Final Report

# Fund Impact Assessment 2020/21 for cherry, vegetables and small tropicals: Evaluation of VG16070

**Project leader:**

George Revell

**Delivery partner:**

Ag Econ

**Project code:**

MT21013

**Project:**

Fund Impact Assessment 2020/21 for cherry, vegetables and small tropicals (MT21013)

**Disclaimer:**



**Funding statement:**

This project has been funded by Hort Innovation, using research and development levies and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

**Publishing details:**

Published and distributed by: Hort Innovation

Level 7
141 Walker Street
North Sydney NSW 2060

Telephone: (02) 8295 2300

www.horticulture.com.au

## Contents

## Executive summary

### What the report is about

This report presents the results of an impact assessment of a Horticulture Innovation Australia Limited (Hort Innovation) investment in project cluster *Investigating novel glass technologies and photovoltaic in protected cropping (VG15038)* and *Research and operations to trial innovative glass and photovoltaic technologies in protected cropping (VG16070)*. The projects were funded by Hort Innovation over the period July 2017 to May 2021.

### Methodology

The investment was first analysed qualitatively within a logical framework that included activities and outputs, outcomes, and impacts. Actual and/or potential impacts then were categorised into a triple bottom line framework. Principal impacts identified were then considered for valuation in monetary terms (quantitative assessment). Past and future cash flows were expressed in 2021-22 dollar terms and were discounted to the year 2021-22 using a real (inflation-adjusted), risk free, pre-tax discount rate of 5% to estimate the investment criteria.

### Key findings

The project cluster VG15034 and VG16070 delivered new knowledge for vegetable growers and industry regarding the performance of novel smart glass (SG) and photovoltaic energy saving technologies for vegetable crop physiology and energy usage in a high tech greenhouse facility. The project cluster identified strong interactions between crop physiology, cooling and heating technologies, and seasonal climate variations. The project cluster demonstrated the significant potential of these technologies for improving the operational efficiencies of high-tech glasshouses.

Due to the ongoing development of the technologies, consultation with industry stakeholders confirmed that no direct adoption has occurred and as such no quantifiable impacts were identified as a result. However several other impacts have been identified qualitatively as a result of investment across the project cluster:

- [Economic] Improved vegetable grower and industry knowledge of the performance of protected cropping light and energy technologies, contributing to the ongoing development of technologies to support the sector realise productivity and operational efficiencies.
- [Social] Improved protected cropping technology research capacity informing future RD&E initiatives that leverage existing knowledge.
- [Social] Increased community awareness of the importance of sustainable and efficient food production systems through industry and community outreach.
- [Social] Improved food security for vulnerable populations through donations to Foodbank.
- [Environmental] Reduced energy use in vegetable protected cropping systems supporting lower emissions.

These impacts were not valued due to data gaps and uncertainties around the extent and magnitude to which these will be realised as the novel glasshouse technologies undergo additional development prior to adoption.

### Investment criteria

Total funding from all sources for the project was $5.6 million (2021-22 equivalent value). As potential project impacts could not be quantified, a full set of investment criteria could not be produced.

### Conclusions

Investment in the project cluster VG15038 and VG16070 has generated valuable knowledge that will impact the future trajectory of development in SG and energy saving technologies through future research. The timeline of the ongoing research has indicated that adoption of these technologies will not occur for at least another 5 years (2027-28) and the extent of the impact is contingent on the extent to which future refinements will bring for energy savings and crop physiology. Given these requirements for ongoing RD&E, and the uncertainties of the future research outcomes and adoption, for the purposes of this impact assessment, economic impacts could not be quantified.

Additional social and environmental impacts were identified through the analysis but could not be valued due to data gaps and uncertainties around the extent and magnitude to which these have and will continue to be realised as the technologies undergo additional development. These included: researcher collaboration improving the research capacity and development of the protected cropping sector within the vegetable industry, community engagement in the importance of sustainable production systems and reductions in energy usage reducing emissions.


