Process efficiency in winery operations: a broad review of potentially beneficial techniques and technologies

Australian Government

Australian Grape and Wine Authority

RESEARCH REPORT

Key Submission Contact:

Nick Palousis, CEO

0408 896 552

nick@2xe.com.au

www.2xe.com.au

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Executive Summary

Through previous engagement with industry stakeholders, the AGWA has recognised the need to identify and prioritise research, development and extension opportunities for process efficiency improvements in wine production. More specifically, it has identified an opportunity to increase knowledge within the wine industry about the potential opportunities from the generic engineering sector, including milk, soft drink, fruit juice, beer, and other fast moving consumer goods (FMCG) producers, and interpret it for the benefit of the wine industry. AGWA has therefore commissioned an independent investigation of existing techniques and technologies used in a broad range of industries that are likely to be beneficial and adoptable by the wine industry to improve process.

The scope of the investigation focused on process efficiency solutions that are or may be realistically available and applicable to the industry over the following 5-7 years, and could demonstrate measurable process efficiency improvements to winery operations in the context of:

- Production speed
- Labour efficiency
- Materials efficiency
- Energy efficiency, and/or
- Water efficiency.

The following report outlines the results of this investigation. In summary, the investigation has shortlisted six key opportunities (both management practices and technologies) that warrant further investigation by AGWA and/or uptake by the wine industry to improve process efficiency to the standard and extent exhibited by FMCG industries:

1. **Metrics measurement.** Production efficiency requires a shift of focus towards key parameters such as production speed, resource use (materials, energy, and water), labour use and costs. An important step in increasing efficiency is to understand and measure current efficiency levels for key each part of the production process. This can be done in a variety of ways from simple logging to more complex software with automated data collection systems. Once these metrics are understood, process efficiency levels within a business can be determined providing a target for future resource efficiency projects.

2. **Automation.** Automation can greatly enhance process efficiency by reducing materials use and labour while increasing production speed and quality. The FMCG industry has been focusing on automation heavily as a way of increasing process efficiency.
3. **Cross flow filtration.** The wine industry is greatly varied in regards to the different methods used in various winery processes. Advances in technology and its application to the wine industry are of high importance, particularly where new technology can greatly reduce resource use. Cross flow filtration provides a rapid, energy- and materials-efficient method for clarification and stabilisation and its diverse application in the food and beverage industry has been steadily increasing.
4. **Fermentation yeast efficiency.** In the context of production efficiency, it is important that process flows are streamlined and ideally continuous with repeatable results. Bottlenecks for the wine industry include fermentation and crushing/pressing processes. Studies into fermentation efficiency have determined that it is important for yeast strains to match juice quality parameters for rapid, problem free fermentation resulting in reduced fermentation times.
5. **Continuous pressing systems.** Continuous processes are more process-efficient than batched systems (due to flow-on effects associated with process scheduling, labour and quality control) and for this reason, crushing and pressing steps have greater efficiencies if continuous methods (such as screw presses) are used to maximise process efficiencies.
6. **Contact cold stabilisation.** Energy prices are continuing to rise and energy efficiency will become increasingly important to wineries. Processes such as contact cold stabilisation with heat exchange and cross flow filtration systems are one way to greatly reduce energy costs with rapidly stabilising wine.

This identified opportunities use commercially available technology and process systems that are commonly applied in other FMCG industries. The investigation did explore whether there existed any unique ‘silver bullet’ technology FMCG industries solutions that could be applied to the wine industry for dramatic improvements in process efficiency, but it was found that such solutions either did not exist, or were not applicable to the unique production characteristics of the wine industry.

The investigation found the greatest process efficiency opportunities lay in a management focus targeting and measuring existing process efficiency within the winery. Once this has been undertaken, it is then possible for wineries to make a clear choice as to which projects will have the greatest impact on improving process efficiencies.

This investigation recommends the greatest process efficiency benefits to be gained by the wine industry are likely to come from opportunity 1 (metric measurement) and opportunity 2 (automation). These opportunities have been identified as critical differentiators in the process efficiency performance of the between FMCG industry and the wine industry – the wine industry therefore has an opportunity to learn from these practices and apply them to their business models.

Introduction

Background

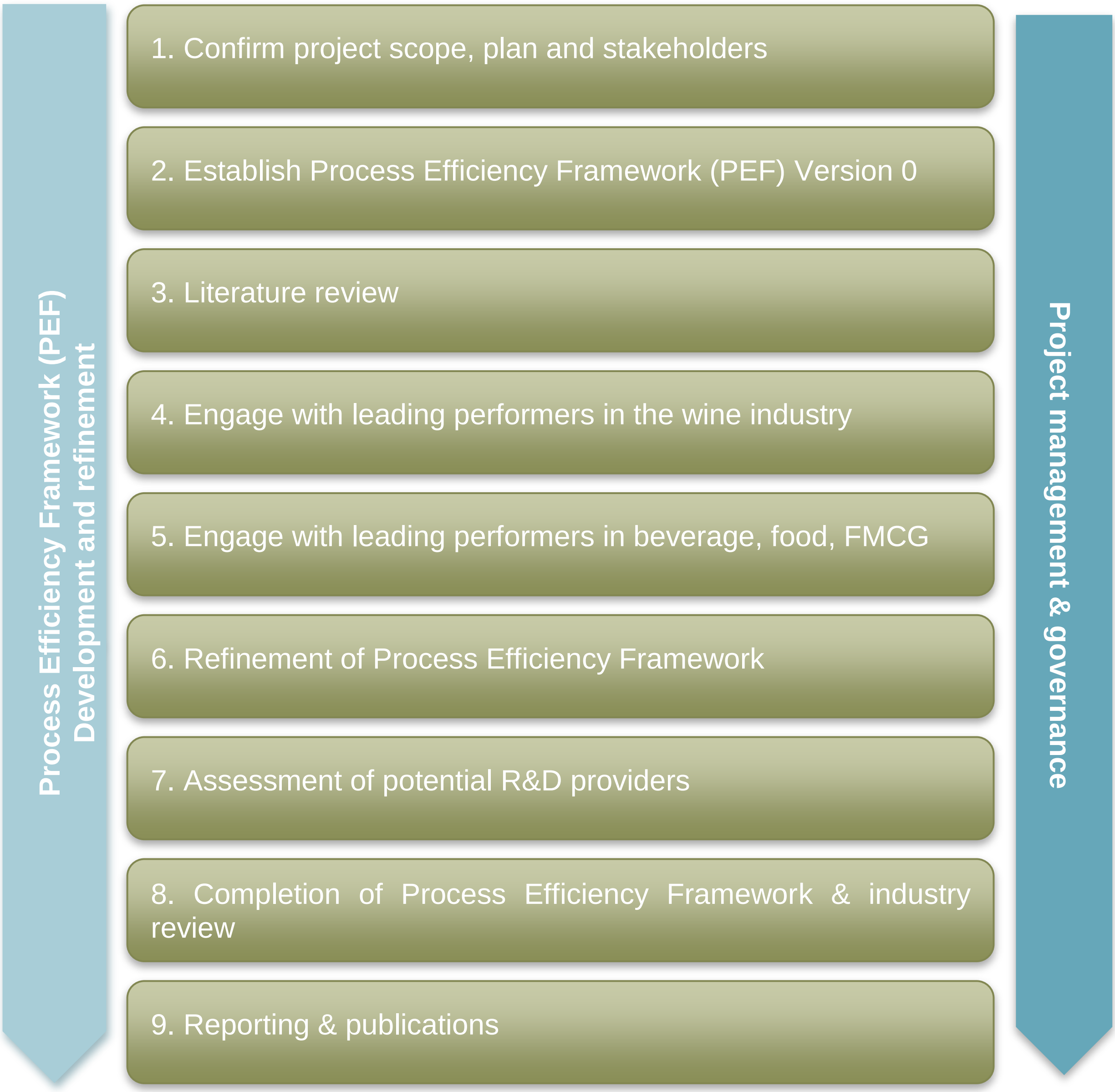
Wineries today are faced with the growing costs of doing business. For example over the past three years the cost of electricity and gas for businesses has increased by 40% on average and an increasing trend is likely to continue. Coupled with the strong Australian dollar placing further pressure on export markets (and increasing competition from lower-cost imports), the result is an industry facing tighter profit margins, and an increased importance on the adoption of techniques and technologies that enable quality wine to be made at lower input cost.

Production efficiency is a business mindset focusing on implementing techniques and technologies to reduce costs, increase speed and flexibility, and optimising resource use. Many Australian industries, such as the fast moving consumer goods (FMCG) industry, have successfully adopted production efficiency as a cornerstone of remaining competitive in local and global markets. Many lessons in production efficiency can be learned from these industries and readily applied to the wine industry, provided that the industry is ready to challenge existing paradigms that, to some extent, treat production efficiency as directly in conflict with product quality. On the contrary, production efficiency and product quality go hand-in-hand. Production efficiency isn't a module or simple step, but an encompassing change to all aspects of winery processes and management, such that profitability can be maintained through two aspects – making quality wine *and* improved cost management.

Process efficiency was identified as a key research priority by AGWA's stakeholders during consultations on the *AGWA Strategic Research, Development and Extension Plan 2012–17* (Strategic Plan). More specifically, it has identified an opportunity to increase knowledge within the wine industry about the potential opportunities from the generic engineering sector, including milk, soft drink, fruit juice, beer, and other fast moving consumer goods (FMCG), and interpret it for the benefit of the wine industry.

Project methodology

AGWA has commissioned an independent study of existing techniques and technologies used in a broad range of industries that are likely to be beneficial and adoptable by the wine industry to improve process. Opportunities in this study have been rated according to the likely benefit and uptake, so that industry can focus on the areas of most value to their businesses. Furthermore, this study has identified potential providers of R&D for future work in this area, which will help industry overcome researchable gaps and barriers to improvement in process efficiency. The diagram below provides an outline of the study methodology, and consists of nine key steps.



The scope of the investigation focused on process efficiency solutions that are or may be realistically available and applicable to the industry over the following 5-7 years, and could demonstrate measurable improvements to winery operations through:

- Production speed/flexibility
- Labour efficiency
- Materials efficiency
- Energy efficiency, and/or
- Water efficiency.

Note: The investigation did explore whether there existed any unique 'silver bullet' solutions used by other FMCG industries that could be applied to the wine industry for dramatic improvements in productivity, but it was found that such solutions either did not exist, or were not applicable to the unique production characteristics of the wine industry.

Report overview

This report is split into five main sections.

Section 1 focuses on process efficiency mapping and in particular potential process efficiency 'hot spots' in wine product and a comparison with the FMCG industry.

Section 2 investigates further general process efficiency issues in the wine industry, in particular production speeds, labour, materials, energy and water efficiency issues. This section further explores efficiency opportunities given the size variation of wineries. It also examines overlying issues such as process metric analysis and the impact of automation on process efficiency.

Section 3 examines the winery process from receival to bottling and examines process efficiency issues and opportunities at each process step.

Section 4 ranks the opportunities from section 3 according the greatest opportunity. The top five opportunities are then examined in greater detail with an overview, the benefits of each opportunity, the barriers to uptake, and potential further R&D opportunities.

Section 5 concludes by ranking the potential R&D providers.

1. Process Efficiency Mapping

The process efficiency framework (PEF) is core to identifying process efficiencies in the wine industry through the resources of FMCG processes. The PEF was established by first identifying (through initial literature review, discussions with industry and authors' experience) 'hot spots' in the winery production process where significant process efficiency issues exist (Table 1), and then identifying which FMCG industry sectors share similar processes to that of wine production (Table 2). Through cross-checking the results outlined in Table 1 and Table 2, the PEF was developed and further expanded in Section 6 to further investigate key process efficiency opportunities for the wine industry.

Process efficiency 'hot spot' mapping in wine production

Table 1. 'Hot spot' mapping – wine production versus areas of process efficiency improvement areas (red denotes key bottlenecks/priority areas for further investigation). This is based on the experience of 2XE in process efficiency, from feedback from wineries across Australia, and literature reviews.

Table 1 - 'Hot spot' mapping

Wine processes	Production speed	Labour efficiency	Materials efficiency	Energy efficiency	Water efficiency
Receival					
Crushing					
Fermentation					
Blending					
Clarification & stabilisation					
Storage					
Maturation					
Bottling					
Warehouse/ dispatch					
Vineyard management					
Transport/ distribution					

Comparison of the FMCG sectors with potential relevance to wine production

Table 1Table 2 Maps the potential relevance of wine production processes to other FMCG manufacturing processes.

