ALTERNATIVES TO TRADITIONAL AGRICULTURAL BIOMASS BURNING IN NAPA VALLEY

Daniela Bazán

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This Master’s Project

ALTERNATIVES TO TRADITIONAL AGRICULTURAL BIOMASS BURNING IN NAPA VALLEY

By

Daniela Bazán

is submitted in partial fulfillment of the requirements

for the degree of:

Master of Science

in

Environmental Management

at the

University of San Francisco

May 2018

Submitted:                   Received:

…………………………………………..                      …………………………………………………

Daniela Bazán       Date       Gretchen Coffman, Ph. D.       Date
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Definitions (Acronyms)

Agricultural Research Service (ARS)
Bay Area Air Quality Management District (BAAQMD)
California Air Resources Board (CARB)
California Department of Food and Agriculture (CDFA)
Climate Action Plan (CAP)
Conservation Innovation Grant (CIG)
Environmental Quality Incentives Program (EQIP)
European grapevine moth (EGVM)
Grapevine Red Blotch associated Virus (GRBaV)
Greenhouse Gas (GHG)
Napa County Department of Agriculture and Weights and Measures (NCDAWM)
Napa County Department of Planning, Building, and Environmental Services (NCDPBES)
Napa Valley Grapegrowers (NVG)
National Institute of Food and Agriculture (NIFA)
Natural Resources Conservation Service (NRCS)
Particulate matter (PM)
Particulate matter 2.5 μm (PM_{2.5})
Polymerase chain reaction (PCR)
San Joaquin Valley Air Pollution Control District (SJVAPCD)
Sonoma Ecology Center (SEC)
Tree Assistance Program (TAP)
United States Department of Agriculture (USDA)
University of California Agriculture and Natural Resources (UCANR)
University of California Cooperative Extension (UCCE)
Vine mealybug (VMB)
Abstract

Vineyard pruning residues and removed vines create an annual biomass waste issue for growers in Napa Valley. Traditionally this agricultural biomass waste is eliminated by open burning, but with increasing public health and climate change concerns as well as public outcry over large smoke plumes in picturesque Napa Valley, it is necessary to evaluate the alternatives to traditional agricultural biomass burning. The purpose of this study is to evaluate and compare these alternatives and to determine the most sustainable and practicable alternatives for use in Napa Valley. The alternatives to traditional agricultural biomass burning analyzed in this study include low-smoke agricultural burning, chipping and mulching, biochar, and bioenergy. Low-smoke agricultural burning and chipping and mulching are among the most practicable of alternatives currently while biochar and bioenergy continue to expand infrastructurally and strive to reduce costs. Each alternative exemplifies techniques that require more funding and collaborative support from local, state, and federal agencies, in order to succeed at the community level with local agricultural producers. Management recommendations include further development of funding and collaborative efforts already in place, expansion of practicable opportunities to minimize greenhouse gas (GHG) and particulate matter 2.5 µm (PM2.5) emissions from agricultural waste while still effectively managing pests and disease, and emphasizing the ecological and possible financial incentives to growers should they invest in any of the alternatives to traditional agricultural biomass burning. Furthermore, it is imperative to consider and improve safety guidelines for farmworkers performing burns or engaging in an alternative to traditional agricultural biomass burning. At the foundation, accessible safety training as well as regulatory and informational materials must be provided in languages other than English to ensure the safety of farmworkers. Sustainable implementation of any alternative to traditional agricultural biomass burning requires full collaboration across every level while burn policy recommendations for Napa Valley require additional awareness and understanding of agricultural operations in an urbanized setting.
1. INTRODUCTION

Traditional agricultural biomass burning is no longer a viable option for farmers and growers confronting growing public health and climate change concerns. Developing efficient and financially sound alternatives to deal with agricultural biomass waste is crucial. The Napa Valley is renowned for its picturesque landscape and world class wines, but the farming and production realities that interrupt the pristine scenery underscore the health and climate issues driving a call to change. Sustainable alternatives to traditional agricultural biomass burning are required to deal with vineyard pruning residues and removed vines. Health and climate change concerns may be the catalyst for policy change, but ecological benefits that stimulate productivity and wine sales can incentivize farmers and growers to voluntarily implement alternatives to traditional agricultural biomass burning.

Agricultural biomass waste is organic matter that is produced as a result of growing products in a biological process (Velázquez-Martí et al. 2011). In Napa Valley, vineyard agricultural biomass is an important waste issue. Vineyards are one of the most adaptable, common and profitable crops in Mediterranean regions, covering nearly eight million hectares worldwide (FAOSTAT 2009). The Napa Valley American Viticultural Area (AVA) is the umbrella appellation representing all Napa Valley grapes or about 4 percent of the California wine grape harvest (Napa Valley Vintners 2018). Furthermore, Napa Valley consists of 16 sub-appellations, each one recognized for distinct microclimates and terrain (Napa Valley Vintners 2018). As of 2017, there were a total of 46,189 planted red and white winegrape acres in Napa Valley (Napa County Department of Agriculture and Weights and Measures (NCDAWM) 2018). The total planted vineyard acres produced approximately 142,413 tons in 2017, generating a total gross value production of $750,832,400 or 99 percent of all agricultural production in the county for 2017 (NCDAWM 2018). As the price per ton of both red and white grapes only increases, the need to address the vineyard biomass waste dilemma stemming from both pruning and vine removal activities is critical.

Vineyards require annual pruning, generating substantial amounts of residues that must be disposed of before tending to the vines for the growing year (Spinelli et al. 2012). Pruning residues as well as vineyard removal contribute to agricultural biomass waste. Vines may be removed to manage for biological pests and disease, but also to change wine grape varietals or replace aging vines that no longer produce the desired tonnage.
Traditionally, agricultural biomass waste is usually destroyed by in-field burning or crushing into the soil without economic benefit (Velázquez-Martí et al. 2011). Open burning of agricultural biomass waste is a rapid method to dispose of vegetative debris, allows clearing of the land, and releasing of nutrients for the next growing cycle, fertilizing the soil, and eliminating pests (Gonçalves et al. 2011). Open burning in agricultural operations includes the burning of materials in the open produced wholly from operations in the growing and harvesting of crops (California Code of Regulations 2001). On site combustion represents an additional management cost although it does not necessarily require specialized equipment (Picchi et al. 2013). However, finding a use for vineyard pruning residues would convert a disposal problem into collateral production with the potential for revenues or reduced management costs (Spinelli et al. 2012). Capitalizing on the repurposing of vineyard residues and removed vines could offset the costs associated with alternative methods of disposal, as well as mitigate for harmful impacts of traditional agricultural biomass burning.

California epitomizes the agriculture-climate challenge, with agriculture accounting for approximately 8 percent of California’s greenhouse gas (GHG) emissions from 2000-2013, but also presents great opportunity as the country’s largest agricultural producing state (Morandé et al. 2017). One big disadvantage and critique of agricultural burning is the emissions of particulate and gaseous pollutants that can impact local and regional air quality (Holder et al. 2017). In its final draft, the Napa County Climate Action Plan (CAP) denotes that agricultural sector emissions account for 10 percent of the county’s GHG emissions, including CO₂, CH₄, and N₂O. Agricultural biomass burning along with farm equipment operations, fertilizer use, and emissions from livestock comprise the overall agricultural GHG emissions for the county (Napa County Climate Action Plan 2017). Additionally, particulate matter (PM) from agricultural biomass burning is important because much of the PM emitted from this combustion source is smaller than 2.5 µm (PM₂.₅) (Wagner et al. 2012). Growing concern over the impact of GHG emissions and PM₂.₅ on both community health and the environment has prompted discussion over the eventual ban of agricultural burning in Napa Valley. The Bay Area Air Quality Management District (BAAQMD) regulates and oversees open burning, controlling any future regulatory changes. The Napa County CAP proposes agricultural measures to reduce GHG emissions, but also notes that the BAAQMD has authority over any decisions regarding burning regulations.
The goal of this paper is to evaluate and compare alternatives to traditional agricultural biomass burning in Napa Valley. I hope to show through my research and analysis that each of the alternatives reviewed are valuable pursuits that require educational development and financial investment to become sustainable. Additionally, I will evaluate how low-smoke agricultural burning remains a necessary tool to manage biological pests and disease. My comparative analysis offers insight into the complexities and complications of banning open agricultural biomass burning altogether. Additionally, the comparative analysis underscores the potential ecological benefits and financial incentives for farmers and growers to voluntarily invest in alternatives to traditional agricultural biomass burning. Finally, I propose management recommendations focused on education and outreach, including the development of safety guidelines for farmworkers, and policy recommendations considering the proposed Napa County CAP.

2. METHODOLOGY
I reviewed available scientific literature on the burning of agricultural biomass waste and its alternatives. While my study area focused on the Napa Valley, my research extended beyond Napa and its vineyards. I analyzed studies from other Mediterranean regions and other crops including olives. I reviewed numerous local studies for case studies and data pertaining to each of the alternatives discussed.

In this study, I reviewed scientific literature, participated in agricultural workshops, reviewed BAAQMD air quality data, and air quality reports. I participated in local workshops demonstrating alternatives to traditional agricultural biomass burning in Napa to better understand the development of such alternatives. I reviewed the most recent data by the BAAQMD summarizing 2017 data for all reported burn material under their open burn permit system. Additionally, I analyzed the 2015-2016 statistics for the BAAQMD Agricultural Waste Chipping Program. I recommend that more research is needed to document the amount of overall vineyard removal in Napa to compare to BAAQMD statistics and to document the practice of alternatives to traditional agricultural biomass burning already in place.

3. BACKGROUND
Agricultural biomass burning in Napa Valley (Figure 1) is not unique in the challenges facing agricultural producers and is similar to the waste management challenges facing crop producers
worldwide. What sets Napa Valley apart in some respects is the reputable drive to be a world-class wine region and destination, and to create exemplary farming practices that are both sustainable and non-invasive to the romanticized landscape and imagery. The realities of farming remain elusive to those not involved in the wine grape industry, including the challenges with disposal of agricultural biomass waste described below.

