# ENERGY EFFICIENCY OPPORTUNITIES IN WINERIES FOR RETROFIT AND NEW CONSTRUCTION PROJECTS


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## ABSTRACT

This paper outlines typical winemaking processes for both white and red wines and the associated major energy consuming systems. Energy efficiency opportunities in retrofit as well as new construction projects are introduced. The opportunities for small/medium wineries as compared to large and very large wineries are discussed. The presented data is based on detailed assessments of 33 wineries and evaluation of designs of 17 new wineries in Northern and Central California. Over 25 major distinct energy efficiency opportunities were identified in all assessments. Electrical consumption distribution per system type will be discussed based on the size of the winery. The energy savings results as well as the simple payback will be outlined per measure base and per facility base for the evaluated existing and new construction wineries.


## INTRODUCTION

Modern wine making is an energy intensive process that involves various stages of refrigerated cooling. The fermentation, cold stabilization, and the storing/aging processes require significant levels of refrigeration. The fermentation process uses yeast to convert grape sugars to alcohol and carbon dioxide with heat released at the same time. This process greatly relies on the cooling system for heat removal. Red wine fermentations are generally controlled between 75 and 80 °F, whereas white wine is fermented between 48 and 60 °F [1]. The solubility of potassium bitartrate decreases as alcohol accumulates, and the crystal may show up in wine bottles. Hence, white wine is usually cold-stabilized at 25 to 36 °F [1] so that potassium bitartrate crystallization forms in the tank and can be removed. The post-fermentation wine is stored and aged at low temperature to prevent oxidation and other chemical reaction in the wine. White wine is generally stored at 40 to 44 °F on average, whereas red wine is generally kept between 45 and 70 °F [1]. The refrigeration systems operate at their heaviest load during the harvesting period between August and November. Since storing and aging wine continues throughout the year, the refrigeration system operates year-round. Figure 1 shows typical white and red wine production process flow diagrams.

According to the U.S. Census Bureau [2], the U.S. had 1,956 wineries in 2007, where 971 of the wineries were in California and produced about 85% of all U.S. wine. According to a Lawrence Berkeley National Laboratory (LBNL) study [1], the California winemaking industry consumes over 400 GWh of electricity annually, the second largest electricity-consuming food industry in California, after fruit and vegetable processing. Thus the wine industry is considered an effective target for application of energy efficient processes and equipment. Energy efficient opportunities can be implemented in retrofit, expansion as well as new construction projects.

The energy consumption distributions per system type are significantly different between small and large wineries. For instance, lighting energy consumption is minimal compared to the refrigeration system in a large winery, whereas the lighting and HVAC energy consumption may be higher than refrigeration system in a small winery, indicating that energy efficiency retrofit should be focused on the lighting and HVAC system as well. Technologies and equipment types for wine making are designed based on the size of winery, indicating that some energy efficiency opportunities are only targeted for certain sizes of facilities. Therefore, it is essential to distinguish the energy efficiency opportunities per winery sizes. The ASHRAE Refrigeration Handbook defines small wineries as those that crush tens of tons grapes per season, and large wineries that crush hundreds or thousands of tons of grapes per season [3]. The BEST Winery Guidebook by LBNL refers to “small/medium”

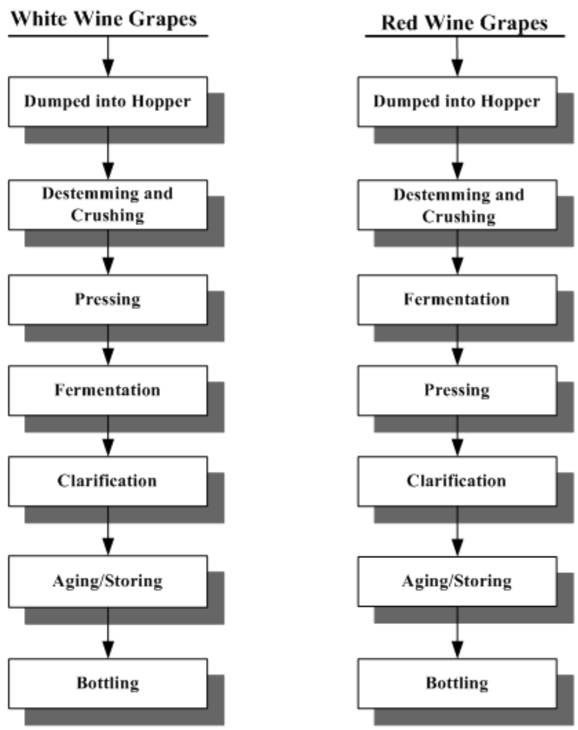


**Figure 1** – Typical Wine Process Flow Diagram

refrigeration system to be less than 100 tons, and "large" with refrigeration systems of 100 tons and up [1]. Since the size of refrigeration system is designed mainly based on the amount of grape to be processed, this paper categorizes the winery sizes based on the refrigeration capacity. In this paper wineries are grouped per refrigeration capacity:

