Benefit Cost Analysis of Wine Australia R&D Investments 2019-20

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Executive Summary

Economic analyses of three research and development (R&D) projects funded by Wine Australia has 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.

Investment in all three projects yielded positive results at a 5% discount rate and a 30 year analysis period. When core analysis assumptions were subject to sensitivity testing, two projects (MQ 1401 and USA 1601) produced benefit-cost ratios less than one for 'lower end' assumptions – Table ES1.

Table ES1: Benefit Cost Analyses Three Wine Australia R&D Investments 2019-20 (discount rate 5%)

Investment Criteria	Investment Project		
	Yield Prediction with Advanced Statistics (MQ 1401)	**Unmanned Air Vehicles to Predict Extreme Weather (USA 1601)**	**Industry Outcomes, Training Centre for Innovative Wine Production (UA 1708)**
Benefit–cost ratio	1.57	2.24	4.02
Benefit-cost ratio range - core assumption sensitivity	0.68 to 3.85	0.75 to 5.52	1.40 to 6.39
Quantified benefits	Grape grower cost savings with accurate yield forecasts.	Progress toward the avoidance of fruit damage in new vineyards that are unprotected from frost.	Additional higher priced sales of Australian wine produced more efficiently and sooner than would otherwise have occurred.
	Wine maker cost savings with accurate yield forecasts.	Progress toward savings from installing too many frost fans.	
Unquantified benefits	Supply chain efficiencies with winery customers assured of the quality and quantity of wine available for marketing.	Possible efficiencies in vineyard heat stress research with the project generated technology and new tools (an algorithm) suitable for this application.	Wine researchers and leaders with additional, relevant skill sets.
	Early adjustment of vineyard practices to manage yield may reduce water and fertiliser waste and deliver environmental benefits.	Minor savings in greenhouse gas (GHG) emission associated with deployment of fewer diesel-burning frost fans.	A more profitable and sustainable wine industry generating additional income, and employment in regional Australia (spill-over impact).
	Transport efficiency and coordination with wineries enabling space and energy to be saved.	Additional scientific and engineering knowledge associated with remote sensing and data interpretation at the micro-climate level.	
	Additional machine learning skills for use in the wine	Long term advancement of the grape and wine industry which will	

	industry and other Australian industries.	maintain income and employment in regional Australia (spill-over impact).	
	A web-based repository of yield data for use in future wine industry research projects.		
	Reduced seasonal variation in production with reduced uncertainties, tensions and anxieties between growers and grape buyers.		
	Additional industry confidence, investment certainty, income, and employment in regional Australia (spill-over impact).		

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.

Wine Australia has shifted away from a focus on individual projects to larger, longer term bilateral agreements. Consequently, only a small number of projects were completed in 2019-20 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 12. An online random number generator was used to select projects until total selection exceeded $1,108,713, 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 2019-20

No.	Code	Project Title	Program	Investment
6	MQ 1401	Accurate and early yield predictions through advanced statistical modelling	4. Grow sustainable environments	323,660
10	USA 1601	Use of Unmanned Air Vehicles for early, real time detection of extreme weather events in vineyards	3. Enhance grape and wine excellence	595,000
8	UA 1708	Translation of Training Centre for Innovative Wine Production Research into Industry Outcomes	5. Build business sustainability, excellence and leadership	296,000
			Investment in projects for analysis	1,214,660
			Total of Wine Australia investment in completed projects	11,087,129
			Analysis projects share of total investment	11%

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 2020 dollar terms. Future costs and benefits were discounted to the 2020 year while past costs were inflated to 2020 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 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.

Table 2 presents the investment criteria for each of the projects analysed at a 5% discount rate and expressed in 2020 dollar terms. Given the assumptions made for each evaluation, all three investments are expected to produce positive net benefits over 30 years from the last year of investment.

Table 2: Benefit Cost Analyses for Three Wine Australia R&D Investments 2019-20 (discount rate 5%)

Investment Criteria	Investment Project		
	Yield Prediction with Advanced Statistics (MQ 1401)	**Unmanned Air Vehicles to Predict Extreme Weather (USA 1601)**	**Industry Outcomes, Training Centre for Innovative Wine Production (UA 1708)**
Present value of benefits ($m)	1.06	4.17	1.52
Present value of costs ($m)	0.67	1.86	0.38
Net present value ($m)	0.38	2.31	1.14
Benefit–cost ratio	1.57	2.24	4.02
Benefit-cost ratio range - core assumption sensitivity	0.68 to 3.85	0.75 to 5.52	1.40 to 6.39
Internal rate of return (%)	7.3	10.4	70.2
Modified internal rate of return (%)	6.2	7.6	9.4
Quantified benefits	Grape grower cost savings with accurate yield forecasts.	Progress toward the avoidance of fruit damage in new vineyards that are unprotected from frost.	Additional higher priced sales of Australian wine produced more efficiently and sooner than would otherwise have occurred.
	Wine maker cost savings with accurate yield forecasts.	Progress toward savings from installing too many frost fans.	
Unquantified benefits	Supply chain efficiencies with winery customers assured of the quality and quantity of wine available for marketing.	Possible efficiencies in vineyard heat stress research with the project generated technology and new tools (an algorithm) suitable for this application.	Wine researchers and leaders with additional, relevant skill sets.
	Early adjustment of vineyard practices to manage yield may reduce water and fertiliser waste and deliver environmental benefits.	Minor savings in greenhouse gas (GHG) emission associated with deployment of fewer diesel-burning frost fans.	A more profitable and sustainable wine industry generating additional income, and employment in regional Australia (spill-over impact)
	Transport efficiency and coordination with wineries enabling space and energy to be saved.	Additional scientific and engineering knowledge associated with remote sensing and data interpretation at the micro-climate level.	
	Additional machine learning skills for use in the wine industry and other Australian industries.	Long term advancement of the grape and wine industry which will maintain income and	

	A web-based repository of yield data for use in future wine industry research projects.	employment in regional Australia (spill-over impact).	
	Reduced seasonal variation in production with reduced uncertainties, tensions and anxieties between growers and grape buyers.		
	Additional industry confidence, investment certainty, income, and employment in regional Australia (spill-over impact).		

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

Wine Australia has shifted away from a focus on individual projects to larger, longer term bilateral agreements. Consequently, only a small number of projects were completed in 2019-20 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 12. An online random number generator was used to select projects until total selection exceeded $1,108,713, 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 2019-20

No.	Code	Project Title	Program	Investment
6	MQ 1401	Accurate and early yield predictions through advanced statistical modelling	4. Grow sustainable environments	323,660
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			Investment in projects for analysis	1,214,660
			Total of Wine Australia investment in completed projects	11,087,129
			Analysis projects share of total investment	11%

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 2020 dollar terms. Future costs and benefits were discounted to the 2020 year while past costs were inflated to 2020 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
Yield Prediction with Advanced Statistics (MQ 1401)	Economic • Grape grower production cost savings with accurate yield forecasts. • Wine maker production cost savings with accurate yield forecasts. • Supply chain efficiencies with winery customers assured of the quality and quantity of wine available for marketing. Environmental • Early adjustment of vineyard practices to manage yield may reduce water and fertiliser waste. • Increased transport efficiency and coordination with wineries enabling space and energy to be saved. Social • Capacity – additional machine learning skills for use in the wine industry and other Australian industries. • Capacity – a web-based repository of yield data for use in future wine industry research projects. • Reduced seasonal variation in production with reduced uncertainties, tensions and anxieties between growers and grape buyers. • Additional industry confidence, investment certainty, income, and employment in regional Australia (spill-over impact).
Unmanned Air Vehicles to Predict Extreme Weather (USA 1601)	Economic • Progress toward the avoidance of fruit damage in new vineyards that are unprotected from frost. • Progress toward savings from installing too many frost fans. • Possible efficiencies in vineyard heat stress research with the project generated technology and new tools (an algorithm) suitable for this application. Environmental • Minor savings in greenhouse gas (GHG) emission associated with deployment of fewer diesel-burning frost fans. Social • Capacity – additional scientific and engineering knowledge associated with remote sensing and data interpretation at the micro-climate level.

