Benefit Cost Analysis of Wine Australia R&D Investments 2018-19

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Table of Contents

Executive Summary

Economic analyses of three research and development (R&D) projects funded by Wine Australia have been undertaken. The main purpose was to demonstrate the outcomes and benefits that have emerged or are likely to emerge from investment. This forms part of the process for the Council of Rural Research & Development Corporations (CRRDC) that aims to demonstrate the impact, effectiveness and return on investment from the Rural Research and Development Corporations. Wine Australia is funded by statutory levies paid by industry participants, with matching funding provided by the Australian Government up to 0.5 per cent of the industry's gross value of production.

Each of the three analyses provides a description of the constituent projects including objectives, outputs, activities, costs, outcomes, and benefits. Benefits are described qualitatively according to their contribution to the triple bottom line of economic, environmental and social benefits. While a range of potential benefits of each project are identified, the analysis focused on the most likely and most significant benefit stream. A number of potential benefits therefore remained unquantified and hence the estimated net benefits of some projects may be considered conservative. The analyses were undertaken for total benefits and Wine Australia benefits, including those expected in the future as a result of the investment.

Investments in two of three projects yielded positive results at a 5% discount rate and a 30 year analysis period. The third project (UA 1503) was close to 'breakeven' with a benefit-cost ratio of 0.98. When core analysis assumptions were subject to sensitivity testing, two projects (UA 1503 and CSP 1303) produced benefit-cost ratios less than one for 'lower end' assumptions – Table ES1.

Table ES1: Benefit Cost Analyses Three Wine Australia R&D Investments 2018-19 (discount rate 5%)

Investment Criteria	Investment Project		
	Epigenetic Memory (UA 1503)	**In-Canopy Misters (UA 1502)**	**Toward Mildew Resistant Selections for 'Cool' Regions (CSP 1303)**
Benefit–cost ratio	0.98	4.36	2.24
Benefit-cost ratio range - core assumption sensitivity	0.49 to 2.28	2.18 to 10.42	0.89 to 6.39
Potential unquantified benefits	Additional scientific knowledge on the epigenetic response of long lived plants to environmental stresses.	Additional scientific knowledge on the value and application of evaporative cooling systems.	Future research cost savings with new techniques for rapid assessment of fruit and micro scale wine making.
		Long term protection of the grape and wine industry in warm inland areas with income and employment maintenance.	Less chemical sprays – reduced risk of spray drift, less greenhouse gas, less risk of residues in wine.
			Additional scientific knowledge and new techniques for grapevine genetic selection.
			Production and consumption of lower alcohol wines with the potential for improved human health outcomes.
			Long term advancement of the grape and wine industry which will maintain income and employment in regional areas.

Comparisons between project results should be made with caution due to uncertainties involved with assumptions and differing frameworks for each of the analyses.

Technical Summary

This report presents the results of economic analyses of investments within the R&D Program of Wine Australia. The Program is funded by statutory levies paid by industry participants, with matching funding provided by the Australian Government up to 0.5 per cent of the industry's gross value of production.

The main purpose of undertaking the analyses was to demonstrate the outcomes and benefits that have emerged or are likely to emerge from investments. This forms part of the process for the Council of Rural Research & Development Corporations (CRRDC) that aims to demonstrate the impact, effectiveness and return on investment of the Rural Research and Development Corporations.

In 2018-19 Wine Australia shifted away from a focus on individual projects to larger, longer term bilateral agreements. Consequently, only a small number of projects were completed in 2018-19 and these projects were a subset of total Wine Australia R&D.

Wine Australia provided AgEconPlus with a list of the completed projects which the analyst numbered 1 to 7. An online random number generator was used to select projects until total selection exceeded $440,000, the equivalent of 10% of the completed total project cost. The results of random project selection, in the order in which they were selected, is shown in Table 1.

Table 1 Projects Randomly Selected for Benefit Cost Analysis 2018-19

No.	Code	Project Title	Program	Investment
7	UA 1503	Epi-breeding - Using the epigenetic memory of stress to prime Australian grapevines for a changing environment.	Climate adaptability	195,176
6	UA 1502	Using in-canopy misters to mitigate the negative effects of heatwaves on grapevines.	Climate adaptability	222,609
3	CSP 1303	Towards elite mildew resistant selections suitable for industry use.	Enhancing grapevine and rootstock performance	1,814,182
Investment in projects for analysis				2,231,967
Total of Wine Australia investment in completed projects				4,428,782
Analysis projects share of total investment				50%

Documentation for each of these projects was assembled with assistance from Wine Australia personnel and included project applications, contract schedules and final reports. Each of the analyses provides a description of the constituent projects including objectives, outputs, activities, costs, outcomes and benefits. Benefits are described qualitatively according to their contribution to the triple bottom line of economic, environmental and social benefits. While a range of potential benefits of each project are identified, the analysis focused on the most likely and most significant benefit stream. A number of potential benefits therefore remained unquantified and hence the estimated net benefit of some projects may be considered conservative.

Benefit cost analysis was conducted on the three projects to generate investment criteria. The Present Value of Benefits (PVB) and Present Value of Costs (PVC) were used to estimate investment criteria of Net Present Value and Benefit-Cost Ratio (BCR) at a discount rate of 5%. The Internal Rate of Return and Modified Internal Rate of Return were also estimated from the annual net cash flows. The PVB and PVC are the sums of the discounted streams of benefits and costs. All dollar costs and benefits were expressed in 2019 dollar terms. Future costs and benefits were discounted to the 2019 year while past costs were inflated to 2019 using the Gross Domestic Product deflator. A 30-year benefit time frame was used in all analyses, with benefits estimated for 30 years from the year of last capital investment in each project. Costs for the R&D

projects included cash contributions (includes both Wine Australia and industry investment), as well as any other resources contributed by third parties (e.g. researchers or additional industry funds). Investment criteria were reported for 5 year intervals of benefits from zero to 30 years.

The analyses were undertaken for total benefits, including benefits expected in the future as a result of the investment. A degree of conservatism was used when finalising assumptions.

Sensitivity analysis was undertaken for several assumptions that had the greatest degree of uncertainty or for those that were seen to be key drivers of the investment criteria.

Some identified benefits were not quantified mainly due to:

- A suspected, weak or uncertain scientific or causal relationship between the research investment and the actual R&D outcomes and associated benefits; and/or
- The magnitude of the value of the benefit was thought to be only minor.

Table 2 presents the investment criteria for each of the projects analysed at a 5% discount rate and expressed in 2019 dollar terms. Given the assumptions made for each evaluation, two of the three investments are expected to produce positive net benefits over 30 years from the last year of investment. The third investment (UA 1503) is expected to come close to 'breakeven'.

Table 2: Benefit Cost Analyses for Three Wine Australia R&D Investments 2018-19 (discount rate 5%)

Investment Criteria	Investment Project		
	Epigenetic Memory (UA 1503)	**In-Canopy Misters (UA 1502)**	**Toward Mildew Resistant Selections for 'Cool' Regions (CSP 1303)**
Present value of benefits ($m)	0.58	6.34	11.60
Present value of costs ($m)	0.59	1.45	5.17
Net present value ($m)	-0.01	4.89	6.43
Benefit–cost ratio	0.98	4.36	2.24
Benefit-cost ratio range - core assumption sensitivity	0.49 to 2.28	2.18 to 10.42	0.89 to 6.39
Internal rate of return (%)	4.9	17.4	9.0
Modified internal rate of return (%)	4.9	9.9	7.4
Potential unquantified benefits	Additional scientific knowledge on the epigenetic response of long lived plants to environmental stresses.	Additional scientific knowledge on the value and application of evaporative cooling systems.	Future research cost savings with new techniques for rapid assessment of fruit and micro scale wine making.
		Long term protection of the grape and wine industry in warm inland areas with income and employment maintenance.	Less chemical sprays – reduced risk of spray drift, less green-house gas, less risk of residues in wine.
			Additional scientific knowledge and new techniques for grapevine genetic selection.
			Production and consumption of lower alcohol wines with the potential for improved human health outcomes
			Long term advancement of the grape and wine industry which will maintain income and employment in regional area.

1. Introduction

This report presents the results of economic analyses of investments within the R&D Program of Wine Australia. The Program is funded by statutory levies paid by industry participants, with matching funding provided by the Australian Government up to 0.5 per cent of the industry's gross value of production.

The main purpose of undertaking the analyses was to demonstrate the outcomes and benefits that have emerged or are likely to emerge from investments made in the program. This forms part of the process for the Council of Rural Research & Development Corporations (CRRDC) that aims to demonstrate the impact, effectiveness and return on investment from the Rural Research and Development Corporations.

Three R&D projects were randomly selected by AgEconPlus for evaluation.

Ascertaining the extent of benefits that have accrued as a result of the program investment can demonstrate to stakeholders such as levy payers, the impact of research investment. In addition, it can inform Wine Australia management regarding program performance from past investment decisions as well as for future allocation of program resources.

A summary of methods used in the analysis, is provided in Section 2, including the process of project selection and the steps involved with individual benefit evaluation. Section 3 reports a summary of the benefits and of the investment criteria estimated for the three projects. A brief conclusion is provided in Section 4. Appendices 1 to 3 provide the detailed analyses for each of the projects.

2. Materials and Methods

2.1 Projects for Evaluation

In 2018-19 Wine Australia shifted away from a focus on individual projects to larger, longer term bilateral agreements. Consequently, only a small number of projects were completed in 2018-19 and these projects were a subset of total Wine Australia R&D.

Wine Australia provided AgEconPlus with a list of the completed projects which the analyst numbered 1 to 7. An online random number generator was used to select projects until total selection exceeded $440,000, the equivalent of 10% of the completed total project cost. The results of random project selection, in the order in which they were selected, is shown in Table 2.1.

Table 2.1 Projects Randomly Selected for Benefit Cost Analysis 2018-19

No.	Code	Project Title	Program	Investment
7	UA 1503	Epi-breeding - Using the epigenetic memory of stress to prime Australian grapevines for a changing environment.	Climate adaptability	195,176
6	UA 1502	Using in-canopy misters to mitigate the negative effects of heatwaves on grapevines.	Climate adaptability	222,609
3	CSP 1303	Towards elite mildew resistant selections suitable for industry use.	Enhancing grapevine and rootstock performance	1,814,182
			Investment in projects for analysis	2,231,967
			Total of Wine Australia investment in completed projects	4,428,782
			Analysis projects share of total investment	50%

2.2 Individual Analyses

Each investment was evaluated through the following steps:

1. Information from the original project application, revised schedule and final report or other relevant reports and material was assembled with assistance from Wine Australia.
2. An initial description of the project background, objectives, activities, costs, outputs and expected outcomes and benefits was drafted. Additional information needs were identified.
3. Telephone and email discussions were held with relevant Wine Australia personnel and principal investigators.
4. Further information was assembled where appropriate, including from contact with key industry representatives, and the quantitative analysis undertaken.
5. Some analyses proceeded through several drafts, both internally within the project team as well as externally via Wine Australia personnel and others.
6. Final drafts were passed to Wine Australia personnel for comment.