3.1 Vineyard Waste Dilemma: Annual Pruning and Vine Removal

Vineyards follow a seasonal cycle, with bud break in Napa Valley typically starting in late February to early March, and harvest season usually running from August through the end of October. The seasonality of wine grapes all depends on temperatures and rain but as soon as grapes are harvested, dormant seasonal activities generating large amounts of vineyard waste commence. Annual vineyard pruning commonly begins in January each year to remove all growth from the previous year. Vineyard pruning biomass residues are typically moved just outside of the vineyard, accumulating in large piles. They must be disposed of to make way for vineyard equipment and farmworker crews accessing the vineyard rows where space may be limited, and the pruning residues can cause farmworkers to trip and fall.

It is important to consider the amount of vineyard biomass waste that Napa Valley vineyards can potentially produce to plan for waste management of that agricultural biomass waste. Older vines cultivated for wine production produce more biomass, while the amount of residual biomass of younger vines produce more tons per hectare due to more intensive inputs such as irrigation (Velázquez-Martí et al. 2011). In particular, the biomass per hectare of irrigated vines compared to the biomass per hectare of non-irrigated vines results in an increase in the number of plants cultivated per hectare, with an increase as high as 42 percent in the amount of biomass per hectare for irrigated vineyards (Velázquez-Martí et al. 2011). While some vineyard growers in Napa have turned to dry farming techniques, and others have planted clones and rootstock with longer root systems that require less frequent irrigation, the majority of vineyards are irrigated with drip systems and will produce more biomass compared to non-irrigated or less frequently irrigated vines. The difference in trellis system can also impact the overall vineyard biomass availability, with variances noted between standard trellis, high or Y-shaped trellis, and horizontal trellis systems. In vineyards cultivated for wine production, the standard trellis and vase shaped trellis systems reach approximately 0.8 kg dry matter per vine tree (Velázquez-Martí et al. 2011).
Additional quantitative variables impacting the amount of vineyard biomass productivity include the height of the tree or vine, age of the vines, diameter of the crown, diameter of the stem, size of the vineyard and row spacing, fruit production, and crown height (Velázquez-Martí et al. 2011). Winegrape varietal has no significant influence on the average amount of the residual biomass produced per vine tree while the structure of the vineyard trellis system remains more relevant (Velázquez-Martí et al. 2011).

Vineyard removal, on the other hand, can occur as early as the end of harvest but can also happen at any point during the year. Typically, healthy and producing vineyards are not removed until after harvest, allowing for one more vintage to be harvested and the wine pressed. The removal of healthy vineyards may occur to replace older and unproductive vines, to change the layout of the vineyard to reduce grape sunburn during hot summer months or to modify row spacing to allow for tractor passage, as well as to change wine grape varietal. Sub-appellation and winegrape varietal contribute to the tonnage contract price a winery pays for grapes as well as the price wineries charge consumers per bottle, enticing winemakers to remove and replant vineyards for suitable, in-demand varietals that will earn top dollar. In 2017, the top earning white winegrape varietals in Napa Valley were Albarino, Marsanne, and Roussanne, earning between $3,765-$4,308 per ton. However, the most in demand and top producing white winegrape varietals were Chardonnay with 20,684 tons produced and Sauvignon Blanc with 12,901 tons produced (NCDAWM 2018). The top earning red winegrape varietals in Napa Valley in 2017 were Cabernet Franc, Cabernet Sauvignon, and Malbec, earning between $5,726-$7,871 per ton. The red winegrape varietals with the greatest production were Cabernet Sauvignon with 66,733 tons produced and Merlot with 13,160 tons produced (NCDAWM 2018). Cabernet Sauvignon continues to dominate the market, and many winemakers and vineyard growers may opt to replace less lucrative varietals with Cabernet Sauvignon in hopes of earning more per ton produced. Cabernet Sauvignon is also a more resilient winegrape varietal. It is not as delicate as other varietals and can survive heat waves with proper irrigation, it has thicker skin and can weather some rain even during harvest, and is adaptable to even the most adverse conditions as evidenced in the 2017 wildfires. The decision to change winegrape varietal usually comes from extensive planning and economic projections. The planned management of vineyard biomass waste should be as extensive.
Extensive planning might not be an option for vineyard growers confronted with pests and disease in the vineyard. As such, vineyard removal to manage for pests and disease can occur at any time throughout the year. Agricultural biomass burning remains an efficient method of disposal for infested vineyard waste.

### 3.2 Traditional Agricultural Biomass Burning

Prior to the adoption of open burning regulations, traditional agricultural biomass burning was a typical way to manage the vineyard waste generated annually. In the past, gasoline or diesel would be used to ignite burn piles, adding tires, trash, leaves, or other items to the burn piles, and burning at all hours of the day. With open burning regulations now in place, many of these “back in the day” practices are now illegal, but the burning persists. The development of alternative practices to traditional agricultural biomass burning attempts to overcome practices that do not take into consideration public health and climate change concerns. Many outside of the industry would prefer that the agricultural burning of biomass waste be banned altogether, particularly in a pastoral setting like the Napa Valley. However, burning remains a critical tool in managing vineyard waste that must be disposed of in a responsible way.

The 2017 BAAQMD Annual Report for the agricultural and prescribed burning for all nine Bay Area counties was submitted in March 2018 to the California Air Resources Board (CARB). The reported information for agricultural burning represents the amount of material “to be burned” but is not necessarily an exact representation of the amount actually burned (BAAQMD 2018). Of all the Bay Area counties, Napa and Sonoma counties reported the largest amounts of material to be burned in 2017 (Table 1). This information was obtained from the burn permits submitted to the BAAQMD for open burn authorization. Napa County reported an estimated 62,034 cubic yards of material burned, while Sonoma County reported an estimated 34,701 cubic yards of material burned. The amount of material burned in Napa County alone represented approximately 44 percent of all agricultural material burned in 2017 (BAAQMD 2018).
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<td><strong>881</strong></td>
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Of the agricultural material burned in Napa County in 2017, approximately 15,120 cubic yards or 24 percent was grapevine material burned due to disease and pests. Approximately 19,469 cubic yards or 31 percent included pruning residues from grapevines as well as olive, fruit and nut trees. Approximately 24,294 cubic yards or 39 percent of the agricultural material to be burned included crop replacement of grapevines, as well as Christmas trees, cleared brush and fir, pine, and shrubs (BAAQMD 2018). No other single county reported any type of agricultural burning more than 20,000 cubic yards, except for the burning of pruning residues including grapevines, fruit and nut trees in Contra Costa County. Every county reported some type of agricultural burning that was related to grapevines and vineyards (BAAQMD 2018). This report captures only the cubic yards of agricultural material burned as reported to the BAAQMD. It is possible that the actual amount of burned material is greater than that reported.

3.3 BIOMASS BURNING AS BEST ECOLOGICAL PRACTICE: MANAGING FOR BIOLOGICAL PESTS AND DISEASE

Vineyard growers must manage for any pests and disease that are found in the vineyard or risk losing their entire crop. The Napa County Agricultural Commissioner’s office works locally with vineyard growers to actively detect and manage for pests and disease found in the vineyard. If an invasive pest is detected in California, it may trigger a regulatory response coordinated by the United States Department of Agriculture (USDA), the California Department of Food and Agriculture (CDFA), and agricultural commissioners (Cooper et al. 2014). This regulatory response may include trapping, quarantine, and treatment protocols (Cooper et al. 2014). In 2017, the Napa County insect trapping program monitored for invasive pests, including Asian citrus psyllid, European grapevine moth (EGVM), exotic fruit flies, glassy-winged sharpshooter, grape leaf skeletonizer, gypsy moth, Japanese beetle, and vine mealybug (VMB) (NCDAWM 2018). Of the 11,233 species-specific pheromone traps placed for monitoring and detection throughout the county, 4,878 or 43 percent of traps were placed for the EGVM while 4,151 or 37 percent of traps were placed for VMB (NCDAWM 2018). If pests or disease are detected in vineyards, removing the infected plant material must be done very carefully so as not to spread the infestation. Traditionally, Native American land management tools included fire to help control pathogens and insects that would otherwise compete for the same resources used by native people, with fire consuming biomass while also releasing some of the plant nutrients (Anderson 2005).
Burning the removed vineyard biomass waste is the most effective method for stopping the threat of spreading any infestation.

### 3.3.1 European Grapevine Moth

The European grapevine moth (EGVM) (*Lobesia botrana*) was first found in Napa County in 2009. This invasive pest and its associated fungal rot caused significant crop damage in 2009 (Cooper et al. 2014). EGVM may complete two to five annual generations with the first male flight beginning slightly before budbreak and continuing for 10-14 weeks (Cooper et al. 2014). The generational sequence follows that first-generation larvae feed on flowers before and during bloom, second generation larvae feed on green berries, and third generation larvae feed inside ripening berries (Cooper et al. 2014). Once treatment protocol was established, conventional and organic insecticide sprays and implementation of Isomate EGVM pheromone mating disruptors were coordinated to coincide with expected flights and generational stages of EGVM.

After confirming the first detection in 2009, the USDA, CDFA, and the Napa County agricultural commissioner deployed 248 sex pheromone-baited traps to delimit the population, capturing only a total of five moths in 2009 (Cooper et al. 2014). Very few moths were trapped in 2009 as the traps were deployed after the third flight. However, in 2010 there were a total of 3,882 traps deployed resulting in 100,831 moths captured (Cooper et al. 2014). In 2014, 22 county insect trappers deployed and continuously monitored more than 11,600 EGVM detection traps in commercial vineyards and urban areas at the recommended density of 100 traps per square mile (NCDAWM 2014).