Table 2 - FMCG with potential relevance to wine production

Wine - processes	Fruit Juice manufacturing	Soft drink manufacturing	Beer manufacturing	Bottled water manufacturing	Spirit manufacturing	Food processing
Receival						
Crushing						
Fermentation						
Blending						
Clarification & stabilisation						
Storage						
Maturation						
Bottling						
Warehouse/ dispatch						
Vineyard management						
Transport/ distribution						

Uniqueness of Wine Industry

There are some key differences in production model between the wine industry and FMCG industries. The most significant difference is the homogeneity of the feedstock for the FMCG industry and the diversity of the processing methods within the wine industry. The wine industry is largely push-driven with processes needing to change depending on the quality of incoming grapes, which subsequently creates challenges in processing. These differences have been summarised succinctly in an industry best practice report developed by the Commonwealth Government:

> *In some ways, the wine industry is quite different to industries such as glass, paper and plastic manufacturing which produce products with well-determined quality characteristics at the cheapest rate. The wine industry uses a diverse variety of processing methods to obtain certain quality characteristics depending on the particular style of wine sought. This diversity of methods in winemaking is a critical character of the wine industry. Best practice in relation to the operation and performance of wineries, therefore, does not mean identifying a single, most efficient process or practice for wine production.*
>
> *Best practice energy efficiency in wineries involves achieving the desired outcome (in terms of quality and quantity of wine) using the least amount of energy at lowest overall cost.* (Innovation, 2003)[1]

It has been over 10 years since the Commonwealth Government released this report on the wine industry. Since that time, the wine industry has come under greater cost-pressure and significant changes to the wine production process (and broader business model) must be implemented to evolve with the changing business environment, including the adoption of practices and technologies that significantly reduce process efficiency and flexibility, producing high quality wine at reduced processing costs to be viable into the future. There are many lessons the wine industry can learn from the FMCG industry to help increase process efficiencies. Some of these differences can be standardised to industry best practices. These lessons will be different depending on the size of the wineries and methods used throughout the wine making process.

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[1] Commonwealth of Australia 2003, *A guide to energy efficiency innovation in Australian wineries*

2. Identification of general process efficiency issues in the wine industry

Overview

This section aims to identify general process efficiency issues faced by the wine industry. These issues were determined by experience with the wine industry and from interviews with various wineries across Australia. This section has looked at the five key process criteria (production speed, labour, materials, energy and water), and has revealed other criteria that have an impact on process efficiency solutions, such as the size of the winery. Through further analysis, two additional key opportunities were found to have the greatest impact on process efficiency in the wine industry. This first is capacity for wineries to measure and understand their current process efficiency. The second is the implementation of automated systems, which have an impact on the five key process criteria.

Measurement of metrics – The beginning of process efficiency

A significant proportion of FMCG industries consistently display a formalised approach to the monitoring, benchmarking and management of production performance (against metrics such as speed, cost, energy, materials and labour utilisation), in order to identify and track opportunities to improve process efficiency and manage product quality. Every winery is different and whilst the wine industry does track some performance measures such as tonnes of grape crushed, these metrics are more of a measure of site capacity utilisation during vintage (or product quality), than they are related to process efficiency and cost performance of the site during vintage and non-vintage.

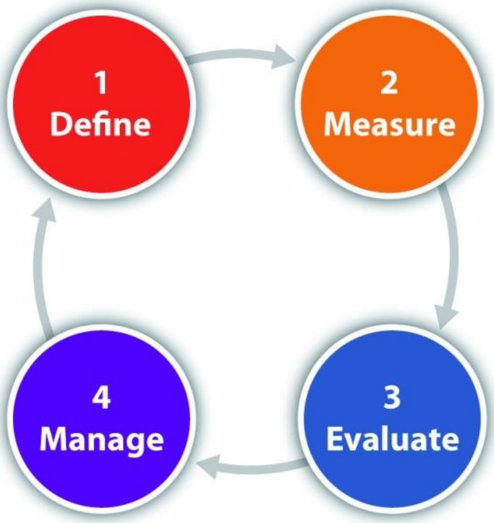

Figure 1 - metric analysis framework

An important step in increasing process efficiency for the wineries is having in-place metrics for assessing the cost-, time- and yieldperformance of the wine production process (such as tonnes of grapes crushed per hour, labour cost per kL of must-in-tank, operating cost per litre of wine produced, number of wine movements for any given period). This is important because it is difficult to manage and improve process efficiency unless the current performance of key processes can be measured and evaluated. A framework for metric analysis is included in Figure 1. Measurement and monitoring of performance against such metrics allows wineries to better identify where current inefficiencies are occurring within the production process. This allows process efficiency projects to be targeted towards production bottlenecks, delays or areas displaying poor utilisation of resources. The measurement of metrics allows wineries to measure the success of projects that have targeted a particular process, and enables wineries to justify ongoing improvement initiatives.

Size of business

The needs of wineries are different depending on the size of the facility. Different winery sizes can have significantly different process efficiency issues and certain solutions only become financially viable once the winery reaches a certain size. Common themes can still be applied across all wineries and the 'best practice' themes will remain constant, including the application of metrics to monitor process efficiencies. Some solutions can be scaled to the applicable size of the business. For example, in relation to automation, a large winery may have a fully incorporated automated process system (such as a full transfer pump, refrigeration control, real time monitoring and correction control). A smaller business may have smaller levels of automation, yet still be effective for the size of the business (such as automatic refrigeration control at a whole-of-system level instead of an individual tank level).

Figure 2 Small winery

Generally, smaller wineries (Figure 2) have the benefit of being flexible to change. The smaller the business, the faster they are able to react to changing conditions through the wine process, however they tend to have less capital available for large purchases. Larger wineries (Figure 3) gain greater efficiencies due to larger volumes of production, and so can effectively utilise expensive capital equipment to its full potential. However these businesses tend to less flexible to changes in production, due to the sheer size of the operation, the level of capital employed, and corporate structures that prevent rapid changes from being implemented.

Figure 3 - larger winery

Production Speed

Production speed is an important efficiency metric for any manufacturing industry. It's important to understand the production process and production speed thoroughly for each winery so bottlenecks and rate limiting steps can be determined and reduced if appropriate. An efficient production speed can also help improve other metrics such as labour, energy and materials efficiency. Bottleneck issues tend to be unique for each winery (for example, some wineries prefer the use of older forms of presses, such as that displayed in Figure 4, to support the character and brand of the wine); however common bottlenecks in the wine industry include primary crushing, fermentation and pressing processes.

Production speed needs to be constant throughout processes with decreased 'stop-start' activities. This ensures processes run smoothly and

Figure 4 - Antique wooden hand press

maximum speeds for processes are obtained (i.e. destemming, crushing and pressing in one continuous movement limited by the slowest process, which is usually pressing).

The FMCG industries actively targets bottlenecks and look for ways to alleviate them. In the FMCG industries, production speed is measured via metrics such as 'widgets per hour' and communicated to staff via visual workflow tools. These techniques can be easily applied to the wine industry.

Labour Efficiencies

Figure 5 - labour efficiencies

Labour resource requirements for the wine industry are relatively high, especially in smaller wineries where less automation and more manual practices are employed. With the cost of labour hire and management representing a significant proportion of total operational costs in a winery, automation is becoming an increasingly attractive option to replacing basic manual labour tasks and utilising this labour on other more complex processes. The FMCG industries have been pursuing labour efficiency for many years, decreasing basic unskilled labour and utilising automation where possible. Labour efficiency doesn't necessarily require wineries to decrease worker numbers, but instead allows staff to be utilised more effectively and this may provide an opportunity to up skill their current workforce.

Materials Efficiency

Material efficiency focuses on reducing waste throughout the wine manufacturing processes using a combination of waste management (both time and goods), waste reduction and lean manufacturing principles. For the wine industry, materials efficiency can include issues like wine movements, poor quality, over production, transport, processing delays, idle time, operator motion, spills (Figure 6), excess inventory and eliminating waste.

Figure 6 - Spilt wine

The wine industry's materials efficiency metrics can include quality which can be a symptom of materials inefficiency through the full supply chain. Materials efficiency can be improved through automation and real time monitoring throughout the process. In a basic sense, materials efficiency may include juice extraction efficiencies, and material waste sent to landfill.

One of the largest contributors to materials loss is wine movement. Every time wine is moved between processes or from one tank to another, wine is lost through stagnating in piping and in equipment. This wine needs to be 'pushed through' with water which increases waste water treatment and adds to water costs. The challenge for wineries targeting materials efficiency is to undertake as many processes as possible with the least amount of wine movements as possible. For example, instead of racking wine following by processing lees, cross flow filtration can be used to process the entire tank of juice and wine including the lees in one movement greatly reducing wine loss, reducing wine aeration and increasing processing speed.

Energy Efficiency

Energy efficiency is important for increasing the overall efficiency of wineries. Energy efficiency opportunities can help reduce operating costs throughout wineries while causing little disruption to existing processes. This is especially important in the context of rising energy costs. Core energy efficiency opportunities for the wine industry include; refrigeration (Figure 7) and tank storage, pumping, compressed air, hot water and steam, heating ventilation and air conditioning (HVAC) and lighting.

It is important for wineries to understand their electricity costs and manage their electricity use. In the FMCG industries, this management can include metering, data logging, performance management, managing peak loads, automatic load control, managing power factor issues, and other techniques.

Figure 7 - Refrigeration compressor

Water Efficiency

Large amounts of water are used in the wine industry for various processes including cleaning and flushing of equipment, tanks and lines. Like energy, water and waste water treatment (Figure 8) costs and charges are increasing.

Figure 8 - Waste water treatment

Water management is a core component for increasing business efficiencies. The FMCG industries use methods including capturing water from roof spaces, recycling water, and examining water usage on site. Water capture is especially important given the large roof space of many wineries and FMCG factories. Water recycling is important and a plausible method for wineries as reusing water at least once essentially halves new water use and therefore halves the cost of water. Other areas of efficiency may include changing process and choosing equipment that reduces water use. It is important to look at water use on site to understand where water reductions can be made.

Automation / Production Control

All manufacturing industries will benefit from automation, real time monitoring (R. Guidetti, 2010) and production control. One of the main differences between FMCG industries and many wineries is the high level of automation and real time monitoring (Figure 9) for production control. Good production control can maximise efficiencies of labour, materials and water while increasing production speed and quality. Automation and production control allows for 24 hour control whether this is for refrigeration control, fermentation profiles, bottling, or other winery processes. This can help decrease variability between products and maximise desired quality parameters increasing the overall quality of the wine.

Figure 9 - Winery automation dashboard

Automation and real time monitoring is seen by leading wineries as one of the most important steps going forward in the industry. There are many engineering and automation solutions providers available today who specialise in the wine industry and deliver tailored solutions to common winery problems.

3. Key process efficiency opportunities across the wine production process

The following section will examine each part of the winery process and identify process efficiency issues, key metrics for measuring efficiency, and compare these process steps with solutions from the FMCG industry. From the below section, the solutions with the greatest process efficiency benefit and likely potential uptake will be short listed for further analysis in Section 6.

Receival

Problems/issues affecting process efficiency	Solutions from other industries
Production speed • Temperature	• Night harvesting • Cool rooms

Key Metrics

Metric	Metric measurement parameter
Temperature of grapes received	Measurement of temperature *C

Temperature

The first critical efficiency step in receival is temperature. The temperature of the grapes at this point influences crushing and fermentation temperatures. This influences the additional energy required for temperate control. Ideally, the cooler the grapes are, the greater the processing efficiency will be in later process stages. Solutions for managing grape temperature include night harvesting. This is easier to regulate where the winery is vertically integrated. Where external deliveries of grapes occur, wineries can encourage delivering vineyards to night harvest or store grapes in cool rooms prior to delivery.

Strategies deployed by FMCG industries

Night harvesting during summer is common in many agricultural industries where temperature control is critical. This is more common in primary industries where the freshness or the fragile nature of fruit is of concern (i.e. olives, some vegetables, eating grapes, and berries). Cooler temperatures allow harvested products to remain stable for longer, decreases biological growth and decreases oxidative changes. This also reduces the requirement of external temperature control and hence reduces energy costs required to cool freshly harvested products.

