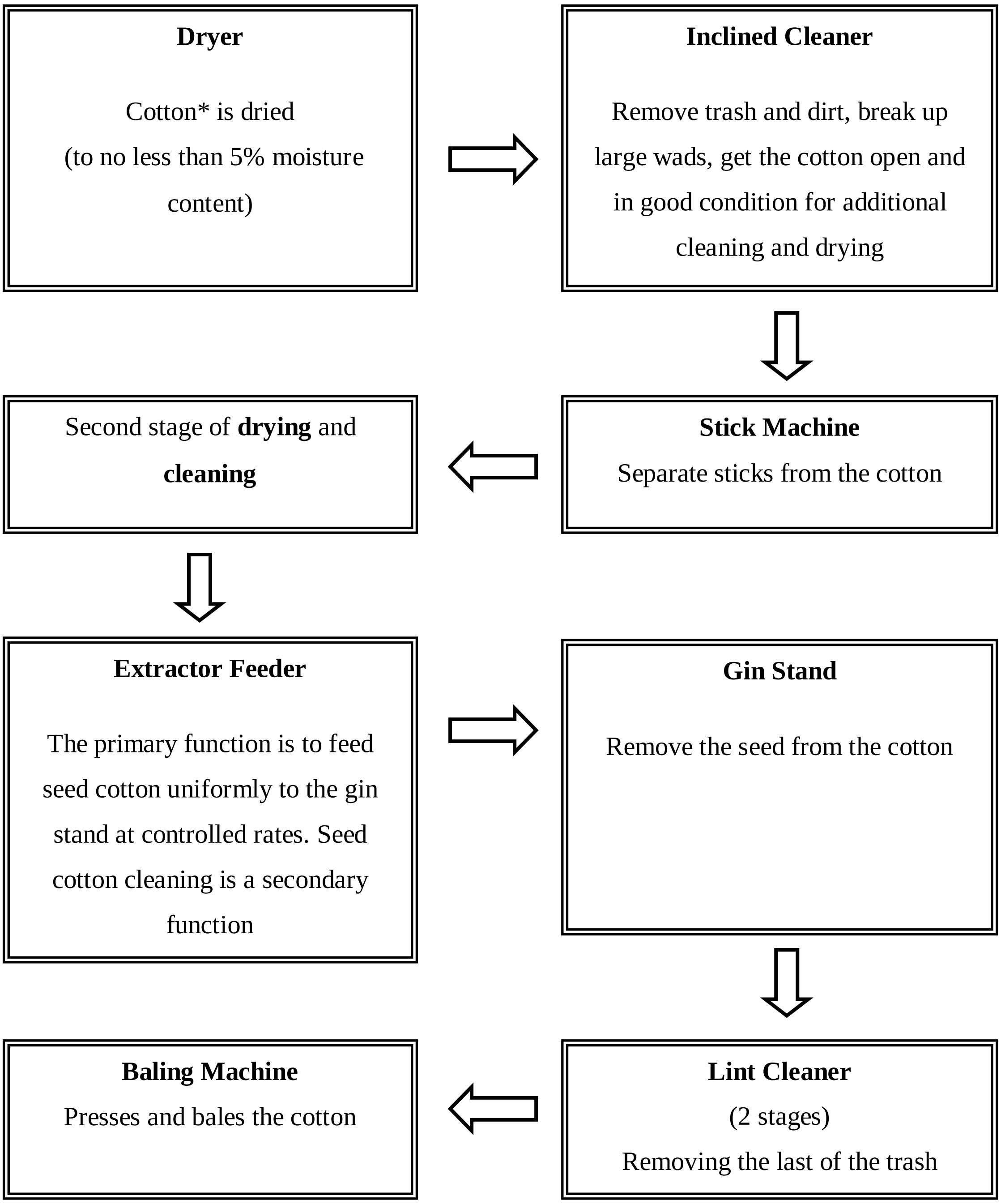
3.1 Overview of cotton ginning

A gin is a factory that cleans and conditions the cotton fibre, separates the fibre from the seeds and removes the leaves and dirt, preparing the lint prior to sending it to textile mill.

Gin serves the cotton from the unloading to packaging and until it is ready to be sent to spinning mills. Once the cotton has been harvested on the farm, it is pressed into modules, to then be taken to a cotton gin for processing. The sizes of modules are normally 11 to 12m long, 2.5m high and 2.5m wide. This will depend on what type of module builder the farmer has used. Each module weighs around 14 tonnes or more, and can produce 22-25 bales of lint. Before the ginning process takes place, the modules may wait outside between 10 to 30 days.

3.1.1 Cotton ginning process

Once the module arrives at the gin, it will be processed according to ginning sequences. The sequences of the process for ginning are typically as the follows: module feeder, dryer, cylinder cleaner, stick machine, dryer (2nd stage), cylinder cleaner (2nd stage), extractor feeder, gin stand, two stages of lint cleaning and lastly the bale press. The sequence and the function for each process are depicted in Figure 3.1. Typically, each module takes approximately 40 minutes to be processed such that each bale takes less than 2 minutes to be produced.



*Only cotton that has high moisture content will be conveyed into the dryer. Otherwise, the dryer can be bypassed.

Figure 3.1: Sequence of the ginning process

The flow of the ginning process shown in Figure 3.1 is the recommended sequence for machine-picked harvester cotton based on research undertaken by cotton ginning laboratories, USDA. These recommendations are designed to achieve satisfactory bale value and to preserve the inherent quality of cotton. The recommendations consider marketing system premiums and discount as well as the cleaning efficiency and fibre damage resulting from various gin machines (Anthony, 1999).

Inside the gin, all the cotton is conveyed from one process to another through pneumatic systems by “push” and “pull” centrifugal fans. When the conveying air is heated or humidified, the pneumatic conveyor becomes a drying or moisture adding system (Baker et al., 1994). Generally, the incoming cotton arriving at the gin varies in the levels of moisture content and trash. As seed cotton goes through the ginning process, seed cotton is conditioned to achieve the optimum state for trash removal, lint separation while at the same time maintaining the seed cotton quality. The dryers are adjusted to supply the gin stand with lint having a moisture content of 6-7 percent.

The level of cotton cleaning inside the gin is dictated by the quantity of trash contained in the seed cotton. If necessary, dryers, seed cotton cleaners and extractors, and lint cleaners may all be bypassed to allow the seed cotton to skip these machines when extra clean, dry cotton is brought to the gin. When the gin machinery is used in the recommended sequence, 75-85 percent of the foreign matter is usually removed from cotton. Mechanical handling and drying may also modify the natural quality characteristic of cotton (Anthony, 1999).

3.1.2 Machinery capacity requirements

The ability of the gin in producing bales depends on the gin's capacity. Because the press baling machine is often the bottleneck of ginning operation, the term of capacity for the gin may indirectly reflect the capacity of the pressing machine in producing a specific quantity of bales per hour. The capacity of other subsystems such as unloading, drying, cleaning, ginning, packaging and waste collection should be balanced to prevent choking and eliminate any other potential bottlenecks within the gin. The number of motors contained within the gin will also vary from gin to gin. In Australia, gin capacity can reach up to maximum 90 bales per hour. Because of the drought conditions of the past several years, there is currently an excess of ginning capacity in Australia; with no new gins having been built since the mid-1990s.

3.1.3 Process controls

The modern Australian gin has a central control room to monitor and control all machines of the ginning processes. From the centralised control room, operators can observe and control the operations of all the machinery. The incoming module moisture content is usually detected at the module feeder bay using microwave moisture sensor units while trash is typically defined visually by the gin operator. The module moisture reading taken then is passed and transferred to a terminal monitor inside the control room for display and as a ginners' reference to regulate the dryer temperature. Over drying can produce deleterious effects to the quality of lint produced. Cotton requiring drying is conveyed through the dryers with heated air whereas ambient air (dryer off) will be used if dry cotton is brought to the gin. The temperature of the heated air depends on the moisture of the cotton to be processed. The higher the moisture the higher the heat required.

The ginner will then determine the sequence of ginning processes to be undertaken according to the level of foreign matter in the seed cotton. The stick machine, second stage cylinder cleaner, and second stage lint cleaner are examples of machines that can be bypassed if extra clean cotton is brought to the gin. By bypassing certain processes, it will prevent the lint from unnecessarily over-processing; and also reduce the energy requirement of the gin. According to Anthony (1999), foreign matters level in seed cotton ranges from 5-10 percent before gin processing, but can reach to up to 12-14 percent.

Based on the survey in Australia, the temperature and process sequence is typically determined by the ginners' experience. Some of the ginners believe that the moisture of seed cotton will lose 1-2 % through the process. As the aim is to reduce the cotton moisture to 6-7 percent, the module with a moisture content less than 8% will need not to be heated. The only instance under which dry cotton will be conveyed with heated air is if the cotton has excessive trash content and may be required to be processed at a lower moisture content to clean the cotton sufficiently. The regulated heat required to dry cotton can vary with factors such as processing rates, external weather conditions, etc.

As the management of cotton ginning is subjective and differs between ginners, there is the possibility that incoming cotton may go through the same cleaning and drying sequence—without regard to differences in moisture content, colour, or foreign matter. This could result in lower quality cotton and higher loss of lint. To overcome this matter, the USDA developed a computerised system that has been registered under the trade name 'IntelliGin' in 1992 to automatically measure the quality of cotton at various stages of ginning process. Sensors determine the quality of incoming cotton and send the information to the computer system. Once the colour of the cotton, foreign matter and moisture content are known, the software decides the best sequence of machine cleaning and drying to get the best market and value (Weaver, 1998); thus, providing a more consistent ginning outcome.

The system also allows ginners to customise their ginning process for each farmer to assist the farmer to increase profits. For instance, if a farmer knows the market price for various grades of cotton in advance, the ginner can integrate the actual market price with initial cotton quality information and determine the sequence needed to optimise dollar returns for that farmer. Research at field gins from 1994 to 1997 showed that fine-tuning ginning operations can bring the cotton farmer additional profits of $10 to $20 per bale. As an example, one gin in Alabama increased returns to farmers by $16.72 per bale on the production of approximately 42,000 bales in 1994, resulting in additional income for farmers of over $700,000. In 1995, the increased per-bale return was $21. The process control system also saved the ginner nearly $1 per bale in reduced energy costs (Weaver, 1998). However, there is no 'IntelliGin' system used in Australia.

3.1.4 Cotton quality

A sample of each bale of the processed cotton is first brought to a cotton classer. Classification of cotton is based on the cottons physical characteristics such as fibre length, length uniformity, fibre strength, micronaire (cotton fineness), colour, and trash. Cotton lint can also be classed by a machine known as a HVI (High Volume Instrument). HVI testing originated in the US to standardise the procedures for measuring cotton quality parameters. The system uses a technically based method used by both marketers and buyers to accurately access the quality and exact value of cotton fibres. The grading process will decide if the cotton is sold for a higher or lower price; known as either premium or discount. A HVI test report includes information related to the following quality indicators of Table 3.1.

Table 3.1: Cotton quality indicators

Grade	Relating to any visible impurities and the degree of whiteness. Grade also refer to/measures the 'preparation' or appearance of the fibre after combing through a gin lint cleaner.
Length	The price of cotton is roughly proportional to staple length. Australian cotton crops typically produce 28mm staple if irrigated, but shorter for dryland crops
Micronaire	The fineness of the cotton that affects how quickly it can be spun
Trash and dust	The quantity of trash and dust particles that are in cotton
Tenacity and elongation	Strength and stretching.

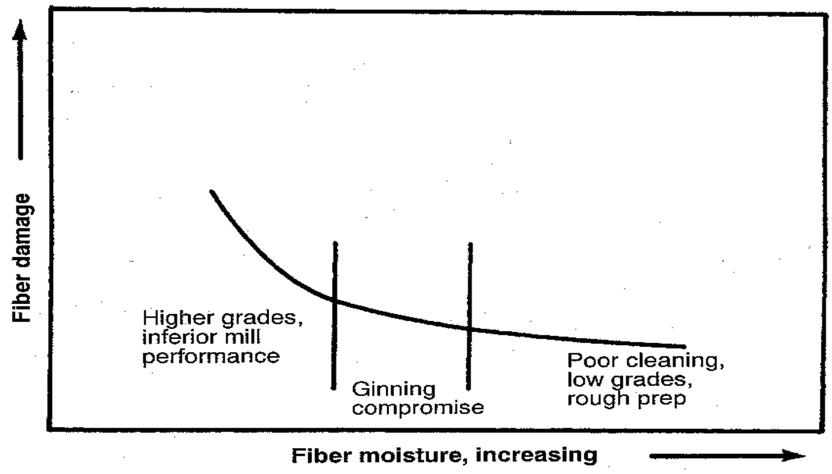
Source: (Cotton Australia)

3.1.4.1 Factors influencing the cotton ginned quality

Cotton quality can be affected at every production step from the first phases of growing until the final processing (ginning) stage. Such factors thus include the selection of the variety, environmental conditions, farmers' practices, harvesting and ginning practices.

The quality of cotton can be deteriorated if it goes through improper ginning processing. The qualities that can be significantly affected are fibre length, uniformity, trash, short fibres, neps and seed coat fragments (Anthony, 1999). The two ginning practices that have the most impact on quality are (1) the regulation of fibre moisture during ginning and cleaning, and (2) the degree of lint cleaning performed.

Cotton arriving at the gin is sometimes too moist, which reduces cleaning efficiency and will form wads that may choke and damage gin machinery. Air, the primary method of conveying cotton, is heated to remove excess moisture from the cotton (Boykin, 2005). The ginners have to carefully regulate the temperature as cotton with too low fibre moisture will become brittle and can easily become damaged by cleaning and other ginning processes. In addition, it may stick to metal surfaces as a result of static electricity generated on the fibres and cause machinery to choke and stop. Anthony (2001) showed that drying at high temperature will also reduce fibre strength. Dryer temperature over 175^0 C for as little as 3 seconds can reduce individual fibre strength and increase fibre breakage even after restoring moisture. Cotton that is too moist will not clean well, and cotton is too dry will be damaged. Thus, in managing the temperature, the ginners have to compromise between fibre quality and fibre damage (Figure 3.2).



Source: (Anthony, 1999)

Figure 3.2: Moisture-ginning cleaning compromise for cotton

The recommended lint moisture range for ginning is 6-7 percent. During ginning, gin saws pull fibres through the ginning ribs that are designed to be too narrow for seed to pass. Fibres may be broken if the force required to extract these fibres exceeds the fibre strength. It was reported that for each 1 percent reduction in fibre moisture content below 5 percent, the number of short fibres will almost equally increase by approximately 1 percent. The quantity of short fibres also can increase if the ginning rate is increased above the manufacturer's recommendation (Boykin, 2005).

Mechanical and pneumatic devices used during cleaning and ginning can increase the nep content, but lint cleaning has the most significant influence (ICAC, 2001). Lint cleaners are much more effective in reducing the lint trash content than are seed cotton cleaners and has the ability to blend the cotton so that fewer bales are classified as spotted or light-spotted. Using the seed cotton cleaner and lint cleaner aggressively may result in the lowest levels of all types of trash particles including particles in the range of 50 to 500 microns (Anthony, 2001). Furthermore, lint cleaners can also damage fibre quality and reduce bale weight (turnout) by removing some of the highest quality fibre.

Boykin (2005) found that much of the fibre damage occurs during lint cleaning but very little occurs during seed cotton cleaning. All lint cleaner treatments decrease staple length which corresponds directly with moisture level. Mangialardi (1993) found that lint cleaners increased the short fibre content to 6.8%, 8.8% and 9.6% respectively as one, two and three stages of lint cleaning were used. As an average, each lint cleaner reduced the average fibre length by 250 microns. However, no difference was found in length values for the seed cotton cleaners. Anthony (USDA, 2004) has also reported that lint cleaning process increases the neps (small entanglements of cotton fibre). When one and two stages of lint cleaning were bypassed, neps decreased by 15% and 42%, respectively (USDA, 2004).

Yarn strength, yarn appearance and spinning end breakage are three important spinning quality elements. These three elements are usually preserved best when cotton is ginned with minimum drying and cleaning.

3.1.4.2 Efforts in preserving cotton quality

As in Australia, at the ginning stage, a ginner will classify the seed cotton that is produced in the gin according to the leaf grade. The leaf grade of the lint produced only refers to the trash level and it ranges from 1 to 5, with 3 leaves being the benchmarking base level. The more the trashes exist, the higher the number will be. The ginners will evaluate the lint produced either visually or by using a scanner if it has been installed (before the baling process) at the gin. It is usually examined for the first bale for each module produced. If the first bale gives the higher leaf grade, for the next bale, ginners will react by increasing the temperature of the dryer, turning on a few of the cleaning machines such as a secondary cylinder cleaner, stick machine, and secondary lint cleaner, or by slowing down the feed rate so that the cotton is slowly processed. Overall, the ginners' practices in this aspect are quite subjective. It is different between gins and heavily depends on the ginner's experience and judgement.

A lot of research has been done and is underway by USDA, especially in developing and modifying the design of machines inside the gin to improve fibre properties. Besides the computerized system (e.g. IntelliGin) that has been discussed above, a new lint cleaner to improve fibre quality and reduce fibre waste was also developed and is available for commercial use. The new cleaner consist of a modified cylinder cleaner combined with two lint cleaner saws as well as a secondary saw to prevent fibre loss. Initial trial results indicated that similar fibre properties were obtained across machine treatments but the fibre loss was reduced by about 50%, therefore adding weight and increasing the bale value by $6 per bale (Anthony, 2005).

Gordon and Van Der Sluijs from CSIRO Materials Science and Engineering, Geelong, Australia, are also working on more gentle ginning machinery, to separate fibres from seeds and other impurities. A modified cleaning system was found to cause less fibre breakage, leading to fewer short fibres and fewer neps. A provisional patent has been granted (CSIRO, 2008). A machine vision-based system for on-line identification of trash objects commonly found in cotton was also developed to configure an optimal set of equipment during ginning to produce quality cotton.

Overall, under the current cotton marketing system, the penalty for reduced lint yield is much greater than the penalty for unacceptable fibre quality. Therefore, it may become less profitable for growers to manage maximum fibre quality if lint yield is sacrificed in the process. Nevertheless, to achieve the best quality and produce profitable cotton, a lot of attention is still being given to every cotton production step from the growing to the processing stage as they will all contribute to the final cotton yield and fibre quality.

3.2 Energy uses and energy management for cotton ginning

3.2.1 Overview

Inside the gin, electricity is used to run all operations except the drying process where the gas is normally used. According to Anthony and Eckley (1994), fuel (natural gas or liquefied petroleum gas LPG) consumed constitutes about 64 percent of the total energy used at a gin and the remainder is occupied by electricity. In 1979, Griffin (1980) surveyed 230 Mid-South gins in the United States and found that on average, 52 kWh of electricity and 312 cubic feet (8.83 m^3) of natural gas or 4.4 gal (16.7 litres) of liquefied petroleum gas (LPG) was used to process each bale.

In another survey with 235 Mid-South gins in the United States in 1987, it was found that the average energy usage of electricity, natural gas and LPG per bale were 44 kWh, 247.8 cubic feet (7 m^3) and 2.33 gal (8.8 litres) respectively (Anthony, 1989).

Electricity use per bale has remained relatively constant since 1962. Watson and Holder (1964) in Anthony and Eckley (1994) have found that the average of 33 gins surveyed was 47.5 kWh/bale. Electrical energy requirements among gins usually range from 40-60 kWh/bale (Anthony and Eckley, 1994).

In a survey with several gins with a capacity of 24 bales/hour, Anthony and Eckley (1994) have compiled the electricity required (rated power) according to different gin processes (Table 3.2). The data was then divided into major ginning processes together with their actual energy usage (Table 3.3).

Table 3.2: Connected power required

Gin Process	**Connected power required (hp)**	**Percentage of gin's connected horsepower**
Seed cotton handling	505	29.6
Seed cotton cleaning	190	11.1
Ginning	200	11.6
Lint handling	164	9.6
Lint cleaning	165	9.6
Trash handling	160	9.4
Packaging	280	16.4
Miscellaneous	45	2.6
Total	**1709**	**100**

Source: (Anthony and Eckley, 1994)

Table 3.3: Average energy use and cost per bale

Gin Process	Connected power required (hp)	Energy per bale		Cost per bale[1] ($)
		kWh	Percent of total	
Cleaning	355	10	19.2	0.83
Ginning	200	7	13.5	0.58
Packaging	280	4	7.7	0.33
Handling	874	31	59.6	2.57
Total	**1709**	**52**	**100.00**	**4.31**

[1]Based on $0.083/kWh Source: (Anthony and Eckley, 1994)

It can be seen from these tables that the energy consumed for handling, cleaning, ginning and packaging was 59.6%, 19.2%, 13.5%, and 7.7% respectively. However, as cotton gins usually contain more than 100 motors of various sizes and are connected in different ways, it would be difficult to classify the motors according to their processes. The way to take the measurement of actual energy usage has not been clearly discussed and specified in their paper.

3.2.2 Factor affecting energy usage

An energy survey was conducted by Griffin (1980) in 1979 and the data from the survey were tabulated by state and gin capacity (bales/hour). Based on that result, it was found that generally the larger gins were more efficient users of electricity and petroleum energy than were the midsize and smaller gins (Table 3.4). Gins operating at a ginning rate of 20 bales/hour or more used an average of 407,000 Btu/b ginned. This was in comparison to gins operating in the range of 10-19 bales/h which required an average of 484,000 Btu/b ginned, and gins handling 9 or fewer bales/h which used 597,000 Btu/b.

Besides, Griffin (1980) found that the energy required for drying cotton reported by individual gins varied widely from area to area. The observed variations were considered to be the result of local weather and harvest conditions that contribute to cotton moisture. Anthony (1989) found that the amount of drier fuel consumed in drying varies directly with dryer temperatures.

Table 3.4: Petroleum and electric energy used by Mid-South gins for ginning

Location	Ginning Rates (bales/hour)	Energy type and rate of use			
		Petroleum (Btu/bale) x 1000	Electric (Btu/bale) x 1000	Total (Btu/bale) x 1000	Gasoline equivalent (gal/bale)
Arkansas	9 or fewer (37)	421	174	595	4.9
	10 -19 (21)	273	191	464	3.9
	20 or more (3)	195	143	338	2.8
Louisiana	9 or fewer (5)	440	184	624	5.2
	10 -19 (17)	320	164	484	4.0
	20 or more (2)	129	123	252	2.1
Mississippi	9 or fewer (32)	443	188	631	5.2
	10 -19 (61)	326	177	503	4.2
	20 or more (8)	268	167	435	3.6
Missouri	9 or fewer (9)	388	164	552	4.6
	10 -19 (5)	208	167	375	3.1
	20 or more (0)	0	0	0	0.0
Tennessee	9 or fewer (20)	385	174	559	4.6
	10 -19 (8)	302	160	462	3.8
	20 or more (2)	321	232	553	4.6
Gin locations combined	9 or fewer (103)	419	178	597	5.0
	10 -19 (112)	308	176	484	4.0
	20 or more (15)	242	165	407	3.4
Gin locations and sizes combined	(230)	354	176	530	4.4

* Numbers in parentheses are number of gins furnishing data. Source: (Griffin, 1980)

In terms of energy, Boykin (2005) had reported that changes in gin stand energy consumption were related to moisture addition, dryer temperature, and lint moisture. Boykin (2005) had demonstrated that an increase in moisture from 4.55% to 5.08% had reduced gin stand energy consumption from 21.4 to 21.1 MJ (5.94 to 5.86 kWh) per bale. The electrical power required to separate the fibre from the cotton seed by gin stand has also been investigated (Boykin, 2004). In this research, it was found that the power consumption may be related to changes in the average fibre to seed attachment of different varieties. However, further studies are required to confirm this finding.

Boykin (2007) in his research investigated the relationship between genetic variations in gin stand energy consumption as an indicator of differences in fibre seed detachment energy. Not considering the idling energy, the gin stand consumed an average of 20.2 Wh/kg lint with a range of 16.4 to 24.3 Wh/kg lint across cultivars in all tests. Changes in ginning energy were found to correlate with changes in seed linters content, ginning rate, seed percentage, and turnout, but ginning energy did not appear to be dependent on these factors. Ginning energy did not change with fibre length, but it did increase with short fibre content as fibres were broken in multiple places. Ginning energy increased with the numbers of neps, numbers of seed coat neps, and weight of seed coat fragments, and it decreased with seed cotton cleaner efficiency. This indicates that energy was used to untangle fibres and remove trash. He also found that the gin stand energy requirements were lower for cultivars with large seed and low seed linters content. Boykin (2004) has found that the cultivar differences in energy consumption at the gin stand are likely closely related to differences in the attachment force of the fibre to the seed.

3.2.3 Electricity cost

By referring to Table 3.3, it can be seen that most of energy cost was associated with handling materials ($2.57/bale) which also required most of the power. Ginning required 200 hp and cost $0.58/bale, while packaging required 280 hp but cost only $0.33/bale. However, energy costs do not always relate directly to connected power. The cost of electricity is determined by usage, demand and power factor.

Usage is the amount of energy used per billing cycle and is expressed in kilowatt-hour (kWh) (Anthony and Eckley, 1994). The usage charge is the largest portion of the electrical cost during operation and the one over which the ginner has control. The amount of electricity can be reduced by increasing the efficiency of equipment and generally eradicating wasteful and unnecessary uses (Payne, 1977).

Demand is the maximum power used during a 15-min period of a billing cycle and is expressed as kilovolt-ampere (kVA) or kilowatt (kW). Although rarely needed, this amount of power must be supplied continuously by the utility company. Utility companies must design power distribution systems to meet the peak demand and ensure that their generating capacity will be able to meet this peak power demand (Patrick and Fardo, 1982). Demand charges can be influenced by start up procedures. Start up load is usually about three and four times the connected and operating load, respectively (Anthony and Mayfield, 1994). A large motor should therefore be started sequentially, not simultaneously to allow the start up power surge of a motor to reduce to a normal idle load before starting the next motor. If the motor starts are staggered properly, most gins can be started in less than 2 minutes without having the starting load exceed the total gin operating load at any instant. This way of reducing the demand should be adopted in order to minimise the electricity cost. The value for maximum demand can be affected by ginners' management in running the duty cycle of motors on the press. In Australia, most of the gins have used Programmable Logic Controller (PLC) that automates the gin to stagger a start cycle of each machine. Besides, developing a more uniform load will reduce the maximum demand and improve the load factor.

The power factor relates the actual amount of work done to the amount of power drawn from the utility lines at any instant in time. The value of the power factor decreases as the reactive power (unused power) drawn by the industry increases. As reactive power is increased, more volt-amperes must be drawn from the power source (Patrick and Fardo, 1982). Some utility companies charge electricity users for operating at power factor below a specified level (e.g, 0.8). Charging the electricity users based on the kVA is another way to charge the power factor where the industry tends to pay for the unused power if the power factor is low. It is desirable for electricity users to 'correct' their power factor and to avoid such charges and to make more economical use of electrical energy. Besides, it will reduce the current drawn from the power distribution lines that supply the loads. Overall, the power factor can be improved by keeping all motors as near fully loaded as possible (Payne, 1977).

In summary, electricity costs per bale can be reduced by giving attention to these aspects:

i) Reducing the total amount of electricity used
ii) Increasing the production
iii) Developing a more uniform load, in order to reduce the maximum demand and improve the load factor
iv) Examining the application and performance of electric motors in order to improve power factor.

3.2.4 Energy management

Energy management is about the effective and efficient use of energy resources. Every ginner has their own way in managing the energy usage inside the gin. An energy management system applied comprises a set of well-planned actions aimed at increasing the efficiency, maximizing profit, reducing a gin's energy bills and increasing productivity.

Energy demand management, also known as demand side management (DSM), entails actions that influence the quantity or patterns of use of energy consumed by end users, such as actions targeting reduction of peak demand during periods when energy-supply systems are constrained. Peak demand management does not necessarily decrease total energy consumption but could be expected to reduce the need for investments in networks and/or power plants. Energy demand management activities should bring the demand and supply closer to a perceived optimum.

Energy conservation is the practice of decreasing the quantity of energy used. It may be achieved through efficient energy use, in which case energy use is decreased while achieving a similar outcome, or by reduced consumption of energy services. Each of these energy conservation measures will reduce energy consumption and lower fuel costs. In order to reduce the energy consumption at gin, Anthony (2006) has outlined a number of actions that can be taken to conserve gas and electricity.

For gas, Anthony (2006) suggested that ginners can do the following to improve dryer efficiency: (1) insulate the drying system (2) avoid unnecessary drying (3) use properly designed dryers (4) adjust the burner flame (5) maintain proper burner control and (6) use heat recovery devices. For electricity: (1) good management decisions (2) improve motor efficiency (3) balance the capacity of subsystems (4) minimize down time (5) avoid oversize motors (6) control air handling systems (7) size fans properly (8) replace inefficient motors (9) reduce gin demand (10) stay informed about new technology (Anthony and Eckley, 1994).

Besides following these guidelines to conserve energy, ginners should occasionally evaluate the energy usage and performance of individual motors. To evaluate the energy usage inside the gin, an energy audit is best taken as part of resource management. Energy audits and surveys are investigations of energy use in a defined area or site. They enable the identification of energy use and cost, from which energy cost and consumption control measures can be implemented and reviewed. An energy audit seeks to prioritize the energy uses according to the greatest to the least cost effective opportunities for energy savings.

3.3 Conclusion

This chapter has discussed the ginning process, a compromise between fibre quality and ginners' decisions, and energy management inside the gin. In managing the variations of incoming cotton conditions, ginners need to carefully regulate the dryer temperature and determine the sequences of machines according to the level of trash.

Every decision taken can affect the energy usage. Besides following the guidelines in conserving energy, ginners should also understand the energy usage patterns based on the incoming cotton process and monitor their energy usage as the first step to increasing gin efficiency and energy savings. The details of the relationship between energy used and incoming cotton and energy auditing inside the gin will be discussed further in the next chapter.

CHAPTER 4

Electricity Consumption and Electricity Profile at Whole Plant Level

This chapter will review the results from energy data collection at a whole-plant basic level assessment. It aims to evaluate the energy consumption and establish the energy use benchmarks in the Australian cotton ginning industry. The energy collection data for the basic level was conducted with the support of Cotton Research and Development Corporation (CRDC), and the Australian Cotton Ginners Association (ACGA).

In this Chapter, the recorded maximum electricity demand, load factor and power factor of monthly electricity bills will also be evaluated. The electricity tariffs will be analysed.

4.1 Ginning electricity consumption in Australia

4.1.1 Methods of electricity data collection

The project was begun by collecting information on historical data for (1) energy usage and energy cost, (2) gin's production and (3) Shift Monitor Control Sheets for the last 24 consecutive months. A Shift Monitor Control Sheet (Sample as Appendix 4.1) is a form that ginners have to fill in while ginning is in progress. It consists of seed variety, incoming module moisture, dryer's temperature, lint moisture at gin stand, and bale moisture. Besides gin's capacity, the average of maximum demand and the list of electricity-consuming equipment for all gins were also gathered. In addition, site visits and interview sessions were conducted at 3 gins in order to understand the practice and procedures of the ginning process.

The energy data collection at basic level covered the energy audit Level 1 which allows for the evaluation of energy used (electricity and gas) for the whole gin. The details of electricity data analysis will be discussed in Chapter 4 while gas use data will be addressed in Chapter 5. The development of a national energy benchmark for electricity and gas will also be discussed in the respective chapters.

4.1.2 Method of electricity data analysis

Data for monthly production and electricity usage (kWh) from January 2007 until December 2008 have been received from 6 gins, and yearly usage and production from 2 gins. All the gins were located in Queensland and New South Wales. The monthly data received has been compiled in Appendix 4.2.

By using Microsoft Excel (Microsoft Office 2007), the yearly electricity data and gin's production were correlated to establish a nation-wide energy performance benchmark. An average of electricity usage per bale for each gin was also calculated.

Maximum electricity demand and required power to run all the electricity equipment for each gin were observed. Load factor and power factor were also calculated.

4.1.3 Development of electricity use benchmark

The electricity use benchmark is developed as an electricity performance indicator for ginners to evaluate their electricity consumption. The benchmark is established using yearly electricity usage and production for all gins gathered. The data is compiled in Table 4.1. It can be seen that yearly minimum and maximum production for the 8 gins varied between 6,303 and 45,000 bales. The benchmark for electricity use (kWh) per bale ranged between 44-66 kWh. This was consistent with the data available from overseas that recorded 40-60 kWh/bale (Anthony and Eckley, 1994). Based on the two year averaged data, the average energy consumption (kWh) needed in processing one bale for each gin varied between 46 – 59 kWh/bale. However, there was no correlation between a gin's capacity and energy use per bale (Table 4.2).

Table 4.1: Electricity consumption and productivity for year 2007 and 2008 for each gin

Year	Gin	kWh	Bales	kWh/bale
2007	**Gin A**	1396886	31284	44.65
	Gin B	1817475	38006	47.82
	Gin C	1527994	30547	50.02
	Gin D	522708	9045	57.79
	Gin E	1332798	29688	44.89
	Gin F	1302476	23132	56.30
	Gin G	1573595	24000	65.57
2008	**Gin A**	1254390	23003	54.53
	Gin B	1657183	34680	47.78
	Gin C	1497047	27313	54.81
	Gin D	635457	10893	58.33
	Gin E	723453	14531	49.78
	Gin F	421245.9	6306	66.80
	Gin G	2496367	45000	55.48
	Gin H	971,989	19,360	50.2

Table 4.2: Average electricity use/ bale for each gin

Gin	Capacity (bales/hour)	Electricity Use (kWh/bale)	Electricity Use (MJ/bale)
Gin E	24	46.50	167.4
Gin D	30	58.00	208.8
Gin A	40	48.80	175.68
Gin F	40	58.60	210.96
Gin B	54	47.80	172.08
Gin G	55	50.2	180.72
Gin C	60	50.80	182.88

As an average, electricity usage contributed to about 61% of total energy use (Figure 4.1) and it constituted about 77% of the overall energy cost (Figure 4.2). Electricity cost per unit of energy provided is normally more than the other fuels because it is a higher grade form of energy.