The USDA issued a federal order in June 2010 initiating a quarantine area within five miles of all detections (Cooper et al. 2014). Additionally, the state interior quarantine was established in March 2010 by the CDFA (Cooper et al. 2014). Because EGVM easily moves via equipment, stakes and end posts, as well as any fruit or green waste material, the affected and subsequent quarantine area included portions of eight California counties by the end of 2010. In 2011, quarantine regulations peaked and extended to 10 California counties covering a total of 2,335 square miles (Figure 2) (Cooper et al. 2014). Napa County achieved its first significant EGVM quarantine reduction in 2014, releasing 12,500 farmed acres from regulation (NCDAWM 2014). As quarantine regulations were lifted throughout California, Napa County was the last county for all regulations to be
removed. On August 18, 2016, the USDA declared the EGVM officially eradicated (NCDAWM 2016).

The eradication of EGVM is an example of successful collaboration between agricultural producers, local, state, and federal departments of agriculture, as well as wineries and grower liaisons. Local, state, and federal departments of agriculture contributed approximately $50 million to manage quarantine efforts, while vineyard growers in Napa County alone spent an additional $50 million in treatment and compliance costs from 2010 to 2015 (NCDAWM 2016). Vineyard growers faced more upfront costs for EGVM treatment and compliance prior to local, state, and federal departments of agriculture allotment of funds to support growers. Compliance agreements were required of all vineyard growers, filed with local agricultural commissioner’s offices, and required upon delivery of harvested grapes to wineries. Completion of compliance agreements was streamlined to attain participation of all growers in the county. Additionally, vineyard growers were required to slack-fill harvest bins and tarp the bins for delivery. If infested vineyards were removed, removed stakes and end posts were required to remain on site no less than 60 feet away from any EGVM host material for a minimum of nine months before transport to the landfill (NCDAWM 2014). Equipment used to transport material from an infested vineyard was required to follow decontamination protocol. Any vines that were removed required burning or transport to the landfill in order to minimize the potential spread of the pest (NCDAWM 2014). Burning of infested vineyard biomass waste was not a compliance issue with EGVM so much as it was an accepted industry standard for dealing with infested vineyard biomass waste. Alternatives that might reintroduce infested vineyard biomass waste into the vineyard do not eliminate this invasive pest. EGVM eradication is an exemplary case of collaboration for the benefit of the agricultural industry and the larger community.

3.3.2 GRAPEVINE RED BLOTCH ASSOCIATED VIRUS

Grapevine Red Blotch associated Virus (GRBaV), associated with Grapevine Red Blotch disease, was identified in fall 2011 by virologists at UC Davis Foundation Plant Services and USDA-Agricultural Research Service (ARS) in three diseased red winegrape varietals (University of California Cooperative Extension (UCCE) Sonoma County 2018). This circular DNA virus affects both red and white winegrape varietals, with red coloration in basal leaf blades among the first symptoms in red winegrape varietals while white winegrape varietals exhibit subtle-to-obvious
discoloration (UCCE Sonoma County 2018). Red leaf symptoms affecting grape foliage were first noticed in planted red winegrape vineyards in Napa Valley in 2008, however, foliar symptoms were not always correctly distinguished from grapevine leafroll disease (GLD), prolonging the diagnosis of GRBaV (USDA-National Institute of Food and Agriculture (NIFA) 2014). Effects of the virus on yield and fruit quality parameters, pH, and titratable acidity appear to vary by winegrape varietal, but the consistent result is reduced juice production from fruit on diseased grapevines (USDA-NIFA 2014). Furthermore, the most significant impact of the disease results in lower winegrape Brix levels with infected vines testing at Brix levels four to five units lower than winegrapes with green canopies (USDA-ARS 2012). The patterns of disease incidence in the vineyards resemble that of movement by insects not commonly found feeding on grapevines, but to date no vector has been identified (USDA-NIFA 2014). No pesticide recommendations are available for the treatment of GRBaV as no vector has been confirmed and, most importantly, there exists no cure for virus infected vines at this time (USDA-NIFA 2014).

Since 2011, an increasing number of symptomatic vines were identified in specific blocks at the UC Oakville Experimental Vineyard in Napa County, yet other blocks at the same location had no evidence of directional spread (UCCE Sonoma County 2018). The virus is known to spread by propagation but the pattern of distribution of the virus inside a healthy plant after it is grafted or how long it takes for a healthy vine to exhibit symptoms are unknown (UCCE Sonoma County 2018). Polymerase chain reaction (PCR) diagnostic testing is critical for determining the presence of GRBaV in planted material, particularly because symptoms may be confused for GLD or even potassium or other nutritional deficiencies (UCCE Sonoma County 2018). In 2011 and 2012, individual symptomatic red winegrape vines were sampled in Napa, Sonoma, and San Luis Obispo counties of which GRBaV was detected in approximately 95 percent of symptomatic grapevines indicating that symptomatic vines are likely to be infected with GRBaV (UCCE Sonoma County 2018). If PCR testing is positive a management decision must be made whether to remove the infected vines and replant. Because the epidemiology of GRBaV is unknown, the management decision to remove infected vines will likely be based on the economic impacts on fruit quality (USDA-NIFA 2014). In recent years, many vineyards have been removed in Napa County because of positive identification of GRBaV in vineyards as well as symptoms associated with GRBaV. It is possible that vineyards exhibiting nutrient deficiency were removed for symptoms mistakenly identified as GRBaV. In September 2014, the USDA extended its Tree Assistance Program (TAP)
to eighteen California counties to provide financial assistance for vine loss due to GRBaV, but PCR testing and site inspection prior to removing vines are requirements for funding (UCCE Sonoma County 2018). Removed vines positively identified or suspected to have GRBaV are burned to mitigate for the spread of the virus, especially because vector identification has yet to be determined.

3.3.3 Vine Mealybug
Vine mealybug (VMB) (*Planococcus ficus*) were found in southern San Joaquin Valley vineyards in 1998 and spread to a total of 16 California counties by the end of 2004 (Smith and Varela 2005). Similar to other grape-infecting mealybugs, VMB produces honeydew that drops onto the grape cluster and other grapevine parts, serving as a substrate for black sooty mold. VMB can also infest the grape clusters making them unfit for consumption and can transmit grapevine leafroll-associated viruses (University of California Agriculture and Natural Resources (UCANR) 2017). Untreated populations can result in crop loss and grapevine death. Preventing the movement of VMB in the vineyard is necessary to reduce the need for chemical insecticide applications (Smith and Varela 2005). While some biological controls exist, including the parasitic wasp (*Anagyrus pseudococci*) and the mealybug destroyer (*Cryptolaemus montrouzieri*), treatment is recommended if VMB is detected (UCANR 2017). Insecticide treatment can include the controversial Chlorpyrifos, an organophosphate pesticide.

Additionally, VMB can potentially spread through contaminated winery waste and survive in unmanaged pomace piles consisting of the unfermented skins, seeds, and cluster stems produced from pressing the winegrapes for juice (Smith and Varela 2005). Pomace, or marc, can be used for compost as a soil amendment in the vineyard. In their study on the fate of VMB in winery whole-cluster press loads, Smith and Varela determined that VMB could survive the press process with some insects always remaining on the cluster parts. They also experimented to see if VMB could survive in pomace piles. They found that significant VMB mortality resulted when pomace piles were covered with clear plastic for one week and when piles are constructed with mostly skins and seeds but limited stems allowing for steady high temperature fluctuations (Smith and Varela 2005). Removed vines from VMB infested vineyards must also be handled to minimize the movement of this destructive pest. Burning of vineyard agricultural biomass waste is a necessary tool for the management of VMB.
The Bay Area Air Quality Management District (BAAQMD) regulates open burning for the entire Bay Area. It first began to regulate agricultural burning in 1968. According to the BAAQMD Regulation 5: Open Burning, an agricultural fire is a fire used for the purpose of initiating, continuing or maintaining agriculture as a gainful occupation with proof of gross profit or loss (Bay Area Air Quality Management District (BAAQMD) 2013). Also following the BAAQMD Regulation 5: Open Burning, a permissive burn day is any day that air pollution caused by open burning will not adversely affect ambient air quality or downwind populations under the meteorological criteria established by the Air Resources Board (ARB) for the San Francisco Bay Area Air Basin (BAAQMD 2013). The BAAQMD established that the open burn season runs from November 1st to April 30th each year. During the open burn season, agricultural producers may submit an open burning notification form, along with applicable fees, prior to conducting an open burn. Also prior to starting an open burn, a call must be placed to the open burn telephone line to verify open burn status for the day of burning.

3.4.1 Overview of Emission Monitoring for Biomass Burning

The burning of agricultural biomass waste has a very real impact on public health. Monitoring for and understanding the type of particulates emitted from burning is essential to reducing the harmful impacts of burn emissions. Particulate matter 2.5 (PM$_{2.5}$) refers to very fine particles with an aerodynamic diameter of 2.5 microns or smaller (California Air Resources Board (CARB) 2015). PM$_{2.5}$ poses an increased health risk because the fine particles can deposit deep into the lungs, exposing the lungs to elements such as carbon and metals as well as organic compounds and nitrates (CARB 2015). Carbon dioxide (CO$_2$), carbon monoxide (CO), particulate matter (PM), and non-methane hydrocarbons (NMHC) are major components of smoke from agricultural burning (Gonçalves et al. 2011). Organic carbon dominates the carbonaceous fraction regardless of particle size or waste type (Gonçalves et al. 2011). Experimenting with agricultural burns in the Imperial Valley in California, Wagner et al. determined that 24-h PM$_{2.5}$ exposures downwind of the burns were up to 17 times higher than exposures measured upwind (Wagner et al. 2012). Throughout the San Francisco Bay Area Air Basin, concentrations of PM$_{2.5}$ are highest during winter months during colder, more stagnant conditions as well as increased residential wood combustion, but winter months also coincide with the permitted open burn season (CARB 2014).
More research is needed to distinguish concentrations of harmful emissions due to traditional agricultural burning to then target those levels for potential reduction by implementation of alternatives.

