Final Report

Economic impact assessment for Hort Frontiers: An evaluation of *New technology for sanitising fresh produce and nuts* (HN15000)

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Delivery partner:

AgEconPlus

Project code:

HA20000

Project:

Economic impact assessment for Hort Frontiers (HA20000)

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Hort Frontiers invests funds from a wide range of co-investors including businesses, research agencies, government departments, education institutions, the Australian Government and horticulture levies. Economic impact assessment of these investments is required to meet Hort Innovation obligations under its Organisational Evaluation Framework, its Statutory Funding Agreement, and to demonstrate a return to a diverse set of co-investors and other stakeholders.

This economic impact assessment of the Hort Frontiers program addresses these requirements through the completion of a series of project-specific, ex-post, independent impact assessments of the program. The economic impact assessment was completed using guidelines prepared by the Council of Rural Research and Development Corporations (CRRDC 2018).

The project assessed in this impact assessment was *HN15000: Innovative Cold Plasma for Horticultural Industries*. The Hort Frontiers project has delivered a novel postharvest technology that offers industry a rapid, chemical-free, non-thermal, environmentally friendly, and effective antimicrobial solution for food safety and decay control in some horticultural products. Analysis of the project shows a positive return on investment even without quantification of four secondary environmental and social benefits.

Technical summary

This report presents the results of an impact assessment of a Hort Frontiers Health, Nutrition & Food Safety Fund project *HN15000: Innovative Cold Plasma for Horticultural Industries*. The project was funded by Hort Innovation over the period June 2016 to May 2022.

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 2022/23 using a discount rate of 5% to estimate the investment criteria and a 5% reinvestment rate to estimate the modified internal rate of return (MIRR).

The project (HN15000) has delivered a novel postharvest technology that offers industry a rapid, chemical-free, non-thermal, environmentally friendly, and effective antimicrobial solution for food safety and decay control in some horticultural products.

Total funding from all sources for the project was $7.99 million (present value terms). The investment produced estimated total expected benefits of $36.1 million (present value terms). This gave a net present value of $28.1 million, an estimated benefit-cost ratio of 4.52 to 1, an internal rate of return of 20.7% and a modified internal rate of return of 10.3%.

Analysis of the project shows a positive return on investment even without quantification of four secondary environmental and social benefits.

Keywords

Impact assessment, cost-benefit analysis, cold plasma, supercharged air, food safety, foodborne bacterial pathogens, postharvest, quality.

Introduction

The Hort Frontiers program facilitates collaborative cross-industry investments that are focused on higher-risk, transformative research, development, and extension (RD&E) with the potential for significant impact. Investments are longer-term, complex, and focus on traditionally underinvested themes.

Hort Frontiers invests funds from a wide range of co-investors including businesses, research agencies, government departments, education institutions, the Australian Government and horticulture levies. Economic impact assessment of these investments is required to meet Hort Innovation obligations under its Organisational Evaluation Framework, its Statutory Funding Agreement, and to demonstrate a return to a diverse set of co-investors and other stakeholders.

This economic impact assessment of the Hort Frontiers program addresses these requirements through the completion of a series of project-specific, ex-post, independent impact assessments of the program. A total of eight (8) RD&E investments (projects) were selected through a stratified, random sampling process. The projects, and the total life-of-project (LOP) value of their Hort Innovation managed investment in nominal terms are described in Table 1.

Table 1: Hort Frontiers Project Sample for Impact Assessment

Hort Frontiers Fund	Project Code	Project Title	Total LOP Investment$^{(a)}$ (nominal $)
Advanced Production Systems	AS19005	Australian Protected Cropping RD&E Strategy 2030	140,322
Fruit Fly	HG14033	SITplus: Raising Qfly Sterile Insect Technique to World Standard	20,502,806
Green Cities	GC15002	Which plant where when and why database	10,573,638
Health, Nutrition & Food Safety	HN15000	Innovative Cold Plasma for Horticultural Industries	5,080,321
International Markets	AM15007	Market Development Program - Almonds	925,499
International Markets	AM17001	Developing a national systems approach for meeting bio-security requirements to access key Asian markets	4,830,614
Leadership	LP15001	Global Masterclass Horticulture	3,235,805
Pollination	HN15000	Securing pollination for productive agriculture: guidelines for effective pollinator management and stakeholder adoption	2,182,967

(a) Hort Innovation managed investment

The project population for each fund from which the random sample was selected included completed projects where a final deliverable had been submitted and accepted in the three-year period from 1 July 2019 to 30 June 2022.

The projects in the random sample were selected such that:

(1) The total LOP sample value (in nominal dollar terms) represented at least 10% of the total Hort Innovation managed investment in the overall Hort Frontiers project population, and
(2) The total Hort Innovation managed investment in each project was greater than, or equal to, $100,000 (to exclude 'trivial' projects).

Further, the random sample was stratified first by Hort Frontiers Fund, to ensure all relevant Funds were represented, and then by LOP value range.

The final stratified random sample shown in Table 1 included the required eight (8) projects. At least one project from each Hort Frontiers Fund was selected and at least one project from each LOP range (as defined by Hort Innovation). The final random sample had a total nominal LOP value of $47.47 million (Hort Managed investment) equivalent to approximately 51.6% of the overall total nominal LOP value in the population. Also, the final random sample included one project completed in 2019/20, two completed in 2020/21, and five completed in 2021/22 (all relevant years represented).

Project HN15000: *Innovative Cold Plasma for Horticultural Industries* was one of the investments randomly selected and is analysed in this report.

Methodology

The impact assessments 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 includes both qualitative and quantitative assessment components that are in accord with the impact assessment guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018).

The evaluation process followed an input to impact continuum and involved identifying and briefly describing project objectives, activities, outputs, actual and expected outcomes, and any actual and/or potential impacts associated with project outcomes. The principal economic, environmental, and social impacts then were summarised in a triple bottom line framework.

Some, but not all, of the impacts identified were then valued in monetary terms. The decision to value an impact identified was based on:

- Data availability and information necessary to form credible valuation assumptions,
- The complexity of the relevant valuation methods applicable given project resources,
- The likely magnitude of the impact and/or the expected relative value of the impact compared to other impacts identified, and
- The strength of the linkages between the RD&E investment and the impact identified.

Where impact valuation was exercised, the impact assessment used cost-benefit analysis (CBA) as a principal tool. The impacts valued are therefore deemed to represent the principal benefits delivered by the project. However, as not all impacts were valued, the investment criteria reported for the individual investment evaluated are likely to represent an underestimate of the true performance of the investment.

Background and Rationale

The Hort Frontiers Health, Nutrition & Food Safety Fund project, "*HN15000: Innovative Cold Plasma for Horticultural Industries*" was a priority for investment given that foodborne illness outbreaks linked to fresh produce adversely affect consumers, the healthcare system, growers, and industry. Microbial pathogens such as *Salmonella* species and *Listeria monocytogenes* continuously pose a problem for horticultural industries from both a food safety and cost standpoint.

Preharvest and postharvest risks of microbial contamination of fresh produce can be mitigated with best management practices but these risks cannot be eliminated. Current postharvest sanitation processes (e.g., chlorination) have limitations due to imperfect effectiveness against pathogens, chemical residues, and environmental regulatory issues. Consequently, a global push towards zero chemical residues and assurance of food safety has created a technological gap that could be filled with an innovative decontamination process acceptable to the industries, consumers, and regulators.

Solid, liquid, and gas are the commonly known states of matter, but plasma is regarded as a fourth state of matter. Plasma is generated by partially or completely ionising a gas under either low pressure or atmospheric pressure. Ionising occurs when high voltage power is passed through the gas or ambient air. Depending on the plasma generation method, plasma temperature can range from near ambient to thousands of degrees Celsius. The plasma with near-room temperature is known as cold plasma or non-thermal plasma, or supercharged air. The ability to generate non-thermal plasma has expanded the horizon of plasma's applications in thermosensitive products such as food and in industries such as healthcare.

Rationale

In the last 10 years, cold plasma has emerged as a leading decontamination technology, with applications expanding into the food and healthcare sectors. This project (HN15000) was to investigate the use of cold plasma to decontaminate fresh horticultural produce to mitigate the risk of food safety incidents and boost consumer confidence. Cold plasma can kill or inactivate a broad range of microorganisms such as bacteria, moulds, yeasts, and viruses leading to improved food safely and postharvest decay control.

Project Details

Summary

Project Code: HN15000.

Title: Innovative Cold Plasma for Horticultural Industries.

Research: New South Wales Department of Primary Industries (NSW DPI).

Project Leader: Dr Sukhvinder Pal (SP) Singh.

Period of Funding: June 2016 to May 2022 (final report date).