	• Long term advancement of the grape and wine industry which will maintain income and employment in regional Australia (spill-over impact).
Industry Outcomes, Training Centre for Innovative Wine Production (UA 1708)	Economic • Additional higher priced sales of Australian wine produced more efficiently and sooner than would otherwise have occurred. Environmental • Nil. Social • Capacity - wine researchers and leaders with additional, relevant skill sets. • A more profitable and sustainable wine industry generating additional 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		
	Yield Prediction with Advanced Statistics (MQ 1401)	**Unmanned Air Vehicles to Predict Extreme Weather (USA 1601)**	**Industry Outcomes, Training Centre for Innovative Wine Production (UA 1708)**
Present value of benefits ($m)	1.06	4.17	1.52
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Internal rate of return (%)	7.3	10.4	70.2
Modified internal rate of return (%)	6.2	7.6	9.4

4. Conclusion

All three investment analyses yielded positive results at the 5% discount rate, with B/C Ratios of 1.57, 2.24 and 4.02.

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 Accurate and Early Yield Predictions Through Advanced Statistical Modelling

1. Background

Managing yields through informed decision-making is important to grape growers because yield-quality interactions and yield targets specified by buyers affect income. Coordination between growers and wineries is disrupted when yields differ from predictions and so poor predictions have flow-on effects through wine production and distribution chains. Wine Australia analysis (CSH96/1) estimated 10% of industry expenditure is dedicated to coping with seasonal variation and that half of this total could be saved through exact yield forecasts. The estimated cost of inaccurate forecasts was $100 million annually.

Yields are influenced by weather up to 18 months prior to harvest and by crop load and vegetative growth from the previous season. As a result, yields vary considerably from year-to-year because of compounding weather effects, with costly unpredictability. The general ways in which weather affects individual components of yield, such as the initiation of inflorescences and flowering are known. However, a model incorporating the multiple factors affecting yield does not exist.

The reason for the lack of a comprehensive model to predict yield is that computational complexity grows exponentially with each additional variable. Standard statistical methods used to identify individual components of yield are not suitable for assessing all the components as a whole. The only methods capable of modelling multiple non-linear relationships are machine learning methods, such as artificial neural networks.

Hiring experts in machine learning is difficult because demand is high across multiple industries. Macquarie University assembled a team of machine learning experts and expert plant modellers for this project. The project built on useful crop forecast modelling completed by Mike Trought (e.g., 2005 ASVO Proceedings) and berry growth analysis completed by Clingeleffer, Dunn and others (e.g., CSH96/1).

2. Summary of Projects

Table 2.1 provides a description of the project in a logical framework.

Table 2.1 Project Description

MQ 1401: Accurate and Early Yield Predictions Through Advanced Statistical Modelling	
Project Details	Research Organisation: Macquarie University Period: July 2014 to June 2019 Principal Investigator: Steven Van Sluyter
Rationale	If an accurate and easy to use yield prediction tool was available and used by wine grape growers it would have the potential to reduce costs associated with yield variation experienced by grape growers, wine makers and the supply chain.
Objectives	The objective of the project was to develop an accurate (+/-5%) and easy to use wine grape yield prediction tool that would be available to growers through a centralised web-based resource. The tool would have two components: • Crop forecasting model – was to have the capacity to predict bunch characteristics and derive crop forecasts from bunch characteristics. It was to focus on pre-fruit set conditions. The forecasts would be updatable as the season progresses and weather data are incorporated at key developmental stages.

	• Berry growth model – was to predict berry size based on vineyard and weather data, with a focus on conditions post-fruit set, although simultaneously informed by conditions before fruit-set. Yield estimates were to be produced by combining berry size predictions with either the bunch characteristics from the crop forecasting model, or from berry data collected post-fruit set.
Activities and Outputs	Stage 1 • Determine which variables to include in the model. Variables were selected to optimise prediction accuracy across major cultivars and regions with the lowest number of possible metrics. • 'Train' the models using historical data. Historical data was sourced from Treasury Wine Estates, Casella Wines, McWilliam's Wine and Brown Brothers. • Complete preliminary testing of the models during the 2016/17 vintage with grape growing and wine making partners. Stage 2 • Incorporation of models into a browser-based user interface and work with additional data and growers to fine-tune the tools. Outputs • The strongest predictors for yields were found to be the average yield of the block and weather at flowering. • The accuracy of the models depended heavily on the sources of data. • The most accurate predictions for a single grower were <10% error; the least accurate were >20% error. • Although prediction errors were higher than the project goal of 5%, the approach used, based on machine learning and weather data to predict vineyard yields, was deemed to be promising. • The main barrier to higher prediction accuracy was the quality of historical grower data for 'training' models. There may also be issues with the quality of weather data, especially when vineyards are in undulating country and some distance from the nearest Bureau of Meteorology weather station. • Other outputs from the project included a final project report which is available online, conference presentations, journal, and industry publications.
Outcomes	• Progress towards delivery of an accurate and early yield prediction tool that will facilitate improved decision making in the vineyard, by wine makers and through the industry's various supply chains. The University of Technology Sydney and commercial interests have subsequently advanced the development of this tool (Steven Van Sluyter, pers. comm., March 2021). • A strategic resource (data and skilled individuals) for future grape and wine research using machine learning. Applications may include predicting stuck ferments and consumer preference analysis.
Impacts (potential)	• Economic – progress toward grape growers using accurate yield forecasts to improve decision making and achieving production cost savings. Production cost savings may be associated with changes to winter pruning, irrigation, fertiliser application, labour use and transport efficiency. • Economic – progress toward wine makers receiving expected grape qualities and quantities from growers using accurate yield forecasts with resulting cost savings. Wine making cost savings may take the form of improved use of capital equipment and labour.

	• Economic – progress toward supply chain efficiencies with winery customers assured of the quality and quantity of wine available for marketing. Supply chain efficiencies might include improved planning and more efficient and profitable marketing programs. • Environmental – when accurate and early forecasts of yield are available and adopted, they will allow early adjustment to vineyard practices to manage yield with reduced water and fertiliser waste. • Environmental – when accurate and early forecasts of yield are available, they will allow increased transport efficiency and coordination with wineries, enabling space and energy to be saved. • Capacity – additional machine learning skills for use in the Australian wine industry and other Australian industries. • Capacity - a web-based repository of yield data for use in future wine industry research projects. • Social – when accurate yield forecasts are available there will be less seasonal variation in production with reduced uncertainties, tensions and anxieties between growers and grape buyers. • Social – when accurate yield forecasts are available and applied, they will add to industry confidence, investment certainty, 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 (both checked for currency February 2021)

The Wine Australia project has addressed Strategic Science/Research Priority 1 and potentially Priorities 2, 3 and 5. The major focus of the project has been on the first 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 Wine Australia, the project funding body. These costs include both project and overhead expenditures.
- In-kind contributions to the research project – non-cash contributions made by the research partners (Macquarie University and NSW Department of Primary Industries).
- 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

The project was focussed on machine learning research, some interaction was required with industry partners and this was included in the project budget. The project did not generate a commercial or even near-commercial product. Further research, development and extension investment will be required to realise potential project impacts.

4.1.4 Adoption

The project has created a 'promising approach' to yield forecasting. Additional investment will be required in RD&E and costs will be incurred by grape growers. Grape grower adoption costs may, in time, include training, data collection and access costs for a central web-based crop forecasting system.

4.2 Benefits

4.2.1 Research Output and Impact Pathway

The potential impact pathway for the project is:

1. Promising approach identified through the current project (MQ 1401).
2. Follow up project required to deliver reliable, yield forecasting product based on machine learning.
3. Ongoing refinement and update of the models as data accumulates.
4. Models established as a centralised web-based resource, technical support and extension supplied to ensure grape grower adoption.
5. Grape growers, wine makers and the supply chain benefit from accurate and early yield prediction.

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			
Progress toward grape growers using accurate yield forecasts to improve decision making and achieving production cost savings.	Nil.	Nil.	If industry choses to share or licence the technology, the final version of the yield prediction model will be

Progress towards wine makers receiving expected grape qualities and quantities from growers using accurate yield forecasts with resulting cost savings. Progress toward supply chain efficiencies with winery customers assured of the quality and quantity of wine available for marketing.			relevant to overseas wine producing countries.
<u>Environmental Benefits</u>			
Accurate and early forecasts of yield will allow early adjustment to vineyard practices to manage yield may reduce water and fertiliser waste. Accurate yield predictions will allow increased transport efficiency and coordination with wineries, enabling space and energy to be saved.	Nil	Nil	Nil
<u>Social Benefits</u>			
Capacity – additional machine learning skills for use in the wine industry and other Australian industries. Capacity - a web-based repository of yield data for use in future wine industry research projects. When accurate yield forecasts are available there will be less seasonal variation in production with reduced uncertainties, tensions and anxieties between growers and grape buyers. When accurate yield forecasts are available and applied, they will add to industry confidence, investment certainty, income, and employment in regional Australia (spill-over impact).	Capacity developed during the project may assist with yield forecasting models for other horticultural industries and machine learning tasks in industries as diverse as finance, marketing, web search, and biotech.	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, wine makers and the supply chain. Private benefits will be realised as saved production and marketing costs. Potential public benefits may include improved environmental outcomes (e.g., reduced water and fertiliser waste) and capacity benefits (e.g., additional machine learning skills).