Quality

Quality of the grapes at receival influences processes downstream, in particular fermentation. It is important that the quality parameters of the incoming grapes are understood so corrective changes and customised processing can be used to account for the variability in the batches of incoming grapes. Currently, most grapes are processed as received with basic parameters measured including sugar (Brix/Baume), pH and titratable acidity (TA). (M Longbottom, 2013) (R. Guidetti, 2010) This is in contrast to the FMCG stream where quality parameters of feedstock are more uniform, extensively analysed and within certain parameters. Greater information at the receival stage should increase quality parameters as wine processing continues. These parameters may include grape colour, and as fermentation begins, redox potential, pH, Oxygen, conductance, colour and alcohol.

Figure 10 - Winery receival

Destemming / Crushing

Problems/issues affecting process efficiency	Solutions from other industries
Production Speed: • Bottlenecks • Discontinuous processes • Fermentation rate	Measuring and managing process efficiency metrics (i.e. tonnes processed per hour) Speed matching (i.e. matching continuous process speeds from destemming, crushing to pressing)
Labour efficiency - High labour use	Automation of processes
Materials efficiency – Waste grapes	Reducing waste material (i.e. ensuring more inputs become a product and not a waste stream)
Energy efficiency – Hot water	Supplementing gas water heating with solar water heating
Water efficiency	Recycling waste water used through processes Purchasing easy clean equipment

Key metrics

Metric	Metric measurement parameter
Destemming/crushing speed	Tonnes of Grapes destemmed / crushed per hour
Destemming/crushing labour intensity	Labour per tonne of grapes destemmed / crushed per hour
Destemming/crushing waste	Waste per day (identify and quantify)
Quality parameters	Quality - Various parameters

Overview

Destemming / Crushing in the wine industry is characterised by high labour and energy use for a short period of time.

Berry or grape crushing is unique to the wine industry; crushing fruit for the fruit juice industry (apples, pears, oranges etc) uses different methods of processing. For example, the apple juice industry uses harder crushes and enzymes to transform apples into a pulp followed by pressing and pasteurisation. In comparison, wine crushing is a gentle process designed to express the grape juice from the grape flesh and reduce the tannins and phenolic compounds from grape skin and from the taint of seeds.

Figure 11 - Auger to destemmer / crusher

Timing is more critical for grape crushing as the fruit is fragile and time taken between picking to crushing needs to be short to reduce spoilage and quality degradation. This is in comparison with other fruit picking (oranges, apples) as the fruit is more robust and can be stored for longer times before processing.

Production Speed

Crushing is a bottle neck for the wine making process during vintage due to the high volume of grapes to be processed over short periods of time. The major risk for the crushing process comes in the form of breakdowns.

Minimising the risk of breakdowns involves contingency planning such as preventative maintenance and crushing within speed parameters. Other contingencies include contracting crushing to other wineries.

Production speeds are restricted by the slowest speed of the following processes

a) Crushing / de-stemming speeds
b) Must pumps
c) Pressing (white wines)

It is important for production efficiency to ensure that crushing capacity matches the capacity of the winery. This prevents the need to switch equipment on and off while waiting for pumps to ‘catch-up’. Switching major equipment on and off increases power spikes, energy consumption and reduces production speed. For these reasons, it is important equipment is limited to the slowest process in the crushing / press step.

Issues can exist if equipment is not running at optimum capacity. Too slow leads to oxygen exposure, growth of aerobes, loss of volatiles, slows processing of harvest. Equipment running too fast can lead to heat from friction and overshooting tanks.

Production speed can also be limited by the need for any cleaning required throughout the crushing step.

To measure the efficiency of the current destemming/crushing operation, ‘tonnes of grapes destemmed and crush per hour’ is a good metric. This would need to include downtime used in cleaning between batches to gain a good overview actual process speed.

These are similar metrics used by FMCG industries for measuring production efficiency including the malting, brewing dairy and fruit juice production areas.

Strategies deployed by FMCG industries

With other FMCG industries (e.g. dairy, brewing industry, etc), the quality parameters of feedstock are well understood before processing and fermentation. This is done less readily in the wine industry as grapes are processed ‘as received’, and variability can have considerable impacts on fermentation efficiency and quality. In the wine industry, grape quality-related information would need to be collected at receival and crushing steps to ensure parameter corrections are made prior to fermentation (Davey, 2002). Having this information can provide an understanding of expected fermentation characteristics which can lead to process efficiencies further through production. In this regard, the wine industry can be compared with most manufacturing industries where a natural variable feedstock is the input into the manufacturing process. This includes fruit juice manufacturing, beer manufacturing, and general food processing.

Automation and real time analysis

The key to automation at crushing is to ensure:

a) key parameters are measured
b) the variability of key parameters is minimised (if possible)
c) reactive controls are implemented (i.e. dosing with tartaric acid at the must pump)

This allows processes to be customised providing the expected performance of a feedstock is understood. Knowing the input quality parameters is important for controlling the rest of the fermentation process. The more corrections that can be done earlier in the process, the more efficient the wine making process will be downstream.

Automation with monitoring and control is not completely foreign to the wine industry -- it has been adopted to some extent by some large Australian wineries, however certainly not across the board with the broader industry.

Key automated monitoring for quality may include brix, pH, oxygen, redox, conductance, alcohol and colour. Going forward, techniques such as near infrared (NIR) spectrometry may help control certain measurement parameters, however these are currently expensive.

Monitoring and control is similar to the brewing, FMCG, and other industrial processes. Real time monitoring and dosing is pertinent for controlling and producing a quality product. In this case, quality is defines as a set of desired parameters throughout the production chain.

Labour Efficiency

Receival destemming and crushing are characterised by high levels of manual activity for short periods of time. This may include manual dumping into hoppers in smaller wineries. Additional time is taken to clean the crushers after each batch and this manual washing is time consuming and labour intensive. Key metrics for labour include labour per kL of grapes crushed and this includes cleaning times to accurately measure the true process cost.

Increases in automation and equipment that reduce labour at the crushing step are one way to increase labour efficiency at this step.

Materials Efficiency

Materials efficiency at the destemming / crushing processes focuses on two aspects

a) the quantity of received grapes compared with the quantity being crushed, and more importantly
b) the waste (including lost juice) created during this crushing destemming step

Materials efficiency at the destemming / crushing step is about minimising waste, spillage and juice loss through transfers.

Waste at this crushing step is a multi-faceted cost. It involves the cost of the lost product, but in addition the cost of waste disposal which may include trade waste fees, additional labour, materials used in pH adjustment (lime) and additional energy costs associated with treating waste. Therefore, it is important that waste is managed and measured at this step to maximise materials efficiency.

Key metrics for materials efficiency at this would include quantifying lost grapes and ensuring stems are sent to an appropriate area for reuse (e.g. for reuse on vines, compost).

Initiatives to increase materials efficiency would include ensuring destemmers do not lose grapes through the destemming chute and the maximum numbers of grapes are sent to the crusher.

The FMCG stream has recognised that materials can account for over 60% of a business' costs and have therefore targeted materials efficiency as critical for minimising costs and increasing efficiency.

Energy Efficiency

Energy consumption at crushing includes electricity for running machinery and for generating hot water used in sterilisation and cleaning during crusher use. It is important that equipment is scoped at the capacity of receival. This ensures electricity is not wasted in running undersized or oversized operations. Hot water too needs to match the capacity of the required winery operations; hot water requirements during the year are not constant and so hot water systems need to satisfy maximum demand while using gas resources efficiently.

FMCG manufacturing facilities, such as the daily industry, have started utilising solar hot water systems to supplement hot water required for pasteurisation. Other high temperature users such as breweries have installed cogeneration systems that produce steam and electricity as an output to their processes.

Supplementing gas hot water systems with solar hot water is one way to reduce energy use on site. This is especially important for wineries in remote locations with no access to main line gas. Using cogeneration systems is less applicable to the wine industry as the need for hot water is not as great as the brewing industry and the high gas requirements for remote locations make projects such as this un-economical.

Water Efficiency

Cleaning of destemmers and crushers is water-intensive but necessary to prevent biological contamination, maintain quality and to ensure equipment is working efficiently. Waste water generated by cleaning may attract trade waste charges or may require treatment before disposal.

Recycling and reusing water is one way of increasing water efficiency. Water efficiency is essentially doubled if water is reused once, or from a cost perspective, waster costs are essentially halved every time water is reused.

If purchasing new crushing equipment, consideration should be made for ease of cleaning. Crushers are available that are sealed and easy to clean. This will both reduce water used for cleaning and reduce labour costs in time spent cleaning equipment.

Key metrics for water efficiency include litres of water used per litre of wine produced. This is more challenging to determine at a process level but is easier to calculate at a whole process level.

Fermentation

Problems/issues affecting process efficiency	Solutions from other industries
Production Speed: • Fermentation process • Microbiological conditions • Microbiological choices	• Real time monitoring and automatic correction of fermentation condition (i.e. pH adjustment) • Temperature control of fermentation • Selection of yeast strains to match feedstock
Wine loss through movement	Decrease unnecessary product movement

Key metrics

Metric	Metric measurement parameter
Fermentation time	Days
Fermentation temperature control	Temperature deviation
Quality parameters	• pH • SO_2 • YAN
Wine movement	Count of wine movements

Overview

Realistically, quality fermentation is a product of good quality crushing.

An occurring theme with wineries interviewed was the issue with finding available tank space to undertake fermentation. Decreasing fermentation time would allow for faster tank turnaround times reducing the need for additional tanks. An issue for winemakers is when fermentation struggles to begin, it run slowly or fails to finish, all of which increases fermentation times (Day, 2013).

Figure 12 - Winery fermentation

Production Speed

Optimal fermentation conditions results in a faster fermentation leading to a faster production speed. Wineries have stated that it is challenging to find fermentation tanks and available space for fermentation during the peak of vintage. Fast fermentation turnaround times would allow wine to be moved out of fermentation tanks as soon as possible and help increase fermentation tank availability. The key to fermentation efficiency is optimising microbiological conditions to ensure high quality fermentation in the quickest time possible.

Microbiological conditions

For the wine industry, selective microbiological control and optimising microbiological conditions (even at the pressing and crushing stages) can help decrease fermentation time and increase quality (Vintessential, 2011). Fermentation is a harsh environment for yeast and so measurement of yeast assimilable nitrogen (YAN), pH, sulfur dioxide, temperature and correcting levels are critical in ensuring rapid efficient fermentation. This requires rapid analysis of fermentation batches and blending to produce optimal efficiency.

Microbiological choices

Wine yeast strains are adaptively evolving and many suppliers have isolated and characterised these yeast strains (Pambianch, 2008). Correct choice of yeast strains can be made to decrease fermentation time. These yeast strains have their own nutrient requirements and these will need to be balanced with microbiological conditions (Jiranek, 2010).

Co-fermentation

Using Lean Production principles, attempts can be made to use the least amount of movements as possible during fermentation. It is possible to undertake primary and secondary fermentation at the same time. Studies suggest that co-inoculation with primary and secondary malolactic fermentation at the beginning of fermentation will reduce secondary fermentation by up to 12 weeks. (Day, 2013)

Automation and Energy Efficiency

Wineries have reported effective temperature control is a critical issue and can be problematic during the fermentation process. Automated refrigeration systems can control the fermentation temperature profile and ensure optimum temperature conditions are maintained throughout the fermentation cycles (i.e. warming then cooling). This decreases the fermentation time and hence increases the efficiency and rate of fermentation. This is similar to the beer brewing industry. In addition, automated refrigeration systems can maximise general refrigeration energy efficiency by optimising brine cooling conditions, balancing compressors to reduce peak demand, utilising off-peak tariffs and ambient night time temperatures.

Preventatives

Quality fermentation is a product of quality crushing, so any preventative measure to maximise fermentation efficiency need to be undertaken at the crushing step (such as must additions and microbiological corrections).

Strategies deployed by FMCG industries

Winery fermentation can best be compared with the brewing industry. The brewing industry demonstrates a much tighter control on the inputs that go into making beer – for example, all malt is measured and analysed for over a dozen parameters before fermentation begins. This ensures fermentation parameters can be optimised prior to fermentation leading to a known fermentation profile. In addition, the brewing industry rejects feedstock that is not within specification, however this is not an approach the wine industry can readily adopt.

Other FMCG industries using fermentation include the dairy industry. The diary industry differs from the wine industry in that the feedstock (milk) is pasteurised prior to fermentation. This ensures that fermentation is only carried out by selected microbiological agents. While this is different, what can be learnt from the dairy industry is that control of microbiological agents, and critically, temperature control, is important in efficiency fermentation. While must is not sterile compared with milk feedstock, the addition of sulphur dioxide reduces many undesirable microbiological agents.