Objectives

The overarching goal of this project was to develop a cold plasma technology that provides a rapid, cost-effective, chemical-free, non-thermal, environmentally friendly, and effective antimicrobial solution for improved food safety of horticultural products, The three broad objectives of HN15000 were:

- Development of cold plasma treatment protocols to achieve food safety and decay control in a range of horticultural products without affecting product quality.
- Design and build a cold plasma treatment prototype to validate laboratory experimental results and to scale-up the technology.
- Demonstration and transfer of the cold plasma technology as a food safety tool for horticultural industries.

Logical Framework

Table 2 provides a detailed description of project HN15000 in a logical framework.

Table 2: Logical Framework for Project HN15000

Activities	RD&E activities as described in the final HN15000 project report (Singh 2022): • Consultation with fresh fruit, vegetable, and fresh-cut product packers and processors to understand their postharvest sanitisation needs. • Formation of a project steering committee with industry representatives (apple, citrus, berry, vegetable), a food safety expert, Hort Innovation, and NSW DPI. • Consultation with plasma research groups in the United States including the USDA to learn more about cold plasma engineering, application, and prerequisites for adoption of the technology by industry. • Proof-of-concept experimentation on foodborne bacterial pathogens using a Danish built corona discharge system. In-vitro (“test tube”) experiments conducted on foodborne bacteria and postharvest fungal pathogens. • Optimization of cold plasma treatment protocols conducted on a custom-built facility with three plasma emitters. The facility was used for optimizing sanitisation both in-vitro and in-vivo (“living body”). The effects of treatment variables such as frequency, voltage, distance, and exposure were investigated. • In-vivo testing on almond, apple, berries, citrus, leafy salad vegetables, and macadamia. • Treatment protocols further refined after assessments on postharvest quality, decay, and shelf-life. • A cold plasma treatment prototype was developed to validate laboratory experimental results and scale-up the technology. Prototype design and construction were completed with a commercial partner (Oxyzone International). Cost-effectiveness, robustness, automation, and worker health and safety were all preeminent considerations during prototype development. • Prototype validation included evaluation of the machine’s capacity to kill / inactivate target pathogens; assessment of the antimicrobial treatment action on fresh horticultural produce; and assessment of the sensory and nutritional quality of the treated produce. • The success of the technology was widely communicated to stakeholders to facilitate its early adoption by industry.

	• Extension of the technology to industry included project steering committee updates; one-on-one consultation with value chain partners and regulators; technical presentations at scientific conferences, industry workshops, and forums; technical articles and media releases; and demonstration of the protype in horticultural growing regions and industry conferences (e.g., Hort Connections). • In time, a technology licensing and commercialization plan will be developed by Hort Innovation and NSW DPI.
Outputs	• Project experiments showed that cold plasma killed/inactivated the target pathogens including *Salmonella enterica*, *Listeria monocytogenes* and *Escherichia coli 0157*. • Comprehensive datasets were generated on the responses to various pathogens and treated products, leading to a greater understanding of the technology and overcoming its application limitations. • Treatment protocols were developed for six horticultural crops – apple, blueberry, leafy salad vegetables, mandarin, orange, and strawberry. NB: While not tested as part of HN15000, rockmelon, honeydew melon, pears, persimmon, peaches, and nectarines are likely to be suitable for cold plasma sanitisation (SP Singh, HN15000 Principal Investigator, pers. comm., July 2022). • A prototype cold plasma sanitisation machine was demonstrated to industry. • There were no adverse impacts from dry plasma treatment on the sensory and nutritional qualities of treated produce (i.e., apple, blueberry, mandarin, orange, and strawberry). • The project showed that apple and citrus (oranges, mandarins) were promising candidates for postharvest treatment with cold plasma. • Berries such as strawberry and blueberry, which currently do not have a postharvest washing step, also showed promising results from cold plasma. Potentially, cold plasma provides a dry, in-package treatment option for berries. • Almond and macadamia were found to be unsuitable for cold plasma treatment. • For leafy salad vegetables, plasma was infused in the wash water, and the antimicrobial potential of plasma-activated water was successfully demonstrated as a chemical-free treatment to achieve postharvest sanitation. • The scaled-up prototype for dry cold plasma treatment is suitable for retrofitting to commercial packing operations. • The project produced a comprehensive final report, industry presentations, technical articles, media releases, and articles in scientific publications.
Outcomes	• The development of a novel postharvest technology that offers industry a rapid, chemical-free, non-thermal, environmentally friendly, and effective antimicrobial solution for food safety and decay control in horticultural products. • Progress toward improved food safety outcomes, additional mitigation of postharvest losses, and reduced reliance on chemicals used in postharvest processes, resulting in improved environmental health and sustainability. • A potential boost that will allow industry to maintain a competitive advantage by consistently supplying safe and healthy fresh produce to consumers in domestic and export markets.
Potential Impacts	• Economic – potential reduction in the risk of a food safety incident with improved foodborne pathogen control (e.g., avoidance of “scares” such as the contamination of leafy vegetables in WA with salmonella in 2020, rockmelon contamination with Listeria in 2018, the loss in consumer confidence following hepatitis contamination of frozen berries in 2015, and Salmonella contamination of orange juice in 1999). Foodborne illness costs include additional demand on the public health system. • Economic – increased grower and packer profit with a reduction in produce safety related recalls, reduced postharvest spoilage and increased demand for horticultural produce. Food safety failures damage consumer confidence, market access and trade opportunities. Growers and packers will lose less of the crop to supply chain spoilage and enjoy additional demand from increased consumer confidence in fresh produce and improved access to export markets. FSANZ 2022 estimated that contamination of rockmelon with Listeria in 2018 cost the melon industry $100 million (FSANZ 2022).

	• Environmental – less reliance on postharvest chemicals and less risk of chemical contamination affecting the farm and post-farm environment. Reduced use of chemical sanitisers (e.g., chlorine) entering the environment and cutting water pollution with degradation products of chemical disinfectants. Cold plasma will reduce the volume of water used in the fresh produce cleaning process but potentially add to electricity consumption. A potential tool to achieve sustainability agenda with ultra-low chemical usage in the postharvest handling of horticultural products. • Social - additional Australian research capacity in the application of plasma technology to practical industry applications (e.g., food and medical industries). • Social – a healthier Australian population with less sickness and productivity loss. • Social - contribution to improved regional community wellbeing from spill-over income and employment benefits as a result of more productive and profitable horticultural industries.

Project Investment

Nominal Investment

Table 3 shows the annual investment made in Project HN15000. In addition to the Hort Frontiers managed contribution, additional funds were invested by NSW DPI.

Table 3: Annual Investment in Project HN15000 (nominal $)

Year (ended 30 June)	HORT FRONTIERS ($)	OTHERS ($)	TOTAL ($)
2016	1,088,763	0	1,088,763
2017	0	25,000	25,000
2018	1,172,990	25,000	1,197,990
2019	0	0	0
2020	760,317	0	760,317
2021	630,925	100,000	730,925
2022	1,427,317	150,000	1,577,317
Total	**5,080,312**	**300,000**	**5,380,312**

Source: Hort Innovation fully executed letter of variation, 17 March 2021

Program Management Costs

For the Hort Frontiers investment the cost of managing the Hort Innovation funding was added to the Hort Innovation contribution for the project via a management cost multiplier (1.143). This multiplier was estimated based on the share of 'payments to suppliers and employees' in total Hort Innovation expenditure (3-year average) reported in the Hort Innovation's Statement of Cash Flows (Hort Innovation Annual Report, various years). This multiplier was then applied to the nominal investment by Hort Innovation shown in Table 3.

Real Investment and Extension Costs

For the 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). The HN15000 project included a substantial allocation of resources for extension, appropriate materials were produced and communicated to horticultural growers and packers. No additional extension costs were incurred to secure forecast impacts. However, further investment costs will be incurred to secure commercialisation of the cold plasma technology.

Impacts

Table 4 provides a summary of the principal types of impacts delivered by the project, based on the logical framework (Table 2). Impacts have been categorised into economic, environmental, and social impacts.

Table 4: Triple Bottom Line Categories of Principal Impacts from Project HN15000

Economic	• Potential reduction in the risk of a food safety incident with improved foodborne pathogen control (e.g., avoidance of "scares" such as the contamination of leafy vegetables in WA with salmonella in 2020, rockmelon contamination with Listeria in 2018, the loss in consumer confidence following hepatitis contamination of frozen berries in 2015, and Salmonella contamination of orange juice in 1999). Foodborne illness costs include additional demand on the public health system. • Increased grower and packer profit with a reduction in produce safety related recalls, reduced postharvest spoilage and increased demand for horticultural produce. Food safety failures damage consumer confidence, market, and trade opportunities. Growers and packers will lose less of the crop to supply chain spoilage and enjoy additional demand from increased consumer confidence in fresh produce and improved access to export markets. FSANZ 2022 estimated that contamination of rockmelon with Listeria in 2018 cost the melon industry $100 million (FSANZ 2022).
Environmental	• Less reliance on postharvest chemicals and less risk of chemical contamination affecting the farm and post-farm environment. Reduced use of chemical sanitisers (e.g., chlorine) entering the environment and cutting water pollution with degradation products of chemical disinfectants. Cold plasma will reduce the volume of water used in the fresh produce cleaning process but potentially add to electricity consumption. A potential tool to achieve sustainability agenda with ultra-low chemical usage in the postharvest handling of horticultural products.
Social	• Additional Australian research capacity in the application of plasma technology to practical industry applications (e.g., food and medical industries). • Social – a healthier Australian population with less sickness and productivity loss. • Contribution to improved regional community wellbeing from spill-over income and employment benefits as a result of more productive and profitable horticultural industries.