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. Supply chain specific benefits may include progress toward efficiencies associated with assured quality and quantity of wine available for marketing.

4.2.5 Benefits to other Primary Industries

Capacity developed during the project may assist with yield forecasting models for other horticultural industries and machine learning tasks in industries as diverse as finance, marketing, web search, and biotech.

4.2.6 Benefits Overseas

If industry choses to share or licence the technology, the final version of the yield prediction model will be relevant to overseas wine producing countries.

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 – grape grower cost savings with accurate yield forecasts.
Overhead costs including time associated with meetings between the researchers and Wine Australia.	Economic – wine maker cost savings with accurate yield forecasts.
Research costs – additional investment will be required to further refine and 'proof' machine learning yield prediction models.	Economic – supply chain efficiencies with winery customers assured of the quality and quantity of wine available for marketing.
Adoption and model maintenance costs – costs will be incurred establishing the model as a centralised web-based resource, providing technical support and extension to ensure grape grower adoption.	Environmental – early adjustment of vineyard practices to manage yield may reduce water and fertiliser waste.
	Environmental – increased transport efficiency and coordination with wineries enabling space and energy to be saved.
	Capacity – additional machine learning skills for use in the wine industry and other Australian industries.
	Capacity – a web-based repository of yield data for use in future wine industry research projects.
	Social – reduced seasonal variation in production with reduced uncertainties, tensions and anxieties between growers and grape buyers.

	Social – additional industry confidence, investment certainty, 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 other investors (Table 5.2). The other investors in the project were Macquarie University and the NSW Department of Primary Industries. 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 2015 to June 2017

Project Code	2015	2016	2017	2018	2019	Total
MQ 1401 – Wine Australia	98,630	107,660	68,821	0	48,549	**323,660**
Total	**98,630**	**107,660**	**68,821**	**0**	**48,549**	**323,660**

Source: Wine Australia record of project expenditure

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

Project Code	2015	2016	2017	2018	2019	Total
MQ 1401 – Other cash	0	0	0	0	0	**0**
MQ 1401 – Other in-kind	51,400	51,400	0	0	51,400	**154,200**
Total	**51,400**	**51,400**	**0**	**0**	**51,400**	**154,200**

Source: Wine Australia executed project agreement

Table 5.3 Annual Investment in the Project (nominal $)

Year Ending 30 June	Wine Australia	Others	Total
2015	98,630	51,400	150,030
2016	107,660	51,400	159,060
2017	68,821	0	68,821
2018	0	0	0
2019	48,549	51,400	99,949
Total	**323,660**	**154,200**	**477,860**

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, Adoption and Maintenance Costs

Further research is required to refine and 'proof' machine learning yield prediction models. Investment will then be needed to establish the model as a centralised web-based resource, provide technical support and extension to ensure grape grower adoption. 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: in the absence of this project, there is a possibility that overseas generated wine grape prediction models such as Mike Trought's work (e.g., 2005 ASVO Proceedings) which produced a 'reasonable job of forecasting yields at regional levels for New Zealand Sauvignon blanc', would have been

adapted for Australia. Consequently, a counterfactual of 30% has been assumed i.e., it is 30% likely that potential project benefits would have been realised in the absence of project investment.

Subsequent to the project, other researchers have incorporated principles developed as part of MQ 1401 into vineyard models. Project IP was licensed to agtech start-up The Yield who subsequently developed a similar model using their own approach. Also, the US company Vinsight have commercialised a yield prediction product but with the addition of satellite data (Steven Van Sluyter, Principal Investigator MQ 1401, pers. comm., March 2021). The Vinsight product is now Bountiful Ag and Deep Planet and Trellis are the other main players in yield prediction (Paul Smith, Senior RD&E Program Manager, Wine Australia, pers. comm., March 2021).

5.2.1 Grape Grower Production Cost Savings with Accurate Yield Forecasts

The project has delivered progress toward grape growers using accurate yield forecasts to improve decision making and realising production cost savings. Production cost savings may be associated with changes to winter pruning, irrigation, fertiliser application, labour use, and transport efficiency.

5.2.2 Wine Maker Cost Savings with Accurate Yield Forecasts

The project has delivered progress toward wine makers receiving expected grape qualities and quantities from growers using accurate yield forecasts with resulting cost savings. Wine making cost savings may take the form of improved use of capital equipment and labour.

A summary of key assumptions used to quantify cost savings associated with accurate yield forecasts is summarised in Table 5.4.

Table 5.4 Summary of Assumptions

Variable	Assumption	Source
Benefit 1: Grape Grower Production Cost Savings with Accurate Yield Forecasts		
Number of wine grape grower businesses.	5,160	Wine Australia 2019.
Average turnover per wine grape grower business.	$150,000 per annum.	Wine Australia 2019.
Costs as a proportion of turnover.	82%	Wine Australia 2019.
Cost reduction attributable to accurate and early yield predictions.	2%	Analyst's estimate.
Benefit 2: Wine Maker Production Cost Savings with Accurate Yield Forecasts		
Number of wine making businesses.	2,268	Wine Australia 2019.
Average turnover per wine making business.	$2,000,000 per annum.	Wine Australia 2019.
Costs as a proportion of turnover.	64%	Wine Australia 2019.
Cost reduction attributable to accurate and early yield predictions.	2%	Analyst's estimate.
Assumptions Common to the Quantification of Both Benefits		
Attribution of benefits to this project (MQ 1401).	15%	Further investment is required to deliver a consistently reliable, yield forecasting product

		based on machine learning. Once a reliable product has been developed investment will be required in establishing a centralised web-based resource, technical support, and extension to ensure grape grower adoption. MQ 1401 is only one, relatively small part of the overall investment 'picture'.
Year in which grape grower and wine maker cost savings first realised.	2029	A ten year lag has been assumed to account for further investment in forecast development, commercialisation, and adoption.
Maximum adoption by grape growers and wine makers.	20% of grape growers. 20% of wine makers.	Analyst's assumption to be tested using sensitivity analysis.
Probability of valuable outputs.	50%	Forecasts from MQ 1401 are not yet proven to be accurate with best results <10% variation from actual yield and worst results >20% variation from actual yield.
Probability of valuable outcomes.	50%	Forecast accuracy is dependent on farm and BOM data which in instances is inaccurate.
Probability of impact.	50%	Wine grape yield forecasts using machine learning are as yet unproven in reducing grape and wine production costs.
Counterfactual	30%	See above explanation.

5.2.3 Other Potential Benefits

Other potential benefits identified but not valued include:

- Supply chain efficiencies with winery customers assured of the quality and quantity of wine available for marketing.
- Early adjustment of vineyard practices to manage yield may reduce water and fertiliser waste and deliver environmental benefits.
- Transport efficiency and coordination with wineries enabling space and energy to be saved.
- Additional machine learning skills for use in the wine industry and other Australian industries.
- A web-based repository of yield data for use in future wine industry research projects.
- Reduced seasonal variation in production with reduced uncertainties, tensions and anxieties between growers and grape buyers.
- Additional industry confidence, investment certainty, 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 2020 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%)

