Characteristics of Energy Efficiency Emerging Technologies for Wineries

Final Report

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Image: Wineries are cutting energy use one bottle at a time (savannahnow.com)

Disclaimer

Abbreviations and Acronyms

Acronym	Meaning
AB	Assembly Bill
BOD	Biochemical Oxygen Demand
Cal TF	California Technical Forum
CARB	California Air Resource Board
CDFA	California Department of Food and Agriculture
CEA	Controlled Environment Agriculture
CEC	California Energy Commission
COP	Coefficient of Performance
CPR	Custom Projects Review
CPUC	California Public Utilities Commission
DEER	Database for Energy Efficient Resources
DO	Dissolved Oxygen
EE	Energy Efficiency
EPA	Environmental Protection Agency
EPIC	Electric Program Investment Charge
FDA	Food and Drug Administration
FPIP	Food Production Investment Program
GHG	Greenhouse Gas
GPM	Gallons per Minute
GWh	Gigawatt-hour
GWP	Global Warming Potential

Acronym	Meaning
HP	Horsepower
HPWH	Heat Pump Water Heater
HVAC	Heating, Ventilation, and Air Conditioning
IHP	Industrial Heat Pump
IOU	Investor-Owned Utility
kW	Kilowatt
kWh	Kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
M&V	Measurement and Verification
MMBTU	Million British Thermal Units
MWh	Megawatt-hour
NEM	Net Energy Metering
NMEC	Normalized Metering Energy Consumption
NTGR	Net-to-Gross Ratio
OSHA	Occupational Safety and Health Administration
PFS	Project Feasibility Study
PG&E	Pacific Gas & Electric
PPP	Public Purpose Program
PV	Photovoltaic
RO	Reverse Osmosis
SB	Senate Bill
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric

Acronym	Meaning
SLNMEC	Site-Level Normalized Metering Energy Consumption
SME	Subject Matter Expert
SWEEP	State Water Efficiency and Enhancement Program
TOU	Time-of-use
TRC	Total Resource Cost
TSB	Total System Benefit
TTB	Alcohol and Tobacco Tax and Trade Bureau
UC	University of California
VFD	Variable Frequency Drive
WDR	Waste Discharge Requirements

Executive Summary

While wineries and vineyards have been leaders in developing and setting sustainability goals, this drive towards sustainability (combined with the reality that many winery energy efficiency improvements require complex deployment projects, often without clearly defined baselines) has led to disqualification of wineries and vineyards from energy efficiency (EE) programs. At the very least, these customers have been discouraged from participating in EE programs due to long review times, reduced incentive payments, and financial uncertainty. This has led to challenges for program implementers, who must evaluate a variety of decision-making scenarios to establish influence. In addition, many historical interventions are now industry standard practice, increasing the need for program implementers to incorporate emerging technologies into their program offerings.

The objective of this project was to identify and assess emerging technologies in the vineyard and winery sector, including pulse cooling for refrigeration, fluidized bed reactors for tartrate removal, and smart irrigation technologies. The approach was to gather information from winery and vineyard customers via interviews to understand their perspective on emerging technologies, with an emphasis on co-benefits of decarbonization, electrification, and water conservation. The project team evaluated emerging technologies in the vineyard and winery sector to guide future program designs. The project team also gathered relevant data on energy use in wineries, industry regulations, and decision-making criteria to focus on the most promising available technologies.

To implement our approach to this project, the project team reviewed literature from various sources, including state agencies and programs, research reports, and stakeholder organizations. The project team also performed structured interviews with seven winery and/or vineyard staff, two winery and vineyard program implementers (our team includes a third program implementer), one winery subject matter expert, and one technology vendor, and reviewed additional data sources such as Food Production Investment Program (FPIP) data, State Water Efficiency and Enhancement Program (SWEEP) data, regulations that impact the industry, and vendor incremental installation and operating cost data, although data for costs were extremely limited.

The project team found several emerging technologies that are not standard practice, but which some wineries and vineyards are piloting or exploring, such as pulse cooling and fluidized bed reactors for tartrate removal. Key factors that affect adoption include sensitivity to risk in the wine making process, sensitivity to operational impacts which can promote adoption or be a barrier to adoption depending on the technology, and payback period, which is generally expected to be two to six years. Key regulations that shape winery decision making and are expected to have an impact on future EE programs include ammonia regulations and the new winery general order. We found that the technologies with the highest potential for future EE programs, in order, are refrigeration technologies, hot water technologies, wastewater technologies, and irrigation technologies. The project team also found that winery and vineyard characteristics such as business size, geographic location, non-IOU fuel source, and utility rate structure impact decision-making. Market segmentation along these characteristics needs to be considered when establishing baselines, and by program implementers when suggesting technologies.

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Introduction

In recent years, California's regulatory agencies have placed a greater emphasis on establishing market influence to justify energy efficiency (EE) program incentives. In addition to providing engineering support, estimating savings, verifying performance, and analyzing costs, EE program implementors must evaluate a variety of decision-making scenarios that comply with specific program application types. This technical support will soon become even more important, as most EE programs will be transitioning from energy saving (i.e., kW, kWh, and Therms) to total system benefit (TSB) performance goals in 2024.

Many historical interventions in the winery and vineyard sector are now industry standard practice, increasing the need for program implementers to incorporate emerging technologies into their portfolio of program offerings. In addition, market segmentation is often not sufficiently considered when determining standard practices for the winery and vineyard sector. Eligible baselines vary significantly depending on characteristics such as business size, geographic location, non-IOU fuel source, and utility rate structure. This approach results in the inappropriate designation of baselines and program influence during the project review process. Program implementers will benefit from improved understanding of the existing market demands for energy efficient technology in wineries and vineyards. Also, a better understanding of needs and barriers can lead to improved program design and effective market intervention resulting in increased adoption of EE technology in winery and vineyard operations.

This study is a market characterization of the California winery market for energy efficient technology that occurred in two phases: 1) secondary research data collection and interview guide development, and 2) market actor interviews, technology assessment, and data analysis. The projects' key findings will further deployment of the most promising energy efficient emerging technology in wineries and vineyards.

Objectives

This study's objective was to explore how emerging technologies can benefit EE programs serving winery and vineyard customers. The study aimed to achieve this objective by gathering and analyzing market information through interviews with winery and vineyard operators and decision-making staff to document industry-specific opportunities and barriers.

The project team evaluated emerging technologies in the vineyard and winery sector with an emphasis on co-benefits of decarbonization, electrification, and water conservation. The project team also gathered relevant data on energy use in the winery, regulations, and market actor decision-making criteria to recommend the most promising EE technologies. The initial emerging technologies that the project team targeted for suitability in wineries and vineyards include:

- Advanced controls and load-reducing technologies for pumping systems
- Alternatives to cold stabilization for tartrate removal
- Refrigeration desuperheater heat recovery
- Onsite treatment and water reuse
- Use of low-global warming potential (GWP) refrigerants in industrial refrigeration
- Heat pumps for hot water generation
- Other technologies that reduce refrigeration loads or enable refrigeration load flexibility

Based on our findings, we reported primarily on technologies in the following end-uses:

- Refrigeration
- Hot Water
- Wastewater Systems
- Vineyard Irrigation

Background

This section provides context for the impact of winery and vineyard loads on total statewide energy use in California. It also includes an overview of the Total System Benefit framework and how the winery and vineyard sector is likely to be impacted.

Our literature review identified the vineyard and winery processes that present the most opportunities for energy savings, and several efficient technologies and strategies, including the emerging technologies described below.

Energy Impact of Wineries and Vineyards

According to a Statewide Agricultural Energy Efficiency Potential and Market Characterization Report, wineries and vineyards accounted for 9.66 million MMBtu of total energy (electric and gas) sales in 2010, or 12.9 percent of the total energy sales in the agriculture sector (Navigant, 2013). Total electric sales amounted to 400 GWh annually. The most energy intensive end use is refrigeration for fermentation cooling, cold stabilization, and cold storage (Galitsky, 2005). Other uses include hot water, pumping, and compressed air, which are variable depending on winery and process specific details. Furthermore, the winery and vineyard sector is highly seasonal with peak energy use in the fall during harvest. **Error! Reference source not found.** below is from the Statewide Agricultural Energy Efficiency Potential and Market Characterization Report and includes self-reported data from wineries and vineyards showing that most respondents think their peak for electricity and natural gas use is in October, with a significant number of responses also reporting September for peak use. The research team interviewed vineyard and winery staff who reinforced the importance of seasonality, and two of seven vineyard and winery staff interviewed specifically told the project team that the seasonality of wine making results in longer payback periods since equipment is sized for a peak period of about ten weeks, with marginal energy savings available outside of the peak period. The respondents cited seasonality as a barrier to technology upgrades that improve energy efficiency, lower the site carbon footprint, or conserve water. One of these staff estimated that 90 percent of their energy and water use occurs in a 10-week period from August to November. Furthermore, the project team was told that the highest usage is from noon to 6 p.m. or 7 p.m. between August and early November. **Figure 1** shows the estimated (by the survey respondent) month of energy usage, with electricity and natural gas shown separately. Because the month of reported peak natural gas usage generally aligns with the month of reported peak electricity use, the research team expects electrification will not shift or smooth electric consumption over the course of a typical year.

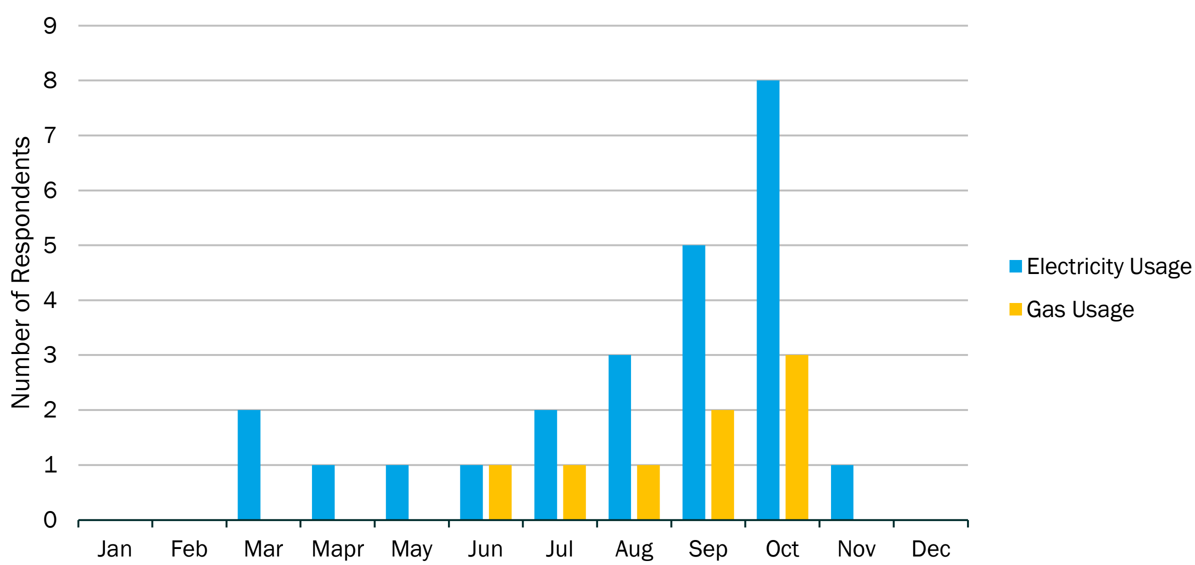

Figure 1: Survey results for vineyard and wineries showing reported months of greatest electricity and natural gas usage.[1]

The research team also conducted an analysis of energy use at one winery in California Climate Zone 13 to further understand seasonality. The winery that was analyzed (who wished to remain anonymous) uses energy for spray irrigation, grape crush, fermentation, wine storage, and wastewater treatment, and for typical winery end uses. Although minor variations are apparent

[1] Results from Technical Field Survey (Navigant, 2013), n = 13 – multiple responses for electricity, “In month do you think your electricity usage is the greatest?” and for natural gas, “In which month do you think your natural gas usage is the greatest?” n= 8 respondents reported that they did not use natural gas at their facility.

between the utility meter data (August peak use) and the survey results in the Statewide Agricultural Energy Efficiency Potential and Market Characterization Report (October peak use), the results of both analyses together show general agreement that for the wineries analyzed, July through October are periods of heightened electrical energy usage.