Public versus Private Impacts

The impacts identified from the investment are both private and public in nature. Private impacts mostly accrue to growers and packers (improved profit due to reduced spoilage and increased sales/improved market access). Public impacts include less risk of chemical contamination affecting the environment, improved public health, increased research capacity, and spill-overs to regional communities from enhanced grower and packer profit.

Distribution of Private Impacts

In the first instance, private impacts will be captured by fresh produce packers and grower-packers who will benefit from reduced spoilage and increased sales. Some of this impact will be passed back to non-packing growers who will benefit from increased demand for their fruit and vegetables. Packer benefits will also be passed forward through the supply chain and captured by transporters, wholesalers, exporters, and retailers. The share of benefit retained by each link in the supply chain will depend on the interplay of both short and long-term supply and demand elasticities.

Impacts on Other Australian Industries

While this project has focussed on fresh and (and to a lesser extent) fresh cut horticultural produce, the technology is also relevant to other fresh commodities such as dairy, eggs and meat.

Impacts Overseas

HN15000 findings are relevant to countries that have a strong focus on food safety. Cold plasma technology to improve food safety is under investigation in the United States and this project will add to the total pool of scientific knowledge available in that country. Project findings will also be relevant to importers of Australian fresh produce. Current and future export market access is highly dependent on the ability of Australian exporters to demonstrate food safety and the implementation of findings from this project will provide Australia with a higher level of attainment and a potential market advantage. This may be particularly relevant in markets like the European Union which may move toward a zero chemical residue requirement.

Match with National Priorities

The Australian Government's National Science and Research Priorities and National Agricultural Innovation Priorities are reproduced in Table 5. The project outcomes and related impacts will contribute to National Science and Research Priority 1, 6, and 8 and National Agricultural Innovation Priority 1.

Table 5: Australian Government Research Priorities

Australian Government Strategies and Priorities	
National Science and Research Priorities[1]	**National Agricultural Innovation Priorities**[2]
1. Food – optimising food and fibre production and processing; agricultural productivity and supply chains within Australia and global markets. **2. Soil and Water** – improving the use of soils and water resources, both terrestrial and marine. **3. Transport** – boosting Australian transportation: securing capability and capacity to move essential commodities; alternative fuels; lowering emissions. **4. Cybersecurity** – improving cybersecurity for individuals, businesses, government and national infrastructure. **5. Energy and Resources** – supporting the development of reliable, low cost, sustainable energy supplies and enhancing the long-term viability of Australia's resources industries. **6. Manufacturing** – supporting the development of high value and innovative manufacturing industries in Australia. **7. Environmental Change** – mitigating, managing or adapting to changes in the environment. **8. Health** – improving the health outcomes for all Australians.	On 11 October 2021, the National Agricultural Innovation Policy Statement was released. It highlights four long-term priorities for Australia's agricultural innovation system to address by 2030. These priorities replace the Australian Government's Rural Research, Development and Extension Priorities which were published in the 2015 Agricultural Competitiveness White Paper. **1.** Australia is a trusted exporter of premium food and agricultural products by 2030 **2.** Australia will champion climate resilience to increase the productivity, profitability and sustainability of the agricultural sector by 2030 **3.** Australia is a world leader in preventing and rapidly responding to significant incursions of pests and diseases through futureproofing our biosecurity system by 2030 **4.** Australia is a mature adopter, developer and exporter of digital agriculture by 2030

Alignment with the Hort Frontiers Health, Nutrition & Food Safety Fund Themes

The Hort Frontiers Health, Nutrition & Food Safety Fund targets four themes (Hort Innovation, 2018):

1) Integrated food safety and nutrition program in horticulture.
2) Tailored superior food products as desired by the end user.
3) Products and tools developed to support efficient supply chains.
4) Robust information to make wise adoption decisions.

This project delivers against the first theme but also contributed to the third investment theme.

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[1] See: 2015 Australian Government Science and Research Priorities. https://www.industry.gov.au/data-and-publications/science-and-research-priorities

[2] See: 2021 National Agriculture Innovation Policy Statement. https://www.awe.gov.au/agriculture-land/farm-food-drought/innovation/research_and_development_corporations_and_companies#government-priorities-for-investment

Case Study

The following section provides real world feedback on how the outputs of the investment have benefited growers.

R&D CASE STUDY: COLD PLASMA TECHNOLOGY FOR ENVIRONMENTALLY FRIENDLY, CHEMICAL FREE, FOOD SAFETY

THE CHALLENGE

Food safety is a critical issue for fruit and vegetable consumers. Current sanitisation methods provide imperfect treatments for bacteria, mound, yeast, and viruses. Consumers want safe food that is chemical-free and environmentally friendly. Cold plasma may meet this challenge.

MEET VITO

Vito Mancini is a third-generation blood orange grower River Best Citrus Farm, Griffith NSW. Vito has about 45 ha of production and his father has a further 5 ha. Vito has his own packhouse and about a third of his fruit is exported to the US, China, and Korea, one third is sold on the fresh domestic market and the balance is juiced. Vito has seen the prototype cold plasma disinfestation equipment demonstrated in the Riverina and was impressed. Vito said "The equipment works, and it can be easily integrated into the packing line. For our operation we have effective, low-cost sanitisation washes that use peracetic acid, so we won't be making an immediate move to adopt. But for other industries that cannot wash postharvest it is ideal".

HN15000 Project Team at Joe's Citrus Packing Shed with the Cold Plasma Sanitisation Prototype (photo credit Singh 2022)

THE APPROACH

The technology was demonstrated to citrus growers in packhouses at Tharbogang, Griffith, and Leeton. Other growers were exposed to cold plasma treatment at the Hort Connections conference.

Citrus packers (Mario's Citrus Packhouse) engaged in discussion about the potential application and retrofitting the Cold Plasma Sanitisation Prototype, Griffith NSW December 2021 (photo credit Singh 2022)

MEET NICKY

Nicky Mann, Family Fresh Farm, Peats Ridge NSW has 5 ha of high-tech glasshouse and produces and packs snacking cucumbers. Pre-packs are supplied to Coles, Woolworths, Aldi, Costco, and the independents. Nicky says "I was first exposed to the cold plasma sanitisation technology at Hort Connections when we were berry growers and packers, and I could see the immediate need for it. The berry industry doesn't have a postharvest sanitisation process and getting one will be essential for market access to extremely particular markets like Japan and for our own domestic food supply. Consumers may not currently be aware of the food safety risk, but this can change very quickly, postharvest treatment will need to become standard".

"Consumers eat snacking lines immediately. Berries and snacking cucumbers are often eaten as consumers leave the supermarket. There is no opportunity to wash the product prior to consumption. Cold plasma sanitisation will provide consumers with food safety certainty. The technology can be added into existing packing lines and could be integrated in the same way a check-weigh machine is integrated. Having a cold plasma machine will be standard and checking for one will be part of a packing plant's audit process. Adoption will prevent food scares and recalls that cost millions".

THE IMPACT

In 2022, the cold plasma technology developed by HN15000 with Hort Frontiers funding is not available commercially. Impacts are still sometime in the future. However, if adoption of the technology can positively impact food safety events such as the Patties Foods, hepatitis A scare of 2015, the benefits will be significant. In 2015 illness caused by consuming imported berries packed by Patties Foods Australia cost that company $14 million in compensation for customers, product recall and disposal (Sydney Morning Herald, 4 September 2017).

Valuation of Impacts

Impacts Not Valued

Not all the impacts identified in Table 4 could be valued in the assessment. Those not valued included:

- An improved environment - less risk of contamination with postharvest chemicals.
- Capacity – new researcher skills in the application of cold plasma postharvest sanitisation and understanding pathogen behaviour in response to sanitisation treatments.
- A healthier Australian population with less sickness and productivity loss.
- Contribution to improved regional community wellbeing from spill-over income and employment benefits.

These impacts were not valued due to lack of data to support credible assumptions.

Impacts Valued

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions, particularly when some uncertainty was involved. 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.

Two impacts were valued:

- Reduced risk of a fresh produce food safety incident.
- Increased profitability of some horticultural crops.