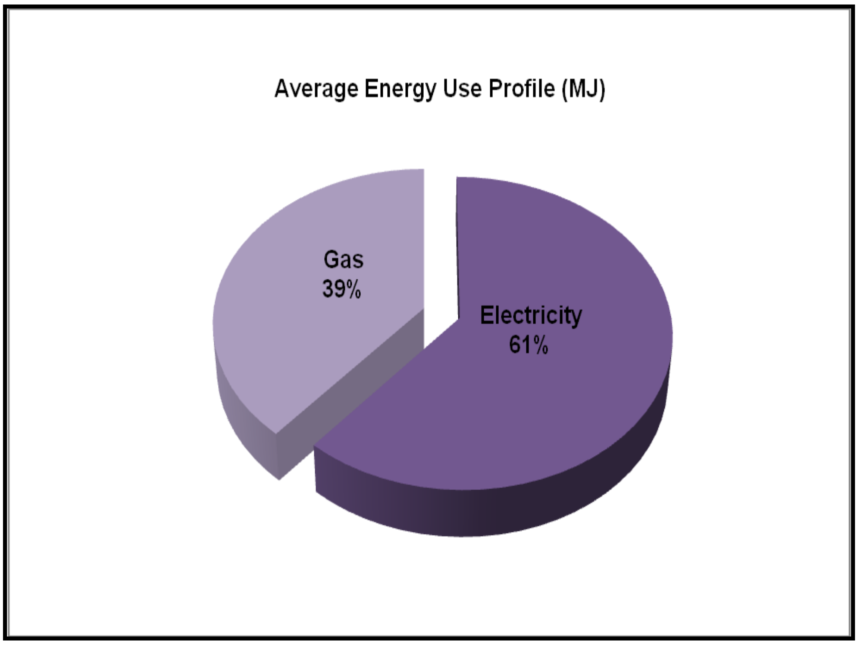


Figure 4.1: Average energy use profile

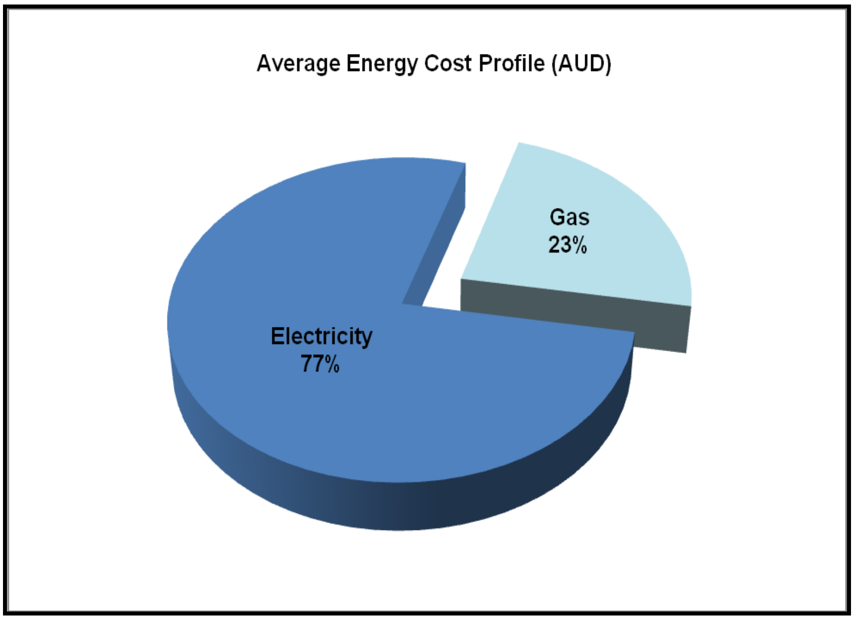


Figure 4.2: Average energy cost profile

4.1.4 Relationship of electricity use (kWh) with production (bales)

Data in Table 4.1 is then plotted in Figure 4.3 to show the relationship between electricity uses and production. From the graph, it can be seen that all points give a good fit, indicating that electricity consumption is nearly linearly correlated with bales produced. Thus, the more quantity of cotton bales processed, the longer motors have to run and the more electricity is consumed.

The close relationship in Figure 4.3 may be a consequence of similar machines following the similar operation procedures for all incoming cotton. Furthermore, all the cotton ginning machines in Australia were imported from the US, being either "Lummus" brand (headquartered in Georgia, US) or "Continental Eagle" (headquartered in Alabama, US). The motors were usually continuously running even in the 'idle' state, meaning that the electric motors were normally not stopped (switched off) at the middle of operation. This was appropriate as when if were to be restarted, it would create "an electrical surge" which is neither good for the electric motor, nor for the electricity network.

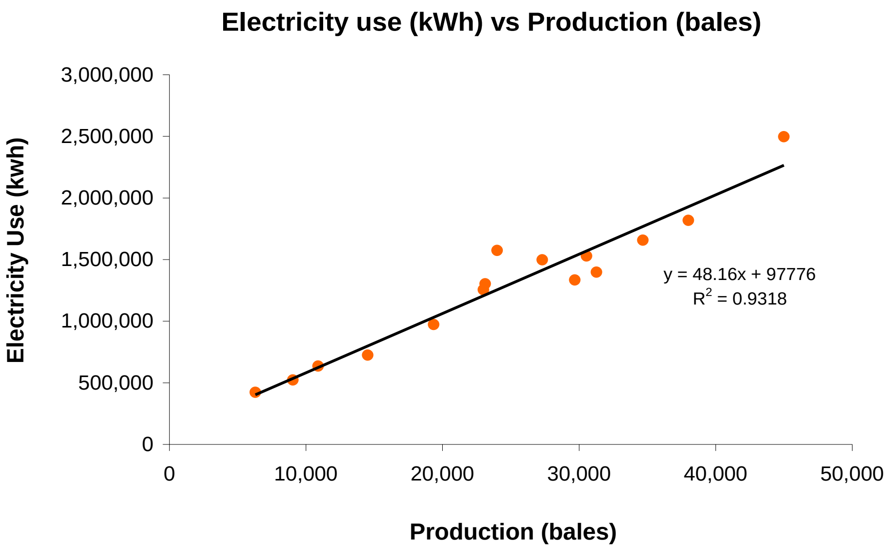


Figure 4.3: Relationship between electricity consumption (kWh) and production (bales)

4.1.5 Maximum demand

Table 4.3 shows the data of maximum demand recorded in electricity bills by the electricity supply company and the required power (rated power) to run all the energy-consuming equipment for cleaning, ginning, packaging and handling processes. The list of electricity-consuming equipment (electrical motors) inside the gin are classified as follows: (a) Cleaning – consists of the motors that are related with seed cleaning and lint cleaning, (b) Ginning - consists of gin stands, (c) Packaging- consists of motors that relate with pressing and (d) Handling –Motors of seed cotton handling, lint handling, trash handling and other motors that are not included in the other three sub-processes (a, b, c). The unit for recorded maximum demand is usually expressed as Kilo-Watts (kW) or Kilo-Volt Amperes (kVA) in certain gins. However, in Table 4.3, all the demand values in kVA have been converted to kW by multiplying the value with the power factor recorded for the respective gins.

The data from Table 4.3 shows that recorded maximum demand and total rated power were increasing with a gin's capacity. Maximum demand has occupied around 48-67% of total rated kW required to run all the energy-consuming equipment. It also shows that the handling process is a higher electricity user than all the other processes and occupies 50-60% of total power, followed by packaging with a percentage of 10-22%. Ginning and cleaning were 11-14% and 12-15% respectively.

Table 4.3: Average of maximum demand and connected power required for each gin

Gin	Capacity (bales/hour)	Average Maximum Demand (kW)	Σ kW	Cleaning	Ginning	Packaging	Handling
Gin E	24	882.2	1836.2	240.0	220.0	273.5	1102.7
Gin D	30	1120.3	2399.8	374.5	350.0	226.5	1448.8
Gin A	40	1799.4	3203.0	404.0	440	375.0	1984.2
Gin F	40	1983.4	3078.0	420.5	440.0	689.9	1527.2
Gin B	54	2256.5	4006.0	629.0	560.0	413.5	2392.5
Gin C	60	2837.3	5199.3	648.0	660.0	684.5	3206.8

Source of maximum demand: (Electricity Supply Company)

The monthly maximum demand for each gin is plotted with the gin's production (Figure 4.4). It appears that there is no significant linkage between average of maximum demand and production. This indicates that ginners use the same procedure in managing and conducting ginning machineries regardless of the volume of cotton being processed. Thus, the maximum demand is not affected by the number of bales produced.

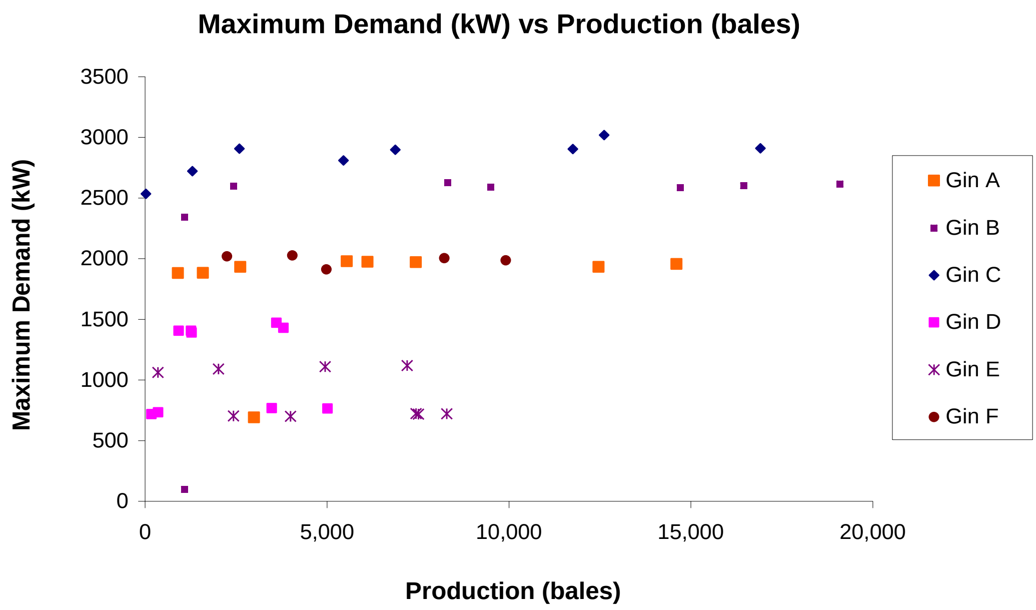


Figure 4.4: Relationship between maximum demand (kW) and production (bales)

4.1.6 Electricity tariff review

4.1.6.1 Electricity tariffs

The energy market in Australia is quite complex and dynamic. Prices shift due to many variables and there are numerous regulatory and government requirements. Tariffs and charges may vary in different areas of the country depending on supplier, consumption profile, and the metering and control that has been fitted. The electricity price may also vary according to time of the day, month or season and charge bands. For example, in many cases, off-peak electricity may cost only 1/3 of the peak electricity cost.

4.1.6.2 Gins' tariff charges profile

All gins' electricity has been supplied by different companies. Based on bills observation and interview sessions, all gins have used Time of Use tariffs which allow the meter to differentiate between peak and off-peak consumption periods. Electricity consumed in the off-peak period will be considerably cheaper than electricity consumed in the peak period. This allows the customer to take advantage of cheaper off-peak electricity and benefit from lower electricity costs. When choosing a Time of Use tariff, customers need to consider the time and application of power usage in order to achieve the lowest cost.

In electricity bills, demand charges have been applied under network charges. A demand charge is based on the highest average rate of usage over any 15 minute period during the month. The demand indicator is reset to zero at each monthly meter reading. It is necessary for all gins to minimize the demand since it may significantly influence electricity costs. Charge rates applied for demand charges are calculated based on kilo-watts (c/kW) or kilo-volt ampere (c/kVA) used. The electricity charges profile for each gin is discussed as below:

Gin C: Gin C is under contract with the AGL Company. The tariff applied is not on a Government tariff while contract rates are set in advance and are agreed upon by both parties. From the last negotiations with AGL, Gin C entered into a one year agreement for 2009. The tariff has been compiled in Table 4.4. The time for the peak period is 7am – 11 pm, Australian Eastern Standard Time, everyday except Saturday and Sunday while the off-peak period is at all times outside the peak period.

Table 4.4: Tariff charge for Gin C

Period	Start Date	End Date	Energy Charge (c/kWh)	
			Peak	Off Peak
1	1/1/2009	31/3/2009	16.2196	4.1006
2	1/4/2009	30/6/2009	5.9523	3.5065
3	1/7/2009	30/9/2009	5.9711	3.2860
4	1/10/2009	31/12/2009	8.8746	3.4387

Gin F: Gin F is under contract with Country Energy. The network charges tariff is the published BLNS1AO tariff (Country Energy, 2007). From the last renegotiations with Country Energy, Gin F entered into a four year agreement with Country Energy - for 2009, 2010, 2011, and 2012. The tariff has been compiled in Table 4.5. The peak period time is from 7.00am – 9.00am and 5pm – 8pm on weekdays, the shoulder period is from 9.00am – 5.00pm and 8.00pm – 10.00pm on weekdays and the off –peak period is at all other times.

Table 4.5: Tariff charge for Gin F

Start Date	End Date	Energy Charge (c/kWh)		
		Peak	**Shoulder**	**Off Peak**
1/1/2009	31/3/2009	9.9261	9.9261	3.5288
1/4/2009	30/6/2009	6.4864	6.4864	3.5288
1/7/2009	30/9/2009	8.3412	8.3412	3.7907
1/10/2009	31/12/2009	7.7862	7.7862	3.5315
1/1/2010	31/3/2010	10.8176	10.8176	3.5315
1/4/2010	30/6/2010	7.5641	7.5641	3.9636
1/7/2010	30/9/2010	8.1595	8.1595	3.9501
1/10/2010	31/12/2010	7.6159	7.6159	3.7160
1/1/2011	31/3/2011	10.5446	10.5446	3.6876
1/4/2011	30/6/2011	7.3460	7.3460	4.1580
1/7/2011	30/9/2011	8.1922	8.1922	3.9605
1/10/2011	31/12/2011	7.6369	7.6369	3.7340
1/1/2012	31/3/2012	10.9000	10.9000	3.7340
1/4/2012	30/6/2012	7.4359	7.4359	4.1986
1/7/2012	30/9/2012	7.9590	7.9590	4.0813
1/10/2012	31/12/2012	8.8008	8.8008	3.8948

Gin A, B, D and E are under contract with Ergon Energy under Time of Use Tariff 22. This tariff can be attractive to customers whose operations can be managed so that about 30% or more of their total usage occurs at night or weekends. Low Rate electricity is available between 9pm and 7am, Monday to Friday and all weekend. Electricity used outside these hours is charged at the higher rate. The rates applied are shown in the Table 4.6 below.

Table 4.6: Tariff charge for Gin A,B,D and E

Rates applied	
Time	**Rates (c/kWh)**
9 p.m – 7 a.m (Monday to Friday and all weekend)	7.810
All other consumption High Rate - (7.00am to 9.00pm Mon-Fri)	22.176
Service fee per metering point per month	25.01

4.1.7 Gin's electricity cost

Based on the last 24 months data, the average electricity cost per kWh used ($/kWh), the electricity usage per bale (kWh/bale) and the total electricity cost per bale ($/bale) are calculated and shown in Table 4.7. The average ranged from $0.10 - 0.23 /kWh, 46.5 – 58.55 kWh/bale and $5.12 – 11.94/bale respectively. The average fixed cost per bale for each gin is calculated by dividing the fixed cost, applied to the gin in non-ginning seasons with the total bales produced. Fixed cost consists of a capacity charge, network access charge, metering and services charge, etc that have been applied by the electricity company. Gin F recorded the highest use of electricity in producing one bale, while Gin C was the highest payer for kWh use and per bale produced. This is because the electricity charge for Gin C was more expensive than for the other gins. Overall, as found in Table 4.7, the fixed charges could occupy up to 68% of the total electricity cost with Gin C recording the highest percentage.

Table 4.7: Average electricity cost per kWh used (c/kWh), electricity usage per bale (kWh/bale) and electricity cost per bale ($/bale) for each gin.

Gin	Capacity (bales/hour)	$/kWh paid	Electricity (kWh/bale)	Total electricity cost ($/bale)	Fixed cost per bale ($/bale)	% Fixed cost
Gin A	40	0.11	48.80	5.22	0.56	10.73
Gin B	54	0.10	47.80	4.60	0.72	15.65
Gin C	60	0.23	52.28	11.94	8.20	68.68
Gin D	30	0.12	58.00	6.96	1.20	17.24
Gin E	24	0.11	46.50	5.12	0.33	6.45
Gin F	40	0.13	58.55	7.47	1.62	21.69

4.1.7.1 Evaluation of electricity cost

An evaluation of the electricity cost has been undertaken for Gin C by analysing 2 years of electricity bills. There are three components which can affect the electricity cost. They are: (1) energy charge (2) network charge and (3) operator charge. Metering and service charge are constant.

Energy Charge

The rate per kWh charged has been agreed upon in the agreement between the gin and the electricity company (AGL Company). As the production increases, the energy usage (kWh) will also increase, leading to higher overall energy costs.

Network Charge

A network charge is charged by network companies to electricity retail companies for supplying electricity to the customer. Electricity retail companies will pass these charges on to the customer without adding a margin. A network charge consists of a charge for (1) recorded demand, (2) capacity charge and (3) network charge for the usage. The capacity charge is the energy networks have reserved. For Gin C, a capacity of 2,900 kW has been reserved at all the times, regardless of whether it is used or not (fixed charge). A certain amount of fees will be applied every month for every kW reserved. The capacity amount is basically based on the average maximum demand of the gin.

Network prices for ginning and non-ginning seasons are almost constant throughout the year. As an average, the total monthly network charge for Gin C has been recorded as being around $23,000 in ginning seasons and $18,000 in other times. The difference of price stated is caused by a demand charge which in average was about $4600 in the ginning seasons. The demand charge is dependent on demand used by ginners while running the gin. From observation, the demand was the same every month in the ginning seasons for Gin C.

Operator Charges (ancillary and market fee)

An operator charge consists of an ancillary and market fee. It has been linked to each kWh used. Thus, the amount of the operator charge is parallel with energy usage.

Metering and Service Costs (fixed charge)

This is the fee charged to the customer for meter reading, reconciliation and billing. For the metering charge, it is constant throughout the year where on average it was about $220.

Figure 4.5 and 4.6 shows the portion inside the electricity cost of Gin C. For non-ginning seasons all the cost (98%) was occupied by the Network charge where it was basically the fixed charge applied (capacity charge and metering/services cost) by the supply company (Figure 4.5). By contrast, in ginning seasons, the network charge only occupied about 36% of the total electricity cost (Figure 4.6). Three quarters of that network charge was also filled by fixed charges, while one quarter was affected by charges for energy usage (TUOS & DUOS) and recorded demand. The component under network charge was shown separately in pie chart in respective season.

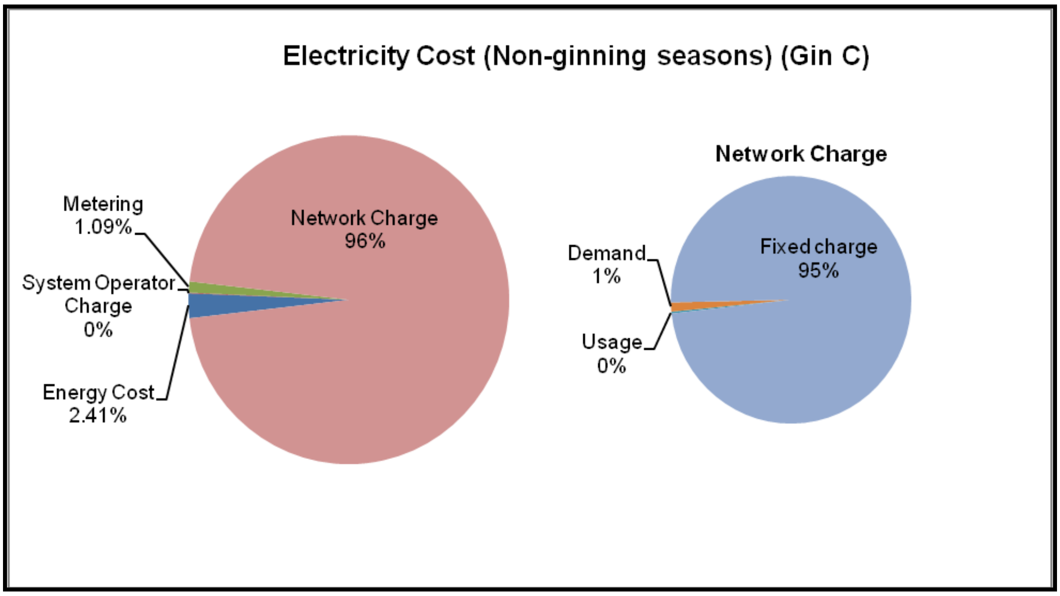


Figure 4.5: Electricity cost for Gin C (non-ginning seasons)

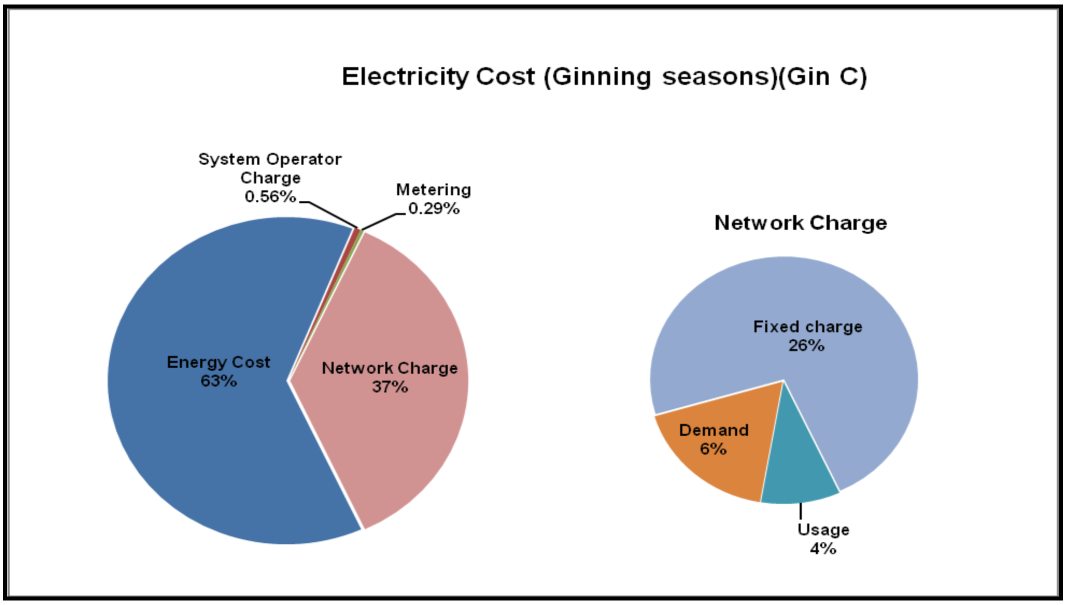


Figure 4.6: Electricity cost for Gin C (ginning seasons)

For Gin F, the corresponding results are shown in the pie chart in Figures 4.7 and 4.8. Different from Gin C, the energy cost at Gin F was influenced by: (1) Energy Charge – charge applied for each kWh used (2) Market participation charge – consisting of fee (ancillary fee, greenhouse reduction fee, etc) that was applied to each kWh use (3) Network charge – which consists of demand, usage, metering and access charge (the components under network charge were shown separately in pie chart for respective season). The only fixed charge was the metering charge and the network access charge and there was no fixed charge such as a capacity charge on this gin. For this gin, the electricity cost can be easily managed by reducing the energy and demand use.

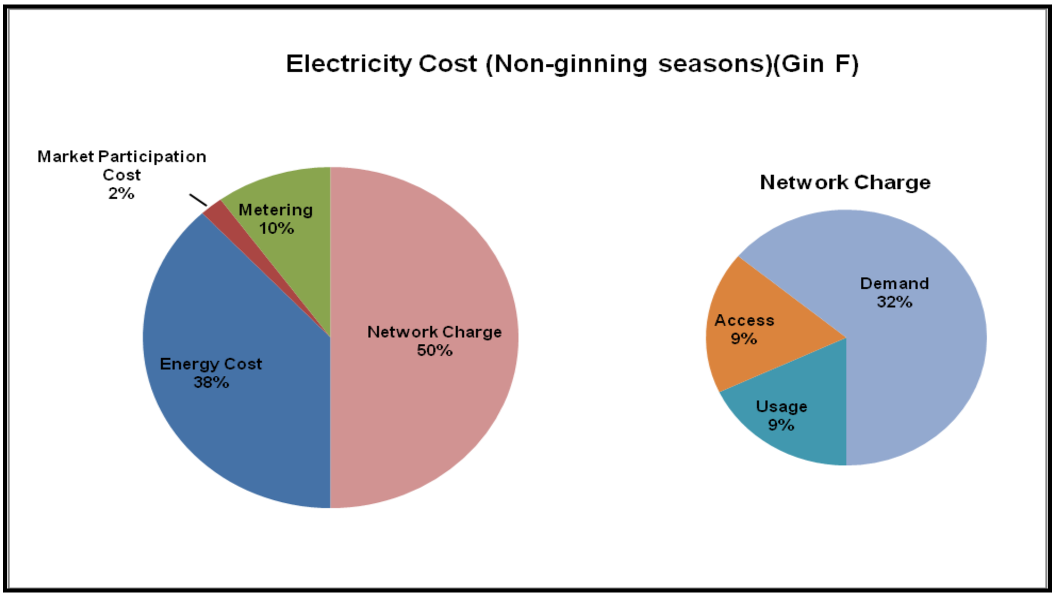


Figure 4.7: Electricity cost for Gin F (non –ginning seasons)

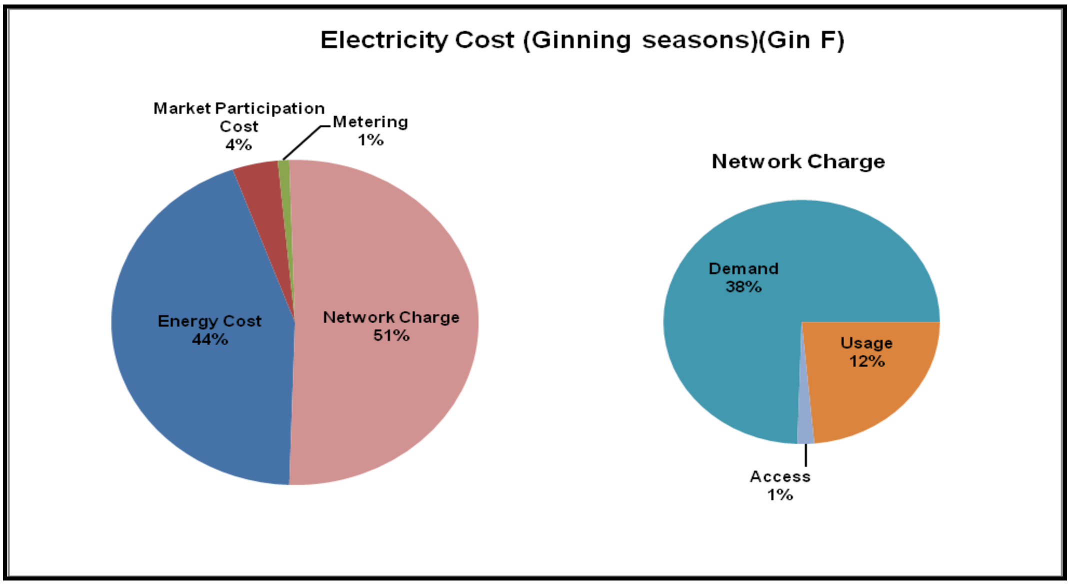


Figure 4.8: Electricity cost for Gin F (ginning seasons)

From these two gins, it can therefore be seen that, in ginning seasons, the electricity cost which is caused by both usage and demand has occupied at least 70% of the total electricity cost. The capacity charge applied to Gin C was really significant to the ginner as they had to pay for each kW reserved every month, regardless of the ginning seasons. The ginner at Gin C may therefore consider changing the tariff or reducing the maximum demand to reduce the capacity charge.

4.2 Load factor

Load factor can be defined as the ratio of the average load supplied during a designated period to the peak load occurring in that period, in kilowatts. Load factor is an indicator of how steady an electrical load is over time. Low load factor means that ginners should look for ways to even out the electrical usage and reduce the maximum demand. By increasing load factor, ginners will reduce the impact of monthly demand (kW) charges on their bills. Using a month as the designated period, the load factor can be calculated by dividing the kilowatt-hours delivered during the month by the peak load for the month times the total number of hours during that month. It can be expressed as:

$$\text{Load factor} = \frac{\text{kWh monthly usage}}{\text{kW peak demand} * \text{number of billing days} * \text{24h/day}} \quad (4.1)$$

By using the above formula, the load factor for each gin has been calculated and shown in the table in Appendix 4.3. Based on the results of that table, it is found that during the ginning seasons, load factors have varied between 1.7-66%, typically around 20-30%.

4.3 Power factor

Power factor is the ratio between real power and apparent power in a circuit. Real power is the actual amount of power consumed by the customer which is expressed as Watts, while apparent power (kVA) is the amount of power drawn from the utility lines at any instant of time. In other words, apparent power is a vector sum of the real power (Watts) and reactive power (VAR), which is the power that transformers and conductor have to carry.

A high power factor means that electrical capacity is being utilized effectively, while a low power factor indicates poor utilization of electric power and more power being wasted. Improving the power factor can reduce the peak load by reducing the 'wattless' currently drawn. The power factor can be expressed as:

$$\text{Power factor} = \frac{\text{Real power (kW)}}{\text{Apparent power (kVA)}} \quad (4.2)$$

Based on the above formula, the power factor for each gin has been calculated and has been compiled in Table 4.8. Some of the data is gathered from the electricity company. It can be seen that the average power factor was not less than 0.85 and the maximum is 0.97 which was recorded at Gin C. These may be the typical values seen in industrial plants, where measures have often been taken to increase the power factor to a reasonable level.

Table 4.8: Average of power factor for each gin while ginning is in progress

Gin	Power Factor
Gin A	0.91
Gin B	0.89
Gin C	0.97
Gin D	0.81
Gin E	0.87
Gin F	0.96

4.4 Conclusion

This chapter has evaluated and reviewed the electricity consumption and electricity profile of the whole gins. Data for monthly production and electricity usage (kWh) from January 2007 until December 2008 have been collected from 6 gins, and yearly usage and production from 2 other gins, out of total 40 gins in Australia. The benchmark of electricity use (kWh) per bale has been found to range between 44-66 kWh, with average around 52.3 kWh. This was consistent with the data identified from overseas research. It has also been found that the electricity consumption is nearly linearly correlated with bale numbers produced between different gins. This may be related to the fact that all gins were using similar machines and following similar operation procedures for all incoming cotton. The electric motors were not switched off or restarted during the ginning process (daily operation).

The total electricity cost per bale ($/bale) has been found to range between $5.12 – 11.94 per bale. From this survey, it has been found that the electricity fixed charges (network charge, capacity charge, etc) was a significant cost for cotton ginning operations. This is understandable because cotton ginning is a seasonal operation, running less than 3 months a year. In particular, it has been found that at Gin C, the fixed charges can be up to nearly 70% of the total electricity cost in this plant. This illustrates the great importance of comparing and selecting suitable tariff structures (e.g., tariff negotiation and shopping around is important).

Overall, it has been found that electricity usage comprised about 61% of total energy use and constituted about 77% of the overall energy cost. Electricity cost was strongly influenced by electricity usage and maximum demand. For similar electricity consumption per bale, the electricity cost per bale ($/bale) could be very different, and there can be up to 100% difference for different electricity tariffs. During the ginning seasons, the electricity cost which was caused by usage and demand charges occupied at least 70% of the total electricity cost. It is therefore necessary to reduce maximum demand and usage as both of them will reduce the electricity cost.

In terms of electricity utilization, it has been found that handling has occupied about 50-60% of total power required. Maximum demand has occupied 48-67% of total kW required to run all the energy-consuming equipment. During the ginning seasons, load factors for each gin have varied between 1.7-66%, typically around 20-30%. All the gins had an average of power factor not less than 0.85, the highest being 0.97 at Gin C.

CHAPTER 5

Drying Gas Consumption at Whole Plant Level

This chapter will discuss gas consumption in cotton ginning. The ginners' practice in regulating the temperature based on incoming moisture will first be described. The relationship between gas usage with temperature, reduction in moisture and production (bales) are then discussed. The thermal efficiency of the drying process is also estimated.

5.1 Ginning gas consumption in Australia

5.1.1 Method of gas data collection and analysis

Data for monthly production and gas usage have been received from 6 gins for the period of from January 2007 until December 2008. Two of the gins used Natural Gas as fuel while the rest used LPG gas. The usage of natural gas was usually recorded every month whereas the LPG usage was taken seasonally. With the data obtained, both types of gas usage had been recorded in volume (litres or m^3) terms. To standardise, both have been converted to energy content (GJ).

Among the 6 gins, 5 gins have also provided the Shift Monitor Control Sheets for the last 24 consecutive months (Gin A, B, D, E, F) but one of them (Gin F) was not complete. Gin F was later contacted by e-mail in order to get the information regarding its practices.

Data from the Shift Monitor Control Sheet were entered into Microsoft Excel and have been arranged to identify the patterns of temperature applied with incoming cotton moisture. The correlation between gas usage with production, temperature applied in the dryer and moisture reduction will also be analysed. Overall thermal efficiency of dryers will then be calculated.

5.1.2 Ginners practices

Based on actual situations, most of the ginners have their own procedures in processing incoming modules. These are generally subjective and experience-based. However, ginners' decisions in regulating the temperature are strongly influenced by module moisture and the amount of trash. Based on the Shift Monitor Control Sheets, ginners' practice in regulating temperature based on incoming moisture is shown in Table 5.1, where the temperature applied is the averaged temperature from all the Shift Monitor Control Sheets provided. A summary of their practices is also provided below.

Gin A: Might have started to dry cotton from as low as 2% moisture, when the incoming modules had a lot of trash. However, the quantities of incoming module moisture less than 4% were quite small (7%). About 50% of incoming module ginned had a moisture content ranging within 4-5%. Gin A used both of the driers in all moisture ranges.

Gin B: Started to dry cotton at 7.5% moisture and it used only one dryer in all moisture percentages. About 68% of incoming module ginned had a moisture content ranging within 7-8%, while another 32% had less than 7.5% moisture.

Gin C: Started to dry cotton at 8% moisture. Cotton with a moisture content of 8% or less was conveyed through the system with ambient temperature. About 70% of incoming module ginned had moisture below 8%, with the remainder being between 8-12% moisture.

Gin D: Started to dry cotton from 4% moisture. The gin uses the second dryer if module moisture is higher than 8%. From the data recorded, this cotton has occupied 16% of incoming modules. About 60% of incoming module ginned had a moisture content of between 6-8%.

Gin E: Started to dry cotton at 5% moisture and it used only one dryer for all moisture percentages. About 65% of incoming module ginned had a moisture content ranging within 6-7%.

Gin F: Started to dry cotton at 8% moisture. The first dryer would be turned on at 21ºC if the incoming cotton was dirty.

Table 5.1: Module moisture (%) and temperature applied (°c) for four gins

Module moisture (%)	Dryer's Temperature (°C)					
	Gin A		Gin B	Gin D		Gin E
	Dryer 1	Dryer 2	Dryer 1	Dryer 1	Dryer 2	Dryer 1
2 to 3	50	50				
3 to 4	48.20	48.20				
4 to 5	52.43	52.45		55		
5 to 6	58.59	58.38		62.14		38.91
6 to 7	72.01	70.48		67.82		41.23
7 to 8	69.37	68.68	40.0	74.07		44.13
8 to9	75.13	75.50		76.86	60.3	45.02
9 to 10	79.08	79.74		82.25	61.25	44.14
10 to 11	83.33	83.33		90.56	60	45.57
11 to 12	90.00	95.00	60	98	60	52
12			70	100	60	
13			80	100	60	
14				110	60	
15				100	60	
16				100	60	
17				100	60	
18				95	60	

5.1.3 Relationship between dryer's temperature and module moisture

Data for the averaged dryer temperature and incoming module moisture for the 6 gins are plotted in Figure 5.1. Based on the graph, it can be seen that among these gins, the regulated temperature generally gradually increased as module moisture increased to up to 16%. After that, the temperatures turned to constant or slightly declined. The constant temperature points were obtained from Gin D (Table 5.1). Because the percentage of incoming modules having a moisture higher than 12% was really small, so the high temperature regime of 80-100°C was only applied to a small number of incoming modules. The maximum module moisture that has ever been recorded was 18%. Overall, Gin E had adopted a lower temperature regime than Gin A and Gin D for each incoming moisture percentage.