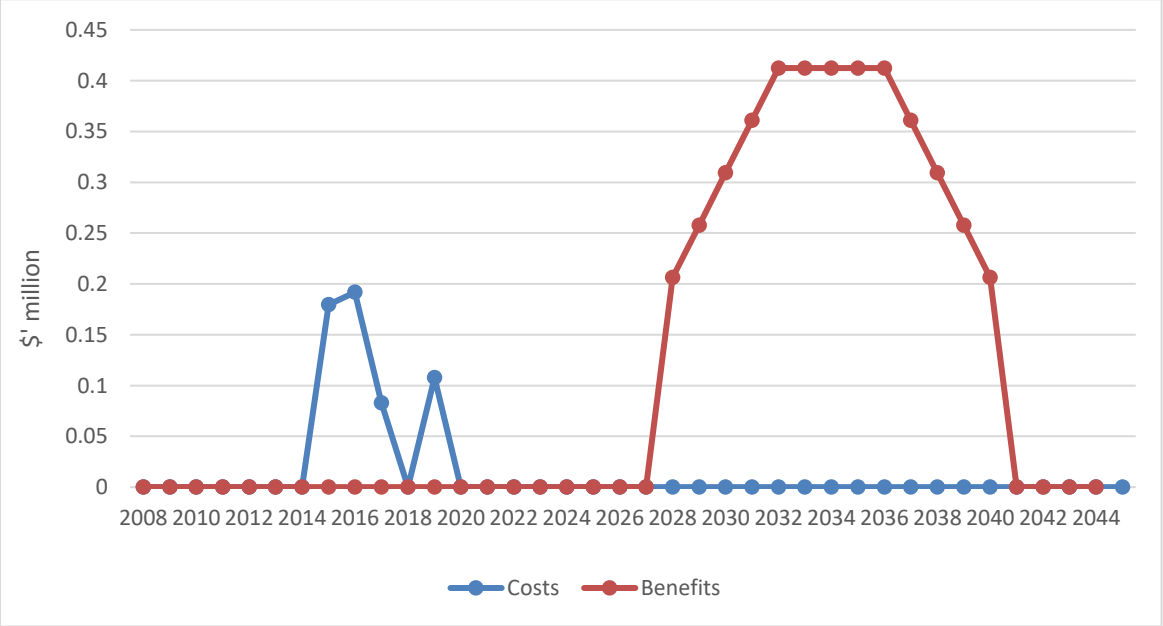
Years	0 years	5 years	10 years	15 years	20 years	25 years	30 years
Present value of benefits ($m)	0.00	0.00	0.07	0.55	0.97	1.06	1.06
Present value of costs ($m)	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Net present value ($m)	-0.67	-0.67	-0.60	-0.12	0.30	0.38	0.38
Benefit–cost ratio	0.00	0.00	0.10	0.82	1.44	1.57	1.57
Internal rate of return (%)	Negative	Negative	Negative	3.1	6.8	7.3	7.3
MIRR (%)	Negative	Negative	Negative	3.4	6.4	6.4	6.2

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 ($m)	0.00	0.00	0.05	0.39	0.68	0.74	0.74
Present value of costs ($m)	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Net present value ($m)	-0.47	-0.47	-0.43	-0.09	0.21	0.27	0.27
Benefit–cost ratio	0.00	0.00	0.10	0.82	1.44	1.57	1.57
Internal rate of return (%)	Negative	Negative	Negative	3.1	6.8	7.3	7.3
MIRR (%)	Negative	Negative	Negative	3.4	6.4	6.4	6.2

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 Yield Predictions 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. The results are sensitive to discount rate due to the long lag between investment in MQ 1401 and the creation of wine industry benefits.

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

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($m)	2.17	1.06	0.55
Present value of costs ($m)	0.56	0.67	0.80
Net present value ($m)	1.60	0.38	-0.25
Benefit-cost ratio	3.85	1.57	0.68

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 maximum adoption of accurate and early yield predictions and the cost saving realised – Table 7.2 and Table 7.3. Results show that the benefit cost ratio is sensitive to both these key assumptions and that for 'lower end' assumptions project costs exceed project benefits.

Table 7.2 Sensitivity to Adoption of Yield Predictions (Total investment, 30 years)

Investment Criteria	Grape Growing and Wine Making Businesses Adopting Yield Predictions (%)		
	10%	20% (base)	40%
Present value of benefits ($m)	0.53	1.06	2.11
Present value of costs ($m)	0.67	0.67	0.67
Net present value ($m)	-0.14	0.38	1.44
Benefit-cost ratio	0.79	1.57	3.14

Table 7.3 Sensitivity to Cost Savings Realised from Yield Predictions (Total investment, 30 years)

Investment Criteria	Cost Saving Realised – Grape Growers and Wine Makers ($/tonne)		
	1%	2% (base)	4%
Present value of benefits ($m)	0.53	1.06	2.11
Present value of costs ($m)	0.67	0.67	0.67
Net present value ($m)	-0.14	0.38	1.44
Benefit-cost ratio	0.79	1.57	3.14

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-High	Low

9. Summary of Results

Funding for MQ 1401 'accurate and early yield predictions through advanced statistical modelling' had a total cost of $0.67 million (present value terms) and is expected to produce aggregate total benefits of approximately $1.06 million (present value terms). This gives an estimated net present value of $0.38 million, a benefit-cost ratio of approximately 1.57, an internal rate of return of 7% and a modified internal rate of return of 6%.

Analysis results are dependent on assumptions made and are positive for core assumptions but become negative for 'lower end' assumptions used during sensitivity testing.

Additional investment in wine grape yield predictions RD&E is required before benefits will be realised.

Abbreviations

BOM	Bureau of Meteorology
DAWR	Department of Agriculture and Water Resources
OCS	Office of Chief Scientist
R&D	Research and Development

Persons Contacted

Paul Smith, Senior RD&E Program Manager, Wine Australia
Steven Van Sluyter, Principal Researcher, previously with Macquarie University

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Appendix 2: Economic Analysis Wine Australia's Investment in Use of Unmanned Air Vehicles for Early, Real-Time Detection of Extreme Weather Events in Vineyards

1. Background

The effects of high temperature and frost on grapevine phenology, yield and quality are well understood and have been shown to reduce the national grape crush by as much as 15%. The synoptic conditions that lead to such events are easily recognised. However, the duration of extreme weather events, exactly where frost will occur, precisely how hot it is within individual vineyards and under canopies and what the impact will be on individual plants is much harder to predict and monitor. Moreover, in the longer term, climate change may lead to additional extreme weather events and an even greater need to understand and accurately manage crop damaging events.

There are a number of protection measures that can be used by grape growers to guard against the effects of extreme weather (e.g., sprinklers, wind machines and heaters), but their use depends on often distant, and therefore less relevant, regional estimates of meteorological conditions. More precise knowledge of the locations, temperatures, and impending impact of extreme weather events at the micro-scale may be required. More precise knowledge delivered in near real-time might permit more effective and efficient use of extreme weather event mitigation measures.

The technology chosen for evaluation in this project was a commercially available, unmanned aerial vehicle (UAV). The UAV was fitted with acoustic sensors that transmit temperature and other climate variables by detecting the variation in sound speed of signals as the aircraft overflies the vineyard. This technique is known as atmospheric acoustic tomography (AAT) and is widely used in other fields such as archaeology.

As the UAV can also be equipped with a camera capable of high resolution thermal imagery, ground, canopy, and fruit temperature data can be fused with the tomographically-derived atmospheric data. Potentially, this would permit real-time detection and monitoring of the micro-climates in and around the vineyard at increased levels of accuracy and resolution. Automatic dissemination of this information to grape growers in near real-time, it was hoped, would enable more efficient crop protection i.e., less fruit damage at a lower intervention cost.

2. Summary of Projects

Table 2.1 provides a description of the project in a logical framework.

Table 2.1 Project Description

USA 1601: Use of Unmanned Air Vehicles for Early, Real-Time Detection of Extreme Weather Events in Vineyards	
Project Details	Research Organisation: Defence and Systems Institute, University of South Australia Period: August 2016 to June 2019 Principal Investigator: Professor Anthony Finn
Rationale	Grape grower production cost and revenue is subject to considerable climatic induced variability. Technology that can provide real-time assessment of weather conditions for grape growers at vineyard level and allow a tailored near real-time response to the use of vine protection measures may deliver less fruit damage at a lower crop protection cost.
Objectives	The objective of the project was to develop and demonstrate a technology that has the potential to deliver high resolution, real-time monitoring of crop damaging weather events at the micro-climate level above and within the vineyard.