Impact 1: Reduced Risk of a Fresh Produce Food Safety Incident

Adoption of cold plasma sanitization technology developed as part of HN15000 has the potential to reduce the number of food safety incidents associated with the consumption of fresh horticultural produce. The most recent data from the Australian Government Department of Health and Aged Care (OzFoodNet 2016) shows that the annual cost of foodborne illness was $1.2 billion per annum, the equivalent of $1.28 billion in 2021/22-dollar equivalents. OzFoodNet 2016 reports that 25% of all illnesses are attributable to the consumption of fresh horticultural produce.

For this analysis, it is assumed that a 2% reduction in the current cost of illness associated with consumption of fresh horticultural produce is possible with adoption of superior cold plasma sanitisation technology. A 2% cost reduction is consistent with previous analyses of improved food safety using new technology completed by AgEconPlus and Agtrans Research (e.g., experimental use of microwaves, innovative controlled atmosphere packaging). These past analyses were tested with a cross-section of industry including leafy salad vegetable and mushroom producers and researchers. The assumption was also reviewed with this projects Principal Investigator (SP Singh, NSW DPI) and an industry representative (Nicky Mann, Family Fresh Farm). The assumption was tested using sensitivity analysis.

Impact 2: Increased Profitability of Some Horticultural Crops

Adoption of cold plasma sanitisation technology also has the potential to increase the profitability of some horticultural crops. Adoption of cold plasma sanitisation will reduce postharvest spoilage, increase consumer confidence in fresh produce, and over time, facilitate improved access to export markets.

The impact is valued for the six horticultural crops for which cold plasma treatment protocols were developed as part of HN15000[3]. Crop farmgate values, packing margins, and increase in packing margins after allowing for the purchase and operation of cold sanitisation equipment are summarised in Table 6.

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[3] NSW DPI advice is that, although not tested as part of the project, cold plasma disinfestation may also be relevant to rockmelon, honeydew melon, pears, persimmon, peaches, and nectarines (SP Singh, HN15000 Principal Investigator, pers. comm., July 2022).

Table 6: Assumptions Performance of Six Crops with Cold Plasma Adoption

Crop	Farmgate Value ($)	Value of Packing Margin ($)	% Increase in Packing Margin with Cold Plasma	Total Impact on Profit ($/year)
Apple	620,000,000	62,000,000	3.00%	1,860,000
Blueberry	411,000,000	41,100,000	3.00%	1,233,000
Leafy salad vegetables	495,000,000	49,500,000	3.00%	1,485,000
Mandarin	341,900,000	34,190,000	3.00%	1,025,700
Orange	437,600,000	43,760,000	3.00%	1,312,800
Strawberry	417,200,000	41,720,000	3.00%	1,251,600
Total				**8,168,100**

Table 6 data was sourced and estimated on the following basis:

- Farmgate value data is from the Australian Horticulture Statistics Handbook 2020/21 (Hort Innovation 2022).
- Value of packing margin was estimated after considering Australian National Accounts: Input-Output Tables 2020-21, for the nearest relevant category i.e., ''fruit and vegetable product manufacturing" (ABS 2023).
- Percentage increase in packing margin with cold plasma – was estimated by the analyst after considering the cost of purchasing and operating the machinery, a potential reduction in food safety recalls, reduced postharvest spoilage, and increased demand for horticultural produce. This assumption was tested using sensitivity analysis.

Some of the target crops such as blueberry and citrus are processed by large-scale packers so this will assist with uptake of cold sanitisation technology. Large scale packers will have scale economies over which they can spread the cost of new technology. Needing to satisfy regulators on the efficacy and safety of cold plasma technology for food sanitisation will take time. The initial capital requirement for the installation and integration of cold plasma technology into postharvest workflows may also impede the rate of adoption by packers. Singh 2022 notes that an uptake of the technology by 20% of production two years after it becomes commercially available would be a major success.

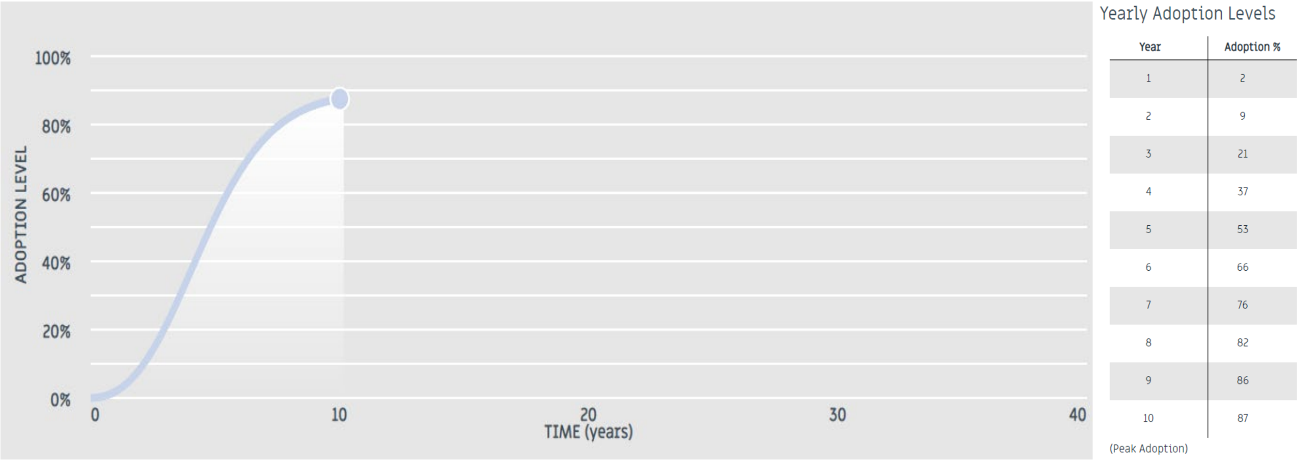
CSIRO Adopt Model Insights

Project parameters were entered into the CSIRO Adopt Model. Assumptions, inputs and outputs used are detailed in Appendix 1. Adopt Model results were:

- Time to peak adoption: 10 years.
- Peak adoption level: 89%.
- In 5 years from start: 53% of the population will have adopted. The population was defined as larger fresh produce packing houses.
- In 10 years from start: 87% of the population will have adopted.
- Time to reach 50% of peak adoption: 4.5 years.

The adoption profile and levels modelled using the CSIRO Adopt Tool are shown in Figure 1 below. These insights were considered when preparing valuation assumptions.

Figure 1: CSIRO Adopt Model, Adoption Level S-Curve for HN15000



Yearly Adoption Levels

Year	Adoption %
1	2
2	9
3	21
4	37
5	53
6	66
7	76
8	82
9	86
10	87

(Peak Adoption)

Summary of Assumptions

Table 7 contains a summary of assumptions required for estimation of both quantified impacts.

Table 7: Summary of Assumptions for Impact Valuation

Variable	**Assumption/Value**	**Source/Comment**
Impact 1: Reduced Risk of Fresh Produce Food Safety Incident		
Cost of fresh produce food safety incidents.	$320 million/year.	See above explanations sourced from Australian Government Department of Health and Aged Care (OzFoodNet).
Reduction in the probability of a fresh produce food safety event with industry adoption of cold plasma sanitisation technology.	2%	A 2% cost reduction is consistent with previous analyses of improved food safety using new technology completed by AgEconPlus and Agtrans Research (e.g., experimental use of microwaves, innovative controlled atmosphere packaging). These past analyses were tested with a cross-section of industry including leafy salad vegetable and mushroom producers and researchers. The assumption was also reviewed with this projects Principal Investigator (SP Singh, NSW DPI) and an industry representative (Nicky Mann, Family Fresh Farm). The assumption was tested using sensitivity analysis.
Impact 2: Increased Profitability of Some Horticultural Crops		
Increase in packing profit for six horticultural crops with application of cold plasma technology	$8,168,100/year.	See above explanation developed by the analyst using data from the Australian Horticulture Statistics Handbook 2020/21, the National Accounts: Input-Output Table 2020/21, and Singh 2022.
Assumptions Common to Quantification of Both Impacts		
Year of first impact.	2023/24.	Assumes two years is required post completion of the project in May 2022 for the first cold plasma machine to be produced commercially and installed in a packing plant.
Year of maximum impact.	2026/27	Three years required to achieve 50% adoption.
Attribution of impacts to this project.	70%	Further investment will be required to produce commercial cold plasma equipment for horticulture.
Probability of the project generating useful outputs.	100%	Outputs have been delivered – scaled-up prototype has been demonstrated to industry.
Probability of valuable outcomes.	50%	There is a significant risk that commercialization will not occur especially within the next few years (Bianca Cairns, R&D Manager, Hort Innovation, pers. comm., November 2022).
Probability of impact (assuming successful outcome)	90%	There is some (relatively minor) risk that once installed, cold sanitisation equipment will not deliver superior food safety.
Counterfactual.	80%	In the absence of HN15000 research, it is possible that prototype cold plasma technology would have been developed by another source and made available to Australian growers e.g., USDA investment. Bianca Cairns, R&D Manager, Hort Innovation noted that this was highly likely (pers. comm., November 2022).