Pressing

Problems/issues affecting process efficiency	Solutions from other industries
• Production speed • Wine and juice extraction from feedstock	• Continuous pressing techniques • Use enzymes to breakdown and feedstock and maximise juice extraction
Wine loss through movement	Decrease unnecessary product movement

Key metrics

Metric	Metric measurement parameter
Pressing speed	Litres of must pressed per hour
Pressing labour use	Labour (time) per kilolitre of must pressed
Wine loss through movement	Decrease unnecessary wine movement

Overview

Wine pressing is a bottleneck for wineries, especially in white grapes where pressing takes place in-line after receival and crushing. This bottleneck requires a coordination of time for scheduling operations to ensure vintage runs smoothly. Reducing bottlenecks in pressing by removing or decreasing this bottleneck allows for faster receival, processing and allows the fermentation process to begin earlier.

Figure 13 - winery membrane press

Production speed

In today's wine industry, pneumatic membrane presses (Figure 13) are commonly used for batch pressing. The main reason for their use is due to low expression of phenolic compounds from the skin and seed of grapes. The main issue with membrane presses is that it is a batch process with low throughput – this is traditionally a rate-limiting step for the winery requiring high labour and monitoring.

Continuous pressing equipment such as screw presses (Figure 14) can offer higher rates of throughput at the expense of increased expression of phenolic compounds. More recently, developments in screw press technology have decreased the higher levels of phenolic expression traditionally found in screw presses (Nordestgaard, Phenolic Extraction and Juice Expression during White Wine Production, 2011). Wine screw presses can be relatively automated requiring less labour. Given the efficiency benefits of screw presses, this technology may be worth greater investigation.

Figure 14 - Winery screw press

Strategies deployed by FMCG industries

Screw presses and continuous pressing is similar to other agricultural supplier industries such as oilseed pressing. Wine screw presses are significantly gentler than the high speeds and high pressures of oilseed screw presses.

The fruit industry and in particular fruit juice manufacturing uses much more rapid but harsh extraction methods that extract phenolic compounds from both the seeds and skin of fruit (e.g. apples). The sweetness of fruit juices tents to disguise taints and so quality is much less an issue compared with wine extraction. These harsh extraction methods result in high juice extraction levels.

Enzymatic degradation

One point of difference between the apple juice manufacturing industry and wine industry is the high level use of enzymatic additions. Enzymatic additions allow juice to be extracted more efficiently and reduce juice being wasted in pulp. In some wineries this practice is already employed.

Clarification

Problems/issues affecting process efficiency	Solutions from other industries
Production speed/energy efficiency	Utilise cross flow filtration techniques to undertake multiple filtering steps in one movement
Wine loss through movement	Decrease unnecessary product movement

Key Metrics

Metric	Metric measurement parameter
Clarification speed	Kilolitres of wine clarified per hour
Clarification labour use	Labour costs per kilolitre of wine clarified
Clarification energy use	Energy costs per kilolitre of wine clarified
Clarification water use	Water use per kilolitre of wine clarified
Wine loss through movement	Count of wine movements

Overview

Clarification in the wine industry involves the removal of suspended matter in the wine before (in conjunction with clarification) prior to bottling.

Production speed, energy efficiency

Many methods are used by the wine industry for primary filtration. These include earth filtration, pad filtration, membrane filtration and more recently cross flow filtration.

Earth filtration is prone to blockages, is relatively slow and requires high energy in the form of high pressures to screen and vacuum filter the earth. It also presents a disposal problem as silicates in the spent earth can be an inhalation hazard.

Cross flow filtration (Figure 15) offers a higher overall liquid removal rate and prevents filter cake formation associated with 'dead-end' filtration. This means less energy is required for filtering due to less pressure. Filtration in cross-flow filters provides a constant pressure over time, unlike traditional dead end and earth filters. Depending on the filter pore size, cross flow filtration can also make the filtrate microbiologically stable (van der Horst & Hanemaaijer, 1990). In the fruit juice industry, the benefits of cross flow filtration (in particular ultra filtration) have resulted in a reduction or elimination of fining agents and filter aids. This helps reduce variability and reduces consumable costs.

Figure 15 - Winery cross flow filtration unit

For the wine industry, cross flow filtration offers additional benefits compared with earth and pad filtration, more specifically the decreased energy, materials and labour use (changing pads, clearing blockages) and an increase in production. Polyphenol and polysaccharide absorption associated with organic filters can be reduced by using ceramic cross flow filters instead of organic filters.

Cross flow filtration provides a more dynamic method for filtration, sterilisation and clarification of wine. To benchmark current clarification processes, it is important to measure speed, labour costs, energy and water.

Strategies deployed by FMCG industries

Cross flow filtration has been used in the dairy, sugar, fruit juice, water purification and wine industry since the late 1980's (Daufin, Escudier, Carrère, Bérot, Fillaudeau, & Decloux, 2011), however, its application is still emerging in some wineries.

Stabilisation

Problems/issues affecting process efficiency	Solutions from other industries
Production Speed / energy efficiency	Cross flow filtration (nanofiltration)
Wine loss through movement	Decrease unnecessary product movement

Key Metrics

Metric	Metric measurement parameter
Stabilisation speed	Kilolitres of wine stabilised per hour
Stabilisation labour use	Labour costs per kilolitre of wine stabilised
Stabilisation energy use	Energy costs per kilolitre of wine stabilised
Stabilisation water use	Water use per kilolitre of wine stabilised
Rework	Records of any rework required for stabilisation
Wine loss through movement	Count of wine movements

Overview

Several methods are available to stabilise wine against tartrate precipitation and fall into the two groups of tartrate reduction and crystallisation inhibition.
These methods are;

- Traditional slow cold stabilisation
- Rapid contact methods including seeded batch cold stabilisation and continuous methods
- Ion Exchange
- Membrane processes such as electrodialysis (ED)

Tartrate precipitation has traditionally taken the form of slow cold stabilisation. This method involves chilling a tank soon after fermentation to around freezing point - between -2 °C and +2 °C, and holding at this temperature for 1 – 3 weeks to allow crystals to form. This method is energy-intensive and runs risks including the likelihood of a ‘failed’ stabilisation where work is required to be repeated requiring additional energy to be spent on refrigeration. Wines stabilised by cold stabilisation may be more prone to later instability because the base tartrate loading has not been sufficiently reduced to overcome the impact of any loss or changes to the wine’s natural crystallisation inhibitors.

Energy Efficiency

Figure 16 - winery sediment

Rapid contact methods such as seeded cold stabilisation tend to overcome the wine’s natural crystallisation inhibitions. Seeded cold stabilisation processed can be undertaken at warmer temperatures and thus greatly reduce energy consumption. The seeded crystal can also reduce tartrate levels much faster than traditional cold stabilisation methods (down to 1 hour in comparison to the 1-3 weeks of traditional cold stabilisation). Tartrate crystals can be recycled for use in subsequent batches reducing the cost of purchasing seed crystals (Rhein & Neradt, 1979). This method still requires significant energy to be spent in chilling, however heat exchangers can be used to reduce the next batch of wine to be cold stabilised significantly reducing energy consumption.

Ion exchange and ED are independent of natural crystallisation inhibitors and can be undertaken at warmer temperatures (Gonçalves, Fernandes, Cameira dos Santos, & Norberta de Pinho, 2003), however ED requires more water than traditional cold stabilisation methods (Forsyth, 2010). ED does use significantly less electricity compared with traditional cold stabilisation, and has the potential to stabilise partial tanks and not an entire tank (unlike other cold stabilisation methods) (Nordestgaard, heat and cold stability - continuous stabilisation methods, 2013).

Key Metrics

An important step in improving the efficiency of current clarification processes is to benchmark current clarification processes against parameters such as speed, labour (and associated costs), energy and water. Once these parameters have been measured, projects that aim to improve these parameters can be chosen which may include the purchase of new capital equipment.

Strategies deployed by FMCG industries

Fruit juice manufacturers have used various methods to reduce post-bottling haze. These include many of the methods used by the wine industry including fining agents, filtering etc.

The fruit juice industry tends to suffer from post-bottling haze which is a polymerisation of high molecular weight particles. This is similar in some aspects to tartrate crystalisation in the wine industry. One method that is being undertaken in the fruit juice industry to reduce post-bottling haze is nanofiltration. Using this method, cross flow filtration with membranes in the nano-pore range are used to screen out low molecular weight particles responsible for hazing and browning in fruit juices post bottling (Vivekanand, Iyer, & Ajlouni, 2012).

Similar trials have been undertaken in the wine industry using nanofiltration to reduce tartrate precipitation. Nanofiltration was found to be successful in reducing tartrate precipitation, however, this resulted in adverse sensory outcomes (Peri, Riva, & Decio, 1988) (Low, 2007) and so at this stage is not an effective alternative to cold stabilisation (seeded or traditional) or ED methods.

Maturation

Problems/issues affecting process efficiency	Solutions from other industries
Energy efficiency	• Refrigeration optimisation • Warmer storage • Load management • Night time loading • Night time overcooling • Insulating temperature dependent equipment
Wine loss through movement	Decrease unnecessary wine movement

Key Metrics

Metric	Metric measurement parameter
Wine maturation time	Wine maturation time (days)
Electricity costs for wine stored	Electricity costs (kWh) per kL of wine stored
Wine loss through movement	Count of wine movements

Overview

Maturation and storage of wine-in-tank is important for the development of aromas and flavour profiles in wine. Two methods exist for creating flavour profiles for high quality wine. The first is aging wine traditionally and the second is using artificial methods to accelerate the characteristics traditionally associated with aged wines.

There are several disadvantages of the traditional aging technology including the long times, high labour, and high energy costs associated with ageing wine (especially wine stored in barrels). The longer the wine takes to mature, the greater the associated costs to the business will be. New technologies that aim to mimic barrel storage include micro-oxygenation and the application of wood staves.

Correct storage of wine is critical to limit the rate of oxidative browning and volatilisation of aroma compounds. This is largely controlled with temperature and preventing oxygen ingress into tanks. Wine maturation and storage then becomes an exercise in refrigeration efficiency.

Energy Efficiency

Refrigeration is the largest consumer of electricity in Australian wineries and typically uses 50% - 70% of total electricity on site. Over the past three years the cost of electricity for businesses has increased by 40% on average and an increasing trend is likely to continue. Improving refrigeration efficiency and use on site is a significant way of reducing energy cost and increasing tank storage efficiency.

There are several basic low cost improvement opportunities that can decrease refrigeration operating costs for wine storage and maturation. These include:

- Turning off the refrigeration plant when not in use
    - is a basic control that immediately decrease refrigeration electricity costs
- Storing wine at warmer temperatures
    - Wineries will need to decide if wine is safe for quality purposes for storing at 10*C instead of 5*C for example
    - can significantly reduce refrigeration cost if lower temperatures are not required
    - on average, 1*C in temperature settings will reduce refrigeration energy consumption by 2-4%
- Load management
    - avoid using refrigeration systems when other high electricity process are in use
    - this will reduce the peak demand of the sites electricity supply
    - reducing peak demand will significantly reduce electricity peak demand charges

- Night time cooling
    - allows cheaper off peak electricity to be used
    - improves the efficiency of refrigerators using cooler night time temperatures to chill refrigeration systems
- Night time overcooling
    - involves cooling wine tanks below their normal set point at night
    - allows cheaper off peak electricity to be used
    - improves the efficiency of refrigerators using cooler night time temperatures to chill refrigeration systems
    - reduces the need for refrigeration systems to be used during the day (at peak rates and warmer temperatures)
- Selective brine recirculation
    - Only circulate brine to tanks that are in use

More expensive higher cost improvement opportunities for wineries include:

- Installing insulation
    - this decreases heat gain of the winery tanks through ambient outside temperature
    - this decreases 20-33% of refrigeration energy consumption
- Installing automated refrigeration management software
    - this increases efficiency by automatically managing refrigeration loads
    - tanks may be selectively targeted for cooling balancing the load of the refrigeration system
    - management software can automatically program efficiencies such as night time cooling and overcooling

Measuring key metrics

Key metrics for wine storage include kWh per kL of wine stored on site. This gives an overview on the current efficiency of the refrigeration plant. It is challenging to account for all refrigeration efficiencies during vintage as cooling capacity may be targeted towards must chilling and fermentation control or cold stabilisation prior to bottling.