- Small/Medium Winery: refrigeration system less than 100 tons
- Large Winery: refrigeration system equal or more than 100 tons
- Very Large Winery: refrigeration system over 2,500 tons

The majority of electrical energy consumption in wine making is by refrigeration systems. Other electric using systems are crush equipment, compressed air system, bottling equipment, transfer pumps, wastewater treatment system and lighting. Figure 2 shows the electrical consumption distribution based on the weighted average energy consumption of the audited small/medium wineries, large wineries and very large wineries summarized in Table 1. This data shows that the refrigeration, compressed air and process equipment energy consumption account for 68% to 84% of overall energy consumption in large and very large wineries, whereas the lighting and HVAC energy consumption is weighted heavily in small/medium wineries accounting for about 36% of total energy consumption.

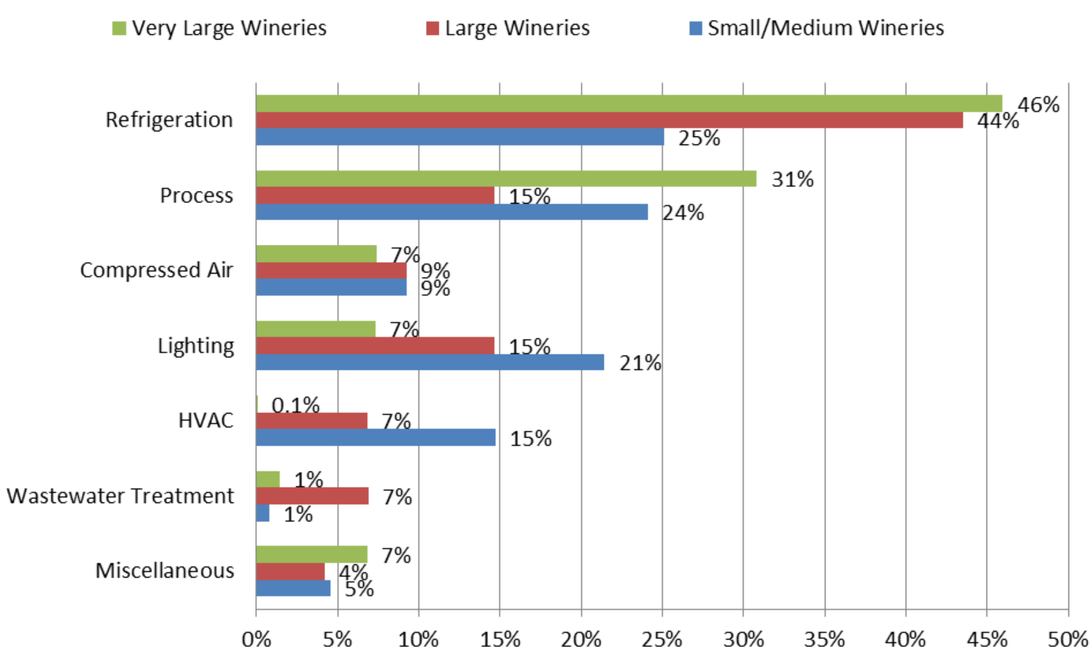


**Figure 2** – Electrical Consumption Distribution

**Note**: For very large wineries, the electrical energy consumption of HVAC is very minimal and is included under Miscellaneous for some of the assessed facilities; also, the wastewater treatment systems were not included for half of the assessed wineries.

## MAJOR ENERGY CONSUMING SYSTEMS

The major energy consuming systems for wine making can be categorized as the refrigeration system, process equipment, heating system and wastewater treatment system.

Refrigeration Systems

The audited small/medium wineries generally had one central refrigeration system to support the process cooling loads for the entire facility. The large wineries that were audited had multiple refrigeration systems that were dedicated to various applications, such as tank farms, barrel rooms, and must cooling. Most refrigeration systems were used to generate chilled glycol, except one very large winery supplied liquid ammonia to shell-and-tube heat exchangers in the tank farm to chill stored wine. The audited plants typically had ammonia refrigeration systems for large wineries and Freon refrigeration systems for small/medium sizes. Chilled glycol was generally generated at 25 to 36 °F during cold-stabilization periods [1] and higher temperature for the rest of the time. The majority of refrigeration applications are fermentation, cold stabilization and cold storage/aging.

The required fermentation temperature and period depend on the type of wine to be made. White wine is fermented at lower temperature resulting in more fruitiness taste and it requires longer fermentation period. The level of dry wine (without residual sugar) also determines the fermentation period. Generally for red wine the must is fermented between 75 and 80 °F for seven to ten days [1]. For white wine the fermentation takes seven to twenty-eight days usually between 48 and 60 °F [1]. Modern wine making utilizes stainless steel tanks as the most common fermentation vessels. Cooling is achieved by jackets, external or internal heat exchangers with chilled glycol or refrigerant circulation.