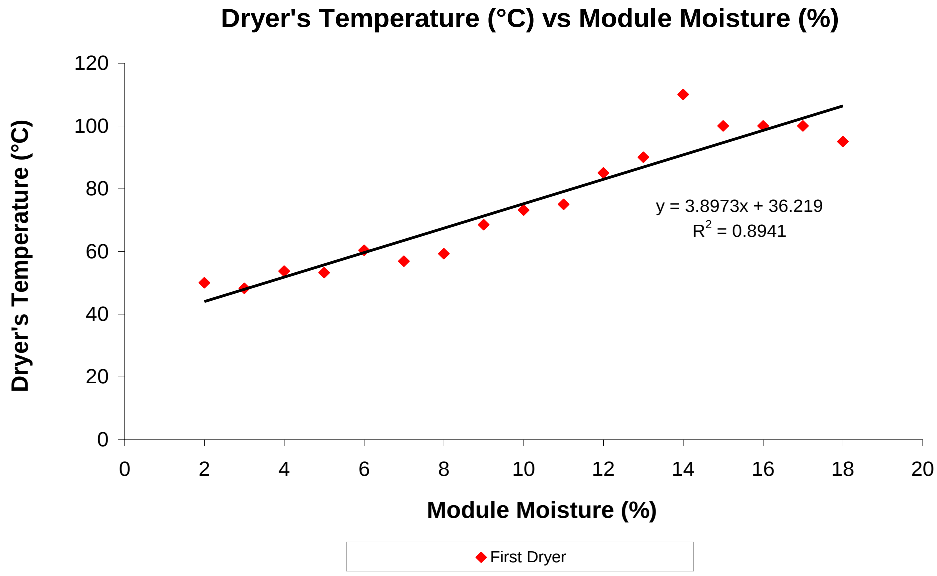


Figure 5.1: Relationship between dryer's temperature and module moisture

5.1.4 Variation between gas usage with dryer's temperature and Δ moisture (%)

Figures 5.2-5.5 show the correlation between gas consumed with temperature and percentage of moisture reduction in modules. This has been plotted using monthly data of gas usage per bale (GJ/bale) and monthly average moisture and temperature at Gin A and Gin E, as both gins' gas usage was recorded each month.. From these figures plotted, it can be seen that gas used per bale varied significantly for the same drying temperature or the same moisture reduction. This indicated that the gas use was also affected by other factors, such as dryer design and drying time.

Visually, Figures 5.2-5.5 show that in general, gas usage would increase when the temperature and percentage of moisture reduction increased. Both of the figures have also illustrated that gas use at Gin A was nearly at the same level as at Gin E, although temperature applied at Gin A was higher and had greater moisture reduction than Gin E, implying that Gin A was more efficient than Gin E in terms of drying efficiency.

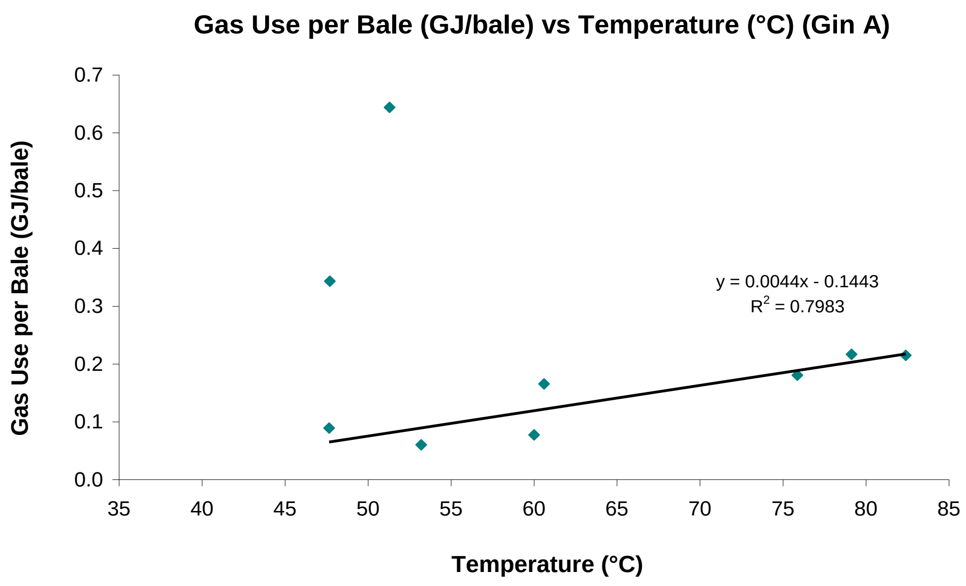


Figure 5.2: Relationship between gas consumption (GJ) / bale with temperature (°C) (Gin A). Note: The two largest results, with respect to the y-axis, were found to be outliers as their data are significantly further away from the majority of the data. These points were removed from the regression as they can strongly influence the classical statistical procedure and even can cause misleading result .

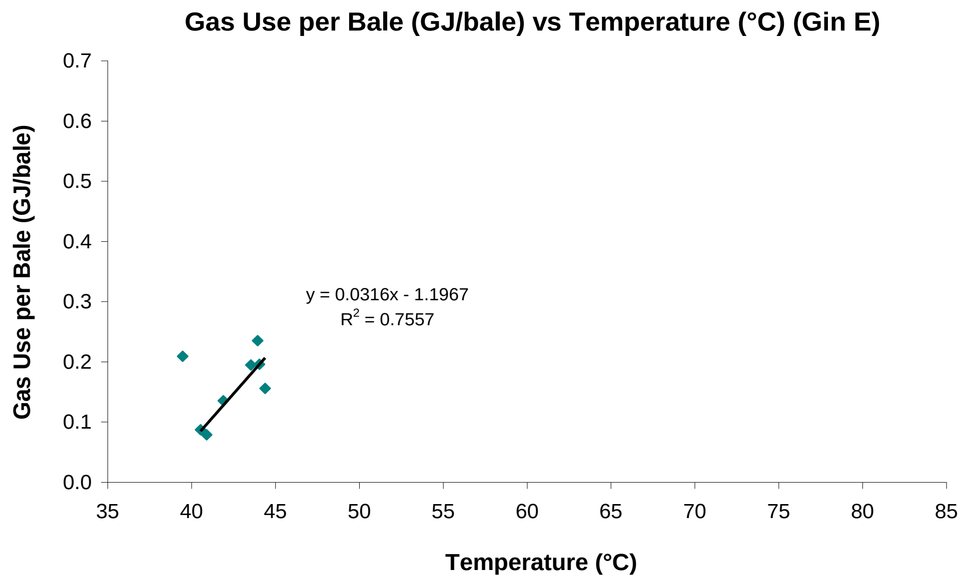


Figure 5.3: Relationship between gas consumption (GJ) / bale with temperature (ºC) (Gin E)

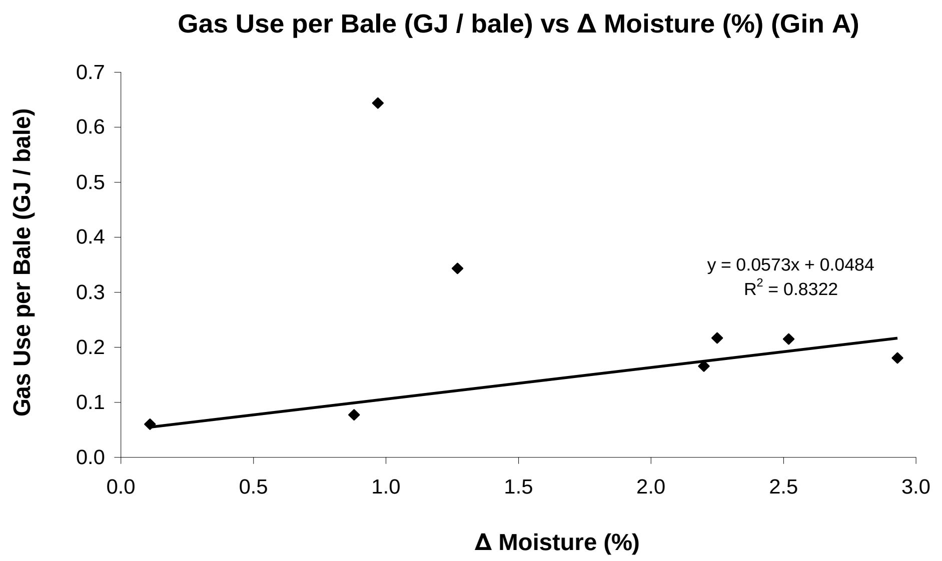


Figure 5.4: Relationship between gas consumption (GJ)/ bale with Δ moisture (Gin A)
Note: The two largest results, with respect to the y-axis, were found to be outliers as their data are significantly further away from the majority of the data. These points were removed from the regression as they can strongly influence the classical statistical procedure and even can cause misleading result .

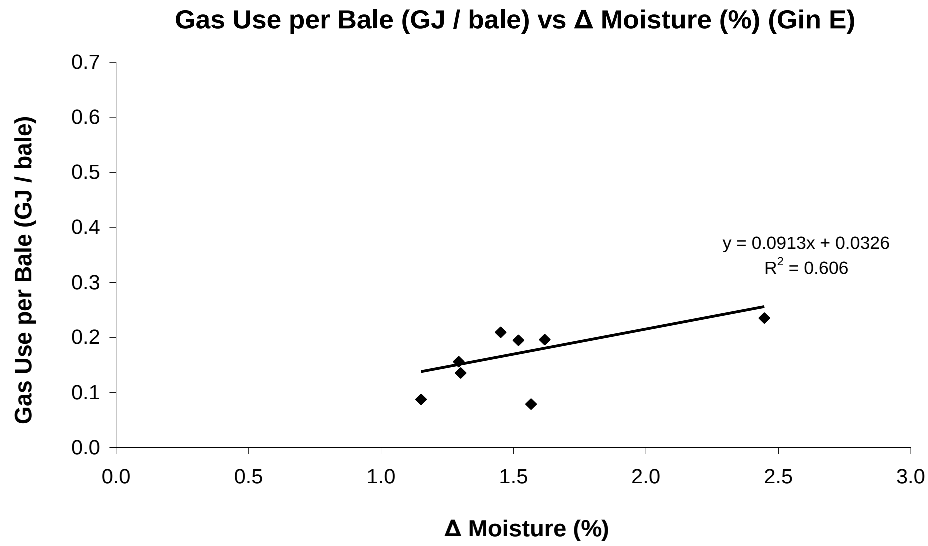


Figure 5.5: Relationship between gas consumption (GJ)/ bale with Δ moisture (Gin E)

5.1.5 Relationship between gas consumption (GJ) with production (bales)

The data of yearly gas usage and production for all gins gathered are compiled in Table 5.2 and have been plotted in Figure 5.6.

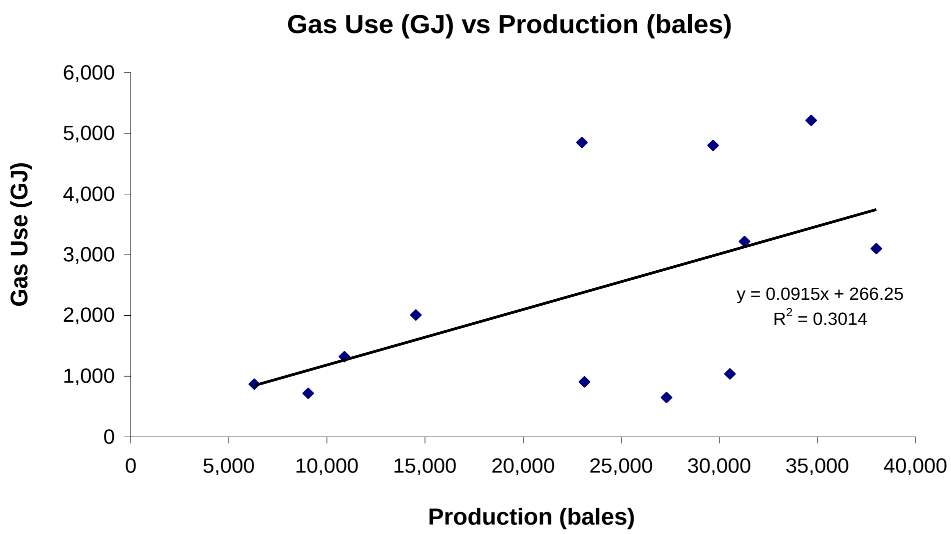


Figure 5.6: Relationship between gas consumption (GJ) with production (bales)

Table 5.2: Gas usage and production for each month

Year	Month	Gas usage (GJ)						Production (bales)					
		Gin A	Gin B	Gin C	Gin D	Gin E	Gin F	Gin A	Gin B	Gin C	Gin D	Gin E	Gin F
2007	Mar	1026.33			714.28	622.78		1,594			3,486	3,997	
	Apr	1109.44	1926.97	90.46	0	655.83	1020.10	12,463	9,503	5,426	5,018	7,515	4,985
	May	878.82	1172.81	484.27		1735.07	- 116.35	14,605	19,097	16,913		8,295	9,918
	Jun	202.57	0	387.97		1459.33	0	2,622	8,320	6,872		7,451	8,229
	Jul		0	73.04	0	328.596			1,086	1,300	362	2,430	
	Aug				0						179		
2008	Mar				468.55	0					3,614	357	
	Apr	1028.93	0	2.92	405.13	568.05	868.44	2,998	1,090	24	3,808	7,205	0
	May	1012.83	2063.06	210.81		964.08	0	6,113	16,447	11,759		4,950	4,050
	Jun	1001.40	2103.57	388.92	0	474.59	0	5,547	14,707	12,620	925	2,019	2,256
	Jul	1612.21	1046.07	27.65	447.04			7,441	2,436	2,595	1,281		
	Aug	194.26		17.46	0			904		315	1,265		

From the Figure 5.6, it can be seen that the relationship between gas consumption and number of bales is not significant. That is, the number of bales produced is not well correlated with the gas usage for the gin. As the condition of incoming module and ginners practice varied across all gins, the gas usage per bale was likely to be more strongly influenced by the moisture and the regulated temperature of the dryer, and the drying time etc.

5.1.6 Development of a gas usage benchmark

The gas usage benchmark is established using yearly gas usage and production for all gins gathered. The data is depicted in Table 5.3. The benchmark of gas use (GJ) per bale around was around 0.029-0.154 GJ/bale. This was less than half of the data available from overseas which had recorded about 0.29 GJ/bale. For normal harvest seasons in Australia, the drying process used about 0.74-3.90 m^3/bale of natural gas or 2.27-5.61 litres/bale of LP gas. By contrast, a survey of gas usage in US in 1987 recorded about 2.3 gal per bale of LPG (8.72 litres) and 248 ft^3 of natural gas per bale (6.94 m^3) (Anthony and Eckley, 1994). The cost of gas in producing one bale in Australia was around $0.98 - 3.39 /bale.

Table 5.3: Gas usage and cost per bale

Gin	Capacity (bales/hour)	Energy usage (GJ/bale)	Gas usage		Cost ($/bale)
			Natural gas (m3/bale)	LPG (litres/bale)	
Gin A	40	0.148		5.61	3.39
Gin B	54	0.114		4.31	2.65
Gin C	60	0.029	0.74		0.98
Gin D	30	0.102		3.85	2.33
Gin E	24	0.154	3.90		1.14
Gin F	40	0.061		2.27	1.30

By relating the drying practices with the gas usage, it can be seen from Table 5.3 that, even though Gin E has used one dryer with a lower temperature at all times, gas usage at Gin E was the same as for Gin A which operated both of its dryers at higher temperatures. Both Gin A and Gin E had used around 0.15 GJ/bale. This shows that gas usage at these gins is not totally dependent on temperature and number of dryers used but may be influenced by other factors such as (1) cotton condition- harvest conditions (2) gin specification – airflow volume, pipe size, pipe length (3) local weather (4) ginner's decision in the drying and heating time.

Overall, from Table 5.3, it can be seen that Gin C and Gin F were among the lowest gas users where they recorded 0.029 and 0.061 GJ/bale respectively. This may be due to their practice where they started using the dryer when incoming cotton contained more than 8% moisture. Table 5.3 also shows that gas usage did not depend on gin capacity.

As an average, most incoming cotton moisture was lower than 8%. It is therefore suggested that cotton with a moisture content of 8% or less should not be conveyed through the system with heated air when the ambient temperature is sufficient. The only instance that dryer cotton should be conveyed with heated air is if the cotton has excessive trash content where it may be required to be processed at a lower temperature for a long time (reducing the processing rates) to clean the cotton sufficiently. However, cotton with excessive trash rarely occurs these days, as a result of improved practices on-farms, e.g. better defoliants/improved varieties.

By combining all the energy data for the 6 gins, it has been found that fuel consumed in dryers averaged about 100 MJ/bale, and constituted about 39% of total energy used at gins (Figure 4.1). It was also found that in any individual gin, gas usage never exceeded 50% of the overall energy use. In terms of a cost profile (Figure 4.2), on average it cost $2.00/bale and it constituted about 23% of the overall ginning cost. The average drying gas cost in Australia was less than half the values recorded overseas.

5.1.7 Greenhouse gas emission

With the increasing community concern about global warming and climate change, the greenhouse gas emissions (GHG) from cotton ginning will also need to be monitored. To calculate GHG emissions from energy used, the algorithms (Equation 5.1) as outlined in the Australian Greenhouse Office Factors and Methods workbook (2005) will be adopted:

$$GHG\,emission\,(kg\,CO_2\,equivalent) = Q * EF \tag{5.1}$$

in which Q is fuel consumed expressed in GJ or electricity (kWh) used. EF is the relevant emission factor given below:

Energy Sources	**Emission Factor kg CO_2 equivalent per GJ LPG, Natural Gas or per kWh electricity**
Liquefied Petroleum Gas (LPG)	59.9
Natural gas (NSW)	71.3
Electricity	1.04

Therefore, the total greenhouse gas emissions (kg CO_2 -e) of an average ginning process due to energy use (if only LPG is used)

= 59.9 * Total LPG use (GJ) + 1.04 * Total electricity use (kWh)

= 59.9 * 0.1 + 1.04 * 52.3

= 60.38 kg CO_2 -e

The calculation of GHG emission above is based on the average of fuel (GJ) and electricity (kWh) used per bale across Australia. It shows that the ginning process on average emits about 60.38 kg CO_2 of greenhouse gases. When there is no drying energy is used, the range of greenhouse gases emitted is around 45.76 to 68.64 kg CO_2 per bale. Chen and Baillie (2007) have found that the total greenhouse gas emission due to on-farm energy uses is between 275-1404 kg CO_2/ha. One hectare of irrigated cotton, on average, can produce 8 bales per hectare. Thus, the CO_2 emission due to on-farm energy uses at the growing stage varies between 35 -176 kg/bale. The CO_2 emission due to ginning (processing) is adding another 35% to 170% to that figure.

5.2 Overall thermal efficiency

In drying, energy input is used to vaporize the moisture and is transformed into latent heat. However, not all the energy put into a system ends up producing a useful result. According to the second law of thermodynamics, a certain amount of energy is unavailable for productive work. In addition, the available energy does not perform an equivalent amount of work because of losses such as friction, heat loss, incomplete combustion and other thermodynamics and mechanical losses incurred during the transfer of energy from one form to another (Eide, 1997). The thermal efficiency will always be between 0% and 100%.

$$\begin{aligned} Energy\ in\ =\ &Available\ energy\ to\ do\ work + Unavailable\ energy\ \ for\ \ poductive\ work \\ &+ losses\ during\ energy\ transferring \end{aligned} \tag{5.2}$$

The overall thermal efficiency is used to estimate the actual performance for a thermal process and can be expressed as:

$$Overall\ thermal\ efficiency\ ,\ \ \eta_{th}\ =\ \frac{Net\ work\ output}{Total\ energy\ input} \tag{5.3}$$

5.2.1 Calculating average dryer's thermal efficiency

Average Thermal efficiency for a dryer may be calculated based on the following procedures:

i) Average energy consumption per bale.
ii) Average incoming moisture content (%) before entering the dryer.
iii) Average desired percentage of moisture content that seed cotton has to reach after the drying process.
iv) By assuming that the thermal efficiency of the dryer is 100% when 2.5 MJ energy is used to remove 1 kg moisture.
v) All percentages for moisture content are based on wet weight basis.

As an example, for an average cotton gin in Australia, the calculation is as follows:

Typical incoming seed moisture (before dryer) = 6.5%
Desired moisture content (Moisture content (%) of seed cotton has to reach after the dryer) = 5.15%
Energy used = 100 MJ/bale = 0.10 GJ/bale

Solution:
The weight of bale = 227kg (at 7% final moisture content)
By using the wet basis moisture percentage formula, weight of solid (dry matter) can be calculated as follows:

$$\text{Wet weight basis percentage moisture, 7\%} = \frac{kg\ H_2O * 100}{kg\ H_2O + kg\ solid} \quad (5.4)$$

$$0.07 = \frac{kg\ H_2O}{227}$$

$$kg\ H_2O = 15.89\ kg$$

By substituting kg H_2O = 15.89 in formula (5.4), thus, weight of solid = 211.11 kg (the weight of solid is fixed in any moisture content (%)).

By using the same formula (5.4), the weight of H_2O for seed cotton with 6.5% and 5.15% percentage moisture can be determined by substituting kg solid into the formula:

When seed cotton is at 6.5%,

$$\text{Wet weight basis percentage moisture, } 0.065 = \frac{kg\ H_2O}{kg\ H_2O + 211.11}$$

$$kg\ H_2O\ \text{ at } 6.5\% = \mathbf{14.68\ kg}$$

When seed cotton is at 5.15%,

$$\text{Wet weight basis percentage moisture, } 0.0515 = \frac{kg\ H_2O}{kg\ H_2O + 211.11}$$

$$kg\ H_2O\ \text{ at } 5.15\% = \mathbf{11.46\ kg}$$

Therefore, kg H_2O removed = 14.68 – 11.46 = 3.22 kg

From the assumption, to remove 1 kg H_2O we need 2.5 MJ of energy at 100% thermal efficiency. So, in an ideal situation (100% thermal efficiency), energy = 2.5 x 3.22 = 8.05 MJ

Based on information above, the actual energy used is 0.1 GJ/bale.

From an overall thermal efficiency formula (5.3),

$$\text{Overall thermal efficiency (\%)}, \ \eta_{th} = \frac{\text{Net work output} * 100}{\text{Total energy output}}$$

$$= \frac{0.00805 * 100}{0.10}$$

$$= \mathbf{8.05\%}$$

Thus, only 8.05% of energy input was converted into work for drying purposes while others were lost. The same calculation procedure has been applied to calculate thermal efficiency for all gins as shown in Appendix 5.1. It can be seen that the highest percentage achieved was 14.25% in Gin D during the month of August 2008. In comparison, it was found by Chen e*t al* (2002) that the overall grain drying thermal efficiency was often between 40-50%.

5.3 Conclusion

This chapter has reviewed the drying process and its effect on drying gas consumption.

Based on the analysis of collected data, it has been found that among the six gins, the regulated temperature gave good fit with incoming module moisture. Drying temperature generally increased as module moisture increased, to up to 16% moisture content. Gas usage was strongly influenced by the moisture and regulated temperature. It may also be significantly affected by the "unnecessary" practice of heating air when the use of ambient temperature may be adequate.

It has also been found that gas usage per bale for each gin ranged between 0.029-0.154 GJ/bale with the average being 0.1GJ/bale. Cost of gas in producing one bale was around $0.98 - 3.39 /bale with the average being $2/bale. By combining all the energy data for the 6 gins, it has been found that fuel consumed in dryers constituted about 39% of total energy used at gins. Generally the lowest cost occurred where Natural Gas was used.

Overall thermal efficiency of the drying process was less than 15%. The highest percentage achieved was 14.25% in Gin D in August 2008.

It was also estimated that 60.38 kg of CO_2 was emitted for ginning each bale of cotton.

CHAPTER 6

Procedures of Detailed Monitoring

In this chapter, the procedures of detailed energy monitoring for the advanced level will be presented. This will include the objectives of monitoring, parameters measured, the equipment used and the procedure used in taking the data.

6.1 Objectives of detailed monitoring

The main objective of detailed monitoring is to estimate the electricity consumption and energy use breakdown in the ginning sub-processes (handling, cleaning, gin stand and packaging) and to investigate the energy usage patterns (electricity and gas) for each sub-process with variables such as incoming cotton moisture, trash and variety, lint quality and bales produced.

Based on the main objective and the procedure performed, it is considered that the advanced level of monitoring discussed in this chapter essentially corresponds to the energy audit at Level 2 and Level 3 (Joint Technical Committee EN/1, 2000).

In the monitoring, the information about each incoming module, lint quality and bales produced was recorded. The data of electricity usage was also collected in the following three different ways: (1) each meter inside the gin that measures each switchboard – as routinely recorded and compiled by the electricity company (2) electricity usage of each motor above 10 kW – measured by the portable power meter and (3) electricity usage of each motor below 10 kW – measured by hand held current tong. Gas usage was recorded in an operator log book by ginners after each shift everyday. The readings of inlet and outlet temperature of the dryer were logged using temperature data logger.

6.2 Monitoring parameters

Detailed monitoring was started by collecting the following relevant data: (1) characteristics of incoming cotton (2) power quality parameters from motors and electricity monitoring (3) lint quality (4) number of bales produced from each module (5) gas usage, and (6) air temperature at inlet and outlet of the dryer.

6.2.1 Incoming cotton

The characteristics of incoming cotton such as moisture, trash content and cotton variety were gathered. The time for each module entered was also recorded. The monitoring parameters and frequency are depicted in Table 6.1.

Table 6.1: Monitoring parameters of incoming cotton

Monitoring parameters	Monitoring frequency
Time for each incoming module	Every module
Incoming moisture content	Every module
Incoming trash content	Every module
Incoming cotton variety	Every module

6.2.2 Bales produced

The total numbers of bales produced were recorded from each module processed (Table 6.2). This was usually recorded manually by the ginners.

Table 6.2: Bales produced parameter

Monitoring parameters	Monitoring frequency
Total numbers of bales produced	Each module

6.2.3 Lint quality

Lint quality produced for each module processed was usually recorded by the ginners (Table 6.3). Lint quality was classified and ranged between '1 leave' to '5 leaves'. The increasing of leave numbers shows low quality of cotton. However, the classification of lint quality inside the gin was unofficial and only for ginners' references.

Table 6.3: Lint quality parameter

Monitoring parameters	Monitoring frequency
Lint Quality	Each module

6.2.4 Motor monitoring

Measurements for motors' electricity usage were divided into two categories depending upon the motors' capacity. The monitoring parameters and interval for each category are outlined in Table 6.4. Overall, motors rated above 10kW typically occupy about 75% of the overall rated capacity of all the motors.

Table 6.4: Motors monitoring profile

Monitoring Motors	Monitoring Parameters	Monitoring Interval
Motors rated above 10kW	Instantaneous active power (kW), voltage (Volt), frequency, apparent power (kVA),Reactive power (kVAR), Power factor (pf) , current (Amps) and Integrated active power (kWh)	Recorded every 5 minutes during one shift
Motors rated below 10kW	Current (Amps)	Spot- measured for a few seconds after a stable reading

6.2.5 Electricity data

The electricity data for each meter were routinely recorded across the monitoring period by the Electricity company. Each such meter measured one switchboard inside the gin where a group of motors was connected. As shown in Table 6.5, the parameters recorded included active power (kW), integrated active power (kWh), apparent power (kVA), reactive power (kVAR) and power factor (pf). The data were recorded every 15 minutes.

Table 6.5: Meter monitoring profile

Meter	Monitoring parameters	Monitoring Interval
1, 2, 3	Instantaneous active power (kW), Integrated active power (kWh), Apparent power (kVA), Reactive power (kVAR), and Power factor (pf).	Recorded every 15 minutes

6.2.6 Air temperature at dryer

The dryer was responsible for conditioning the cotton to achieve suitable moisture before entering the gin stand. The air was then flowed together with cotton across the dryer and discharged while entering into the inclined cleaner. The measurement of air temperature was taken at the inlet and outlet of the first stage dryer (Table 6.6).

Table 6.6: Temperature measurement at first stage dryer

Monitoring parameters	Monitoring frequency
Inlet temperature	Every five minutes
Outlet temperature	Every five minute

6.2.7 Gas usage

Gas usage inside the gin was directly related to the change of dryer temperature. Both of the sites were using Liquefied Petroleum Gas (LPG) as fuel. The gas use was read and recorded at the end of each shift (Table 6.7)

Table 6.7: Gas usage parameter

Monitoring parameters	Monitoring frequency
Gas usage (litre)	End of shift

6.3 Monitoring equipment

6.3.1 Incoming cotton

The incoming cotton parameters such as cotton variety and cotton moisture were usually recorded manually by the ginners for each module entering the gin. The degree of cotton moisture was detected by a microwave moisture sensor located at the gin feeder bay (Figure 6.1). This sensor took the reading when the module passed through it. The system then transferred the information to a Terminal monitor in the control room (Figure 6.2) for display and as a ginners' reference to adjust the dryer temperature. However, module moisture measurement was also taken using a moisture spear as it arrived from the field, but for the regulation of dryer's temperature, ginners were usually only referring to the reading taken by the moisture sensor. In this thesis, the module moisture readings as taken by the moisture sensor were used.

To measure the quantity of trash contained in the module, the removed trash was taken out from the gin and was accumulated in a truck at trash disposal place and was weighted at the weighing bay. The trash gathered was the trash that was removed from first stage cleaning until the extracting (Extractor feeder) process. The weight of the truck that was earlier measured was deducted from the total weight (truck and trash) to get the net weight of the trash. The time for each module entered was also recorded.

Figure 6.1: Microwave moisture sensor located at gin feeder bay

Figure 6.2: Terminal monitor in the control room

6.3.2 Lint quality

There are two different ways of determining the lint quality. In Gin F, the lint was scanned on its way to the battery condenser and the information of the scanned lint quality was transferred and recorded in the system. To do this, the presser pressed the lint to the scanner (Figure 6.3) and the result was shown and recorded in the monitor located at the control room (Figure 6.4). In Gin H, the lint quality was defined visually and manually recorded.

Figure 6.3: Lint scanner

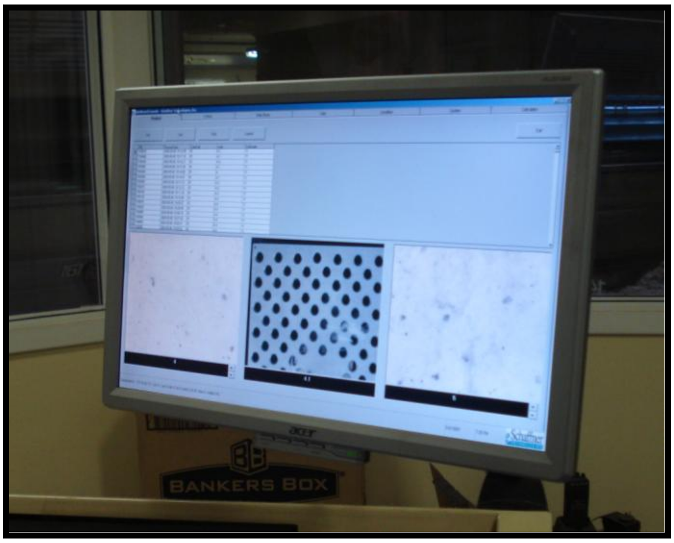


Figure 6.4: A screenshot displaying the results of scanned lint

6.3.3 Motor monitoring

Motors above 10 kW

As shown in Table 6.4, the monitoring was divided into two levels according to the rated capacity of the motors. For motors rated above 10 kW, both the power meter model Kyoritsu 6310 and Clamp-On Power HiTester 3169 from Hioki were used in this monitoring. Table 6.8 shows the basic specifications of the two power meters.

Table 6.8: Basic specification of power meters used

Power Meter	Specification	
	Kyoritsu 6310	**Hioki Clamp on power hi-tester**
Wiring system	Measure up to two 3- phase, 3-wire system	
Parameters	Can measure up to 12 kinds of power measurements	Can measure up to 8 kinds of power measurements
Current range	1A – 3000A	0.5A – 5000 A
Power supply	2 ways power supply (AC and battery)	AC power supply
Recording data	1.8 MB internal memory (period of data storage is depending on parameters measured and the capacity of PC card)	1 MB internal memory (period of data storage is depending on parameters measured and the capacity of PC card)

To measure two 3-phase motors at the same time, each power meter had to have 4 clamp sensors to make the measurement. In this monitoring, Kyoritsu 6310 has 4 clamps and can therefore measure 2 motors at the same time. For Hioki 9625, only 2 clamps were available so it could only measure one motor at a time. This means that, in one shift, only three motors above 10 kW could be measured using the two available power meters. Figure 6.5 shows one of the power meters being used.

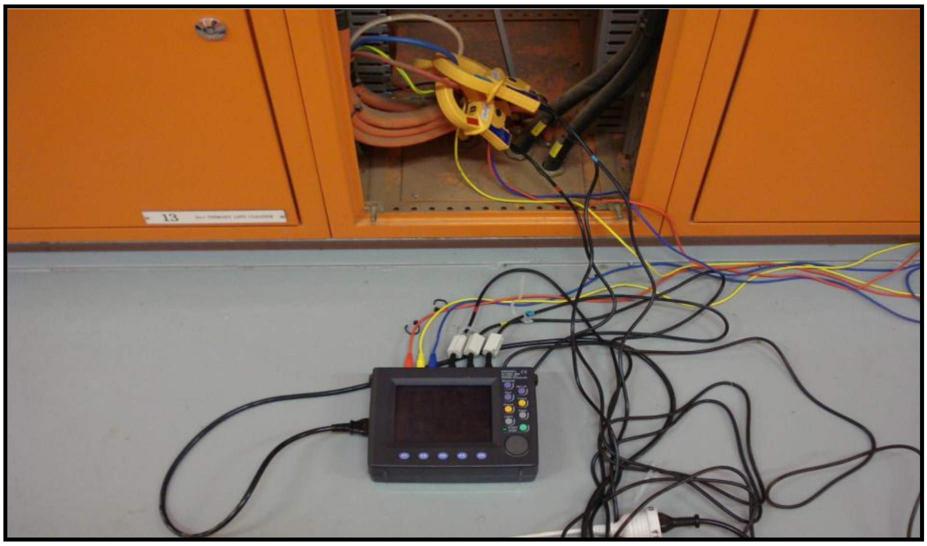


Figure 6.5: Clamp On Power HiTester 3169 from Hioki

Motors below 10 kW

For motors below 10 kW, only the current was measured. The measuring equipment used to take the data was a hand held current tong model Clamp On HiTester 3280 from Hioki (Figure 6.6).

Figure 6.6: Hand held current tong

6.3.4 Air temperature

Two temperature probes and one temperature data logger were used in this monitoring. Two temperature probes were inserted to the drilled dryer’s inlet and outlet air pipes. A Kamel GPL-80T 16 Bit data logger with National Semiconductor LM-34 precision temperature sensors were used in this monitoring.