3.5 NAPA COUNTY CLIMATE ACTION PLAN

The Napa County Department of Planning, Building, and Environmental Services finalized the draft of the Napa County Climate Action Plan (CAP) in 2017. The CAP is intended to quantify and reduce GHG emissions in the unincorporated county and its adoption would implement an “action item” from the county’s 2008 general plan update (Napa County Department of Planning, Building, and Environmental Services (NCDPBES) 2017). In particular, the CAP identified the top GHG emitting sectors within the county. The top GHG emitting sectors based on 2014 GHG emissions include building energy use accounting for 31 percent of emissions, on-road vehicles accounting for 26 percent of emissions, solid waste accounting for 17 percent of emissions, and agriculture accounting for 11 percent of emissions (Figure 3) (NCDPBES 2017). Agricultural emissions include emissions from livestock, fertilizer use, and emissions from agricultural equipment that account for over 60 percent of agricultural emissions in 2014. CAP measures to reduce GHG emissions by 18 percent by the year 2030 target equipment emissions and residue burning (Table 2) (NCDPBES 2017).

While agricultural GHG emissions rank fourth in the breakdown of GHG emissions by sector, public outcry is focused on the agricultural sector. Knowledge of agricultural operations is limited outside of the industry. Measures to reduce GHG emissions in the agricultural sector listed in the CAP touch on possible alternatives to traditional agricultural biomass burning, but do not investigate their feasibility in depth. Furthermore, while open burning is recognized as a preventable measure to curb pests and disease in vineyards, the CAP does not educate readers on the significance of pest and disease threats or their prevalence in Napa County.
4. ALTERNATIVES TO TRADITIONAL AGRICULTURAL BIOMASS BURNING: ANALYSIS AND RESULTS

The CAP underscores public concern over the open burning of agricultural biomass waste in Napa County. Specifically, concerns about public health and climate change impacts are catalysts for the need to develop alternatives to traditional agricultural biomass burning. The CAP outlines measures to reduce agricultural biomass waste burning yet does not have the authority to regulate open burning in the county. Furthermore, the CAP briefly touches on the importance of agricultural biomass burning in the case of pest and disease management, but focuses more on pursuing its alternatives without offering any insight as to the infrastructure needed to sustain such alternatives. The need to develop alternatives to traditional agricultural biomass burning is vital to enhance farming and specifically burning technologies, but real alternatives that are both sustainable and practicable to agricultural producers is key.
Low-smoke agricultural burning is a modification to traditional agricultural biomass burning, with the goal of reducing harmful smoke emissions (Photo 1). It is an important tool in dealing with vineyard management waste when confronted with vineyard pests and disease. Vineyard pruning residues and removed vines must be burned to eliminate the threat of pests and disease and to limit contamination of other crops as well as equipment. Low-smoke agricultural burning also takes into consideration concerns to public health as well as climate change.

4.1.1 NAPA VALLEY GRAPEGROWERS BEST PRACTICES FOR LOW-SMOKE AGRICULTURAL BURNING

The Napa Valley Grapegrowers (NVG) is a non-profit organization representing grapegrowers, vineyard owners and managers, and businesses in Napa County. They offer educational curriculum for members as well as farmworkers through the Napa Valley Farmworker Foundation, including industry specific and safety trainings in Spanish, and sponsor events and services to address the specific challenges of the wine growing industry (Napa Valley Grapegrowers (NVG) 2018). In 2015, the Vineyard Burning Task Force was formed and set out to develop a three-year plan to reduce smoke and preserve air quality in Napa Valley (NVG 2017). They developed a six-step best practices approach for low-smoke agricultural burning that included the following steps: schedule and discuss vineyard removal with a contractor; contact your vine removal contractor; prepare the vineyard; vineyard removal; vine piling; and burning the piles (NVG 2017).

The decision to remove a vineyard can coincide with biological pest and disease management, but vineyards are often removed post-harvest to change wine grape varietal, remove older, low-producing vines, and to change layout or directionality of the vines themselves. Planning for vineyard removal allows time to strategize, determine if a contractor will remove vines, and plan the efficient use of equipment and budgeting (NVG 2017). Prior to vineyard removal, it is important to remove all end posts and stakes, plastic irrigation dripline, trellis wires and clips, as well as mow any excessive vegetation in the vine rows that can generate smoke (NVG 2017). Also, removing excess dirt from vines is part of the essential vine cleaning important to low-smoke burns.

Once a vineyard is removed and the vines are cleaned, it is essential to ensure the vines have dried sufficiently before beginning the process of stacking the vines into piles that adhere to the
BAAQMD regulations (NVG 2017). Once the piles are constructed, it is recommended, where possible, to tarp the top center of the piles to assist in keeping the center of the piles dry during any rain events. Additionally, the NVG recommend uncovering the piles during any prolonged dry periods leading up to the burn (NVG 2017). Maintaining dry piles is crucial to producing a rapid burn when the time comes, thereby limiting the amount of smoke emitted.

Following the best practices outlined by the NVG as well as BAAQMD regulations, it is likely that the piles will burn with a minimum amount of smoke (NVG 2017). This includes starting burns after 10 am, making sure that the day to burn is a permissive burn day, and, if possible, using a propane torch to light the downwind side of the top of the burn pile (NVG 2017). Furthermore, it is recommended to light one pile as a test pile to evaluate the level of smoke generated, then determine if it is appropriate to ignite the remaining piles or if additional drying or modifications are necessary (NVG 2017). The low-smoke agricultural burning outlined in the NVG best practices is relatively low cost and low job risk to farmworkers, with the potential to return the ash to the vineyard as fertilizer. However, apart from using ash as potential fertilizer, this technique lacks ecological and economic incentives for growers, such as increasing crop yield or slowing weed growth in the vineyard. Developing more efficient burning technologies to manage for biological pests and disease could prove economically beneficial and also help reduce smoke and PM emissions.

4.1.2 Burn Boss® Air Curtain Burner
An interesting option for low-smoke agricultural burning is the BurnBoss Air Curtain Burner designed by Air Burners, Inc. Air Curtain Burners, also called FireBoxes, act as an air pollution control device by reducing the PM, smoke or black carbon that results from burning clean, dirt-free wood waste (Photos 2-3) (Air Burners, Inc. 2017). This alternative to traditional open burning mitigates the amount of smoke released from agricultural burning, but the BurnBoss is only a receptacle for burning and does not actually burn anything itself. The BurnBoss was designed for the high temperature burning of forest slash, agricultural waste, land-clearing debris, green waste, and storm debris in compliance with US EPA 40CFR60 (Air Burners, Inc. 2018). Air Curtain Burners including the BurnBoss control the results of the burning material by slowing down the smoke particles on their way out of the FireBox, subjecting the particles to the highest temperatures in the FireBox (Air Burners, Inc. 2017).
For proper operation, a curtain of air must be maintained over the fire at a mass flow and velocity in balance with the potential mass flow and velocity of the burning material (Figure 4) (Air Burners, Inc. 2017). A high velocity of 1600-2000 revolution per minute (RPM) blocks various air pollutant emissions including GHG’s and PM, while also returning air pollutant emissions by circulation of air flow (Lee and Han 2017). Any over-agitation or pressure that is too high can lift the air curtain rendering it ineffective and can cause embers and ash to blow out of the FireBox. Adversely, if the mass flow of the air curtain is too low, any unburned particles or smoke can penetrate the air curtain (Air Burners, Inc. 2017). Air Curtain Burners are easy to clean out with no floor or barrier, allowing for the ashen waste to be turned back into the soil (Air Burners, Inc. 2018). The ash from the burning of agricultural waste can be a useful soil additive as well, with some biochar included in the residual ashes (Air Burners, Inc. 2017).

In a comparative study between two types of Air Curtain Burners and open burning, the S-220 and the BurnBoss, it was noted that the S-220 was a good fit for centralized locations with forest residues delivered for burning, while the BurnBoss worked well being frequently moved to the site of the forest residues (Lee and Han 2017). Additionally, the S-220 is potentially more effective where there are large amounts of fuel on landing areas and high wildfire risk areas. The BurnBoss is more effective due to its easy transport for disposal of small volume of fuels such as hand-pile slash, paper trays or small forest residues, or a few drought/insect damaged trees in public parks (Lee and Han 2017). The BurnBoss offers an alternative to open burning on site that is portable and effective at handling smaller volumes of fuels, ideal for smaller, and more remote vineyard sites. In Lee and Han’s study (2017) the S-220 offered a higher burning consumption rate at 85 percent and incurred a lower cost than the BurnBoss. However, the BurnBoss’ burning consumption rate was 40-80 percent greater than and produced much less smoke than the hand-pile burning (Lee and Han 2017).

In a separate study, Sun-Maid Growers partnered with the Nisei Farmers League in California’s San Joaquin Valley to test the BurnBoss in vineyard operations. The premise of their study was to figure out a method of compliance with required agricultural reductions of ambient air emissions from farming practices in San Joaquin County following guidelines in Rule 4103, open burning, and reducing PM\(_{2.5}\) emissions (Figure 5) (San Joaquin Valley Air Pollution Control District (SJVAPCD) 2012). They evaluated the BurnBoss unit by burning both vineyard biomass waste
and raisin paper trays. They also evaluated the cost effectiveness of keeping the unit stationary versus moving the unit to various vineyard locations. Modifications were made to the BurnBoss to include an attached screen cage over the top of the unit to capture flying ash generated from the paper tray burning (Photo 3). Also, modifications added an opening to the back of the screen to allow for an ash rake to help break up the layers of ash while burning. Additionally, the gas motor unit was replaced with connections for a Power-Take-Off and hydraulic hose to raise and lower the BurnBoss by means of a tractor (SJVAPCD 2012). They found that the burn down rate of vineyard removal materials is faster than paper trays, but that the rate of paper tray burning can be assisted by raking and separating the ash buildup (SJVAPCD 2012). Overall, comparative testing and consideration for costs of labor, labor hours, acres, and commission, resulted in a mobile unit cost per acre of $3.91 compared to a stationary unit cost per acre of $3.44\(^1\) (Table 3) (SJVAPCD 2012). Fuel, tractor finance or rental, tractor repair, and the cost of the BurnBoss unit as well as any modifications to the unit, were not included in the cost analysis. Both methods proved to be productive, however, they determined that a stationary unit at a central location was more cost effective to burn paper trays (SJVAPCD 2012).