Cold stabilization chills the white wine to about 25 to 36 °F [1]to extract the potassium bitartrate since the salt solubility decreases at lower temperatures. Wine is typically maintained at this temperature for a period of 1.5 to 3 weeks [4], depending on how easy it is to crystallize the potassium bitartrate, i.e. how "stable" the wine is. The crystalized potassium bitartrate is then removed by racking.

The last wine making step is storage/aging. White wine is generally stored at 40 to 44 on average, whereas red wine is generally kept between 45 and 70 °F with 59 °F on average [1]. White wine is usually stored in tanks and consumed relative early to provide the fruity flavors. Red wine is generally aged in oak barrels for up to six months for light red wines and up to three years for robust red wines [1].

Process Equipment

Based on the audited wineries, wine making process equipment account for about 24%, 17% and 35% of the total energy consumption for small/medium, large and very large wineries, respectively. The process equipment includes de-stemmer, crush equipment, presses, clarification and must and juice transfer pumps. The harvested grapes are first de-stemmed and then crushed to form the must, a mixture of juice, skins, seeds and pulp. The juice is extracted by pressing the must before fermentation for white wine and after fermentation for red wine. Juice may be drained out from the must by filters. Larger wineries use presses to extract juice as the main method. Clarification is used to separate wine from suspended yeasts and other solids after fermentation. Racking is the most traditional technique for clarification, which is simply siphoning off the relatively clear wine. Fining and filtering are also the common clarification techniques. Large wineries commonly apply centrifuges for clarification, and very large wineries may use double stack floatation solid separation to clarify wine in far less time.

Heating System

The majority of natural gas energy consumption in wine making is process hot water usage. Hot water in wineries is mainly used for heating of tanks, cleaning, and heating wine after cold-stabilization. The audited wineries utilize hot water boilers, except the very large wineries that may use steam boilers, and hot water is generated by steam to water heat exchangers.

Wastewater Treatment

Most conventional winery wastewater treatment processes utilize 'aerobic' treatment, meaning that oxygen is taken in to break down the waste products. The common aerator types are brush aerator, mechanical surface aerator, and diffused air aeration system. Fine bubble diffuser system is the most efficient aeration system that has up to 20% standard oxygen transfer efficiency (SOTE) [5]. Anaerobic digesters are less energy intensive compared to aerobic systems but have higher initial investment costs.

***Modern Technologies***

Modern technologies are developed to improve the productivity rate and shorten the process time compared to traditional wine making processes. New technologies are generally adopted by large and very large wineries that process large amounts of grapes. Major technologies that impact the clarification, stabilization, cooling system and wastewater treatment system for winemaking are briefly outlined below.

Electrodialysis

Electrodialysis process is an alternative method for wine stabilization instead of cold-stabilization. Electrodialysis removes the tartaric acids from the wine by passing it through an electric field and collecting ions (potassium ($K^+$), calcium ($Ca^{++}$) and negatively charged tartaric acids) on anionic and cationic membranes. Electrodialysis eliminates the need for freezing and pre-heating the wine in cold-stabilization. According to an emerging technologies case study [6], for about 20,000 gallons of wine, the stabilization period for electrodialysis was 31 hours as opposed to 1,108 hours for cold-stabilization and the energy consumption reduced to be less than 1% of the energy required by cold-stabilization. However, electrodialysis resulted in a water consumption increase of about 3,000 gallons.

Clarification

Centrifuge and double stack floatation solid separation system are the modern technologies for the clarification process in large and very large wineries. Both systems can process high throughput of wine and have high clarification efficiency with low solid content output. Centrifuges are compact devices that mainly consist of one main drive and require less maintenance. Double stack floatation solid separation system uses coagulants, also known as “finings”, to clarify the wine, and it uses compressed air to induce separation between the solids and the liquid. It consists of a floatation tank, separated solid pumps, tank mixer and saturation tank. Double stack floatation solid separation system is more energy efficient than centrifuge.

High Efficiency Turbocor Chillers

Turbocor chillers are centrifugal chillers with frictionless magnetic bearing, which are controlled by variable frequency drives. Turbocor chillers are oil-free and hence eliminate the needs for oil cooling. At partial loads, Turbocor chillers are much more efficient than screw, centrifugal and reciprocating chillers. The integrated part load value (IPLV) can be as low as 0.34 kW/ton based on the operating conditions. According to manufacturer data, the largest water-cooled Turbocor chiller available has a capacity of 1,000 tons.

Anaerobic Wastewater Treatment

Anaerobic treatment processes do not use oxygen. The energy requirements and sludge production is much less than aerobic processes, thus making the process less costly and simpler. However, one of the main disadvantages of anaerobic processes is that they are much slower than aerobic processes and are only good at removing organic waste. Biogas generated from the anaerobic digesters is used to heat the digester. Excess biogas can be used for power generation. Anaerobic wastewater treatment systems are used in large and very large wineries.