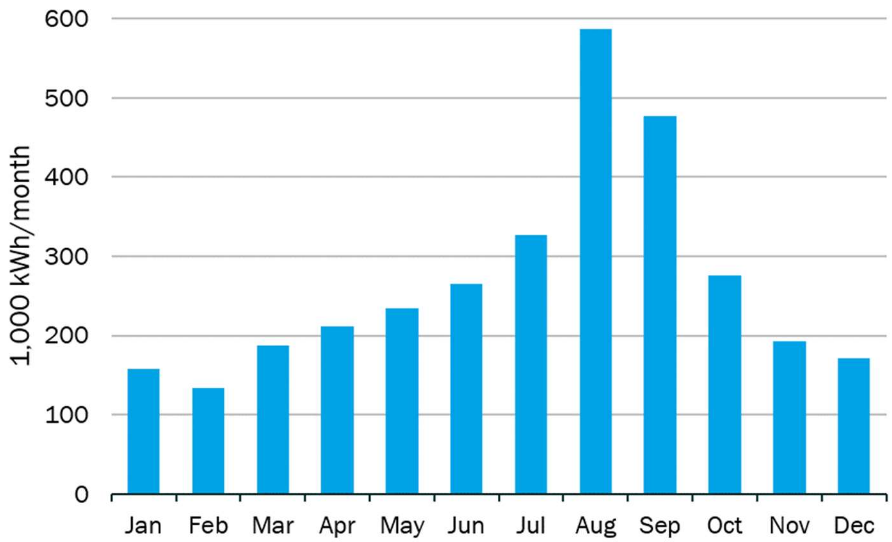

Figure 2: Average electricity use at one winery in climate zone 13.

Winery and Vineyard Total System Benefit impacts

The seasonality of winemaking is particularly interesting through the lens of recent changes to align programs with the new framework of Total System Benefit (TSB). While previous energy efficiency programs were driven by kW and kWh metrics, as of January 2024, this framework has defined the goals for program administrators as being tied directly to the avoided costs realized by technology deployment. This realignment encourages program administrators to pursue energy savings that deliver high value in the following categories: energy, generation capacity, ancillary services, transmission and distribution capacity, high global warming potential (GWP) gases, and greenhouse gasses (GHG) (California Public Utilities Commission, 2021). Figure 3, which is adapted from a California Public Utilities Commission (CPUC) report on TSB, illustrates the avoided costs for saving 1 MWh of energy during each month in 2024. Because there is meaningful overlap between the months of highest energy use by wineries and the months with the highest avoided costs, the switch to TSB is expected to be a positive change for winery programs. This is especially important to overcome the seasonality barrier.

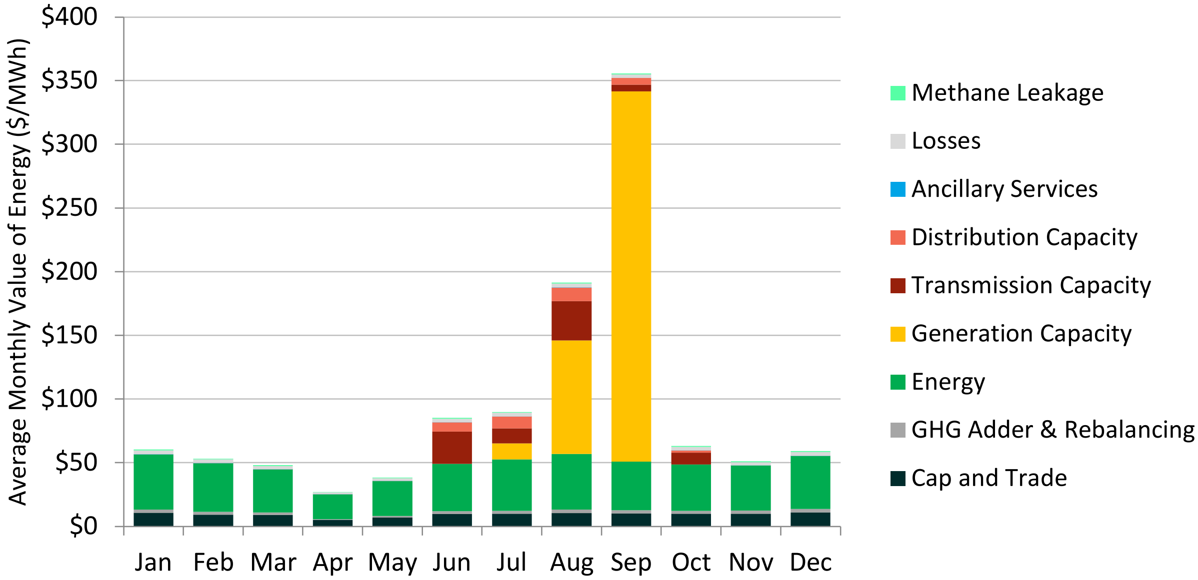

Figure 3: Avoided cost values for saving 1 MWh of energy during each month in 2024, Climate Zone 13 – Adapted from Total System Benefit v1.1, created using the 2022 CPUC Avoided Cost Calculator v1b.

Methods

Literature Review

The project team identified emerging energy efficient and load flexible emerging technologies that can be adopted in the winery and vineyard sector to deliver a combination of energy savings, decarbonization, electrification, and/or water conservation. The project team also documented the scale of energy use in the wineries and vineyards sector, and documented baseline winery and vineyard processes and current energy and technology practices. Where possible, the project team summarized sector specific drivers and barriers that influence current practices. They also looked at the current market penetration of select emerging technologies, and the factors that affect incremental installation costs and the operating costs of deploying select emerging technologies. The project team also reviewed the literature to gather data related to total system benefit potential in the following three areas: greenhouse gas reductions, energy savings, and demand reduction.

Interviews

The project team built on the literature review by interviewing winery staff, vendors, and subject matter experts to verify its own understanding of the process loads that have the greatest potential for emerging technologies, which energy efficient and load are flexible, the technologies they are implementing, and the factors that make these upgrades challenging. The project team also asked about the decision-making process for investing in these technologies. Decision points included operational considerations, financial considerations, how decision making differs between energy efficient technologies and other investments, and how specific regulations impact the process. The project team also asked wineries whether they were familiar with or had implemented the technologies the project team had identified as promising in its literature review or in early interviews. The project team also performed a site visit to a leading winery to further inform its understanding of some promising emerging technologies and winery operations. Where possible, the project team asked about the cost and energy impacts of different emerging technologies. The project team also performed a site visit and conducted informal interviews at an industry expo.

The project team performed structured interviews for the following market actors:

- Seven winery and/or vineyard staff
- Two winery and vineyard program implementers (our team includes a third program implementer)
- One winery subject matter expert
- One technology vendor

Additional Data Collection

The project team supplemented the interviews and literature review by performing additional data collection from web sites for other programs in California, including the Food Production Investment Program (FPIP) and the State Water Efficiency and Enhancement Program (SWEEP), regulations that impact the industry, and vendor incremental installation and operating cost data. Although the project team searched for vendor incremental installation and operating cost data, cost data is generally not published, and the project team had to rely on limited results from the literature and interviews where applicable. The emerging nature of the technologies the project team reviewed also impacts the availability of cost data since some of the technologies are being developed and costs are currently unknown.

Results

Market Drivers and Barriers

Market Segmentation

The role of market segmentation cannot be ignored when considering market drivers and barriers to technology adoption in the winery and vineyard sector. During the project, the project team identified several possible ways to segment the market. Options included size of the winery or parent company, geographic location and associated climate, whether the winery purchases energy from an IOU or from an irrigation district (which one respondent indicated have significantly lower energy costs), and the price range and target market for the wine produced. Market segmentation can affect the operations of the winery and vineyard in significant ways that affect the suitability of different technologies. For instance, some of the winery staff the project team spoke to rent use-of-production capacity at production facilities instead of owning their production facility. Including these kinds of arrangements in planning can help program staff to target outreach to customers most willing to invest in emerging technologies. The research team expects that some segments will be more receptive to certain technologies, which also provides a focus for program design and marketing efforts.

Decision Making Criteria

The project team asked winery and vineyard staff to share their decision-making criteria with it to better understand how energy efficiency and electrification may influence operations. Respondents indicated that the key considerations are the impacts of the technology on the wine making process, perceived risk of changes, whether the technology can reduce uncertainty, and its potential to shorten the payback periods. One winery staff member told the team that "there's as much art as there is science in wine. Telling Picasso what brush to use can be an uphill battle." The project team observed general agreement amongst winemakers that they want to protect their livelihood and are sensitive to anything that changes processes.

On the other hand, the project team also heard about and witnessed the innovative spirit at wineries and vineyards, and remains optimistic that this sector will continue to embrace emerging technologies, if enabled with the appropriate technical and financial support. Winery staff generally expect a technology to pay back within two to six years, although the expected payback period varies across wineries and is based on several important considerations. For example, if the technology is perceived as risky, wineries require incentives to offset the risk. If a technology has non-energy benefits such as improving quality or operations, these benefits must be quantified somehow in the payback period. Technologies that negatively affect operations are less likely to be adopted. Finally, reducing uncertainty is extremely important and one winery staff specifically said that the process needs to be shorter and less uncertain to encourage EE program participation.

Policy Environment for Wineries and Vineyards

Other Programs

The project team reviewed competing programs that serve wineries and vineyards to understand how those program offerings and processes compare to the offerings and process for EE programs. This is especially important because winery staff attitudes towards EE programs can be shaped by comparing the ease of implementation in EE programs versus those of other programs. Without a level set of rules and processes for similar technologies across different programs, there is the possibility that wineries and vineyards won’t engage with EE programs because EE programs are dismissed as being too challenging to navigate.

This would significantly impede California’s decarbonization goals in the winery and vineyard sector. The goal of this review is to lay the groundwork for constructive conversations to prevent negative perceptions about EE programs. The project team found differences between the SWEEP program and EE programs that it believes disadvantages EE programs. These differences are summarized in the following section. The project team found limited participation by the winery sector in the Food Production Investment Program (FPIP). The FPIP provides grants to help food processors accelerate the adoption of advanced energy and decarbonization technologies to support electrical grid reliability and reduce GHG emissions. The details of the refrigeration upgrades in FPIP are not publicly available but additional research into the details of what was allowed in this program and how it compares to EE programs would be insightful.