Results

All costs and benefits were discounted to 2022/23 using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the Modified Internal Rate of Return (MIRR). The base analysis used the best available estimates for each variable, notwithstanding a level of uncertainty for many of the estimates. 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

Table 8 and Table 9 show the investment criteria estimated for different periods of benefits for the total investment and Hort Frontiers investment. Hort Frontiers present value of benefits (Table 9) was estimated by multiplying the total present value of benefits by the Hort Frontiers proportion of total undiscounted costs expressed in 2021/22-dollar terms.

Table 8: Investment Criteria for Total Investment in Project HN15000

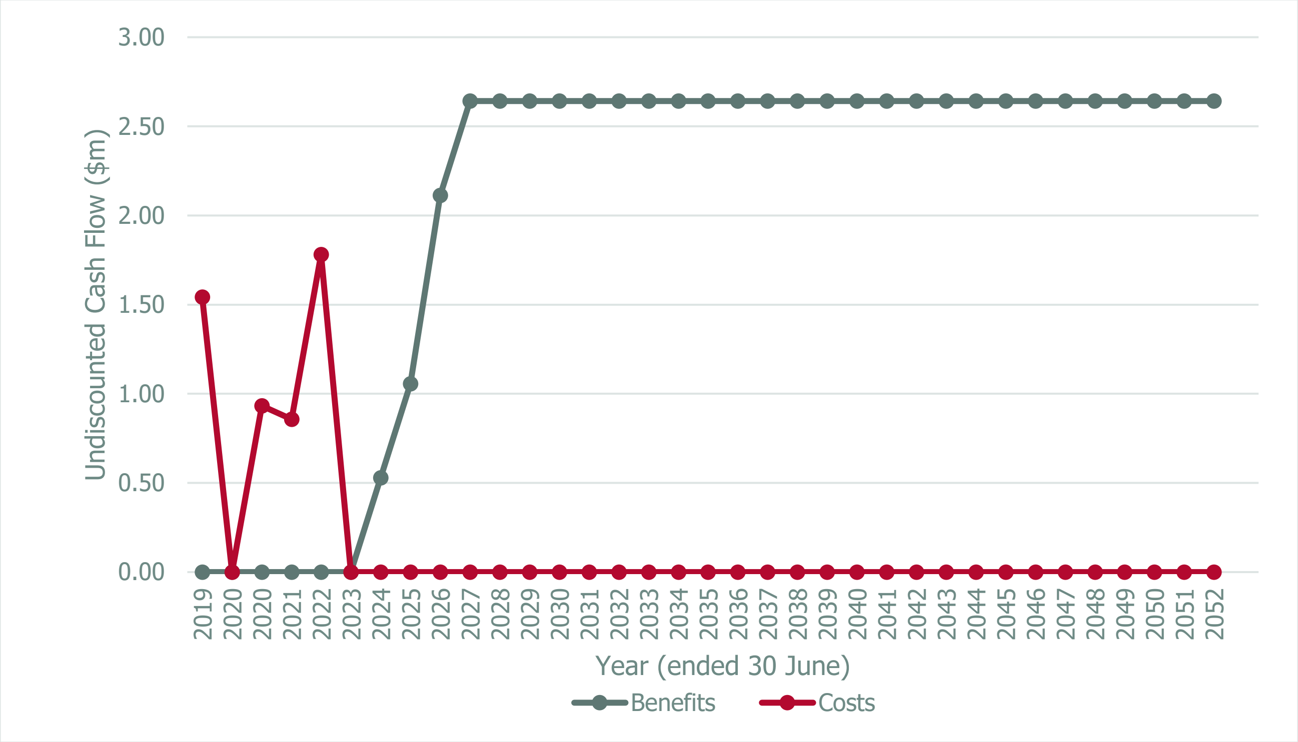
Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	5.46	14.87	22.24	28.02	32.55	36.10
Present Value of Costs ($m)	7.99	7.99	7.99	7.99	7.99	7.99	7.99
Net Present Value ($m)	-7.99	-2.53	6.88	14.25	20.03	24.56	28.10
Benefit-Cost Ratio	0.00	0.68	1.86	2.78	3.51	4.07	4.52
Internal Rate of Return (%)	negative	negative	15.3	19.1	20.2	20.6	20.7
MIRR (%)	negative	negative	11.3	12.1	11.6	10.9	10.3

Table 9: Investment Criteria for Hort Innovation Managed Investment in Project HN15000

Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	5.20	14.17	21.20	26.71	31.02	34.40
Present Value of Costs ($m)	7.62	7.62	7.62	7.62	7.62	7.62	7.62
Net Present Value ($m)	-7.62	-2.41	6.56	13.58	19.09	23.40	26.78
Benefit-Cost Ratio	0.00	0.68	1.86	2.78	3.51	4.07	4.52
Internal Rate of Return (%)	negative	negative	15.3	19.1	20.2	20.6	20.7
MIRR (%)	negative	negative	11.3	12.1	11.6	10.9	10.3

The annual undiscounted benefit and cost cash flows for the total investment for the duration of the HN15000 investment plus 30 years from the last year of investment are shown in Figure 2.

Figure 2: Annual Cash Flow of Undiscounted Total Benefits and Total Investment Costs



Source of benefits

Table 10 shows the contribution to total benefits from each of the two benefits valued. Reduced risk of a fresh produce food safety incident was the principal contributor.

Table 10: Source of Total Benefits
(Total investment, 30 years)

Impact	**Contribution to PVB ($m)**	**Share of Total Benefits (%)**
Impact 1: Reduced risk of a fresh produce food safety incident	22.03	61.0
Impact 2: Increased profitability of some horticultural crops	14.06	39.0
Total	**36.10**	**100.0**

Sensitivity Analyses

A sensitivity analysis was carried out on the discount rate. 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 11 presents the results. The results are moderately sensitive to the discount rate.

Table 11: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	Discount Rate		
	0%	**5% (base)**	**10%**
Present Value of Benefits ($m)	72.39	36.10	21.13
Present Value of Costs ($m)	6.63	7.99	9.67
Net Present Value ($m)	65.76	28.10	11.46
Benefit-cost ratio	10.92	4.52	2.19

A sensitivity analysis was then undertaken on the reduced risk of a food safety incident as a result of adoption of cold plasma sanitisation technology. Results are provided in Table 12. Even when assumed reduction in food safety risk is halved, the project continues to generate a favourable return on investment.

Table 12: Sensitivity to Reduced Risk of Food Safety Incident from HN15000 Adoption
(Total investment, 30 years)

Investment Criteria	Reduced Risk of Food Safety Incident		
	1%	**2% (base)**	**4%**
Present Value of Benefits ($m)	25.08	36.10	58.13
Present Value of Costs ($m)	7.99	7.99	7.99
Net Present Value ($m)	17.09	28.10	50.14
Benefit-cost ratio	3.14	4.52	7.27

A final sensitivity analysis tested assumed increase in the profitability of some horticultural crops with adoption of cold plasma technology. The results (Table 13) show that if assumed increase in profitability is halved, the project continues to generate a favourable return on investment.

Table 13: Sensitivity to Increase in Profitability of Some Horticultural Crops with HN15000 Adoption
(Total investment, 30 years)

Investment Criteria	Increase in Profitability		
	1.5%	**3% (base)**	**6%**
Present Value of Benefits ($m)	29.06	36.10	50.16
Present Value of Costs ($m)	7.99	7.99	7.99
Net Present Value ($m)	21.07	28.10	42.16
Benefit-cost ratio	3.64	4.52	6.28

Confidence Rating

The results produced are highly dependent on the assumptions made, some 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 14). 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 14: Confidence in Analysis of Project

Coverage of Benefits	Confidence in Assumptions
High	Medium

Coverage of benefits valued was assessed as High, the key impact (reduced risk of a food safety incident) and a secondary impact (increased profitability of some horticultural crops) were valued. Confidence in assumptions was rated as Medium, some data were estimated by the analyst.

Conclusions

The project (HN15000) has delivered a novel postharvest technology that offers industry a rapid, chemical-free, non-thermal, environmentally friendly, and effective antimicrobial solution for food safety and decay control in some horticultural products.

Total funding from all sources for the project was $7.99 million (present value terms). The investment produced estimated total expected benefits of $36.1 million (present value terms). This gave a net present value of $28.1 million, an estimated benefit-cost ratio of 4.52 to 1, an internal rate of return of 20.7% and a modified internal rate of return of 10.3%.

Analysis of the project shows a strong return on investment even without quantification of four environmental and social secondary benefits.