## ENERGY EFFICIENCY OPPOTUNITES

This section details the energy efficiency opportunities and the savings summary in retrofit as well as new construction projects. The opportunities for small/medium wineries as compared to large and very large wineries are discussed. The presented data is based on detailed assessments of 33 wineries and design evaluation of 17 new wineries in Northern and Central California. Over 25 distinct energy efficiency opportunities were identified in all assessments. Tables 1 and 2 below summarized the plant characteristics of the audited existing wineries and reviewed new construction wineries considered in this paper.

| TABLE 1 - SUMMARY OF PLANT CHARACTERISTICS FOR AUDITED EXISTING WINERIES* | | | |
|---|---|---|---|
| **Average Value** | **Small/Medium Wineries** | **Large Wineries** | **Very Large Wineries** |
| Number of Plants | 5 | 22 | 6 |
| Annual Electrical Energy Usage (kWh/yr) | 481,000 | 2,000,000 | 14,000,000 |
| Maximum Electrical Demand (kW) | 130 | 510 | 3,100 |
| Annual Gas Energy Usage (Therm/yr) | 5,900 | 48,000 | 764,000 |
| Refrigeration Compressor Capacity | 55 hp | 500 hp | 5,200 hp |

* The values in the table have been rounded.

| TABLE 2 - SUMMARY OF PLANT CHARACTERISTICS FOR NEW CONSTRUCTION* | | | |
|---|---|---|---|
| **Average Value** | **Small/Medium Wineries** | **Large Wineries** | **Very Large Wineries** |
| Number of Plants | 6 | 9 | 2 |
| Refrigeration Compressor Capacity | 40 ton | 350 hp | N/A |

* The values in the table have been rounded.

Major energy efficiency opportunities are discussed in the following section and categorized per refrigeration system, process equipment, lighting, hot water system and wastewater treatment system. For each measure the application for small/medium (S/M), large (L) and very large (VL) wineries are indicated. Tables 3 and 4 summarize the number of times each measure was recommended, as well as the ranges of energy savings percentage compared to the associated system or equipment energy consumption and years of simple payback for the assessed small/medium, large and very large wineries.

***Refrigeration Systems***

Sequence Refrigeration Compressors (L, VL)
The refrigeration systems in large and very large wineries typically consist of multiple compressors of various types, cooling capacities and control systems. The performance of these compressors is different under the same operating point. Therefore, optimizing the sequence control of multiple compressors can result in significant electrical energy savings.

Implementing this measure could result in about 9% electrical energy savings of the associated refrigeration system energy consumption, with a simple payback of about 2 years.

High Efficiency Refrigeration Compressors and Chillers (S/M, L, VL)
The compressor performance can be evaluated at kW/ton, where kW is the compressor power consumption for providing a certain tonnage of cooling load. Under the same suction and discharge operating conditions, and providing the same amount of cooling load, the lower kW/ton indicates a more efficient compressor.

Implementing this measure could result in 6% to 42% electrical energy savings of the associated refrigeration system energy consumption, with a simple payback of 1-5 years, and up to 8 years for new construction projects.

Interconnect Multiple Refrigeration Systems (VL)
It was recommended to interconnect individual ammonia refrigeration systems into a single system with common discharge and suction headers. A single interconnected refrigeration system can be controlled to sequence and optimize the operation of compressors to minimize the number of compressors needed to run. Minimizing the number of compressors to match a refrigeration load results in energy savings and system reliability.

Implementing this measure could result in about 16% electrical energy savings of the associated refrigeration system energy consumption, with a simple payback of about 3 years.

Floating Head Pressure Control on Refrigeration Compressors (S/M, L, VL)
If the head pressure were to adjust itself based on the systems' heat rejection rate and the ambient wet-bulb temperature, the system would be operating with a "floating" head pressure. Allowing the head pressure to "float" would permit the refrigeration system to operate much more efficiently. As a rule-of-thumb, one degree (°F) reduction in saturated condensing

temperature will result in about 1.3% efficiency improvement of the compressor [7].

Implementing this measure could result in 14% to 23% electrical energy savings of the associated refrigeration system energy consumption, with a simple payback of 1-6 years.

Enable Air Economizer Free Cooling (S/M, L, VL)
Barrel rooms and case good storage rooms are air-conditioned to maintain the required room set point temperature. Red wine is generally kept between 45 and 70 °F with 59 °F on average for storage and aging [1]. When the outside dry-bulb temperature is below room set point, free outside air cooling, also known as night air cooling, can be introduced to the room instead of using mechanical cooling.

Implementing this measure could result in 6% to 42% electrical energy savings of the associated refrigeration system energy consumption, with a simple payback of 1-4 years, and up to 14 years for new construction projects.