6.3.5 Gas

In this monitoring, measuring gas use accurately has proven to be very difficult, as the commonly available gas meter was only be able to accurately measure the gas flow when it was over 2L/sec. It was estimated that typical gas usage at both trial gins would be less than 50 ml/sec, so no gas meter was used in the present study. Instead, the percentage of gas usage was recorded from the gauge of LPG tank (Figure 6.7) outside each gin.

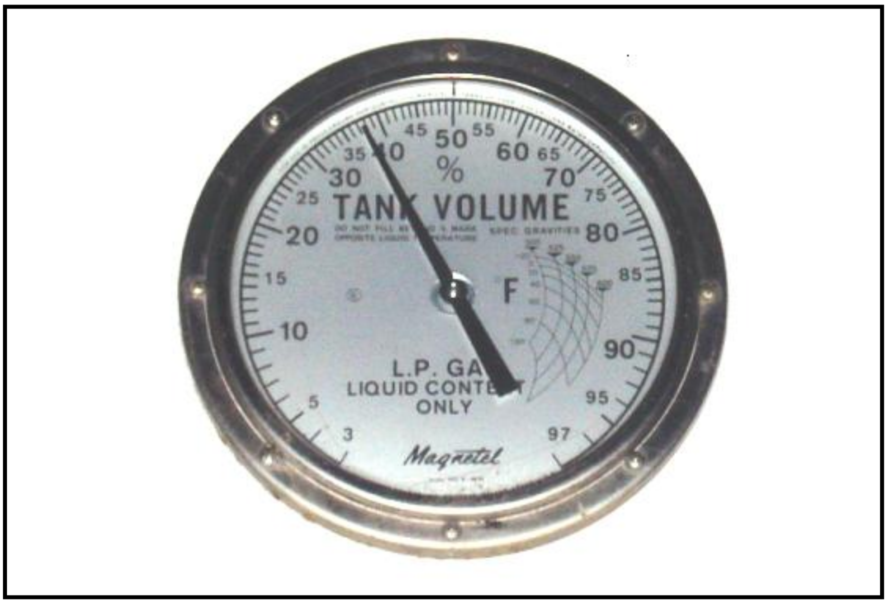


Figure 6.7: Gas gauge at LPG tank

6.4 Monitoring procedures

6.4.1 Before monitoring

Monitoring Preparation - Site selection

To accomplish the monitoring, a list of target gins was initially developed. They were then approached for the suitability of the site and the interest of the ginners. Because the control systems used in all the ginning plants encountered were reasonably basic and not able to extract historical data of plant operations, it was decided, in order to determine energy use, that 2 cotton gins would be instrumented during the 2009 ginning season.

From the target list, two gins (Gin F and Gin H) from different companies were finally selected for the monitoring. This had the advantage that we could also investigate the possible difference of energy usage patterns between these two companies. The availability of electricians during the monitoring period was also considered to be important in helping with the data collection. Their familiarity with the gin electricity connection details was essential in making sure that the monitoring work went smoothly. The two gins were also selected for their close location to each other. This helped in saving time and making the site visits easier.

Analysis of gin flowchart and motor's rating

The flowchart of the ginning process for each gin was first studied to understand the flow of incoming cotton through all the processes to packaging. For Gin F (Figure 6.8), the incoming cotton first entered the gin through the module feeder and gin feed. The cotton was then been split into two lines for the cleaning process. After the second stage of cleaning, the cotton was further distributed into four lines for ginning until the lint cleaning stage. All the motors that operated across each line were duplicated with the motors in the other lines except for the common motors that operated for all lines. At the battery condenser, all the cotton was gathered for packaging.

Furthermore, the information about total numbers of motors and their range of rating inside the gin was recorded and analysed. Understanding the gin layout and knowing the range of motor ratings was essential in deciding the way of motor monitoring.

Motor selection

The total numbers of motors inside the gin were usually more than one hundred. Because of the constraints of available monitoring equipment (only two power meters and one hand-held tong were available. Each of the power meters costed around A$8,000 in Australia. Renting costed around $800 per week), time and budget, the motors had to be selected to minimize the number of motors to be measured. After reviewing the flowchart and motors' ratings, the motors that operated under one line including the common motors that operated for all lines were selected for monitoring (shown in the grey boxes in Figure 6.8). It was assumed that the identical motors located in other lines were also operating at the same load. It was believed that this selection was the best option to estimate the electricity consumption for all the motors.

Site Visit

A visit to the gin was also arranged after the motor selection process. This was to confirm the location of selected motor connection and to investigate the probability of hooking up the monitoring equipment. The list of motors with the information of those motors' connections according to the switchboard was also gathered from the ginners. This information was essential in determining the schedule of motor monitoring.

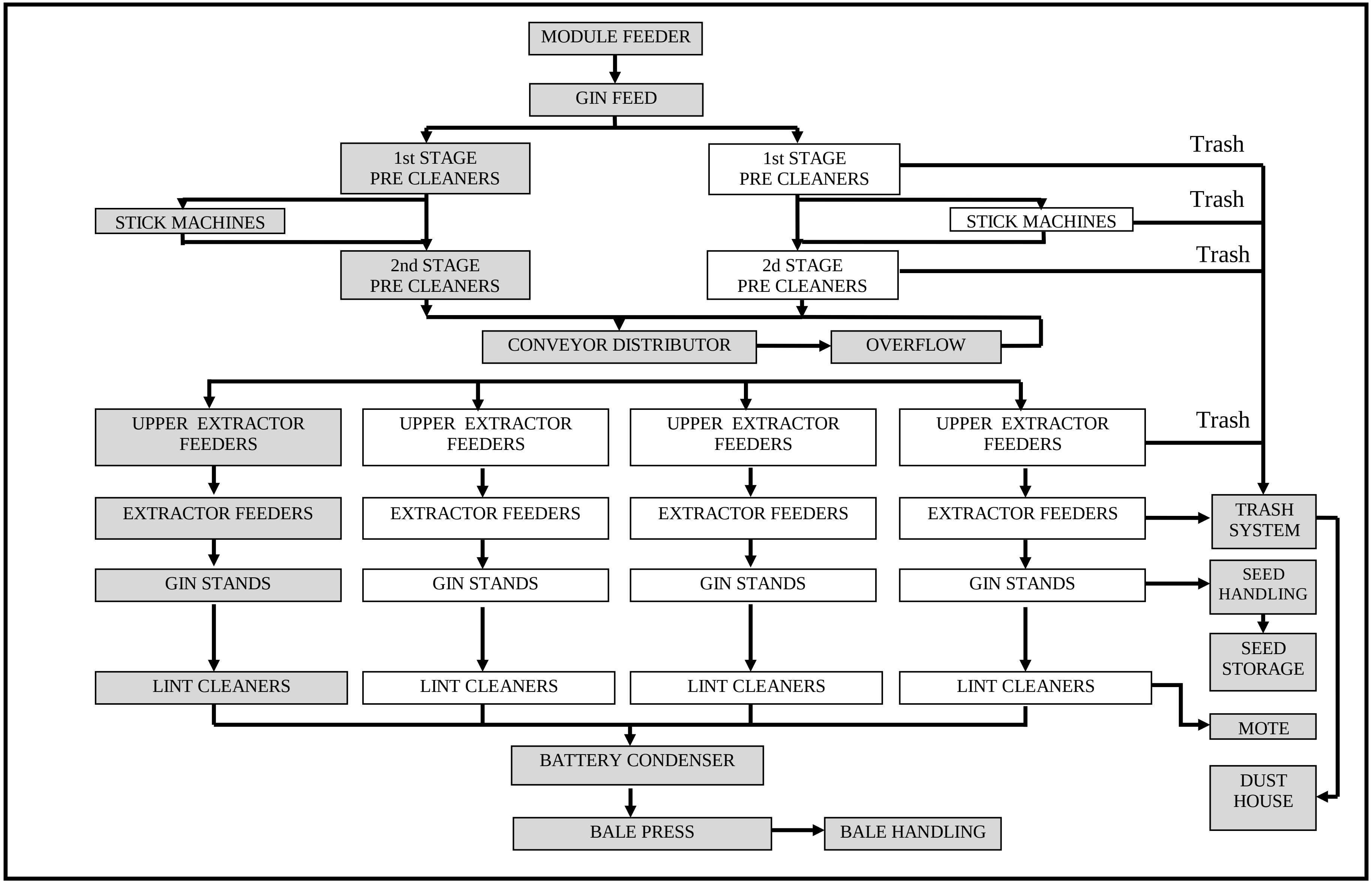


Figure 6.8: Flowchart of ginning process (Gin F)

Schedule of monitoring

The way of monitoring the selected motors was according to the motor's capacity. The motors with 10 kW and above rating were monitored intensively by the power meter during the shift hour (from 7pm to 7am for Gin F). The motors below 10 kW were only spot-measured using the current tong. The motors that consumed the most of power (e.g., gin stand and pressing machine) were also re-monitored to improve the quality of data. The monitoring profile is shown in Table 6.9.

Table 6.9: Monitoring profile

Monitoring motors	Monitoring frequency	Monitoring length	Monitoring instruments
Motors rated above 10kW	Once	One shift	Power meter
Motors rated below 10kW	Every 4 days	Spot measurement	Hand Held Tong
Gin stand and pressing machine	Re-monitored	One shift	Power meter

For motors above 10 kW, only three motors were measured in one shift and both of the power meters had to be moved from one motor to another everyday. To prevent confusions in hooking up the equipment and to ensure the monitoring went smoothly, the schedule was arranged according to the actual motor connection inside the switchboard. The schedule is shown in Appendix 6.1. Motors below 10 kW, were spot-measured every two to three days across monitoring time. The monitoring schedule for motors below 10 kW is shown in Appendix 6.2.

Incoming cotton condition, trash, lint quality and bales produced

Inside the gin, ginners used the Shift Monitoring Control Sheet to record all the information of each module being processed. This sheet was at first evaluated to ensure that all the parameters needed for the research (cotton moisture, cotton variety, total numbers of bales produced) were recorded. As a result, two more columns of time and first bale numbers were added to the existing monitoring sheet. The modified Shift Monitoring Control Sheet is shown in Appendix 6.3. A separate sheet was also developed to record the quantity of trash removed. This is shown in Appendix 6.4. The way to record the lint quality was also identified.

Air temperature

As there was only one portable temperature data logger with two probes available, the measurement was carried out only at the first-stage dryer to get a continuous reading as it operated continuously while second stage dryers were bypassed depending on the incoming cotton condition. Small holes were drilled at the air pipes wall before and after the first dryer to insert the temperature probes. The drilled holes are shown by the arrows in Figure 6.9.

Figure 6.9: Temperature probes were inserted to drilled inlet and outlet air pipes

6.4.2 During the monitoring

Motor monitoring

The motor performance was measured according to the schedule already developed. The monitoring data for motors above 10 kW was recorded in the power meter memory card while current data for motors below 10 kW were recorded in the same sheet as the schedule (Appendix 6.2).

Electricity data

Electricity data for each switch board meter were automatically recorded by the Electricity company.

Filling the monitoring sheets

As the cotton entered the gin, Shift Monitor Control Sheet (Appendix 6.3) was filled in by gin operators with the information of each module processed: namely time entered, moisture, variety, bales produced and first bale number.

Quantity of trash

The quantity of trash removed for each module processed was weighted at the weighing bay. The value was recorded in the sheet prepared (Appendix 6.4).

Lint quality

For the gin that used the lint scanner, the result of the lint quality was automatically recorded in the system and was extracted at the end of monitoring. For the gin that determined the lint quality by visual inspection, the information was recorded manually.

Gas usage

The gas usage was recorded manually by gin operators at the end of the shift.

Air temperature

The temperature data logger was set to record the readings of inlet and outlet dryer temperature during the monitoring.

6.5 Conclusion

This chapter has developed and described a method for the detailed monitoring of energy performance in cotton gins. The objectives of the monitoring, parameters measured, the equipment used, and procedures in taking the data have been described. It has been identified that the main objective of a detailed monitoring program was to obtain necessary data to estimate the electricity consumption and energy use breakdown in the ginning sub-processes (handling, cleaning, gin stand and packaging) and to investigate the energy usage patterns (electricity and gas) for each sub-process with variables such as incoming cotton moisture, trash and variety, lint quality and bales produced. This will be further discussed in the next chapter.

CHAPTER 7

Results of Detailed Monitoring

This chapter will discuss the results from the detailed monitoring performed at two gins (Gin F and Gin H) located at Wee Waa and Narrabri, New South Wales. Gin F and Gin H belong to two different cotton companies and were built around 1994 and 1998 respectively. Gin H consisted of two separate gins which were named as Gin H1 and Gin H2. All these gins have the capacity to produce up to 60 bales per hour. It took about 25 days (5 May ‘09 – 30 May ‘09) to complete the monitoring at Gin F while at Gin H, the monitoring took about two weeks (16 June ’09 – 30 June ’09). The data gathered will be analysed for both Gin F and Gin H. The result is first discussed for Gin F, followed by Gin H.

7.1 Gin F

The monitoring time was initially planned for 15 days (5 May ‘09 – 20 May ’09). As there were problems initially in monitoring the motors, the monitoring length was extended to 30 May ’09. However, only the monitoring of individual electrical motors was extended while other parameters related to incoming module e.g. moisture, trash levels, bales produced and lint quality were measured for the period defined in the original plan. The switchboard meters recorded the electricity parameters continuously during the whole ginning period. The main objective of the monitoring of individual electrical motors was to determine the motor performance and to estimate the power and energy breakdown between different sub-processes. The purpose of switchboard metering was to investigate the overall relationships between energy usage and incoming cotton variables.

After the monitoring, all the data were collected and analysed. These data included:

a) The information of incoming cotton conditions (moisture, variety and total numbers of bales produced) for each module being processed
b) Data of trash extracted for each module for the first six shifts
c) Inlet and outlet temperature of the dryer
d) Electricity data recorded by electricity company across the whole monitoring period; and
e) Electricity data for individual motors monitored.

However, problems occurred with recording and reporting the results for lint quality and gas usage at this site. That made the data for these two items unavailable. The relationship between gas usage and regulated temperature could therefore not be analysed.

Gin F has a capacity to produce up to 60 bales per hour. As the monitoring occurred, the gin was operating 7 days per week on night shift only (7 pm until 7 am) to take advantage of lower electricity costs. It was observed that as an average, each module took about 37-40 minutes to be processed. For each module, the gin could make around 24-27 bales. The average production rate for Gin F was calculated to be 40 bales per hour.

The minimum and maximum module moisture within the monitoring period was 6% and 14% respectively with the average of 7%. It was found that the quantities of trash for the modules analysed ranged between 400 to 4400 kg. By taking 14 tonne as the average of module weight, the percentage of trash in the module was around 2.8% to 31%. The wide range of trash levels found in Gin F reflects spindle and stripped harvested cotton. Various varieties of cotton, namely: DP210BRF, Sicot 60B, Sicot 70BR, Sicot 71B, Sicot 80, Sicot 80B, Siokra V-1 were ginned during the monitoring period. All of the information regarding the module processed (moisture, variety and bale produced) were recorded in the Shift Monitor Control Sheet.

15 minute interval electricity consumption data was routinely recorded by the electricity company for each meter. The individual meters were connected to each of

the three switchboards or motor control centres (MCCs) inside the gin. Motors were "randomly" connected to their respective MCC with the intention of evenly distributing the load rather than to supply to a specific process. Thus, it was not possible to monitor any specific process or combination of processes by simply measuring the total consumption at any one meter/MCC.

Meter 1 measured the power usage of MCC 1, where the majority of motors connected represented the motors associated with the 4 lines of primary lint cleaners and fans for handling purposes. Meter 2 measured the power usage of MCC 3 which included 78 motors across all processes including the gin stand. Meter 3 measured the pressing machines and associated bale handling equipment (Table 7.1).

Table 7.1: Summary of each electricity meter

Meter	Switchboard (MCC)	Motors
1	1	30 motors including 4 lines of primary lint cleaners and fans for handling purposes
2	3	78 motors from all the process including gin stand
3	2	23 motors of bale handling and pressing machine

In the following analysis, the relationship between electricity for each meter and information of module processed (moisture, variety, trash and bales produced) is analysed. The relationship was correlated by time recorded. Their relationship is then plotted and discussed.

By following the procedure of selecting the motors to be monitored, 93 out of 131 of total motors were selected for individual monitoring at this site (among them, 45 motors were over 10 kW). The electricity measurement for individual motors is then analysed and energy for each sub-process is calculated. The way to analyse electrical data and recommendations to improve individual motors is also discussed.

7.1.1 Relationship between electricity usages and incoming cotton

7.1.1.1 Electricity usage and trash removed

Figure 7.1 shows the relationship between electricity usage and trash removed per minute. It was plotted from the data of electricity power recorded (kW) from the electricity company for each meter while the parameter of trash per min was calculated by dividing the quantities of trash contained in the module (kg) by the processing time of the respective module.

From the graph, it can be seen that the power consumption at Meter 1 and Meter 3 were nearly constant as the quantity of trash removed per time increased while Meter 2 gave scattered values within the same range.

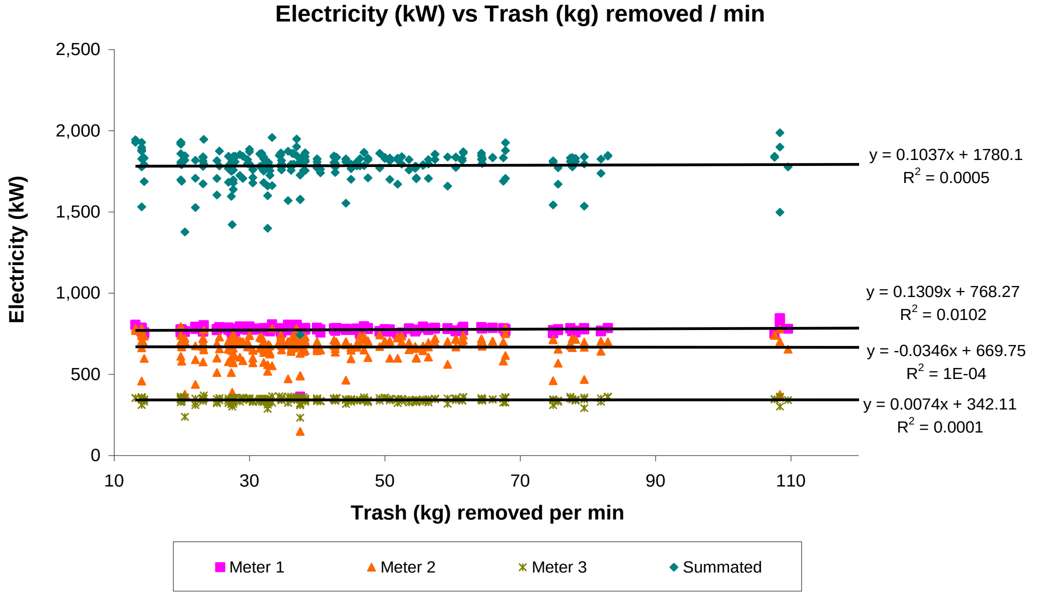


Figure 7.1: Relationship between electricity (kW) with trash removed

The constant value at Meter 1 and Meter 3 may be understandable because the function of most of the motors connected for these two meters was not closely related with trash removal. It can be seen from Figure 7.1 that the motors were nearly running at the same load regardless of the quantity of trash removed.

The quantity of trash collected in this research was the accumulation of the trash removed after the first stage inclined cleaner, stick machine, second stage inclined cleaner and after upper and lower extractor feeder. Most of the motors responsible for removing trash were connected to Meter 2. However, the patterns in Meter 2 essentially showed that the increasing of trash quantity did not lead to significant increases to the respective motors that are responsible for cleaning. This can be explained by the function of cleaning motors as shown below.

The inclined cleaner consisted of a series of spiked cylinders that agitated and conveyed the dispersed seed cotton across cleaning surfaces, which contained small openings or slots. The trash that dislodged from the seed cotton, by the action of the cylinders, fell through the slots for disposal. The stick machine and extractor feeder used sling-off action of high-speed saw cylinders to extract trash from seed cotton by centrifugal force. The centrifugal force was usually 25-50 times the force of gravity (Baker et al., 1994).

Based on the cleaning function and by referring to Figure 7.1, the process of agitating and slinging by centrifugal force appeared to operate at the same load regardless of the quantity of trash removed. Obviously, seed cotton which has more trash would be removed more by these actions since a high percentage of the trash in the seed cotton consisted of loosely attached particles that were relatively easy to remove.

The quantity of trash did not significantly affect the energy usage. This was because that although the quantity of trash may influence the ginners' decision in adding or eliminating the cleaning motors in the operating sequence, it is not likely to show a consistent pattern. It would also appear that the percentage of energy usage by the individual cleaning motors was relatively low in relation to the total energy use for Meter 2. Instead, the scattering data may possibly indicate the changing load in the motors connected to Meter 2 as a result of the variation in the weight of seed cotton (module) coming in.

To calculate the amount of energy required to remove a kilogram of trash (kWh/kg trash), the summation of electricity used (kW) from these three meters may be divided by kilograms of trash removed per hour (kg/hour). This gave 0.16 - 2.47 kWh/kg trash.

7.1.1.2 Electricity usage patterns based on incoming cotton moisture

Figure 7.2 shows the relationship between the electricity usages for the 3 meters with respect to the incoming module moisture. The data was again plotted from the electricity recorded by the electricity company for each meter and the incoming module moisture across the monitoring period.

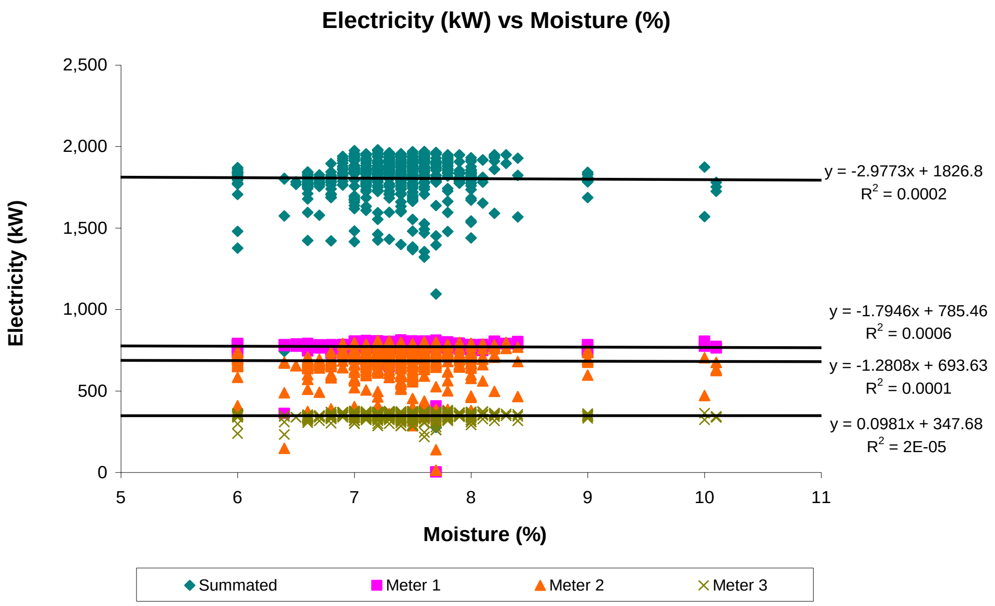


Figure 7.2: Relationship between electricity (kW) with incoming moisture

The graph shows that the electricity usage for the three meters was quite scattered even when the module moisture was the same. So it appeared that the electricity usage was not significantly influenced by the incoming module moisture. This may be understandable since the incoming moisture was already reduced to the optimum moisture in the dryer (an earlier process) before it actually went through other processes. In particular, the motors that were involved in the earlier process, especially seed cotton handling motors (located at Meters 1 and 2), were not likely to have been influenced by the incoming moisture.

7.1.1.3 Electricity usage patterns based on cotton variety

The variations of electricity consumption based on the increasing number of bales produced per minute for each variety are shown in Figure A 7.1 through Figure A 7.9 (Appendix 7.1). The figures were plotted from the data of electricity usage recorded from the electricity company for each meter and the number of bales produced per minute with respect to their variety.

These figures show that Meter 1 and Meter 3 were almost constant for most of the variety but electricity data from Meter 2 increased significantly for most of the varieties.

The variations that occurred at Meter 2 which measured switchboard 3 (MCC 3) may be due to the changes in energy requirements by the gin stands.

This was because, as ginning was progressing, all the seed cotton (regardless of the variety) had been prepared by the drying and cleaning processes to achieve optimum conditions before going through a fibre-seed detachment process at the gin stand. By referring to the data recorded, before entering the gin stand, the average of all seed cotton moisture ranged between 6.5-6.8%.

Boykin (2007) has found that ginning energy was also used to remove tangled fibres and trash. Baker et al. (1994) has found that the cotton which has gone through the process of trash removal using cleaning machines before the gin stand usually has 40-80% of trash removed.

By considering the above matter, it may be inferred that the remaining differences in gin stand power consumption in different varieties may be mostly attributed to changes in the average fibre-to-seed attachment force of different varieties.

The energy used to produce one bale for each variety is compiled in Table 7.2. Most of the varieties used energy within the same range. However, Sicot 71BR and Sicot 80B recorded the highest energy usage where the maximum of electricity usage can reach almost twice that of other varieties.

Table 7.2: Range of electricity used (kWh) to produced one bale for each variety

Variety	Electricity used per bale (kWh/bale)	
	Minimum	**Maximum**
DP 210 BRF	40.90	65.84
Sicot 60B	41.00	72.11
Sicot 70 BR	29.51	66.14
Sicot 71	37.12	48.44
Sicot 71B	27.66	69.14
Sicot 71BR	21.71	146.84
Sicot 80	20.64	64.73
Sicot 80B	12.50	103.38
Siokra V-1	38.16	69.04

7.1.1.4 Electricity usage pattern with increasing bales

Figure 7.3 shows the relationship of electricity usage patterns as the quantity of bales produced per minute were increasing. It was plotted from the data of electricity usage recorded from the electricity company for each meter, while the parameter of bale per min was calculated by dividing the quantities of bales produced for each module by the processing time of the respective module (regardless of the variety).

From the graph of Figure 7.3 it can be seen that the electricity use of Meter 1, Meter 2 and Meter 3 were slightly increased as the bales produced increased. The increase in bales produced was due to the increased quantity of the cleaned seed cotton entering into the process after cleaning. The processes that were responsible for processing and producing a bale after the cleaning process were the gin stand, lint cleaning, batt condensing, pressing and bale handling.

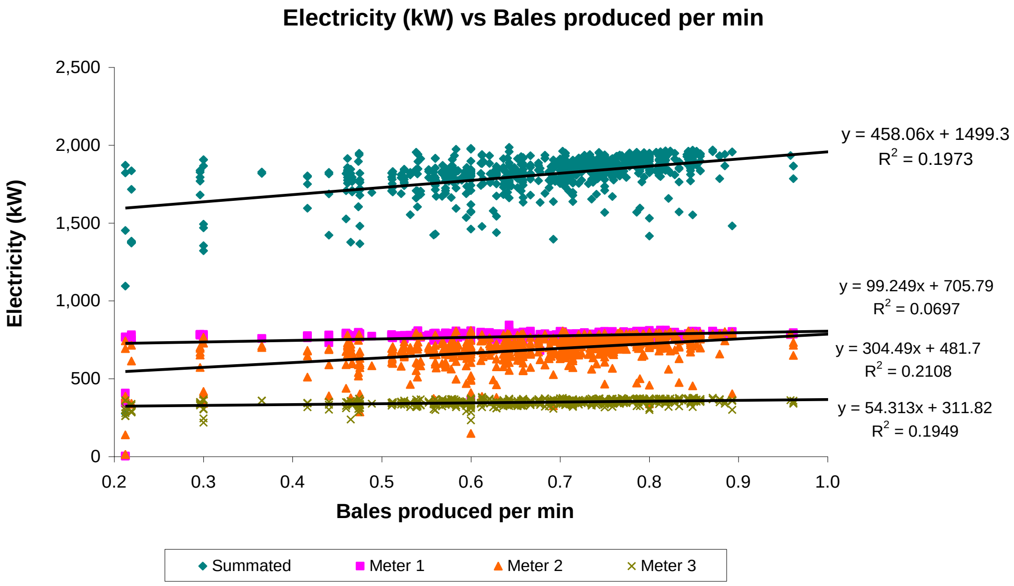


Figure 7.3: Relationship between electricity (kW) with bales produced

As the quantity of seed cotton increased, the rates of detachment processes at the gin stand, and the processing load of lint cleaning, pressing and other processes related to processing and handling bales, also all tended to rise. In addition, as the capacities of these motors were quite large, they tended to have a significant impact on the total electricity use as their load increased.

7.1.2 Individual motor monitoring

7.1.2.1 Data analysis

Based on the individual motor monitoring, motor loading and power factor were calculated and observed. The finding was discussed as follows:

7.1.2.1.1 Motor loading

Most electric motors are designed to run at 50% to 100% of rated load. Maximum efficiency is usually near 75% of the rated load. Based on the data gathered in the monitoring, the percentage of motor loading for each motor is calculated. The procedures for calculating the motor loading for motors above 10kW are outlined in Appendix 7.2, while for motors less than 10kW in Appendix 7.3. The results from the calculation are discussed below.

From the measurement and calculation undertaken, overall, it was found that in Gin F (of total 131 motors), 30% (39) of motors inside the gin operated at less than 40% motor loading. 27% (35) of total motors operated between 40% - 60% motor loading, and 31% (41) and 8% (11) operated between 60% - 80% and 80% - 100% motor loading respectively (Figure 7.4). 5 motors which have occupied 4% of total motors were detected operating over their specified maximum loading. These motors are identified as: the Cotton Cross Conveyer, No.2 Stripper Fan, Disperser Bottom, No.1B Oil Cooler and MF Bed 3 VS Low Speed.

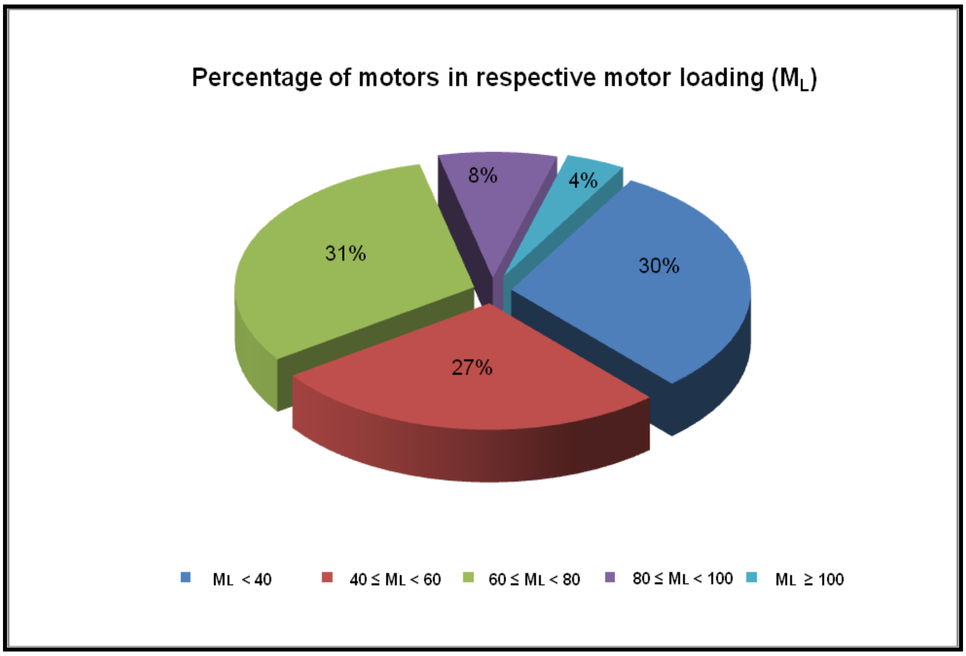


Figure 7.4: Percentage of motor that operated under certain percentage of motor loading (Gin F)

7.1.2.1.2 Power factor

Figure 7.5 shows the distribution of power factors measured for individual motors (before the correction by the capacitors). The measurements were only done for the selected motors which have a rated output of 10kW and above, as the motors less than 10 kW were measured using the current tong. The values measured were then duplicated to identical motors in the other lines.

For motors above 10 kW, it was also observed that some of the input power measurements gave negative values. These motors are: No.1 Lint Cleaner Discharge Fan, Mote Press, Lint Belt, 1A Stick Machine, Disperser Bottom and MF Bed 2 High Speed. The motors that gave continuous negative values were the No.1 Secondary Lint Cleaner, Seed Conveyor and Battery Condenser. Negative values of power may caused by lagging power factor of respective motor. The linkage between negative values of power with lagging power factor is further explained in Appendix 7.4.

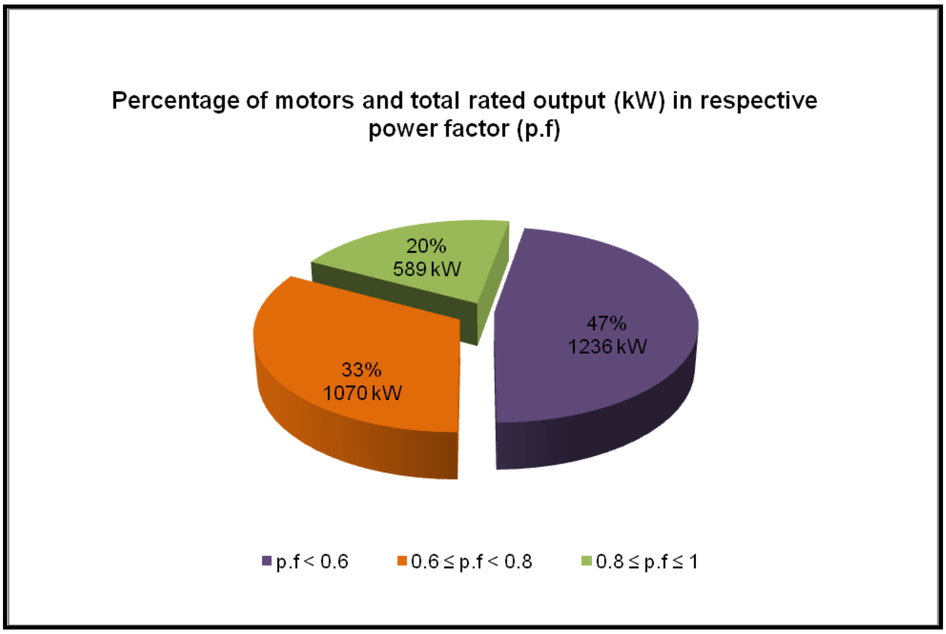


Figure 7.5: Percentage of motors and total rated output (kW) in respective power factor (pf)

It can be seen from Figure 7.5 that 47% of total motors (70 motors) above 10 kW having a total rated output of 1236 kW was operating with a power factor lower than 0.6. 33% (1070 kW of total rated output) had a power factor of between 0.6 and 0.8 while the remaining motors (20%) with 589 kW of total rated output operated with a power factor of 0.8 and above. From the total rated output power for 70 motors, assuming that efficiency of motors range around 0.8-0.9, the rated input power needed would thus be about between 3216.67 kW to 3618.75 kW, while the rated current needed (assume, pf = 0.95 voltage = 415V) is around 4710.58 Amps to 5299.40 Amps. However, the effect of the low motor's power factor may cause the gin to draw more current to perform the same amount of useful work. This is further explained in Appendix 7.5.