Activities and Outputs	• Set up of instruments in a ten-hectare vineyard with acoustic sensors to generate horizontal observations of air temperature and wind velocity. • Use of a small quad rotor UAV to fly over the vineyard and generate observations of sound speed both between and among the ground sensors and the UAV. • Readings from UAV and ground sensors combined to obtain 3D snapshots of temperature and wind velocity up to a height of 500 metres. • Thermal imagery transmitted to the UAV ground station where it was mosaicked into a single high-resolution image and fused with atmospheric data. • Micro-climates were assessed across vineyard blocks permitting computation of plant stress factors like evapotranspiration and crop water stress index. • The project developed and demonstrated technology to measure and map whole vineyard micro-climate at a sub-metre scale in 3D using AAT coupled with long-wave infrared thermography. • Accurate, 3D, concurrent, continuous observation and visualisation of air, vine and ground temperatures, and wind speeds across vineyard blocks of around 10 ha is now technically possible as a result of the project. • High-resolution plant and heat stress factors and thermal maps of frost patterns can thus be derived as a function of geographic and temporal variation across a vineyard. • The project also delivered an algorithm that offers an efficient non-destructive way to visualise plant vigour and may be relevant to future decision-support software development. • Other outputs from the project included a final project report which is available online, journal, and industry publications.
Outcomes	• Progress toward delivering a commercial solution for better management of extreme weather events. • The technology to measure and map whole vineyard micro-climates has not yet reached a level of maturity that would allow non-specialist users to deploy and operate it in the field. However, in the right hands, it offers significant research potential for examination of vineyard blocks subject to weather stress events (e.g., University of Adelaide research on the effectiveness of groundcovers in mitigating heat stress). • Grape growers were asked to review the project as part of the reporting for the RnD4Profit program (Sas 2020). Growers were less than enthusiastic about the potential product indicating that historical damage was a reliable indicator of future impacts and that temperature sensors were an inexpensive alternative to tomography. However, they did see a potential role for the technology when assessing a new development site that is frost prone.
Impacts (potential)	• Economic – progress toward the avoidance of fruit damage in new vineyards that are unprotected from frost. • Economic – progress toward savings from installing too many frost fans. • Economic – possible efficiencies in vineyard heat stress research with the project generated technology and new tools (an algorithm) suitable for this application. • Environmental – minor savings in greenhouse gas (GHG) emission associated with deployment of fewer diesel-burning frost fans.

	• Capacity – additional scientific and engineering knowledge associated with remote sensing and data interpretation at the micro-climate level. Academic disciplines addressed included earth system modelling, weather forecasting, climate change studies, and environmental modelling. • 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 (both checked for currency February 2021)

The Wine Australia project has addressed Strategic Science/Research Priority 1 and Priority 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, the Australian Government Department of Agriculture, Water and Environment as part of its Rural R&D for Profit program (RnD4Profit) as well as the University of South Australia (UniSA), Barton Vale Technologies, Treasury Wine Estates, and Pernod Ricard Winemakers.
- In-kind contributions to the research project – non-cash contributions made by the research partners.
- 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

The project was focussed on technology development and took place at two vineyard sites – Wynn's Coonawarra and Jacob's Creek in the Barossa Valley. Costs of working with and communicating with the two wineries were included in the project budget. Also included in the project budget was production of articles for industry newsletters. There were no other extension costs.

4.1.4 Adoption

The project has created a 'proof of concept' technology. Additional development costs will be incurred prior to an adoption-ready product. Growers will then incur costs purchasing a technology package or engaging a service provider.

4.2 Benefits

4.2.1 Research Output and Impact Pathway

The key output from this project was a 'proof of concept' technology for early detection of extreme weather events. The potential impact pathway is:

1. Further development of the technology so that a commercial product is available for those planning new vineyards in frost prone areas.
2. Once commercialised, the technology might be either purchased by a grape grower or viticultural consultant planning new vineyards or, more likely, provided as a value-added service by a frost fan supplier.
3. Cost savings for new vineyards in frost prone areas including avoided fruit loss and savings from installing too many fans.

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			
Progress toward the avoidance of fruit damage in newly planted vineyards that are unprotected from frost. Progress toward savings from installing too many frost fans. Possible efficiencies in vineyard heat stress research with new tools (an algorithm) available for research projects.	When the technology is fully developed and commercialised it will be relevant to other agricultural industries affected by extreme weather events including other grape industries, cherries, almonds, olives, apples, and strawberries.	Nil.	The technology will be relevant to overseas vineyards especially in countries prone to extreme weather events including frost e.g., New Zealand, South Africa, and California USA.
Environmental Benefits			
Minor saving in GHG emission associated with deployment of fewer diesel-burning frost fans.	Nil	Nil	Nil
Social Benefits			

Capacity – additional scientific and engineering knowledge associated with remote sensing and data interpretation at the micro-climate level. Long term advancement 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 avoided fruit loss and savings from installing to many frost fans. Potential public benefits may include improved environmental outcomes (e.g., reduced GHG emissions) and regional spillover benefits from a stronger grape and wine industry.

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

The technology is relevant to other agricultural sectors affected by extreme weather events including other grape industries (table grapes and dried grapes), cherries, almonds, olives, applies and strawberries.

4.2.6 Benefits Overseas

The technology, when it is commercialised, will be relevant to overseas wine industries especially New Zealand where a large share of production is in frost prone areas.

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 – progress toward the avoidance of fruit damage in new vineyards that are unprotected from frost.
Overhead costs including time associated with meetings between the researchers and Wine Australia.	Economic – progress toward savings from installing too many frost fans.
Research costs – additional investment will be required to further develop and commercialise the technology.	Economic – possible efficiencies in vineyard heat stress research with the project generated technology and new tools (an algorithm) suitable for this application.
Adoption costs – costs will be incurred by wine grape growers to either purchase the technology or pay for it through a service provider (e.g., value-added service by frost fan supplier).	Environmental – minor saving in GHG emission associated with deployment of fewer diesel-burning frost fans.
	Capacity – additional scientific and engineering knowledge associated with remote sensing and data interpretation at the micro-climate level.

	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 other investors (Table 5.2). Wine Australia investment includes contributions made by the Australian Government Department of Agriculture, Water and Environment as part of its Rural R&D for Profit program. Other investors in the project included the University of South Australia, Barton Vale Technologies, Treasury Wine Estates, and Pernod Ricard Winemakers. 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
USA 1601 – Wine Australia	220,000	215,000	108,090	**543,090**
Total	**220,000**	**215,000**	**108,090**	**543,090**

Source: Wine Australia record of project expenditure accounting for an underspend of $51,910

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

Project Code	2017	2018	2019	Total
USA 1601 – Other cash	50,000	50,000	50,000	150,000
USA 1601 – Other in-kind	266,068	260,669	313,469	840,206
Total	**316,068**	**310,669**	**363,469**	**990,206**

Source: Wine Australia certified financial statement supplied 21 April 2021

Table 5.3 Annual Investment in the Project (nominal $)

Year Ending 30 June	Wine Australia	Others	Total
2017	220,000	316,068	536,068
2018	215,000	310,669	525,669
2019	108,090	363,469	471,559
Total	**543,090**	**990,206**	**1,533,296**

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 develop the technology into a commercial product and costs will be incurred either by grape growers purchasing the technology when planning new vineyards or more likely, purchasing the technology as a value-adding service supplied by a frost fan retailer. 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, it is assumed that there is a 5% chance that another researcher may have adapted the technology from another industry, independent of Wine Australia funding. Counterfactual developed following feedback from Alex Sas, Senior RD&E Program Manager, Wine Australia, May 2021.

5.2.1 Avoided Fruit Damage in New Vineyards Unprotected from Frost

The project has delivered progress toward an atmospheric acoustic tomography (AAT) technology that may be used to improve vineyard planning and avoid frost damage in new vineyards. The impact may be realised as avoided yield loss in some newly planted areas.

5.2.2 Savings from Installation of too many Frost Fans

AAT technology may also assist grape growers with the optimal placement of frost fans. Optimal placement will avoid over purchase of frost fans with resulting cost savings for grape growers.

A summary of key assumptions used to quantify avoided fruit damage and savings from installing too many fans is summarised in Table 5.4.

Table 5.4 Summary of Assumptions

Variable	Assumption	Source
Avoided Fruit Damage in New Vineyards Unprotected from Frost		
New vineyards planted in frost prone areas.	800 ha/year	Consultant's estimate prepared following consultation with Wine Australia.
Share of annual frost prone new plantings that may be unprotected without using AAT technology.	15%	Consultant estimate focussing on smaller 'pockets' that may be missed using conventional frost fan planning.
Cost of fruit lost to frost.	$7,595/ha	Industry average fruit value sourced from AgEconPlus and Gillespie Economics 2019. Wine grape growing total revenue 2017/18 was $1,110,000,000 (Wine Australia – National Vintage Report 2018) with a wine grape growing area of 146,128 ha (Wine Australia, National Vineyard Scan) creating an average gross revenue of $7,596/ha.
Savings from Installation of too many Frost Fans		
Area of new vineyard within frost prone areas that install frost fans.	300/ha/year	Consultant's estimate prepared following consultation with Wine Australia.
Share of annual frost prone new plantings that install frost fans that are overprotected with too many fans.	15%	Consultant estimate focussing on areas where fans overlap and are not required.
Cost of overprotecting frost prone vineyards.	$12,000/ha	Frost fans cost $60,000 per unit and each unit protects between 4 and 6 ha ($60,000 divide an average of 5 ha).
Other Factors		
Year in which AAT technology first available commercially.	2024	Assumption based on successful commercialisation five years after project completion.
Year in which maximum adoption occurs.	2028	Maximum adoption assumed to occur four years after AAT technology first commercialised.