Strategies deployed by FMCG industries

There are only a few FMCG-based products that are matured and these include cheese, meats, soy sauce, and spirits. As with wine, maturation takes place in cold temperature controlled environments. Like the wine industry, storage is an exercise in refrigeration efficiency. This efficiency includes insulated cool rooms, and managing refrigeration use.

Bottling

Problems/issues affecting process efficiency	Solutions from other industries
Production speed	• Automation of bottling • Benchmarking of bottling speeds • Software to understand bottling time losses • Reduce stoppages in the bottling line
Water efficiency	• Recycle water use in the bottle line • Water treatment to allow reuse in the bottling line • Ensure glass is sterilised by the bottle supplier
Energy efficiency	Use labels that are able to be applied on bottles that are 'wet' with condensation
Wine loss through movement	Decrease unnecessary product movement

Key metrics

Metric	Metric measurement parameter
Bottling speed	Bottles per minute (bpm) or cases per hour (including down time)Electricity costs (kWh) per kL of wine stored
Bottling water use	Water (litres) per litre of product (ratio)
Bottling labour cost	Labour per case
Wine loss through movement	Count of wine movements

Engineered bottling line process are relatively energy efficient. The process involves receiving bottles, sterilising the inside of the bottle (air or water), filling, capping, labeling and packaging. Some businesses in the beer brewing industry have fully automated their operating system with real-time analysis capabilities allowing processes to be fine-tuned, thereby increasing bottling efficiency (Packaging-gateway, 2007).

Production speed

Speed of bottling is an important step in bottling efficiency. In this case, speed is related to the decrease in stops and rate limiting factors for a winery. Micro strops and ramp up times decrease bottling efficiency so keeping the bottling line and the associated equipment active is important for maximising bottling efficiency (Uhlmann Packaging, 2014). Analysis of the cause of micro or macro stops is important for ensuring the bottling line is running at capacity (Rockwell Automation, 2014). Continuous bottling transport systems (empty bottles to the bottling line and full bottles away from the line) are one way of maximising bottling operations.

Water efficiency

Bottle sterilisation

Figure 17 - winery bottling line

Several methods of bottling sterilisation are available for wineries including air cleaning and water cleaning. Air cleaning uses compressed air for blowing clean the inside of the bottle. This method does require validation that the air blown bottles are sterile. This method uses significantly less water than bottle washing, however this increases air demand.

Internal bottle washing uses sterilised water to wash the inside of bottles. This method is water intensive, however, recycling and re-sterilising this water is possible using nanofiltration and / or UV light sterilisation.

External bottle washing does not need the same sterile conditions and so can be reused multiple times.

Energy efficiency

Typically, wine bottles are filled with cold wine which leads to condensation before labels are attached. Several methods are available for preventing this condensation including humidity management, and spraying the cold bottles with hot water prior to adhering labels. These are both energy intensive processes. Recently label manufacturers have developed a new type of label specifically for wine bottles which can be attached to condensation-coated wine bottles. It is likely these labels are more expensive, however it decreases energy requirements for heating the outside of the bottles.

Materials efficiency

The waste backing materials from labels comes in two main forms which are glassine and Polyethylene terephthalate (PET). Glassine is an air and water resistant paper product however it currently cannot be recycled in Australia. The alternative label backing is PET, which can easily be recycled in plastics bins reducing waste charges for the winery.

Strategies deployed by FMCG industries

There are various FMCG bottling lines across Australia. One of the main differences between bottling in the wine industry and other FMCG industries (such as soft drink fruit juice, milk and other bottlers) is the cool temperature of the liquid filling the bottle. The wine industry uses cold fill where other industries fill bottles with room temperature or hot liquid.

Businesses such as Coca-Cola have undertaken benchmarking to improve water efficiency by 20 percent compared with their baseline. This was done by using a water efficiency toolkit to understand where water was used and how it could be reduced (Coca-cola, 2012).

A South Australian brewery recently undertook a $16.5 million dollar installation of their new bottling line. This bottling line focuses on two aspects, flexibility and reduced downtime. This flexibility means the business can reduce the time taken between switching products and reduce stoppages in the production line which has greatly increases the bottling efficiency of the plant (Coopers , 2013).

Automation

Depending on the size of a winery's bottling operations, bottling may be fully automated or partially automated. This depends in part on the quantity of wine to be bottled. Large wineries or contract bottles would have a greater need for full automation. Full automation only becomes economical once businesses reach a critical bottling capacity through efficiencies of scale. Whether using full automation or partial automation, bottling wineries can still use these metrics to improve process efficiencies.

Bottling lines are only as strong as their weakest link. Casella Wines recently employed a Manufacturing Execution System (MES) by Rockwell Automation to identify bottle necks and breakdowns within their bottling line. This recorded various plant metrics to create a bottling efficiency baseline. Once this baseline was recorded, reoccurring issues and breakdown were identified which provided targets to improve bottling efficiency. This mixture of administrative and line alterations resulted in a 20% increase in the bottling lines efficiency through reduced down time (Rockwell Automation, 2014).

Warehouse / dispatch

Problems/issues affecting process efficiency	Solutions from other industries
Production speed	• Pick ordering by storing frequently used goods in the fastest access area • Warehouse layout ensuring goods are easy to obtain • Reduction in double handling by avoiding restocking material

Key metrics

Metric	Metric measurement parameter
Movement	Quantity the movements required to access stored goods

Overview

FMCG companies have displayed consistent activity in looking for ways to improve warehouse efficiency for the lowest cost. Best practices in warehouse management can be used to improve productivity, but more importantly, reduce double handling and labour costs. Although warehouse management practices do vary in applicability between FMCG industries and the wine industry, a number of general best practices can be applied to both industries. These include:

- Pick orders
- Warehouse layout
- Decreasing double handling.

Pick orders

Pick order efficiency ensures frequently picked (as in short term goods) are stored close to the shipping area. This requires an inventory inspection to ensure these goods are stored in appropriate areas.

Warehouse layout

The layout of warehouses is critical in ensuring good are easily accessed and can be moved to distribution location. This may include racking systems for ease of access, and forklifts suited to racking system layouts. Efficiencies come from the time taken to access goods and minimising travel time between picking locations.

Decreasing double handling

Ideally, goods should be manufactured using Just In Time (JIT) principles (Lean Production). This means as orders are placed, goods are manufactured to fill the order reducing long storage times in the warehouse. JIT also reduces double handling as traditional storage requires goods be manufactured, stored, brought out of storage, sent to dispatch areas, and then loaded. JIT would allow orders to be manufactured and sent to dispatch in one movement.

Transport / Distribution

Problems/issues affecting process efficiency	Solutions from other industries
Transport efficiency	Optimised loading of transport vehicles

Key Metrics

Metric	Metric measurement parameter
Weight based lading factor	Actual goods weight / maximum capacity of vehicle (ratio)
Space-utilisation for a vehicle	space occupied by the load vs. the maximum capacity of the load
Empty running	Count

Overview

Road transport in Australia is the dominant mode of freight movement for bottled and bulk wine. Transport and distribution is therefore important for efficiency practices especially considering the often remote locations of wineries in Australia and the likelihood of fuel prices rising in the future.

Figure 18 - wine transport

Strategies deployed by FMCG industries

FMCG industries have recognised the importance of transport efficiency and studies have been undertaken for measuring and increasing transport efficiency. This has important application to the wine industry where the objective of transport efficiency is maximising the quantity of product transported in one movement. The following metrics can be used to maximise this efficiency and can be applicable to both packaged and bulk wine.

Measuring key metrics

Weight based lading factor

This is a measure of the weight of the actual goods moved compared with the maximum carrying capacity of the vehicle. In this metric, higher weights result in more efficient transport of goods.

Space-utilisation / vehicle fill

This is a measure in three dimensions of the space occupied by the load vs. the maximum capacity of the load. In this metric, higher area values results in a more efficient the transport of goods. An improvement to this metric involves addressing the packaging of pallets, boxes and ultimately the bottle configuration of the finished wine.

Empty Running

Empty running is a measure of vehicle-kilometres transport vehicles run empty. This is a consequence of the uni-directional movement of freight and the challenge of balancing freight flows to and from wineries. It is challenging to improve this value as the wine industry is generally a one way transport trip to distributors.

4. Prioritisation Framework

Section 4 provides an overview on the six prioritised process efficiency opportunities for implementation in the wine industry. These six opportunities were determined after the evaluation of all process efficiency issues determined in section 3 of the report. Details on this evaluation can be found in appendix 5.

Process efficiency metrics

Table 3 – Process efficiency metrics - Applicability to wine industry

Criterion	Rating	Comment
Commercial availability	High	Readily available commercially, or simple internal system can be used
Adoptability (ease of implementation)	Medium	This depends on level of complexity required for the plant
Level of risk to quality or productivity	Low	Will increase quality and productivity
Capital and recurring costs	Medium	Capital and ongoing costs required
Regulatory requirements	Not applicable	
Other technology or project risks	Medium	May require some additional skill sets to drive metric improvement
Overall Score	High	

Overview

Metric measurement involves determining and measuring key metrics throughout the wine making process. Once these measurements have been taken, it is important to continually measure these metrics, analyse trends, manage the processes and display key information to staff to help drive production efficiency.

Benefits

Measurement of metrics allows a business to understand where current inefficiencies lay within a particular winery. This allows process efficiency projects to be targeted towards bottle necks or poor efficiency areas. The objective of measuring these metrics is to continually improve their performance as it is these metrics that drive performance and therefore increase process efficiency.

Measuring metrics allows a business to understand their current process efficiencies. Once this information is understood it is important this information is communicated to staff and staff are empowered to improve these metrics. Staff will usually find methods to improve these processes using their familiarity of winery operations. Staff empowerment and enabling teams to influence these metrics is an important way to increase process efficiencies.

Measuring metrics can be relatively simple, however, the purpose of measuring metrics is needed so a business can undertake a paradigm shift and move their primary focus to the continuous improvement of their processes, to use resources more efficiently, and increase process efficiencies. Measuring these metrics is one way of helping this paradigm shift.

The main benefits for increasing process efficiencies are decreased costs, increased productivity, and a more competitive business. This is applicable for every part of the winery operations. For these reasons, the benefits for measuring metrics have been related as HIGH.

Uptake

Measuring process metrics involves recording data about specific processes, (i.e. hours required to undertake a task, quantities of material processes during a certain process, water use at a given process, etc). This requires some additional time for monitoring and data logging. This data can be logged in simple Microsoft Excel sheets or Microsoft Access.

More advanced wineries may have automated systems for recording this type of information. It is important that this information is communicated to all staff, ideally visually using graphs or other visual indicators (Figure 19). This provides staff with a clear direction on how a task is evaluated and as stated earlier tends to motivate staff to improve these metrics.

Figure 19 - Visual display targets

Commercial software systems are available for integration into a business to measure metrics. These systems collect data from a variety of sources including programmatic Logic Controllers (PLC), Energy Managements Systems (EMS), automation systems, real time analytical equipment, manual entry, servers, etc. Once this information has been captured, it is stored into databases in real time. Information from the databases can be searched and displayed against various criteria or analysed in real time. This information can then be used to trigger notifications or control processes when certain conditions are met (such as adding TA to must, temperature control (Nordestgaard, 2012)). This data can also be displayed via real time displays around the plant so conditions throughout the plant are well understood. (OSIsoft, 2014) (VinWizard, 2014).

Excel or Access systems are easily adoptable for smaller wineries and require only moderate skills to implement. Full commercial systems tend to require a higher level of skill (particularly IT and database interrogation) and a greater dedication for customisation. Because of this, full commercial systems are not as easily adoptable if staff do not have the required skill set.

Capital and recurring costs for measuring metrics varies depending on the level of complexity. Smaller excel or access based systems require continuous manual input and so are labour intensive. More automated systems (Figure 20) are less labour intensive (once they are set-up) however they require a capital cost to purchase the software and many systems require an ongoing cost. Support from software companies is available to implement the system and customise parameters for the businesses; however, this does come at an additional cost. Capital costs for the control software can be around the ~$50,000 and require ~$7,000 for annual licensing.