### Keywords

Impact assessment, cost-benefit analysis, protected cropping, vegetable, smart glass, photovoltaic, energy

## Introduction

Evaluating the impacts of levy investments is important to demonstrate to levy payers, Government and other industry stakeholders the economic, social and environmental outcomes of investment for industry, as well as being an important step to inform the ongoing investment agenda.

The importance of ex-post evaluation was recognised through the Horticulture Innovation Australia Limited (Hort Innovation) independent review of performance completed in 2017, and was incorporated into the Organisational Evaluation Framework.

Reflecting its commitment to continuous improvement in the delivery of levy funded research, development and extension (RD&E), Hort Innovation required a series of impact assessments to be carried out on a representative sample of investments across a cohort of Funds in its RD&E portfolio. The assessments were required to meet the following Hort Innovation evaluation reporting requirements:

- Reporting against the Hort Innovation's Strategic Plan and the Evaluation Framework associated with Hort Innovation's Statutory Funding Agreement with the Commonwealth Government.
- Reporting against strategic priorities set out in the Strategic Investment Plan for each Hort Innovation industry fund.
- Annual Reporting to Hort Innovation stakeholders.
- Reporting to the Council of Rural Research and Development Corporations (CRRDC).

As part of its commitment to meeting these reporting requirements, Ag Econ was commissioned to deliver the *Fund Impact assessment 2020/21: Cherry, Sweetpotato, Vegetables, Small Tropicals (MT21013)*. This program consisted of a once-off impact assessment series of randomly selected Hort Innovation RD&E investments (projects) within each of the nominated Funds.

Project VG16070 *Research and operations to trial innovative glass and photovoltaic technologies in protected cropping* was randomly selected as one of the 9 investments in the 2021-22 sample for the Vegetable Fund. Given the close coordination of outcomes, VG16070 was clustered with VG15038 *Investigating novel glass technologies and photovoltaic in protected cropping* and evaluated as a single investment. This report presents the analysis and findings of the project cluster impact assessment.

## General method

The 2020-21 population for the Vegetable Fund was defined as an RD&E investment where a final deliverable had been submitted in the five year period from 1 July 2016 to 30 June 2021. This generated an initial population of 315 Hort Innovation investments, worth an estimated $88.7 million (nominal Hort Innovation investment). Projects in the Frontiers Fund, those of less than $80,000 Hort Innovation investment, multi industry projects where the Vegetable Fund was less than 50% of total Hort Innovation investment, enabler projects that don't directly support a 2017-2021 Vegetable Strategic Investment Plan (SIP) Outcome, and projects that have had a previous impact assessment completed were removed from the sample. A total of 90 projects with a combined value of $54.8 million satisfied these criteria and formed the eligible population. The eligible population was then stratified according to the 2017-2021 Vegetable SIP outcomes, and four project value clusters based on the distribution of project value within the population ($80,000-$265,000; $265,000-$440,000; $440,000-$695,000; $695,000-$8,680,000). A random sample of 9 projects was selected worth a total of $5.86 million (nominal Hort Innovation investment), equal to 10.7% of the eligible RD&E population (in nominal terms).

The impact assessment followed general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including Research and Development Corporations, Cooperative Research Centres, State Departments of Agriculture, and some universities. The approach included both qualitative and quantitative descriptions that are in accord with the impact assessment guidelines of the CRRDC (CRRDC, 2018).

The evaluation process involved reviewing project contracts, milestones, and other documents; interviewing stakeholders including Hort Innovation staff, project delivery partners, growers and other industry stakeholders where appropriate (see Acknowledgements); and collating additional industry and economic data where necessary. Through this process, the project activities, outputs, outcomes, and impacts were identified and briefly described; and the principal economic, environmental, and social impacts were summarised in a triple bottom line framework.

Some, but not all, of the impacts identified were valued in monetary terms. Where impacts were valued, the impact assessment used cost-benefit analysis as its principal tool. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, a high degree of uncertainty surrounding the potential impact, or the likely low relative significance of the impact compared to those that were valued. As not all impacts were valued, the investment criteria reported potentially represents an underestimate of the performance of that investment.