Attribution of benefits to this project.	50%	Attribution factor recognises the need for further research, commercialisation, and the cost to grape growers of using the technology.
Probability of valuable outputs.	100%	Project has demonstrated 'proof of concept'.
Probability of valuable outcomes.	75%	Further investment is required to deliver a commercial product and securing this investment is not assured.
Probability of impact.	75%	There is no guarantee that AAT technology will identify additional frosted/ overprotected areas or be adopted by industry.
Counterfactual	5%	If this project had not been funded, it is assumed that there is a 5% chance that another research project would have investigated the technology for the Australian wine industry. Counterfactual developed following feedback from Alex Sas, Senior RD&E Program Manager, Wine Australia, May 2021.

5.2.2 Other Potential Benefits

Other potential benefits identified but not valued include:

- Possible efficiencies in vineyard heat stress research with the project generated technology and new tools (an algorithm) suitable for this application.
- With the potential for a reduction in fruit damage caused by frost, there will be less waste requiring disposal and less GHG emission from the waste.
- Research capacity including additional scientific and engineering knowledge associated with remote sensing and data interpretation at the micro-climate level.
- 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%)

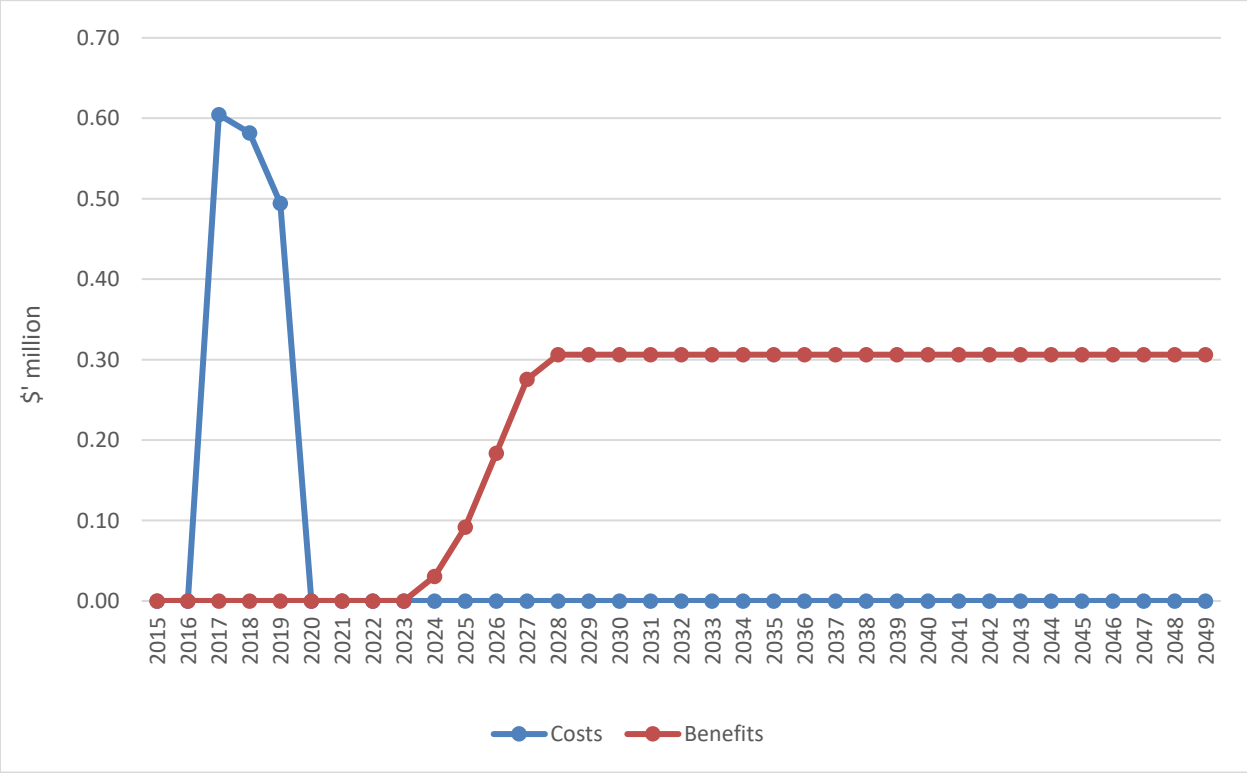
Years	0 years	5 years	10 years	15 years	20 years	25 years	30 years
Present value of benefits ($m)	0.00	0.03	1.06	2.14	2.99	3.65	4.17
Present value of costs ($m)	1.86	1.86	1.86	1.86	1.86	1.86	1.86
Net present value ($m)	-1.86	-1.83	-0.80	0.28	1.13	1.79	2.31
Benefit–cost ratio	0.00	0.01	0.57	1.15	1.61	1.96	2.24
Internal rate of return (%)	Negative	Negative	Negative	6.3	8.7	9.8	10.4
Modified internal rate of return (%)	Negative	Negative	Negative	5.8	7.2	7.6	7.6

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 ($m)	0.00	0.01	0.40	0.82	1.14	1.40	1.59
Present value of costs ($m)	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Net present value ($m)	-0.72	-0.70	-0.31	0.10	0.43	0.68	0.88
Benefit–cost ratio	0.00	0.02	0.56	1.14	1.59	1.95	2.23
Internal rate of return (%)	Negative	Negative	Negative	6.2	8.6	9.7	10.2
Modified internal rate of return (%)	Negative	Negative	Negative	5.8	7.2	7.5	7.6

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 UAV Extreme Weather 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 the project approaches break even.

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

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($m)	9.27	4.17	2.15
Present value of costs ($m)	1.68	1.86	2.05
Net present value ($m)	7.59	2.31	0.10
Benefit-cost ratio	5.52	2.24	1.05

A sensitivity analyses was undertaken for the variable where there was greatest uncertainty, and which acted as a key driver of the investment criteria – share of new plantings not protected/overprotected (Table 7.2). The analysis was 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.

Table 7.2 Sensitivity to New Planting Protection Levels (Total investment, 30 years)

Investment Criteria	5% under protected 5% over protected	15% under protected 15% over protected (base)	20% under protected 20% over protected
Present value of benefits ($m)	1.39	4.17	5.56
Present value of costs ($m)	1.86	1.86	1.86
Net present value ($m)	-0.47	2.31	3.70
Benefit-cost ratio	0.75	2.24	2.99

Results show that if only 5% of frost prone new vineyards are under protected and 5% are overprotected prior to adoption of the project generated AAT technology, then the investment fails to breakeven.

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-Low

9. Summary of Results

Funding for USA 1601 'use of unmanned air vehicles for early, real-time detection of extreme weather events in vineyards' had a total cost of $1.86 million (present value terms) and is expected to produce aggregate total benefits of approximately $4.17 million (present value terms). This gives an estimated net present value of $2.31 million, a benefit-cost ratio of 2.24, an internal rate of return of 10% and a modified internal rate of return of 8%.

Analysis results are dependent on assumptions made and are positive for core assumptions but become negative for credible alternatives.

Further investment will be required before benefits are realised by grape growers.

Abbreviations

AAT	Atmospheric Acoustic Tomography
BOM	Bureau of Meteorology
DAWR	Department of Agriculture and Water Resources
GHG	Greenhouse Gas
OCS	Office of Chief Scientist
R&D	Research and Development
RnD4Profit	Rural Research and Development for Profit program
UAV	Unmanned Aerial Vehicle
UniSA	University of South Australia

Persons Contacted

Alex Sas, Senior RD&E Program Manager, Wine Australia
Anthony Finn, Principal Researcher, UniSA

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Appendix 3: Economic Analysis Wine Australia's Investment in Translation of Training Centre for Innovative Wine Production Research into Industry Outcomes

1. Background

Following the success of the first Training Centre for Innovative Wine Production (TC-IWP) 2014-2018, the Australian Research Council granted a further $4.6 million in funding for the period 2018-2022, with an additional $11.6 million in cash and in-kind contributed from research and industry partners.