7.1.2.1.3 Recommendations

Power factor improvement

Although power factor correction capacitor banks can be employed to correct the overall power factor (pf) of a specific MCC or the gin overall, correcting the power factor for each motor individually is also important as it decreases the current drawn and subsequently any associated voltage drop in the motors connection cabling and thus increases the efficiency of the motor as well as possibly allows the selection of smaller cabling or a smaller motor itself.

The power factor in the plant can be possibly corrected in the following two ways:

i) To correct the power factor for an individual motor: a capacitor may be installed at each motor. This will shift the phase of the power line current of the inductive motor so it is back in phase (or very close to unity) with the voltage and will subsequently decrease the magnitude of reactive power (kVAR) component, thus increasing the power factor close to unity (pf =1).

ii) Power factor correction capacitor banks: the combined low power factors of the all motors can be corrected through the pf correction capacitor banks.

An example of using Power Factor Correction Capacitor Banks can be seen in Gin F where although 80% of the individual large capacity motors (occupying about 75% of total rated output in the gin) had an average pf less than 0.8 (Figure 7.5), the pf of the whole gin as recorded by the Electricity company was actually very high at

0.96 (Table 4.8). This is because the recorded pf values for each individual motor was on the "load" side of the capacitor banks, while the electricity company recorded the combined pf of all motors after they were corrected by the capacitor banks. Thus, the power factor at this plant has been successfully corrected by the capacitor banks, though inefficiencies at each motor and for the cabling to each motor still existed.

Motor loading improvement

Ginners will also need to pay attention to keeping the gin running at high loading. Most electric motors are designed to run at 50% to 100% of rated load. The maximum efficiency of a motor is usually near 75% of the rated load. A motor’s efficiency tends to decrease dramatically if it operates below 50% load. Low load operation can also affect the power factor of motors which means that more power is being wasted. Besides wasting power, low power factors can also affect motor efficiency. Operating at highl load will maximize the efficiency and increase the production. Thus, it will increase the profit and save energy. Because this plant had some 60% of motors running at below 60% motor loading, it is suggested that attention should be given to the use of variable speed drives and through appropriate selection of motor size.

Despite the above ‘generic’ recommendations, it is noted that they will still need to be subject to evaluation and satisfaction of suitable economic and operational criteria for the particular site. It is estimated that the installation of capacitors and variable speed drives would typically cost around $100~200/kW each. This is compared with the electricity supply and network charge of $50~100/kW each year.

7.1.3 Electricity usage breakdowns for sub-processes and cost per bale

Inside the gin, electricity is used to run all the processes except for drying which uses gas instead. In terms of monitoring, only motors that operated under line 1 were measured. The input power measured and calculated from the monitoring may be considered as the average of the input power of motors. By assuming that the load and power usage is the same, the measured and calculated input power value from monitoring was then duplicated to the identical motors that operated in line 2, 3 and 4.

From a complete motor list, all motors in Gin F have been divided into 4 major ginning processes according to their functions (Table 7.3). The definition of the classification is:

(a) Cleaning – consists of the motors that have relevance to seed cleaning and lint cleaning
(b) Ginning - consists of gin stands
(c) Packaging – consists of motors that have relevance to pressing and bale packaging
(d) Handling – consists of motors used for seed cotton handling, lint handling, trash handling and other motors that are not included in other three sub-processes stated (a, b, c).

The complete list of motors that defines the motors according to their sub-processes is shown in Appendix 7.6. The total rated output power for the gin is 3077.6 kW.

Energy usage (kWh) for each bale is calculated by dividing the average measured input power (kW) with the average production rate of 40 bales per hour. From the utility bills, the cost is then estimated by the average dollar paid by the ginner (Gin F) per kWh. All the information has been compiled in Table 7.3.

Table 7.3: Average energy use and cost per bale (Gin F)

Gin Process	Input power (kW)	Energy use per bale		Cost per bale[1]
		kWh	Percent of total	
Cleaning	147.63	3.69	8.84	0.48
Ginning	296.00	7.40	17.72	0.96
Packaging	374.27	9.36	22.42	1.22
Handling	852.00	21.30	51.02	2.77
Total	**1669.9**	**41.75**	**100**	**5.43**

[1]Based on $0.13/kWh , (see Table 4.7)

Based on the overall average price/kWh for this gin, it can be seen that most of its energy cost was associated with the handling process ($2.77/bale) which also required the most energy, 21.30 kWh/bale. This was followed by the packaging process which cost $1.22/bale by using 9.36 kWh of electricity. Ginning used 7.4 kWh of energy and cost about $0.96/bale, while cleaning used 3.69 kWh with a cost of $0.48/bale.

7.2 Gin H

Gin H has two separate identical gins, Gin H1 and Gin H2. The monitoring for both gins was carried out for two weeks during 16 June ’09 - 30 June ’09. Individual motor monitoring was done in one day for the two gins (Gin H1 and Gin H2), while other monitoring was carried out within the dates stated above. The data collected in this monitoring were (a) the information about module processing, namely the time of each module entering the gin, module moisture, lint quality and bales produced for each module processed (b) electricity usage for each gin, which was recorded by the Electricity company and (c) the measurement of individual motors for both gins (only the electricity current was measured at this site, as explained below).

Other data such as trash and dryer temperature were not recorded at this site. Gas usage was not collected since the gin did not have a separate meter for Gin H1 or H2. The analysis for this gin is performed based on data available.

Basically, the total numbers of motors for both gins are the same. The Gin H1 and Gin H2 have a maximum capacity to produce up to 60 bales per hour. As the monitoring occurred, both of the gins were operating continuously on a day shift from 7 am until 7 pm. It was observed that as an average, each module in both gins took about 28-29 minutes to be processed. Each module would make around 25 and 22 bales for Gin H1 and Gin H2 respectively. As an average, the production rate for Gin H1 is 54 bales/hour and for Gin H2 51 bales/hour.

The minimum and maximum of module moisture within the period were 6 and 14% respectively. Lint quality produced was always between 3 to 4 leaves. All of the information regarding the incoming cotton was recorded in the Shift Monitor Control Sheet.

For electricity, 30 minutes interval data for each gin was routinely recorded by the Electricity company. Data of electricity and information of module processed (moisture, variety, bales produced and lint quality) was correlated with the time recorded. Their relationship was then plotted and discussed.

Electricity measurements for individual motors (in both Gin H1 and Gin H2) were measured in one shift. The motors above 10 kW were monitored for two minutes using the power meter. Due to the installation of protective plastic insulator plates to all busbars, it was not possible to attach connections to any live terminals, thus it was not possible to record voltages at this site. The only monitoring possible was to use current tongs for the power recorder and so only the current drawn by the motors was measured. This meant that power factor as well as all other power readings (kW, kVA and kVAR) were not recorded. For motors less than 10 kW, as Gin F, only current was measured, and only by using the Hioki handheld current tong to obtain an instantaneous value.

7.2.1 Relationship between electricity usages with the factors of incoming cotton, bales produced and lint quality

The following Figures of 7.6 -7.11 show the relationship between electricity used (kW) with bales produced, incoming moisture and lint quality produced for both Gin H1 and H2.

7.2.1.1 *Electricity usage patterns from producing bales*

Figures 7.6 and 7.7 show that the electricity patterns used were similar with Gin F where the electricity used increased as bales produced increased. This result was the same trend as that found in Gin F. The explanation of the relationship between the two variables has been discussed previously in Gin F (subsection 7.1.1.4).

The minimum and maximum of electricity energy used per bale (kWh/bale) was calculated by dividing the electricity use (kW) with the production rate (bales/h). It ranged between 22.8 - 49.8 kWh/bale and 37.43 - 102.4 kWh/bale for Gin H1 and H2 respectively. The large variation was a result of either high electricity usage with low production or extra clean cotton coming in. Overall, the energy use per bale at Gin H2 is 39% - 50% higher than Gin H1.

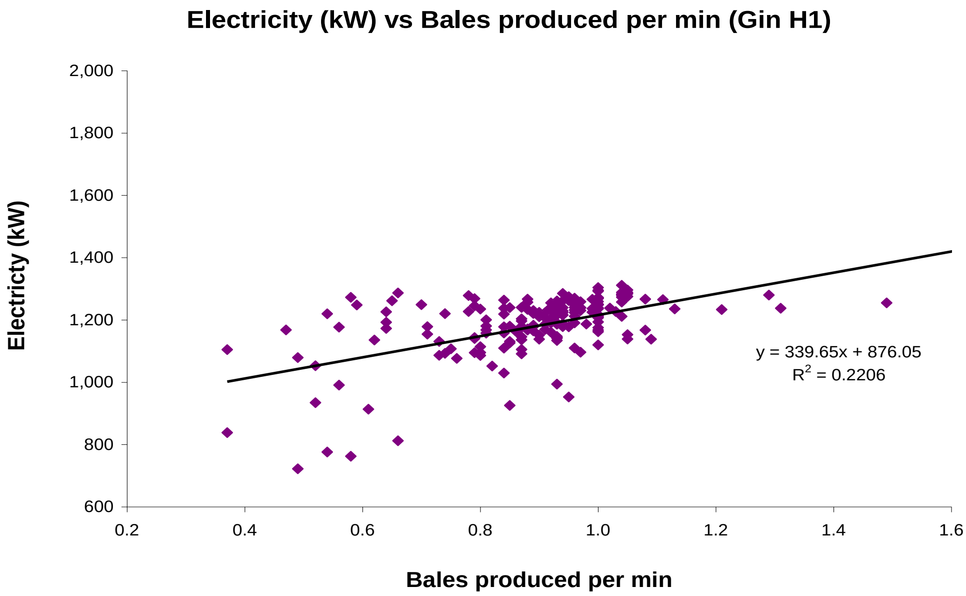


Figure 7.6: Relationship between electricity (kW) with bales produced (Gin H1)

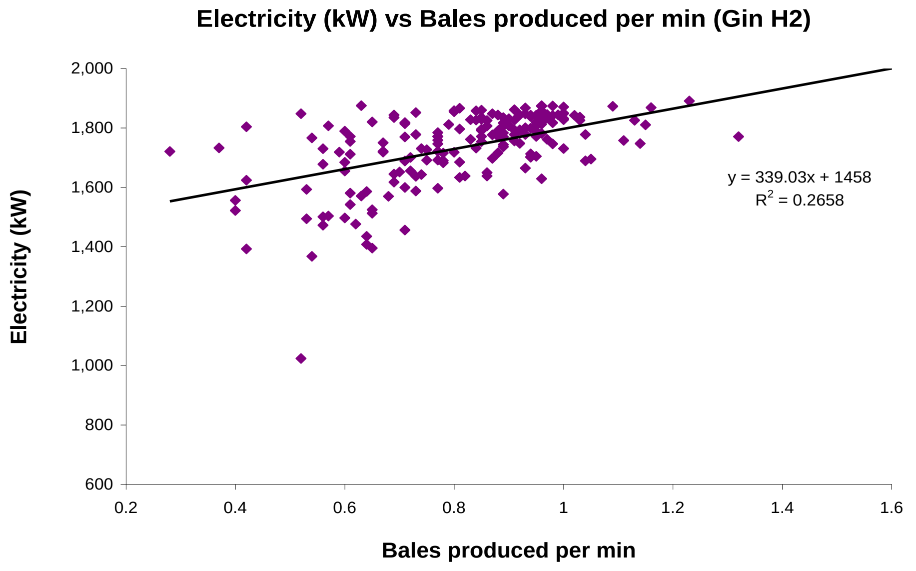


Figure 7.7: Relationship between electricity (kW) with bales produced (Gin H2)

7.2.1.2 Electricity usage patterns based on incoming cotton moisture

Figures 7.8 and 7.9 show that the electricity pattern used was the same for both gins H1 and H2 where the electricity used was not significantly affected by incoming moisture. The reason of this has been discussed in Gin F (subsection 7.1.1.2).

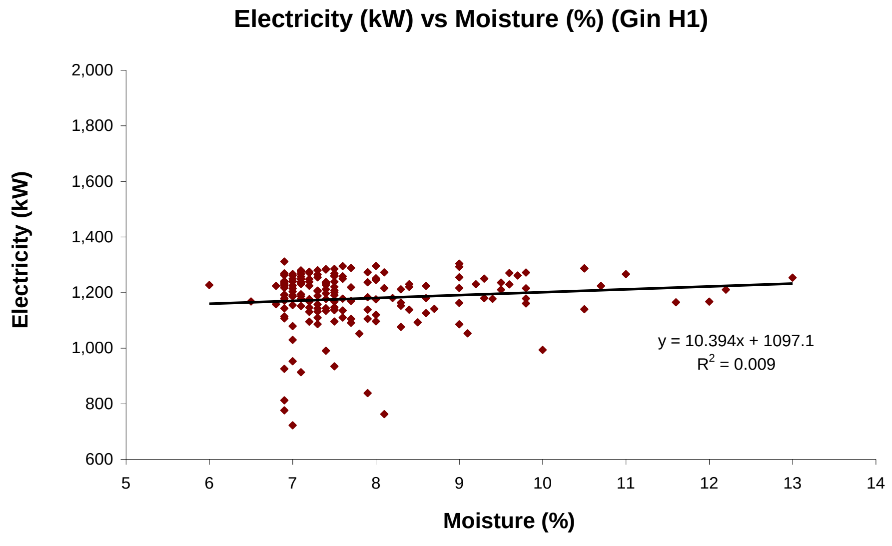


Figure 7.8: Relationship between electricity (kW) with incoming moisture (Gin H1)

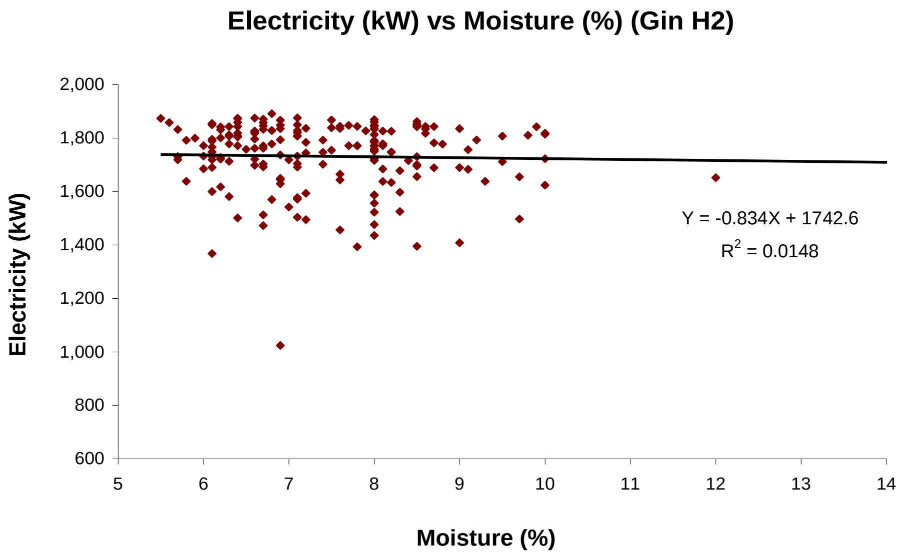


Figure 7.9: Relationship between electricity (kW) with incoming moisture (Gin H2)

7.2.1.3 Electricity usage patterns from lint quality

Figures 7.10 and 7.11 depict the relationship between electricity used and lint quality produced. The graphs have been plotted from the data of electricity usage recorded (kW) by the electricity company with the lint quality produced for each module. The lint that was examined manually by ginners was correlated with electricity recorded by time. From both graphs, it can be seen that lint quality only ranged from 3 to 4 and appeared to have little impact on electricity use.

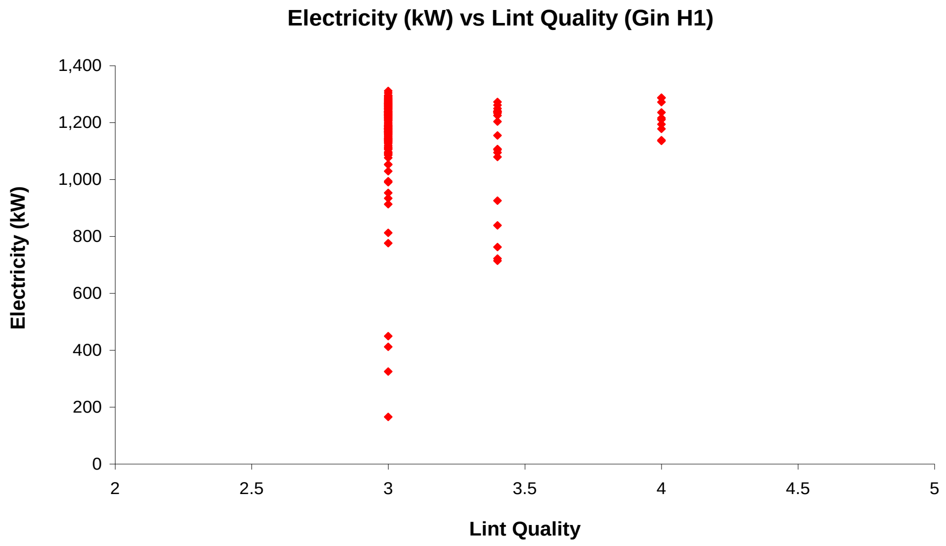


Figure 7.10: Relationship between electricity (kW) with lint quality (Gin H1)

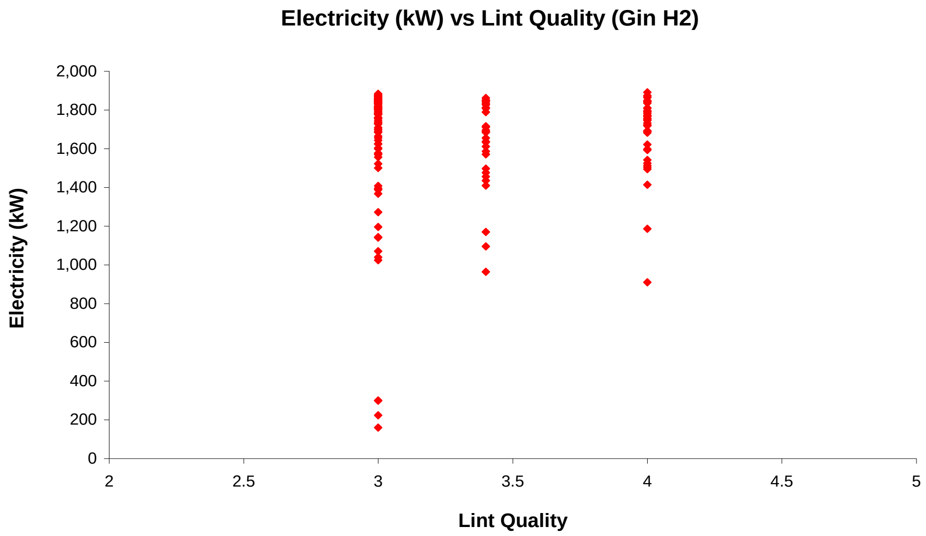


Figure 7.11: Relationship between electricity (kW) with lint quality (Gin H2)

7.2.2 Individual motor monitoring

7.2.2.1 Data analysis

7.2.2.1.1 Motor loading

From the monitoring, the currents for each motor both above and less than 10 kW were measured. By assuming individual motors' power factor, pf = 0.85, and adopting the same procedures as for Gin F (Appendix 7.3), the measured current data were used to calculate input power and percentage of motor loading. The efficiency of individual motors was assumed to range between 0.7-0.9 for motors with rated output 0.37 kW-132 kW respectively. For the motors where measurements couldn't be taken, the input power was calculated by assuming that these motors were using 50% of the rated input power (50% motor loading). The data was then used to calculate the energy used and the cost per bale for each plant.

The percentage of motors and their respective percentage of motor loading for both Gin H1 and H2 (each gin has about 120 motors) are shown in Figure 7.12 and 7.13. It can be seen that, as an average, the motors that had less than 40% motor loading was around 25 and 35 for Gin H1 and H2 respectively. 60% (72) and 47% (56) of total motors had operated with between 40% - 60% motor loading. 15% (18) and 18% (21) operated with between 60% - 80% motor loading for Gin H1 and H2 respectively. 3% (4) operated with between 80% - 100% for both gins. Another 1% (1) and 2% (2) for Gin H1 and H2 were recorded as operating at above maximum loading.

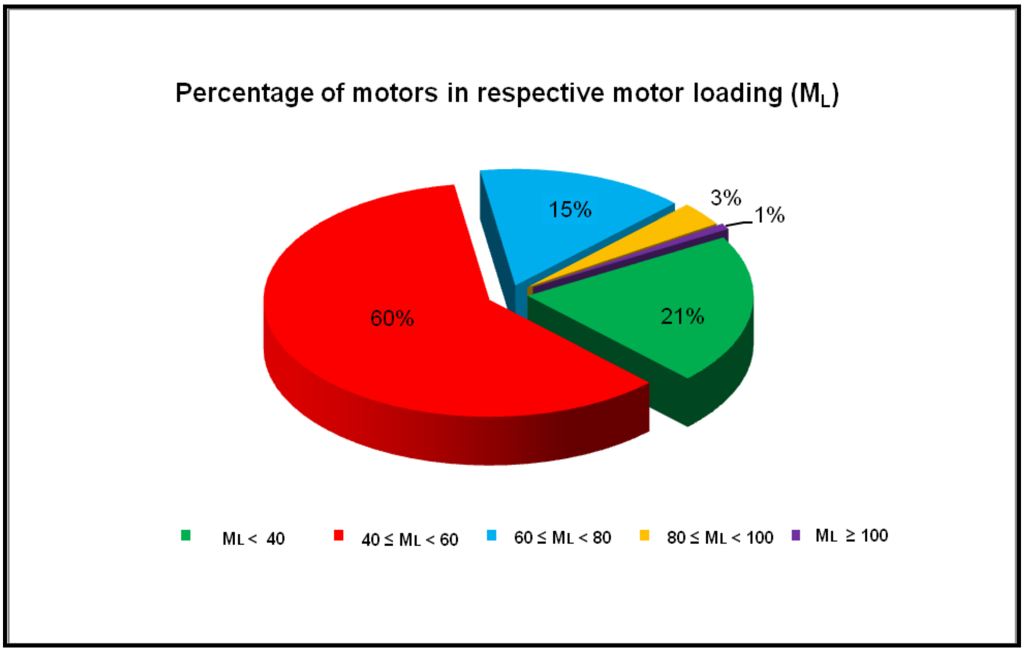


Figure 7.12: Percentage of motors in respective motor loading (Gin H1)

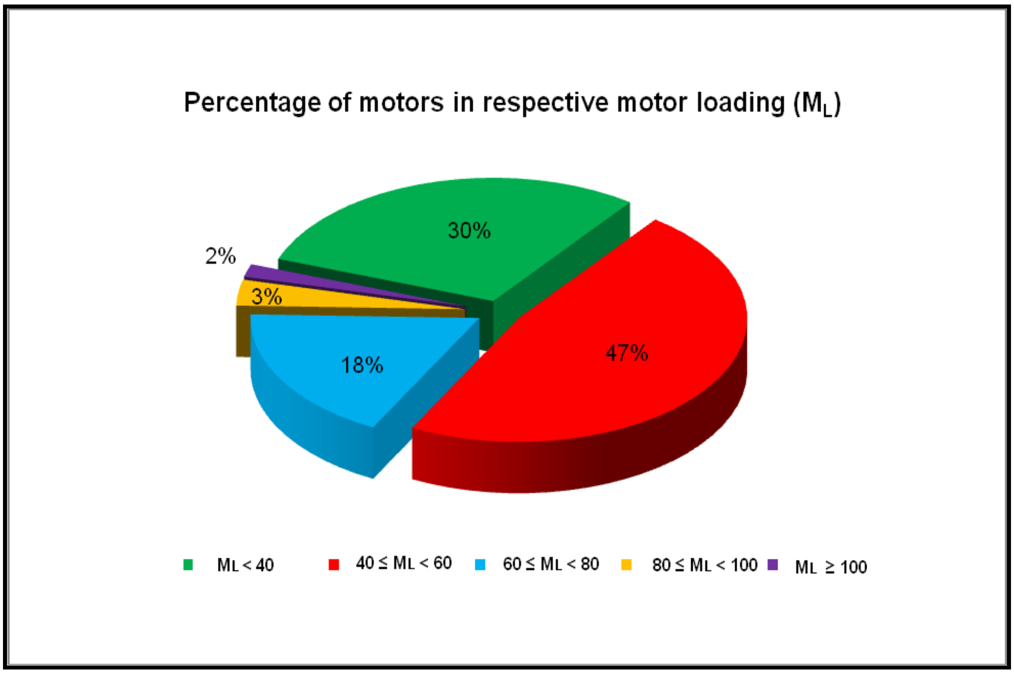


Figure 7.13: Percentage of motors in respective motor loading (Gin H2)

7.2.3 Electricity energy usage and cost per bale

All the motors at Gins H1 and H2 were divided into 4 major ginning processes according to their function (Tables 7.4 and 7.5). The definition of the classification was as stated in subsection 7.1.3. The complete list of motors for both gins that defines the motors according to their sub-process is shown in Appendix 7.7. From the calculated input power (kW), the energy usage per bale (kWh/bale) was calculated by dividing the input power with the average production rates for Gin H1 and H2 respectively (54 and 51 bales/hour). From the utility bills, the cost was estimated by the average dollar paid by the ginner (Gin H) per kWh. This was also \$0.13/kWh.

Table 7.4: Average energy use and cost per bale (Gin H1)

Gin Process	Input power (kW)	Energy per bale		Cost per bale
		kWh	Percent of total	
Cleaning	376.93	6.98	18.49	0.91
Ginning	429.41	7.95	21.07	1.03
Packaging	368.58	6.83	18.10	0.89
Handling	862.91	15.98	42.34	2.08
Total	**2037.83**	**37.74**	**100**	**4.91**

Table 7.5: Average energy use and cost per bale (Gin H2)

Gin Process	Input power (kW)	Energy per bale		Cost per bale
		kWh	Percent of total	
Cleaning	327.82	6.43	15.70	0.84
Ginning	439.91	8.63	21.07	1.12
Packaging	345.76	6.78	16.56	0.88
Handling	974.75	19.11	46.67	2.48
Total	**2088.24**	**40.95**	**100.00**	**5.32**

From Tables 7.4 and 7.5, it can be seen that similar to Gin F, the handling process also required the most energy. The total of the average input power used by Gin H1 and H2 was 2073.83 kW and 2088.24 kW respectively. This was 19 - 20% higher than that of Gin F. Although gins H1 and H2 were identical, the average of input power used was different. This may be associated with the handling process since the process had the greatest difference between these two gins. Possibly, there were some machines related to handling process were not operating when the measurement was taken. The average of energy uses per bale in Gins H1 and H2 were 37.74 kWh/bale and 40.95 kWh/bale respectively. As explained above, these values were strongly dependent on the processing rates for each gin. However, the average of energy usage per bale for Gin H1 and H2 were actually 2 and 9.6% lower than that of Gin F.

7.3 Comparison of energy usage between gins

7.3.1 Gin capacity (rated output)

A comparison of power usage was made between Gin F, Gin H1 and Gin H2. By reviewing the profile of both gins, it can be seen that although both gins were using ginning machineries from the same US company (Continental Eagle brand), the total number of motors in these three gins and in their sub-process were quite different. Gin F consisted of 131 motors while Gin H had around 120 motors. The total rated output motor or total capacity of motors for Gin F was 3077.6 kW and this was 3051.6 kW for each gin in Gin H. A lower number of motors with higher capacity indicated that some of the motors in Gin H may have been upgraded. As the difference of age between these two gins was 4 years (Gin H was newer), the possibility that the machinery company had upgraded its machinery was high.

7.3.2 Total power usage (kW)

The average input power used at Gin F was 1669.9 kW, while at Gin H1 and H2 were 2073.83 kW and 2088.24 kW respectively. The difference of total input power may be due to the percentage of individual motor loading inside the gin. As total rated output and efficiency (referring to the age) were nearly the same for both gins, Gin H1 and H2 appeared to be running the motors at higher load than Gin F. This can be seen in the pie charts of motor loading (%) for each gin (Figure 7.4, 7.12 and 7.13) and the number of motors that occupied each percentage, where Gin F recorded the highest number (39) of motors with less than 40% motor loading. This was in comparison with 25 and 35 motors in Gins H2 and H1 with respectively.

Motors in the gin were also classified according to their sub-processes. Tables 7.3, 7.4 and 7.5 show that the power usage (kW) in each process was different between these two gins. Besides the influence of power being used (depending on percentage of motor loading) for each motor, the value was also dependent on the total number of motors that were responsible for each sub-process.

For the percentage of energy usage in different sub-processes, Gin F and Gins H1 and H2 were compared with overseas data recorded in the literature review (Table 3.3). It can be seen that the percentage of energy use per bale for each part of the sub-process was quite different between gins.

This may be due to the following factors: (1) number of motors in each sub-process - Although Anthony and Eckley (1994) have differentiated the motors (Table 3.2), cotton gins usually contain more than 100 motors of various sizes and are connected in different ways, and it would therefore be difficult to classify the motors according to their processes, (2) power used (kW) – this will depend on motor loading, (3) production rate (bale/hour), (4) motor’s capacity, (5) probability that each gin uses different brands and designs of machinery. Also, the way to measure the electricity usage was not clearly defined by Anthony and Eckley (1994).

7.3.3 Energy use per bale

Energy was calculated by dividing the input power (kW) with the production rate of each gin (bale/hour). The average production rate for Gin F was 40 bales/hour (b/h), while for Gins H1 and H2 it was 54b/h and 51b/h respectively where they nearly reached the maximum capacity of the gin (60b/h). The energy used in producing one bale was 41.75 kWh/bale for Gin F, 37.74 kWh/bale for Gin H1 and 40.95 kWh/bale for Gin H2.

7.3.4 Cost per bale

Cost is calculated by multiplying the energy use with the average price charge/kWh by the Electricity company. At the current production rate, the cost per bale for Gin F, Gin H1 and Gin H2 were $5.43, $4.91and $5.32 respectively. As the production rate at Gin H was also higher than at Gin F, Gin H may be expected to have a higher net profit.

7.4 Conclusion

Detailed monitoring of the cotton ginning operation was undertaken at two ginning sites. The monitoring involved the measurement of power and energy for individual motors as well as at the switchboard meters. For this purpose, the information of plant layout and motor rating was first analysed. To reduce the number of motors to be monitored, only the motors that operated under one particular line of ginning process were selected for detailed monitoring.

The relationship between electricity usage and incoming cotton for both gins has shown that the electricity usage increased as production rates of bales increased. However, changes in trash content in the module, degree of moisture and lint quality produced did not have a significant influence on electricity usage. The cotton variety has been shown to affect the energy usage, because the gin stand energy consumption was related to fibre-seed detachment.

From the monitoring carried out at these two gins, it has also been found that the average energy used in producing one bale was 41.75 kWh/bale for Gin F, 37.74 kWh/bale for Gin H1 and 40.95 kWh/bale for Gin H2. The energy used within the sub-processes has been found to be quite different for each gin. This was related to the total number of motors that were responsible for each sub-process and the influence of the power used for each motor within the sub-process. Overall, cotton handling was the largest energy user and took up nearly 50% of power use in both gins.

From the individual motor monitoring, in Gin F, it was found that 80% of total motors with capacity 10kW and above had a power factor lower than 0.8. This was subsequently corrected by the capacitor banks so that the power factor of the whole gin was still high (0.96). It has also been found that 30% of motors inside the gin operated at less than 40% loading. It is therefore suggested that ginners may need to pay more attention to keep the gin running at high load and should endeavour to increase the power factor of individual motors.

By comparing the energy consumption at both sites, it has been found that although Gin H used more power, however because the production rate at Gin H was also higher, the average energy use per bale (kWh/bale) at Gin H was actually slightly lower than Gin F. The electricity cost per bale for Gin F, Gin H1 and Gin H2 were $5.43, $4.91and $5.32 respectively.

CHAPTER 8

Conclusions

Ginning is an energy intensive process. This project has evaluated the energy usage inside the cotton gins in Australia. In this thesis, the evaluation of energy usage has been divided into two levels: (1) basic level – reviewing the energy usage and energy profile at the whole gin level (2) advance level – finding the performance of individual motors and the energy usage breakdowns in each sub-process. The energy usage patterns based on the conditions of incoming cotton have also been identified. The conclusions of this study are discussed below based on each level:

Basic level

- Electricity usage comprised about 61% of total energy use while another 39% was occupied by gas.

- Electricity use (kWh) per bale was found to range between 44-66 kWh, with national average around 52.3 kWh. This was consistent with the data identified in overseas research.

- The drying process used about 0.74-3.90 m^3/bale of natural gas or 2.27-5.61 litres/bale of LP gas. The average of fuel consumed in dryers was about 100 MJ/bale.

- The electricity cost per bale ($/bale) was found to range between $5.12 – 11.94/bale and constituted about 77% of the overall energy cost. Cost of gas in producing one bale was around $0.98-3.39/bale. On average, the "national benchmark" energy cost (both electricity and gas) was $ 10.70/ bale.

- It was estimated that 60.38 kg of CO_2 was emitted for ginning each bale of cotton. This was approximately ¼ of the weight of the bale.

Electricity

- The electricity consumption was nearly linearly correlated with the bale numbers produced between different gins. This may be related to the fact that all gins were using similar machines and following similar operation procedures for all incoming cotton. The electric motors were not switched off or restarted during the ginning process.

- Electricity cost was strongly influenced by both electricity usage and maximum demand. For similar electricity consumption per bale, the electricity cost per bale ($/bale) could be very different, and up to 100% for different electricity tariffs. This illustrated the great importance of selecting suitable electricity tariffs based on the load profiles of a particular site.

- The electricity fixed charges (network charge, capacity charge, etc) was a significant cost for cotton ginning operations. During the ginning seasons, electricity cost, which was caused by usage and demand charges occupied at least 70% of the total electricity cost. It is therefore necessary to reduce maximum demand and usage as both of them will reduce the electricity cost.

- Handling was found to be the largest energy user and took up 50-60% of total power required. Packaging and handling together used some 70% of total power required.

- Maximum demand and total of kW required for all the processes increased with the gin‘s capacity. Maximum demand occupied 48-67% of total kW required to run all the energy-consuming equipment.

- During the ginning seasons, the load factors varied between 1.7-66%, typically around 20-30%. All the gins also had an average of power factor of not below 0.85. This was acceptable for most of the electricity companies.

Gas

- Based on the analysis of collected data, it was found that among the six gins, the averaged drying temperature showed a good fit with incoming module moisture. Drying temperature generally increased as module moisture increased, to up to 16% moisture content.

- Gas usage was strongly influenced by the moisture and regulated temperature. It may also be significantly affected by the "unnecessary" practice of heating air where the use of ambient temperature may be adequate.

- Overall thermal efficiency of the drying process was less than 15%. The highest percentage achieved was 14.25% in Gin D in August 2008. There may be a significant scope to improve the performance in the aspect.

Advanced level

- A method for the detailed monitoring of energy performance in cotton gins has been developed and described in this study.

- The monitoring involved the measurement of power and energy for individual motors. For this purpose, the information of plant layout and motor rating was first analysed. To reduce the number of motors to be monitored, only the motors that operated under one line of the ginning process were selected for detailed monitoring. In addition, electricity data were also obtained from the electricity company which routinely recorded electricity usage at the switch boards.

- Detailed monitoring was undertaken at two selected ginning sites (Gin F and Gin H). However, due to the site constraints, only electricity current measurements were carried out at Gin H.