STATE WATER EFFICIENCY AND ENHANCEMENT PROGRAM

The State Water Efficiency and Enhancement Program (SWEEP) offers grants for irrigation measures that reduce greenhouse gases and save water on California agricultural operations. The program is currently closed but has been funding irrigation projects from 2016 through 2023. Its population priorities are based on the California Air Resource Board (CARB)'s California Climate Investment Project Map. Eligible system components include (among others) soil moisture monitoring, drip systems, switching to low pressure irrigation systems, pump retrofits, variable frequency drives and the installation of renewable energy to reduce on-farm water use and grid-supplied energy. Project eligibility and performance are based on water conservation and GHG reduction. Each project requesting funding must include at least one of the following: (1) pump and motor enhancement and/or replacement, (2) irrigation system enhancement, and (3) fuel conversion. In EE program efficiency terms, the first two refer to the water/energy nexus. The third item requires a more detailed discussion and is further discussed below. Program eligibility and performance are based on the SWEEP Project Assessment Tool. The California Department of Food and Agriculture (CDFA) closed the 2023 SWEEP program, but updates to the solicitation status will be forthcoming in early 2024. Applicants must be able to estimate GHG reductions due to on-farm energy use reductions, fuel conversions related to water pumping, or nitrous oxide reductions that result from a change in crop or irrigation method. Participants must use the CDFA-provided tools to estimate if the proposed project will result in on-farm GHG emission reductions (for more information, see Resources: CDFA Tools).

SWEEP overlaps IOU EE programs and is not required to follow the same regulatory requirements imposed on IOU programs by the CPUC. For the IOU programs, pump overhauls, replacements, monitoring, variable frequency drive (VFD) controls and irrigation measure are either ineligible or have low savings or net-to-gross ratios. This means that implementing them through pay-for-performance programs is not cost-effective, and instead negatively impacts program performance metrics. In 2023, an effort was made by a current agriculture EE program implementer to offer a more comprehensive pump and irrigation system incentive that focused on the customer decision making process. It included processes designed to screen for and minimize free ridership. However, the CPUC's early opinion imposed numerous restrictions on the proposal, most of which removed the custom and program benefits proposed. To bring innovative and customer-focused solutions to the market, a more collaborative, transparent, and casual discussion between regulators and implementors is recommended. Even though agency goals, requirements, and funding sources may not align between IOU implementer and SWEEP, lessons learned, program ideas and collaborations can only lead to better agricultural market segment support, improved solutions, and funding distribution.

The recognition and accounting of water and emission impacts on pump and irrigation projects adds value to the energy units saved. This allowance of co-benefits has been slow to develop in the targeting and evaluation of IOU EE programs. For example, the CPUC developed a water nexus tool to convert water savings into energy savings. However, typically the impact on energy savings and incentives are marginal for most projects, and the emission impacts have not been valued. Something unique to SWEEP that would benefit IOU winery customers is a recognition and accounting of non-regulated sources like the eligibility of diesel to electric pump projects and the associated emission savings. In the agricultural sector, the heating source wineries, dairies, and Controlled Environment Agriculture (CEA) is often propane. Therefore, even though a customer may be paying public purpose program (PPP) charges on their electricity usage, they are not eligible for gas savings, or, more importantly, electrification measures such as domestic, HVAC, or industrial heat pump retrofits. Eligible fuel substitutions measures are CPUC-regulated fuel to other CPUC-regulated fuel. Measures involving non-utility (unregulated) fuels, such as propane or fuel oil, are termed as fuel switching measures. Fuel switching measures are outside the scope of the fuel substitution decision (CPUC, 2019).

Starting in 2024, program performance is shifting from total resource cost (TRC) to total system benefit (TSB). This is a significant change to how EE programs are deployed, priced, and evaluated. It is not clear how TRC and TSB compare to CDFA/SWEEP performance metrics. A more detailed comparative analysis of the CDFA grants versus IOU incentive offerings could help clarify potential differences.

Moreover, a thorough review of how these assets are valued statewide by all government agencies supporting this market segment could improve clarity of how program performance is best evaluated. A risk of this approach, however, is that such a study could become a means of disqualifying projects simply based on comparative differences, statewide accounting efforts, or simply a means of easily rejecting projects. The goal should be to recognize (and if applicable) stipulate the measure co-benefits as verified by other programs or government agencies.

FOOD PRODUCTION INVESTMENT PROGRAM

The California Energy Commission's Food Production Investment Program (FPIP), as mentioned earlier provides grants to help food processors. In 2022, Assembly Bill (AB) 209 (Chapter 251, Statues of 2021) provided funding to continue the program with $25 million in the fiscal year 2022 – 2023 and an additional $40 million proposed in the fiscal year 2023 – 2024. Projects eligible for FPIP funding overlap with EE agricultural program targets. The CEC defines target projects as:

- Energy Efficiency: Support the adoption of commercially available ("drop-in ready") and emerging energy-efficient equipment upgrades that are replacements or additions to existing equipment or processes that provide greater GHG emission and energy reductions than current best practices or industry-standard equipment.
- Grid Reliability: Support the adoption of commercially available and emerging technologies needed to support grid reliability, especially during net peak periods.

Based on the November 2021 FPIP Project List, of the 50 projects listed, only four involved winery projects, and were primarily refrigeration upgrades and controls. The projects involved different sites but were all with the same company. It is not clear why winery participation is low in this program, though it is presumed that project size may be a contributing factor. Despite low participation, this funding source could be applied to emerging technologies in this winery industry. For more information on FPIP, see Resources: FPIP[2].

Winery and Vineyard Regulations

Regulations and regulatory oversight are constantly expanding, evolving, and often complicating discussions focused on improving the design, implementation, and reporting for current and future

[2] Food Production Investment Program. https://www.energy.ca.gov/programs-and-topics/programs/food-production-program

EE programs in California. The impacts on the industry in general, and emerging technologies specifically, are beyond the scope of this study. However, one of the team's SMEs has been in numerous California Technical Forum (Cal TF) meetings where talks on the topic often led to the conclusion that "existing EE program regulations are 'leaving energy efficiency measures to die on the vine'."

Yet this grim opinion is only taking into account the direct oversight of IOU EE public purpose program (PPP) funds regulated by state policy, and their somewhat rigid system for ex ante review, project dispositions, and specific project and program guidelines. This oversight is managed by the CPUC and is meant to protect rate payer PPP funding from being misused, exploited and/or incorrectly reported or verified. However, from a potential participant's perspective, current CPUC regulations can seem to be more punitive and costly, than technically or financially influential. Therefore, it is important to highlight what program participation is like for winery and vineyard customers relative to EE programs, as well as other winery and vineyards regulations that can impact project baselines and eligibility (for more information, see Resources: Cal TF Meeting Materials). Regulations that most commonly and directly impact EE projects include:

- California Public Utility Commission - This often includes legislative decisions, project dispositions, preponderance of evidence requirements, non-IOU fuel source and fuel substitution policies, and determination of standard/customer baseline practices. Participants may not directly understand or interact with these regulations as often as they do others, but they are affected during project development, implementation, and verification through engagement with project developers, 3rd party programs and utility account representatives. The current regulatory paradigm creates uncertainty throughout the process – i.e., from preliminary savings estimates, to pre-measurement and verification (M&V), Project Feasibility Study (PFS) development, to IOU review and approval, and finally to CPUC ex ante review and approval. The level of scrutiny projects face creates an atmosphere of uncertainty and mistrust, which in the end builds barriers to participation and implementation. One example that highlights the challenges faced by program implementers and winery staff was a "slam dunk" project to implement a more efficient wastewater aeration system. The project still has not been approved by the CPUC even after four months of review. Winery staff told us that the process and timeline for approval negatively impacts implementation of energy efficient projects and is a significant barrier. Other projects exist for which the CPUC questioned reasonable assumptions regarding standard baselines and program influence, such that standard practice (SP) studies were requested, and approval times were extended, turning simple low-cost measures into non-profitable, research projects delaying installation and implementation of the proposed measures.

A wineries' foremost priority is to make quality wine. They will never allow a three- to six-month pre-approval process delay the winery operations' readiness to process grapes, resulting in stranded energy savings.

- Title 24 of the California Code of Regulations – It is the California building standards code that governs structural safety and sustainability. Part-6, California Energy Code has energy conservation standards applicable to all residential and non-residential buildings. Section 120.6, Mandatory Requirements for Cover Processes, includes requirements governing compressed air and refrigeration systems. Refrigeration systems with process loads greater than 20 percent are exempt from these regulations.

The most common and important regulations to consider during the project development and pre-review process are summarized below. A list of state agencies with which a winery customer must comply (along with reporting requirements) illustrates how winery customers may perceive EE program regulations as overly restrictive. The broader set of regulations that wineries must follow are numerous and not limited to the following:

- California Air Resource Board (CARB) – Regulates industrial process air source pollutants for wine fermenting and aging. Also, as part of the California Global Warming Solutions Act of 2006 (AB 32), they oversee the state's Refrigerant Management Program to reduce refrigerant emissions from stationary sources. New CARB regulations expand the state's refrigerant restrictions considerably. Starting in 2022, new equipment with more than 50 lb. of refrigerant – typically used by supermarkets and industrial facilities – will be required to use refrigerant with a GWP of less than 150. This applies to new stores and remodeled facilities with new refrigeration systems. The 150-GWP cap is expected to cut emissions reduction per facility by more than 90 percent (Garry, 2020).

- California State Water Board - On January 20, 2021, the California State Water Board (State Water Board) adopted the General Waste Discharge Requirements (WDRs) for Winery Process Water (Winery Order/Winery General Order). The Winery Order will apply statewide to process water from wineries, grape juice storage facilities, and wine distillation facilities (collectively wineries). This includes any generated winery process water that is discharged to land for reuse or disposal.

- Cal Recycle – Senate Bill (SB) 1013 was approved on September 27, 2022, and brings wine and distilled spirits into the California Beverage Container Recycling Program, effective January 1, 2024.

- Alcohol and Tobacco Tax and Trade Bureau (TTB) – Per Title 27, Chapter 1, Subpart a, "The regulations in this part relate to requirements governing the issuance, amendment, denial, revocation, suspension, automatic termination, and annulment of basic permits and the duration of permits, except that the provisions of part 71, Rules of Practice in Permit Proceedings, of this chapter are hereby made applicable to administrative proceedings with respect to the application for, and to the suspension, revocation, or annulment of, basic permits under the Federal Alcohol Administration Act." In other words, wineries are subject to the TTB insurance tax collection and total process regulation.

- US Food and Drug Administration (FDA) – Wineries and other producers of alcohol beverages are required to be registered with the FDA for food facility registration purposes if they manufacture, process, package, or hold food for human consumption in the U.S.