The potential benefits from each investment were identified and described in a triple bottom line context. The value of some of these benefits was then quantified.

The factors that drive the investment criteria for R&D include:

- The cost of the R&D.
- The magnitude of the net benefit per unit of production affected; this net benefit per unit also takes into account the costs of implementation.
- The quantity of production affected by the R&D, in turn a function of the size of the target audience or area, and the level of initial and maximum adoption ultimately expected, and level of adoption in the intervening years.
- The discount rate.
- The time elapsed between the R&D investment and commencement of the accrual of benefits.
- The time taken from first adoption to maximum adoption.
- An attribution factor can apply when the specific project or investment being considered is only one of several pieces of research or activity that has contributed to the outcome being evaluated.

It is also necessary when quantifying benefits to define a 'without R&D' scenario, referred to as the 'counterfactual'. The counterfactual usually lies somewhere between the status quo or business as usual case and the more extreme positions that the research would have happened anyway but at a later time; or the benefit would have been delivered anyway through another mechanism. The important issue is that the definition of the counterfactual scenario is made as consistently as possible between analyses.

Benefit cost analysis was conducted on all projects to generate investment criteria. The Present Value of Benefits (PVB) and Present Value of Costs (PVC) were used to estimate investment criteria of Net Present Value and Benefit-Cost Ratio (BCR) at a discount rate of 5%. The Internal Rate of Return and Modified Internal Rate of Return were also estimated from the annual net cash flows. The PVB and PVC are the sums of the discounted streams of benefits and costs. All dollar costs and benefits were expressed in 2019 dollar terms. Future costs and benefits were discounted to the 2019 year while past costs were inflated to 2019 using the Gross Domestic Product deflator. A 30-year benefit time frame was used in all analyses, with benefits estimated for 30 years from the year of last capital investment in each project. Costs for the R&D projects included the cash contributions of the Project (includes both Wine Australia and industry investment), as well as any other resources contributed by third parties (e.g. researchers or additional industry funds). Investment criteria were reported for 5 year intervals of benefits from zero to 30 years.

The analyses were undertaken for total benefits, including benefits expected in the future as a result of the investment. A degree of conservatism was used when finalising assumptions.

Sensitivity analysis was undertaken for several assumptions that had the greatest degree of uncertainty or for those that were seen to be key drivers of the investment criteria.

Some identified benefits were not quantified mainly due to:

- A suspected, weak or uncertain scientific or causal relationship between the research investment and the actual R&D outcomes and associated benefits; and/or
- The magnitude of the value of the benefit was thought to be only minor.

3. Summary of Results

3.1 Qualitative Results

Table 3.1 identifies the benefits from investment in each of the projects. Each benefit is categorised as economic, environmental or social.

Table 3.1: Summary of Benefits for the Three Projects

Project	Benefits
Epigenetic Memory (UA 1503)	Economic • Efficiencies (cost savings and/or enhanced varieties sooner) in Australian wine grape breeding programs. Environmental • Nil. Social • Capacity – additional scientific knowledge on the epigenetic response of long lived plants to environmental stresses.
In-Canopy Misters (UA 1502)	Economic • Avoided loss of yield and quality during heatwave conditions. Environmental • Nil. Social • Capacity – additional scientific knowledge on the value and application of evaporative cooling systems for grape vines in warm inland areas. • Long term protection of the grape and wine industry in warm inland areas which will maintain income and employment in these areas (spill-over impact).
Toward Mildew Resistant Selections (CSP 1303)	Economic • Improved vineyard profitability with wine grape varieties that require fewer chemical sprays to control mildew, have consistent yields and produce wines with desirable attributes. • Future research cost savings with new techniques for the rapid assessment of fruit (SNP DNA techniques) and micro-scale wine making for sensory analysis. Environmental • Less chemical sprays in the vineyard and less risk of spray drift into the vineyard's surrounds. • Less use of fuel to apply sprays with resultant small reductions in greenhouse gas emissions. • Fewer chemical sprays will allow use of beneficial insects to control pests such as caterpillars, mealy bugs, aphids and thrip. Social

	• Capacity – additional scientific knowledge and new techniques for grapevine genetic selection. • Social - production and consumption of lower alcohol wines with the potential for improved human health outcomes. • Social – reduced potential for chemical fungicide residues in wine with potential for improved human health outcomes. • Long term protection of the grape and wine industry which will maintain income and employment in regional Australia (spill-over impact).

3.2 Quantitative Results

The investment criteria calculated for each research area were the Net Present Value (NPV), the Benefit Cost Ratio (B/C Ratio), the Internal Rate of Return (IRR) and the Modified IRR (MIRR). The NPV is the difference between the Present Value of Benefits (PVB) and the Present Value of Costs (PVC). Present values are the sum of discounted streams of benefits and/or costs. The B/C Ratio is the ratio of the PVB to the PVC. The IRR is the discount rate that would equate the PVB and the PVC, thus making the NPV zero and the B/C Ratio 1:1. The MIRR is the same as the IRR but assumes that the reinvestment rate is the same as the assumed discount rate i.e. 5%, rather than the level of the estimated IRR.

Table 3.2 presents the investment criteria for each of the project investments analysed at a 5% discount rate.

Further details on each of these investments and the associated results are provided in the individual project reports (Appendices 1 to 3).

Table 3.2: Investment Criteria for Three Wine Australia Investments (discount rate 5%, 30 years from last year of investment)

Investment Criteria	Investment Project		
	Epigenetic Memory (UA 1503)	**In-Canopy Misters (UA 1502)**	**Toward Mildew Resistant Selections for 'Cool" Regions (CSP 1303)**
Present value of benefits ($m)	1.04	6.59	11.60
Present value of costs ($m)	0.59	1.45	5.17
Net present value ($m)	0.45	5.14	6.43
Benefit–cost ratio	1.76	4.53	2.24
Benefit-cost ratio range - core assumption sensitivity	0.88 to 4.10	2.04 to 9.08	0.89 to 6.39
Internal rate of return (%)	9.0	17.8	9.0
Modified internal rate of return (%)	6.9	10.1	7.4

4. Conclusion

Two of three investment analyses yielded positive results at the 5% discount rate, with B/C Ratios of 2.2 and 4.4. The third project (UA 1503) was close to 'breakeven' with a benefit-cost ratio of 0.98.

The results from the analyses are dependent on the assumptions made, which in places are uncertain. Assumptions and frameworks could be refined in the future as research outputs are realised, to improve the overall analysis. Comparisons between project results should be made with caution due to uncertainties involved in assumptions and differing frameworks for each of the three analyses.

Appendix 1: Economic Analysis Wine Australia's Investment in Epi-Breeding - Using the Epigenetic Memory of Stress to Prime Australian Grapevines for a Changing Environment

1. Background

Epigenetic mechanisms are at the interface between the environment and the plant genotype (the plant's collection of genes) that regulate gene expression in response to changing environments. When the epigenetic 'memory' of an environmental stress improves the response to subsequent stress, the plant is said to be epigenetically primed.

Wine grape production is highly sensitive to environmental stress. Soil water deficit is probably the environmental stress most commonly faced in Australian viticulture and can occur during periods of low rainfall in rain-fed vineyards, during the application of regulated deficit irrigation, or due to the lack of available irrigation water.

As the effects of climate change start to be seen, heatwaves have become more common in Australia, often occurring in summer when there is a higher probability of a soil water deficit. Anecdotally, the impacts of heatwaves on grapevine performance are more pronounced during periods of water stress.

Climate change will expose wine grape production to unprecedented changes in the availability and price of water, higher degrees of salinity in soil/water, heatwaves and a predicted reduction of suitable land with adequate water supply (Anderson et al. 2008). Consequently, the wine grape industry needs to be able to adapt quickly to the pressure imposed by climatic irregularities.

To address the impact of climate change, industry needs to understand and exploit grapevine plasticity, potentially including epigenetic memory, to make the crop more adaptable.

2. Summary of Projects

A single epi-breeding project supported by Wine Australia was analysed and Table 2.1 provides a description in a logical framework.

Table 2.1 Project Description

Project No. UA 1503 Epi-Breeding - Using the Epigenetic Memory of Stress to Prime Australian Grapevines for a Changing Environment	
Project Details	Research Organisation: University of Adelaide Period: 1 July 2016 to 30 September 2018 Principal Investigator: Penny Tricker
Rationale	Epigenetic memory could be used to enhance plant resilience while maintaining a level of plasticity that tends to be lost by lengthy, conventional, genetic breeding programs. For seed-propagated plants, the maintenance of epigenetic memory of stress has been shown to improve the offspring's tolerance to stress. However, grapevines are propagated vegetatively, and little was known about how vegetative propagation affects the epigenetic memory and long-term maintenance of stress-induced epigenetic modifications.

Objectives	To determine whether long term epigenetic memory of stress could be used for propagation and breeding purposes in grapevines. To deliver this objective the project was to: 1. Understand the time scale over which stress-induced epigenetic modifications in grapevines was maintained. 2. Determine whether epigenetic memory of stress confers grapevines with a measurable advantage against future episodes of the same stresses. 3. Compare how different vegetative propagation methods affect the maintenance of epigenetic memory of stress. 4. Investigate the genomic contexts where stress-induced epigenetic differences persist and where they do not.
Activities and Outputs	• Cabernet Sauvignon plants were exposed to drought, heat and combined drought and heat stresses in the first year of the project and monitored for their physiological responses and gene expression. • The plants were propagated via different vegetative methods (i.e. layering and dormant buds). In year two the vegetatively propagated plants and the original plants were re-challenged with combined drought and heat stresses. • The study showed that environmental stresses had a significant effect on the plant's gene expression in both experiments and the profile of expression was different with each of the stresses. • Plant gene expression was more sensitive following combined stress treatment than in either stress alone i.e. more genes were up and down regulated. • The effect of heat on top of drought was found to be more than additive. • Plant gene expression was more sensitive to drought and heat stress in plants that had been propagated by layering than from dormant buds. • However, there was no significant differences in plant growth between the two propagation methods during the vegetative phase i.e. gene expression was different but vegetative growth was the same. • There was no effect of the previous year's exposure on any of the stresses after propagation by either method i.e. the impact of gene expression was short lived. For the purposes of plant breeding, this finding means that it is possible to identify some of the genes whose expression was altered under stress and incorporate these genes into breeding programs. • The genes changing expression in each of the treatments are likely to be important for response and adaptation to the stresses. Genes in heat shock response pathways and sugars metabolism were over-represented in this category and any genetic variation in these genes could be useful for the breeding of improved varieties to cope with climate change.
Outcomes (potential)	• Improved understanding of how long living plants such as grapevines use epigenetic mechanisms to adapt to changes in their environment. • Additional knowledge of drought and heat stress response genes to inform plant breeding.
Impacts (potential)	• Economic – efficiencies (cost savings and/or enhanced varieties sooner) in Australian wine grape breeding programs. • Capacity – additional scientific knowledge on the epigenetic response of long lived plants to environmental stresses.