- It was found that the electricity usage at both gins increased as production rates of bales increased.

- Changes in trash content in the module, degree of moisture and lint quality produced did not have significant influence on electricity usage. The cotton variety was shown to affect the energy usage.

- The average energy used in producing one bale was 41.75 kWh/bale for Gin F, 37.74 kWh/bale for Gin H1 and 40.95 kWh/bale for Gin H2. These values were lower than the "national benchmark" found in the Basic Level.

- The energy used within sub-processes was found to be quite different for each gin. Overall, cotton handling was the largest energy user and took up of nearly 50% of power use in both gins.

- From the individual motor monitoring, in Gin F, it was found that 80% from total motors with a capacity of 10kW and above had a power factor of less than 0.8. This has been subsequently corrected by the capacitor banks so that the power factor of the whole gin was still high (0.96).

- By comparing the energy consumption at both sites, it was found that although Gin H used more power, however because the production rate at Gin H was also higher, the average energy use per bale (kWh/bale) at Gin H was actually slightly lower than Gin F. The electricity cost per bale for Gin F, Gins H1 and Gin H2 were $5.43, $4.91and $5.32 respectively.

- It is suggested that ginners may need to pay more attention to keep the gin running at high load and should increase the power factor of individual motors. However, before undertaking these improvements, detailed assessments of the economic and operational criteria should be carried out first.

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APPENDICES

Appendix 1.1

Questionaire

The entire question has to be answered based on gin's practice.
The ginner is recommended to attach the gin layout which is clearly shown the gin's arrangement.

Seed Cotton

i) Type of cotton (*please tick the appropriate box*)
( ) Dryland cotton ( ) Irrigated Cotton

ii) The cotton brought to your gin are harvested by (*please tick the appropriate box*)
( ) Machine-picked harvester ( ) Stripped harvester

iii) Cotton variety: ___

Module

i) How the module is built?

ii) Size of module
Height: ______m Width: _______m Long: ___*ft*

iii) Weight for each module: ___

iv) Is there any possibility to modify the size of module?
( ) Yes (*l*) No, (*please state*):

v) How long usually modules are stored before ginning processes take place?

vi) Are there any manners that you use to manage the module before ginning in a way of preserving cotton quality? *(exp: cover the module, give the priority to high moisture content modules, etc)*

vii) How many module processed each day : ________stacks

viii) How many bales that can we produce in one module?

Ginning process

i) Please state the sequences of the ginning process in your gin

ii) The capacity of gin: ____bales/hour

iii) What had been regulated by the control unit once the modules moisture content detected? (*This question has to be attached with the information regarding the data availability from the control software)* (*please tick the appropriate box*)
( ) Exposure time in dryer

( ) Dryer Temperature
( ) Fan speed / air velocity in (dryer / conveying pipes)
( ) Air volume in dryer and conveying pipes
( ) Air temperature in conveying pipes
( ) Sequences of ginning process
( ) Others, (*please state*): _________________

iv) Bypass only will be applied when

( ) Moisture content of module at: ________%
( ) Trash content at:
( ) Others, (*please state*): _________________

v) Does the gin apply the moisture restoration process?
Please state the location: ______________

vi) Please state the brand and model no. of every machine involved:

<u>Dryer</u>

i) Dryer's capacity: ____________ bales/hr

ii) Are there any sensors located in the dryer?
( ) Yes ( ) No
If yes, please state type of sensors and the location:

iii) What type of fuels use for dryer?
( ) Natural gas ( ) Liquefied Propane (LP)

iv) Does the air in conveying pipe also been heated?
( ) Yes ( ) No
If yes, the temperature of air is based on (*exp: moisture contents of modules, etc*):
If the temperature is static: ____________^{o}C

v) What's the limit of moisture content of cotton that allows you to bypass the dryer?

vi) If the temperature in the dryer is regulated manually;
Have you recorded the data of initial moisture and regulated variable (temp, etc):

Please state the rules of thumb of the operator
Range of initial moisture content:
Range of temperature inside the dryer:
Conveying air:

vii) Does the temperature inside the dryer and conveyor same?

viii) Are there any sensors located in the air conveyor pipes?
( ) Yes ( ) No
If yes, please state type of sensors and the location: ___________

Seed cotton cleaning and extracting

i) Cylinder cleaner is powered by (*exp: electric motor, etc*):
ii) Extractor feeder is powered by (*exp: electric motor, etc*):
iii) Does the extractor feeder will automatically stop and start when the gin breast is engaged or disengaged
( ) Yes ( ) No

Gin Stand

i) Gin stand's capacity: _____________bales/hr
ii) Gin stand is powered by (*exp: electric motor, etc*):

Lint Cleaner

i) Lint cleaner is powered by (*exp: electric motor, etc*):

Baling machine

i) Baling machine's capacity: ___bales/hr
ii) Baling machine is powered by (*exp: electric motor, etc*):

Practice

i) Start up: Did all the machines are started simultaneously?
ii) Idle: Did you slowdown the machine once it idles?

Conveying System

i) How did you reduce the flow of air if material is not being moved?
(Using gate valves or slows down the fan speed?)

ii) How many push and pull centrifugal fan involved and what is the capacity and power for each fan.

(Push/pull) Fan 1: ___________m^3/min, __________hp_________m/s
(Push/pull) Fan 2: ___________m^3/min, __________hp_________m/s
(Push/pull) Fan 3: ___________m^3/min, __________hp_________m/s
(Push/pull) Fan 4: ___________m^3/min, __________hp_________m/s

iii) Please state the responsible area of each fan:

Fan 1:
Fan 2:
Fan 3:
Fan 4:
Fan 5:
Fan 6:

Ginning Machine

Name of machine	Quantity
Dryer	
Cylinder cleaner	
Gin stand	
Baling	

Appendix 4.1

Shift Monitor Control Sheet

Date	Pick (1) 2	Grower's Name	First Bale 611 946
Gin	Rain Grown / Spindle Pick ✓	Farm Name	Last Bale
Shift Number / Day / Afternoon / (Night)	Irrigated ✓ / Stripper Pick	Field Number	Total Bales

No	Module Number	Seed Variety	Seed Moisture	Module Weight	Module Moisture	Turnout	Bales per Hour	Bales per Module	Moisture Gin	Moisture Bale	Burners 1	Burners 2	Lint Cleaners Running (L/C)	Comments
1	706004	S71BR		15460	4	41.1	50	28	4	6.3	48	48		
2	706003	"		13680	4	40.9	50	25	4	6	48	48		
3	706086	"		15500	4	41.2	50	28	4	6.2	48	48		
4	706005	"		14700	4	40.5	50	26	4	6.3	48	48		
5	706007	"		14680	4	40.0	50	26	4	6.5	48	48		
6	706008	"		11160	4	41.8	50	21	4	6.5	48	48		
7	706996	"		13800	4	40.0	50	23	4	6.5	55	55		
8	705995	"		14580	4	40.5	50	27	4	6.3	55	55		
9	705998	"		13200	4	39.3	50	23	4	6.5	58	58		
10	705997	"		13220	4	39.8	50	24	4	6	58	58		
11	706000	"		14660	4	39.6	50	26	4	6.3	58	58		
12	705999	"		12700	4	41.1	50	24	4	6.5	58	58		
13	706084	S80BRF		13040	4	38.8	50	23	4	6.5	58	58		
14	706085	"		13220	4	37.2	50	22	4	6.3	60	60		
15	706086	"		13220	4	37.6	50	22	4	6.3	60	60		SICOT 80 BRF MODULES
16	706092	"		14520	4	35.2	50	23	4	6.4	63	63		VERY HIGH IN TRASH
17	706093	"		15640	4	35.9	50	25	4	6.3	63	63		CONTENT. HAD TO PUT
18	706094	"		17370	4	35.1	50	27	4	6.5	63	63		BURNERS UP TO 63
19	706095	"		17340	4	36.6	50	28	4	6.5	63	63		TO CLEAN UP SAMPLES
20	706096	"		12210	4	45.3	50	25	4	6.3	63	63		
21	706097	"		12240	4	39.9	50	22	4	6.4	63	63		
22	706098	"		11440	4	37.9	50		4	6.5	63	63		
23	706087	"		7680	4	36.8	50	13	4	6	63	63		
24	706099	"		9300	4		50		4	6.5	63	63		
25	706088	"		13280	4		50		4	6.5	63	63		
26	706089	"		14020	4		50							

Hourly Control from Commencement Time	Hours	1	2	3	4	5	6	7	8	9	10	11	12
First Bale Number													
Bales Produced in Hour													
Progressive Hourly Total													
Half Hourly Bale Moisture First %													

Comments

Appendix 4.2

Electricity usage and production for all gins

Year	Month	Electricity usage (kWh)						Production (bales)					
		Gin A	Gin B	Gin C	Gin D	Gin E	Gin F	Gin A	Gin B	Gin C	Gin D	Gin E	Gin F
2007	**Jan**	11,240	16,274	15,106	8,340	4,077	10,009						
	Feb	12,017	12,047	15,367	7,420	5,395	13,953						
	Mar	100,299	14,135	18,563	185,559	185,481	15,789	1,594			3,486	3,997	
	Apr	518,018	435,277	271,105	247,813	313,979	273,943	12,463	9,503	5,426	5,018	7,515	4,985
	May	580,739	839,448	715,464	5,371	353,959	534,493	14,605	19,097	16,913		8,295	9,918
	Jun	127,970	423,212	339,465	3,926	333,453	403,899	2,622	8,320	6,872		7,451	8,229
	Jul	12,264	24,892	83,608	24,755	116,135	16,935		1,086	1,300	362	2,430	
	Aug	8,245	12,226	16,458	15,642	6,787	9,683				179		
	Sep	5,513	10,508	10,300	5,704	3,946	6,199						
	Oct	7,255	12,277	23,592	6,581	3,684	6,798						
	Nov	7,334	9,393	10,088	6,095	2,783	5,856						
	Dec	5,992	7,786	8,878	5,502	3,119	4,919						
2008	**Jan**	8,742	11,626	9,760	6,798	3,787	6,324						
	Feb	9,027	11,409	10,525	5,917	3,651	9,311						
	Mar	10,589	9,564	10,251	178,391	36,849	8,500				3,614	357	
	Apr	156,244	79,758	29,828	212,402	328,392	16,969	2,998	1,090	24	3,808	7,205	

	May	307,036	676,685	521,420	5,907	234,514	220,897	6,113	16,447	11,759		4,950	4,050
	Jun	305,640	675,466	590,315	56,727	93,136	117,267	5,547	14,707	12,620	925	2,019	2,256
	Jul	360,011	133,373	181,271	71,711	6,625	11,452	7,441	2,436	2,595	1,281		
	Aug	71,007	19,338	90,819	73,722	2,967	6,754	904		315	1,265		
	Sep	5513	10,508	10,300	5,704	3,946	6,199						
	Oct	7255	12,277	23,592	6,581	3,684	6,798						
	Nov	7334	9,393	10,088	6,095	2,783	5,856						
	Dec	5992	7,786	8,878	5,502	3,119	4,919						

Appendix 4.3

Load Factor (Gin A)

Year	Month	kWh	kW demand	Days	Load Factor (%)	Bales produced
2007	Jan	11,240	60	31	25.18	
	Feb	12,017	119	29	14.51	
	March	100,299	1882	31	7.16	1,594
	Apr	518,018	1931	30	37.26	12,463
	May	580,739	1956	31	39.91	14,605
	Jun	127,970	1931	30	9.20	2,622
	Jul	12,264	133	31	12.39	
	Aug	8,245	85	31	13.04	
	Sep	5,513	62	30	12.35	
	Oct	7,255	54	31	18.06	
	Nov	7,334	51	30	19.97	
	Dec	5,992	52	31	15.49	
2008	Jan	8,742	49	31	23.98	
	Feb	9,027	74	29	17.53	
	March	10,589	1017	31	1.40	
	Apr	156,244	691	30	31.40	2,998
	May	307,036	1974	31	20.91	6,113
	Jun	305,640	1978	30	21.46	5,547
	Jul	360,011	1971	31	24.55	7,441
	Aug	71,007	1881	31	5.07	904
	Sep	5513	123	30	6.23	
	Oct	7255	84	31	11.61	
	Nov	7334	75	30	13.58	
	Dec	5992	79	31	10.19	

Load Factor (Gin B)

Year	Month	kWh	kW demand	Days	Load Factor (%)	Bales produced
2007	Jan	16,274	94	31	23.27	
	Feb	12,047	87	29	19.90	
	March	14,135	175	31	10.86	
	Apr	435,277	2589	30	23.35	9,503
	May	839,448	2617	31	43.11	19,097
	Jun	423,212	2625	30	22.39	8,320
	Jul	24,892	97	31	34.49	1,086
	Aug	12,226	62	31	26.50	
	Sep	10,508	63	30	23.17	
	Oct	12,277	209	31	7.90	
	Nov	9,393	49	30	26.62	
	Dec	7,786	52	31	20.13	
2008	Jan	11,626	60	31	26.04	
	Feb	11,409	64	29	25.61	
	March	9,564	49	31	26.23	
	Apr	79,758	2341	30	4.73	1,090
	May	676,685	2601	31	34.97	16,447
	Jun	675,466	2585	30	36.29	14,707
	Jul	133,373	2597	31	6.90	2,436
	Aug	19,338	290	31	8.96	
	Sep	10,508	56	30	26.06	
	Oct	12,277	73	31	22.60	
	Nov	9,393	104	30	12.54	
	Dec	7,786	55	31	19.03	

Load factor (Gin C)

Year	Month	kWh	kW demand	Days	Load Factor (%)	Bales produced
2007	Jan					
	Feb					
	March	18562.55	129.82	31	19.22	
	Apr	271105.27	2809.22	30	13.4	5455
	May	715463.89	2910.12	31	33.04	16913
	Jun	339465.17	2896.78	30	16.28	6879
	Jul	83608.44	2720.76	31	4.13	1300
	Aug	16457.78	474.52	31	4.66	
	Sep	10299.99	67.66	30	21.14	
	Oct	23591.97	119.28	31	26.58	
	Nov	10088.19	141.8	30	9.88	
	Dec	8877.96	48.62	31	24.54	
2008	Jan	9760.08	58.18	31	22.55	
	Feb	10525.66	71.12	29	21.26	
	March	10251.13	74.74	31	18.44	
	Apr	29828.12	2533.82	30	1.63	24
	May	521420.35	2903.42	31	24.14	11759
	Jun	590314.85	3017.94	30	27.17	12620
	Jul	181270.56	2906.12	31	8.38	2595
	Aug					315
	Sep					
	Oct					
	Nov					
	Dec					

Load factor (Gin D)

Year	Month	kWh	kW demand	Days	Load Factor (%)	Bales produced
2007	Jan	8,340		31	0	
	Feb	7,420		29	0	
	March	185,559	767	31	32.52	3,486
	Apr	247,813	764	30	45.05	5,018
	May	5,371	49	31	14.73	
	Jun	3,926	33	30	16.52	
	Jul	24,755	733	31	4.54	362
	Aug	15,642	717	31	2.93	179
	Sep	5,704	38	30	20.85	
	Oct	6,581	38	31	23.28	
	Nov	6,095	81	30	10.45	
	Dec	5,502	64	31	11.55	
2008	Jan	6,798	47	31	19.44	
	Feb	5,917	111	29	7.66	
	March	178,391	1471	31	16.30	3,614
	Apr	212,402	1429	30	20.64	3,808
	May	5,907	346	31	2.29	
	Jun	56,727	1406	30	5.60	925
	Jul	71,711	1391	31	6.93	1,281
	Aug	73,722	1405	31	7.05	1,265
	Sep	5,704	1487	30	0.53	
	Oct	6,581	63	31	14.04	
	Nov	6,095	62	30	13.65	
	Dec	5,502	79	31	9.36	

Load factor (Gin E)

Year	Month	kWh	kW demand	Days	Load Factor (%)	Bales produced
2007	Jan	4,077	56	31	9.79	
	Feb	5,395	124	29	6.25	
	March	185,481	699	31	35.67	3,997
	Apr	313,979	718	30	60.74	7,515
	May	353,959	721	31	65.98	8,295
	Jun	333,453	722	30	64.15	7,451
	Jul	116,135	702	31	22.24	2,430
	Aug	6,787	345	31	2.64	
	Sep	3,946	46	30	11.91	
	Oct	3,684	48	31	10.32	
	Nov	2,783	72	30	5.37	
	Dec	3,119	111	31	3.78	
2008	Jan	3,787	117	31	4.35	
	Feb	3,651	120	29	4.37	
	March	36,849	1061	31	4.67	357
	Apr	328,392	1118	30	40.80	7,205
	May	234,514	1109	31	28.42	4,950
	Jun	93,136	1090	30	11.87	2,019
	Jul	6,625	70	31	12.72	
	Aug	2,967	29	31	13.75	
	Sep	3,946	77	30	7.12	
	Oct	3,684	111	31	4.46	
	Nov	2,783	50	30	7.73	
	Dec	3,119	39	31	10.75	

Load Factor (Gin F)

Year	Month	kWh	Demand (kVA)	pf	kW (demand)	Days	Load Factor (%)	Bales produced
2007	**Jan**	10,009	61	0.7809	47.63	31	28.24	
	Feb	13,953	88.46	0.8007	70.83	29	28.30	
	March	15,789	352.38	0.7981	281.23	31	7.55	
	Apr	273,943	1,987.97	0.96	1911.04	30	19.91	4,985
	May	534,493	2,059.76	0.96	1985.61	31	36.18	9,918
	Jun	403,899	2,075.89	0.97	2003.44	30	28.00	8,229
	Jul	16,935	304.62	0.859	261.67	31	8.70	
	Aug	9,683	255	0.8065	205.66	31	6.33	
	Sep	6,199	70.25	0.7852	55.16	30	15.61	
	Oct	6,968	59.53	0.6978	41.54	31	22.55	
	Nov	5,856	63.11	0.6501	41.03	30	19.82	
	Dec	4,920	56.65	0.7324	41.49	31	15.94	
2008	**Jan**	6,324	63.88	0.7574	48.38	31	17.57	
	Feb	9,311	88.14	0.7337	64.67	29	20.69	
	March	8,500	80.71	0.7548	60.92	31	18.75	
	Apr	16,968	215.84	0.8257	178.22	30	13.22	
	May	220,897	2,106.94	0.96	2025.40	31	14.66	4,050
	Jun	117,268	2,101.97	0.96	2017.68	30	8.07	2,256
	Jul	11,452	295.72	0.8127	240.33	31	6.40	
	Aug	6,754	87.85	0.8154	71.63	31	12.67	
	Sep	5,975	71.28	0.7509	53.52	30	15.50	
	Oct	6,746	64.36	0.7658	49.29	31	18.40	
	Nov	6,454	66.79	0.7216	48.20	30	18.60	
	Dec	4,733	45.25	0.6867	31.07	31	20.47	

Appendix 5.1

Thermal Efficiency

Gin	Year	Month	Module MC (%)	H2O (kg)	Desired MC (%)	H2O (kg)	kg H2O removed	MJ (1 kg H_2O =2.5 MJ)	GJ	Bales	GJ Input	GJ/bale	Thermal eff (%)
Gin A	**2007**	**Mar**	4.97	11.04	4.00	8.80	2.24	5.61	0.006	1594	1026.33	0.64	0.87
		Apr	4.00	8.80	4.00	8.80	0.00	0.00	0.000	12463	1109.44	0.09	0.00
		May	4.11	9.05	4.00	8.80	0.25	0.63	0.001	14605	878.82	0.06	1.05
		Jun	4.88	10.83	4.00	8.80	2.03	5.09	0.005	2622	202.57	0.08	6.58
	2008	**Apr**	5.27	11.74	4.00	8.80	2.95	7.37	0.007	2998	1028.93	0.34	2.15
		May	6.20	13.95	4.00	8.80	5.16	12.89	0.013	6113	1012.83	0.17	7.78
		Jun	6.93	15.72	4.00	8.80	6.92	17.31	0.017	5547	1001.40	0.18	9.59
		Jul	6.25	14.07	4.00	8.80	5.28	13.19	0.013	7441	1612.22	0.22	6.09
		Aug	6.52	14.72	4.00	8.80	5.93	14.82	0.015	904	194.26	0.21	6.90
Gin D	**2007**	**Mar**	7.78	17.81	6.60	14.92	2.89	7.23	0.007	3,486	275.29	0.08	9.16
		Apr	6.90	15.65	6.60	14.92	0.73	1.82	0.002	5,018	396.27	0.08	2.31

		Jul	7.76	17.76	6.60	14.92	2.84	7.11	0.007	362	28.59	0.08	9.00
	2008	**Mar**	6.96	15.79	6.60	14.92	0.88	2.19	0.002	3,614	468.55	0.13	1.69
		Apr	6.06	13.62	6.60	14.92	-1.29	-3.24	-0.003	3,808	405.13	0.11	-3.04*
		Jun	7.33	16.71	6.60	14.92	1.79	4.48	0.004	925	119.14	0.13	3.48
		Jul	8.67	20.03	6.60	14.92	5.11	12.78	0.013	1,281	164.99	0.13	9.92
		Aug	9.54	22.26	6.60	14.92	7.34	18.35	0.018	1,265	162.93	0.13	14.25
Gin E	**2007**	**Mar**	6.29	14.18	5.00	11.11	3.07	7.67	0.008	3997	622.78	0.16	4.92
		Apr	6.15	13.84	5.00	11.11	2.73	6.82	0.007	7515	655.83	0.09	7.81
		May	6.45	14.56	5.00	11.11	3.45	8.62	0.009	8295	1735.07	0.21	4.12
		Jun	6.62	14.96	5.00	11.11	3.85	9.63	0.010	7451	1459.33	0.20	4.92
		Jul	6.30	14.20	5.00	11.11	3.09	7.71	0.008	2430	328.60	0.14	5.70
	2008	**Apr**	6.57	14.84	5.00	11.11	3.73	9.31	0.009	7205	568.05	0.08	11.81
		May	6.52	14.72	5.00	11.11	3.61	9.03	0.009	4950	964.08	0.19	4.64
		Jun	7.45	16.99	5.00	11.11	5.88	14.69	0.015	2019	474.59	0.24	6.25

***Obviously, this data (negative value) was incorrect. The may be because of the mistake while recording the data.**

Appendix 6.1

(USQ - RESEARCH)

Schedule for Electricity Monitoring (For 10 kW Motors and Above)

			Switchboard 1 (05/05 – 09/05)					
Count	**Drive No.**	**MCC**	**Motors**	**05/05**	**06/05**	**07/05**	**08/05**	**09/05**
1	**4**	**1**	**Overflow Fan**					
2	**5**	**1**	**2A Pull Fan**					
3	**13**	**1**	**No. 1 Primary Lint Cleaner**					
4	**14**	**1**	**2A Push Fan**					
5	**21**	**1**	**Cotton Cross Conveyer**					
6	**23**	**1**	**No. 1 L/C Discharge Fan**					
7	**28**	**1**	**No. 1 Stripper Fan**					
8	**31**	**1**	**No. 2 Stripper Fan**					
9	**32**	**1**	**1A Pull Fan**					
10	**33**	**1**	**No. 3 Stripper Fan**					
11	**36**	**1**	**No. 4 Stripper Fan**					
12	**38**	**1**	**No. 1 Mote Fan**					
13	**39**	**1**	**No. 2 Mote Fan**					
14	**40**	**1**	**Battery Cond Discharge Fan**					
15	**130**	**2**	**Mote Room Fan**					

			Switchboard 2 (10/05 – 12/05)			
Count	**Drive No.**	**MCC**	**Motors**	**10/05**	**11/05**	**12/05**
1	**131**	**2**	**Mote Press**			
2	**132**	**2**	**No. 1 Booster Pump**			
3	**139**	**2**	**No. 2 Booster Pump**			
4	**146**	**2**	**No. 3 Booster Pump**			
5	**153**	**2**	**Tramper Pump**			
6	**154**	**2**	**Lint Belt**			
7	**157**	**2**	**No. 1 Press Pump**			
8	**161**	**2**	**No. 2 Press Pump**			
RE	**51**	**3**	**No. 1 Gin Stand**			

Details:

	HIOKI – 1 motor per monitored
	KYORITSU – 2 motor per monitored
	Re- monitor

			Switchboard 3 (13/05 – 20/05)								
Count	**Drive No.**	**MCC**	**Motors**	**13/05**	**14/05**	**15/05**	**16/05**	**17/05**	**18/05**	**19/05**	**20/05**
1	43	3	Elevator Fan								
2	47	3	1A Incline Cleaner								
3	49	3	1A Stick Machine Vac Wheel								
4	50	3	1A Stick Machine								
5	51	3	No. 1 Gin Stand								
6	64	3	2A Incline Cleaner								
7	76	3	No. 1 Upper Feeder								
8	77	3	No. 1 Lower Feeder								
9	79	3	Steam Roller Exhaust Fan								
10	82	3	Conveyor Distributor								
11	86	3	Big J Separator								
12	87	3	Big J Spiked Roller								
13	88	3	No. 1 Secondary Lint Cleaner								
14	90	3	Big J Vacuum Wheel								
15	91	3	Disperser Bottom								
16	92	3	No. 1 Push Fan								
17	93	3	Seed Blower								
18	97	3	Seed Conveyor								
19	91A		Disperser Top								
20	101	3	Battery Condenser								
21	117	3	MF Bed 2 High speed								
22	126	3	MF Bed 3 VS High Speed								
RE	153	2	Tramper Pump								
RE	157	2	No. 1 Press Pump								

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Appendix 6.2

Schedule for Spot Measurement (for Motors below 10kW)

Count	Drive No.	MCC	Motors	05/05	07/05	09/05	11/05	13/05	15/05	17/05	19/05
1	10	1	Cyclone Conv Vac Wheel								
2	11	1	Cyclone Conveyor								
3	20	1	Big J Feed rollers								
4	29	1	No. 1 Manifold Drum								
5	30	1	No. 2 Manifold Drum								
6	34	1	No. 3 Manifold Drum								
7	35	1	No. 4 Manifold Drum								
8	128	2	Mote Cleaner								
9	129	2	Mote Vac. Wheel								
10	133	2	No. 1A Oil Cooler								
11	134	2	No. 1B Oil Cooler								
12	135	2	No. 2A Oil Cooler								

13	**136**	**2**	**No. 2B Oil Cooler**								
14	**137**	**2**	**No. 1 Oil Cooler Pump**								
15	**138**	**2**	**No. 2 Oil Cooler Pump**								
16	**142**	**2**	**Bale Lift Conveyor**								
17	**143**	**2**	**Bale Roller Conveyor**								
18	**144**	**2**	**Bagger Ram**								
19	**145**	**2**	**No. 1 Bale Conveyor**								
20	**147**	**2**	**No. 2 Bale Conveyor**								
21	**151**	**2**	**Press Rotator**								
22	**48**	**3**	**1A Incline Clnr Vac Wheel**								
23	**57**	**3**	**Cross Conveyor Vac Wheel**								
24	**58**	**3**	**Trash Cross Conveyor**								
25	**59**	**3**	**Stick Machine Trash Conveyor**								
26	**60**	**3**	**Upper Feeder Trash Conveyor**								
27	**61**	**3**	**Centrifugal Trash Conveyor**								
28	**62**	**3**	**Gin Hull Conveyor**								
29	**65**	**3**	**2A Incline Clnr Vac Wheel**								
30	**78**	**3**	**Humidifier Fan**								

31	**89**	**3**	**Overflow Separator**								
32	**94**	**3**	**Overflow Breaker Cylinder**								
33	**95**	**3**	**1A Rock Trap**								
34	**99**	**3**	**Steam Roller**								
35	**102**	**3**	**Overflow Feed Rollers**								
36	**107**	**3**	**MF Bed 1 VS Drive**								
37	**108**	**3**	**No. 1 Seed Bin Auger**								
38	**109**	**3**	**No. 2 Seed Bin Auger**								
39	**116**	**3**	**MF Bed 2 Low Speed**								
40	**121**	**3**	**No. 1 Upper Feeder VS Drive**								
41	**122**	**3**	**No. 1 Lower Feeder VS Drive**								
42	**123**	**3**	**No. 1 Primary L/C VS Drive**								
43	**124**	**3**	**No. 1 Secondary L/C VS Drive**								
44	**125**	**3**	**MF Bed 3 VS Low Speed**								
45	**CB**		**Trash Hopper Hydraulics**								
46	**CB**		**No. 1 Seed Bin Hydraulic**								
47	**CB**		**No. 2 Seed Bin Hydraulic**								

Appendix 6.3 (USQ - RESEARCH)

GIN:______________________________ **SHIFT** **MONITOR CONTROL SHEET**

Date				**Pick (1/2)**						**Farm Name**				**First bale**		
Grower's Name				**Rain Assisted**			**Spindle Pick**			**Field Number:**				**Last bale**		
Shift (day/night)				**Irrigated**			**Stripper Pick**							**Total Bales**		
No	**Time**	**Module No.**	**Module weight**	**Seed Variety**	**Module Moisture**	**Lint Cleaner**	**Dryer's temp**		**Lint Turnout**	**A.B.W**	**B.P.H**	**B.P.M**	**First Bale No.**	**Moisture Moisture**		**Comments**
							1	**2**						**Gin Gin**	**Bale Bales**	
Hourly Control From Comm. Time				**Hours**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**		**9**	**10**	**11**
First Bale No																
Bales Produced In Hour																
Progressive Hourly Total																
Half Hourly Bale Moisture First %																

Appendix 6.4

TRASH

Date	Module No.	Weight

Date	Module No.	Weight

Appendix 7.1

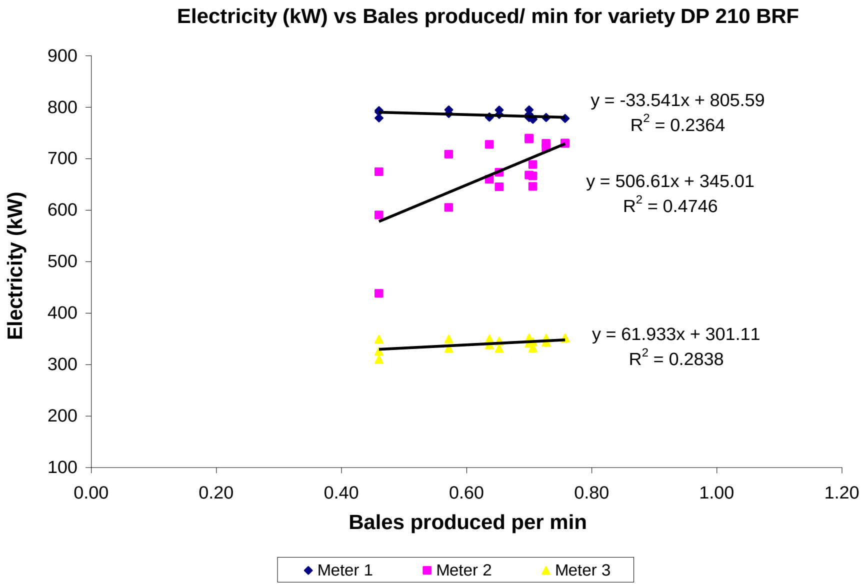


Figure A 7.1: Relationship between electricity (kW) with bales produced for DP 210BRF

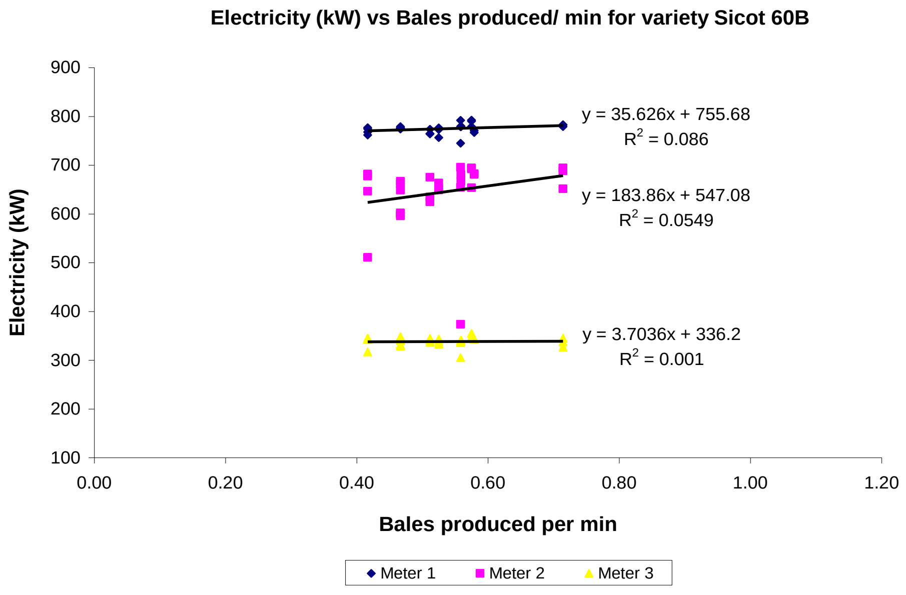


Figure A 7.2: Relationship between electricity (kW) with bales produced for Sicot 60B

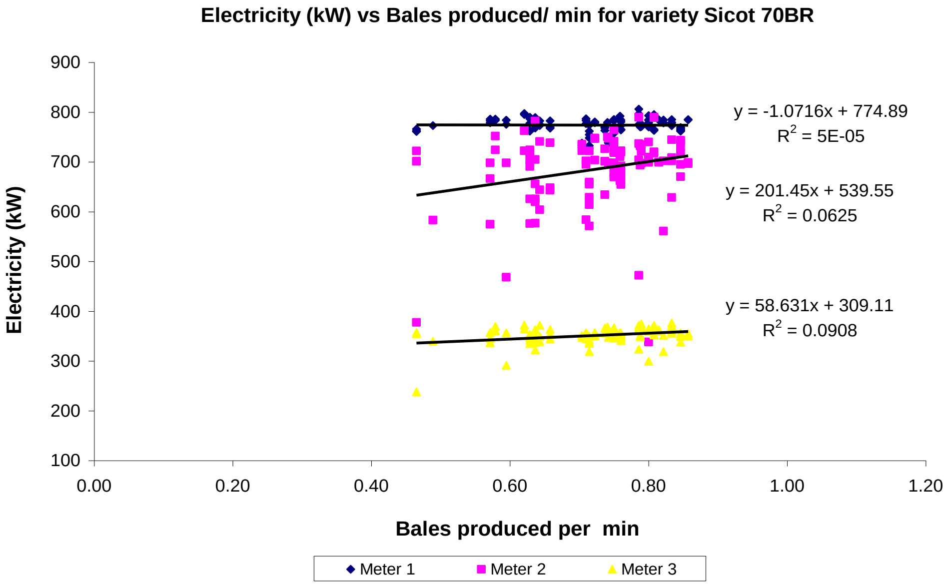


Figure A 7.3: Relationship between electricity (kW) with bales produced for Sicot 70BR