Raise the Glycol Temperature and Refrigeration System Suction Pressure Set Points When Not Cold Stabilizing Wine (S/M, L, VL)
It is common that a winery utilizes a central refrigeration system to provide cooling for various applications, including cooling for fermentation, cold stabilization, barrel room, tank cellars and process cooling load. Cold stabilization chills the white wine to about 25 to 36 °F [1], while other applications are generally maintained at 50 °F and above. Cold stabilization is only required for short periods during the year. Refrigeration systems are more efficient at a higher suction pressure set point. Therefore, raising the glycol temperature and refrigeration system suction pressure set points when not cold stabilizing wine will result in significant energy savings.

Implementing this measure could result in 23% to 29% electrical energy savings of the associated refrigeration system energy consumption, with a simple payback of 0-2 years.

Replace the Air-Cooled Condensers with Water-Cooled Evaporative Condensers for Refrigeration Systems (S/M, L, VL)
The performance of air-cooled condensers is dependent on ambient dry-bulb temperature, while the performance of evaporative condensers (similar to a cooling tower) is dependent on ambient wet-bulb temperature. The ambient wet-bulb temperature is always less than or equal to the ambient dry-bulb temperature. Using evaporative condensers rather than the air-cooled condensers will allow the compressors to operate at a lower discharge pressure, which will reduce the energy consumed by the compressors.

Implementing this measure could result in 34% to 47% electrical energy savings of the associated refrigeration system energy consumption, with a simple payback of 3-5 years.

Insulate Wine Tanks (S/M, L, VL)
Wine tanks are used for wine fermentation, storage and stabilization. Generally for red wine the must is fermented between 75 and 80 °F for seven to ten days [1]. For white wine the fermentation takes seven to twenty-eight days usually between 48 and 60 °F [1]. White wine is generally stored in tanks at 40 to 44 °F on average [1]. For outdoor wine tanks, the surfaces of the tanks are exposed to the ambient. When the ambient temperature is higher than the tank temperature, it will increase the heat gain to the tank resulting in an increase of cooling load to the refrigeration system. Insulating the outdoor wine tanks will reduce their heat gain, which in turn will reduce the energy consumption of the refrigeration systems.

Implementing this measure could result in 65% to 97% electrical energy savings of the portion of electrical energy consumption of the refrigeration system for cooling the un-insulated wine tanks, with a simple payback of 2-5 years.

VFD Controlled Refrigeration Screw Compressor as the Trim Unit (L, VL)
Based on performance characteristics of screw compressors, a variable frequency drive (VFD) controlled screw compressor is more efficient at part-load compared to modulation valve controlled fixed speed screw compressor of the same size [8]. Also, screw compressors are most energy efficient at full load. Therefore, for refrigeration systems that consist of multiple compressors, it is more efficient to install a variable frequency drive compressor as a trim unit.

Implementing this measure could result in about 3% electrical energy savings of the associated equipment energy consumption, with a simple payback of about 1 year.

VFD Control on Condenser Fans, Glycol Circulation Pumps and Air Handler Fans (S/M, L, VL)
Since the cooling load required by the winery is determined based on seasonal grape process, different wine temperature requirement and the amount of wine being processed, optimum control of

refrigeration system components based on the actual cooling load will result in significant electrical energy savings. Variable frequency drives (VFD) can be installed on condenser fans, glycol circulation pumps and air handler fans to achieve the optimal control for the needed supply flow rate.

Implementing this measure could result in 20% to 93% electrical energy savings of the associated refrigeration system energy consumption, with a simple payback of 1-6 years.

***Process Equipment***

VFD on Process Equipment (S/M, L, VL)
Since winery process loads fluctuate depending on the amount of grape/wine being processed, it is recommended to install variable frequency drives (VFD) to control the speeds of process equipment, such as must transfer pumps, screw presses, destemmer and wine transfer pumps, whenever it is feasible.

Implementing this measure could result in 29% to 60% electrical energy savings of the associated process equipment energy consumption, with a simple payback of up to 5 years, and up to 11 years for new construction projects.

Double Stack Solid Separation Device (L, VL)
Double stack solid separation devices can process high throughput of wine and have high clarification efficiency with low solid content output. It consists of a floatation tank, separated solid pumps, tank mixer and saturation tank. Double stack solid separation is less energy intensive than centrifugal clarification, although centrifuges can reduce outgoing solids contents of wine to a fraction of a percent.

Implementing this measure could result in 66% to73% electrical energy savings of the associated process equipment energy consumption.

VFD Controlled Air Compressor (S/M, L, VL)
Rotary screw type air compressors are commonly used in wineries. The control methods for a screw air compressor include load/unload, inlet modulation and variable frequency drive (VFD) controls. Based on typical screw compressor performance [9], VFD is the most energy efficient control method, while inlet modulation is the least for part-load operation. When the compressor is unloading, inlet modulations controlled and load/unload controlled screw compressors still draw over 25% of the full load power.

Implementing this measure could result in 20% to 55% electrical energy savings of the associated process equipment energy consumption, with a simple payback of 1-3 years.