3. Match with Government Priorities

Table 3.1 Strategic Science/Research Priorities and Rural R&D Research Priorities

Australian Government	
Strategic Science/Research Priorities	**Rural R&D Priorities**
1. **Food** – optimising food and fibre production and processing, agricultural productivity and supply chains within Australia and global markets 2. **Soil and water** – improve use of soil and water resources, both terrestrial, marine 3. **Transport** – moving essential commodities, alternative fuels, lowering emissions 4. **Cybersecurity** – for individuals, businesses, government, national infrastructure 5. **Energy** – improve efficiency, reduce emissions and integrate diverse sources into the grid. 6. **Resources** – support exploration traditional resources, rare earths and new technologies. 7. **Advanced manufacturing** – high value and innovative industries in Australia. 8. **Environmental change** – mitigating, managing or adapting to changes. 9. **Health** – improving health outcomes for all Australians.	1. **Advanced technology**: to enhance innovation of products, processes and practices across the food and fibre supply chains through technologies such as robotics, digitalisation, big data, genetics and precision agriculture. 2. **Biosecurity**: to improve understanding and evidence of pest and disease pathways to help direct biosecurity resources to their best uses, minimising biosecurity threats and improving market access for primary producers. 3. **Soil, water and managing natural resources:** to manage soil health, improve water use efficiency and certainty of supply, sustainably develop new production areas and improve resilience to climate events and impacts. 4. **Adoption of R&D:** focussing on flexible delivery of extension services that meet primary producers' needs and recognising the growing role of private service delivery.

Source: OCS 2015 and DAWR 2015

The Wine Australia project has addressed Strategic Science/ Research Priorities 1, 2 and 8. The major focus of the project has been on the first and third of the Rural R&D Priorities.

4. Identification of Potential Costs and Benefits

4.1 Costs

4.1.1 R&D Investment

The R&D investment costs comprised:

- Direct financial outlays by collaborators and participants in the research project, namely Wine Australia.
- In-kind contributions to the research project – non-cash contributions made by research partner the University of Adelaide.
- In-kind contributions to the research project – time associated with meetings between the researchers and Wine Australia (project overhead costs).

4.1.2 Administration

No additional administration costs were identified.

4.1.3 Extension

Extension costs such as communication of project progress to plant breeders and other parts of the industry were included in the project budget.

4.1.4 Adoption

Adoption costs will be incurred by plant breeders to incorporate project findings into the development of new grape vine varieties.

4.2 Benefits

4.2.1 Research Output and Impact Pathway

A key output of the project was the identification of genes that are potentially important for grapevine response and adaptation to drought and heat stress. With verification, these genes may be incorporated into Australian grapevine breeding programs, lifting program efficiency and saving research cost.

4.2.2 Triple Bottom Line Benefits

A summary of potential benefits from the project in triple bottom line categories is shown in Table 4.1.

Table 4.1 Triple Bottom Line Categories Benefits from Project Investment

Levy Paying Industry	**Spillovers**		
	Other Industries	**Public**	**Foreign**
Economic Benefits			
Efficiencies (cost savings and/or enhanced varieties sooner) in Australian wine grape breeding programs.	Drought and heat stress genes identified may be relevant to breeding programs in other grape industries e.g. table and dried grape production. Knowledge of epigenetic response in long lived plants will be relevant to other horticultural industries including vine, shrub and tree crops.	Nil	Drought and heat stress genes identified may be relevant to other wine producing countries affected by water shortage and heat stress including the United States, Chile and South Africa.
Environmental Benefits			
Nil	Nil	Nil	Nil
Social Benefits			
Capacity – additional scientific knowledge on the epigenetic response of long lived plants to environmental stresses.	Nil	Nil	Nil

4.2.3 Public versus Private Benefits

The project will produce a mix of public and private benefits. Private benefits will be realised when enhanced varieties are released. Public benefits will include breeding program cost savings and the creation of additional scientific capacity.

4.2.4 Distribution of Benefits along the Supply Chain

The benefits to the wine industry from investment in this project will be shared along the supply chain with wine grape growers, wine makers, wholesalers, retailers and exporters all sharing some of the benefits.

4.2.5 Benefits to Other Primary Industries

Benefits to other primary industries include identification of drought and heat stress adaptation genes that may be relevant to table grape and dried grape production in the future. Knowledge generated on the epigenetic response in long lived plants may be relevant to other horticultural industries including tree, vine and shrub crops.

4.2.6 Benefits Overseas
Drought and heat stress genes identified may be relevant to other wine producing countries affected by water shortage and heat stress including the United States, Chile and South Africa.

4.3 Summary of Costs and Benefits
A summary of principal categories of costs and benefits from the project is shown in Table 4.2.

Table 4.2 Incremental Cost and Benefit Categories

Costs	Benefits
R&D investment costs (cash and in-kind) as well as project administration costs.	Economic – efficiencies (cost savings and/or enhanced varieties sooner) in Australian wine grape breeding programs.
Overhead costs including time associated with meetings between the researchers and Wine Australia.	Capacity – additional scientific knowledge on the epigenetic response of long lived plants to environmental stresses.

5. Valuation of Costs and Benefits

5.1 Costs
5.1.1 R&D Investment Costs including Administration
The following tables show annual investment in the Project by Wine Australia (Table 5.1) and for researchers and other investors (Table 5.2). Table 5.3 provides the total investment by year for both sources.

Table 5.1 Investment by Wine Australia in the Project for Years Ending June 2017 to June 2019

Project Code	2017	2018	2019	Total
UA 1503 – Wine Australia	92,712	51,233	51,231	**195,176**
Total	**92,712**	**51,233**	**51,231**	**195,176**

Source: Wine Australia Final Project Application revised with Dr Penny Tricker, Principal Investigator (pers. comm., Nov 2019)

Table 5.2 Investment by Others in the Project for Years Ending June 2017 to June 2019

Project Code	2017	2018	2019	Total
UA 1503 – UA cash	0	0	0	**0**
UA 1503 – UA in-kind	96,563	96,563	96,564	**289,690**
UA 1503 – Yalumba Nursery supplied vine material	5,000	0	0	**5,000**
Total	**101,563**	**96,563**	**96,564**	**294,690**

Source: Wine Australia Final Project Application revised with Dr Penny Tricker, Principal Investigator (pers. comm., Nov 2019)

Table 5.3 Annual Investment in the Project (nominal $)

Year Ending 30 June	Wine Australia	Others	Total
2017	92,712	101,563	**194,275**
2018	51,233	96,563	**147,796**
2019	51,231	96,564	**147,795**
Total	**195,176**	**294,690**	**489,866**

5.1.2 Overhead Costs including Meetings between the Researchers and Wine Australia
Wine Australia overhead costs are in addition to those shown in the above tables and are estimated at 12%.

5.2 Benefits

5.2.1 Cost Savings in Wine Grape Breeding Programs

Counterfactual: if this project had not been funded, it is unlikely that additional grapevine genes for drought and heat stress tolerance would have been identified through alternative research.

The project has identified genes that when incorporated into Australian wine grape breeding programs may lift the efficiency of these programs, resulting in enhanced varieties sooner and saving these programs R&D investment costs.

A summary of key assumptions used to quantify this benefit is shown in Table 5.4.

Table 5.4 Summary of Assumptions

Variable	Assumption	Source
Cost Savings in Wine Grape Breeding Programs		
Annual investment by Wine Australia in improving vineyard performance – investment in technologies and processes such as enhanced or new grapevine varieties, clones and rootstocks.	$5.88 million	Three year average of Wine Australia investment sourced through its 2016-17, 2017-18 and 2018-19 annual reports.
Efficiency gain from incorporation of genes identified in the project into Australian wine grape breeding programs.	5%	Consultant estimate tested using sensitivity analysis.
Attribution of benefits to this project.	70%	Estimate assumed after considering additional investment required for gene verification research.
Probability of output.	50%	Estimate recognises the possibility that genes may not be verified and incorporated into breeding program activities.
Probability of impact.	50%	Consultant assumption that genes will positively impact breeding programs.
Counterfactual	90%	If this project had not been funded, it is unlikely that additional grapevine genes for drought and heat stress tolerance would have been identified through alternative research.

5.2.2 Other Potential Benefits

The other potential benefit identified but not valued was:

- Additional scientific knowledge on the epigenetic response of long lived plants to environmental stresses.

This benefit was not quantified due to the difficulty in securing data for quantification.

6. Results

All past costs were expressed in current dollar terms using the implicit price deflator for GDP. All costs and benefits from 2019 onwards were discounted to current dollar terms using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the Modified Internal Rate of Return (MIRR). The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for some of the estimates. All analyses ran for the length of the investment period plus 30 years from the last year of investment (2019).

Table 6.1 and Table 6.2 show the investment criteria estimated for the different periods of benefits for both the total investment and for Wine Australia investment. The present value of benefits (PVB) for the Wine Australia investment, shown in Table 6.2, is estimated by multiplying the total PVB by the Wine Australia proportion of investment.

Table 6.1 Investment Criteria for Total Investment by Wine Australia and Project Partners (discount rate 5%)