# Background and rationale

## Industry background

The national vegetable levy is payable on all vegetable crops excluding potatoes, onions, mushrooms, sweetpotatoes, asparagus, garlic, ginger, herbs (except fresh shallots and parsley) and tomatoes. The levy is payable on vegetables that are produced in Australia and either sold by the producer or used by the producer in the production of other goods. Producers pay levies to the Department of Agriculture, Fisheries and Forestry (DAFF), which is responsible for the collection, administration and disbursement of levies and charges on behalf of Australian agricultural industries. Hort Innovation manages the vegetable levy funds which are directed to R&D investments.

The Australian levy paying vegetable industry has approximately 1,700 growers across Australia (Hort Innovation 2022a), with a 5-year average (to 2020-21) production value of $2.5 billion, growing at a trend 6.19% and a volume trend of 1.77% per annum (Hort Innovation 2022b). The majority of leviable vegetables are supplied to the domestic market, with approximately 10% exported at a total value of $170 million in 2020-21 growing at an average 1.19% per annum from 2016-17. Leviable vegetables are grown across Australia, however Queensland accounts for the highest share (32%), followed by Victoria (24%), Western Australia (16%), New South Wales (8%), South Australia (9%) and Tasmania (8%) in 2020-21.

## Rationale

The vegetable levy investments are guided by a Strategic Investment Plan (SIP). The Vegetable SIP 2017-21 (under which project cluster VG15038 and VG16070 was delivered) identified “Improved farm productivity” as a priority outcome for Australia’s vegetable industry. This outcome was supported by the strategy “Protected Cropping: Adapt and improve current protected cropping and intensive production technologies for the Australian environment”.

Protected cropping offers a range of advantages for intensive vegetable production. Protected cropping production systems provide the capacity to control and influence key environmental variables, including temperature, atmospheric conditions, moisture and plant nutrition, depending on the level of technology that is utilised. Protected cropping systems such as glasshouses also mitigate the risk of adverse weather events (e.g. flooding, hail, wind) that would otherwise impact production, offering greater supply certainty.

While the productivity potential of protected cropping systems is significantly greater than traditional systems, the establishment and ongoing costs can represent a barrier for new entrants who may be seeking to utilise these technologies. Compared to traditional field-based production systems, high-tech protected cropping systems like glasshouses require significantly higher upfront capital expenditure, and higher maintenance costs in order to support the infrastructure, climate and nutrition control. As the fastest growing food-production sector in Australia representing approximately 15% of the total vegetable and cut flower production in 2017 (Protected Cropping Australia 2020), the vegetable industry recognised the importance of developing energy efficient technologies to support the ongoing development and evolution of protected cropping.

Project VG15038 was delivered to evaluate various smart glass and renewable energy technologies to improve the energy efficiency of glasshouses. Building on the findings of VG15038, project VG16070 was commissioned to test the specific Smart Glass Film recommended through VG15038 at the state of the art National Vegetable Protected Cropping Centre to understand the performance on energy use, water & nutrient use efficiency and crop yields.

In summary, the overall objectives of the project cluster were as follows:

VG15038

- survey the advanced smart glass (SG) and renewable energy technologies available worldwide
- evaluate SG cost-effectiveness through field trials, based on the energy and productivity requirements
- recommend optimal solutions for the growers who wish to use advanced energy efficient technologies in their greenhouses.

VG16070:

- Using a high-tech glasshouse facility, determine the impact of SG on vegetable crops considering:
    - light quality and quantity
    - photosynthesis and carbon assimilation
    - leaf biochemistry, yield and nutritional quality.

### *Alignment with the Vegetable Strategic Investment Plan 2017-2021*

With a focus on developing growth in the domestic vegetable market, VG15070 was closely aligned with the Vegetable SIP Outcome 3: *Improved farm productivity*.