### Table 3. Cost Analysis Tables of the BurnBoss Air Curtain Burner testing units.

<table>
<thead>
<tr>
<th>Location 1 - 69 Acres</th>
<th>ACB Unit Mobile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acres</td>
<td>Hours</td>
</tr>
<tr>
<td>69</td>
<td>10</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Detailed Costs</th>
<th>Commission</th>
<th>Cost per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>Rate per Hour</td>
<td>Cost per Hour</td>
</tr>
<tr>
<td>2</td>
<td>$10.00</td>
<td>$20.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location 2 - 51 Acres</th>
<th>ACB Unit Stationary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acres</td>
<td>Hours</td>
</tr>
<tr>
<td>51</td>
<td>6.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Detailed Costs</th>
<th>Commission</th>
<th>Cost per Acre</th>
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<tbody>
<tr>
<td>Labor</td>
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<td>Cost per Hour</td>
</tr>
<tr>
<td>2</td>
<td>$10.00</td>
<td>$20.00</td>
</tr>
</tbody>
</table>

\(^1\) Cost per acre for Location 2/Stationary Unit was listed incorrectly on report. The total of 69 acres from Location 1/Mobile Unit was applied rather than the 51 acres that should have been applied to make the calculation. The resulting cost of $3.44 per acre was calculated for the corrected 51 acres.
Chipping is an increasingly common alternative to traditional agricultural biomass burning. It eliminates the burning of agricultural biomass altogether. Chipping and then mulching pruning residues and vines can prove beneficial to the overall health of vineyards and similar crops including olive orchards. Pruning residues decompose slowly due to high content of cellulose and lignin, medium to low content of moisture, and a high Carbon-Nitrogen (C/N) ratio, ensuring long lasting soil protection (Ordóñez 1999). Chipping and mulching of vineyard pruning residues and vine waste can be beneficial to the soil health of agricultural fields if incorporated into the soil and can help reduce soil erosion. Ecological agriculture bases the management of soil fertility on organic matter and biological soil processes with increased soil organisms when organic matter is readily available (Repullo 2012). On the other hand, mulching can disadvantageously spread diseases onto healthy vines and provide a food resource for some pathogens, acting as a reservoir for potential infestation in the future (Spinelli et al. 2014).

Chipping agricultural biomass waste can incorporate use of a chipper (Photo 4), or a grinder or shredder in the case that trellis wire is left mixed in with the waste material. Many vineyard growers in Napa Valley have access to chippers, but the cost is substantial and could be cost prohibitive in some cases.

4.2.1 BAY AREA AIR QUALITY MANAGEMENT DISTRICT AGRICULTURAL WASTE CHIPPING PROGRAM

The BAAQMD oversees permits for open burning for agriculture in the nine Bay Area counties. Additionally, they offer the Agricultural Waste Chipping Program as an alternative to open burning. Agricultural operators can apply to participate in the program, following the guidelines provided. Their overall goal is to reduce the amount of emissions from open burning. Convincing vineyard growers to invest in chipping as an alternative helps achieve that goal.

Results from the BAAQMD Agricultural Waste Chipping Program from 2015-2016 reveal that Napa County has the largest volume of chipped material between all Bay Area counties (Tables 4A and 4B) (BAAQMD 2018). In 2015, Napa County participants chipped 7,103 cubic yards of material or approximately 50 percent of the total 14,235 cubic yards chipped across the Bay Area during a six-month program run. In 2016, Napa County participants chipped 5,243 cubic yards of
material or approximately 51 percent of the total 10,289 cubic yards chipped across the Bay Area during a nine-and-a-half-month program (BAAQMD 2018).

Table 4A & 4B. BAAQMD Agricultural Waste Chipping Program: Program Statistics 2015-2016.

### 4A. PROGRAM STATISTICS - 2015

<table>
<thead>
<tr>
<th>Counties</th>
<th>Napa</th>
<th>Sonoma</th>
<th>Santa Clara</th>
<th>Alameda</th>
<th>San Mateo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Projects</td>
<td>21</td>
<td>16</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>42</td>
</tr>
<tr>
<td>Volume Chipped (yd³)</td>
<td>7,103</td>
<td>4,131</td>
<td>41</td>
<td>2,900</td>
<td>60</td>
<td>14,235</td>
</tr>
<tr>
<td>PM₂.₅ Emissions Avoided (lbs)</td>
<td>4,200</td>
<td>2,443</td>
<td>35</td>
<td>1,715</td>
<td>24</td>
<td>8,417 (or 4.2 tons)²¹</td>
</tr>
</tbody>
</table>

### 4B. PROGRAM STATISTICS - 2016

<table>
<thead>
<tr>
<th>Counties</th>
<th>Napa</th>
<th>Sonoma</th>
<th>Santa Clara</th>
<th>Solano</th>
<th>Totals</th>
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<tr>
<td>Number of Projects</td>
<td>14</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>Volume Chipped (yd³)</td>
<td>5,243</td>
<td>1,371</td>
<td>55</td>
<td>3,620</td>
<td>10,289</td>
</tr>
<tr>
<td>PM₂.₅ Emissions Avoided (lbs)</td>
<td>3,100</td>
<td>823</td>
<td>33</td>
<td>2,141</td>
<td>6,097 (or 3.1 tons)²²</td>
</tr>
</tbody>
</table>

The 2017 annual report highlights the potential growth of the Agricultural Waste Chipping Program if more agricultural operators were to switch to chipping. Both the 2017 Annual Report as well as the 2015-2016 statistics for the Agricultural Waste Chipping Program underscore the need for Napa County especially to invest in alternatives to traditional open burning.

4.2.2 CALIFORNIA AIR QUALITY CHIPPING EQIP INITIATIVE

The California Air Quality Chipping Environmental Quality Incentives Program (EQIP) Initiative assists agricultural producers with the chipping of woody debris from removed orchards or vineyards. Specifically, the California Air Quality Chipping EQIP Initiative program assists producers impacted by extreme drought conditions, particularly in areas with severely curtailed or suspended water delivery and no other source of water for continued irrigation (NRCS 2014). The Natural Resources Conservation Service (NRCS) resource concerns or items approved for
financial assistance through the California Air Quality Chipping EQIP Initiative are priority based. The prioritized resource concerns include soil and wind erosion as well as air quality impacts, particularly emissions of PM and PM precursors, emission of GHG’s, and emissions of ozone precursors (NRCS 2014). Only those applicants that can demonstrate immediate impacts of the drought, including economic loss or crop loss due to insufficient irrigation water supply, qualify for funding as the drought worsens in California and growers face sudden crop removal. Specifically, the proposed conservation practices that can be carried out within three months of the contract date are given priority to address the immediate impacts of the drought (NRCS 2014). The potential to divert PM<sub>2.5</sub> emissions from open burning is significant with the California Air Quality Chipping EQIP Initiative programs, as illustrated in Table 5.

Table 5. SJVUAPCD comparison of annual PM<sub>2.5</sub> emissions between open Burning and Shredding.

<table>
<thead>
<tr>
<th>Crop Name</th>
<th>Burn Acres</th>
<th>PM 2.5 Emissions (Tons)</th>
<th>Open Burn</th>
<th>Shred</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almond Pruning</td>
<td>51718</td>
<td>203.0</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>Apple Pruning</td>
<td>331</td>
<td>3.5</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Fig Pruning</td>
<td>558</td>
<td>4.8</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Pear Pruning</td>
<td>110</td>
<td>1.1</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Pecan Pruning</td>
<td>295</td>
<td>2.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Quince</td>
<td>28</td>
<td>0.2</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Walnut Pruning</td>
<td>14236</td>
<td>67.0</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Total:</td>
<td>67336</td>
<td>281.6</td>
<td>6.4</td>
<td></td>
</tr>
</tbody>
</table>

In Fiscal Year 2018, the California Air Quality Initiative for Ozone and PM Reductions is designed to help agricultural producers comply with air quality requirements. Additionally, the initiative offers support for practices that address impacts associated with GHG’s, with financial assistance priority targeting areas identified as having significant air quality concerns. Areas with poorer air quality, such as San Joaquin Valley, are prioritized by being designated as “Nonattainment” or predesignated “Attainment (Maintenance Area)” (Figures 6 and 7) (USDA 2018).

4.3 BIOCHAR

Biochar is the solid residue obtained from the oxygen-limiting conditions or pyrolysis of plant and waste feedstocks when subject to high temperatures between 350-700°C (Lehmann and Joseph 2009). The residue is a specialized form of charcoal that can be combined with compost or similar
nutrient-rich materials (Sonoma Ecology Center (SEC) 2016). The main characteristics of biochar include its high carbon (C) content compared to the raw material, as well as higher stability, porosity, and surface area, which generally vary between 0.5-450m²g⁻¹ (Brassard et al. 2016). The physicochemical properties of biochar produced from any given biomass are influenced by critical pyrolysis parameters including heating rate, highest temperature treatment (HTT), pressure, and reaction residence time (Lehmann and Joseph 2009). Pyrolysis results in the conversion of carbon compounds into stable forms that can degrade slowly (Brassard et al. 2016). In addition to biochar, pyrolysis also produces byproducts of bio-oil and an uncondensed gas that are generally used to produce energy. Pyrolysis conditions and technology determine the final product (Brassard 2016). Biochar is also highly dependent on the type of feedstock and its characteristics, with sustainable raw material sourcing of critical importance to the sustainability of this alternative to traditional agricultural biomass burning.