High Efficiency Humidifier (S/M, L, VL)
Humidification is required in barrel storage rooms for maintaining the humidification level. Energy efficient humidifiers, such as high pressure mechanical humidifier and ultrasonic humidifiers, are recommended in applications requiring simultaneous cooling and humidifying, but not when simultaneous heating and humidifying is required.

Implementing this measure could result in 76% to 95% electrical energy savings of the associated process equipment energy consumption, with a simple payback of less than about 2 years.

***Lighting***

High Efficiency Lighting (S/M, L, VL)
High efficiency lighting consumes less electrical energy for providing comparable amount of lighting intensity. The common high efficiency lighting opportunities include:

- Replace the High Intensity Discharge (HID) Lighting with High Intensity T5
- Replace T12 fluorescent lighting with T8 fluorescent lighting
- Replace 32-Watt T8 lamps with 28-Watt T8 lamps
- Replace HID and fluorescent lightings with LED or induction lighting

Implementing this measure could result in 25% to 83% electrical energy savings of the associated lighting energy consumption, with a simple payback of 1-6 years.

Automatic Lighting Controls (S/M, L, VL)
The two common automatic lighting controls are occupancy sensor control and daylight sensor control. When a space is unoccupied or there is sufficient daylight, the lighting can be reduced or turned off resulting in electrical energy savings. For the case of HID lighting this measure would include bi-level controllers.

Implementing this measure could result in 33% to 83% electrical energy savings of the associated lighting energy consumption, with a simple payback of 1-6 years.

***Hot Water System***

High Efficiency Boiler (S/M, L, VL)
Hot water in wineries is mainly used for heating of tanks, cleaning, and heating wine after cold-stabilization. High efficiency boilers consume less natural gas energy for generating the same amount of heating load.

Implementing this measure could result in up to about 6% natural gas energy savings of the associated hot water system energy consumption, with a simple payback of 1-3 years.

Recover Waste Heat from Refrigeration System to Preheat Boiler Make-Up Water (L, VL)
Discharge refrigerant from compressors (except with liquid injection oil cooling) is superheated at high temperature. Generally the rejected heat from the refrigeration system is removed by the condenser system. The available heat depends on the head (discharge) pressure set point for each particular type of compressor. The discharge temperature can be as high as 190 °F for the head pressure of 165 psia for an ammonia compressor. The waste heat from the refrigeration system can be used to preheat boiler make-up water that is generally at about 60 °F. Desuperheating the high-pressure refrigerant will also reduce the heat load to the evaporative condensers, which will reduce the energy consumption of the condenser fans if it is properly controlled.

Implementing this measure could result in 6% to 20% natural gas energy savings of the associated hot water system energy consumption, with a simple payback of 3-6 years.

***Wastewater Treatment System***

Install an Automated Dissolved Oxygen (DO) Control System for Aeration Control (S/M, L, VL)
The amount of wastewater generated in a winery and the biological oxygen demand (BOD) level are significantly higher during crush season than in non-crush season. In manual systems, plant operators tend to provide excess oxygen into the bioreactor to avoid violating standards, which in turn results in excess electrical energy usage by the aeration system. An automatic dissolved oxygen (DO) system will measure the level of dissolved oxygen in the wastewater using DO sensors. Control of aerators (e.g. through VFDs) can result in significant energy savings. According to the extensive literature search [10], the energy savings achievable by automatic aeration of DO control is typically 25% to 40%, but can be as high as 50%.

Implementing this measure could result in 10% to 75% electrical energy savings of the associated wastewater treatment system energy consumption, with a simple payback of 1-3 years, and up to 8 years for new construction projects.

Anaerobic Digester System (L, VL)
Most conventional wastewater treatment processes utilize ‘aerobic’ treatment, meaning that oxygen is taken in to break down the waste products. This results in a high energy consumption since oxygen has to be supplied by aeration equipment, which is probably one of the most energy intensive process in a wastewater treatment facility. ‘Anaerobic’ treatment processes do not use oxygen. The energy requirements and sludge production is much less than for aerobic processes, thus making the process less costly and simpler.

Implementing this measure could result in up to 98% electrical energy savings of the associated wastewater treatment system energy consumption, with a simple payback of about 1 year.

***Other Energy Efficiency Opportunities***

There are other common energy efficiency opportunities for wineries that are not described in the above sections. These measures should also be considered for energy assessments for existing and new construction facilities.