### *Alignment with national priorities*

The Australian Government's National RD&E priorities (2015a) and Science and Research Priorities (2015b) are reproduced in Table 1. The VG15071 project outcomes and related impacts will contribute to RD&E Priority 1 and 4; and to Science and Research Priority 1.

**Table 1. National Agricultural Innovation Priorities and Science and Research Priorities**

| Australian Government | |
|---|---|
| **National RD&E Priorities (2015a)** | **Science and Research Priorities (2015b)** |
| 1. Advanced technology<br>2. Biosecurity<br>3. Soil, water and managing natural resources<br>4. Adoption of R&D. | 1. Food<br>2. Soil and Water<br>3. Transport<br>4. Cybersecurity<br>5. Energy and Resources<br>6. Manufacturing<br>7. Environmental Change<br>8. Health. |

## Project details

### Summary

**Table 2. Project details**

| | | |
|---|---|---|
| **Project code** | VG15038 | VG16070 |
| **Title** | Investigating novel glass technologies and photovoltaic in protected cropping | Research and operations to trial innovative glass and photovoltaic technologies in protected cropping |
| **Research organization** | Swinburne University of Technology | Western Sydney University |
| **Project leader** | Professor Baohua Jia | Professor David Tissue |
| **Funding period** | July 2016 to June 2021 | May 2017 to May 2021 |

### Logical framework

A logical framework is shown in Table 3 to highlight the connection between the project activities, outputs, outcomes, and impact.

**Table 3. Project logical framework**

| | |
|---|---|
| Activities | • Literature review on state-of-the-art applications of novel technologies (energy saving smart glass and renewable energy generation (photovoltaic and solar thermal collector)) in greenhouses (VG15038).<br>• Establish a cost-effectiveness model to understand the annual energy generation, energy cost saving, and payback period of glass technologies (VG15038).<br>• Validation of productivity and energy impact of four identified technology bundles through a two-year continuous trial across four dedicated research bays on eggplant, capsicum and lettuce crops (VG15038 and VG16070). |

| | |
|---|---|
| | • Collect field data on all renewable energy solutions to compare productivity and cost effectiveness against the cost effectiveness model: Concentrated photovoltaic (CPV); concentrated solar thermal collector (CSTC); Flat Panel Photovoltaic (FPPV); and Flat Panel Solar Thermal Collector (FPSTC) (VG15038).<br>• Complete statistical analysis of crop performance (VG16070).<br>• Ongoing stakeholder engagement through Industry Consultation Forums and project Steering Committee (VG15038 and VG16070).<br>• Industry training and capacity building (VG16070). |
| Outputs | • Smart glass technology identified for trial based on a cost-effectiveness model: Solar Gard® Solar Control Window Films Sentinel™ Plus SX 80 OSW (VG15038).<br>• Trial data across eggplant, capsicum, lettuce crops at the National Protected Cropping Centre measuring smart glass influence on energy and water consumption (VG15038) and plant physiology, growth and yield (VG16070).<br>• Recommendations and guidelines developed for growers (VG16070).<br>• Training and development opportunities for 1 Masters, 2 PhD and 1 post-doctoral research to support the project, in addition to casual personnel exposure (VG16070).<br>• Donated surplus vegetable production to Foodbank charity |
| Outcomes | • Knowledge of SG on plant performance across eggplant, capsicum and lettuce trials (VG16070):<br>○ Reduced yields: eggplant (21-23%), capsicum (up to 27%), and lettuce (up to 15%).<br>○ Reduced water and nutrient use.<br>○ No change to crop quality.<br>• Knowledge of SG on energy usage across eggplant, capsicum and lettuce trials (VG15038):<br>○ Reduced cooling energy use by 4.4% in warm and cool months and fertigation demand by 29% in cooler months and 18% in warm months.<br>• Knowledge of limitations of current SG technologies for supporting plant growth. Recommendations to re-engineer the current SG to increase UV light and more red light, and less high wavelength IR radiation (which contributes heat but not plant-based productivity) (VG16070).<br>• Knowledge regarding renewable energy solutions for implementation on glasshouses, including cost effectiveness and pay back periods (VG15038):<br>○ Solar thermal collector (STC) is a more cost-effective renewable energy solution compared to the photovoltaic (including FPPV and CPV), which has a lower installation cost and shorter payback period.<br>○ Electricity used to cool down the greenhouses, including water flow and ventilation, is the main cost of energy use (around 80% of running costs).<br>○ The cost-effectiveness of renewable energy solutions depends on the scale of installation, the larger the scale the better cost-effectiveness and the shorter payback period.<br>○ Pay back period estimated to vary from 1.9 years (FPSTC) to 29.9 years (FPPV).<br>• Collaboration in the protected cropping industry to promote broader economic development across Australia. Including ccollaboration between Western Sydney University and start-up company LLEAF (Luminescent-Light Emitting Agricultural Films) (VG16070).<br>• Increased number of skilled personnel in the Australian protected cropping sector (VG15038 and VG16070). |
| Impacts | • [Economic] Improved vegetable grower and industry knowledge of the performance of protected cropping light and energy technologies, contributing to the ongoing development of technologies to support the sector realise productivity and operational efficiencies.<br>• [Social] Improved protected cropping technology research capacity informing future RD&E initiatives that leverage existing knowledge.<br>• [Social] Increased community awareness of the importance of sustainable and efficient food production systems through industry and community outreach.<br>• [Social] Improved food security for vulnerable local community members through donations to Foodbank for the duration of the project.<br>• [Environmental] Potential for reduced energy use in vegetable protected cropping systems supporting lower emissions. |