Some research suggests that applying biochar to agricultural soil can improve soil health, retain soil moisture, increase crop yields, and sequester carbon, keeping carbon out of the atmosphere (SEC 2016). Biochar also has the potential to immobilize pollutants, reducing the risk of pollution caused by leachate and runoff (Brassard 2016). Additionally, biochar could be a great waste management tool to handle agricultural, municipal, and industrial residues. Biosolids, straw, rice husk, maize straw, barley stover, nut shells, and coffee grounds can be pyrolyzed to produce biochar (Brassard 2016). Utilizing biochar to handle both pruning residues and removed vines could have significant benefits for vineyard waste management and benefits in the vineyard itself.

When biochar is applied to soil, the carbon compounds of the biochar can be sequestered in the soil for long periods of time (Brassard et al. 2016). Biochar production from agricultural and forestry wastes such as forest residues, mill residues, field crop residues and urban wastes, has an estimated C sequestration capacity of 0.16 Pg C/yr (Lehmann et al. 2006). The worldwide maximum capacity for storing biochar carbon in agricultural soils totaling approximately 1,411 million hectares is estimated to be about 428 GtC (Lee et al. 2010).

4.3.1 SONOMA COUNTY BIOCHAR PROJECT
Starting in 2013, the Sonoma Ecology Center (SEC) received funding from the NRCS-USDA Conservation Innovation Grant (CIG) program to engage in the Sonoma County Biochar Project. The purpose of this specialized project was to produce biochar from local wood wastes and test its
effectiveness at three local farms (SEC 2016). The CIG program funds innovative, on-the-ground conservation projects, including pilot projects and field demonstrations on a diversity of topics and resource concerns. Projects have included work in soil health, irrigation efficiency, wildlife and pollinator habitat, water and air quality, GHG markets, on-farm energy use and conservation finance. The competitive grant funding comes from the EQIP program, and as such CIG does not fund projects already eligible for funding through EQIP (NRCS-USDA 2018). The innovative Sonoma County Biochar Project tested the overall agricultural impacts of biochar at three field trial experiment sites: Swallow Valley Farm, Oak Hill Farm, and Green String Farm (SEC 2016). The Sonoma County Biochar Project was the first of its kind in California (SEC 2016).

Research suggests that adding biochar, when combined with compost or similar nutrient-rich materials, can improve soil health, retain soil moisture, increase crop yields, and sequester carbon (SEC 2016). To test these outcomes, biochar/compost mixtures were applied in test plots at each site while compost alone was applied in the adjacent control plots (SEC 2016). Prior to application, project staff members confirmed the soil type of each test and control plot to ensure that each site fell entirely within a single NRCS soil characteristics category (SEC 2016). Monitoring the effects of the biochar/compost mix on soil health characteristics and moisture retention capacity were just one of the objectives of the project. Additionally, the project staff members monitored for the quality of biochar being produced, the effects and results of the biochar application on crops grown and harvested, they recorded the farm manager’s overall opinions about the benefits and costs of using biochar, and they analyzed and reported on the overall effectiveness of using biochar as a soil amendment in Sonoma County (SEC 2016).

All three field trial farm sites were impacted by California’s intense drought. The unanticipated lack of irrigation water at Green String Farm caused the project team to alter the trial site chosen, disrupting the planned experiment schedule (SEC 2016). Additionally, measured biochar impacts at Swallow Valley Farm were disrupted by grazing animals getting through the temporary fencing around the test and control plots (SEC 2016). The most successful results were seen at Oak Hill Farm, but after irrigating the biochar/compost test plot equally to the control plot, some of the farmer’s winter squash plants became too large to be market-acceptable (SEC 2016).
4.3.1.1 **Adam Retort Biochar Production Machine**

The Adam Retort biochar production pyrolysis machine was chosen to make the biochar for the Sonoma County Biochar Project (Photo 5). It was deemed the most appropriate for community-scale, on-farm use based on design, operation, and cost, producing excellent high-quality biochar while operating with minimal air emissions (SEC 2016). The project team learned that while the Adam Retort runs very productively and efficiently, its gasifier start-up system had some operational challenges. The gasket seals on the top to the tub did not always remain tight enough to ensure adequate closure, with heat warping some of the metal closure (SEC 2016). Also, there was difficulty keeping the water-based condenser functioning properly (SEC 2016). Furthermore, the operation of the Adam Retort created more liquid wastes or “wood vinegar” than initially anticipated. Each run of the machine generated about 45 gallons of the “wood vinegar” by-product that requires a high level of careful onsite storage and handling (SEC 2016). This additional management waste issue has the potential for commercial sale as it can be used for personal health and to promote soil health but comes with additional management costs.

Throughout the course of the Sonoma County Biochar Project, the team learned that the total amount of skilled labor required to operate the Adam Retort was much higher than anticipated, requiring direct, hands-on supervision at all times during operation (SEC 2016). It took approximately 12 hours of labor to complete each full operational production cycle, including loading the tub with feedstock, starting the burn cycle with the gasifier, running the complete pyrolysis cycle, and waiting for the machine to cool before unloading the biochar from the tub (SEC 2016). Prior to feeding agricultural biomass waste into the Adam Retort, it is necessary to run the feedstock through a chipper, grinder, or shredder, costs that were assumed in general operations and not analyzed in the overall cost of operation of the Adam Retort. The project team learned that the overall labor costs associated with the Adam Retort daily operation exceed the commercial value of the approximate 500 pounds of biochar produced in each production run. The cost prohibitive research results led the Sonoma County Biochar Project to discontinue operation of the Adam Retort at Swallow Valley Farm. At the end of the three-year project run, SEC and the Sonoma County Water Agency were actively looking to donate the Adam Retort to a local educational organization in Sonoma County in hopes that it could prove effective for research and educational purposes (SEC 2016). Without significant funding to develop this alternative for
community scale, on-farm use of the Adam Retort or similar equipment, biochar pyrolysis machines may prove cost prohibitive for agricultural producers.

4.4 BIOENERGY: GRAPEVINE BIOMASS RESIDUES AS ALTERNATIVE FUEL

Grapevine biomass residues can be used as alternative fuels within energy conversion chains, driving renewable energy exploration as an alternative to traditional agricultural biomass burning. Agriculture generates large amounts of biomass residues, and while alternatives such as chipping and mulching and biochar return biomass residues to the field for nutrient recycling and erosion control purposes, some residues could be used to produce energy without harming the soil (Marculescu and Ciuta 2013). Vineyard pruning residues can be used as wood biomass to produce energy, potentially achieving energy self-sufficiency for vineyards (Fernández-Puratich et al. 2015). Furthermore, the wine industry generates large amounts of biomass waste every year, estimating that for every kilogram of grape processed into wine, more than 20 percent is residue (Ministry of Agricultural and Rural Development 2009). The potential to convert grapevine biomass residues into energy is potentially a valuable alternative to develop.

4.4.1 BIOFUEL

Renewable energy produced from agricultural raw materials is extremely complex. One of the complications of biomass fuel production is locating a consistent source of biomass. Waste biomass such as vine shoots and olive tree pruning residues could be a large and constant source of biomass, as these products must be disposed of regularly (Torquati et al. 2016). In the Maule region of Chile, the physical and energetic characteristics of the wood biomass chippings of five grape varietals were studied to establish their potential as solid biofuel, compared with pine pellets, the most commonly used solid biofuel in the industry (Fernández-Puratich et al. 2015).

Once grapes are pressed into wine, the main industry waste represents grape pomace (marc) containing grape skins, pulp, seeds, and stems. Worldwide grape marc is treated differently. In some regions grape seeds are recovered for food consumption and made into pomace brandy, used to make perfumery, pharmaceuticals, soaps, feed or fertilizer (Marculescu and Ciuta 2013). In Canada, Italy and France marc is used to produce energy. Additionally, grape marc can be applied as a post-harvest compost to vineyards to recycle nutrients on site. While energy recovery is perhaps less exploited, a problem for the energy valorization of the product is represented by the
seasonality of grapes, which are available only for 2-3 months per year (Marculescu and Ciuta 2013). Determining the optimum pyrolysis treatment may successfully overcome the fast degradation properties of grape marc, transforming it into high carbon content derived fuels that can be stored and rendering the pyrolysis process self-sufficient (Marculescu and Ciuta 2013).

4.4.2 WASTE TO ENERGY FACILITIES
The analysis of the agro-energetic chain requires a multidisciplinary approach, encompassing four main approaches: spatial, technical-engineering, economic, and environmental analyses (Torquati et al. 2016). Spatial analysis identifies sources or areas that can provide biomass for energy production, evaluates land suitability of areas, identifies transportation logistics, and locates property boundaries (Torquati et al. 2016). The spatial approach could be useful particularly for county or state agencies responsible for grower assistance, compliance, and for evaluating the regional biomass availability in considering biomass plant development or expansion. Technical-engineering evaluations of biomass shredders, biomass conversion plants, and the physico-chemical properties of the biomass itself help explain the conversion process (Torquati et al. 2016). Cost-benefit analyses including transportation costs and potential profitability, sustainability, and cost of the energy produced of specific agro-energetic chains comprise the economic approach (Torquati et al. 2016). Environmental analyses assess the environmental impact of renewable energies and help identify technologies to minimize GHG emissions (Torquati et al. 2016).

Larger agro-energetic chains may not be sustainable. In an attempt to support agricultural producers growing, harvesting, and transporting biomass to waste-to-energy facilities, the USDA-Farm Service Agency (FSA) offers the Biomass Crop Assistance Program (BCAP) (USDA-FSA 2016). BCAP funding does not go directly to waste-to-energy or biomass conversion facilities, but rather supports the continued availability and delivery of BCAP funded biomass (USDA-FSA 2016).