The 20 research projects in TC-IWP2 focussed on industry-related issues that can be grouped as:

- Response to climate extremes, diseases, spoilage, water limitations, and quality loss.
- Production of distinct wines that attract higher prices and/or are made through more efficient processes.

Multi-disciplinary teams of researchers and industry partners were assembled for TC-IWP2 and their work was to have a strong emphasis on commercialisation of project outputs. Most TC-IWP2 team members were participants in TC-IWP1. TC-IWP1 had a strong emphasis on the production of high quality, lower alcohol wines.

Wine Australia supported TC-IWP1 and TC-IWP2 by funding a senior post-doctorate fellow, Dr Renata Ristic (UA 1304 and UA 1708), whose role was to create synergies across projects and collate, translate, and disseminate research outcomes to the wine industry. UA 1708 was to have a role in the further dissemination of outputs from TC-IWP1.

2. Summary of Projects

Table 2.1 provides a description of the project in a logical framework.

Table 2.1 Project Description

UA 1708: Translation of Training Centre for Innovative Wine Production Research into Industry Outcomes	
Project Details	Research Organisation: University of Adelaide Period: January 2018 to February 2020 Principal Investigators: Prof. Vladimir Jiranek and Dr Renata Ristic
Rationale	UA 1708 was to oversee research projects in the TC-IWP2 to ensure they were assembled into integrated strategies and that the research outcomes from TC-IWP1 and TC-IWP2 were disseminated to the wine industry.
Objectives	The primary objectives of UA 1708 were to: • Build collaborative research teams across TC-IWP2 partners and deliver additional, valuable project outputs. • Link projects with a similar focus, e.g., grapevine response due to environmental stresses such as drought, salinity, and smoke. • Drive the collation, interpretation, and dissemination of outcomes from IWP-TC projects using relevant extension mechanisms.
Activities and Outputs	Collation and dissemination • The UA 1708 post-doctorate fellow, Dr Ristic, prepared and disseminated nine articles describing different methods used to produce low alcohol wines. • The TC-IWP1 final report written by Dr Ristic described the benefits of various wine making approaches and recommendations that arose from TC-IWP activities 2014-2018. This report and the TC-IWP2 activity update were

	distributed to project partners (Wine Australia, University of Adelaide, Charles Sturt University, etc.) and relevant members of the wine industry. • Dr Ristic also co-authored scientific publication that are available online. • A TC-IWP2 presentation was made at an industry seminar in the Margaret River, May 2019. The seminar focussed on 'An integrated approach to achieving lower alcohol levels in wine' and TC-IWP students and early mid-career researchers received feedback from industry on their projects. • A TC-IWP2 workshop at the Australian Wine Technical Conference addressed 'Exploring regional diversity in Cabernet Sauvignon' and 'Managing wine alcohol under challenging conditions'. • A TC-IWP2 industry seminar in the Barossa Valley addressed two broad themes 'Responding to environmental challenges' and 'Increasing profitability'. The seminar also included a presentation on 'An integrated approach to managing alcohol levels while maintaining quality and style'. Dr Ristic reported that industry engaged with the presentations and students received useful feedback from industry on their work. • Centre-wide seminars were held in December 2018, May 2019, and November 2019 so that students (higher degree by research and post-docs) could present their research and receive feedback on their research. Dr Ristic organised and chaired these seminars and disseminated project notes. Building a collaborative research team • Team building was made difficult by delays in identification of 16 appropriate higher degree by research students. However, all positions were filled with suitable candidates by early 2020. • Coordination and supervision of wine making activities in 2018/19 included training in small-lot winemaking, followed by sensory evaluation of wines and statistical analysis of sensory data. • Teams worked on projects addressing the characterisation of Australian Cabernet Sauvignon wines from both a chemistry and sensory perspective. An additional PhD was pursued and delivered because of the collaboration. • Project activities in 2019/20 added to TC-IWP2 research addressing the sugar: flavour nexus and managing berry heterogeneity under various irrigation systems. • Dr Ristic organised professional development workshops enabling post-docs and students to develop capabilities and tools required for wine researchers. Centre-wide seminars were organised for students focusing on 'Collaboration experiences and expectations, selling your science'. Masterclasses in viticulture and winemaking were held in three major wine regions. Students secured permanent employment via masterclass participation. • Dr Ristic and the UA 1304 and UA 1708 projects achieved a high level of PhD completion and employment and the TC-IWP was awarded for excellence in graduate research supervision. Research • Completion of a follow-up study on the potential of non-Saccharomyces yeasts to boost wine aroma and flavour. Manuscript submitted for the special issue of the Australian Journal of Grape and Wine Research (AJGWR). • Changes in the chemical and sensory composition of wines made with the substitution of juice with water or 'green harvest' wines after 4 years of bottle

	aging. The study showed that water or up to 30% 'green harvest' wine can be added to produce lower alcohol wines without detrimental effect. Manuscript submitted for the special issue of the AJGWR. • Technical Notes on research activities made available online and distributed at industry events.
Outcomes	• Better trained students with additional research and leadership capacity. • Completion of additional and more relevant wine research. • Valuable outcomes realised sooner with superior research dissemination.
Impacts	• Economic – more rapid uptake and additional TC-IWP findings resulting in sales of distinctive, higher priced, efficiently produced Australian wine, sooner than would otherwise have occurred. • Capacity – wine researchers and leaders with additional, relevant skill sets. • Social – a more profitable and sustainable wine industry generating additional 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 (both checked for currency February 2021)

The Wine Australia project has addressed Strategic Science/Research Priority 1 and Priority 7. The major focus of the project has been on the first and fourth 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 Wine Australia, the project funding body. These costs include both project and overhead expenditures.
- In-kind contributions to the research project – none identified for UA 1708.
- 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
A major focus of the project was information dissemination, and this was accomplished through industry seminars, workshops, technical notes, and the posting of online resources. Information dissemination was achieved with resources included in the project budget. No other extension costs were incurred.

4.1.4 Adoption
Adoption costs will be incurred by wine makers changing current practices to align with research recommendations from TC-IWP1 and TC-IWP2.

4.2 Benefits
4.2.1 Research Output and Impact Pathway
The potential impact pathway for the project is:

1. Valuable research targeting low alcohol wine, distinctive wine, avoided quality loss and more efficient wine production generated by TC-IWP 1 and TC-IWP 2.
2. UA 1304 and UA 1708 ensure more useful research outputs and better trained students associated with TC-IWP 1 and TC-IWP 2.
3. UA 1304 and UA 1708 dissemination activities ensure more rapid uptake of TC-IWP 1 and TC-IWP 2 outputs than would otherwise have occurred.
4. The economic impact of UA 1304 and UA 1708 is additional higher priced sales of Australian wine produced more efficiently and sooner than would otherwise have occurred.

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			
More rapid update and additional TC-IWP findings resulting in sales of distinctive, higher priced, efficiently produced Australian wine, sooner than would otherwise have occurred	Nil.	Nil.	Overseas consumers of Australian wine enjoying new low alcohol and distinctive style wines sooner than would otherwise have occurred.
Environmental Benefits			
Nil	Nil	Nil	Nil
Social Benefits			
Capacity – wine researchers and leaders with additional, relevant skill sets.	Graduates trained may find roles in other Australian industries or contribute	Nil	Nil

A more profitable and sustainable wine industry generating additional income and employment in regional Australia (spill-over impact).	leadership skills to regional communities.		

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 mostly captured by wine makers. Private benefits will be realised as additional profit from new wine styles realised earlier than would otherwise have occurred. Potential public benefits will include additional researcher capacity and regional spill-over benefits.

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

Capacity developed during the project may, in time, move to other primary industries and contribute to researcher outcomes in these sectors.

4.2.6 Benefits Overseas

Overseas consumers of Australian wine may enjoy new low alcohol and distinctive wine styles sooner than would otherwise have occurred.

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 as well as project administration costs.	Economic – additional higher priced sales of Australian wine produced more efficiently and sooner than would otherwise have occurred.
Overhead costs including time associated with meetings between the researchers and Wine Australia.	Capacity – wine researchers and leaders with additional, relevant skill sets.
Adoption costs will be incurred by wine makers changing current practices to align with research recommendations from TC-IWP1 and TC-IWP2.	Social – a more profitable and sustainable wine industry generating additional 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

Table 5.1 show annual investment in the project by Wine Australia. Wine Australia was the only investor in AU 1708.