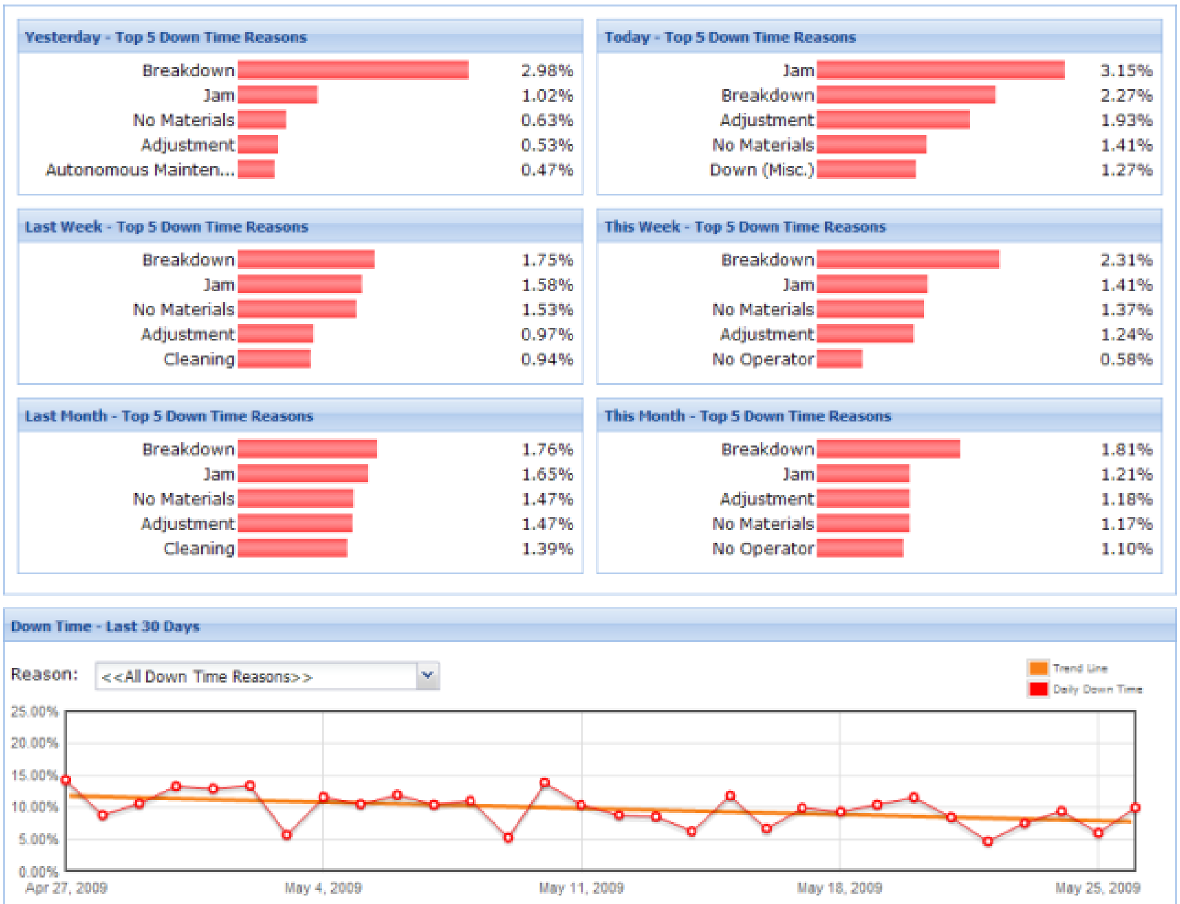

Figure 20 – Example - automated monitoring & benchmarking of utilities

Some of the potential barriers to uptake include the time taken for up-keep and running these systems. These tend to be barriers until businesses recognise the value of measuring and monitoring as core to process efficiency and driving and improving business performance. In some businesses, additional external coaches and resources may be required to facilitate a cultural change within the organisation and help with this transition. These cultural changes will likely be the biggest barrier to uptake (excluding costs). It is only when winery management understand the importance of metric analysis and lean manufacturing practices that wineries can greatly improve process efficiencies.

These barriers are not insurmountable and depending on the level of complexity (or simplicity) of the system, uptake is generally straight forward. For this reason, uptake for this process improvement has been rated as HIGH.

Potential providers

There are several software systems available for real time data infrastructure solutions. Details for three of these systems are provided below. In addition, many business consultants are available to train and implement systems for measuring metrics.

Rockwell Automation – FactoryTalk ProductionCentre

http://www.rockwellautomation.com/rockwellsoftware/production/productioncentre/overview.page

FactoryTalk ProductionCentre is Rockwell Automations management and analytic software. Software capabilities include auditing, data model, licensing, real-time data, historical data, configuration and alarms and events. The software aims to improve operational efficiencies while ensuring quality is maintained or improved. This software enables manufacturers to:

- Improve quality while reducing cost of quality
- Improve business efficiencies by helping identify issues
- Improve global operational efficiencies
- Implement Six Sigma and lean initiatives

- Reduce manufacturing cycle times and inventory
- Share real-time data on quality and shop floor status

SAGE Automation http://www.gotosage.com/

SAGE Automation provides various software management solutions for automated manufacturing processes and lean manufacturing practices including:

- MIS Manufacturing Information Systems
- OEE (Overall equipment effectiveness) measurements
- MES Manufacturing Execution systems (providing the right information at the right time)
    - Resource scheduling
    - Materials tracking
    - Process control systems
    - Improving production and minimising waste
- Throughput measurement and monitoring
- Downtime measurement and management
- Real time feedback on actual vs. target and efficiency
- Quality systems (paperless shop floor quality issues)
- Alarms for quality issues

OSIsoft – Pi System

http://www.osisoft.com/Default.aspx

OSIsoft, LLC is a manufacturer of application software for real-time data infrastructure solutions, called the PI System. OSIsoft, LLC develops and supports software used to capture, process, analyse, and store any form of real-time data. OSIsoft's target markets include: oil and gas; chemicals and petrochemicals; materials, mines, metals and metallurgy; power and utilities; pulp and paper; pharmaceuticals, food and life sciences; critical facilities, data centers and IT; and federal.

The PI System is a suite of software products that are used for data collection, historicising, finding, analysing, delivering, and visualising. It is marketed as an enterprise infrastructure for management of real-time data and events. The term PI System is often used to refer to the PI Server but the two are not same. The PI System refers to all OSIsoft software products whereas the PI Server is the core product of the PI System.

Data can be automatically collected from many different sources (Control systems, Lab equipment, Calculations, Manual Entry, and/or Custom software). Most information is gathered using built in and third party PI Interfaces. Users can access this information using a common set of tools (ex. Excel, web browser, PI ProcessBook) and look for correlations. Some examples include:

- Analysing seasonal trends
- Determining if utilities are meeting the demands of production
- Comparing the performance of different lots of raw material
- Determining when maintenance is required on equipment
- Optimising the utilisation or performance of a production line (OSIsoft, 2014)

Automation

Criterion	Rating	Comment
Commercial availability	High	Readily available commercially for both equipment and service providers
Adoptability (ease of implementation)	Medium	This depends on level of complexity required for the plant
Level of risk to quality or productivity	Low	Will increase quality and productivity
Capital and recurring costs	High	High capital costs
Regulatory requirements	Not applicable	
Other technology or project risks	Not applicable	
Overall Score	High	

Overview

Automation involves the use of various control systems for operating equipment with minimal or reduced human intervention. From discussion with leading wineries, automation and real time monitoring is seen by leading wineries as one of the most important steps going forward in the industry. FMCG industries are already heavily automated and this is one of the main differences in process efficiency standards between between FMCG businesses and wine industry.

Most manufacturing-related industries could benefit from automation and production control. Good production control can maximise efficiencies on both labour, materials/resource efficiency and production speed. Automation and production control allows 24 hour control, whether it is refrigeration control or quality systems, and reduces variability between processing batches.

Automation and real time monitoring is seen by leading wineries as one of the most important steps going forward in the industry.

Benefits

Automation reduces operating costs, increases productivity, availability, reliability and performance and does this through reducing labour, materials and energy consumption while increasing quality. The biggest benefit of automation is that it saves labour, however, it is also used to save energy and materials and to improve quality, accuracy and precision. For these reasons, the benefits of automation have been rated as HIGH.

Uptake

Automation can take many forms within a winery (Figure 21). Automation equipment and automation service providers are readily available. Service providers have worked through a variety of industries including oil and gas; chemicals and petrochemicals; materials, mines, metals and metallurgy; power and utilities; pulp and paper; pharmaceuticals, food and more importantly, beverage providers like the wine industry.

The adoptability of automation depends of the level of complexity of automation. Generally a higher skill set is required to implement an automation system. Once installed, the level of adoptability is generally high as work flows change to maximise the benefit of the automation systems. This generally reduces labour issues, however some additional training is usually required for staff.

The level of risk automation poses to wine quality or production is very low. Automation will significantly increase productivity and quality. Automation allows plants to run continuously and improves quality by removing human error.

Capital costs for automation are generally quite high. Additional recurring costs for increased maintenance and servicing are generally required, however, these are offset by the savings made from increased productivity, decreased labour and increased quality.

For the above reasons, the potential uptake has been rated as HIGH.

Figure 21 - Full winery automation

Potential providers

Various automation providers are available on the market. For basic refrigeration control, VinWizard is becoming popular with many smaller to mid range wineries as an off the shelf solution. For more complex full automation systems, service providers such as Rockwell Automation, SAGE Automation have undertaken extensive automation work in the Australia wine industry. Bürkert also provide automation solutions focusing on fluid and automation control.

Rockwell Automation http://www.rockwellautomation.com.au/

Based on Supervisory Control and Data Acquisition (SCADA) industrial control computer system, Rockwell Automation provides a turnkey customised automation service including control of:

- Screw feeds
- Crushers
- Pumps
- Agitators
- Temperature
- Sugar content
- Yeast cell monitoring
- Crushing speeds,
- Full refrigeration control
- Fermentation control
- Must temperature control
- Full monitoring of entire plant
- Interfacing with existing plant data systems

In 2006, Rockwell Automation implemented this control system at Yalumba's Moppa site.

SAGE Automation **http://www.gotosage.com/**

SAGE Automation provide engineering, automation and software control solutions including:

- Turnkey solutions
- SCADA system design
- PLC Networking
- Commissioning
- Testing
- Screw feeds
- Crushers
- Pumps
- Agitators
- Temperature
- Sugar content
- Crushing speeds,
- Full refrigeration control
- Fermentation control
- Must temperature control
- Full monitoring of entire plant
- Interfacing with existing plant data systems
- Product recovery systems
- Water treatment systems
- Packaging and bottling lines
- Energy control / monitoring
- Load shedding

Bürkert **http://us.burkert.com/**

Bürkert provide both hardware and engineering solution for wineries.

Must Delivery Automation

- Fermentation and temperature control
- Wine aging tank management
- Gas dosing, micro oxygenation, sparging and blanketing
- Water and waste treatment
- Resource management
    - Manage electricity and water usage
    - Control usage rates for peak efficiency
    - Optimise refrigeration efficiency
- Auxiliary services
- Must temperature control:

VinWizard **http://www.vinwizard.us/**

The VinWizard system is focused around refrigeration and temperature control for the winery and has additional automated control capabilities including pump-over, stirrer, crusher pad automation, humidity, CO_2, water usage, must lines, plant rooms, Production Database etc, which can be added to the core temperature control module as required.

The software is internet based and so winery control can be undertaken remotely. The software can control a variety of winery processes. To provide a brief summary:

- Increment to temperature set point over a given time (for gentle temperature changes)
- Event notifications via sms
- Temperature profiles for fermentation
- Adjustable dead band (means the tank will be warmed to 21C and then the ferment will take over up to 29C at which point the cooling comes back on.
- Power Saving features such as night cooling and peak load management, cold stabilisation mode etc.
- Whiteboard Replacement using LCD displays to replace circle information on traditional winery white boards
- Reports including ullage, tank status, tank volume, status, station report
- Graphing
- Data allows trend analysis from past procedures and historical data.
- Tank and Plant Alarms

User testimony:

General Manager Salena Estate: *"The cost savings and increase in energy efficiency have been "black and white". After a capital outlay of $80,000; $30,000 of which was for the refrigeration, the system has paid for itself over the first vintage. VinWizard's pumpover support program has seen incredible savings in human resources as it eliminated the need for the nine staff Selena Estate required to undertake the pumpover across three shifts per day."*

Cross flow filtration

Criterion	Rating	Comment
Commercial availability	High	Readily available commercially for both equipment and service providers
Adoptability (ease of implementation)	High	Direct replacement of existing filtration systems
Level of risk to quality or productivity	Low	Little or no impact on quality, increase in production speeds
Capital and recurring costs	Medium	Capital costs are low to moderate and recurring costs for replacement membranes are low
Regulatory requirements	Not applicable	
Other technology or project risks	Not applicable	
Overall Score	High	

Overview

Cross flow filtration is an energy efficient form of filtration compared with other wine filtration methods such as earth, pad and membrane filtration. Cross flow filtration uses a selective porous membrane to purify, or clarify liquids. Traditional dead-end filtration (cartridges, plate filters, etc) causes fouling of filter pads as the filtrate is forced liquid through the filter. Cross-flow filtration allows the filtrate to move in parallel to the membrane essentially preventing filtered particles from settling on the membrane reducing fouling (refer to Figure 22).