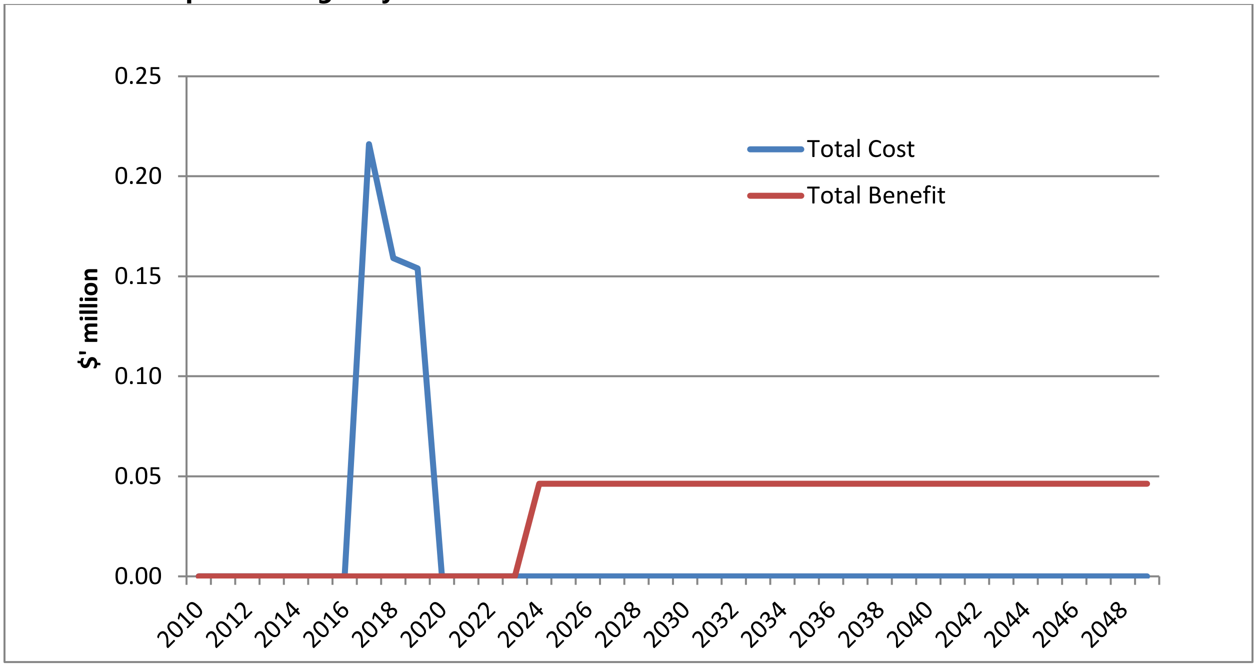
Years	0 years	5 years	10 years	15 years	20 years	25 years	30 years
Present value of benefits ($m)	0.00	0.04	0.20	0.33	0.43	0.51	0.58
Present value of costs ($m)	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Net present value ($m)	-0.59	-0.55	-0.38	-0.25	-0.15	-0.07	-0.01
Benefit–cost ratio	0.00	0.06	0.35	0.57	0.74	0.87	0.98
Internal rate of return (%)	Negative	Negative	Negative	Negative	2.6	4.0	4.9
Modified internal rate of return (%)	Negative	Negative	Negative	Negative	3.6	4.5	4.9

Table 6.2 Investment Criteria for Wine Australia (discount rate 5%)

Years	0 years	5 years	10 years	15 years	20 years	25 years	30 years
Present value of benefits ($m)	0.00	0.02	0.09	0.14	0.19	0.22	0.25
Present value of costs ($m)	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Net present value ($m)	-0.25	-0.24	-0.17	-0.11	-0.07	-0.03	-0.01
Benefit–cost ratio	0.00	0.06	0.34	0.56	0.73	0.87	0.97
Internal rate of return (%)	Negative	Negative	Negative	Negative	2.5	4.0	4.9
Modified internal rate of return (%)	Negative	Negative	Negative	Negative	3.5	4.5	4.9

The annual undiscounted benefits and cost cash flows for the total investment for the duration of the investment period plus 30 years from the last year of the initial investment are shown in Figure 6.1.

Figure 6.1 Annual Undiscounted Cash Flows for Estimated Total Benefits and Total RD&E Investment Costs for the Epi-Breeding Project



7. Sensitivity Analysis

A sensitivity analysis was carried out for the central analysis results reported in Section 6 and variations in the discount rate. Table 7.1 presents the results. At a 10% discount rate, the project slips from near breakeven (benefit-cost ratio of 0.98), to a position where project costs clearly exceed quantified project benefits (benefit-cost ratio of 0.49).

Table 7.1 Sensitivity to Discount Rate (Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($m)	1.20	0.58	0.32
Present value of costs ($m)	0.53	0.59	0.65
Net present value ($m)	0.67	-0.01	-0.33
Benefit-cost ratio	2.28	0.98	0.49

Sensitivity analysis was undertaken for variables where there was uncertainty or for those that were identified as key drivers of the investment criteria. The analyses were performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values.

For this project, the greatest uncertainty related to the cost saving/efficiency gain realised from incorporating genes identified during the project into Australian wine grape breeding programs – Table 7.2. Results show that if cost saving is 3% then project costs clearly exceed project benefits.

Table 7.2 Sensitivity to Cost Savings/Efficiency Gains in Australian Wine Grape Breeding Programs (Total investment, 30 years)

Investment Criteria	Saving in Research Costs Following Incorporation of Project Genes into Australian Wine Grape Breeding Programs		
	3%	5% (base)	7%
Present value of benefits ($m)	0.35	0.58	0.81
Present value of costs ($m)	0.59	0.59	0.59
Net present value ($m)	-0.24	-0.01	0.22
Benefit-cost ratio	0.59	0.98	1.37

8. Confidence Ratings

The results produced are highly dependent on the assumptions made, many of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 8.1). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 8.1 Confidence in Analysis of Program

Coverage of Benefits	Confidence in Assumptions
High	Medium

9. Summary of Results

Funding for UA 1503 'epi-breeding – using the epigenetic memory of stress to prime Australian grapevines for a changing environment' had a total cost of $0.59 million (present value terms) and is expected to produce aggregate total benefits of approximately $0.58 million (present value terms). This gives an estimated net present value of negative 0.01 million, a benefit-cost ratio of approximately 0.98, an internal rate of return of 5% and a modified internal rate of return of 5%.

Analysis results are dependent on assumptions made and for this analysis results are breakeven for core assumptions and negative for a number of sensitivity tests.

Abbreviations

UA University of Adelaide
DAWR Department of Agriculture and Water Resources
DPIPWE Tasmania Department of Primary Industries, Parks, Water and Environment
OCS Office of Chief Scientist

Persons Contacted

Angelica Crabb, Analyst, Wine Australia
Sharon Harvey, R&D Program Manager, Wine Australia
Alex Sas, Senior RD&E Program Manager, Wine Australia
Penny Tricker, Researcher, University of Adelaide

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Appendix 2: Economic Analysis Wine Australia's Investment in Using In-Canopy Misters to Mitigate the Negative Effects of Heatwaves on Grapevines

1. Background

Climate change in Australian viticultural regions has prompted much research in the areas of drought stress mitigation, and, more recently heat stress mitigation in vineyards. With an increasing incidence, severity and duration of heatwaves, practical strategies are being sought by the industry to manage grape vines under adverse heatwave conditions and to improve grapevine resilience to future events.

Canopy temperatures during heatwaves can be lowered using a range of technologies including overhead shade cloth, canopy skirting netting, sprinklers, reflective particle film sprays, increased irrigation to promote transpirational cooling, adjustment of row orientation/vine training and cultural practices. However, evaporative cooling is the most effective technique to lower canopy temperatures during heatwaves since it takes advantage of the high latent heat of vaporisation of water to convert sensible heat to latent heat.

The benefits of cooling the canopy during heatwave conditions include maintenance of canopy photosynthesis and carbohydrate production and increased berry size and yield. Potentially, cooling may also produce wine grapes with deeper colour, delayed ripening and preservation of aroma and flavour compounds.

Prior to this project, few studies have investigated the efficiency of water-based evaporative cooling in vineyards during heatwaves and the resultant effects of cooler vines on grape quality.

2. Summary of Projects

A single grapevine cooling project supported by Wine Australia was analysed. Table 2.1 provides a description in a logical framework.

Table 2.1 Project Description

Project No. UA 1502 Using In-Canopy Misters to Mitigate the Negative Effects of Heatwaves on Grapevines	
Project Details	Research Organisation: University of Adelaide Period: 1 July 2016 to 30 June 2018 Principal Investigator: Vinay Pagay
Rationale	Strategies such as overhead sprinklers are currently being utilised in vineyards in Australian inland regions and although effective they are large consumers of water, much of which is lost through evaporation. This study looked at three alternatives to overhead sprinklers: (1) in-canopy misting, (2) under vine sprinklers, and (3) supplementary irrigation prior to heatwave conditions.
Objectives	1. Evaluate the efficiency of alternatives to overhead sprinklers including their ability to lower canopy temperatures. 2. Develop a simulation model to determine optimum mister configuration. 3. Use the simulation model to configure misters and their schedules to lower canopy temperatures by 5°C and 10°C below ambient.
Activities and Outputs	• Sauvignon Blanc and Cabernet Sauvignon grapevines in the Riverland and Adelaide regions were cooled using a range of technologies during the 2016/17 and 2017/18 growing seasons.

	• Grapevines were cooled using water-based evaporative cooling either in the canopy with fine mist applications when temperatures exceeded 35ºC or with under canopy sprinklers or supplemental drip irrigation during warm nights preceding heatwaves. • The project showed that canopy temperatures were 5ºC cooler than ambient using all three cooling treatments. • Cooling resulted in improved vine water status, physiological performance (gas exchange) and yield in many of these treatments, but especially in the under canopy sprinkler treatment in the Riverland when applied to Sauvignon Blanc. • In-canopy misting while using the least amount of water requires high quality water to avoid leaf scorch caused by salt deposits – water of this quality is rarely available to grape growers. In-canopy misting also requires additional vineyard posts and labour to install and remove misters prior to harvest. • Under-canopy sprinklers are effective and are more water efficient than current practice which uses overhead sprays. • Supplementary irrigation achieved the highest grape yields but also used more cooling water than under-canopy sprays. • A simulation model of canopy cooling based on misting was developed and accurately predicted canopy, leaf and bunch temperatures resulting from mist applications under various environmental conditions. The simulation model is suitable for immediate incorporation into automated vineyard mist controllers. • The research found that the method of water application was critical for effective cooling and improved vine performance. • The project final report provided specific recommendations for growers to mitigate heatwave events including application of drip irrigation on the day preceding a heatwave; use of under vine sprinklers to increase water distribution to the vineyard floor; maintenance of fruit shading; and the establishment of a green vineyard floor (cover crop) to improve water retention and lower soil/root temperatures. • Project results were communicated to grape growers and industry advisors via factsheets, articles and field day seminars.
Outcomes (potential)	• Adoption of a new heatwave mitigation strategy capable of maintaining non-heatwave fruit yield and quality. The new heatwave mitigation strategy is capable of achieving a 5ºC reduction in ambient temperature.
Impacts (potential)	• Economic – avoided loss of yield and quality in warm inland production regions during heatwave conditions. • Capacity – additional scientific knowledge on the value and application of evaporative cooling systems for grape vines grown in warm inland areas. • Social – long term protection of the grape and wine industry in warm inland areas which will maintain income and employment in these areas (spill-over impact).

3. Match with Government Priorities

Table 3.1 Strategic Science/Research Priorities and Rural R&D Research Priorities

Australian Government	
Strategic Science/Research Priorities	**Rural R&D Priorities**
1. **Food** – optimising food and fibre production and processing, agricultural productivity and supply chains within Australia and global markets 2. **Soil and water** – improve use of soil and water resources, both terrestrial, marine 3. **Transport** – moving essential commodities, alternative fuels, lowering emissions 4. **Cybersecurity** – for individuals, businesses, government, national infrastructure 5. **Energy** – improve efficiency, reduce emissions and integrate diverse sources into the grid. 6. **Resources** – support exploration traditional resources, rare earths and new technologies. 7. **Advanced manufacturing** – high value and innovative industries in Australia. 8. **Environmental change** – mitigating, managing or adapting to changes. 9. **Health** – improving health outcomes for all Australians.	1. **Advanced technology**: to enhance innovation of products, processes and practices across the food and fibre supply chains through technologies such as robotics, digitalisation, big data, genetics and precision agriculture. 2. **Biosecurity**: to improve understanding and evidence of pest and disease pathways to help direct biosecurity resources to their best uses, minimising biosecurity threats and improving market access for primary producers. 3. **Soil, water and managing natural resources:** to manage soil health, improve water use efficiency and certainty of supply, sustainably develop new production areas and improve resilience to climate events and impacts. 4. **Adoption of R&D:** focussing on flexible delivery of extension services that meet primary producers' needs and recognising the growing role of private service delivery.