- Environmental Protection Agency (EPA) - The EPA focuses on pollution prevention in wineries and vineyards. Facilities that process more than 50 tons of grapes per annum as declared under Part 8 of the Environment Protection Act 1993 (the Act) must have an EPA license. Licensed wineries and distilleries must develop and implement an environmental monitoring program and submit the data collected to the EPA annually.
- Occupational Safety and Health Standards (OSHA) - A recent hazard alert posted by California's Division of Occupational Safety and Health, better known as Cal/OSHA, reminds workers and managers at the state's wineries about the dangers of anhydrous ammonia, which is used under pressure as a liquefied refrigerant.

Based on the breadth and depth of winery regulations, it is easy to see how a customer may experience EE program participation as just another mandatory regulation, rather than a positive incentive for adopting energy efficient practices and technology. Incentives that are simple to understand, significant to customers, and deployable with minimal risk will be most effective in positively influencing program participation. The team's review indicates winery and vineyard owners and staff do not tend to view most current EE program offerings as simple, significant, and minimally risky.

Non-IOU Fuel Sources

A necessary question when developing project feasibility studies for Normalized Metering Energy Consumption (NMEC) and Custom projects is, "does the site use non-IOU fuel sources such as solar, wind, propane or distributed generation?" This is important because EE program savings have been valued for their time-of-use (TOU) impacts on the grid. Savings that exceed coincidental usage are limited by that amount. This requires an hourly TOU usage and savings analysis. To not penalize customers for installing PV systems, some net energy metering (NEM) accounts are limited by the monthly electricity purchased. However, changes in solar and NEM policy may not be accounted for or are clearly applicable to the document. The latest CPUC guidance is an Energy Efficiency Savings Eligibility at Sites with non-IOU Supplied Energy Sources — Guidance Document, Version 1.1, November 6, 2015. The focus of the discussion in this document is the "accounting" method that shall be utilized to establish the claimable savings for these situations" (CPUC, 2015).

Two common non-IOU fuel sources in wineries and vineyards are solar electricity generation and propane as a heating source. Solar onsite generation can easily bring down electrical demand to the extent that during the off-season and crush, coincidental TOU demand can fall below estimated savings or result in power being supplied to the grid. The economics for electrical retrofits are already challenged by the fact that the majority of the energy consumed (and potentially energy saved) at a winery may only occur three months out of the year. This is a common problem with seasonal food processing facilities that often extends payback periods beyond the company's investment criteria. Disqualifying additional electrical energy savings resulting from onsite generation further reduces the eligible incentive and make projects cost-prohibitive.

Fuel substitution opportunities from gas to electricity are part of the state's plan to electrify California. Eligible fuel substitution projects require a portion of the existing energy use to be converted from one CPUC-regulated fuel to another. Equipment powered by electricity and/or natural gas fuels and provided by a CPUC-regulated investor-owned utility or a municipal utility are eligible for inclusion in the energy efficiency portfolio as a fuel substitution measure. Fuel substitution measures are distinct from fuel switching measures. Fuel switching measures involve non-utility fuels such as propane or fuel oil. Fuel switching measures are outside the scope of the Fuel Substitution Decision (D.19-08-009) and hence, are not considered in the CPUC technical guidance.

The non-IOU guidance was developed at a time when EE programs were evaluated using a total resource cost (TRC) test. Starting January 1, 2024, program performance will be measured by their total system benefits (TSB). Along with the new TSB program performance metrics, new NEM tariffs (post 2015) and fuel-switching exclusions have resulted in stranded electricity and gas savings. A review of the non-IOU guidance by CPUC staff offers the possibility of capturing these stranded savings to help meet state goals of GHG emissions reduction. Global warming does not distinguish between non-IOU and IOU fuel sources. If a customer purchases electricity and pays PPP to a CPUC regulated-IOU, but gets its propane from a non-regulated source, disqualifying a process industrial heat pump (IHP) retrofit as a fuel-switching measure instead a fuel-substitution measure seems to ignore of urgency of our time. It does not acknowledge the fact that the low-hanging fruit has been picked in this and other sectors. Hot water, space heating, and process heating retrofits may provide some highest TSB in the winery sector, but because of this policy, many IOU electricity customers may be excluded from this opportunity.

Winery and Vineyard Operations

A 2013 market characterization of the wine industry estimates that wineries in California consume over 400 GWh of electricity annually (Navigant, 2013). The team has organized its discussion of winery processes and its findings in order of perceived opportunity for energy savings, load flexibility, water savings, and decarbonization.

Refrigeration

Refrigeration is used for process cooling such as for fermentation cooling, cold stabilization cooling, and cold storage. It accounts for a significant portion of energy use at the winery. The team found one report that gives estimates ranging from 37 percent to 48 percent of total winery electric energy use, on average, depending on the source data (Navigant, 2013). One of the interviewees stated that refrigeration can be up to 70 percent of electricity end use at a winery. There are a variety of technology-based opportunities to reduce refrigeration energy use, and several of the winery staff the project team interviewed are actively pursuing projects to reduce refrigeration energy use. Some wineries have multiple refrigeration systems that can be set to different temperatures, but most have one refrigeration system and will operate the entire refrigeration system at the lowest temperature required by any process. Respondents told the team that one process in particular – cold stabilization for tartrate removal – drives the operating temperature requirements for the refrigeration system when it is active. An example response from one winery indicated that their process temperatures range from 26°F when cold stabilization is required, to 45°F when cold stabilization is not required. This winery actively resets their refrigeration system set point when cold stabilization is not occurring, due to the significant potential for energy savings. This lines up with the team’s literature review findings that white wine stabilization, which is typically performed at temperatures of about 25°F – 32°F, is lower than other refrigeration process temperatures including fermentation temperatures, which typically range down to 48°F, and cold storage temperatures, which typically range down to 40°F (Galitsky, 2005).

The research team ranks emerging refrigeration technologies as a high priority, based on its impact on overall site energy use and demand, and the interest from winery staff in reducing their refrigeration energy use. Several of the emerging technologies the project team explored were focused on the tartrate removal process. Because cold stabilization temperature requirements drive the minimum temperature required from the refrigeration system, there may be additional system benefits for projects that implement emerging technologies related to cold stabilization. The project team also heard some interest for thermal energy storage for load shifting of refrigeration loads. Potential non-energy benefits related to reducing refrigeration energy use include water savings due to reduced evaporation at the cooling tower and the possibility of reducing equipment or infrastructure requirements.

Hot Water

Hot water is needed for various cleaning processes such as barrel washdown, tank washdown, and washdown of other equipment. It is also used for tank heating for malolactic fermentation of red wines and yeast generation, and for reheating wine before bottling or after cold stabilization. The fuel source for water heating is predominantly natural gas, although the project team interviewed one winery staff who had experience with on-demand electric resistance water heating and another who had experience with solar thermal water heating. Furthermore, propane is used instead of natural gas at some wineries. Although the project team did not find an estimate of total natural gas used to generate hot water, we did find that natural gas use overall is significant at approximately 22 percent of the energy sales to the winery and vineyard sector by the IOUs and that hot water generation is the main end-use of fuel gas within the winery (Galitsky, 2005).

One of the technologies the project team investigated for this project is heat pump water heaters.To do so, the team gathered data on typical hot water set points to understand the feasibility of heat pumps for this application. In interviews the project team found that operating temperatures for washdown varies considerably but is generally within the range of 120°F – 180°F. Other processes such as tank heating require lower temperatures of around 100°F. All of these process temperature requirements fall within the range of available industrial heat pumps according to a market study by Lawrence Berkeley National Laboratory (LBNL) which demonstrates that there are several industrial heat pump (IHP) manufacturers that can provide temperatures of up to 194°F (Zuberi et. al., 2022).

Respondents indicated that there are a variety of hot water system layouts, and in some cases lower process temperatures are achieved by use of heat exchangers. This means that the entire load is generated at the highest required process temperature with impacts for electrification. Several winery staff the team spoke with have either reduced or plan to reduce the hot water set point at their facilities. In addition to energy considerations, some winery staff expressed concerns about safety and the high operating temperatures.

Wastewater Systems

The team's review of the literature and interviews with market actors revealed that wastewater systems are critical to the operation of a winery, and that many wineries treat and dispose of wastewater onsite. Wastewater disposal is typically accomplished by either means of evaporation, absorption to the earth, or sometimes by irrigation of the vineyard. Winery wastewater aeration ponds are often used to reduce biochemical oxygen demand (BOD) of wastewater and are a critical component for many facilities. One study the project team reviewed claims that aeration ponds alone consume five percent of the winery's total electric energy end-use on average (Navigant, 2013).

Wastewater is a critical system at the winery, and one winery staff the project team interviewed summed up the importance of the wastewater systems, stating "wastewater can shut you down if done wrong". Adding to the importance of the wastewater systems is California's recently adopted General Wastewater Discharge Requirements for Winery Process Water regulation, also referred to as the Winery General Order. It is a new regulation that applies to wineries that discharge waste to land for reuse or disposal and is intended to mitigate adverse impacts to water quality. The Winery General Order was adopted in 2021 but effectively began impacting wineries during this study, in January 2024. When asked about winery specific regulations, winery staff frequently told the team that they are working to comply with the Winery General Order. Details of the Winery General Order are documented in the referenceError! Reference source not found. section of this report.

Vineyard Irrigation

Irrigation pumping is a potentially significant end use of electrical energy in the vineyard. Although the project team did not find a clear estimate for how much electrical energy is consumed by vineyard irrigation, authors of one report concluded that water pumping operations generally are "a significant electrical end use in all vineyard and winery operations" (Navigant, 2013). Vineyard irrigation pumps are often diesel operated and can even be powered by solar photovoltaic (PV) technology, which makes estimating the opportunity for energy programs more challenging. Energy programs currently exist for the end use in the form of incentives for variable speed drives. The project team chose to explore this end use further in interviews due to the opportunity for water and energy savings.

Other Operations

PUMPING

The project team found that pumping represents a significant end use for the winery and vineyard sector overall, but was not able to find a literature source that clearly disaggregates the winery end uses. One literature source found that, in instances where respondents used both refrigeration and pumping, water pumping consumed 30 percent of the operation's total electric energy end use on average. The project team believes this includes irrigation pumping, which is covered separately in its findings (Navigant, 2013). Within the winery, pumps are used to pump juice, wine, cooling water, hot water, and wastewater, if water is treated on site (Galitsky, 2005).

COMPRESSED AIR

Compressed air represents about nine percent of total winery electric energy use on average (Navigant, 2013). Actual compressed air demand is highly variable from winery to winery, and the biggest use of compressed air is in the presses which are only used for about 1,200 hours or less per year. The compressor must have sufficient capacity to charge the air receiver, to ensure it is ready for each pressing cycle (Galitsky, 2005). Other uses include dedusting bottles as part of the bottling process. The team reported one technology that recovers heat from the compressed air process, although the project team classified this as a hot water technology, since the recovered heat was used for water heating.

HVAC, LIGHTING, AND WHOLE BUILDING TECHNOLOGIES

The IOUs offer rebates for commercial building heating, ventilation, and air conditioning (HVAC) equipment. They can be applied to Database for Energy Efficient Resources (DEER) building types at the winery, i.e., office, warehouses or tasting room buildings. However, they are not eligible for industrial facilities and are not the focus of this work. The team has reported briefly on interview findings regarding carbon dioxide ventilation and insulation.