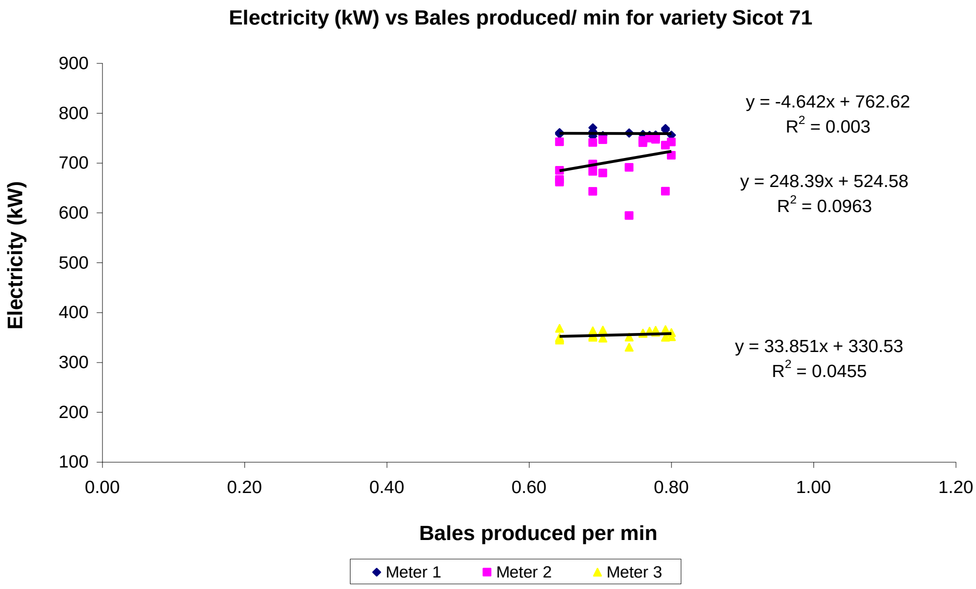


Figure A 7.4: Relationship between electricity (kW) with bales produced for Sicot 71

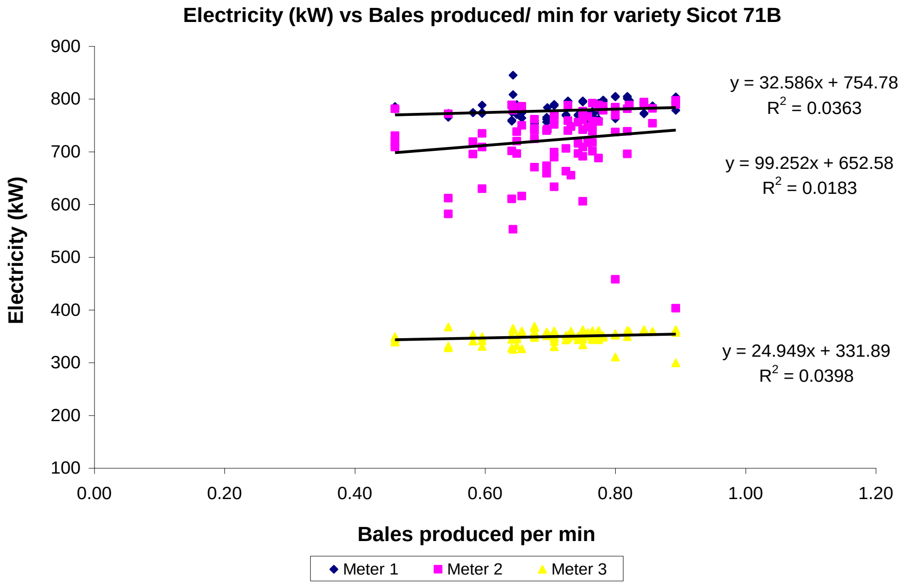


Figure A 7.5: Relationship between electricity (kW) with bales produced for Sicot 71B

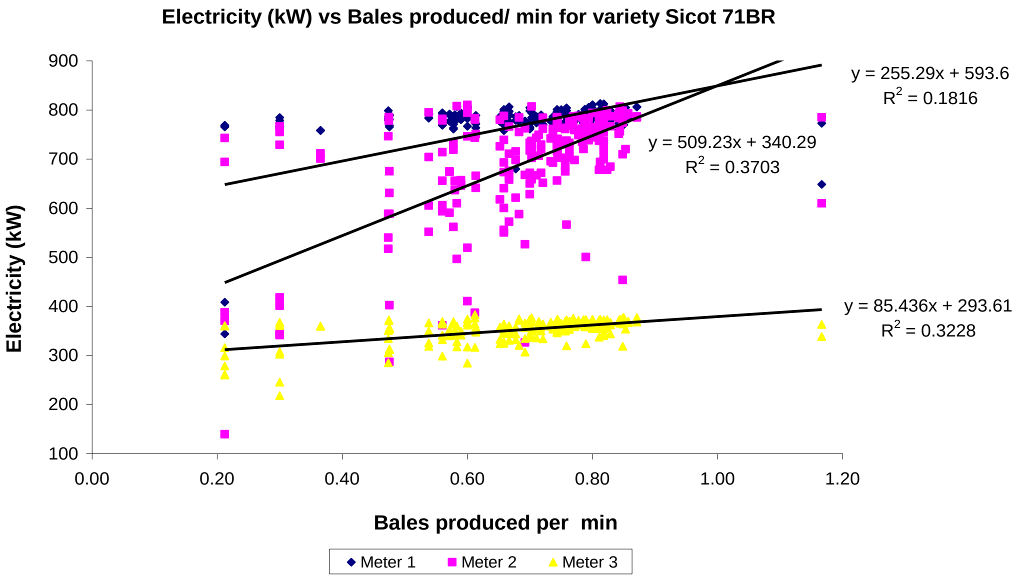


Figure A 7.6: Relationship between electricity (kW) with bales produced for Sicot 71BR

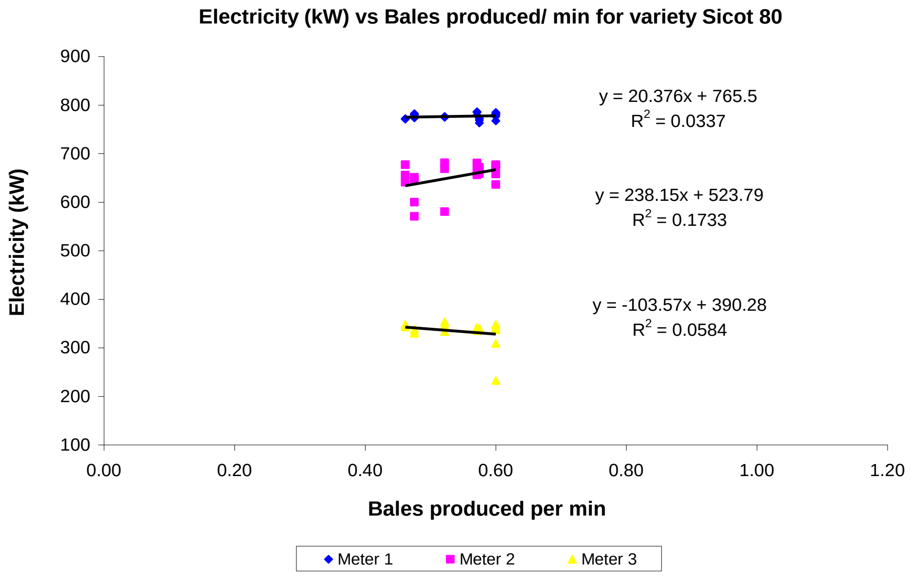


Figure A 7.7: Relationship between electricity (kW) with bales produced for Sicot 80

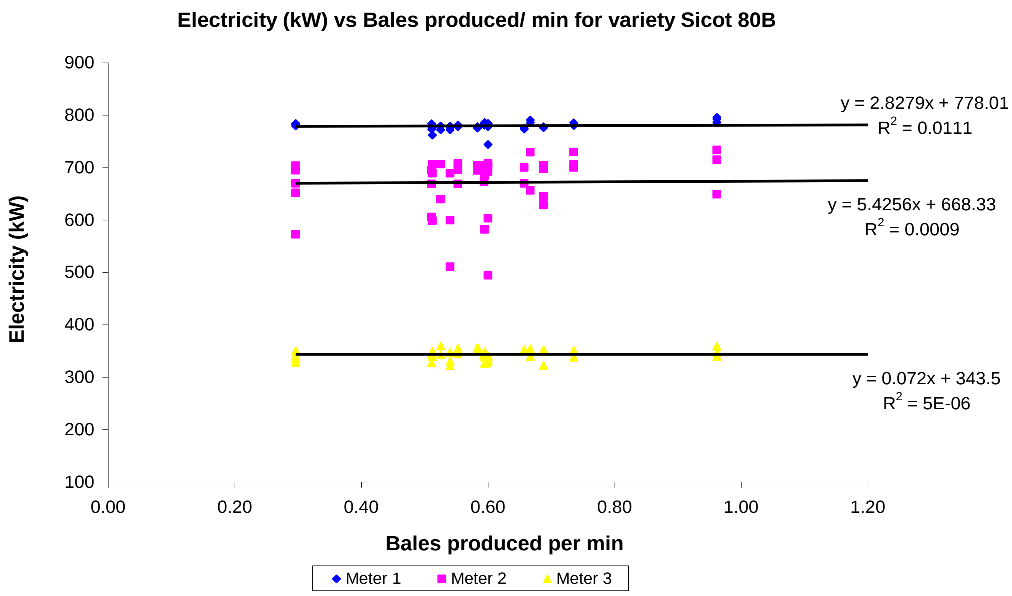


Figure A 7.8: Relationship between electricity (kW) with bales produced for Sicot 80B

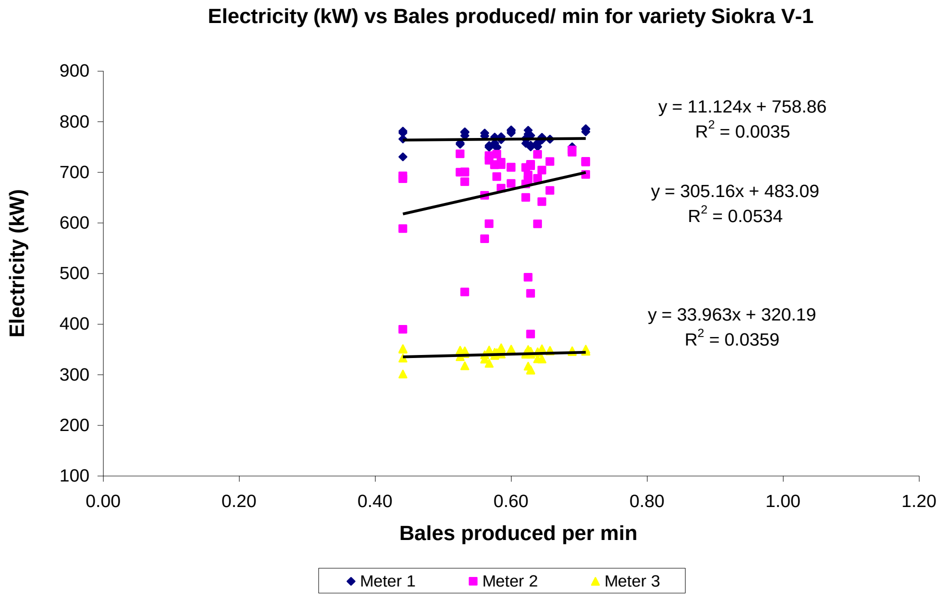


Figure A 7.9: Relationship between electricity (kW) with bales produced for Siokra V-1

Appendix 7.2

Procedures for calculating the percentage of motor loading for motors above 10 kW

The power meter was connected live to each motor for one shift (7pm-7am) and the data was recorded every 5 minutes. For each motor measured, the parameters of recorded averaged instantaneous data are shown in Table 6.4. In order to calculate the individual motor loading, the instantaneous real power usage recorded for each motor was first averaged.

The motors' power usage have been averaged and compiled in Appendix 7.2.1 (Column B). By referring to the table in Appendix 7.2.1, the steps to calculate the motor loading are shown below:

i) Column A – Motors' rated output power (P_{Or}). The rated output power for each motor was gathered from the ginners.

ii) Column B – Motors' input power (measured) (P_{Im}). The values in this column were from the average of instantaneous real power resulting from the monitoring

iii) Column C – Motors' full load efficiency (η). Based on experience, the full load efficiency for each motor has been assumed according to the rated output power and motors' age.

Full load efficiency (η) for 11 kW rated output power motors = 0.8
Full load efficiency (η) for 110 kW rated output power motors = 0.9.
The full load efficiency (η) for the rated output power motors between 11kW and 110kW was calculated by using interpolation.

iv) Column D – Motors' rated input power (P_{Ir}). Rated input power was calculated using the formula

$$Rated\ input\ power, P_{Ir} = \frac{Rated\ output\ power, P_{or}}{Full\ load\ efficiency, \eta} \quad (A7.1)$$

v) Column E – Percentage of motor loading (M_L). This was calculated by using the following formula:

$$Motor\ loading, M_L(\%) = \frac{Measured\ input\ power, P_{Im}}{Rated\ input\ power, P_{Ir}} \quad (A7.2)$$

Appendix 7.2.1

List of measured and calculated data for motors above 10 kW

No	Motors	(A) Rated output power, P_{Or} (kW)	(B) Measured input power, P_{Im} (kW)	(C) Full Load Efficiency (η)	(D) Rated input, P_{Ir} (kW)	(E) Motor loading (%)
1	Overflow Fan	37.00	19.46	0.83	44.78	43.5
2	2A Pull Fan	55.00	21.19	0.84	65.13	32.5
3	No. 1 Primary Lint Cleaner	30.00	18.08	0.82	36.62	49.4
4	2A Push Fan	37.00	33.27	0.83	44.78	74.3
5	Cotton Cross Conveyer	11.00	30.13	0.80	13.75	219.1
6	No. 1 L/C Discharge Fan	45.00	0.12	0.83	53.93	0.2
7	No. 1 Stripper Fan	37.00	25.48	0.83	44.78	56.9
8	No. 2 Stripper Fan	37.00	62.7	0.83	44.78	140.0
9	1A Pull Fan	75.00	23	0.86	86.74	26.5
10	No. 3 Stripper Fan	37.00	24.2	0.83	44.78	54.0
11	No. 4 Stripper Fan	37.00	23.5	0.83	44.78	52.5
12	No. 1 Mote Fan	55.00	50.86	0.84	65.13	78.1
13	No. 2 Mote Fan	55.00	52.3	0.84	65.13	80.3
14	Battery Cond Discharge Fan	75.00	50	0.86	86.74	57.6
15	Mote Room Fan	37.00	34.17	0.83	44.78	76.31
16	Mote Press	22.00	4.73	0.81	27.12	17.44
17	No. 1 Booster Pump	110.00	76	0.90	122.22	62.18
18	No. 2 Booster Pump	110.00	60	0.90	122.22	49.09
19	No. 3 Booster Pump	110.00	65.5	0.90	122.22	53.59
20	Tramper Pump	110.00	57.51	0.90	122.22	47.05
21	Lint Belt	15.00	0.46	0.80	18.66	2.47
22	No. 1 Press Pump	110.00	54.5	0.90	122.22	44.59
23	No. 2 Press Pump	110.00	42.5	0.90	122.22	34.77
24	Elevator Fan	132.00	106.28	0.92	143.13	74.25
25	1A Incline Cleaner	15.00	5.52	0.80	18.66	29.59
26	1A Stick Machine Vac Wheel	11.00	2.79	0.80	13.75	20.29
27	1A Stick Machine	18.50	0.006	0.81	22.91	0.03

28	No. 1 Gin Stand	110.00	74	0.90	122.22	60.55
29	2A Incline Cleaner	15.00	5.59	0.80	18.66	29.96
30	No. 1 Upper Feeder	11.00	8.4	0.80	13.75	61.09
31	No. 1 Lower Feeder	11.00	6.92	0.80	13.75	50.33
32	Steam Roller Exhaust Fan	11.00	9.31	0.80	13.75	67.71
33	Conveyor Distributor	11.00	4.81	0.80	13.75	34.98
34	Big J Separator	15.00	5.41	0.80	18.66	29.00
35	Big J Spiked Roller	11.00	2.8	0.80	13.75	20.36
36	No. 1 Secondary Lint Cleaner	30.00	-0.54	0.82	36.62	-1.47
37	Big J Vacuum Wheel	11.00	32.03	0.80	13.75	232.95
38	Disperser Bottom	30.00	0.06	0.82	36.62	0.16
39	No. 1 Push Fan	37.00	0.25	0.83	44.78	0.56
40	Seed Blower	55.00	31.3	0.84	65.13	48.06
41	Seed Conveyor	11.00	-0.22	0.80	13.75	-1.60
42	Battery Condenser	11.00	-2.89	0.80	13.75	-21.02
43	MF Bed 2 High speed	11.00	0.65	0.80	13.75	4.73
44	MF Bed 3 VS High Speed	11.00	0.48	0.80	13.75	3.49
45	Disperser Top	22.00	5	0.81	27.12	18.43

Appendix 7.3

Procedures in calculating the percentage of motor loading for motors below 10 kW

The less than 10 kW motors were spot-measured using a hand-held current tong. The current reading was taken 9 times for each motor across the monitoring period (Appendix 7.3.1). All the values have been averaged and collated in column G (Appendix 7.3.2). By referring to the table in Appendix 7.3.2, the averaged values were used to calculate the motor loading, according to the following steps:

i) Column F – Motors' rated output power (P_{Or}). The rated output power for each motor has been gathered from the ginners.

ii) Column G - Motors' current (measured) (I_m). The values in this column are from the average of currents measured as a result of the monitoring (Appendix 7.3).

iii) Column H – Motors' full load efficiency (η). The full load efficiency for each motor has been assumed according to the rated output power and motors' age.

Full load efficiency (η) for 0.75 kW rated output power motors = 0.7
Full load efficiency (η) for 5.5 kW rated output power motors = 0.8

For the rated output power motors between 0.75 kW and 10 kW the full load efficiency (η) was calculated by using interpolation.

iv) Column I - Motors' rated input power (P_{Ir}). Rated input power was calculated from Equation A7.1.

v) Column J – Rated current (I_L). By using the rated input power from Column I, assuming line voltage V_L = 415 V and power factor (pf) = 0.8, the rated current was calculated using the following formula:

$$Rated\ current, I_L = \frac{Rated\ input\ power, P_{Ir}}{\sqrt{3} * V_L * p.f} \quad (A7.3)$$

The rated current, I_L was then compared to the measured current, I_m (Column G). The power factor of 0.8 was used to find input power, P_I if the rated and measured current were close.

vi) Column K - Input power (P_I)

$$Input\ power, P_I = \sqrt{3} * V_L * I_m * p.f \quad (A7.4)$$

Where Line voltage, V_L = 415V and power factor, pf = 0.8

vii) Column L – Percentage of motor loading (M_L). This was calculated by using the formula below:

$$Motor\ loading, M_L(\%) = \frac{Input\ power, P_L}{Rated\ input\ power, P_{Ir}} \quad (A7.5)$$

Appendix 7.3.1

List of measured current for motors below 10 kW

No	Motors	Current Measured (Amps)									
		05/05/09	06/05/09	08/05/09	10/05/09	13/05/09	14/05/09	16/05/09	18/05/09	20/05/09	Average (Amps)
1	Cyclone Conv Vac Wheel	5.4	5.21	5.45	5.42	5.37	5.67	5.32	5.4	5.57	5.42
2	Cyclone Conveyor	2.81	2.65	2.76	2.74	2.72	2.73	2.75	2.7	2.77	2.74
3	Big J Feed rollers	2.82	3.61	2.26	2.26	3.01	3.12	2.87	2.31	2.53	2.75
4	No. 1 Manifold Drum	1.19	1.25	1.27	1.27	1.23	1.22	1.25	1.25	1.24	1.24
5	No. 2 Manifold Drum	1.22	1.27	1.29	1.31	1.27	1.3	1.3	1.31	1.29	1.28
6	No. 3 Manifold Drum	1.23	1.24	1.36	1.39	1.27	1.26	1.35	1.35	1.27	1.30
7	No. 4 Manifold Drum	1.29	1.25	1.31	1.30	1.28	1.3	1.31	1.29	1.3	1.29
8	Mote Cleaner	5.84	5.87	6.27	6.41	5.83	5.94	5.75	6.2	5.96	6.01
9	Mote Vac. Wheel	6.18	5.95	6.36	6.30	5.94	6.22	6.1	6.2	6.36	6.18
10	No. 1A Oil Cooler	1.45	1.42	1.52	1.52	1.44	1.4	1.45	1.44	1.42	1.45
11	No. 1B Oil Cooler	4.53	1.58	1.61	1.61	1.54	1.57	1.55	1.58	1.5	1.90
12	No. 2A Oil Cooler	1.42	1.50	1.52	1.50	1.5	1.52	1.48	1.51	1.49	1.49
13	No. 2B Oil Cooler	1.53	1.52	1.59	1.72	1.54	1.64	1.52	1.64	1.7	1.60
14	No. 1 Oil Cooler Pump	4.65	4.84	4.78	4.82	4.57	4.8	4.75	4.72	4.5	4.71
15	No. 2 Oil Cooler Pump	4.65	4.87	4.9	4.90	4.48	4.76	4.8	4.87	4.9	4.79

16	Bale Lift Conveyor	1.35	1.40	1.11	1.15	1.05	1.17	1.04	1.15	1.1	1.17
17	Bale Roller Conveyor	0.92	0.90	0.93	0.92	0.91	0.92	0.91	0.91	0.91	0.91
18	Bagger Ram	1.74	2.00	1.85	1.82	1.69	1.68	1.72	1.85	1.68	1.78
19	No. 1 Bale Conveyor	0.92	0.90	0.95	0.96	0.95	0.95	0.96	0.95	0.95	0.94
20	No. 2 Bale Conveyor	4.56	1.61	1.65	1.66	1.59	1.65	1.66	1.6	1.64	1.96
21	Press Rotator	15	15.00								15.00
22	1A Incline Clnr Vac Wheel	9.48	9.80	9.85	9.80	9.64	9.79	9.64	9.65	9.64	9.70
23	Cross Conveyor Vac Wheel	5.35	5.35	5.69	5.72	5.69	5.58	5.7	5.7	5.68	5.61
24	Trash Cross Conveyor	5.63	5.62	5.86	5.82	5.67	5.72	5.82	5.82	5.7	5.74
25	Stick Machine Trash Conveyor		5.85	6.12	6.10			6.1			6.04
26	Upper Feeder Trash Conveyor	3.38	3.39	3.36	3.51	3.35	3.33	3.42	3.3	3.5	3.39
27	Centrifugal Trash Conveyor	6.24	5.75	6.23	6.23	6.05	6.12	6.25	6.22	6.25	6.15
28	Gin Hull Conveyor	5.2	5.10	5.21	5.22	5.07	5.13	5.05	5.05	5.2	5.14
29	2A Incline Clnr Vac Wheel	8.79	8.77	8.44	8.34	9.21	8.78	8.8	8.34	9.2	8.74
30	Humidifier Fan	5.86	5.42	5.62	5.61	5.35	5.54	5.5	5.54	5.5	5.55
31	Overflow Separator	6.43	6.33	6.86	6.84	6.54	7.12	6.95	6.9	7	6.77
32	Overflow Breaker Cylinder	5.1	5.12	5.27	5.31	5.29	5.22	5.25	5.25	5.3	5.23
33	1A Rock Trap	2.22	2.17	2.32	2.30	2.28	3.31	2.26	2.2	2.31	2.37
34	Steam Roller	2.52		2.65	2.75	2.72	2.77	2.75	2.75	2.6	2.69
35	Overflow Feed Rollers	2.75	2.83	3.26	3.30	3.4	3.4	3.22	3.33	3.4	3.21
36	MF Bed 1 VS Drive	2.07	2.07	2.17	2.18	2.31	2.25	2.2	2.2	2.15	2.18
37	No. 1 Seed Bin Auger	2.6	2.82	2.76	2.75	2.69	2.7	2.65	2.7	2.66	2.70
38	No. 2 Seed Bin Auger										

39	MF Bed 2 Low Speed	2.9	2.38	2.6	2.37	2.49	2.54	2.32	2.48	2.3	2.49
40	No. 1 Upper Feeder VS Drive	1.09	1.12	1.14	1.14	1.13	1.14	1.16	1.15	1.14	1.13
41	No. 1 Lower Feeder VS Drive	1.09	1.11	1.13	1.15	1.13	1.14	1.14	1.15	1.15	1.13
42	No. 1 Primary L/C VS Drive	5.62	5.61	6.32	6.30	6.05	6.12	6.24	6.2	6.2	6.07
43	No. 1 Secondary L/C VS Drive	3.85	4.26	5.15	5.32	4.75	4.92	4.9	4.7	5.12	4.77
44	MF Bed 3 VS Low Speed			5.65	5.71	5.21	5.65	5.35	5.66	5.4	5.52
45	Trash Hopper Hydraulics										
46	No.1 Seed Bin Hydraulics										
47	No. 1 Seed Bin Hydraulics										

Appendix 7.3.2

List of measured and calculated data for motors below 10 kW

Count	Motors	(F) Rated output power (kW)	(G) Ave current measured (Amps)	(H) Full load Efficiency (η)	(I) Rated Input in (Watt)	(J) Rated current (Amps)	(K) Input power (Watt)	(L) Motor loading (%)
1	Cyclone Conv Vac Wheel	5.50	5.42	0.80	6875.00	11.96	3118.64	45.36
2	Cyclone Conveyor	2.20	2.74	0.73	3011.53	5.24	1573.70	52.26
3	Big J Feed rollers	2.20	2.75	0.73	3011.53	5.24	1583.92	52.60
4	No. 1 Manifold Drum	0.75	1.24	0.70	1071.43	1.86	713.69	66.61
5	No. 2 Manifold Drum	0.75	1.28	0.70	1071.43	1.86	738.61	68.94
6	No. 3 Manifold Drum	0.75	1.30	0.70	1071.43	1.86	748.83	69.89
7	No. 4 Manifold Drum	0.75	1.29	0.70	1071.43	1.86	743.08	69.35
8	Mote Cleaner	4.00	6.01	0.77	5205.48	9.05	3454.72	66.37
9	Mote Vac. Wheel	4.00	6.18	0.77	5205.48	9.05	3553.11	68.26
10	No. 1A Oil Cooler	0.75	1.45	0.70	1071.43	1.86	834.45	77.88
11	No. 1B Oil Cooler	0.75	1.90	0.70	1071.43	1.86	1090.66	101.80
12	No. 2A Oil Cooler	0.75	1.49	0.70	1071.43	1.86	858.73	80.15
13	No. 2B Oil Cooler	0.75	1.60	0.70	1071.43	1.86	920.07	85.87

14	No. 1 Oil Cooler Pump	2.20	4.71	0.73	3011.53	5.24	2711.00	90.02
15	No. 2 Oil Cooler Pump	2.20	4.79	0.73	3011.53	5.24	2755.72	91.51
16	Bale Lift Conveyor	0.75	1.17	0.70	1071.43	1.86	672.16	62.73
17	Bale Roller Conveyor	0.75	0.91	0.70	1071.43	1.86	525.84	49.08
18	Bagger Ram	1.50	1.78	0.72	2095.59	3.64	1024.21	48.87
19	No. 1 Bale Conveyor	0.75	0.94	0.70	1071.43	1.86	542.46	50.63
20	No. 2 Bale Conveyor	1.50	1.96	0.72	2095.59	3.64	1125.80	53.72
21	Press Rotator	7.50	15.00	0.84	8906.25	15.49	8625.61	96.85
22	1A Incline Clnr Vac Wheel	7.50	9.70	0.84	8906.25	15.49	5577.26	62.62
23	Cross Conveyor Vac Wheel	4.00	5.61	0.77	5205.48	9.05	3224.06	61.94
24	Trash Cross Conveyor	7.50	5.74	0.84	8906.25	15.49	3300.73	37.06
25	Stick Machine Trash Conveyor	7.50	6.04	0.84	8906.25	15.49	3474.68	39.01
26	Upper Feeder Trash Conveyor	4.00	3.39	0.77	5205.48	9.05	1951.31	37.49
27	Centrifugal Trash Conveyor	5.50	6.15	0.80	6875.00	11.96	3535.86	51.43
28	Gin Hull Conveyor	5.50	5.14	0.80	6875.00	11.96	2953.79	42.96
29	2A Incline Clnr Vac Wheel	7.50	8.74	0.84	8906.25	15.49	5026.50	56.44
30	Humidifier Fan	7.50	5.55	0.84	8906.25	15.49	3190.84	35.83
31	Overflow Separator	5.50	6.77	0.80	6875.00	11.96	3895.58	56.66
32	Overflow Breaker Cylinder	4.00	5.23	0.77	5205.48	9.05	3010.02	57.82
33	1A Rock Trap	2.20	2.37	0.73	3011.53	5.24	1365.40	45.34
34	Steam Roller	3.70	2.69	0.76	4854.97	8.44	1546.14	31.85
35	Overflow Feed Rollers	2.20	3.21	0.73	3011.53	5.24	1845.88	61.29
36	MF Bed 1 VS Drive	1.50	2.18	0.72	2095.59	3.64	1252.31	59.76
37	No. 1 Seed Bin Auger	2.20	2.70	0.73	3011.53	5.24	1554.53	51.62
38	No. 2 Seed Bin Auger	2.20						

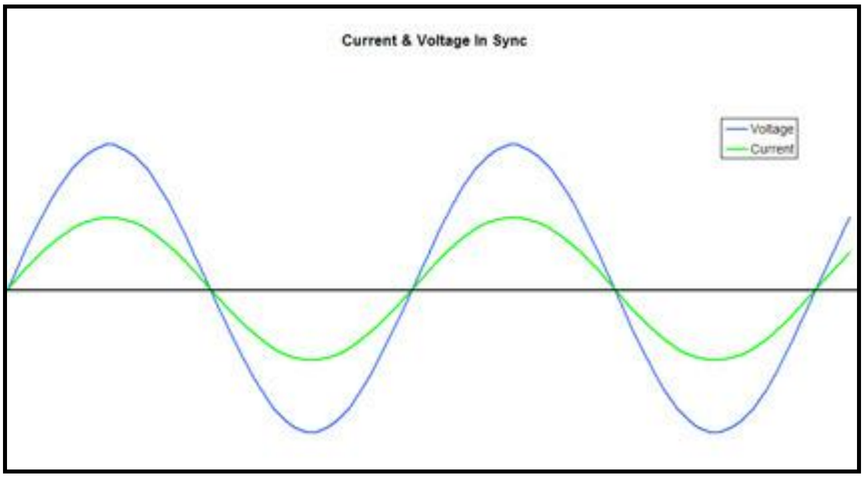
39	MF Bed 2 Low Speed	1.50	2.49	0.72	2095.59	3.64	1429.93	68.24
40	No. 1 Upper Feeder VS Drive	0.75	1.13	0.70	1071.43	1.86	652.35	60.89
41	No. 1 Lower Feeder VS Drive	0.75	1.13	0.70	1071.43	1.86	651.07	60.77
42	No. 1 Primary L/C VS Drive	3.00	6.07	0.75	4014.08	6.98	3492.41	87.00
43	No. 1 Secondary L/C VS Drive	3.00	4.77	0.75	4014.08	6.98	2745.50	68.40
44	MF Bed 3 VS Low Speed	1.50	5.52	0.72	2095.59	3.64	3173.40	151.43
45	Trash Hopper Hydraulics							
46	No.1 Seed Bin Hydraulics							
47	No. 1 Seed Bin Hydraulics							

Appendix 7.4

The relationship between negative values of power with lagging power factor

In AC circuits, power is delivered as Volts and Amps and measured as Watts. In a simple DC circuit, a watt is a volt-amp or volts multiplied by amps (e.g., 1 watt = 1 volt x 1 amp). The voltage (E) and the current (I) in the circuit follow a simple relationship known as Ohm's law (E = I x R or I = E/R, where R is the resistance to the flow of the current in the circuit). In AC, R is replaced by **impedance** (Z), which is a combination of resistance and another element called **reactance**. Reactance consists of two parts: inductive reactance and capacitive reactance. These two reactive components are added together and determine how much of the voltage and current in an AC circuit is consumed in the form of a watt.

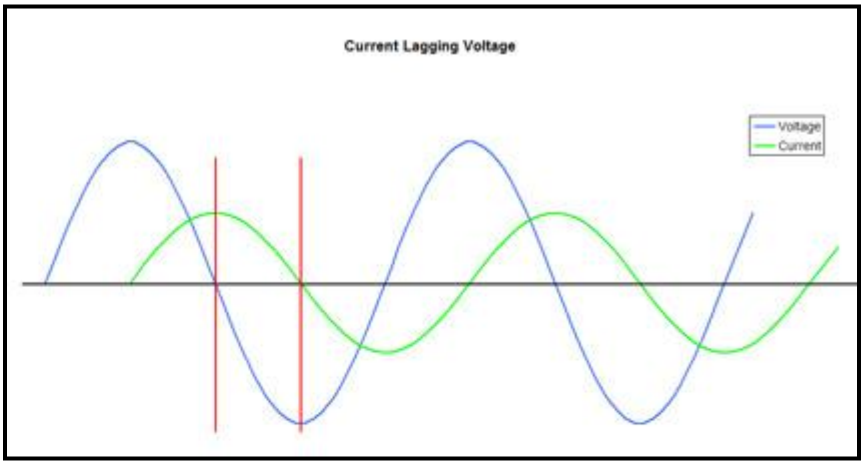
In a purely resistive AC circuit, the power consumption tends to follow the simple rules of DC. Figure A7.10 shows voltage and current in a resistive circuit travelling in sync or in phase (0 degree lag). Because power is the product of the voltage and the current (P = I*E), the power will always be a positive number whenever the instantaneous current and voltage are both positive (above the line) and negative (both are below the line) as negative times negative is positive. In the case of purely resistive load the power factor also always equals 1 and all the power in the circuit is available to perform work.



Source: (Evans, 2007a)

Figure A7.10: Voltage and current waveforms in a purely resistive circuit

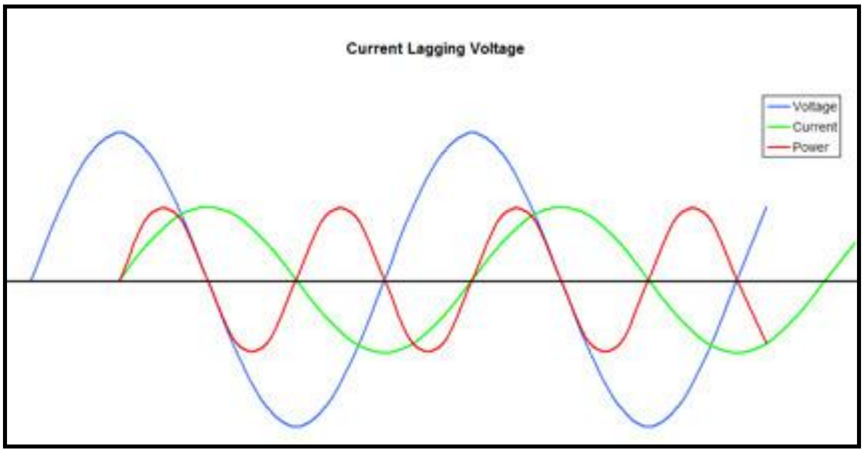
However, if the load is not purely resistive and contains one or both of the reactive components, this synchronous relationship will not hold true. Figure A7.11 shows the relationship between voltage and current waveforms for purely inductive circuits. The curves visualize the current, lagging the voltage by 90 degrees. In this case, the power factor is equal to 0, where none of the power in the circuit is available to do the work. The lagging effect has to do with the resulting value of the volt-amp. The portion of the two curves that falls between the two vertical red lines illustrates the current curve as being positive but the voltage curve is negative. The product of a positive current with negative voltage is negative power.