- Install Premium Efficiency Motors
- Replace Standard V-Belts with Cog-Type Belts
- Repair Compressed Air Leaks
- Replace Compressed Air Jets with High-Pressure Blower
- Reduce Air Compressor Discharge Pressure
- High Efficiency Pumps
- Insulate Chilled Water Lines
- Insulate Glycol Storage Tanks
- High Efficiency HVAC Units
- VFD Controlled Hot Water Pumps

| TABLE 3 - SUMMARY OF ENERGY EFFICIENCY OPPORTUNITIES FOR AUDITED EXISTING WINERIES* | | | | | | |
|---|---|---|---|---|---|---|
| **Energy Efficiency Measure** | **Small/Medium Wineries** | | **Large Wineries** | | **Very Large Wineries** | |
| | **No.** | **Ranges of % EES (and Simple Payback)** | **No.** | **Ranges of % EES (and Simple Payback)** | **No.** | **Ranges of % EES (and Simple Payback)** |
| **Refrigeration System** | | | | | | |
| Sequence Refrigeration Compressors | | | | | 1 | 9% (2 yrs) |
| High Efficiency Refrigeration Compressors and Chillers | 1 | 16% (5 yrs) | | | 1 | 13% (4 yrs) |
| Interconnect Multiple Refrigeration Systems | | | | | 1 | 16% (3 yrs) |
| Floating Head Pressure Control on Refrigeration Compressors | 1 | 20% (5 yrs) | 7 | 14-18 % (1-6 yrs) | 3 | 18-23 % (< 1 yrs) |
| Enable Air Economizer Free Cooling | | | | | 2 | 41% (1 yr) |
| Raise the Glycol Temperature and Refrigeration System Suction Pressure Set Points When Not Cold Stabilizing Wine | | | 2 | 28 % (< 2 yrs) | 2 | 23-27 % (0 yr) |
| Replace the Air-Cooled Condensers with Water-Cooled Evaporative Condenser for Refrigeration Systems | 1 | 47% (3 yrs) | | | 1 | 34% (5 yrs) |
| Insulate Wine Tanks | | | 3 | 84-91 %[£] (2-4 yrs) | | |
| VFD Control on Condenser Fans, Glycol Circulation Pumps and Air Handler Fans | 4 | 75-93 % (1-5 yrs) | 32 | 32-93 % (1-6 yrs) | 3 | 48-61 % (2-3 yrs) |
| **Process Equipment** | | | | | | |
| VFD on Process Equipment | | | | | 2 | 29-46 % (n/a) |
| VFD Controlled Air Compressor | 1 | 40% (2 yrs) | | | | |
| Energy Efficient Humidifier | | | 1 | 76% (2 yrs) | | |
| **Lighting** | | | | | | |
| High Efficiency Lighting | 4 | 43-80 % (1-6 yrs) | 24 | 31-83 % (1-6 yrs) | 2 | 45-49 % (2-3 yrs) |
| Automatic Lighting Controls | 4 | 33-63 % (1-2 yrs) | 18 | 15-83 % (1-6 yrs) | 3 | 41-52 % (2-6 yrs) |
| **Hot Water System** | | | | | | |
| VFD Controlled Hot Water Pumps | | | 3 | 57-91 % (1-3 yrs) | 1 | 33% (2 yrs) |
| Recover Waste Heat from Refrigeration System to Preheat Boiler Make-Up Water | | | 3 | 8-20 % (3-6 yrs) | 1 | 6 % (3yrs) |
| **Wastewater Treatment System** | | | | | | |
| Install an Automated Dissolved Oxygen (DO) Control System for Aeration Control | 1 | 75% (3 yrs) | 3 | 10-53 % (1-2 yrs) | 1 | 22% (3 yrs) |

*This table summarizes the following results for the assessed wineries: number of times the measure was recommended, percentage of energy savings compared to the associated system/equipment energy consumption, and the simple payback periods with energy efficiency incentives (about $0.09/kWh savings, $100/kW demand reduction, and $1/therm savings).

£ The baseline energy consumption is considered to be the portion of electrical energy consumption of the refrigeration system for cooling the un-insulated wine tanks.

| TABLE 4 - SUMMARY OF ENERGY EFFICIENCY OPPORTUNITIES FOR NEW CONSTRUCTION WINERIES* | | | | | | |
|---|---|---|---|---|---|---|
| **Energy Efficiency Measure** | **Small/Medium Wineries** | | **Large Wineries** | | **Very Large Wineries** | |
| | **No.** | **Ranges of % EES (and Simple Payback)** | **No.** | **Ranges of % EES (and Simple Payback)** | **No.** | **Ranges of % EES (and Simple Payback)** |
| **Refrigeration System** | | | | | | |
| High Efficiency Refrigeration Compressors and Chillers | 3 | 6-42 % (1-8[£] yrs) | 8 | 12-43 % (1-4 yrs) | | |
| Enable Air Economizer Free Cooling | 2 | 6-42 % (4-12[£] yrs) | 1 | 6% (14[£] yrs) | | |
| Raise the Glycol Temperature and Refrigeration System Suction Pressure Set Points When Not Cold Stabilizing Wine | | | 1 | 29 % (0 yrs) | | |
| Insulate Wine Tanks | | | 4 | 65- 97 %[**] (2-5 yrs) | | |
| VFD Controlled Refrigeration Screw Compressor as the Trim Unit | | | | | 1 | 3% (1 yr) |
| VFD Control on Condenser Fans, Glycol Circulation Pumps and Air Handler Fans | 3 | 57-69 % (2-5 yrs) | 6 | 20 -79 % (1-5 yrs) | 1 | 74 % (3 yrs) |
| **Process Equipment** | | | | | | |
| VFD on Process Equipment | | | | | 2 | 29-60 % (5-11[£] yrs) |
| Double Stack Solid Separation Device | | | | | 2 | 66-73 % (0 yrs) |
| VFD Controlled Air Compressor | 3 | 20-44% (2 yrs) | 3 | 36-55% (1-3 yrs) | | |
| Energy Efficient Humidifier | | | 3 | 91-95% (0-1 yrs) | | |
| **Lighting and HVAC** | | | | | | |
| High Efficiency Lighting | 5 | 25-54% (1-5 yrs) | 8 | 28-71% (1-2 yrs) | | |
| Automatic Lighting Controls | | | 2 | 60% (3-4 yrs) | | |
| High Efficiency HVAC | 3 | 22-29% (3-14[£] yrs) | | | | |
| **Hot Water System** | | | | | | |
| High Efficiency Boiler | | | 2 | 6 % (1- 3 yrs) | | |
| **Wastewater Treatment System** | | | | | | |
| Install an Automated Dissolved Oxygen (DO) Control System for Aeration Control | | | 2 | 22-23% (1- 8[£] yrs) | 1 | 23 % (2 yrs) |
| Anaerobic Digester System | | | | | 1 | 98 % (1 yr) |