In an attempt to establish a shorter agro-energetic chain, Napa Recycling and Waste Services proposed two small biomass gasification plants located at local facilities to divert wood and vineyard waste from burning (Napa Recycling and Waste Services 2017). Through biomass gasification, renewable energy could be produced. Furthermore, the compost and biochar produced by the biomass facilities could potentially be sold to local consumers. Future funding support could make this proposal a reality in Napa County.
### 4.5 Comparative Analysis

In the literature, there are suggested ecological benefits for each of the alternatives to traditional agricultural biomass burning, implied equipment and labor costs to consider, other operational nuances like associated job risk and required job training, as well as information on the existing and potential funding programs for alternatives. A synthesized breakdown of this data is listed in Table 6. It is important to note that with each alternative, there are disadvantages that correlate with some type of emission, including emissions from low-smoke burning, agricultural equipment and hauling. Assessing the practicability of each alternative is critical.

Table 6. Comparative Analysis Table with Overview of Each of the Alternatives to Traditional Agricultural Biomass Burning.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Ecological Benefits &amp; Incentives for Growers</th>
<th>Equipment &amp; Labor Costs</th>
<th>Associated Job Risks for Farmworkers</th>
<th>Funding Opportunities</th>
<th>Disadvantages for Prescribed Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Smoke Ag Burning</td>
<td>Low</td>
<td>$</td>
<td>Low Risk</td>
<td>None-Low Opportunity</td>
<td>Smoke/PM$_{2.5}$ Emissions</td>
</tr>
<tr>
<td>Low-Smoke Ag Burning with Burn Boss ® Air Curtain</td>
<td>Low</td>
<td>$§</td>
<td>Moderate Risk</td>
<td>Moderate Opportunity</td>
<td>Equipment, Hauling, &amp; Smoke/PM$_{2.5}$ Emissions</td>
</tr>
<tr>
<td>Chipping &amp; Mulching</td>
<td>High</td>
<td>$§</td>
<td>Moderate Risk</td>
<td>Good Opportunity</td>
<td>Equipment &amp; Hauling Emissions</td>
</tr>
<tr>
<td>Biochar</td>
<td>High</td>
<td>$$$$$</td>
<td>Moderate Risk</td>
<td>Good Opportunity</td>
<td>Equipment, Hauling, &amp; Smoke/PM$_{2.5}$ Emissions &amp; “Wood Vinegar” Waste Management</td>
</tr>
<tr>
<td>Grapevine Biomass Residues as Alternative Fuel</td>
<td>Moderate</td>
<td>$$$$$</td>
<td>Moderate Risk</td>
<td>Moderate Opportunity</td>
<td>Transportation &amp; Equipment Emissions</td>
</tr>
</tbody>
</table>
4.5.1 ECOLOGICAL INCENTIVES FOR GROWERS
Ecological benefits or incentives are important to ecologically conscious growers and farmers, but also are the goal of financially driven investors wanting to promote standout wine in a saturated market. Already in Napa County, vineyards and the subsequent wines can apply for Fish Friendly Farming certification, creating farm plans to minimize soil runoff into creeks and streams, Napa Green Land or Winery membership, California Sustainable Winegrowing Alliance certification, as well as organic or biodynamic certification. Vineyard waste is a disposal dilemma each year, with resulting costs incurred each year to manage vineyard waste. If that waste could be managed in an ecologically sustainable way to give back to the development and maintenance of the vineyard, it would be a win-win scenario for growers and farmers who could promote more sustainable wine products while reaping the ecological benefits. Like Integrated Pest Management (IPM), implementing alternatives to traditional agricultural biomass burning such as chipping and mulching or biochar can have direct benefits to the vineyard. The cost of labor, equipment, permits, and insurance could be offset by decreased bills for running irrigation systems, for instance, if water retention could be increased by alternatives to traditional agricultural biomass burning.

Low-smoke agricultural burning, both with and without the BurnBoss machine, results in ash from the burned biomass. This ash can be reintroduced into the vineyards as a soil amendment. The overall ecological benefits of this process remain minimal but low-smoke agricultural burning can decrease smoke and PM$_{2.5}$ emissions. The Conservation Burn Technique recommended by the Sonoma Biochar Initiative is a variation of the low-smoke agricultural burning recommended by the Napa Valley Grapegrowers.

4.5.2 FINANCIAL INCENTIVES FOR GROWERS
Financial incentives for growers to actively implement alternatives to traditional agricultural biomass burning are obvious if the cost of such alternatives results in budget offsets throughout the growing season. Even with EQIP program funding, growers must pay costs upfront and wait for reimbursement for the implemented program measures. Increasing the amount of funding support available to growers as well as streamlining program priorities to include measures for alternatives to traditional agricultural biomass burning are critical. Equally important is emphasizing the potential costs that growers may recoup through, for example, less frequent irrigation after biochar application or reduced soil erosion material costs after applying chipped
mulch to vineyards. Additionally, financial incentives could be offered to growers purchasing chippers as a way to subsidize the high cost of such equipment.

4.5.3 JOB RISK TO FARMWORKERS ASSOCIATED WITH EACH ALTERNATIVE

Traditional agricultural biomass burning is not without risks to the farmworkers performing the activity, including risks associated with equipment such as rippers for vineyard removal, risks with igniting the burn piles, and inhalation of smoke emissions and PM$_{2.5}$. Likewise, the alternatives to traditional agricultural biomass burning also result in potential job risks to farmworkers. Training farmworkers on the procedure and hazards of each alternative may result in additional costs. High turnover of farmworkers would increase this cost.

Low-smoke agricultural burning still presents farmworkers with the hazards of vineyard removal as well as starting burns, using open flames, and working around the burning piles while inhaling PM$_{2.5}$. The risk of a controlled burn turning into a wildfire may seem low, but when it does happen the results can be disastrous. In the case of the BurnBoss Air Curtain Burner, farmworkers must know how to use the equipment, load the material and burn vineyard pruning residues or removed vines at a rate to keep the fire going.

Heavy equipment is required for the chipping and mulching of vineyard pruning residues and removed vines, with chippers most commonly used but grinders and shredders also used for larger biomass or in the case that trellis wire is not completely removed. After pruning or vineyard removal, vines must be handfed into a chipper. Farmworkers must use personal protective equipment (PPE) including gloves, safety glasses, and possibly ear plugs and a hard hat as well. Regardless of proper use of PPE, vines can bounce out of the chipper and strike farmworkers. If proper care and attention are lacking, farmworkers also risk serious injury while operating and cleaning chippers, including lacerations, amputation, and even death if they are entangled in the moving parts. Chipper operation requires trained personnel. Currently there are no certification programs dedicated to chipper safety as there are for forklift or ATV safety. Additionally, chipper manuals are readily available but only in English.

Agricultural biomass used as feedstock for biochar must first be removed and then chipped with a chipper, grinder, or shredder. Pyrolysis produced biochar can include Conservation Burn Technique similar to low-smoke agricultural burning with similar job risks. Additionally, pyrolysis
machines like the Adam Retort can be used to make biochar but they run at very high temperatures and require constant trained supervision during operation. Safety training around pyrolysis machines is not developed and information on the equipment is available only in English.

Moving agricultural biomass waste to waste-to-energy or biomass conversion facilities requires equipment to remove vines, load the vineyard waste for transport and then hauling the biomass to such facilities. Larger agro-energetic chains increase farmworker exposure to equipment and transportation dangers. If there is a way to use vineyard biomass on site, then a chipper, grinder, or shredder would be required to make the biomass available for use.

The labor hours that farmworkers operate heavy equipment for each alternative must be thought about in terms of job risks to farmworkers but also in terms of the costs for safety training. While workers’ compensation companies and local organizations offer periodic safety trainings free of charge, more specialized training on specific pieces of equipment require additional training. Agricultural producers incur these costs along with costs for the personal protective equipment (PPE) required for each task. Each piece of equipment has a correlating insurance cost as well, regardless if the equipment is owned or rented.

5. MANAGEMENT RECOMMENDATIONS

Each alternative to traditional agricultural biomass burning evaluated in this paper represents a step in the right direction. It is crucial for growers and farmers to invest and strategize to protect public health and mitigate for climate change. This must be the goal even when managing for vineyard pests and disease by minimizing smoke output. Community collaboration as well as support from local, state, and federal authorities and organizations is vital.

After evaluating each alternative to traditional agricultural biomass burning, low-smoke agricultural burning and chipping and mulching are recommended as the most sustainable and practicable alternatives to implement in Napa Valley. These alternatives are already being implemented but the technology and support for further investment and application is critical for the greatest diversion of traditionally openly burned agricultural waste.

Low-smoke agricultural burning is an optimal alternative that requires just slightly more planning than traditional agricultural biomass burning. Further planning and preparation, including cleaning
the vines as much as practicable of all dirt and organic matter and tarping the burn piles, are required to minimize the emissions from the burn. This alternative can also be applied when managing for pests and disease in the vineyard, making it the most practicable of the alternatives. Additionally, the ash can be returned to the vineyard as a soil amendment. Low-smoke agricultural burning already has industry support and a set of recommended best practices. Building upon these efforts, implementing this alternative would be possible immediately.

Likewise, chipping and mulching is a sustainable and practicable alternative that can be expanded upon in Napa Valley. Chipping and mulching offers ecological incentives for vineyard growers to invest in this alternative, including the recycling of nutrients, improving soil health, and reducing soil erosion. If more funding support was made available, this alternative could be fully developed in Napa Valley. Particularly, building upon preexisting funding programs could be the key to diverting GHG emissions, PM$_{2.5}$, and ozone emissions from burning.