Table 5.1 Investment by Wine Australia in the Project for Years Ending June 2018 to June 2020

Project Code	2018	2019	2020	Total
UA 1708 – Wine Australia	60,465	169,950	95,185	**325,600**
Total	**60,465**	**169,950**	**95,185**	**325,600**

Source: Project agreement for UA 1708

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

Adoption costs will be incurred by wine makers changing current practices to align with research recommendations from TC-IWP1 and TC-IWP2. 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 by Wine Australia, it is likely that some early uptake of TC-IWP 1 and TC-IWP 2 outputs would have occurred through researcher interactions with industry. Consequently, a counterfactual of 50% has been assumed i.e., it is 50% likely that potential project benefits would have been realised in the absence of UA 1304 and UA 1708 project investment.

5.2.1 More Profitable Sales of Australian Wine Sooner than would Otherwise have Occurred

The project has increased the efficiency of TC-IWP research and disseminated research outputs to industry sooner than would otherwise have occurred. As a consequence, increased profit will be realised by Australian wine makers sooner than would otherwise have occurred. A summary of key assumptions used to quantify this benefit is summarised in Table 5.4.

Table 5.4 Summary of Assumptions

Variable	Assumption	Source
Benefit: Additional higher priced sales of Australian wine produced more efficiently and sooner than would otherwise have occurred		
Annual Australian wine production.	1,090 million litres	Wine Australia 2021.
Share of annual wine production adopting TC-IWP research outputs.	10%	Analyst's assumption to be tested using sensitivity analysis.
Profit on wine adopting TC-IWP research outputs.	$1.34/litre	10% higher than industry average. Industry average of $1.22/litre sourced from AgEconPlus and Gillespie Economics 2019 which identified industry average revenue of $3.40/litre (after allowing for the cost of packaging) less wine production costs of $2.18/litre.
Decrease in lag between TC-IWP research and industry adoption attributable to UA 1304 and UA 1708.	3 years	Analyst's assumption to be tested using sensitivity analysis.
Attribution of benefits to this project (AU 1708).	30%	Estimate prepared after considering contribution made by UA 1304 and costs incurred by wine makers adopting new production practices sourced from TC-IWP research.

Year in which profit increase first realised by winemakers.	2021 vintage	UA 1708 concluded in 2020 and production changes adopted for the next vintage.
Probability of valuable outputs.	90%	UA 1708 has delivered TC-IWP research efficiencies and a package of information to the Australian wine industry.
Probability of valuable outcomes.	60%	Wine makers are enthusiastic about the opportunity to meet market demand for unique, low alcohol wine styles.
Probability of impact.	50%	The impact of TC-IWP research is yet to be established.
Counterfactual	50%	See above explanation.

5.2.3 Other Potential Benefits

Other potential benefits identified but not valued include:

- Wine researchers and leaders with additional, relevant skill sets.
- A more profitable and sustainable wine industry generating additional 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 2020 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 (2020).

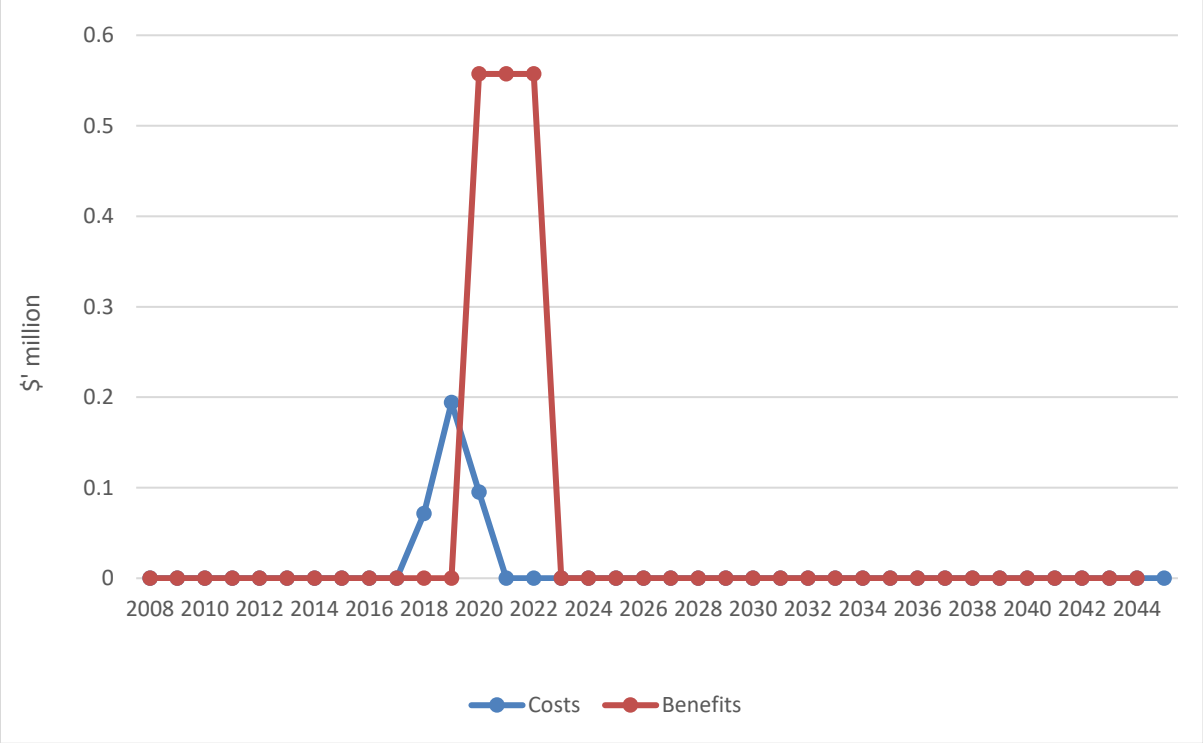
Table 6.1 shows the investment criteria estimated for the different periods of benefits for total investment. Wine Australia was the only investor in the project.

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 ($m)	0.00	1.52	1.52	1.52	1.52	1.52	1.52
Present value of costs ($m)	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Net present value ($m)	-0.38	1.14	1.14	1.14	1.14	1.14	1.14
Benefit–cost ratio	0.00	4.02	4.02	4.02	4.02	4.02	4.02
Internal rate of return (%)	Negative	70.2%	70.2%	70.2%	70.2%	70.2%	70.2%
MIRR (%)	Negative	22.5%	16.0%	13.0%	11.3%	10.2%	9.4%

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 Higher Priced Wine Produced More Efficiently Sooner



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. The results are moderately sensitive to discount rate.

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

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($m)	1.67	1.52	1.39
Present value of costs ($m)	0.36	0.38	0.40
Net present value ($m)	1.31	1.14	0.99
Benefit-cost ratio	4.63	4.02	3.51

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 uncertainties related to the decrease in lag for new wine styles and the share of Australian wine production adopting TC-IWP findings – Table 7.2 and Table 7.3. Results show that the benefit cost ratio remains positive if the adoption lag avoided is as little as a single year and the share of wine makers adopting TC-IWP recommendations is 5%.

Table 7.2 Sensitivity to Decrease in Lag for Adoption of TC-IWP Findings (Total investment, 30 years)

Investment Criteria	Decrease in Adoption Lag Due to UA 1708 (years)		
	1 year	3 years (base)	5 years
Present value of benefits ($m)	0.53	1.52	2.41
Present value of costs ($m)	0.38	0.38	0.38
Net present value ($m)	0.15	1.14	2.03
Benefit-cost ratio	1.40	4.02	6.39

Table 7.3 Sensitivity to Share of Australian Wine Production Adopting TC-IWP Findings (Total investment, 30 years)

Investment Criteria	Share of Wine Production Adopting TC-IWP Findings (%)		
	5%	10% (base)	15%
Present value of benefits ($m)	0.76	1.52	2.28
Present value of costs ($m)	0.38	0.38	0.38
Net present value ($m)	0.38	1.14	1.90
Benefit-cost ratio	2.01	4.02	6.03

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 UQ 1708 'translation of Training Centre for Innovative Wine Production research into industry outcomes' had a total cost of $0.38 million (present value terms) and is expected to produce aggregate total benefits of approximately $1.52 million (present value terms). This gives an estimated net present value of $1.14 million, a benefit-cost ratio of approximately 4.02, an internal rate of return of 70% and a modified internal rate of return of 9%.

Analysis results are dependent on assumptions made and are positive for core assumptions and assumptions used during sensitivity testing.

Abbreviations

AJGWR	Australian Journal of Grape and Wine Research
DAWR	Department of Agriculture and Water Resources
OCS	Office of Chief Scientist
R&D	Research and Development
TC-IWP	Training Centre for Innovative Wine Production

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