Recommendations

Impact assessment is now a mature process within Hort Innovation. No recommendations are made for further refinement.

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Specific acknowledgements:

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- Bianca Cairns, R&D Manager, Hort Innovation
- Sarah Cumpston, Evaluation and Measurement Specialist, Hort Innovation
- Vito Mancini, River Best Citrus Farm
- Nicky Mann, Family Fresh Farm

Abbreviations and Acronyms

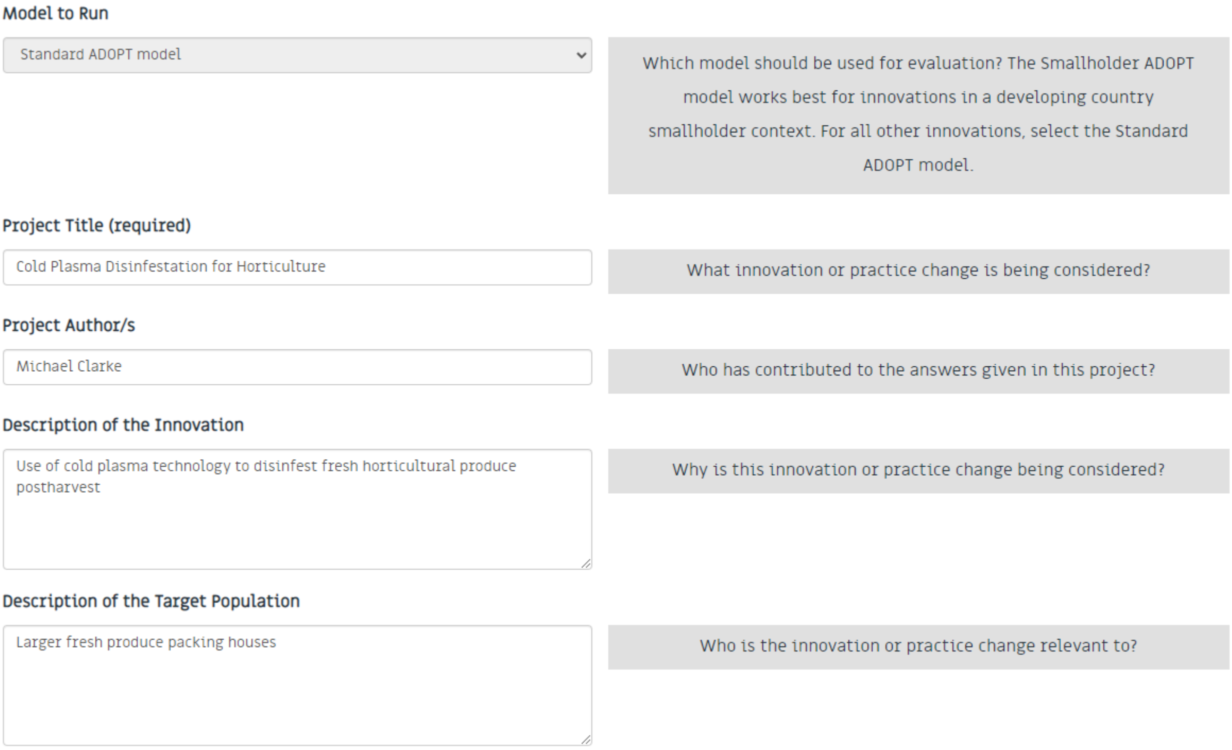
CBA	Cost Benefit Analysis
CRRDC	Council of Research and Development Corporations
DAWR	Department of Agriculture and Water Resources (Australian Government)
DPI	(NSW) Department of Primary Industries
FSANZ	Food Standards Australia and New Zealand
GDP	Gross Domestic Product
GVP	Gross Value of Production
IRR	Internal Rate of Return
LOP	Life of Project
MIRR	Modified Internal Rate of Return
PVB	Present Value of Benefits
R&D	Research and Development
RD&E	Research, Development and Extension
USDA	United States Department of Agriculture

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.
Investment criteria:	Measures of the economic worth of an investment such as Net Present Value, Benefit-Cost Ratio, and Internal Rate of Return.
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.

Appendix 1: CSIRO Adopt Model Detailed Assumptions, Inputs, and Outputs

Assumptions, inputs and outputs used to develop an adoption profile for HN15000 – Innovative Cold Plasma for Horticultural Industries are reproduced in this appendix.



Model to Run

Standard ADOPT model

Which model should be used for evaluation? The Smallholder ADOPT model works best for innovations in a developing country smallholder context. For all other innovations, select the Standard ADOPT model.

Project Title (required)

Cold Plasma Disinfestation for Horticulture

What innovation or practice change is being considered?

Project Author/s

Michael Clarke

Who has contributed to the answers given in this project?

Description of the Innovation

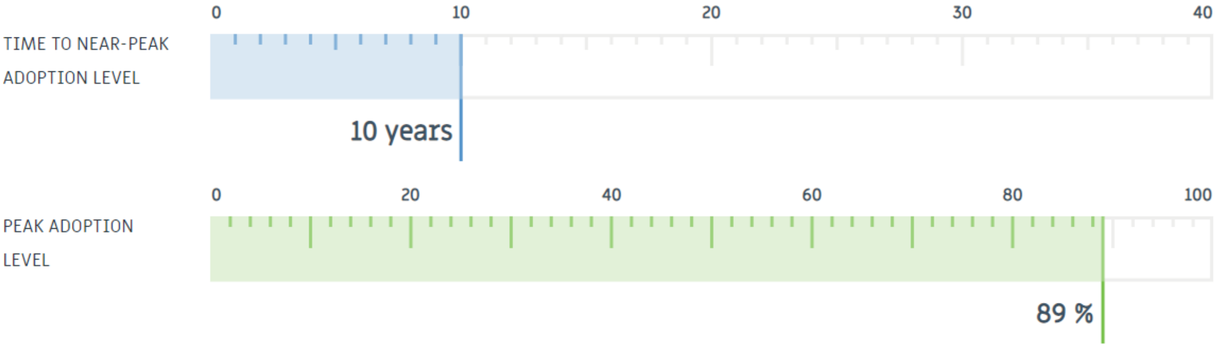
Use of cold plasma technology to disinfest fresh horticultural produce postharvest

Why is this innovation or practice change being considered?

Description of the Target Population

Larger fresh produce packing houses

Who is the innovation or practice change relevant to?