Source: (Evans, 2007a)

Figure A7.11: Current waveform lagging the voltage waveform in an inductive circuit

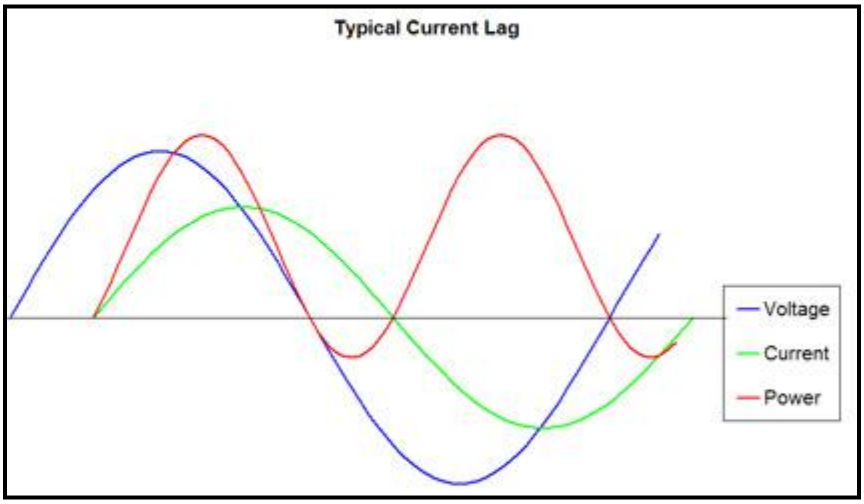
The clear picture of actual power in the circuit is shown by the red curve in the Figure A7.12. Because the current and voltage waves are 90^o out of phase, there are times when power is positive while the other is negative, resulting in equally frequent occurrences of *negative instantaneous power*. Negative power means that no power is transferred or generated and it is simply returned to the circuit.



Source: (Evans, 2007a)

Figure A7.12: Power waveform in an inductive circuit

All the figures above show the condition of a purely resistive and purely inductive circuit, but in normal conditions, almost all circuits are a combination of resistive and inductive loads and in some cases, they are capacitive as well. Figure A7.13 shows an example of the typical circuit that is feeding both inductive and resistive devices. This circuit has a lag of 45 degrees (pf = 0.7) which means that 70% of actual power has been converted to real power. Almost 30 percent of the remainder or "reactive" power is returned to the circuit and this can result in some undesirable consequences such as voltage drop, or increases in current drawn (Evans, 2007a).



Source: (Evans, 2007b)

Figure A7.13: Voltage, current and power waveforms in a typical resistive and inductive circuit

Appendix 7.5

Consequences of low power factor

Current drawn

Serious attention should be given to the motors which gave a negative value of power. For inductive motors, lagging power factor (low power factor) has a strong effect on the value of power produced. If the monitoring data is looked at in detail, the power factor for the motors that gave negative power was often quite low.

Power factor is the ratio of the real, useful power to apparent power. Apparent power is measured in Volt-Amps and it is the product of voltage in the AC system with the currents that flows in. In an electric system, a load with low power factor draws more current than a load which has a high power factor to produce the same amount of useful power (e.g., to perform the same amount of work). The relationship of power factor and current amount can easily be explained through Equation A7.6. Since the quantity of voltage in a circuit is the same, the power factor becomes lower as the amount of current in the circuit increases.

The large amount of current that flows in the individual motor with a lower power factor can affect the amount of current for the whole plant. Figure A7.14 shows the example of the summation of current draws by two motors that have a low and high power factor.

As seen in Figure A7.14, Motor 1 has a power factor of 0.85 ($\theta = 31.8°$) while Motor 2 has a power factor of 0.1 ($\theta = 84.3°$) which is too low. The current draws by each motor can be calculated using Equation A7.6:

$$Current\ draws, I_m = \frac{Input\ power}{\sqrt{3} * V_L * p.f} \qquad \text{(A7.6)}$$

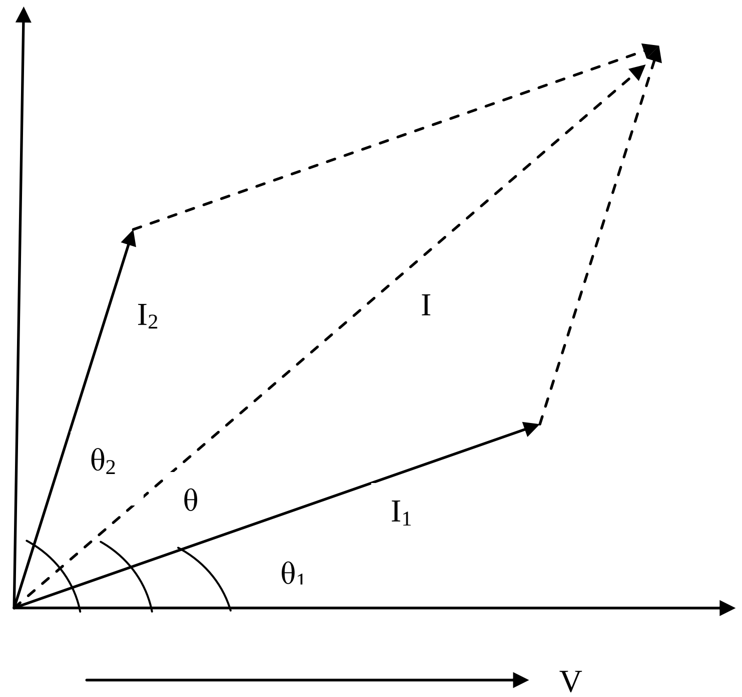


Figure A7.14: Example of the summation of current draws by two motors that has low power factor and high power factor.

Assume that both motors have the same input power = 20 kW and Voltage line = 415 V

Motor 1:

$$I_1 = \frac{20,000}{\sqrt{3} * 415 * 0.85}$$

$$= \mathbf{32.7 \ Amps}$$

Motor 2:

$$I_2 = \frac{20,000}{\sqrt{3} * 415 * 0.1}$$

$$= \mathbf{278.16 \ Amps}$$

Thus, total current drawn from source pf = 0.53 ($\theta = 58.05^o$):

$$I = \frac{20,000}{\sqrt{3} * 415 * 0.53}$$

$$= \mathbf{52.5 \ Amps}$$

From the calculation it can be seen that although Motor 1 has a high power factor, because of another motor which has a poor power factor, the total amount of current drawn is still high. The same concept applies to the whole plant where the total amount of current drawn will be high because it is affected by the low power factor motors.

The higher currents increase the energy lost in the distribution system, and require larger wires and other larger components in the system (supply transformer, switch gear, etc) to accommodate the additional current required by a low pf installation.

Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor.

As the negotiated tariff is applied based on the facilities prepared and energy supplied to the gin, correcting the power factor will help to reduce the tariff applied and prevent the penalty being charged by electrical utilities.

Voltage drops

Low power factors will cause the power system loss in the distribution system to increase. As loss increases, this will maximize the voltage drops. The reduction in voltage is very sensitive to a motor’s torque and it reduces the starting torque in motors. Motor output torque varies approximately as the square of applied voltage (T α V2). For example, a reduction of 10% in voltage means a 20% drop in torque, which is enough to keep some drives from ever reaching full speed (Mcketta, 1989).

Excessive voltage drops can also cause overheating and failure of motors and other equipment. Besides, voltage drops waste energy and cause reduction in the efficiency of a motor.

Appendix 7.6

List of motors according to the sub-process (Gin F)

Count	Motors	Process	Measured and calculated input power (kW)	kWh per bale (kWh/40)
1	Cotton Cross Conveyer	Handling	30.13	0.75
2	Big J Feed rollers	Handling	1.58	0.04
3	Overflow Fan	Handling	19.46	0.49
4	Cyclone Conveyor	Handling	1.57	0.04
5	Cyclone Conv Vac Wheel	Handling	3.12	0.08
6	Battery Cond Discharge Fan	Handling	50.00	1.25
7	No. 4 Manifold Drum	Handling	0.74	0.02
8	No. 3 Manifold Drum	Handling	0.75	0.02
9	No. 2 Manifold Drum	Handling	0.74	0.02
10	No. 1 Manifold Drum	Handling	0.71	0.02
11	No. 4 Stripper Fan	Handling	23.50	0.59
12	No. 3 Stripper Fan	Handling	24.20	0.61
13	No. 2 Stripper Fan	Handling	62.70	1.57
14	No. 1 Stripper Fan	Handling	25.48	0.64
15	Mote Cleaner	Handling	3.45	0.09
16	Mote Vac. Wheel	Handling	3.55	0.09
17	Mote Press	Handling	4.73	0.12
18	Mote Room Fan	Handling	34.17	0.85
19	Bale Lift Conveyor	Handling	0.67	0.02
20	Bale Roller Conveyor	Handling	0.53	0.01
21	Bagger Ram	Handling	1.02	0.03
22	No. 1 Bale Conveyor	Handling	0.54	0.01
23	No. 2 Bale Conveyor	Handling	1.13	0.03
24	MF Bed 3 VS High Speed	Handling	0.48	0.01
25	MF Bed 3 VS Low Speed	Handling	3.17	0.08
26	MF Bed 2 High speed	Handling	0.65	0.02
27	MF Bed 2 Low Speed	Handling	1.43	0.04
28	MF Bed 1 VS Drive	Handling	1.25	0.03
29	Disperser Bottom	Handling	0.06	0.00
30	1A Rock Trap	Handling	1.37	0.03

31	Big J Seperater	Handling	5.41	0.14
32	Elevator Fan	Handling	106.28	2.66
33	Big J Spiked Roller	Handling	2.80	0.07
34	Big J Vacuum Wheel	Handling	32.03	0.80
35	Conveyor Distributor	Handling	4.81	0.12
36	Overflow Feed Rollers	Handling	1.85	0.05
37	Overflow Breaker Cylinder	Handling	3.01	0.08
38	Overflow Separator	Handling	3.90	0.10
39	No. 1 Upper Feeder VS Drive	Handling	0.65	0.02
40	No. 2 Upper Feeder VS Drive	Handling	0.65	0.02
41	No. 3 Upper Feeder VS Drive	Handling	0.65	0.02
42	No. 4 Upper Feeder VS Drive	Handling	0.65	0.02
43	No. 1 Upper Feeder	Handling	8.40	0.21
44	No. 2 Upper Feeder	Handling	8.40	0.21
45	No. 3 Upper Feeder	Handling	8.40	0.21
46	No. 4 Upper Feeder	Handling	8.40	0.21
47	Upper Feeder Trash Conveyor	Handling	1.95	0.05
48	No. 1 Lower Feeder VS Drive	Handling	0.65	0.02
49	No. 2 Lower Feeder VS Drive	Handling	0.65	0.02
50	No. 3 Lower Feeder VS Drive	Handling	0.65	0.02
51	No. 4 Lower Feeder VS Drive	Handling	0.65	0.02
52	No. 1 Lower Feeder	Handling	6.92	0.17
53	No. 2 Lower Feeder	Handling	6.92	0.17
54	No. 3 Lower Feeder	Handling	6.92	0.17
55	No. 4 Lower Feeder	Handling	6.92	0.17
56	Gin Hull Conveyor	Handling	2.95	0.07
57	Centrifugal Trash Conveyor	Handling	3.53	0.09
58	Trash Cross Conveyor	Handling	3.30	0.08
59	Cross Conveyor Vac Wheel	Handling	3.22	0.08
60	Seed Conveyor	Handling	-0.22	-0.01
61	Seed Blower	Handling	31.30	0.78
62	No. 1 Seed Bin Auger	Handling	1.55	0.04
63	No. 2 Seed Bin Auger	Handling	Nil	
64	Battery Condenser	Handling	-2.89	-0.07
65	Steam Roller Exhaust Fan	Handling	9.31	0.23
66	Steam Roller	Handling	1.55	0.04
67	Humidifier Fan	Handling	3.19	0.08
68	Disperser Top	Handling	5.00	0.13
69	Trash Hopper Hydraulics	Handling	Nil	
70	No. 1 Seed Bin Hydraulic	Handling	Nil	
71	No. 2 Seed Bin Hydraulic	Handling	Nil	

72	1A Pull Fan	Handling	23.00	0.58
73	1B Pull Fan	Handling	23.00	0.58
74	2A Push Fan	Handling	33.27	0.83
75	2B Push Fan	Handling	33.27	0.83
76	2A Pull Fan	Handling	21.19	0.53
77	2B Pull Fan	Handling	21.19	0.53
78	No. 1 L/C Discharge Fan	Handling	0.12	0.00
79	No. 2 L/C Discharge Fan	Handling	0.12	0.00
80	No. 3 L/C Discharge Fan	Handling	0.12	0.00
81	No. 4 L/C Discharge Fan	Handling	0.12	0.00
82	No. 1 Mote Fan	Handling	50.86	1.27
83	No. 2 Mote Fan	Handling	52.30	1.31
84	No. 1 Push Fan	Handling	0.25	0.01
		TOTAL	**852.00**	**21.30**
85	No. 1 Primary Lint Cleaner	Cleaning	18.08	0.45
86	No. 2 Primary Lint Cleaner	Cleaning	18.08	0.45
87	No. 3 Primary Lint Cleaner	Cleaning	18.08	0.45
88	No. 4 Primary Lint Cleaner	Cleaning	18.08	0.45
89	1A Incline Cleaner	Cleaning	5.52	0.14
90	1B Incline Cleaner	Cleaning	5.52	0.14
91	1A Incline Clnr Vac Wheel	Cleaning	5.58	0.14
92	1B Incline Clnr Vac Wheel	Cleaning	5.58	0.14
93	1A Stick Machine	Cleaning	0.01	0.00
94	1B Stick Machine	Cleaning	0.01	0.00
95	1A Stick Machine Vac Wheel	Cleaning	2.79	0.07
96	1B Stick Machine Vac Wheel	Cleaning	2.79	0.07
97	Stick Machine Trash Conveyor	Cleaning	3.47	0.09
98	2A Incline Cleaner	Cleaning	5.59	0.14
99	2B Incline Cleaner	Cleaning	5.59	0.14
100	2A Incline Clnr Vac Wheel	Cleaning	5.03	0.13
101	2B Incline Clnr Vac Wheel	Cleaning	5.03	0.13
102	No. 1 Primary L/C VS Drive	Cleaning	3.50	0.09
103	No. 1 Secondary L/C VS Drive	Cleaning	2.74	0.07
104	No. 2 Primary L/C VS Drive	Cleaning	3.50	0.09
105	No. 2 Secondary L/C VS Drive	Cleaning	2.74	0.07
106	No. 3 Primary L/C VS Drive	Cleaning	3.50	0.09
107	No. 3 Secondary L/C VS Drive	Cleaning	2.74	0.07
108	No. 4 Primary L/C VS Drive	Cleaning	3.50	0.09
109	No. 4 Secondary L/C VS Drive	Cleaning	2.74	0.07
110	No. 1 Secondary Lint Cleaner	Cleaning	-0.54	-0.01
111	No. 2 Secondary Lint Cleaner	Cleaning	-0.54	-0.01

112	No. 3 Secondary Lint Cleaner	Cleaning	-0.54	-0.01
113	No. 4 Secondary Lint Cleaner	Cleaning	-0.54	-0.01
		TOTAL	**147.63**	**3.69**
114	No. 1 Gin Stand	Gin Stand	74.00	1.85
115	No. 2 Gin Stand	Gin Stand	74.00	1.85
116	No. 3 Gin Stand	Gin Stand	74.00	1.85
117	No. 4 Gin Stand	Gin Stand	74.00	1.85
		TOTAL	**296.00**	**7.40**
118	Lint Belt	Packaging	0.46	0.01
119	Tramper Pump	Packaging	57.51	1.44
120	Press Rotator	Packaging	8.63	0.22
121	No. 1 Press Pump	Packaging	54.50	1.36
122	No. 1 Booster Pump	Packaging	76.00	1.90
123	No. 2 Booster Pump	Packaging	60.00	1.50
124	No. 3 Booster Pump	Packaging	65.50	1.64
125	No. 2 Press Pump	Packaging	42.50	1.06
126	No. 1 Oil Cooler Pump	Packaging	2.71	0.07
127	No. 2 Oil Cooler Pump	Packaging	2.76	0.07
128	No. 1A Oil Cooler	Packaging	0.83	0.02
129	No. 1B Oil Cooler	Packaging	1.09	0.03
130	No. 2A Oil Cooler	Packaging	0.86	0.02
131	No. 2B Oil Cooler	Packaging	0.92	0.02
		TOTAL	**374.27**	**9.36**

Appendix 7.7

Gin H1

No.	Motors	Process	Input power (kW)	kWh per bale (kW/54)
1	Module Feeder Deck Drive	Handling	23.29	0.43
2	Module Feeder Dispersing Cylinders Drive	Handling	15.65	0.29
3	Module Feeder Hydraulic Oil Cooling Fan Drive	Handling	0.39	0.01
4	Module Feeder Dust Extraction Fan Drive	Handling	10.39	0.19
5	Module feeder Hi -slip	Handling	1.63	0.03
6	Feed Bin Vari Control Drive	Handling	0.94	0.02
7	Feed Bin Spike Roller/Rotary Valve Drive	Handling	8.70	0.16
8	No. #1 Heater Push Fan Drive	Handling	37.69	0.70
9	Vertical Flow 'A' Drive	Handling	5.28	0.10
10	Vertical Flow 'B' Drive	Handling	5.28	0.10
11	Impact 'A' Drive	Handling	8.81	0.16
12	Impact 'A' Trash Auger Drive	Handling	1.57	0.03
13	Impact 'B' Drive	Handling	9.93	0.18
14	Impact 'B' Trash Auger Drive	Handling	1.57	0.03
15	Conveyor Distributor Auger Drive	Handling	7.68	0.14
16	Overflow Rotary Valve Drive	Handling	4.04	0.07
17	Overflow Bin Invertor Drive	Handling	1.57	0.03
18	Overflow Bin Spike Roller Drive	Handling	1.78	0.03
19	Overflow Fan Drive	Handling	27.37	0.51
20	No. #1 Extractor Drive	Handling	8.90	0.16
21	No. #2 Extractor Drive	Handling	8.68	0.16
22	No. #3 Extractor Drive	Handling	8.88	0.16
23	No. #4 Extractor Drive	Handling	9.67	0.18
24	GinStand Dust Extraction Fan Dive	Handling	7.68	0.14
25	No. #1 GinStand Feed Drive	Handling	0.39	0.01
26	No. #2 GinStand Feed Drive	Handling	0.39	0.01
27	No. #3 GinStand Feed Drive	Handling	0.39	0.01
28	No. #4 GinStand Feed Drive	Handling	0.39	0.01
29	Seed Plug Drive	Handling	3.23	0.06
30	Seed Conveyor Drive	Handling	3.09	0.06

31	Seed Blower Drive	Handling	49.56	0.92
32	Seed Bin Auger Drive	Handling	1.57	0.03
33	Seed Bin Hydraulic Pack Drive	Handling	15.01	0.28
34	Hull Conveyor 'B' line Drive	Handling	1.10	0.02
35	Trash Cross Auger Drive	Handling	5.28	0.10
36	Trash Blower Rotary Valve Drive	Handling	3.40	0.06
37	Trash Blower Drive	Handling	31.80	0.59
38	Cyclone Rack Rotary Valve Drive	Handling	3.51	0.07
39	Cyclone Rack Auger Drive	Handling	5.28	0.10
40	Trash House Auger Drive	Handling	2.84	0.05
41	Trash Conveyor 'A' line Drive	Handling	1.19	0.02
42	Trash Cross Conveyor	Handling	3.12	0.06
43	Centrifugal L/C Trash Conveyor	Handling	2.28	0.04
44	MotePress Hydraulic Pump Drive	Handling	35.13	0.65
45	MotePress Oil Cooler Pump Drive	Handling	0.26	0.00
46	Mote Room Bale Trolley Drive	Handling	0.26	0.00
47	Mote Room LintCleaner Drive	Handling	7.68	0.14
48	Mote Room Rotary Valve Drive	Handling	0.65	0.01
49	Mote Room Separator Drive	Handling	1.07	0.02
50	Mote Room Sepatator Fan Drive	Handling	13.17	0.24
51	Mote Room Transfer Fan Drive	Handling	10.39	0.19
52	Battery Condenser Drive	Handling	7.78	0.14
53	Battery Condenser Fan Drive	Handling	53.83	1.00
54	No. #1 Bale Conveyor Drive (strapper)	Handling	0.54	0.01
55	No. #2 Bale Conveyor Drive (old cart)	Handling	0.54	0.01
56	Bagger Ram Drive	Handling	2.30	0.04
57	Bale Exit Conveyor Drive	Handling	1.07	0.02
58	Front Mote Fan Drive	Handling	35.90	0.66
59	Rear Mote Fan Drive	Handling	35.57	0.66
60	Moisture Fan Drive	Handling	2.00	0.04
61	Overflow Vari Drive	Handling	1.03	0.02
62	Hull Conveyor	Handling	3.24	0.06
63	Horizontal Cleaner 'A' Fan Drive	Handling	57.43	1.06
64	Horizontal Cleaner 'B' Fan Drive	Handling	55.81	1.03
65	No. #1 Incline 'A' Fan Drive	Handling	45.84	0.85
66	No. #1 Incline 'B' Fan Drive	Handling	45.34	0.84
67	No. #2 Incline 'A' Fan Drive	Handling	41.19	0.76
68	No. #2 Incline 'B' Fan Drive	Handling	39.60	0.73
69	No. #1 'A' & 'B' LintCleaner Fan Drive	Handling	49.32	0.91
70	No. #2 'A' & 'B' LintCleaner Fan Drive	Handling	48.44	0.90
71	No. #3 'A' & 'B' LintCleaner Fan Drive	Handling	46.65	0.86

72	No. #4 'A' & 'B' LintCleaner Fan Drive	Handling	42.63	0.79
		Total	**862.91**	**15.98**
73	Horizontal Cleaner 'A' Rotary Valve Drive	Cleaning	2.86	0.05
74	Horizontal Cleaner 'B' Rotary Valve Drive	Cleaning	2.48	0.05
75	No. #1 Incline 'A' Rotary Valve Drive	Cleaning	8.23	0.15
76	No. #1 Incline 'B' Rotary Valve Drive	Cleaning	8.28	0.15
77	Top Super III Stick Machine 'A' Rotary Valve Drive	Cleaning	2.34	0.04
78	Top Super III Stick Machine 'B' Rotary Valve Drive	Cleaning	2.21	0.04
79	Bottom Super III Stick Machine 'A' Rotary Valve Drive	Cleaning	2.25	0.04
80	Super III Stick Machine 'A' Rotary Valve Drive	Cleaning	3.89	0.07
81	Bottom Super III Stick Machine 'B' Rotary Valve Drive	Cleaning	2.26	0.04
82	Super III Stick Machine 'B' Rotary Valve Drive	Cleaning	3.89	0.07
83	No. #2 Incline 'A' Rotary Valve Drive	Cleaning	8.42	0.16
84	No. #2 Incline 'B' Rotary Valve Drive	Cleaning	8.69	0.16
85	Horizontal Cleaner 'A' Drive	Cleaning	20.40	0.38
86	Horizontal Cleaner 'B' Drive	Cleaning	20.14	0.37
87	No. #1 Incline 'A' Drive	Cleaning	13.69	0.25
88	No. #1 Incline 'B' Drive	Cleaning	14.82	0.27
89	Top Super III Stick Machine 'A' Drive	Cleaning	7.84	0.15
90	Top Super III Stick Machine 'B' Drive	Cleaning	8.00	0.15
91	Bottom Super III Stick Machine 'A' Drive	Cleaning	8.00	0.15
92	Bottom Super III Stick Machine 'B' Drive	Cleaning	7.72	0.14
93	No. #2 Incline 'A' Drive	Cleaning	12.59	0.23
94	No. #2 Incline 'B' Drive	Cleaning	12.35	0.23
95	No. #1 Front LintCleaner Drive	Cleaning	25.60	0.47
96	No. #2 Front LintCleaner Drive	Cleaning	23.09	0.43
97	No. #3 Front LintCleaner Drive	Cleaning	22.99	0.43
98	No. #4 Front LintCleaner Drive	Cleaning	23.39	0.43
99	No. #1 Rear LintCleaner Drive	Cleaning	26.29	0.49
100	No. #2 Rear LintCleaner Drive	Cleaning	23.82	0.44
101	No. #3 Rear LintCleaner Drive	Cleaning	25.01	0.46
102	No. #4 Rear LintCleaner Drive	Cleaning	25.37	0.47
		Total	**376.93**	**6.98**
103	No. #1 GinStand Drive	Gin Stand	105.82	1.96
104	No. #2 GinStand Drive	Gin Stand	107.41	1.99
105	No. #3 GinStand Drive	Gin Stand	108.31	2.01
106	No. #4 GinStand Drive	Gin Stand	107.87	2.00
		Total	**429.41**	**7.95**
107	Electric Lint Belt Drive	Packaging	7.68	0.14

108	No. #1 Press Pump Drive (main ram & box strips)	Packaging	106.92	1.98
109	No. #2 Press Pump Drive (main ram pusher)	Packaging	102.34	1.90
110	No. #3 Press Pump Drive (tramper)	Packaging	58.04	1.07
111	No. #4 Press Pump Drive (main ram)	Packaging	51.93	0.96
112	Auxillary Pump Drive (platten, bale eject, chokes)	Packaging	9.37	0.17
113	Press Box Rotator Drive	Packaging	1.57	0.03
114	No. #1 Heat Exchange / Oil Cooler Drive	Packaging	1.57	0.03
115	No. #2 Heat Exchange / Oil Cooler Drive	Packaging	1.07	0.02
116	No. #3 Heat Exchange / Oil Cooler Drive	Packaging	1.07	0.02
117	Heat Exchange Fan Drive	Packaging	1.94	0.04
118	Humidifier Pump Drive	Packaging	1.20	0.02
119	Oil Cooler Circulation Pump Drive	Packaging	3.75	0.07
120	Samuel Automatic Strapper Circuit	Packaging	20.14	0.37
		Total	**368.58**	**6.83**

Gin H2

No.	Motors	Process	Input power (kW)	kWh per bale (kW/51)
1	Module Feeder Deck Drive	Handling	21.29	0.42
2	Module Feeder Dispersing Cylinders Drive	Handling	15.66	0.31
3	Module Feeder Hydraulic Oil Cooling Fan Drive	Handling	0.39	0.01
4	Module Feeder Dust Extraction Fan Drive	Handling	17.35	0.34
5	Module feeder hi-slip	Handling	1.94	0.04
6	Feed Bin Vari Control Drive	Handling	0.86	0.02
7	Feed Bin Spike Roller/Rotary Valve Drive	Handling	10.39	0.20
8	Feed bin Vary Drive C/B	Handling	0.82	0.02
9	No. #1 Heater Push Fan Drive	Handling	39.23	0.77
10	Vertical Flow 'A' Drive	Handling	4.66	0.09
11	Vertical Flow 'B' Drive	Handling	4.48	0.09
12	Impact 'A' Drive	Handling	9.65	0.19
13	Impact 'A' Trash Auger Drive	Handling	1.57	0.03
14	Impact 'B' Drive	Handling	8.99	0.18
15	Impact 'B' Trash Auger Drive	Handling	1.57	0.03
16	Conveyor Distributor Auger Drive	Handling	5.98	0.12
17	Overflow Rotary Valve Drive	Handling	4.84	0.09
18	Overflow Bin Invertor Drive	Handling	0.90	0.02
19	Overflow Bin Spike Roller Drive	Handling	2.12	0.04
20	Overflow Fan Drive	Handling	29.49	0.58
21	No. #1 Extractor Drive	Handling	9.70	0.19
22	No. #2 Extractor Drive	Handling	9.01	0.18
23	No. #3 Extractor Drive	Handling	9.15	0.18
24	No. #4 Extractor Drive	Handling	9.53	0.19
25	GinStand Dust Extraction Fan Dive	Handling	11.26	0.22
26	No. #1 GinStand Feed Drive	Handling	0.39	0.01
27	No. #2 GinStand Feed Drive	Handling	0.39	0.01
28	No. #3 GinStand Feed Drive	Handling	0.39	0.01
29	No. #4 GinStand Feed Drive	Handling	0.39	0.01
30	Seed Plug Drive	Handling	2.98	0.06
31	Seed Conveyor Drive	Handling	2.94	0.06
32	Seed Blower Drive	Handling	35.42	0.69

33	Seed Bin Auger Drive	Handling	1.57	0.03
34	Seed Bin Hydraulic Pack Drive	Handling	15.01	0.29
35	Hull Conveyor 'B' line Drive	Handling	1.19	0.02
36	Trash Cross Auger Drive	Handling	3.02	0.06
37	Trash Blower Rotary Valve Drive	Handling	3.16	0.06
38	Trash Blower Drive	Handling	31.75	0.62
39	Cyclone Rack Rotary Valve Drive	Handling	2.00	0.04
40	Cyclone Rack Auger Drive	Handling	3.09	0.06
41	Trash House Auger Drive	Handling	2.84	0.06
42	Trash Conveyor 'A' line Drive	Handling	1.21	0.02
43	MotePress Hydraulic Pump Drive	Handling	20.02	0.39
44	MotePress Oil Cooler Pump Drive	Handling	0.45	0.01
45	Mote Room Bale Trolley Drive	Handling	0.26	0.01
46	Mote Room LintCleaner Drive	Handling	0.55	0.01
47	Mote Room Rotary Valve Drive	Handling	0.88	0.02
48	Mote Room Separator Drive	Handling	2.44	0.05
49	Mote Room Sepatator Fan Drive	Handling	11.78	0.23
50	Mote Room Transfer Fan Drive	Handling	10.39	0.20
51	Battery Condenser Drive	Handling	7.89	0.15
52	Battery Condenser Fan Drive	Handling	35.57	0.70
53	No. #1 Bale Conveyor Drive (strapper)	Handling	0.54	0.01
54	No. #2 Bale Conveyor Drive (old cart)	Handling	0.56	0.01
55	Bagger Ram Drive	Handling	2.47	0.05
56	Bale Exit Conveyor Drive	Handling	1.28	0.03
57	Moisture Fan Drive	Handling	1.89	0.04
58	Front Mote Fan Drive	Handling	37.64	0.74
59	Rear Mote Fan Drive	Handling	37.94	0.74
60	Overflow drive	Handling	0.57	0.01
61	Horizontal Cleaner 'A' Fan Drive	Handling	57.77	1.13
62	Horizontal Cleaner 'B' Fan Drive	Handling	59.47	1.17
63	No. #1 Incline 'A' Fan Drive	Handling	43.54	0.85
64	No. #1 Incline 'B' Fan Drive	Handling	42.83	0.84
65	No. #2 Incline 'A' Fan Drive	Handling	36.51	0.72
66	No. #1 'A' & 'B' LintCleaner Fan Drive	Handling	45.71	0.90
67	No. #2 'A' & 'B' LintCleaner Fan Drive	Handling	46.56	0.91
68	No. #3 'A' & 'B' LintCleaner Fan Drive	Handling	46.86	0.92
69	No. #4 'A' & 'B' LintCleaner Fan Drive	Handling	46.53	0.91
70	No. #2 Incline 'B' Fan Drive	Handling	37.31	0.73
		Total	**974.75**	**19.11**
71	Horizontal Cleaner 'A' Rotary Valve Drive	Cleaning	2.88	0.06
72	Horizontal Cleaner 'B' Rotary Valve Drive	Cleaning	2.82	0.06

73	No. #1 Incline 'A' Rotary Valve Drive	Cleaning	8.22	0.16
74	No. #1 Incline 'B' Rotary Valve Drive	Cleaning	8.53	0.17
75	Top Super III Stick Machine 'A' Rotary Valve Drive	Cleaning	1.17	0.02
76	Top Super III Stick Machine 'B' Rotary Valve Drive	Cleaning	1.32	0.03
77	Bottom Super III Stick Machine 'A' Rotary Valve Drive	Cleaning	1.30	0.03
78	Super III Stick Machine 'A' Rotary Valve Drive	Cleaning	3.89	0.08
79	Bottom Super III Stick Machine 'B' Rotary Valve Drive	Cleaning	1.30	0.03
80	Super III Stick Machine 'B' Rotary Valve Drive	Cleaning	3.89	0.08
81	No. #2 Incline 'A' Rotary Valve Drive	Cleaning	8.61	0.17
82	No. #2 Incline 'B' Rotary Valve Drive	Cleaning	8.54	0.17
83	Horizontal Cleaner 'A' Drive	Cleaning	18.34	0.36
84	Horizontal Cleaner 'B' Drive	Cleaning	19.01	0.37
85	No. #1 Incline 'A' Drive	Cleaning	12.01	0.24
86	No. #1 Incline 'B' Drive	Cleaning	12.02	0.24
87	Top Super III Stick Machine 'A' Drive	Cleaning	0.12	0.00
88	Top Super III Stick Machine 'B' Drive	Cleaning	7.49	0.15
89	Bottom Super III Stick Machine 'A' Drive	Cleaning	7.91	0.16
90	Bottom Super III Stick Machine 'B' Drive	Cleaning	7.52	0.15
91	No. #2 Incline 'A' Drive	Cleaning	14.29	0.28
92	No. #2 Incline 'B' Drive	Cleaning	13.05	0.26
93	No. #1 Front LintCleaner Drive	Cleaning	12.73	0.25
94	No. #2 Front LintCleaner Drive	Cleaning	22.15	0.43
95	No. #3 Front LintCleaner Drive	Cleaning	20.14	0.39
96	No. #4 Front LintCleaner Drive	Cleaning	17.03	0.33
97	No. #1 Rear LintCleaner Drive	Cleaning	25.18	0.49
98	No. #2 Rear LintCleaner Drive	Cleaning	22.89	0.45
99	No. #3 Rear LintCleaner Drive	Cleaning	22.42	0.44
100	No. #4 Rear LintCleaner Drive	Cleaning	20.14	0.39
101	Lint Condenser	Cleaning	0.92	0.02
		Total	**327.82**	**6.43**
102	No. #1 GinStand Drive	Gin Stand	102.88	2.02
103	No. #2 GinStand Drive	Gin Stand	103.02	2.02
104	No. #3 GinStand Drive	Gin Stand	116.57	2.29
105	No. #4 GinStand Drive	Gin Stand	117.44	2.30
		Total	**439.91**	**8.63**
106	Electric Lint Belt Drive	Packaging	7.68	0.15
107	No. #1 Press Pump Drive (main ram & box strips)	Packaging	92.62	1.82
108	No. #2 Press Pump Drive (main ram pusher)	Packaging	97.44	1.91
109	No. #3 Press Pump Drive (tramper)	Packaging	48.88	0.96

110	No. #4 Press Pump Drive (main ram)	Packaging	54.99	1.08
111	Auxillary Pump Drive (platten, bale eject, chokes)	Packaging	9.70	0.19
112	Press Box Rotator Drive	Packaging	1.57	0.03
113	No. #1 Heat Exchange / Oil Cooler Drive	Packaging	1.57	0.03
114	No. #2 Heat Exchange / Oil Cooler Drive	Packaging	1.57	0.03
115	No. #3 Heat Exchange / Oil Cooler Drive	Packaging	1.41	0.03
116	Heat Exchange Fan Drive	Packaging	1.20	0.02
117	Humidifier Pump Drive	Packaging	3.55	0.07
118	Oil Cooler Circulation Pump Drive	Packaging	3.46	0.07
119	Samuel Automatic Strapper Circuit	Packaging	20.14	0.39
		Total	**345.76**	**6.78**