## Project costs

### Nominal investment

**Table 4. Project nominal investment**

| Year end 30 June | Hort Innovation ($) | | Swinburne University | Western Sydney University | Total ($) |
|---|---|---|---|---|---|
| | VG15038 | VG16070 | VG15038 | VG16070 | |
| 2017 | 519,249 | 159,071 | 688,410 | 263,573 | **1,630,303** |
| 2018 | 121,434 | 114,189 | 160,994 | 169,823 | **566,440** |
| 2019 | 91,075 | 280,000 | 120,746 | 416,421 | **908,242** |
| 2020 | 45,538 | 100,000 | 60,373 | 148,722 | **354,633** |
| 2021 | 42,246 | 130,000 | 56,008 | 193,338 | **421,592** |
| *2022 | | 30,000 | | 44,617 | **74,617** |
| **Total** | **819,542** | **813,260** | **1,086,531** | **1,236,494** | **3,955,827** |

*Project activities concluded in the 2020-21 year however final payment did not occur until 2021-22.

### In-kind costs

Where in kind costs have been provided as a single whole-of-project figure, these have been apportioned based on the Hort Innovation annual costs to reflect the underlying investment delivery.

### Program management costs

R&D costs should also include the administrative and overhead costs associated with managing and supporting the project. The Hort Innovation overhead and administrative costs were calculated for each project funding year based on the data presented in the *Statement of Comprehensive Income* in the *Hort Innovation Annual Report* for the relevant year. Where the overhead and administrative costs were equal to the total expenses, less the research and development and marketing expenses. The overhead and administrative costs were then calculated as a proportion of combined project expenses (RD&E and marketing), averaging 15.8% for the VG15038 and VG16070 funding period (2017-2022). This figure was then applied to the nominal Hort Innovation investment shown in Table 4.

### Real Investment costs

For purposes of the investment analysis, the investment costs of all parties were expressed in 2021-22 dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2022).

### Extension costs

There were no additional costs associated with VG15038 and VG16070 for project extension. Results were communicated through researchers as part of the project.

## Project impacts valuation

None of the impacts identified through the logical framework process were able to be valued for the project cluster VG15038 and VG16070. Investment in the project cluster provided an important evidence base to demonstrate the merit of smart glass and energy saving technologies for reducing input costs, when growing common vegetable crops in high-tech glasshouses. However, material reductions in vegetable yield in the smart glass field trial compared to the control highlights that additional research and development is necessary before these technologies are suitable for broader industry adoption. In the absence of the tested technologies' suitability for immediate adoption, and uncertainty around the performance characteristics of smart glass and energy saving technologies, the valuation of impacts is not possible.