Source: OCS 2015 and DAWR 2015

The Wine Australia project has addressed Strategic Science/ Research Priorities 1, 2 and 8. The major focus of the project has been on the first and third of the Rural R&D Priorities.

4. Identification of Potential Costs and Benefits

4.1 Costs

4.1.1 R&D Investment

The R&D investment costs comprised:

- Direct financial outlays by collaborators and participants in the research project, namely Wine Australia.
- In-kind contributions to the research project – non-cash contributions made by research partners the University of Adelaide (UA) and Charles Sturt University (CSU).
- In-kind contributions to the research project – time associated with meetings between the researchers and Wine Australia (project overhead costs).

4.1.2 Administration

No additional administration costs were identified.

4.1.3 Extension

Extension costs for communicating the availability of the simulation model for canopy cooling and the new heatwave mitigation strategy were included in the project budget.

4.1.4 Adoption

The new heatwave mitigation strategy can be incorporated into existing vineyards at minimal additional cost if growers choose drip treatment – they will simply apply more water immediately prior to a heatwave event. However, to gain a more significant heatwave mitigation benefit, growers will need to install under-vine sprinklers, which is a significant capital cost.

4.2 Benefits

4.2.1 Research Output and Impact Pathway

A key output of this project was a new heatwave mitigation strategy for grape growers in warm inland areas. The output was communicated directly to growers and as a consequence the impact pathway is straightforward:

1. New heatwave mitigation strategy generated as part of this project (UA 1502).
2. Heatwave mitigation strategy communicated directly to grape growers and their advisors in warm in-land areas.
3. Grape growers assess the applicability of the heatwave mitigation strategy for their enterprise and a percentage of growers adopt the strategy.

4.2.2 Triple Bottom Line Benefits

A summary of potential benefits from the project in triple bottom line categories is shown in Table 4.1.

Table 4.1 Triple Bottom Line Categories Benefits from Project Investment

Levy Paying Industry	**Spillovers**		
	Other Industries	**Public**	**Foreign**
Economic Benefits			
Avoided loss of yield and quality during heatwave conditions.	Heatwave mitigation strategy may also be relevant to other grape industries e.g. table and dried grape production.	Nil	Heatwave mitigation strategy may be relevant to other wine producing countries affected by heatwave conditions including the United States, Chile and South Africa.
Environmental Benefits			
Nil	Nil	Nil	Nil
Social Benefits			
Capacity – additional scientific knowledge on the value and application of evaporative cooling systems for grape vines in warm inland areas. Long term protection of the grape and wine industry in warm inland areas which will maintain income and employment in these areas (spill-over impact).	Nil	Nil	Nil

4.2.3 Public versus Private Benefits

The majority of benefits that will arise from project investment will be private in nature. The private benefits will be captured by wine grape growers. Private benefits will be realised as avoided loss in yield and quality in warm inland production regions during heatwave conditions.

4.2.4 Distribution of Benefits along the Supply Chain

The benefits to the wine industry from investment in this project will be shared along the supply chain with wine grape growers, wine makers, wholesalers, retailers and exporters all sharing in some of the benefits.

4.2.5 Benefits to other Primary Industries

Benefits to other primary industries include potential adoption of the heatwave mitigation strategy by the table grape and dried grape industries based in warm inland areas.

4.2.6 Benefits Overseas

Heatwave mitigation strategy may be relevant to other wine producing countries affected by heatwave conditions including the United States, Chile and South Africa.

4.3 Summary of Costs and Benefits

A summary of principal categories of costs and benefits from the project is shown in Table 4.2.

Table 4.2 Incremental Cost and Benefit Categories

Costs	Benefits
R&D investment costs (cash and in-kind) as well as project administration costs.	Economic – maintenance of yield and quality during heatwave conditions.
Overhead costs including time associated with meetings between the researchers and Wine Australia.	Capacity – additional scientific knowledge on the value and application of evaporative cooling systems for grape vines in warm inland areas.
Adoption costs incurred by grape growers implementing the new heatwave strategy – relatively minor if drip existing drip irrigation systems are used but a major capital expense if the grower installs under-vine sprinklers.	Social – long term protection of the grape and wine industry in warm inland areas which will maintain income and employment in these areas (spill-over impact).

5. Valuation of Costs and Benefits

5.1 Costs

5.1.1 R&D Investment Costs including Administration

The following tables show annual investment in the Project by Wine Australia (Table 5.1) and for researchers (Table 5.2). Table 5.3 provides the total investment by year for both sources.

Table 5.1 Investment by Wine Australia in the Project for Years Ending June 2017 to June 2019

Project Code	2017	2018	2019	Total
UA 1502 – Wine Australia	126,261	86,713	9,635	**222,609**
Total	**126,261**	**86,713**	**9,635**	**222,609**

Source: Wine Australia Final Project Application

Table 5.2 Investment by Others in the Project for Years Ending June 2017 to June 2019

Project Code	2017	2018	2019	Total
UA 1502 – UA cash	0	0	0	**0**
UA 1502 – UA in-kind	650,723	185,142	20,571	**856,436**
UA 1502 – CSU cash	0	0	0	**0**
UA 1502 – CSU in kind	56,421	52303	5812	**114,536**
Total	**707,144**	**237,445**	**26,383**	**970,972**

Source: Wine Australia Final Project Application

Table 5.3 Annual Investment in the Project (nominal $)

Year Ending 30 June	Wine Australia	Others	Total
2017	126,261	707,144	**833,405**
2018	86,713	237,445	**324,158**
2019	9,635	26,383	**36,018**
Total	**222,609**	**970,972**	**1,193,581**

5.1.2 Overhead Costs including Meetings between the Researchers and Wine Australia

Wine Australia overhead costs are in addition to those shown in the above tables and are estimated at 12%.

5.1.4 Adoption Costs

The new heatwave mitigation strategy will result in additional capital costs for most growers who adopt (i.e. installation of under-vine sprinklers). This cost is accounted for in the analysis through the application of a research benefit attribution factor – see Table 5.4 below.

5.2 Benefits

5.2.1 Avoided Loss of Yield and Quality During Heatwave Conditions

Counterfactual: if this project had not been funded, it is 75% likely that knowledge on the efficiency of alternative vineyard evaporative cooling systems would have been generated through alternative research.

Adoption of the new heatwave mitigation strategy developed as part of this project (UA 1502) will allow wine grape growers in warm inland areas to avoid yield and quality losses during heatwaves. A summary of key assumptions used to quantify this benefit is shown in Table 5.4.

Table 5.4 Summary of Assumptions

Variable	Assumption	Source
Avoided Loss of Yield and Quality During Heatwave Conditions		
Value of wine grapes grown in areas classified by Wine Australia as warm inland (Riverina, Murray-Darling-Swan Hill and Riverland).	$448,509,188	Three year average of national vintage data for 2017, 2018 and 2019 sourced from the relevant National Vintage Reports.
Loss in value of warm inland production following a heatwave.	15%	Alex Sas, Senior RD&E Program Manager, Wine Australia, pers. Comm., March 2020.
Frequency of heatwave events.	Annual event	Alex Sas, Senior RD&E Program Manager, Wine Australia, pers. Comm., March 2020.
Percentage of warm inland grape production adopting research recommendations.	20%	Consultant estimate that recognises constraints associated with significant capital investment.

Year in which project benefits first realised.	2020	Results communicated to warm inland grape growers in 2019.
Year in which maximum adoption occurs	2034	Fifteen years from initial communication of results to grape growers.
Attribution of benefits to this project.	20%	Attribution factor makes allowance for the cost of adopting the new heatwave mitigation strategy.
Probability of output.	100%	Strategy has already been documented.
Probability of impact.	80%	Consultant assumption that new heatwave mitigation strategy will be effective.
Counterfactual	75%	If this project had not been funded, it is likely that knowledge on the efficiency of alternative vineyard evaporative cooling systems would have been generated through alternative research.

5.2.2 Other Potential Benefits

Other potential benefits identified but not valued include:

- Additional scientific knowledge on the value and application of evaporative cooling systems for grape vines grown in warm inland areas.
- Long term protection of the grape and wine industry in warm inland areas which will maintain income and employment in these areas (spill-over impact).

Other potential benefits were not quantified due to their relatively minor contribution to total impact and difficulty in securing data for quantification.

6. Results

All past costs were expressed in current dollar terms using the implicit price deflator for GDP. All costs and benefits from 2019 onwards were discounted to current dollar terms using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the Modified Internal Rate of Return (MIRR). The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for some of the estimates. All analyses ran for the length of the investment period plus 30 years from the last year of investment (2019).

Table 6.1 and Table 6.2 show the investment criteria estimated for the different periods of benefits for both the total investment and for Wine Australia investment. The present value of benefits (PVB) for the Wine Australia investment, shown in Table 6.2, is estimated by multiplying the total PVB by the Wine Australia proportion of investment.