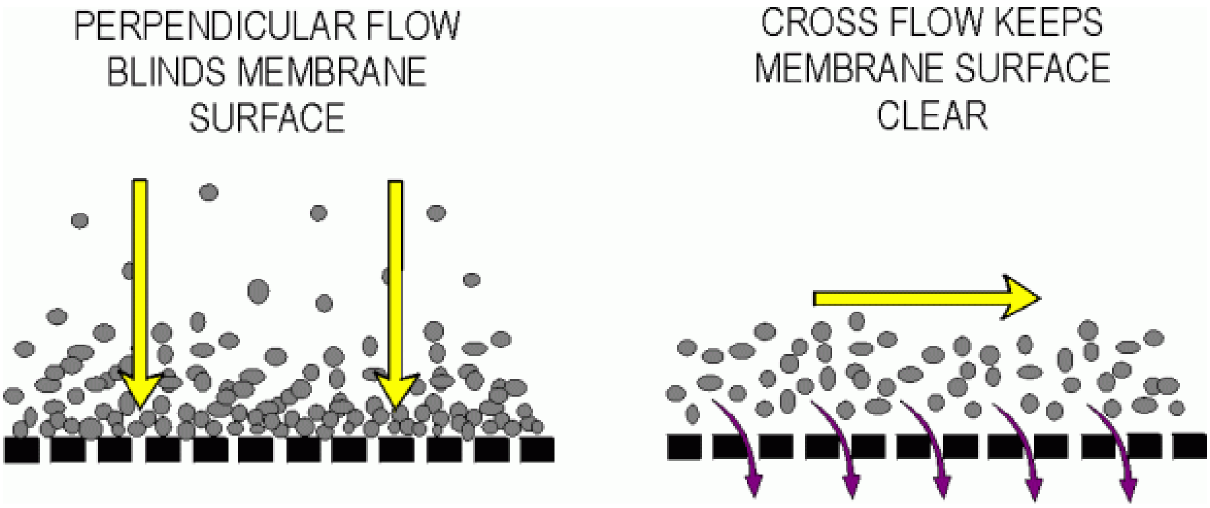

Figure 22 - Cross flow filtration principle

Benefits

The wine industry still uses a variety of techniques for filtering but from a process efficiency position, cross flow filtration is a faster method, has a greater filtration capacity, and uses less power than traditional filtration. (Baggio, 2004). For these reasons, cross flow filtration benefits have been rated as HIGH.

Uptake

Cross flow filtration units (Figure 23) are readily commercially available from a variety of suppliers and installers. New units can easily be installed in place of existing filtration methods with the benefit of filtering lees. There is little risk associated with this technology.

Capital costs have been decreasing over the years and vary depending on the size of the cross flow filtration unit required. Ongoing costs include replacement filters, however ceramic filters are longer lasting than organic filters. There are no regulatory requirements associated with this technology. Indicative costs of cross low filtration equipment have been included in Figure 24.

R and D providers

Figure 23 - Cross flow filter setup

Additional information regarding the benefits of cross flow filtration would be beneficial to the wine industry.

Australian Providers

Pall http://www.pall.com/

Contact: Eric Bosch 0419 139 910

Pall Australia have developed cross flow filtration systems specifically for the wine industry. Their filtration systems allow both protein stabilisation and clarification in a single step. http://www.pall.com/main/food-and-beverage/wine-filtration-53924.page

Della Toffola

Contact: Distributed by Australian & New Zealand Winemakers P/L

Ph (03) 8405 9000

www.ausnzwinemakers.com

Cross flow filter prices vary significantly, but below is a guide on pricing:

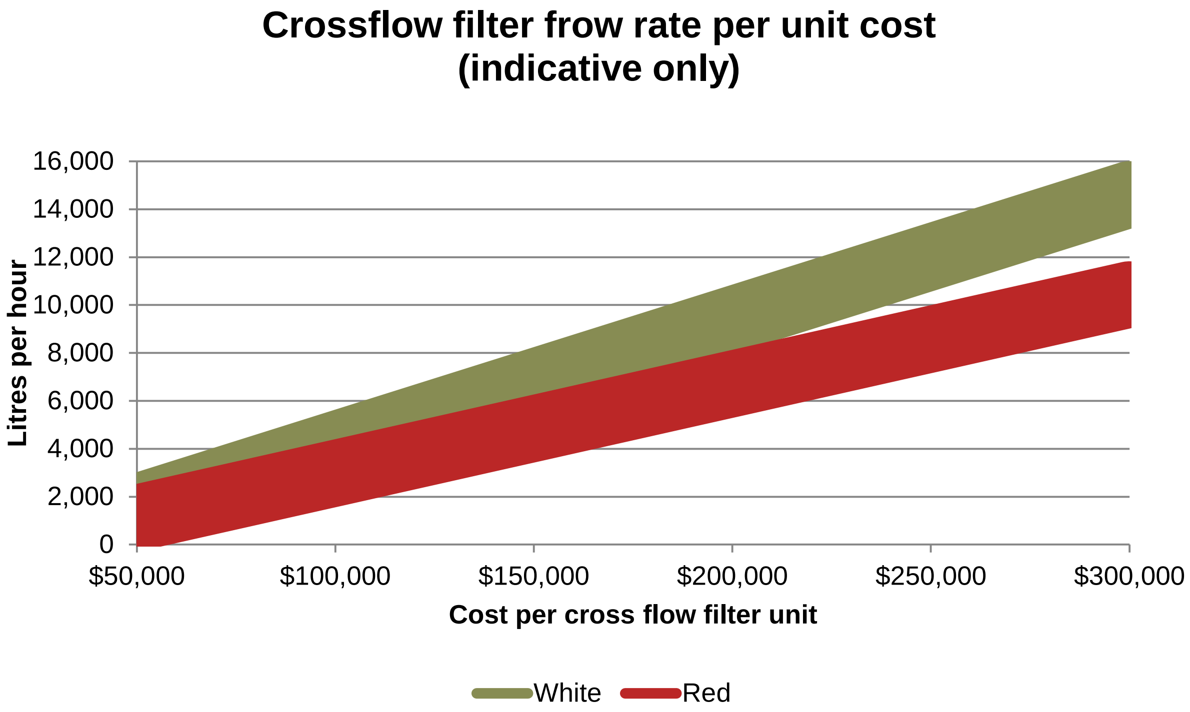

Figure 24 - Indicative costing of cross flow filters

Fermentation efficiency

Criterion	Rating	Comment
Commercial availability	Medium	Analytical equipment readily available Additional work required to characterise and publicise yeast strains and their suitability to must parameters
Adoptability (ease of implementation)	High	Minor additional analysis prior to standard yeast addition so simple changes.
Level of risk to quality or productivity	Low	Little or no impact on quality, increase in production speeds, increase in energy efficiency
Capital and recurring costs	Low	Little or no capital costs required depending on level of automation. No recurring costs other than purchasing specific yeast strains.
Regulatory requirements	Not applicable	
Other technology or project risks	Not applicable	
Overall Score	High	

Overview

Efficient fermentation is the end result of quality pressing, wild microbiological control, current microbiological conditions (nutrient levels) and introduced microbiological strains. In the context of fermentation efficiency, it would be beneficial if the steps prior to and including fermentation follow a standardised format with corrective steps taken to optimise fermentation conditions. This is more in line with FMCG industries where variables are minimised and processes are standardised, established and controlled through a set of guidelines.

As an overview these control processes would include:

Pressing and Crushing

- Monitoring (ideally real time) of pH, SO2, titratable acid, sugar levels and temperature

- Adjustment of pH, SO2, YAN

Fermentation

- Monitoring of pH, SO2, YAN, Potassium (K+) availability and temperature.
- Adjustment of pH, SO2, YAN, K+ and temperature

It is important that the choice of yeast strain matches these pH, SO2 and potassium conditions (Day, 2013) and temperature is controlled for ideal fermentation conditions.

Benefits

The benefits of efficient fermentation include production speed and decreased energy use. This will also decrease the risk of fermentation struggling to start, running slowly and failing to finish. This has the additional benefits of quicker turnaround times making fermentation tanks available for subsequent fermentation batches. Using standardised fermentation parameters with must correction can increase quality and help produce a consistent wine. Co-fermentation with Malolactic bacterial at the primary fermentation stage can also decrease malolactic fermentation times by up to 12 weeks (Day, 2013).

Standardising wine making conditions for certain parameters takes the 'guess work' out of wine making. It also allows the winemaker to focus on other projects by allowing other staff members to follow a recipe and prevent the winemaker from needing to make every decision regarding the wine making process.

For these reasons and scarce availability of additional fermentation tanks, the benefits of fermentation efficiency have been rated as MEDIUM-HIGH.

Uptake

Uptake of fermentation efficiency is more complicated than other process efficiencies for wineries as it is a multi dependent process requiring changes from receival to crushing / pressing as well as changes during fermentation.

Equipment is currently available for analysing fermentation parameters. Yeast strains are continually evolving driven in part by winery conditions. Additional research is required for identifying and matching yeast strains to must conditions, and publicising this information for use by the wine industry.

The adoptability of fermentation efficiency should be relatively simple once the identification of yeast strains and their relation to must conditions have been created. Additional analysis of must and receival strains would be of additional benefit for helping understanding fermentation conditions and correcting these fermentation conditions to optimal conditions. Standardisation of fermentation parameters will simplify the wine making process however, some resistance to standardisation may be felt by winemakers believing this is 'dumbing down' the wine making process.

There is no risk for productivity and this method is likely to significantly increase productivity. Choice of yeast strains may influence some sensory effects as will co-fermentation and it will need to be determined if these sensory changes are acceptable for the type of wine being produced.

Capital costs are required to increase testing capabilities, however should have basic laboratories capable of undertaking basic availability. Additional capital would be required for real time controlling fermentation temperature profiles would be undertaken refrigeration control equipment to correct and monitor not compulsory (refer to

Automation for more details).

Further work

Additional research is required to ‘map’ yeast and bacterial strains to fermentation parameters and publicise the findings. This work has begun through AGWA projects AWR 1301, AWR 1302, AWR 1303 and UA 1302.

Contact cold stabilisation

Criterion	Rating	Comment
Commercial availability	High	Readily available commercially for both equipment and service providers. Little or no additional equipment required
Adoptability (ease of implementation)	Very High	Direct replacement of existing traditional cold stabilisation methods
Level of risk to quality or productivity	Low	Little or no impact on quality, increase in production speeds, increase in energy efficiency
Capital and recurring costs	Low	Little or no capital costs required. No recurring costs required if recycling KHT crystals
Regulatory requirements	Not applicable	
Other technology or project risks	Not applicable	
Overall Score	High	

Overview

Traditional cold stabilisation involves chilling a tank to around freezing point - between -2 °C and +2 °C, and holding at this temperature for 1 – 3 weeks to allow potassium bitartrate (KHT) crystals to form. This method is energy intensive and runs risk including the potential of a ‘failed’ stabilisation where work is required to be repeated requiring additional energy to be spent in refrigeration. Rapid contact methods of cold stabilisation have significant benefits compared with traditional cold stabilisation.

An overview of the contact process procedure has been included below.