### Public versus private impacts

The impacts identified from the investment are predominantly public in nature in the form of improved research capacity. Potential future private economic benefits were also identified in the form of productivity gains for growers.

## Distribution of private impacts

The identified potential private impacts of VG15038 and VG16070 would include direct and flow-on (spillover) impacts. Spillover impacts would include:

- Production-induced effects, which reflect the flow-on changes to the supply chain (upstream and downstream) that result from farm level changes in inputs (such as labour, technology) associated with smart glass and energy saving technologies.
- Consumption induced effects, which reflect the flow-on changes generated through changes in payments of wages and salaries to employees along the supply chain and the subsequent expenditure of those incomes in purchasing household goods and services.

Furthermore, the true impact would also be influenced by the equilibrium (price) effect, which reflects changes in prices (of inputs and outputs) as a result in changes in supply and demand of those inputs and outputs. The price effect, essentially shifts benefits along the supply chain and between producers to consumers. The extent to which this would occur would depend on the slope of the short and long term supply and demand curves.

## Impacts on other Australian industries

The project activities were explicit to the Australian vegetable industry. However the technologies may be modified following future research and development to support productivity improvements for other industries that utilise protected cropping infrastructure, including the nursery and cut flower industries.

## Impacts overseas

Impacts may be realised for overseas protected cropping growers through the adoption and refinement of smart glass technologies.

# Results

All costs and benefits were discounted to 2020-21 using a real discount rate of 5%. All analyses ran for the length of the project investment period plus 30 years from the last year of investment (2021-22) as per the CRRDC Impact Assessment Guidelines (CRRDC, 2018).

## Investment criteria

As no impacts were valued, the investment criteria were limited to the Present Value of Investment Costs (PVC) (Table 5). Table 5 shows the impact metrics estimated for different periods of benefit for the total investment.

**Table 5. Impact metrics for the total investment in VG15038 and VG16070**

| Impact metric | Years after last year of investment | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
| PVC ($m) | 5.63 | 5.63 | 5.63 | 5.63 | 5.63 | 5.63 | 5.63 |
| PVB ($m) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| NPV ($m) | -5.63 | -5.63 | -5.63 | -5.63 | -5.63 | -5.63 | -5.63 |
| BCR | NA | NA | NA | NA | NA | NA | NA |
| IRR | NA | NA | NA | NA | NA | NA | NA |
| MIRR | NA | NA | NA | NA | NA | NA | NA |

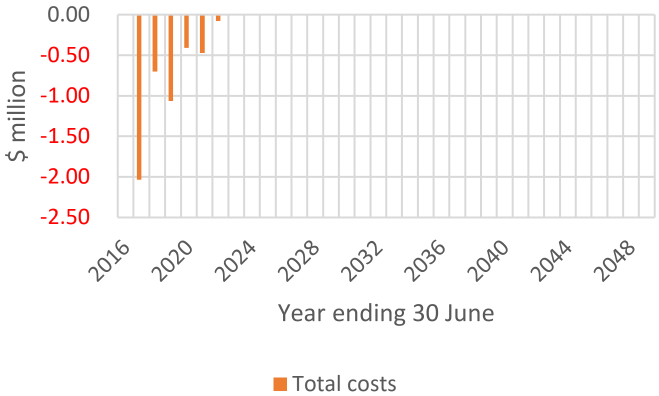
Table 6 shows the impact metrics estimated for different periods of benefit for the Hort Innovation investment. The benefits attributable to Hort Innovation were based on a total funding share (including admin costs) of 45%.