Future Program Design Opportunities for Wineries

The research team conducted a literature review and discussed emerging technology trends with 11 winery staff, vendors, program implementers, and subject matter experts, and found the following:

Table 1

End Use	Refrigeration	Hot Water	Wastewater
Existing Incentives	Deemed measure program offerings to reduce refrigeration system energy include an incentive for implementing floating head pressure control, compressor variable frequency drive (VFD control), compressor sequencing, evaporator fan VFDs, and condenser fan VFDs. Historically, utilities have not allowed agricultural customers to use site-level normalized metering energy consumption (SLNMEC) which considers utility meter savings based on metered energy use before and after installation. However, the trend moving forward after 2023 is expected to make SLNMEC a verification priority methodology.	The program implementation SME found that current deemed measure program offerings include boiler retrofits and boiler economizers. There is also a deemed domestic hot water heat pump water heater (HPWH) measure which may be applicable to some winery sites. There is a pathway for custom incentives for process water heating with industrial heat pumps (IHP). Since IHP for process heating are still emerging, our implementation SME has not seen any project submittals for an IHP successfully incentivized. Understanding this trend, and how this emerging technology is being received by the winery and vineyard sector, is a focus of this work.	Based on theinterviews and SME experience in this industry, wastewater system modifications are often influenced by capacity requirements, odor control and/or regulatory matters. On January 20, 2021, the State Water Resources Control Board adopted Resolution No. 2021-0001 for the California Environmental Quality Act Mitigated Negative Declaration for the Waste Discharge Requirements for Winery Process Water and associated General Order (State Water Resources Control Board, 2021).

End Use	Refrigeration	Hot Water	Wastewater
Emerging Technology	Emerging technologies for tartrate removal Emerging control methods Ice banking Low-GWP refrigerants	Industrial heat pumps Heat recovery systems for water heating Thermal banking Alternative washdown technologies	Jameson cells Biofiltration Advanced methods and controls

End Use	Irrigation
Existing Incentives	Variable frequency drive (VFD) controlled pumps: Pump VFDs are supported by EE rebates in Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E) territories. High efficiency pump: PG&E added high efficiency pump rebates in 2023, and SCE and SDG&E have yet to add them. Deployment of high efficiency pump rebates in PG&E has been challenging to date. Other irrigation distribution efficiency improvements: Drip irrigation and micro-sprinklers are also incentivized by IOU EE programs. However, the seasonality and mobility of this equipment presents eligibility challenges. The SWEEP grant program may have less restrictions on pump efficiency, pump controls and distribution measures since this program is focused on irrigation efficiency upgrades.
Emerging Technology	Advanced irrigation monitoring and control

Emerging Refrigeration Technologies

The project team identified several emerging refrigeration technologies in the winery sector including:

1. Emerging technologies for tartrate removal
2. Emerging control methods
3. Ice banking
4. Low-GWP refrigerants

Another technology that was mentioned but which the project team did not explore further is the carbon capture and sequestration of CO_2 from the fermentation process. Although carbon capture itself is not a refrigeration technology, it has significant potential to reduce refrigeration loads in rooms that have fermentation tanks. The reason for this is that CO_2 is commonly ventilated directly into the room and requires ventilation to maintain CO_2 below 5,000 PPM. Because these tanks are often uninsulated, and because significant airflow is required to dilute CO_2 from the fermentation process to below 5,000 PPM, the ventilation loads can be quite significant. While carbon capture and sequestration is not currently implemented at any winery that the project team are aware of, simply piping the CO_2 outdoors could significantly reduce cooling loads. Several winery staff the project team interviewed agreed this could be feasible, with one winery staff indicating that he previously worked at a facility that piped the CO_2 outside.

Emerging Technologies for Tartrate Removal

Several interviewees expressed interest in emerging technologies and methods for tartrate[3] removal, but rates of implementation among staff the project team interviewed are currently low. The practice of tartrate removal is widely accepted in industry to prevent the formation of harmless tartrate crystals in shipping, where the wine might be exposed to cold temperatures. The motivation for preventing the formation of harmless tartrate crystals is to prevent customer concerns related to the visibility of these crystals in un-stabilized wine. Because of the interest in alternatives to the current practice of batch cold stabilization process of tartrate removal, and the high-energy intensity of the process, the project team believes that alternatives to batch cold stabilization could significantly benefit future energy programs, due to the potential for significant energy savings and load reductions.

Currently, tartrate removal is typically performed by a batch cold stabilization process in tanks of various sizes. Tank size varies by operation but can exceed 100,000 gallons. Tanks are often uninsulated metal with glycol or ammonia jackets on the outer surface of the tank. Wine is pumped into tanks, and then cooled to 25°F – 32°F. Due to various effects, including the thermal mass of the wine, slow crystallization, and settling conditions in large tanks, batch cold stabilization can take several weeks, and requires cooling throughout the process to make up for tank skin heat gains (Geveke, 2021). After the batch of wine is cold stabilized, it can be bottled, although, depending on operations, it can be held in storage before bottling. Often, the batch cold stabilized wine is heated to

[3] In our interviews and literature, tartrate is referred to interchangeably as tartrate and bitartrate.

prevent condensate from forming on the bottle in the bottling process, adding to the overall energy intensity of the batch cold stabilization process. Based on interviews, the project team found that cold stabilization in California is primarily performed for white wines, although red wine can also be cold stabilized, especially if it is being shipped long distances.

The project team found technologies that can be described as replacing the batch cold stabilization process or making the batch cold stabilization process more efficient.

Technologies that replace the cold stabilization process include:

1. Electrodialysis
2. Fluidized bed reactor
3. Addition of agents that prevent tartrate crystal nucleation

Technologies that can make the batch cold stabilization process more efficient include:

1. Wine-to-wine heat exchange
2. Pulse cooling which applies to several processes, including tartrate removal

From the technologies the project team identified that could replace batch cold stabilization, only electrodialysis is currently commercialized. The fluidized bed reactor is a more nascent concept that was previously piloted by University of California Davis. The project team interviewed one winery that is currently developing a pilot scale fluidized bed reactor at a facility in California, and the project team interviewed staff at another winery that expressed interest in the technology. The project team also heard of additive materials such as a cellulose gum additive that can prevent tartrate nucleation. Although such additives have a high potential for energy savings by removing the need for cold stabilization altogether, they also are not a technology that can be incentivized and are not the focus of this work.

Among the technologies that can make the batch cold stabilization process more efficient, pulse cooling has been implemented by two of the winery staff the project team interviewed, whereas the wine-to-wine heat exchanger was piloted at one winery under an Electric Program Investment Charge (EPIC) grant.

ELECTRODIALYSIS

Electrodialysis is an emerging technology that proposes an alternate approach to tartrate removal. Based on the team's review of the literature and the interviews conducted, the technology, while not new, appears to not be widely adopted. Five of the winery staff the project team interviewed were familiar with the technology, yet none have adopted it. Despite this, the technology has significant potential to reduce refrigeration electrical energy use and demand and utilizes only about 12 percent of the energy required in traditional batch cold stabilization (i.e. 88 percent savings), due to savings in both refrigeration and natural gas reheating. Electrodialysis systems function by passing un-stabilized wine through a charged membrane within an electrodialysis cell. This process, illustrated in Figure 4, removes tartrate potassium ions and other ions, reducing the likelihood of bitartrate crystal precipitation in the wine.

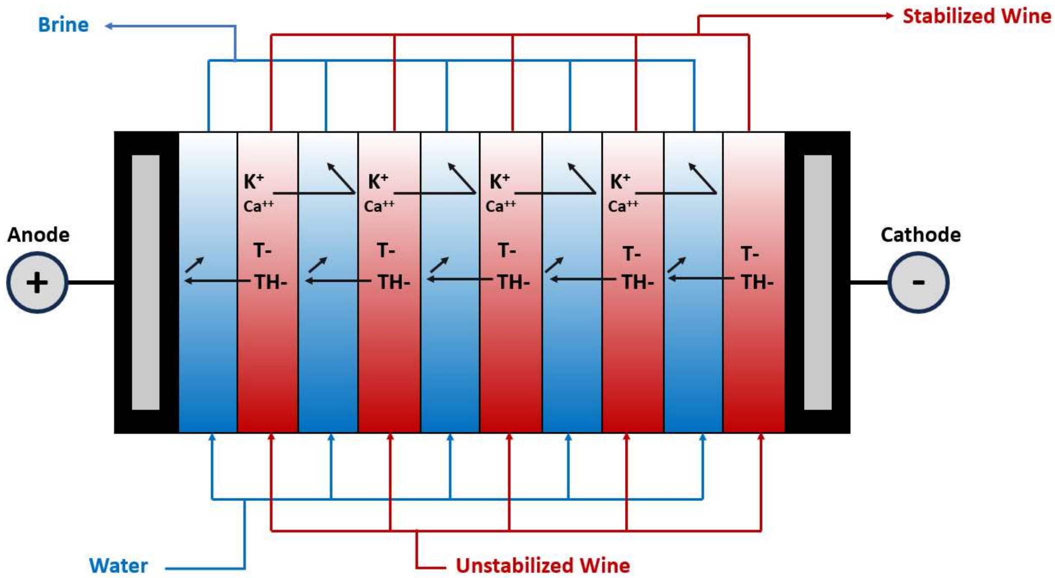

Figure 4: Diagram of electrodialysis adapted from a manufacturer diagram

An electrodialysis vendor the project team interviewed highlighted the economic impact of electrodialysis, noting that installations typically result in a payback period of less than three years, factoring in decreased wine loss. Winery staff also pointed out the considerable monetary savings from reduced wine losses compared with batch cold stabilization, where wine often clings to the sides of tanks during tartrate crystal formation – a problem avoided with electrodialysis. Another vendor highlighted the space-saving potential of electrodialysis, which is especially beneficial for new wineries, as it reduces the need for multiple tanks.

However, electrodialysis is not without its challenges. Winery staff expressed concerns about the system changing the wine's chemical composition beyond just tartrate removal. A UC Davis wine expert added that electrodialysis does not only remove ions that affect tartrate crystallization, but also removes other charged ions like iron, copper, calcium, and magnesium. This alteration can impact the wine's redox potential and aging process, a significant factor for wines valued for their terroir-specific composition.

Other noted concerns include the potential increase in wastewater loads due to water consumption and the addition of Biological Oxygen Demand (BOD) to the winery's wastewater system, since the tartrate is not recovered but discharged. This raises questions about water savings and wastewater treatment impacts, particularly for wineries with on-site wastewater treatment facilities.

Interviewees outlined specific challenges including:

- The system removes essential ions like calcium and magnesium, which, while not substantially affecting taste, is seen by some as making the process less "natural."
- The inability to recover tartrate, preventing its sale to cream of tartar manufacturers.

- Increased water usage and potential heightened energy consumption due to increased load on wastewater treatment facilities.

On the upside, one of the primary benefits of electrodialysis, as identified by interviewees, is the reduction in wine wastage due to more efficient tank and pumping processes. The technology's financial viability is thus seen more in terms of wine recovery than energy savings.

Program implementers who hope to implement electrodialysis for their customers should consider site specific details, such as 1) are there water savings due to reduced cooling that can offset water used for flushing? And 2) is wastewater treated on-site, and if yes, how will the waste stream impact wastewater practice and energy use?