Table 6.1 Investment Criteria for Total Investment by Wine Australia and Project Partners (discount rate 5%)

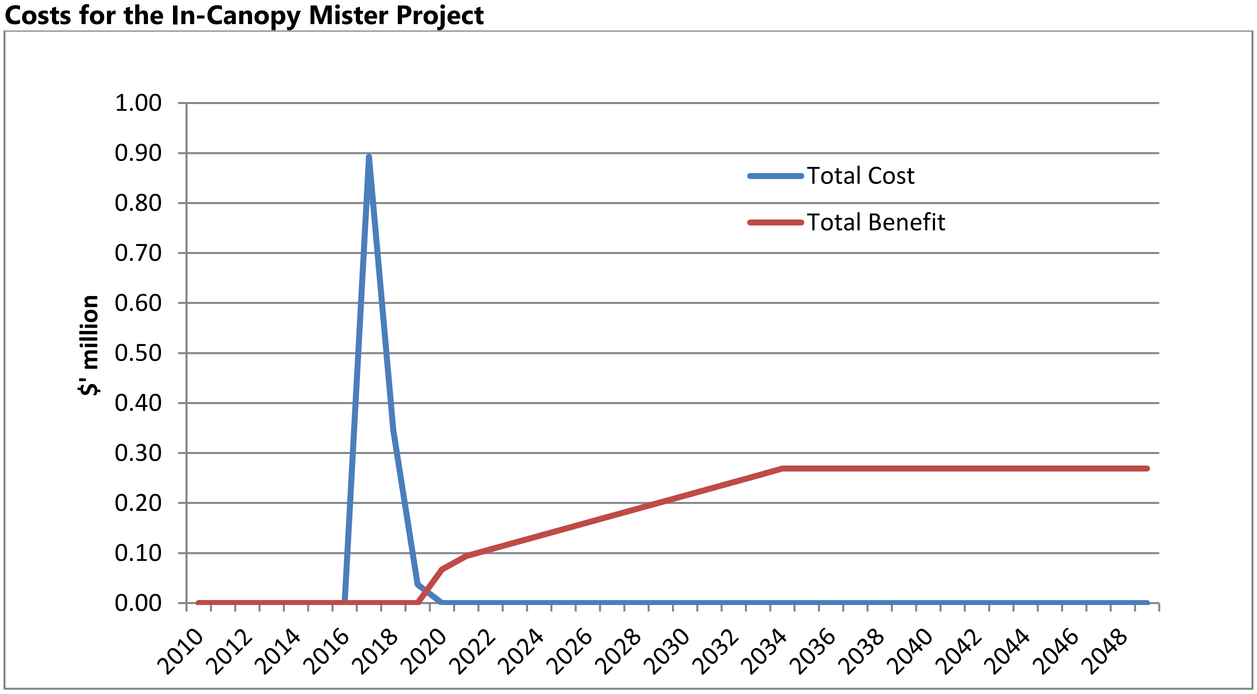
Years	0 years	5 years	10 years	15 years	20 years	25 years	30 years
Present value of benefits ($m)	0.00	0.94	2.18	3.52	4.70	5.62	6.34
Present value of costs ($m)	1.45	1.45	1.45	1.45	1.45	1.45	1.45
Net present value ($m)	-1.45	-0.51	0.72	2.07	3.24	4.17	4.89
Benefit–cost ratio	0.00	0.65	1.50	2.42	3.23	3.87	4.36
Internal rate of return (%)	Negative	Negative	10.8	15.2	16.7	17.2	17.4
Modified internal rate of return (%)	Negative	Negative	8.6	10.6	10.8	10.4	9.9

Table 6.2 Investment Criteria for Wine Australia (discount rate 5%)

Years	0 years	5 years	10 years	15 years	20 years	25 years	30 years
Present value of benefits ($m)	0.00	0.19	0.44	0.72	0.96	1.15	1.29
Present value of costs ($m)	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Net present value ($m)	-0.29	-0.10	0.15	0.42	0.66	0.85	1.00
Benefit–cost ratio	0.00	0.65	1.51	2.44	3.25	3.89	4.39
Internal rate of return (%)	Negative	Negative	11.1	15.4	16.9	17.4	17.7
Modified internal rate of return (%)	Negative	Negative	8.7	10.7	10.8	10.4	10.0

The annual undiscounted benefits and cost cash flows for the total investment for the duration of the investment period plus 30 years from the last year of the initial investment are shown in Figure 6.1.

Figure 6.1 Annual Undiscounted Cash Flows for Estimated Total Benefits and Total RD&E Investment Costs for the In-Canopy Mister Project



7. Sensitivity Analysis

A sensitivity analysis was carried out for the central analysis results reported in Section 6 and variations in the discount rate. Table 7.1 presents the results. These indicate that all indicators remain positive for all discount rate assumptions.

Table 7.1 Sensitivity to Discount Rate (Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($m)	13.29	6.34	3.59
Present value of costs ($m)	1.28	1.45	1.65
Net present value ($m)	12.02	4.89	1.94
Benefit-cost ratio	10.42	4.36	2.18

Sensitivity analyses were undertaken for those variables where there was greatest uncertainty or for those that were identified as key drivers of the investment criteria. The analyses were performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values.

For this project there was uncertainty related to the loss of yield and quality of wine grapes during heatwaves and the level of adoption of project generated strategy in warm inland growing areas – Table 7.2 and Table 7.3. Results show that benefit cost ratios remain positive for a range of assumptions.

Table 7.2 Sensitivity to Loss of Production Value During Heatwave (Total investment, 30 years)

Investment Criteria	Avoided Loss of Wine Grape Yield and Quality During Heatwave (%)		
	10%	15% (base)	20%
Present value of benefits ($m)	4.23	6.34	8.46
Present value of costs ($m)	1.45	1.45	1.45
Net present value ($m)	2.77	4.89	7.00
Benefit-cost ratio	2.91	4.36	5.82

Table 7.3 Sensitivity to Adoption of Strategy by Growers (Total investment, 30 years)

Investment Criteria	Adoption of New Heatwave Mitigation Strategy by Warm Inland Growers – Percentage of Production (Maximum %)		
	10%	20% (base)	30%
Present value of benefits ($m)	3.17	6.34	10.69
Present value of costs ($m)	1.45	1.45	1.45
Net present value ($m)	1.72	4.89	9.23
Benefit-cost ratio	2.18	4.36	7.35

8. Confidence Ratings

The results produced are highly dependent on the assumptions made, many of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 8.1). The rating categories used are High, Medium and Low, where:

High:	denotes a good coverage of benefits or reasonable confidence in the assumptions made
Medium:	denotes only a reasonable coverage of benefits or some uncertainties in assumptions made
Low:	denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 8.1 Confidence in Analysis of Program

Coverage of Benefits	Confidence in Assumptions
High	Medium

9. Summary of Results

Funding for UA 1502 'using in-canopy misters to mitigate the negative effects of heatwaves on grapevines' had a total cost of $1.45 million (present value terms) and is expected to produce aggregate total benefits of approximately $6.34 million (present value terms). This gives an estimated net present value of $4.89 million, a benefit-cost ratio of approximately 4.36, an internal rate of return of 17% and a modified internal rate of return of 10%.

Analysis results are dependent on assumptions made and are positive for core assumptions and remain positive through sensitivity testing.

Consideration of the heatwave mitigation strategy developed as part of this project would appear to be a priority for grape growers in warm inland areas.

Abbreviations

CSU	Charles Sturt University
UA	University of Adelaide
DAWR	Department of Agriculture and Water Resources
OCS	Office of Chief Scientist
WFA	Winemakers Federation of Australia

Persons Contacted

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Vinay Pagay, Researcher, University of Adelaide
Alex Sas, Senior RD&E Program Manager, Wine Australia

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Appendix 3: Economic Analysis Wine Australia's Investment in Towards Elite Mildew Resistant Selections Suitable for Industry Use

1. Background

The breeding of new disease resistant wine grape selections has become a priority in a number of countries (Dry, et al 2010). These new varieties with resistance to powdery and downy mildew offer the opportunity to substantially reduce the use of fungicide sprays and lower the cost of wine grape production.

A 2010, GWRDC project (Scholefield Robinson and Econsearch, GWR 08/04) estimated the annual cost to the wine industry of powdery mildew at $76 million and the cost of downy mildew at $63 million. Cost estimates include preventative chemical spray programs and yield losses from infestation. Mildew causes serious quality issues in wines, notably 'off' flavours and aromas.

A previous Wine Australia project (Thomas and Dry, CSP 0904) described the use of DNA markers in a marker-assisted selection vine breeding process to identify 1,200 new mildew resistant selections that were planted in the field for evaluation. As a consequence of the previous project, further research was required to identify the 20 best red and 20 best white berry individuals from those 1,200 selections and progress them toward commercialisation.

2. Summary of Projects

A single, mildew resistant selection project supported by Wine Australia was analysed. Table 2.1 provides a description in a logical framework.

Table 2.1 Project Description

Project No. CSP 1303 Towards Elite Mildew Resistant Selections Suitable for Industry Use	
Project Details	Research Organisation: CSIRO Period: 1 July 2013 to 21 December 2018 Principal Investigator: Mark Thomas
Rationale	Reduced inputs, including chemical sprays for mildew, will be a key factor in maintaining the competitiveness of the Australian wine industry in addition to having unique desirable products and improving profitability. A mother block planting of elite vines will demonstrate the advantages of combining mildew resistance with high yielding vines and provide source material for industry and nursery propagation.
Objectives	The objective of the project was to evaluate the first generation of downy and powdery mildew resistant vines to identify elite individuals that have acceptable yields and produce robust, desirable wine styles.
Activities and Outputs	• Evaluation of 1,200 field planted downy and powdery mildew resistant vines to identify elite selections with superior agronomic and wine attributes. • Introduction of red-flesh as a trait of some of the new mildew resistant selections which will produce higher levels of anthocyanins than traditional wine varieties and offer the potential for earlier harvests to produce lower alcohol wines. • A mother source block of both white and red downy and powdery mildew resistant selections was established to provide material for nurseries and for second generation breeding.

	• The performance of the vines was assessed over multiple seasons. • Sensory and chemical analysis of berries and wine was completed to identify elite material with desirable flavours and winemaking properties. • Elite selections with a range of flavour styles were identified and the potential for robust flavours at low sugar levels for low alcohol wine was investigated. • Methods for rapid evaluation of selections were developed and DNA markers linked to genes responsible for flavour investigated using marker-assisted selection studies. • The data obtained during the selection process provided a genetic insight into trait diversity within the population of mildew resistant germplasm. • A DNA marker was developed that can be employed in new breeding efforts using marker assisted selection. The marker assists with the identification of 'grassy' methoxypyrazine flavours – desirable in white wine (e.g. Sauvignon Blanc) and undesirable in red wine (e.g. Cabernet Sauvignon). • The results showed that small-scale wine made from single vines is effective for screening for superior selections when a wine sensory panel made up to wine makers and researchers is employed. • The research found that in future studies it is not necessary to collect data on all of the traits measured in this study and that only a subset of traits needs to be measured for an effective section process. • The project produced the first large-scale screening of mildew resistant vines in Australia and mildew-resistant selections were identified and planted for regional field trials to determine whether the selected vines produce acceptable yields under different management treatments and different climates (i.e. Barossa Valley SA, Irymple VIC, Riverina NSW and Orange NSW). • Vine selection results were communicated to growers and their advisors through industry magazines, conference presentations and online forums.
Outcomes	• Progress towards the development of new IP protected wine grape varieties that require fewer chemical inputs, have acceptable yields and produce wine that is desirable to consumers.
Impacts (potential)	• Economic – improved vineyard profitability with wine grape varieties that require fewer chemical sprays to control mildew, have consistent and acceptable yields and produce wines with desirable attributes (aromas, flavours and lower calorie/lower alcohol content wine). • Economic – future research cost savings with new techniques for the rapid assessment of fruit (SNP DNA techniques) and micro-scale wine making for sensory analysis. • Environmental – less chemical sprays in the vineyard and less risk of spray drift into the vineyard's surrounds. • Environmental – less use of fuel to apply sprays with resultant small reductions in greenhouse gas emissions. • Environmental – fewer chemical sprays may assist beneficial predatory insects to control pests such as caterpillars, mealy bugs, aphids and thrip. • Capacity – additional scientific knowledge and new techniques for grapevine genetic selection. • Social - production and consumption of lower alcohol wines with the potential for improved human health outcomes.