**Table 6. Impact metrics for the Hort Innovation investment in in VG15038 and VG16070**

| Impact metric | Years after last year of investment | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
| PVC ($m) | 2.54 | 2.54 | 2.54 | 2.54 | 2.54 | 2.54 | 2.54 |
| PVB ($m) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| NPV ($m) | -2.54 | -2.54 | -2.54 | -2.54 | -2.54 | -2.54 | -2.54 |
| BCR | NA | NA | NA | NA | NA | NA | NA |
| IRR | NA | NA | NA | NA | NA | NA | NA |
| MIRR | NA | NA | NA | NA | NA | NA | NA |

Figure 1 shows the annual undiscounted benefit and cost cash flows for the total investment of project cluster VG15038 and VG16070. Cash flows are shown for the duration of the investment plus 30 years from the last year of investment.

**Figure 1. Annual cash flow of undiscounted total benefits and total investment costs**




## Conclusions

The project cluster VG15034 and VG16070 delivered new knowledge for vegetable growers and industry regarding the performance of novel smart glass and energy saving technologies for vegetable crop physiology and energy usage in a high tech greenhouse facility. The project cluster identified strong interactions between crop physiology, cooling and heating technologies, and seasonal climate variations. The research demonstrated the significant potential of these technologies for improving the operational efficiencies of high-tech glasshouses.

Discussions with industry stakeholders confirmed that the technologies trialled through the project cluster are not suitable for adoption by industry participants in their current form. While the SG technology supported significant reductions in overall energy requirements (a cost saving), stakeholders identified that reductions in plant yield represent a significant barrier to adoption for growers. However the initial research has generated important information that is guiding development of bespoke smart glass technologies compared to the 'off the shelf' technologies tested as part of the project cluster. The recommended solution is working to re-engineer the SG to increase penetration of UV and photosynthesis active radiation light, while maintaining blockage of glasshouse heat gain. The development and refinement of bespoke technologies will enable specific guidance for suitable technologies that will achieve targeted energy savings without compromised yield.

Investment in the project cluster VG15038 and VG16070 has generated valuable knowledge that will impact the future trajectory of development in SG and energy saving technologies through future research. The timeline of the ongoing research has indicated that adoption of these technologies will not occur for at least another 5 years (2027-28) and the extent of the impact is contingent on the extent to which future refinements will bring for energy savings and crop physiology. Given these requirements for ongoing RD&E, and the uncertainties of the future research outcomes and adoption, for the purposes of this impact assessment, economic impacts could not be quantified.

This impact assessment still identified several social and environmental impacts that have been realised through investment in the project cluster. These impacts related to researcher collaboration improving the research capacity and development of the protected cropping sector within the vegetable industry, community engagement in the importance of sustainable production systems and reductions in energy usage reducing emissions. These impacts were not valued due to data gaps and uncertainties around the extent and magnitude to which these have and will continue to be realised as the technologies undergo additional development.

## Acknowledgements

Ag Econ would like to acknowledge the input from the following:

Sarah Cumpston, Hort Innovation; Adrian Hunt, Hort Innovation; David Tissue, Zhonghua Chen and Yi-Chen Lan, Western Sydney University; Baohua Jia, Swinburne University; Alex Soeriyadi , LLEAF.

## References


Australian Bureau of Statistics (ABS) (2022). 5206.0 – *Australian National Accounts: National Income, Expenditure and Product, Dec 2021*. Table 5. Expenditure on Gross Domestic Product (GDP), Implicit price deflators. Retrieved from Australian Bureau of Statistics: https://www.abs.gov.au/statistics/economy/national-accounts/australian-national-accounts-national-income-expenditure-and-product/latest-release#data-download

Chavan, S.G, Maier C., Alagoz Y., Filipe J., Warren, C.R., Lin H., & Jia, Baohua J., Loik M., Cazzonelli C., Chen, Z.H., Ghannoum O. & Tissue, D. (2020). Light Limited Photosynthesis under Energy-Saving Film Decreases Eggplant Yield. *Food and Energy Security*. 9(2): 1-18 https://doi.org/10.1002/fes3.245.

Commonwealth of Australia (2015a). *Agricultural Competitiveness White Paper*. Retrieved from https://www.awe.gov.au/agriculture-land/farm-food-drought/agriculture-white-paper. Accessed July 2022.