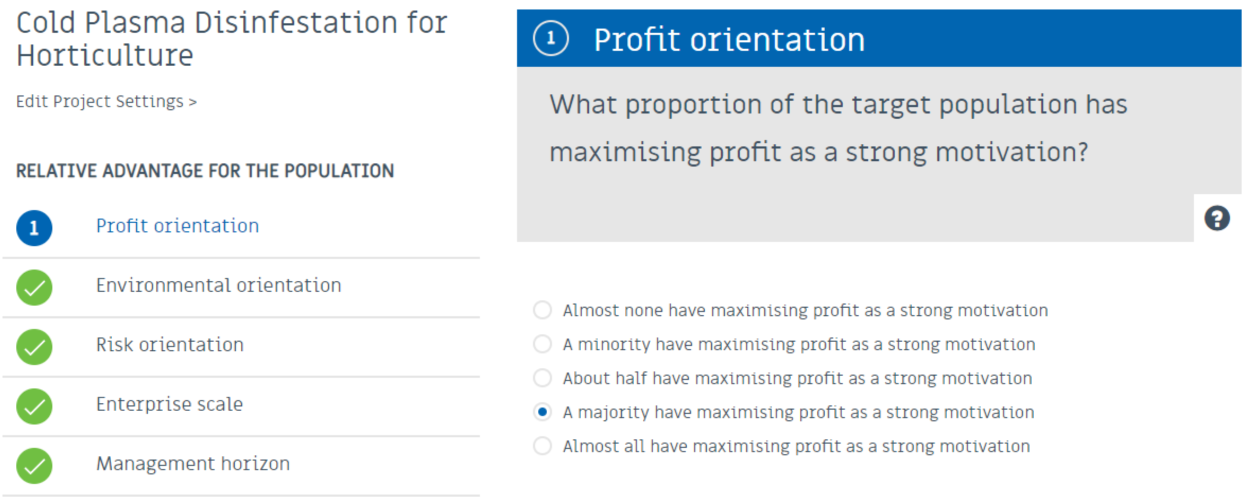


TIME TO NEAR-PEAK ADOPTION LEVEL

10 years

PEAK ADOPTION LEVEL

89 %



Cold Plasma Disinfestation for Horticulture

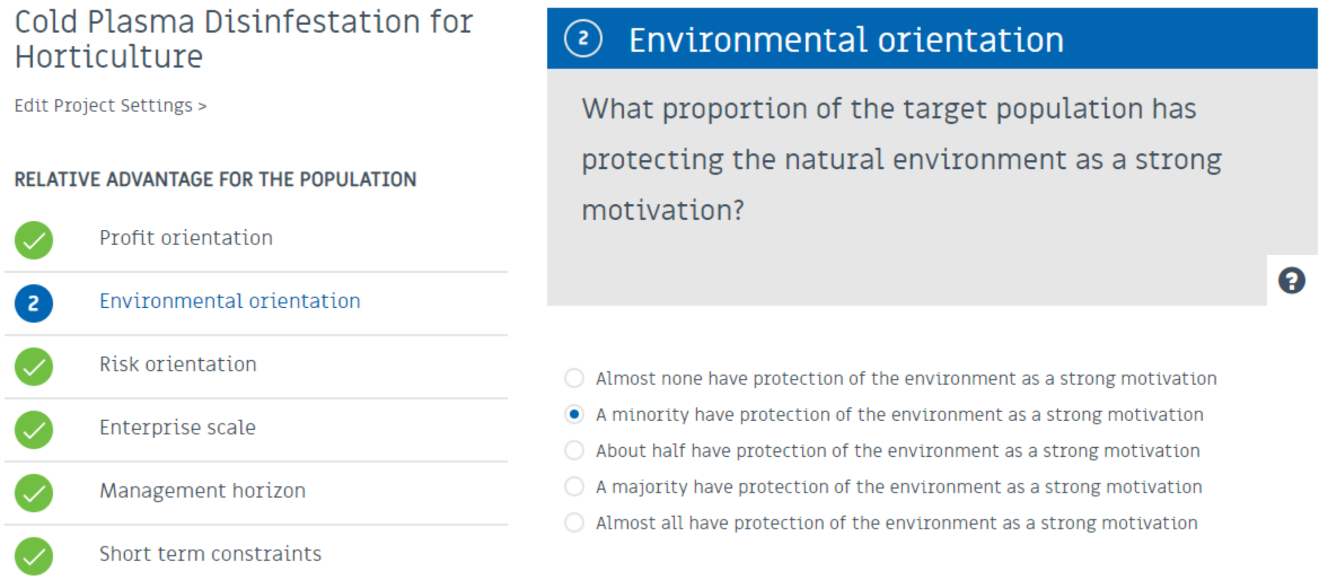
RELATIVE ADVANTAGE FOR THE POPULATION

1 Profit orientation
✓ Environmental orientation
✓ Risk orientation
✓ Enterprise scale
✓ Management horizon

① Profit orientation

What proportion of the target population has maximising profit as a strong motivation?

○ Almost none have maximising profit as a strong motivation
○ A minority have maximising profit as a strong motivation
○ About half have maximising profit as a strong motivation
● A majority have maximising profit as a strong motivation
○ Almost all have maximising profit as a strong motivation



Cold Plasma Disinfestation for Horticulture

Edit Project Settings >

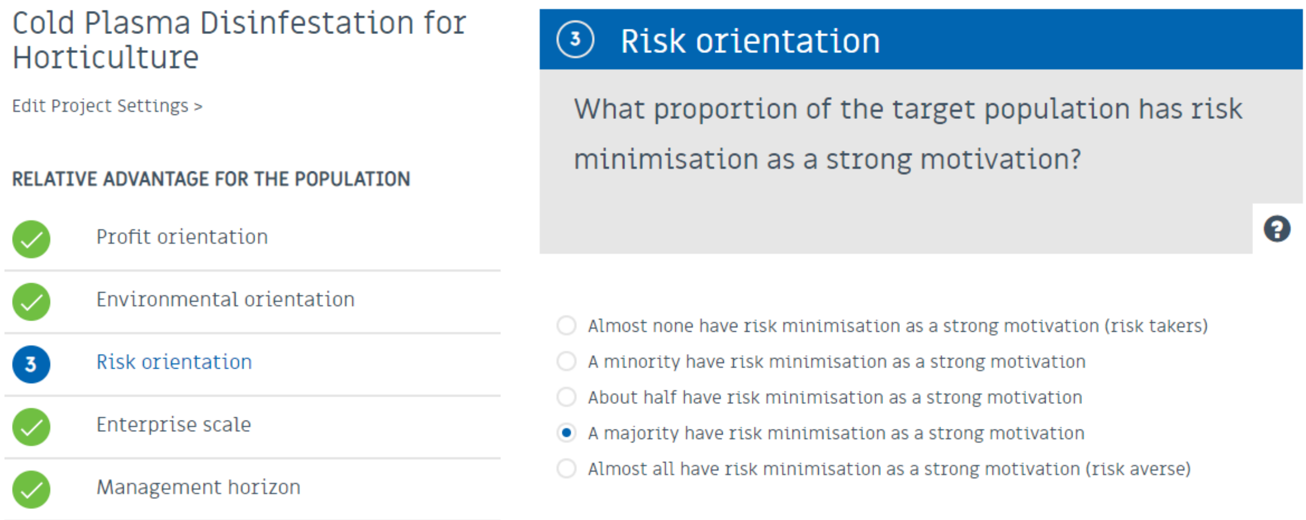
RELATIVE ADVANTAGE FOR THE POPULATION

✓ Profit orientation
2 Environmental orientation
✓ Risk orientation
✓ Enterprise scale
✓ Management horizon
✓ Short term constraints

② Environmental orientation

What proportion of the target population has protecting the natural environment as a strong motivation?

○ Almost none have protection of the environment as a strong motivation
● A minority have protection of the environment as a strong motivation
○ About half have protection of the environment as a strong motivation
○ A majority have protection of the environment as a strong motivation
○ Almost all have protection of the environment as a strong motivation



Cold Plasma Disinfestation for Horticulture

Edit Project Settings >

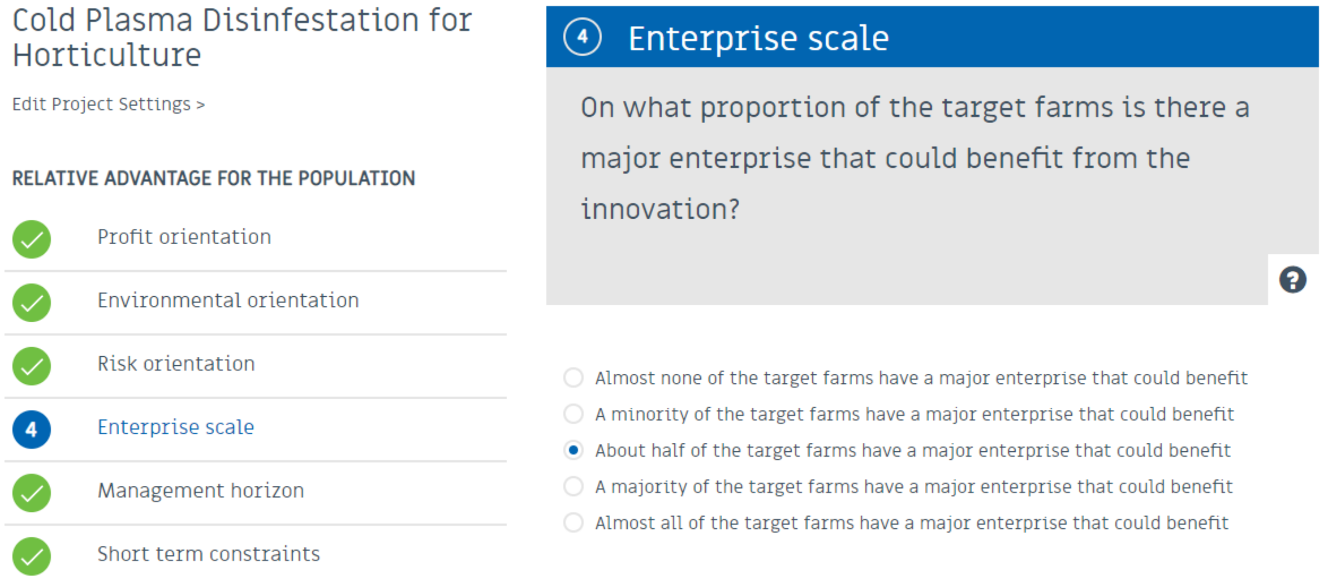
RELATIVE ADVANTAGE FOR THE POPULATION

✓ Profit orientation
✓ Environmental orientation
3 Risk orientation
✓ Enterprise scale
✓ Management horizon

③ Risk orientation

What proportion of the target population has risk minimisation as a strong motivation?