	• Social – reduced potential for chemical fungicide residues in wine with potential for improved human health outcomes. • Social – long term advancement of the grape and wine industry which will maintain income and employment in regional Australia (spill-over impact).

3. Match with Government Priorities

Table 3.1 Strategic Science/Research Priorities and Rural R&D Research Priorities

Australian Government	
Strategic Science/Research Priorities	**Rural R&D Priorities**
1. **Food** – optimising food and fibre production and processing, agricultural productivity and supply chains within Australia and global markets 2. **Soil and water** – improve use of soil and water resources, both terrestrial, marine 3. **Transport** – moving essential commodities, alternative fuels, lowering emissions 4. **Cybersecurity** – for individuals, businesses, government, national infrastructure 5. **Energy** – improve efficiency, reduce emissions and integrate diverse sources into the grid. 6. **Resources** – support exploration traditional resources, rare earths and new technologies. 7. **Advanced manufacturing** – high value and innovative industries in Australia. 8. **Environmental change** – mitigating, managing or adapting to changes. 9. **Health** – improving health outcomes for all Australians.	1. **Advanced technology**: to enhance innovation of products, processes and practices across the food and fibre supply chains through technologies such as robotics, digitalisation, big data, genetics and precision agriculture. 2. **Biosecurity**: to improve understanding and evidence of pest and disease pathways to help direct biosecurity resources to their best uses, minimising biosecurity threats and improving market access for primary producers. 3. **Soil, water and managing natural resources:** to manage soil health, improve water use efficiency and certainty of supply, sustainably develop new production areas and improve resilience to climate events and impacts. 4. **Adoption of R&D:** focussing on flexible delivery of extension services that meet primary producers' needs and recognising the growing role of private service delivery.

Source: OCS 2015 and DAWR 2015

The Wine Australia project has addressed Strategic Science/ Research Priorities 1 and to a lesser extent 9 (lower alcohol wine). The major focus of the project has been on the first and second of the Rural R&D Priorities.

4. Identification of Potential Costs and Benefits

4.1 Costs

4.1.1 R&D Investment

The R&D investment costs comprised:

- Direct financial outlays by collaborators and participants in the research project, namely Wine Australia.
- In-kind contributions to the research project – non-cash contributions made by research partners CSIRO and the University of Adelaide (UA).
- In-kind contributions to the research project – time associated with meetings between the researchers and Wine Australia (project overhead costs).

4.1.2 Administration

No additional administration costs were identified.

4.1.3 Extension

Extension costs for communicating progress with new mildew resistant wine grape varieties included in the project budget.

4.1.4 Adoption

Adoption costs will be incurred by wine grape growers when new varieties replace current varieties in existing vineyards and when new vineyard areas are developed. These costs will not be incurred until further investment in the evaluation of selections has been made.

4.2 Benefits

4.2.1 Research Output and Impact Pathway

A key output of this project was a set of selections for further field trials, grape and wine evaluation. The potential impact pathway is:

1. Downy and powdery mildew resistant breeding lines identified through a previous Wine Australia research project (CSP 0904).
2. This project (CSP 1303) further assesses previously identified lines and shortlists 20 of the most prospective red and white berry selections.
3. Shortlisted selections established in larger scale regional field trials to determine their ability to produce vines with acceptable yields under different management treatments and different climates (CSP 1303).
4. Large scale wine making trials required along with regional industry input to assist in the evaluation of resultant wines.
5. 'Best of the best' selections made available to nurseries and growers for commercial production.

4.2.2 Triple Bottom Line Benefits

A summary of potential benefits from the project in triple bottom line categories is shown in Table 4.1.

Table 4.1 Triple Bottom Line Categories Benefits from Project Investment

Levy Paying Industry	**Spillovers**		
	Other Industries	**Public**	**Foreign**
Economic Benefits			
Improved vineyard profitability with wine grape varieties that require fewer chemical sprays to control mildew, have consistent yields and produce wines with desirable attributes. Future research cost savings with new techniques for the rapid assessment of fruit (SNP DNA techniques) and micro-scale wine making for sensory analysis.	Nil	Production and consumption of lower alcohol wines with the potential for improved human health outcomes.	New IP protected varieties may be licenced to overseas wine industries in the future.
Environmental Benefits			
Less chemical sprays in the vineyard and less risk of spray drift into the vineyard's surrounds. Less use of fuel to apply sprays with resultant small reductions in greenhouse gas emissions.	Nil	Nil	Nil

Fewer chemical sprays will allow use of beneficial insects to control of pests such as caterpillars, mealy bugs, aphids and thrip.			
Social Benefits			
Capacity – additional scientific knowledge and new techniques for grapevine genetic selection. Social - production and consumption of lower alcohol wines with the potential for improved human health outcomes. Social – reduced potential for chemical fungicide residues in wine with potential for improved human health outcomes. Long term protection of the grape and wine industry which will maintain income and employment in regional Australia (spill-over impact).	Nil	Nil	Nil

4.2.3 Public versus Private Benefits

The majority of benefits that will arise from project investment will be private in nature. The private benefits will be captured by wine grape growers. Private benefits will be realised as saved chemical spray costs. Potential public benefits may include improved environmental outcomes (e.g. reduced chemical load in the environment) and health benefits (e.g. production and consumption of lower alcohol wines).

4.2.4 Distribution of Benefits along the Supply Chain

The benefits to the wine industry from investment in this project will be shared along the supply chain with wine grape growers, wine makers, wholesalers, retailers and exporters all sharing in some of the benefits.

4.2.5 Benefits to other Primary Industries

No benefits to other primary industries were identified.

4.2.6 Benefits Overseas

No overseas benefits identified at this stage. New IP protected varieties may be licenced to overseas wine industries in the future.

4.3 Summary of Costs and Benefits

A summary of principal categories of costs and benefits from the project is shown in Table 4.2.

Table 4.2 Incremental Cost and Benefit Categories

Costs	Benefits
R&D investment costs (cash and in-kind) as well as project administration costs.	Economic – improved vineyard profitability with wine grape varieties that require fewer chemical sprays to control mildew, have consistent yields and produce wines with desirable attributes
Overhead costs including time associated with meetings between the researchers and Wine Australia.	Economic – future research cost savings with new techniques for the rapid assessment of fruit and micro-scale wine making for sensory analysis.
Research costs – additional investment will be required to appraise shortlisted red and white berry selections.	Environmental – less chemical sprays in the vineyard and less risk of spray drift into the vineyard's surrounds.
Adoption costs – costs will be incurred by wine grape growers planting new varieties.	Environmental – less use of fuel to apply sprays with resultant small reductions in greenhouse gas emissions.
	Environmental – fewer chemical sprays will allow use of beneficial insects to control of pests such as caterpillars, mealy bugs, aphids and thrip.
	Capacity – additional scientific knowledge and new techniques for grapevine genetic selection.
	Social - production and consumption of lower alcohol wines with the potential for improved human health outcomes.
	Social – long term advancement of the grape and wine industry which will maintain income and employment in regional Australia (spill-over impact).

5. Valuation of Costs and Benefits

5.1 Costs

5.1.1 R&D Investment Costs including Administration

The following tables show annual investment in the Project by Wine Australia (Table 5.1) and for researchers (Table 5.2). Table 5.3 provides the total investment by year for both sources.

Table 5.1 Investment by Wine Australia in the Project for Years Ending June 2014 to June 2019

Project Code	2014	2015	2016	2017	2018	2019	Total
CSP 1303 – Wine Australia	686,936	452,043	403,076	272,127	0	0	**1,814,182**
Total	**686,936**	**452,043**	**403,076**	**272,127**	**0**	**0**	**1,814,182**

Source: Wine Australia executed agreement and subsequent contract variations

Table 5.2 Investment by Others in the Project for Years Ending June 2017 to June 2019

Project Code	2014	2015	2016	2017	2018	2019	Total
CSP 1303 – CSIRO cash	0	0	0	0	0	0	**0**
CSP 1303 – CSIRO in-kind	342,726	362,422	383,077	404,735	0	0	**1,492,960**
CSP 1303 – UA cash	0	0	0	0	0	0	**0**
CSP 1303 – UA in-kind	66,186	70,110	74,212	79,181	0	0	**289,689**
Total	**408,912**	**432,532**	**457,289**	**483,916**	**0**	**0**	**1,782,649**

Source: Wine Australia executed agreement and subsequent contract variations

Table 5.3 Annual Investment in the Project (nominal $)

Year Ending 30 June	Wine Australia	Others	Total
2014	686,936	408,912	**1,095,848**
2015	452,043	432,532	**884,575**
2016	403,076	457,289	**860,365**
2017	272,127	483,916	**756,043**
2018	0	0	**0**
2019	0	0	**0**
Total	**1,814,182**	**1,782,649**	**3,596,831**

5.1.2 Overhead Costs including Meetings between the Researchers and Wine Australia

Wine Australia overhead costs are in addition to those shown in the above tables and are estimated at 12%.

5.1.4 Research and Adoption Costs

Further research is required to appraise shortlisted red and white berry selections. Adoption costs will be incurred by wine grape growers planting the new varieties. These costs are accounted for in the analysis through the application of a research benefit attribution factor – see Table 5.4 below.

5.2 Benefits

Counterfactual: if this project had not been funded, there is a 25% chance that another funding body (e.g. CSIRO or UA) would have evaluated the 1,200 selections grown as part of Wine Australia project CSP 0904 to identify the 20 best white and red berry prospects.

A previous benefit cost analysis evaluated the benefits of 20 best white and 20 best red berry selections to warm inland areas (AgEconPlus, 2019 - Evaluation and Demonstrating New Disease Resistant Varieties for Warm Inland Areas (CSP 1401)). Consequently, this benefit cost analysis focusses on the remaining Australian production areas.

5.2.1 Chemical Spray Cost Savings with Mildew Resistant Vines

Development and release of mildew resistant vines will save grape growers chemical (fungicide) spray costs. Powdery and downy mildew is particularly problematic in high humidity, moderate temperature areas but growers incur chemical and application costs in all production regions (Scholefield Robinson and Econsearch, 2010). A summary of key assumptions used to quantify chemical spray cost savings associated with Mildew resistant vines is summarised in Table 5.4.