FLUIDIZED BED REACTOR

Fluidized bed reactor technology, traditionally implemented in industrial applications, has not yet been utilized in the wine making industry in a commercial setting (Geveke, 2021). According to a subject matter expert the project team interviewed, the idea of using this technology in wineries dates to 1970s, but it has only recently been pilot tested in winemaking, a delay attributed largely to limited funding for its development. The team's engagement in this area included a comprehensive site audit at a commercial winery, which offered a firsthand view of this emerging technology and the opportunity to discuss its numerous potential benefits with the winery staff.

The fluidized bed reactor technology stands out for its ability to revolutionize the batch cold stabilization process into a continuous process. This shift addresses numerous inefficiencies of the batch process without altering the chemical process, a crucial aspect for winemakers. This avoids concerns from winery staff about alternative technologies like electrodialysis and additives that prevent tartrate crystal nucleation. It should be noted that batch cold stabilization can be performed with or without seeding by tartrate crystals, which speeds up the reaction time by providing a nucleation site for tartrate crystallization. The fluidized bed reactor requires seeding with tartrate crystals to operate correctly, but this does not change the chemistry of the process.

From an energy perspective, the literature reported 76 percent energy recovery with an un-optimized pilot scale system and suggested further improvements to increase efficiency including improved insulation and optimization of infeed flow and heat exchanger area. A subject matter expert suggested that up to 90 percent of the energy input could be recuperated with further optimization. This potential was further evidenced during discussions with winery staff, who are planning to employ a portable ten horsepower chiller for wine stabilization at 40 gallons per minute (GPM), significantly smaller than the typical equipment size required for batch cold stabilization. At a 40 GPM speed, it may be possible to reduce process time. Future work should characterize the process time associated with the fluidized bed reactor at a commercial winery to see how the process time is affected. In addition to energy recovery, the fluidized bed reactor could enable improved refrigeration system efficiency by allowing winery staff to reset the set point of the main refrigeration plant up to 15°F higher.

Challenges to the fluidized bed reactor technology include a current lack of market familiarity and the non-existence of a commercialized product. Additionally, the technology requires some changes to the existing process that could impact operations, necessitating thoughtful integration into existing operations for successful adoption. Another critical gap identified in our study is the absence of detailed cost data for the technology. To advance the technology, the project team recommends that future efforts focus on developing case studies to document outcomes and lessons learned from the winery that is currently piloting the technology. This could include project costs and cost compression opportunities, on-bill cost savings, and operational impacts of adopting the technology to support adoption into programs.

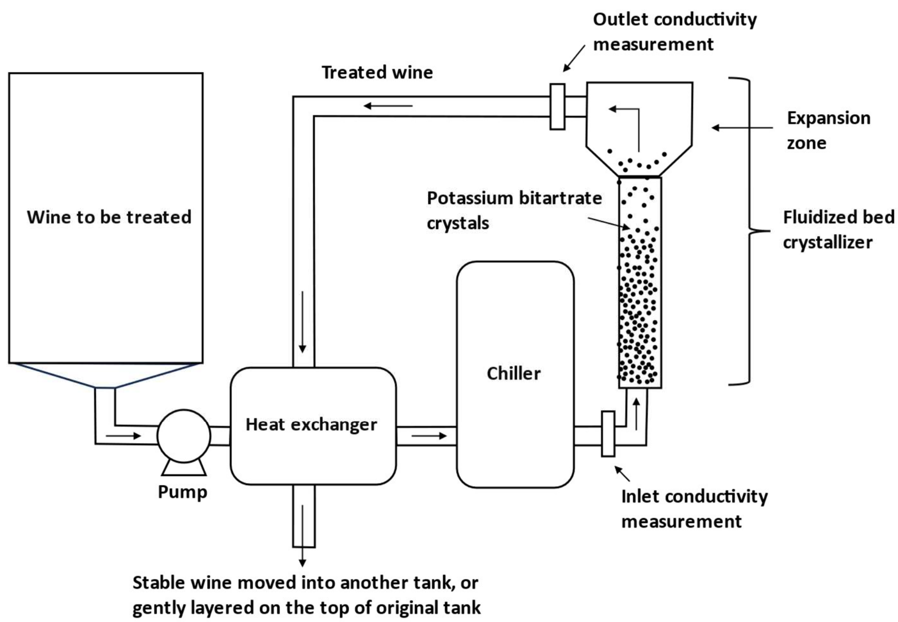

Figure 5: Schematic of a fluidized bed reactor in the winemaking process[4]

ADDITION OF AGENTS THAT PREVENT TARTRAVE CRYSTAL NUCLEATION

Additives exist that prevent tartrate crystal formation as an alternative method for wine cold stabilization. This approach was mentioned by one winery staff member interviewed for this report who used CELSTAB, a brand product produced by Laffort. CELSTAB is a cellulose gum solution that inhibits crystal nucleation. CELSTAB is added to wine, given 48 hours to react, and the wine-CELSTAB solution is filtered before bottling (Laffort, 2021). Although this is a promising technology for some segments or the market, the team's program implementation SME doesn't believe that this technology can easily translate into a program offering. Process changes related to a change in input or output are usually considered production and business, not energy efficiency investments, and as a result are not eligible. Additionally, measures that provide little or no guarantee of persistence are not eligible.

WINE TO WINE HEAT EXCHANGER

The integration of wine-to-wine heat exchanger technology in cold stabilization has significant energy savings potential, especially for white wines. This approach, highlighted in a study conducted by UC

[4] Recreation based on a diagram by Geveke, 2021.

Davis in Santa Rosa and funded by the California Energy Commission (CEC) in 2018, has demonstrated its potential for substantial electrical and natural gas energy savings (CEC, 2018).

Although a final report has not been released to the public, the project team discussed the project with two winery staff who were familiar with this project, and the project team also includes a project engineer who evaluated the technology. Because the wine-to-wine heat exchanger operates at the same temperatures as traditional batch cold stabilization, it may yield lower energy savings compared with electrodialysis. However, its compatibility with existing winemaking processes was noted as potentially more appealing to certain winery owners, particularly those who are sensitive to changes in wine chemistry.

The operation of the wine-to-wine heat exchanger is centered around using the energy from cooled, stabilized wine to pre-cool incoming, warm, unstabilized wine. This innovative approach not only reduces the refrigeration load required for cooling but also warms the stabilized wine before bottling, cutting down the heating load. Winery staff regard this system's effectiveness positively, with a former staff who was familiar with the project stating "that is legit," reflecting a strong endorsement of its efficiency. Another interviewee expressed their keen interest in the technology, an example of the emerging curiosity regarding this technology within the industry.

Interviewees have pointed out several key advantages of this technology. They believe that the payback period could be impressively quick, possibly within a year, offering an economical argument for its adoption. Additionally, the technology could reduce the process time by days, a significant improvement in operational efficiency, as highlighted by our interviewees.

However, this technology comes with certain challenges. A continuous flow of wine is necessary for the system’s effective functioning, a requirement that may not be practical for smaller wineries. This was a concern shared by several winery staff, emphasizing the need for wineries to consider their production volumes. The awareness and application of this technology in the winemaking community is varied. Some winery staff, especially from smaller operations, are familiar with the concept, but its practical application in smaller wineries may be more challenging.

PULSE COOLING FOR TARTRATE REMOVAL BY BATCH COLD STABILIZATION

Pulse cooling as a method can be implemented for several cooling processes, including tartrate removal by batch cold stabilization. Because the tank hardware is identical across processes, the concepts discussed for tanks in the Pulse Cooling section apply for this process.

Emerging Controls for Refrigeration

PULSE COOLING CONTROLS

Pulse cooling is a tank refrigeration technique that enhances cooling efficiency by shifting from a continuous flow of coolant, like glycol or brine, to a batched flow in the tank’s refrigeration jacket. This system allows the batched coolant to stay in place, absorbing more heat over time before being cycled back. This process leverages the time for improved heat transfer efficiency as well as reducing the amount of coolant needed, resulting in lower energy consumption for pumping. Additionally, the coolant returns to the heat exchanger warmer which facilitates a more efficient heat exchange with the refrigerant, improving compressor energy usage. This method ensures a more effective heat exchange back at the winery's main refrigeration plant, optimizing the overall energy efficiency of the refrigeration system.

There are three methods of pulse cooling in the wine industry, with varying implementation complexity and efficiency improvement potential. The first two methods, timed pulse and tank temperature pulse, utilize existing tank solenoid valves and temperature sensors, making them relatively low-cost options. In the third method, jacket temperature pulse, the cascade routine modifies the wait time between pulses, based on the jacket coolant temperature itself. A second coolant temperature sensor monitors the coolant warming in the tank's jacket. This method, while more challenging to implement and requiring additional capital for an extra temperature sensor, offers the most significant efficiency gains, and is implemented and studied at Beringer Winery (Treasure Tine Estates, 2021).

Beringer Winery used this method to achieve a notable 3.5 times reduction in coolant volume during standard temperature storage and 3.1 times less coolant volume during temperature reduction processes. This significant decrease in coolant usage translates to lower energy demands on coolant circulation pumps and contributes to more consistent pressure management across the coolant loop. This prevents tanks from being deprived of coolant due to usage by neighboring tanks.

Interview feedback reflects a strong interest in pulse cooling. One implementer identified its potential as a deemed measure and discussed the concept's relevance, especially during off-harvest seasons when the glycol circulation loop, typically oversized for harvest demands, operates less efficiently. This shows pulse cooling's applicability across various winery operations, from tanks to barrel room air handlers, making it a versatile solution to improve refrigeration efficiency.

The positive response from the wineries already implementing or considering pulse cooling for different applications shows a promising trend towards broader scale adoption. In addition to that, documented success at Beringer Winery indicates the technology's potential to revolutionize refrigeration practices in the wine industry.

BARREL ROOM CONTROLS

According to two winery staff the project team interviewed, barrel room controls for temperature and humidity can be improved for better energy performance and to better achieve the requirements of the barrel room. Respondents indicated that barrel rooms are typically kept in the 50 – 55ºF range, to prevent wine aging. Due to the low set point, humidification systems are required to reduce wine loss through evaporation. These humidification systems are often piped to distribute a fine mist in the barrel room. One winery staff indicated concern with the practice of misting due to the potential for increased microbial activity in the room. By increasing the barrel room set point to 60°F or 65°F, wineries could reduce their cooling loads while also reducing their humidification loads, saving energy and water. Increasing the set point in barrel rooms can help to reduce condensation. Additionally, in coastal wineries, increasing the barrel room temperature set point may increase the potential for night air cooling, further reducing energy use.

Challenges to adoption include the perception that higher temperatures will negatively impact wine aging, increase wine evaporation, and encourage microbial activity with a high potential for economic losses. Barrel rooms tend to be tall, and temperature stratification is one potential concern when implementing this control strategy. The project team also heard feedback that fans could address concerns about stratification in barrel rooms. Future work should be performed to develop a case study with a winery to assess the impacts of this promising control strategy on energy use, water use, and product quality.