Contact Process Procedure (Dharmadhikari, 1994)

In order to stabilize a wine using the contact process, the following procedure is suggested:

1. *Clarify, fine and filter the wine to remove colloidal material. (Remember this causes fouling of crystals.)*
2. *Chill the wine to the desired stability temperature. For table wine the stabilized temperature is generally between -4 to 0ºC (24.8 to 32ºF).*
3. *Chilling the wine may cause precipitation on unstable material (especially red wines). In such a case, polish filtration of chilled wine may be needed. Filtration before seeding makes later removal of KHT crystals easy.*
4. *Add KHT powder crystals @ 4/g/L.*
5. *Provide a CO2 or nitrogen blanket to minimise oxygen pickup. It is important to remember that a larger amount of oxygen is dissolved at the lower temperature, but the oxidation effect becomes evident later when the wine is warmed.*
6. *Agitate the wine thoroughly. Agitation promotes crystal growth.*
7. *Allow 1 ½ to 2 hours of contact time.*
8. *Take the conductivity reading of the filtered wine sample and compare it with the reading obtained during the laboratory trial. This assumes that a lab trial for a given batch of wine was conducted earlier and the conductivity reading of the wine stabilised to the desired temperature is known. In place of conductivity reading, changes in the tartaric acid level can be determined analytically and compared with the tabulated value to determine wine stability.*
9. *After the treatment, the KHT can be allowed to settle and the wine can be racked and filtered. If time is too short to allow settling, the wine can be filtered to remove KHT. (The wine should be filtered while cold.)*
10. *To lower the cost of processing the wine, the KHT crystals should be ground and reused.*
11. *Repeated use of the KHT powder can cause microbial contamination of the wine. To prevent contamination, the KHT slurry should be stored with 500 ppm SO2*

http://www.extension.iastate.edu/NR/rdonlyres/173729E4-C734-486A-AD16-778678B3E1CF/73948/Cold...

Benefits

The main benefit for contact cold stabilisation methods is that it is a fast, energy saving and therefore process efficient alternative for wineries currently undertaking traditional cold stabilisaiton. It requires little new equipment and can be substituted easily with traditional cold stabilisation practices.

Rapid contact methods such as seeded cold stabilisation tend to overcome the wines natural crystallisation inhibitions. Seeded cold stabilisation processes can be undertaken at warmer temperatures thus greatly reduce energy consumption. The seeded crystal can also reduce tartrate levels much faster than traditional cold stabilisation methods (down to 1 hour in comparison to the 1-3 weeks of traditional cold stabilisation) (Rhein & Neradt, 1979). Tartrate crystals can be recycled via cross flow filtration for use in subsequent batches reducing the cost of purchasing seed crystals. This method still requires significant energy to be spent in primarily chilling the tank of wine to cold stabilising temperatures. Heat exchangers can be used to chill the next batch of wine to be cold stabilised temperatures using the previously stabilised wine as a cold source. This significantly reduce energy consumption.

Uptake

Contact process equipment is readily available from wine suppliers. The only additional equipment likely to be required are grinders for the KHT crystals and a storage tank for the KHT slurry. KHT can be recycled and reused as required and does not require an additional cost. It is also possible to sell this KHT.

As mentioned earlier, the contact cold stabilisation process is highly adoptable to wineries currently undertaking traditional cold stabilisation. There is no risk to quality for wineries currently undertaking traditional cold stabilisation and productivity will be increased using this method.

Pressing (continuous vs. batch processing)

Criterion	Rating	Comment
Commercial availability	High	Readily available commercially for both equipment and service providers. Little or no additional equipment required
Adoptability (ease of implementation)	High	Direct replacement of existing pressing techniques
Level of risk to quality or productivity	Medium	Increase in production speeds, potential issues for quality
Capital and recurring costs	Low	High capital costs are required, however units tend to be less than membrane presses.
Regulatory requirements	Not applicable	
Other technology or project risks	Not applicable	
Overall Score	High	

http://www.vincentcorp.com/content/free-run-grape-juice

Overview

Wine pressing is a bottleneck for wineries, especially in white grapes where pressing takes place soon after receival and crushing. Many wineries use membrane press filters which are a batch system. This creates process flow issues reducing production speed and decreasing the receival, destemming and crushing speed for white grapes. An alternative is a continuous pressing method such as screw presses which are used throughout the FMCG industry.

Benefits

The benefits for screw pressing include the continuous nature of the press therefore creating smooth production flows. As mentioned above, this increases the receival, destemming and crushing speeds and reduces ‘down time’ or idle equipment compared with batch process systems.

Typical screw presses are capable of processing up to approximately 50 tonnes / hours of crushed grapes which is closer to production flows from destemmers and crushers which are approximately 80 tonnes / hour. This is in contrast to batch pneumatic membrane presses which crush between 10-15 tonnes / hour. Higher yields of juice can also be achieved using screw presses compared with membrane systems (Nordestgaard, Phenolic Extraction and Juice Expression during White Wine Production, 2011).

Screw presses require electricity as a resource compared with the membrane press systems which require large quantities of compressed air and electricity. Many wineries have reported issues when running membrane presses other systems requiring compressed air can go ‘off-line’ due to the large air volume requirements of membrane presses. This however, can usually be rectified by installing additional air receivers at the membrane press location.

Labour costs for screw presses tend to be lower compared with membrane systems based on the quantity of must pressed. In addition, cleaning and maintenance of screw presses is quicker compared with membrane batch systems.

For the above reasons, the process efficiency benefits from continuous systems like screw presses have been rated as HIGH.

Uptake

Screw presses are commercially available for the wine industry. Significant engineering changes have taken place to make screw presses suitable for the wine industry. These screw presses are however becoming less common from suppliers where membrane presses are dominating the Australian market.

Screw presses are adoptable for wineries and can take place of existing press systems with little or no significant infrastructure changes other than purchased capital equipment.

There is no level of risk for wine productivity in using screw presses; however there is a moderate risk to quality when using some styles of screw presses. The main issues for screw presses are that the higher level of phenolic expression during pressing. This phenolic expression has decreased through changes in screw press technology. Modern screw presses are larger in diameter and run at lower speeds which decreases shear forces and reduce phenolic expression.

Potential providers

Existing Australian distributors of screw presses include:

- Australian and New Zealand Winemakers http://www.ausnzwinemakers.com/
- Della Toffola http://www.dellatoffola.com/enology/ENOLOGY_2_0_94_
- Machinery & Equipment Co, Inc http://www.machineryandequipment.com/

Existing manufacturers of screw presses include:

- Della Toffola http://www.dellatoffola.com/enology/ENOLOGY_2_0_94_
- Rietz
- Vincent Corporation http://www.vincentcorp.com/
- Marzola http://www.marzola.es/en/

Additional work to improve continual press systems like screw press technology would be beneficial, however, there are no Australian manufacturers of screw presses.

Conclusion

The process efficiency framework was developed to look for opportunities in the wine industry to increase process efficiencies. This was done by analysing the Fast Moving Consumer Goods industry and looking at solutions this industry had developed to problems that are similar to those in the wine industry. Once this was done, analysis was undertaken to understand if these solutions could be applied to the wine industry.

During analysis, it was found the wine industry was advance in a number of ways compared with the FMCG industry and much of the technology available to the wine industry is best practice and suitable to winery production needs. There are some gaps in the uptake of this technology and processes, in particular, cross flow filtration, traditional cold stabilisation and manual vs. automatic operations. These gaps in uptake are not characteristic of the available technology, but due to capital availability and in some cases not fully understanding the best processes

The largest efficiency point of difference between the wine industry and FMCG industry is not technology based, but a different management focus. Many of the leading FMCG industries have a business core focus around process efficiency and continuous improvement. This requires the FMCG industry to understand current process efficiencies through measuring metrics, analysing these metrics to understand process efficiencies, and improving on these efficiencies. Every winery is different and every process efficiency opportunity different, however, it is only after analysing current process efficiencies can these opportunities be fully understood and realised.

Once a winery has undertaken a change in focus to process efficiency and understood their current efficiencies, specific process can be targeted for increasing efficiencies. For example, the receival, destemming, crushing and pressing steps are a common process speed issue in a winery and the bottleneck tends to be the pressing step. Projects such as continuous high volume pressing systems tend to alleviate this bottleneck and increase production speed.

If a winery has undertaken a process efficiency analysis and determined that fermentation steps are a process efficiency issue, projects to increase this fermentation efficiency become important. This may include selecting yeast strains that are customised to the feedstock and that produce desirable fermentation characteristics. There is an opportunity for further study in this field.

Understanding current process efficiencies should be seen as key to improving business process efficiencies. Undertaking these steps can lead to significant savings for the business in resources used, materials efficiencies and production speeds. This will require a change in paradigm for many wineries but is necessary to ensure wineries remain viable and more important, profitable in a changing business environment.

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A2. List of figures

A3. Identification of key wineries for engagement

Leading wineries were identified for participation in this project. This was based on their reputation in the wine industry and their relationship with 2XE.

The leading businesses were identified as small, medium and large depending on their crush size. The distribution of wine sizes is summarised in Table 4.

Table 4: Business size classification

Business Size	Grape crush size
Small	<1,000
Medium	1,000 – 20,000
Large	> 20,000

The key wineries identified for engagement are summarised in Table 5.

Table 5: Leading wineries

Size	Name
Large	Kingston Estate
Large	Yalumba
Large	Treasury
Large	Orlando
Large	Accolade
Large	De Bortili
Medium	Henschke
Medium	Barossa Vintners
Medium	Pikes Wines
Medium	Salena Estate
Medium	McLaren Vintners
Medium	Bird in hand

Size	Name
Medium	Taylors Wines
Medium	Wirra wirra
Medium	LCW (Limestone coast wines)
Medium	Rutherglen Estates
Medium	Campbells Wines
Medium	Brokenwood
Small	Lloyd Brothers
Small	Mitchell Clare Wines
Small	O'Leary Walker Wines
Small	Bethany
Small	Loadstone
Small	Pfeiffer Wines

A4. Leading performers in beverage, food and other FMCG industries

Associations contacted

Food SA

Zero Waste

Businesses contacted

Best Bottlers

Mildura Fruit Company

The Better Drinks Co

Udder Delights

BD Farm Paris Creek

La Casa Del Formaggio

Businesses contacted

Golden North

SPQR

VRA The Yoghurt Shop

AlmondCo

References to case studies

Coopers Brewery

Unilever

Coca-Cola

A5. Prioritised issue framework

The framework in Table 6 (below) summarises key process improvement opportunities adopted by FMCG industries and relevant to the wine industry, and provides a means of prioritising these improvements based on their potential to improve process efficiency. Each opportunity is scored based on weightings associated with relevance to process (Process Weighting), likely process efficiency gain to be generated (Benefit), and ease of uptake by the wine industry (Predicted Uptake ease).

Based on this prioritisation process, the highest-priority process efficiency technologies and techniques have been further assessed to determine their level of applicability as viable solutions for the wine industry. The criterion used to assess each option includes:

- Commercial availability (whether the solution is commercially-available-off-the-shelf technology, or whether it requires significant R&D, pilot trials etc.)
- Adoptability (level of ease to which the solution can be introduced into the existing production system e.g. plug-and-play vs. complete process re-engineering)
- Level of risk that the solution poses to wine quality or productivity
- Capital and recurring costs
- Regulatory requirements (e.g. environmental, OH&S or HACCP approvals)
- Other technology or project risks.

Based on the assessment, each option has been given an ‘Opportunity Rating’, comprising of a ‘benefit’ score and ‘uptake’ score with greater detail than the original prioritised framework.

Table 6 - Prioritised issue and framework

Prioritised Framework		Low = 1; Medium = 3; High = 5		
Score	**Opportunity**	**Process Weighting**	**Benefit**	**Predicted Uptake ease**
Efficiency level (site)				
14	Process efficiency metrics (site wide)	5	5	4
12	Automation (benefits for all efficiencies)	5	5	2
Efficiency criteria				
13	Materials	5	4	4
12	Labour Efficiencies	5	5	2
12	Energy Efficiency	5	2	5
11	Water efficiency	5	3	3
10	Production Speed	5	3	2
Efficiency level (process)				
14	Stabilisation (energy efficiency / production speed)	5	5	4
12	Clarification (production speed / energy efficiency)	3	5	4
11	Fermentation (production speed)	3	5	3
11	Pressing (production speed)	2	5	4
11	Maturation (tank storage / energy efficiency)	4	4	3
10	Fermentation (real time monitoring)	3	4	3
10	Fermentation (automation)	3	4	3
9	Destemming / Crushing (production speed)	1	5	3
9	Destemming / Crushing (Energy efficiency)	1	3	5
9	Bottling (water efficiency)	2	4	3
9	Bottling (automation efficiency)	2	5	2
8	Receival Temperature	1	4	3
8	Destemming / Crushing (Materials efficiency)	1	5	2
8	Bottling (production speed)	2	3	3
7	Destemming / Crushing (labour efficiency)	1	3	3
7	Destemming / Crushing (water efficiency)	1	3	3
5	Bottling (energy efficiency)	2	2	1
5	Warehouse (production speed)	1	2	2
4	Transport (energy efficiency)	1	1	2