Table 5.4 Summary of Assumptions

Variable	**Assumption**	**Source**
Chemical Spray Cost Savings with Mildew Resistant Vines		
Wine grape growing area - Australia.	146,128 ha	Wine Australia, National Vineyard Scan, 2019 retrieved at https://www.wineaustralia.com/news/media-releases/first-ever-clear-picture-of-australias-vineyards.
Percentage of Australian wine grape growing area relevant to this analysis i.e. area outside the warm inland region.	62%	Alex Sas, Senior RD&E Program Manager, Wine Australia, pers. comm., February 2020.
Cost of eradication and preventative treatments	$908/ha	Current cost of powdery and downy mildew control varies between $533 and $1,284/ha (Alex

for both powdery and downy mildew.		Sas, Senior RD&E Program Manager, Wine Australia, pers. comm., December 2019).
Reduction in mildew treatment costs with new resistant vines.	60%	Percentage cost savings based on discussions with researchers during the preparation of AgEconPlus, 2019.
Maximum adoption area for new mildew resistant varieties.	10%	Alex Sas, Senior RD&E Program Manager, Wine Australia, pers. comm., February 2020.
Year in which chemical cost saving first realised.	2026	Assumption based on three years of field and large-scale wine making trials, three years of nursery or grower scale up to produce a commercial quantity of vine planting material.
Year in which maximum adoption occurs.	2031	Five years after first chemical cost saving realised.
Attribution of benefits to this project.	40%	A modest attribution factor has been used in recognition of the importance of previous CSIRO/Wine Australia research, the need for further research to appraise shortlisted red and white berry selections as well as the adoption costs that will be incurred by wine grape growers planting the new varieties. This assumption is consistent with the evaluation of CSP 1401 (AgEconPlus, 2019).
Probability of output.	90%	Proven process for new vine selection and release is in place.
Probability of impact.	100%	Consultant assumptions after feedback from Alex Sas, Senior RD&E Program Manager, Wine Australia, February 2020.
Counterfactual	25%	If this project had not been funded, there is a 25% chance that another funding body (e.g. CSIRO or UA) would have evaluated the previous 1,200 selections to identify the 20 best red and white berry prospects for areas outside the warm inland.

5.2.2 Other Potential Benefits

Other potential benefits identified but not valued include:

- Future research cost savings with new techniques for the rapid assessment of fruit and micro-scale wine making for sensory analysis.
- Less chemical sprays in the vineyard and less risk of spray drift into the vineyard's surrounds.
- Less use of fuel to apply sprays with resultant small reductions in greenhouse gas emissions.
- Less risk of chemical residue from fungicide in wine.
- Additional scientific knowledge and new techniques for grapevine genetic selection.
- Production and consumption of lower alcohol wines with the potential for improved human health outcomes.

- Long term advancement of the grape and wine industry which will maintain income and employment in regional Australia (spill-over impact).

Other potential benefits were not quantified due to their relatively minor contribution to total impact and difficulty in securing data for quantification.

6. Results

All past costs were expressed in current dollar terms using the implicit price deflator for GDP. All costs and benefits from 2019 onwards were discounted to current dollar terms using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the Modified Internal Rate of Return (MIRR). The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for some of the estimates. All analyses ran for the length of the investment period plus 30 years from the last year of investment (2019).

Table 6.1 and Table 6.2 show the investment criteria estimated for the different periods of benefits for both the total investment and for Wine Australia investment. The present value of benefits (PVB) for the Wine Australia investment, shown in Table 6.2, is estimated by multiplying the total PVB by the Wine Australia proportion of investment.

Table 6.1 Investment Criteria for Total Investment by Wine Australia and Project Partners (discount rate 5%)

Years	0 years	5 years	10 years	15 years	20 years	25 years	30 years
Present value of benefits ($m)	0.00	0.00	0.58	3.90	7.11	9.63	11.60
Present value of costs ($m)	5.17	5.17	5.17	5.17	5.17	5.17	5.17
Net present value ($m)	-5.17	-5.17	-4.59	-1.27	1.94	4.46	6.43
Benefit–cost ratio	0.00	0.00	0.11	0.75	1.38	1.86	2.24
Internal rate of return (%)	Negative	Negative	Negative	1.7%	6.4%	8.2%	9.0%
Modified internal rate of return (%)	Negative	Negative	Negative	2.2%	6.0%	7.1%	7.4%

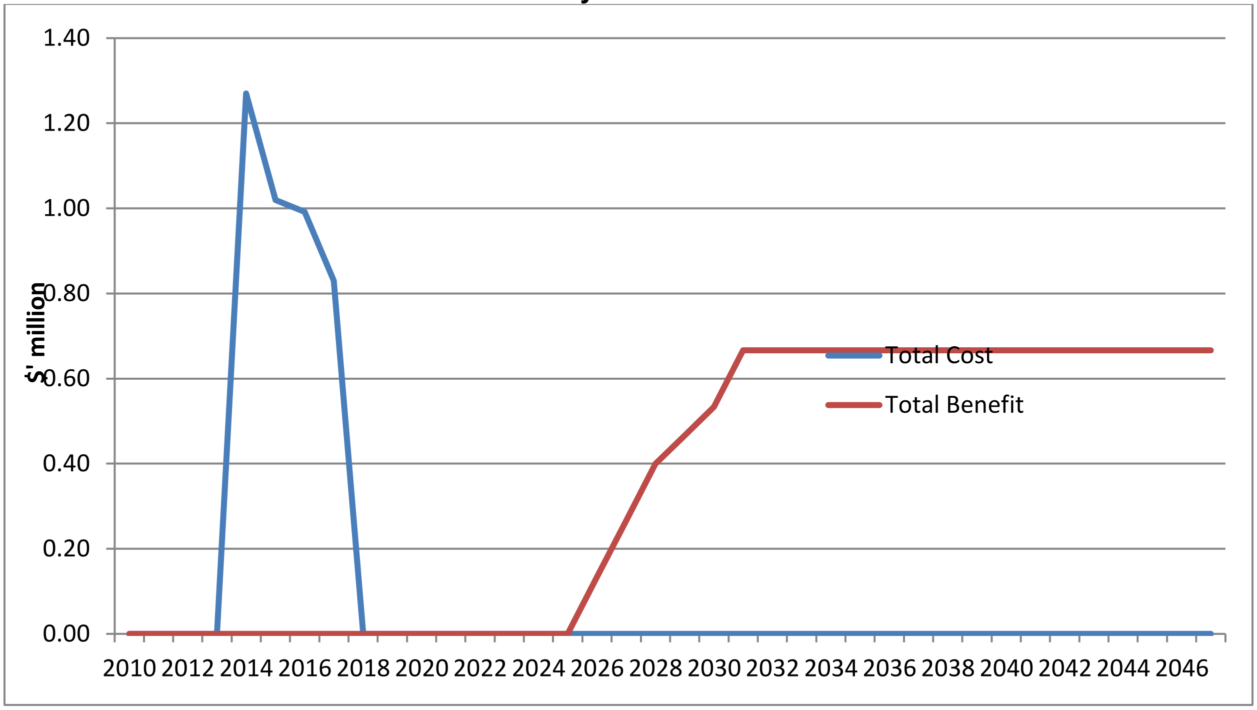
NB: present value of costs is the 2019 dollar value of Wine Australia expenditure (including overhead costs) plus the present value of CSIRO and University of Adelaide expenditures.

Table 6.2 Investment Criteria for Wine Australia (discount rate 5%)

Years	0 years	5 years	10 years	15 years	20 years	25 years	30 years
Present value of benefits ($m)	0.00	0.00	0.31	2.08	3.79	5.13	6.19
Present value of costs ($m)	2.78	2.78	2.78	2.78	2.78	2.78	2.78
Net present value ($m)	-2.78	-2.78	-2.47	-0.71	1.01	2.35	3.40
Benefit–cost ratio	0.00	0.00	0.11	0.75	1.36	1.84	2.22
Internal rate of return (%)	Negative	Negative	Negative	1.6	6.3	8.1	8.9
Modified internal rate of return (%)	Negative	Negative	Negative	2.1	6.0	7.1	7.4

The annual undiscounted benefits and cost cash flows for the total investment for the duration of the investment period plus 30 years from the last year of the initial investment are shown in Figure 6.1.

Figure 6.1 Annual Undiscounted Cash Flows for Estimated Total Benefits and Total RD&E Investment Costs for Elite Mildew Resistant Selections Project



7. Sensitivity Analysis

A sensitivity analysis was carried out for the central analysis results reported in Section 6 and variations in the discount rate. Table 7.1 presents the results. These indicate that at a 10% discount rate project costs exceed project benefits.

Table 7.1 Sensitivity to Discount Rate (Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($m)	26.25	11.60	5.73
Present value of costs ($m)	4.11	5.17	6.45
Net present value ($m)	22.14	6.43	-0.72
Benefit-cost ratio	6.39	2.24	0.89

Sensitivity analyses were undertaken for those variables where there was greatest uncertainty or for those that were identified as key drivers of the investment criteria. The analyses were performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values.

For this project the greatest uncertainty related to the reduction in mildew treatment costs with new resistant vines and the maximum adoption area for new mildew resistant vines – Table 7.2 and Table 7.3. Results show that the benefit cost ratio remains positive with either a 30% saving in mildew treatment costs or a 5% maximum adoption of the new vines.

Table 7.2 Sensitivity to Reduction in Mildew Treatment Costs with New Vines (Total investment, 30 years)

Investment Criteria	Saving in Mildew Treatment Costs (%)		
	30%	60% (base)	90%
Present value of benefits ($m)	5.80	11.60	17.40
Present value of costs ($m)	5.17	5.17	5.17
Net present value ($m)	0.63	6.43	12.23
Benefit-cost ratio	1.12	2.24	3.37

Table 7.3 Sensitivity to the Maximum Adoption Area for New Mildew Resistant Vines (Total investment, 30 years)

Investment Criteria	Maximum Adoption Area of New Vines (% of Cooler Production Areas)		
	5%	10% (base)	20%
Present value of benefits ($m)	5.80	11.60	23.20
Present value of costs ($m)	5.17	5.17	5.17
Net present value ($m)	0.63	6.43	18.03
Benefit-cost ratio	1.12	2.24	4.49

8. Confidence Ratings

The results produced are highly dependent on the assumptions made, many of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 8.1). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 8.1 Confidence in Analysis of Program

Coverage of Benefits	Confidence in Assumptions
Medium	Medium

9. Summary of Results

Funding for CSP 1303 'towards elite mildew resistant selections suitable for industry use' had a total cost of $5.17 million (present value terms) and is expected to produce aggregate total benefits of approximately $11.60 million (present value terms). This gives an estimated net present value of $6.43 million, a benefit-cost ratio of approximately 2.24, an internal rate of return of 9% and a modified internal rate of return of 7%.

Analysis results are dependent on assumptions made and are positive for core assumptions and remain positive through sensitivity testing.

Completion of large-scale wine making trials along with regional industry input to assist in the evaluation of resultant wines is now a priority for the Australian wine industry.

Abbreviations

DAWR	Department of Agriculture and Water Resources
IP	Intellectual Property
OCS	Office of Chief Scientist
UA	University of Adelaide

Persons Contacted

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Ian Dry, Researcher, CSIRO (co-researcher on CSP 1303)
Alex Sas, Senior RD&E Program Manager, Wine Australia
Mark Thomas, Principal Researcher, CSIRO (has retired and could not be contacted)

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