Ice Banking

Ice banking, a variant of thermal banking, involves cooling an ice bank during off-peak demand hours, typically at night, to reduce the energy draw from refrigeration systems or air chillers during peak daytime hours. This method of load shifting can offer significant energy savings and cost reductions for wineries, particularly in managing cooling demands.

The concept of ice banking was met with interest from the wineries the team interviewed, especially in the context of potentially removing cold stabilization from the winemaking process. One expert pointed out that ice banking would be particularly sensible if cold stabilization were eliminated, as the driving temperature would be greater than 32°F, thus offering greater efficiency.

Similar to thermal banking, the practical implementation of ice storage faces challenges. Space requirements remain a significant concern, with one winery staff member indicating that the necessary square footage for an ice banking system could deter its adoption. One winery is considering solving the challenge of space by using a surplus 150,000-gallon tank for ice banking. Despite these challenges, there's an acknowledgment of the technology's potential, particularly in optimizing energy usage and capitalizing on time-of-use rates, as noted by winery staff interested in exploring innovative solutions to energy management.

Low Global Warming Potential Refrigerants

The literature and the experience of our project team suggests that ammonia is the primary low-GWP refrigerant that is used in the wine industry. The project team found a study that looked broadly at refrigerant use for commercial and industrial customers in SCE territory and found that while many new large industrial/food processing facilities are already using ammonia, R-22 systems are commonly used in existing facilities (Goebes, 2021). This study also highlights an interview that indicates that wineries have switched from R-22 to R-422D when the conversion was incentivized. An older study by LBNL indicates that ammonia is suitable for systems greater than 100 tons, but that systems less than 100 tons were historically R-22 (Galitsky, 2005).

Our team asked winery staff what options they consider for low-GWP refrigerants. The project team found that some wineries use ammonia as a zero-GWP refrigerant, while other wineries, especially those with smaller operations, are concerned about the strict regulations, toxicity, and corrosiveness of ammonia and are not actively searching for low-GWP refrigerants. One interviewee shared their concerns about the reliability and safety of ammonia systems, saying, "you know, in the event of trying to be energy efficient, ammonia systems in general to me, they kind of just scare me. And they're not going to last as long." Another respondent told us that refrigeration is “a separate category I think is we always look, we're not going to do use ammonia for example. I remember years ago people said ‘you can use ammonia,' but ammonia is dangerous and it's not good for you. It's not a great product.” This demonstrates a lack of awareness about alternatives among some winery staff. The concerns and regulatory hurdles related to ammonia, combined with the limited knowledge of other low-GWP refrigerants, highlight the need for more efforts to inform and educate some segments of the wine industry about safe and efficient low-GWP alternatives.

Emerging Hot Water Technologies

Industrial Heat Pumps

As discussed in the Hot Water section of this report, winery hot water processes are considered a good candidate for industrial heat pumps due to the relatively low process hot water temperature requirements. In addition, hot water generation is the main end-use of natural gas within the winery so electrifying this end-use is particularly important to meet California's electrification goals in this sector. Industrial heat pumps (IHP) are capable of providing heating for process loads and can, in some cases, be used to develop both useful heating and cooling. As referenced earlier, the results of a market analysis study done by LBNL shows that there are several IHP manufacturers that can provide temperatures of up to 194°F (90°C). Because food and beverage industrial processes generally require lower hot temperatures than other industrial applications, coefficient of performance (COP) and product availability are more favorable for these applications.

Even though IHPs are a clear fit for wineries, winery staff seem to be on the fence about installing heat pumps. During a site audit, one winery staff member shared that they had considered heat pumps but found the costs associated with the upgrade was too high, leading them to look at solar thermal systems instead. This sentiment was echoed by other interviewees, showing a common thread that wineries recognize heat pumps but don't implement them due at least in part to cost. Another challenge is familiarizing winery staff with the potential and practicalities of heat pumps. As one staff member shared, "It feels like a technology that's ready to be implemented, but there is not enough experience with onsite staff and installers". This gap in understanding shows the need for programs to also offer clear training and guidance on integrating heat pumps into winery operations, especially for critical uses like sanitation. A programs implementer also noted that hot water is seen as low priority due to its seasonal demand, mainly for cleaning purposes concentrated in one part of the year. However, with the shift towards Total System Benefit (TSB) metrics, as outlined in the "Winery and Vineyard Total System Benefit Impacts" section, this perspective is expected to change. The new TSB approach could elevate the significance of IHP in program considerations, recognizing their potential to contribute more substantially to overall system benefits despite their seasonal usage.

The project team interviewed one winery staff who plans to implement heat pumps for water heaters in the future who suggested that heat pumps could be used to heat to 120°F, serving most loads, and that the remaining high temperature loads could (primarily cleaning) could be served by an electric resistance booster heater. Additionally, we identified efforts by some winery staff to lower their hot water set points for safety reasons. By adopting these strategies, programs can reduce the costs and address the safety issues associated with high hot water temperatures, making heat pumps a more attractive option. The project team believes that heat pumps present a significant emerging opportunity for energy programs to serve winery and vineyard customers.

Heat Recovery Systems for Water Heating

The project team found that heat recovery systems are sometimes implemented in wineries to produce process hot water, but that there are limitations to implementation, especially around the timing of the loads. One winery staff the project team interviewed had implemented a heat recovery system in one of their processes, but it failed to deliver savings due to the non-simultaneous timing of the heat generation and the hot water use. The same staff told us that another process, a bottling process, was able to successfully implement heat recovery since there is machinery that needs to be cooled, while the bottles need to be warmed. The project team specifically asked winery staff about refrigeration desuperheater heat recovery and found that none had implemented it. It is worth noting that heat recovery in general is a component of several promising emerging technologies the project team explored including the Fluidized Bed Reactor and the Wine to Wine Heat Exchanger, and that several winery staff we interviewed were familiar with heat exchanger technology.

Thermal Banking

Thermal banking, or heat banking, is a method of load shifting that can also be paired with heat recovery systems, for instance, from bottling line air compressors or other heat sources. Among the wineries the team interviewed, none had thermal banking systems installed, but one winery is actively exploring the concept for a solar thermal heating system. Three out of four wineries recognized the potential benefits of thermal banking, however the team also heard concerns about the space required for such a system, which could be prohibitive, or even "make the system a non-starter", especially for smaller winemaking facilities.

As discussed in the Heat Recovery Systems for Water Heating section, one of the challenges with implementing heat recovery is that heat generation and hot water use aren't always concurrent. Thermal banking could be a solution to this problem.

Alternative Washdown Technologies

One winery staff the team interviewed had experience using ozonated water for barrel washing and tank sanitization. LBNL estimates that barrel cleaning consumes around 1.6 gallons of warm water per barrel (Galitsky, 2005), while ozone cleaning can eliminate the need for hot water use for barrel cleaning and reduce water use for barrel cleaning overall by 50 percent. The winery staff who had implemented an ozone system noted that it sanitizes without leaving chemical residue or affecting the taste of the wine. Program implementers should be aware that ozone is a toxic gas, and the literature suggests that ozone is typically made on demand by an ozone generator to eliminate the risks of storage.

Emerging Wastewater Technologies

The team identified several emerging wastewater processing approaches and technologies in the winery sector including:

1. Jameson cells
2. Biofiltration
3. Advanced methods and controls

Jameson cells

The Jameson cell was initially developed for the coal and mineral extraction industries but is also applicable in winery wastewater treatment, according to a subject matter expert at the UC Davis winery. This flotation cell technology stands out for its ability to efficiently separate suspended solids from effluent, which significantly reduces the load on wastewater ponds' aerators. This efficiency not only saves energy by minimizing the aerators' work but also reduces the amount of settled sludge. A key advantage of the Jameson cell over traditional flotation methods, caused by lack of mechanical moving parts is its operational simplicity, efficiency, and minimal maintenance requirement (XT, 2014). A winery staff member is planning to install a Jameson cell and a subject matter expert spoke positively about the potential of using this technology. This sentiment is driven by the technology's potential to reduce biological oxygen demand (BOD) and thus lower the energy needed for pond treatment.

Advanced Methods and Controls

Several interviewees expressed interest in upgrading their methods and controls for wastewater treatment. Two interviewees, a subject matter expert, and a winery staff spoke to the importance of reducing BOD that enters the wastewater system by capturing solids at multiple points within the system. Although this is a simple intervention, we understood that many wineries are discharging water with higher BOD than necessary, which leads to a high aeration load. Although this type of intervention is not a technology, it’s important that any winery that looks to implement emerging technologies first address this issue. The same winery staff is testing alternative treatment methods including the use of hydrogen peroxide, potassium bisulfate, and potassium hydroxide as opposed to more traditional methods that involve citric acid and phosphate-based chemicals to reduce BOD (including at the tanks) and improve dissolved oxygen (DO). The potassium bisulfate can be recovered by nano filters reducing overall resource use, and the hydrogen peroxide is generated by a hydrogen peroxide generator which could potentially be incentivized.

Three winery staff the project team interviewed discussed the relationship between DO levels and aeration pond energy use. One of the functions of aeration ponds is to increase the DO in an effort to reduce BOD in the water. Respondents indicated that there are surprisingly unautomated processes that could be improved by increasing monitoring. The project team also heard that wineries can be overly cautious about DO and that DO might not even be the appropriate metric since it is quite insensitive; Redox was suggested as an alternate, more sensitive, parameter. There may be potential to incentivize advanced controls for monitoring and adjustment of DO or other relevant parameters.

Other Wastewater Technologies

One of the wineries the team interviewed has an anaerobic sludge digester, although they also stated that their wastewater system needs to be upgraded and that they are piloting a reverse osmosis (RO) system. A drawback of anaerobic digesters is that they require sustained volumes of wastewater, and the system cannot be sized for peak loads since the off-peak loads would not be able to sustain the digester.

The project team found one emerging technology report where the authors had demonstrated an emerging forward osmosis plus reverse osmosis technology. The goals for this technology involved reducing the volume of wastewater ponds and providing high quality water for use in mechanical systems, while using less energy than other competing treatment and re-use technologies (Bakajin 2021). One winery staff respondent who is piloting an RO system said that a challenge with RO is figuring out what to do with the brine waste stream.

Some wineries are using biofiltration for wastewater treatment. Biofiltration involves passing water through a biological filter, typically consisting of wood chips, where worms actively aerate the medium, facilitating the breakdown of waste. This method has low energy requirements, as it primarily relies on pumps to spray the water over the biofilter. According to feedback from industry participants, biofiltration, while introducing some complexity due to the living components like worms, is generally well-regarded for its efficiency. One expert noted, "BioFiltro. There's actually quite a few wineries that have done biofiltration. Some people think worms are awesome and some people feel like worms add complexity that they don't want to deal with". For wastewater management purposes, some wineries consider innovative approaches like biofiltration using worm farms. As one winery staff shared, "we're going to keep septic, but we're adding a worm farm... I don't like worms, but we could use Mother Nature to solve a problem". This highlights an interest in leveraging natural processes for water treatment. Although this is a promising technology, it might not be a fit for energy efficiency programs, given that it is a process change related to a change in input or output, which are usually considered production and business, rather than energy efficiency, investments.

Emerging Irrigation Technologies

The project team found two emerging irrigation technologies that show promise for integrating advanced monitoring and controls to reduce load for irrigation pumping, The two technologies, discussed below, would ideally be implemented together.