Commonwealth of Australia (2015b). *Strategic Science and Research Priorities*. Canberra: Commonwealth of Australia. Retrieved from https://www.industry.gov.au/data-and-publications/science-and-research-priorities#:~:text=Australia%20depends%20on%20science%20and,and%20improve%20national%20well%2Dbeing. Accessed July 2022.

Council of Rural Research and Development Corporations (CRRDC) (2018). *Cross-RDC Impact Assessment Program: Guidelines*. Canberra: Council of Rural Research and Development Corporations. Retrieved from http://www.ruralrdc.com.au/wp-content/uploads/2018/08/201804_RDC-IA-Guidelines-V.2.pdf

Hort Innovation (2017). *Vegetable Strategic Investment Plan 2017-2021*. Retrieved from https://www.horticulture.com.au/globalassets/hort-innovation/levy-fund-financial-and-management-documents/sip-pdfs-new/hortinnovation-sip-vegetable-2017-2021-web.pdf. Accessed December 2022.

Hort Innovation (2022a). *Vegetable Strategic Investment Plan 2022-2026*. Retrieved from https://www.horticulture.com.au/globalassets/hort-innovation/levy-fund-financial-and-management-documents/sip-2022-2026-pdfs/hort-innovation-sip-2022-26-vegetable-r3.pdf. Accessed December 2022.

Hort Innovation (2022b). *Horticulture Statistics Handbook 2012-13 to 2020-21*. Received from Hort Innovation pers comm. Data available https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/grower-resources/ha18002-assets/australian-horticulture-statistics-handbook/

Lin, T., Goldsworthy, M., Chavan, S., Liang, W., Maier, C., Ghannoum,O., Cazzonelli, C.I., Tissue, D.T, Lan, Y. Sethuvenkatraman, S., Lin, H., Jia, B., & Chen, Z.H (2022). A novel cover material improves cooling energy and fertigation efficiency for glasshouse eggplant production. *Energy*. 251. https://doi.org/10.1016/j.energy.2022.123871

Protected Cropping Australia (2020). *Growing Protected Cropping in Australia to 2030.* https://protectedcropping.net.au/wp-content/uploads/Protected-Cropping-2030-140120.pdf. Accessed December 2022.

Swinburne University of Technology (2021). *Investigating novel glass technologies and photovoltaics in protected cropping*. Final report, funded by Hort Innovation using the vegetable research and development levy and contributions from the Australian Government. Retrieved from https://www.horticulture.com.au/contentassets/1e43c46b16b24d488f16e7eb0966ab5f/vg15038-final-report-complete.pdf. Accessed November 2022.

Western Sydney University (2021). *Research and operations to trial innovative glass and photovoltaic technologies in protected cropping (VG16070)*. Final report, funded by Hort Innovation using the vegetable research and development levy and contributions from the Australian Government. Retrieved from https://www.horticulture.com.au/contentassets/1e43c46b16b24d488f16e7eb0966ab5f/vg16070-final-report-complete.pdf. Accessed November 2022.

## Glossary of economic terms

| | |
|---|---|
| Cost-benefit analysis | A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue. |
| Benefit-cost ratio | The ratio of the present value of investment benefits to the present value of investment costs. |
| Discounting | The process of relating the costs and benefits of an investment to a base year using a stated discount rate. |
| Internal rate of return | The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs. |
| Modified internal rate of return | The internal rate of return of an investment that is modified so that the cash inflows from an investment are re-invested at the rate of the cost of capital (the re-investment rate). |
| Net present value | The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs. |
| Present value of benefits | The discounted value of benefits. |
| Present value of costs | The discounted value of investment costs. |

## Abbreviations

CRRDC Council of Rural Research and Development Corporations

GDP Gross Domestic Product

GVP Gross Value of Production

PVB Present Value of Benefits

PVC Present Value of Costs

RD&E Research, Development and Extension

SIP Strategic Investment Plan

*Ends*.