Following the devastating wildfires in 2017, Cal Fire offered chipping services beyond their regular chipping program for residents in fire prone areas of the county. Recognizing that on-site chipping can be beneficial to landowners dealing with immediate agricultural waste and disturbed land issues, local agencies stepped up and offered their support free of charge. Conversely funding to help growers replace erosion control measures in affected wildfire areas had very strict parameters attached to it. Through the Fish Friendly Farming program, grant opportunities to replace erosion control measures were made available but with funding only obtainable later in 2018. This funding opportunity required that all work be completed after approval. Inherently, it disqualified a lot of applicants that had to immediately replace erosion control measures in November and December of 2017 after the fires and in time for winter rains. These challenges to funding and the real time needs of vineyard growers must be taken into account in terms of making chipping and mulching an accessible and sustainable alternative. With funding support, chipping and mulching can become an ideal alternative to traditional agricultural biomass burning with the potential to secure the ecological benefits of this alternative year-round.

5.1 Education and Outreach Recommendations

Collaboration between agricultural producers in Napa Valley and state and local agencies is key to achieving greater participation in alternatives to traditional agricultural biomass burning. The
working relationship between agricultural producers and agencies should go beyond regulatory enforcement to include partnership and funding opportunities, increasing educational and training opportunities, increasing accessibility to educational as well as regulatory information in languages other than English, and developing safety guidelines for farmworkers.

5.1.1 Partnership and Funding Opportunities for Developing Alternatives
Collaboration and funding opportunities are key for developing alternative technologies and participation rates in alternatives to traditional agricultural biomass burning. As in the example of the eradication of the EGVM in Napa County and California, support, communication, educational seminars, streamlining of permits, and in-the-field outreach are necessary to get agricultural producers to buy into best management practices (BMP) and measurable goals beneficial to the entire agricultural community. It is in the best interest of the agricultural community and the larger public that GHG emissions, PM$_{2.5}$, and ozone emissions be reduced in managing for agricultural biomass waste. Currently most of the financial burden to implement alternatives to traditional agricultural biomass burning fall of the individual agricultural producer, with limited funding opportunities for agricultural producers in Napa Valley.

Low-smoke agricultural burning is a relatively low-cost alternative to traditional agricultural biomass burning. In addition to costs associated with vineyard removal, anticipated costs must account for the tarps needed to keep the center of the burn piles dry and a hand torch to ignite the piles. The NVG Burn Task Force could further develop curriculum to support vineyard growers adapting to low-smoke agricultural burning. The NVG and the Napa Valley Farmworker Foundation have many business sponsors as well as agency collaborators for most of their events. It would be great if more sponsorships could be secured to further develop low-smoke agricultural burning training curriculum in English and Spanish as well as indigenous languages including Zapotec, Mixtec, and Triqui, and offer educational training opportunities at no cost to farmworkers. Furthermore, it is strongly recommended that the BAAQMD have a representative available at such educational training opportunities to answer open burn compliance questions but also to promote their Agricultural Waste Chipping Program.

Low-smoke agricultural burning can turn costlier with the use of the BurnBoss Air Curtain Burner. If enough local interest is generated, it would be beneficial to see a funding opportunity created for vineyard growers to purchase or rent the BurnBoss as part of a grant program. Much like grant
programs that exist to update or replace non-efficient agricultural equipment, funding could be strung together from investors to be matched by agencies to encourage another form of low-smoke agricultural burning.

Perhaps the greatest opportunity for funding exists with chipping and mulching as the prescribed alternative to traditional agricultural biomass burning. The BAAQMD Agricultural Waste Chipping Program has a limited annual budget of $150,000 for chipping activities. Driving up participation and applicant rates for the Agricultural Waste Chipping Program could possibly positively impact this budget and create more opportunities for participation. However, while the BAAQMD staff are currently available by contacting them directly with questions regarding their programs, they do not actively recruit participants for the Agricultural Waste Chipping Program at educational or industry seminars and events. While many vineyard growers have managed to acquire their own chipping equipment, it still can be cost prohibitive for some to invest in this alternative. Having BAAQMD representatives available at local educational training opportunities to assist with applications and streamline approval for the Agricultural Waste Chipping Program would be extremely beneficial. Additionally, opportunities exist to further entice growers and farmers to implement alternatives particularly through targeted assistance such as the USDA Natural Resources Conservation Service (NRCS) California Environmental Quality Incentives Program (EQIP). As such, representatives from the NRCS-USDA would be a great addition to any such events to also promote funding programs already in place, but more importantly for those representatives to gain deeper understanding of the logistical challenges and needs vineyard growers and farmworkers must confront applying chipping and mulching as the primary alternative to traditional agricultural biomass burning. Safety training curriculum must also be developed for operation of any chipper, grinder, or shredder, including safety training curriculum in languages other than English. Grant funding to bring such training to farmworkers would be ideal. Like NVG train-the-trainer workshops on forklift and ATV safety, train-the-trainer certification could be offered for chippers, grinders, or shredders provided that funding for such programming can be obtained.

Developing biochar as a sustainable and practicable alternative to traditional agricultural biomass burning would require substantial funding from private investors and local, state, and federal agencies. Even the Sonoma County Biochar Project that received NRCS-USDA Conservation
Innovation Grant (CIG) funding could not manage operating costs of the Adam Retort biochar production pyrolysis machine after the conclusion of the three-year funded project. Moving any biochar initiatives or field trial experiments beyond the experimental phase would involve significant planning, preparation, and investment. Without proper funding in place, this alternative may not be sustainable to implement.

Likewise, using grapevine biomass as an alternative fuel would require substantial funding and infrastructure development in proximity to Napa Valley. Unless waste-to-energy applications can be realized on-site in vineyards or wineries, the large agro-energetic chain associated with the transportation of agricultural biomass waste to waste-to-energy or biomass conversion facilities would prove unsustainable. Potential funding from the USDA-FSA could help facilitate the transport of agricultural biomass waste from Napa Valley to such facilities, but those funding opportunities need to be further researched and the practical applications require further development.

5.1.2 ACCESSIBILITY TO EDUCATIONAL AND REGULATORY INFORMATION IN LANGUAGES OTHER THAN ENGLISH

Currently, the BAAQMD website offers information on open burns, including permit information, in Spanish as well as Tagalog, Vietnamese, and Chinese (BAAQMD 2016). However, the downloadable PDF’s available on open burning as well as chipping program requirements are only available in English. Moreover, the BAAQMD open burn line phone number to check the permissible burn day status is only available in English. Operators are available to assist during regular business office hours. Many farmworkers, including supervisory staff, need access to such important information in languages other than English, and such information must be readily accessible as most farming operations start the day well before business office hours. The California Air Resources Board (CARB) website information is only available in English.

Most equipment manuals and training materials are only available in English. The BurnBoss Air Curtain Burner, for example, offers very detailed information on how to operate the BurnBoss with diagrams, warnings, how-to-tow information, and recommendations on how to feed and shutdown the fire (Air Burners, Inc. 1998-2018). This information is only available in English. Chipper manuals are also only readily available in English, making it difficult to educate farmworkers or mechanics that may speak a different language, requiring assistance to order
replacement parts. It is of necessity that this information be made readily available in languages other than English to improve compliance, education, and training capacitisation.

5.1.3 Safety Guidelines for Farmworkers

There are currently no regulations overseeing the safety of farmworkers performing agricultural biomass burning or alternatives to traditional agricultural biomass burning. Safety glasses and gloves are recommended for open burning by the BAAQMD and are also recommended for chipping. However, the use of the N-95 particulate filtering face piece respirators or other face masks is not required. Legally, it is rather difficult to require that farmworkers performing agricultural burns wear the N-95 particulate respirators due to the California Code of Regulations governing respiratory protection. When employers require their employees to use respirators, they must establish a written respiratory protection program, and ensure medical evaluations and fit tests for each designated employee that will be assigned work with a respirator (California Department of Pesticide Regulation 2008). Establishing a voluntary respirator policy, employers do not have to comply with as many regulations as long as the voluntary program only involves the use of filtering face pieces (California Department of Pesticide Regulations 2008). The need for guidelines for face pieces or masks while burning became painfully evident during the devastating wildfires in Napa County in fall 2017. Furthermore, the goals of implementing alternatives to traditional agricultural biomass burning include minimizing the negative impact on public health. It is imperative to set the example and protect the health of the farmworkers performing agricultural burns.

5.2 Policy Recommendations

The final draft of the Napa County CAP underscores the public desire and the need to reduce GHG emissions and implement measures to reduce traditional agricultural biomass burning in Napa County. While the proposed measures to reduce GHG emissions acknowledge the regulatory authority of the BAAQMD concerning the burning of agricultural waste, it is imperative that before the county attempts to adopt and enforce such measures that winegrape growers and the organizations that represent them be consulted and included in the process. Efforts should also be made to educate the larger public on the duration of the open burn season, especially after so many were traumatized by the devastating 2017 wildfires, and educate on the importance of burning as a tool to manage for pests and disease in the vineyard.
6. LITERATURE CITED


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Figure 1. Napa Valley Vintners map of Napa Valley Appellation and its 16 different sub-appellations.
Figure 2. CA regulated areas of EGVM, 2009 to 2014 (Cooper et al. 2014).
Figure 3. Napa County 2014 GHG emissions by emission sector as outlined in the Napa County Climate Action Plan Final Draft.
Figure 4. The principle of air curtain burning as can be seen with the BurnBoss Air Curtain Burner.
Figure 5. SJVUAPCD Average Annual PM$_{2.5}$ emissions from the San Joaquin Valley. Map also shows location of existing as well as proposed biomass plants.
Figure 6. USDA map of EPA region 9 designations for the 1997 and 2012 annual PM$_{2.5}$ National Ambient Air Quality Standards (NAAQS). EPA Region 9: [https://www3.epa.gov/region9/air/maps/](https://www3.epa.gov/region9/air/maps/).
Figure 7. USDA map of EPA region 9 designations for the 2008 8-hour Ozone National Ambient Air Quality Standards (NAAQS). EPA Region 9: https://www3.epa.gov/region9/air/maps/.
8. Photo Appendix


Photo 3. Burn Boss® Air Curtain Burner modified with cage. Photo credit: San Joaquin Valley Air Pollution Control District.

Photo 5. Adam Retort biochar production pyrolysis machine. Photo credit: Sonoma Ecology Center.