The project team also learned about efforts to electrify diesel pumping, potentially with solar plus batteries, but unfortunately current EE program policy is not supportive of this kind of retrofit as described in the Non-IOU Fuel Sources Error! Reference source not found.section of this report. Finally, respondents indicated a need for new program offerings to replace measures such as VFD in irrigation systems since the net-to-gross ratio (NTGR) is dropping to 0.4 from its current level of 0.5 to 0.6. One interesting concept that the project team identified in interviews but did not explore, due to its niche application, is the potential to load shift pumping by storing pumped water at elevation. Although application of this concept is limited, it shows that some wineries and vineyards are interested in load shifting their irrigation loads.

Advanced Irrigation Monitoring and Control

The first technology allows vineyard staff to optimize irrigation by measuring evapotranspiration. This technology reduces pumping energy use associated with vineyard irrigation by preventing overwatering with one panelist claiming a 47 percent reduction in water use. This technology has sparked interest among winery and vineyard staff, as discussed at an industry expo we attended. This technology can be complemented with a flow metering device that allows vineyards to monitor and control their irrigation flows. One such flow metering technology that the team reviewed is a wireless, solar powered device that costs $599 per device plus between $100 – $200/acre/year. Current marketing is focused on improving fruit production and quality, and re-purposing labor from irrigation to other needs. However, the valve can also enable load flexible watering at night, which would also save energy due to less evaporation of the applied water. The watering period can also be extended for pumps with VFDs increasing their efficiency.

Once challenge that program implementers would need to address is how to properly account for the savings associated with this system, since it can be deployed over large areas that are served by multiple electric meters.

Key Findings and Recommendations

The research team gathered market information to help steer future program designs for wineries and to assess the most promising emerging technologies, considering the unique market drivers and barriers associated with the winery and vineyard sector. The team also reported on possible segmentations of the winery and vineyard sector, including characteristics such as business size, geographic location and associated climate, and energy costs which should be considered when recommending technologies to winery and vineyard customers. The key findings include policy recommendations, and technology and market recommendations.

Policy recommendations

Policy recommendations center around streamlining the incentives process and improving the customer experience to encourage program participation, based on data the team gathered about decision making criteria. Key decision-making criteria that the project team identified includes balancing the payback period and non-energy benefits against the risks, including changes to the wine making process and the uncertainty of navigating the programs process. The project team recommends that policy makers consider the following key changes to encourage greater adoption of emerging technologies:

- Coordinating efforts between state agencies and IOU third party programs to streamline market transformation with regards to energy efficiency as well as decarbonization and other environmental efforts. Currently, these various regulatory requirements can be seen as competing or disqualifying factors of influence, whereas the engagement with program administrators should be viewed as opportunities to address these various concerns and provide technical support and financial incentives to meet customers' payback period requirements as well as reach or exceed all regulatory requirements.
- Reconsidering the eligibility of fuel switching based on the high use of propane for small and medium wineries, given that greenhouse gas emissions have no recognition of their sources.
- Not diminishing incentives for first order energy efficiency projects that have on-site renewable energy generation, since that makes them less financially influential and less supportive of larger statewide goals.

Technology and Market Readiness Recommendations

The project team reviewed various emerging technologies ranging from emerging technologies that are commercially available but not widely used in wineries, due to specific technical and market barriers to technologies that have low technology readiness and are being piloted by wineries. Some of these technologies, such as electrodialysis or heat recovery for water heating, have significant and real potential for energy savings but have what the project team believes is a low potential for market penetration for various reasons and would benefit from targeted marketing to customers who are likely to adopt the technology as defined in Table 2. Other technologies such as ice banking and thermal storage have significant potential to provide positive total system benefits, but do not fit within the typical framework of energy efficiency programs. Considering these technologies may help energy efficiency program implementers improve customer cost savings potential, particularly due to the recent change to TSB metrics, but may also be a best fit for programs focused on load flexibility or demand responsiveness. Controls based technologies such as pulse cooling and advanced barrel room controls may be a good fit for retro commissioning (BRO-RCx) or Add-on Equipment (AOE) projects. Technologies with low technology readiness levels but high potential for energy savings, such as the fluidized bed reactor and wine-to-wine heat exchanger, present an opportunity to partner on research oriented or IOU funded projects to further evaluate technology performance and cost, and identify trade ally partners who could work with programs teams to deploy the technology. Funding sources could be collaborative or program specific depending on project size and complexity.

Additionally, the project team reported on promising methods or technologies that may not have a mechanism for programs funding, such as process changes related to a change in input or output which are usually not eligible for incentives. Although these technologies are not a good fit for program offerings, program implementers can benefit from being aware of these technologies and recommending them, as appropriate based on the customer profile, as best practices for winery owners to consider. Examples include:

- Addition of agents that prevent tartrate crystal nucleation, which are not eligible for incentives but could reduce the refrigeration load and make implementation of other refrigeration measures less costly.
- Biofiltration for wastewater treatment.
- Advanced methods and controls for wastewater treatment
- Reducing hot water set points, especially when considering electrifying water heating. Reducing hot water set points has the added benefit of reducing safety concerns. Additionally, where it is not possible to reduce hot water set points consider using electric resistance for the higher temperature applications, which are typically limited to a fraction of the overall hot water demand, to reduce the size of the heat pump.

Table 2: Emerging Technologies for Programs Implementation

Emerging Technology	Benefits	Barriers/Opportunities
Refrigeration: 50 - 70% of winery and vineyard electrical energy use		
Electrodialysis (for tartrate removal)	88% process energy savings compared to batch cold stabilization High potential for demand reduction due to high electrical energy savings Refrigeration plant impacts: • High potential to increase plant set point • Potential to downsize the refrigeration plant • Potential water savings Potential for natural gas savings in some applications GHG savings are likely positive	Barriers: Increased water use at the process level[5] Increased wastewater load Not suitable for all market segments Program implementation opportunities: Customers with high cold stabilization costs who are comfortable with the process chemistry are best targets for programs featuring this technology. Evaluating the trade-off between energy savings and water use and design incentives appropriately are importance considerations when developing programs featuring this technology.

[5] Overall site water use should also be considered. There is potential for water savings for refrigeration plants with evaporative condensing due to refrigeration load reduction.

Emerging Technology	Benefits	Barriers/Opportunities
Fluidized Bed Reactor (for tartrate removal)	76% to 90% process energy savings compared with batch cold stabilization High potential for demand reduction due to high electrical energy savings Refrigeration plant impacts: • Potential to downsize the refrigeration plant • Potential water savings Same chemistry as existing process Potential for natural gas savings in some applications Positive GHG savings	Barriers: Not a commercialized product Program implementation opportunities: Partner on research-oriented or IOU-funded projects to further evaluate technology performance and cost effectiveness. Funding sources could be collaborative or program specific depending on project size and complexity. Other Opportunities: Research projects to demonstrate the feasibility and conduct market studies

Emerging Technology	Benefits	Barriers/Opportunities
Wine-to-wine Heat Exchanger (for tartrate removal)	Potential for high electrical and gas energy savings with payback period under a year based on interview data High potential for demand reduction due to high electrical energy savings Refrigeration plant impacts: • Potential to downsize the refrigeration plant • Potential water savings Same chemistry as existing process Potential for natural gas savings in some applications Positive GHG savings	Barriers: No published performance data Not a commercialized product Program implementation opportunities: Partner on research-oriented or IOU-funded projects to further evaluate technology performance and cost effectiveness. Funding sources could be collaborative or program specific depending on project size and complexity. Other opportunities: Research projects to demonstrate the feasibility and conduct market studies
Pulse Cooling Controls	Moderate electrical energy savings Moderate potential for demand reduction due to moderate electrical energy savings Positive GHG savings Low-cost controls implementation	Barriers: Not tested in channel jackets Program Implementation Opportunities: Implement the project as a retro commissioning project (BRO-RCx), or Add-on Equipment project (AOE) depending on the level of control existing vs. the additional equipment required.

Emerging Technology	Benefits	Barriers/Opportunities
Advanced Barrel Room Controls	Moderate electrical energy savings Moderate potential for demand reduction due to moderate electrical energy savings Positive GHG savings Low-cost controls implementation	Barriers: Lack of case studies publicly documenting performance in wineries Program implementation opportunities: Implement the project as a retro commissioning project (BRO-RCx) if new fans are not required to address stratification, or Add-on Equipment project (AOE) if new fans are required to address stratification.
Ice banking	High potential for load flexibility Positive GHG savings	Barriers: Space requirements Program implementation opportunities: Load shifting program opportunities or direct customer cost benefits from shifting time-of-use charges.

Emerging Technology	Benefits	Barriers/Opportunities
Low-GWP refrigerants	Positive GHG savings for some systems	Barriers: Market size is limited for refrigeration due to common use of ammonia as a zero-GWP refrigerant Program implementation opportunities: Consider implementing low-GWP refrigerants for customers who do not have ammonia systems or would like to move away from ammonia systems due to regulatory or safety concerns.
Hot Water: Roughly 22% of energy sales to wineries and vineyards		
Industrial heat pumps	High natural gas savings Positive GHG savings Enables load flexibility	Barriers: High cost Competition with solar thermal heating Program implementation opportunities: Consider developing a deemed measure package for standard retrofits, if such a standard condition can be determined, to facilitate market penetration. Consider custom measures for supplemental or unique high efficiency designs.

Emerging Technology	Benefits	Barriers/Opportunities
Heat recovery systems for water heating	Moderate to low natural gas savings Positive GHG savings	Barriers: Non-simultaneous loads reduces effectiveness for many customers. Program Implementation Opportunities: Consider, on a case-by-case basis, potential for direct customer cost benefits due to reduced energy use.
Thermal banking	Potential to enable heat recovery High potential for load flexibility in heat pump systems Positive GHG savings	Barriers: Space requirements are a concern Program implementation opportunities: Load shifting program opportunities or direct customer cost benefits from shifting time-of-use charges.
Alternative washdown technologies	High natural gas savings Positive GHG savings Can enable HP by reducing load	Barriers: Toxicity to humans Program implementation opportunities: This is an operational measure, which are typically not well supported by a customer program due to difficulties with verifying savings and ensuring persistence. Consider direct customer cost benefits due to reduced energy use.

Emerging Technology	Benefits	Barriers/Opportunities
Wastewater: 5% of winery and vineyard electrical energy use		
Jameson cells	Likely low electrical energy savings Likely positive GHG savings	Barriers: Lack of case studies publicly documenting performance in wineries Other opportunities: Requires further field demonstration to document performance.
Advanced methods and controls	Likely low electrical energy savings Likely positive GHG savings	Barriers: Limited program potential Other opportunities: Consider potential for direct customer benefits from improved wastewater system performance.
Irrigation		

Emerging Technology	Benefits	Barriers/Opportunities
Advanced irrigation monitoring and control	Likely low electrical savings Enables load flexibility Positive GHG savings Positive water savings	Barriers: May be challenging to incentivize in some cases if pumps are diesel operated or served by several utility meters. Challenging to verify savings year after year. Program implementation opportunities: Opportunities exist if policies are updated to be more supportive of Ag pump projects in terms of Net to Gross and pump overhaul eligibility.

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