*This table summarizes the following results for the evaluated new construction wineries: number of times the measure was recommended, percentage of energy savings compared to the associated baseline energy consumption, and the simple payback with energy efficiency incentives (about $0.09/kWh savings, $100/kW demand reduction, and $1/therm savings). Note that the simple years of payback periods were calculated based on the premium implementation cost compared to purchasing the baseline equipment. The baseline is considered to be common practices in California wineries.

** The baseline energy consumption is considered to be the portion of electrical energy consumption of the refrigeration system for cooling the un-insulated wine tanks.

£ Measures with long simple payback were included in the original designs by the facility.

Tables 5 and 6 summarize the overall average electrical energy and gas savings percentages as well as payback ranges from implementation of energy efficiency opportunities for the assessed small/medium, large and very large wineries.

| TABLE 5 - SUMMARY OF OVERALL AVERAGE SAVINGS FOR AUDITED EXISTING WINERIES | | | |
|---|---|---|---|
| | **Small/Medium Wineries** | **Large Wineries** | **Very Large Wineries** |
| Electrical Energy Usage Overall Savings (%)* | 18% | 13% | 17% |
| Natural Gas Usage Overall Savings (%)* | N/A | 3% | 1% |
| Payback Range (yrs) | 2 - 4 | 1 - 6 | 0.5 – 4.5 |

*Based on total electrical and gas energy consumption of assessed facilities.

| TABLE 6 - SUMMARY OF OVERALL AVERAGE SAVINGS FOR NEW CONSTRUCTION WINERIES | | | |
|---|---|---|---|
| | **Small/Medium Wineries** | **Large Wineries** | **Very Large Wineries** |
| Electrical Energy Usage Overall Savings (%)* | 26% | 38% | 55% |
| Natural Gas Usage Overall Savings (%)* | 22% | 6% | 2% |
| Payback Range (yrs)[#] | 1 - 4 | 0.5 - 4 | < 1 |

*Based on baseline electrical and gas energy consumption of energy efficiency opportunities outlined in Table 4.
[#] Payback was evaluated based on implementation cost premium.

## CONCLUSIONS

Wine making is an energy intensive process, and the wine industry consumes over 400 GWh of electricity annually, the second largest electricity-consuming food industry in California. Therefore, the wine industry becomes an effective target for energy efficiency opportunities in both existing and new construction facilities.

The energy savings results presented are based on detailed plant-wide energy audits of 33 wineries and design reviews of 17 new wineries in Northern and Central California. Energy savings are discussed for small/medium, large and very large wineries categorized based on the size of the refrigeration system capacity. The electrical energy distribution data shows that the refrigeration system consumes about 45% of overall energy consumption in large and very large wineries. The lighting and HVAC energy consumption in small/medium wineries is about 36% of the total energy consumption, which is more than the 25% share of the refrigeration systems. Therefore, it indicates that energy efficiency retrofit should be focused on the lighting and HVAC system as well in small/medium wineries.

Over 25 major distinct energy efficiency opportunities were briefly discussed. Overall results of our findings are:

- For the audited wineries, on a facility-wide basis, up to 18% of the total electrical energy consumption and 3% of the total natural gas consumption can be conserved through energy efficiency measures. Payback periods for these facilities are between 0.5 years and 6 years.
- For the evaluated new construction wineries, on a project-wide basis, up to 55% of the total baseline electrical energy consumption, and 22% of the total baseline natural gas consumption can be conserved through energy efficiency measures. The baseline is considered to be common practices in California wineries. Payback periods for these facilities are between 0.5 years and 4 years.

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