○ Almost none have risk minimisation as a strong motivation (risk takers)
○ A minority have risk minimisation as a strong motivation
○ About half have risk minimisation as a strong motivation
● A majority have risk minimisation as a strong motivation
○ Almost all have risk minimisation as a strong motivation (risk averse)



Cold Plasma Disinfestation for Horticulture

Edit Project Settings >

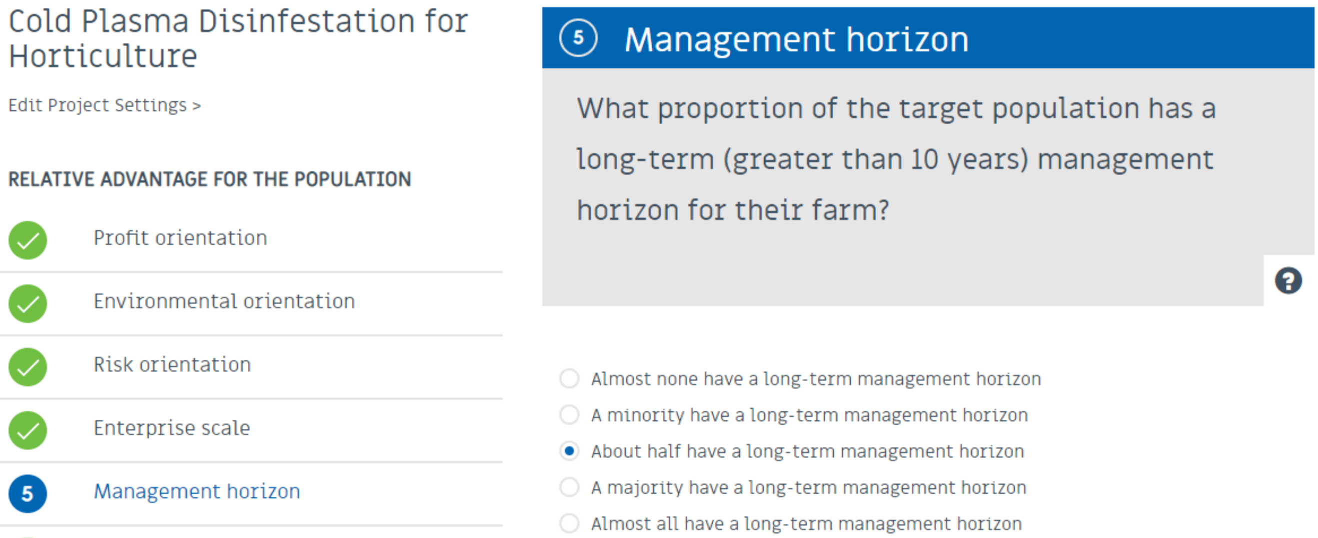
RELATIVE ADVANTAGE FOR THE POPULATION

✓ Profit orientation
✓ Environmental orientation
✓ Risk orientation
4 Enterprise scale
✓ Management horizon
✓ Short term constraints

④ Enterprise scale

On what proportion of the target farms is there a major enterprise that could benefit from the innovation?

○ Almost none of the target farms have a major enterprise that could benefit
○ A minority of the target farms have a major enterprise that could benefit
● About half of the target farms have a major enterprise that could benefit
○ A majority of the target farms have a major enterprise that could benefit
○ Almost all of the target farms have a major enterprise that could benefit



Cold Plasma Disinfestation for Horticulture

Edit Project Settings >

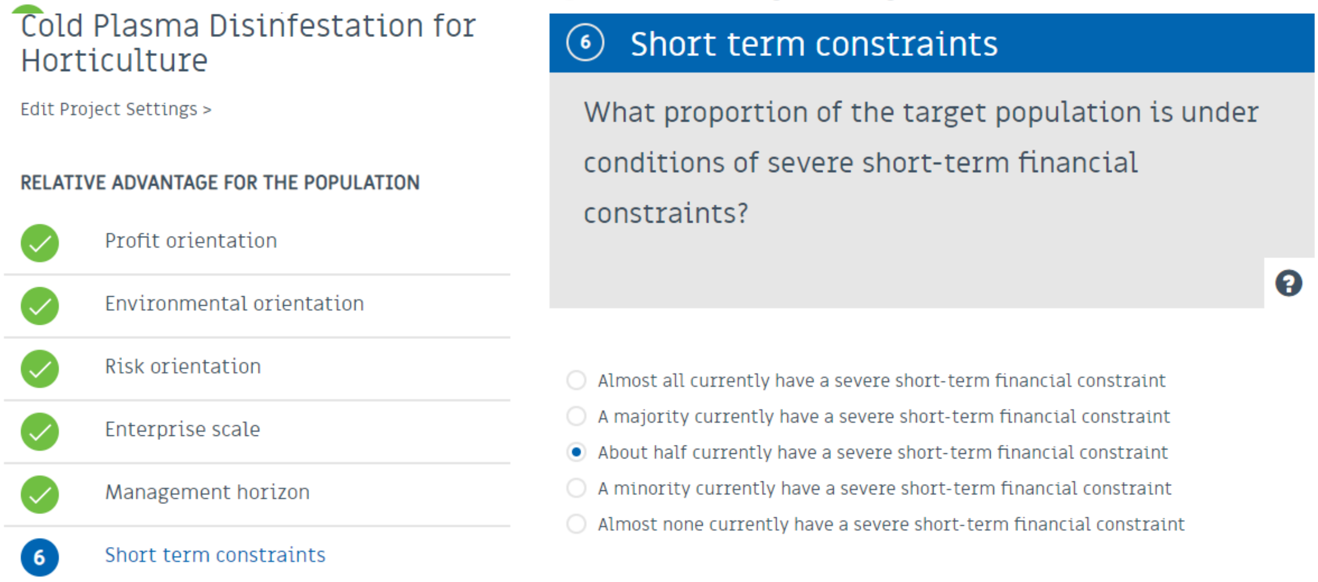
RELATIVE ADVANTAGE FOR THE POPULATION

- ✓ Profit orientation
- ✓ Environmental orientation
- ✓ Risk orientation
- ✓ Enterprise scale
- 5 Management horizon

5 Management horizon

What proportion of the target population has a long-term (greater than 10 years) management horizon for their farm?

○ Almost none have a long-term management horizon
○ A minority have a long-term management horizon
● About half have a long-term management horizon
○ A majority have a long-term management horizon
○ Almost all have a long-term management horizon



Cold Plasma Disinfestation for Horticulture

Edit Project Settings >

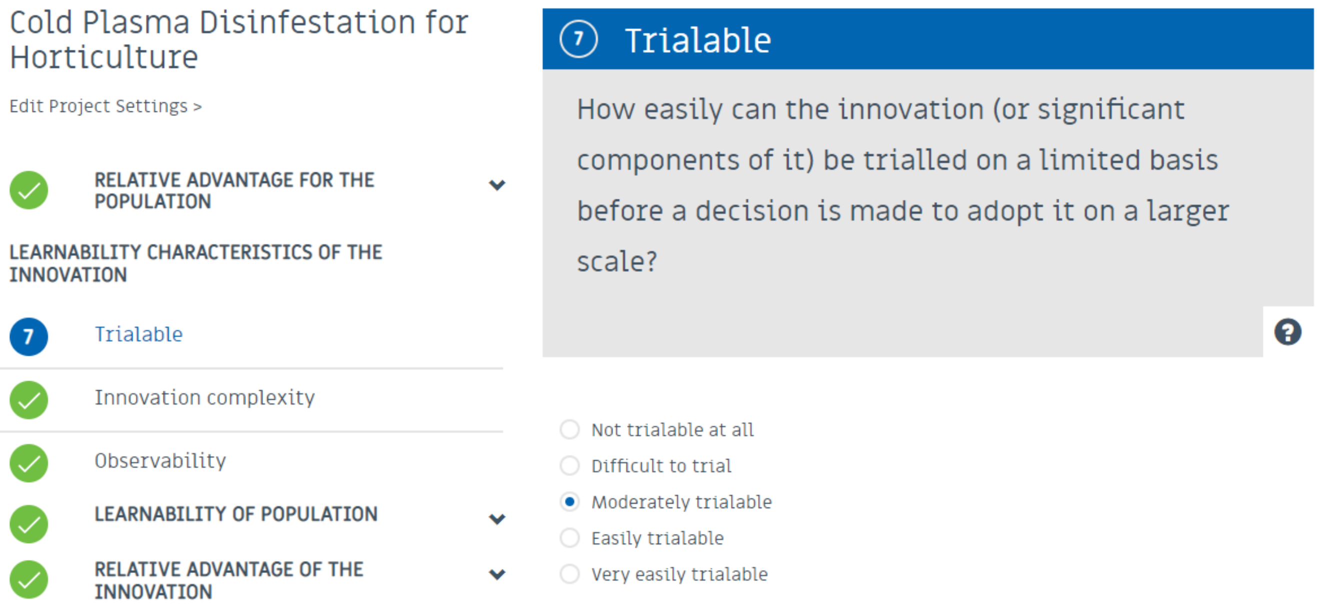
RELATIVE ADVANTAGE FOR THE POPULATION

- ✓ Profit orientation
- ✓ Environmental orientation
- ✓ Risk orientation
- ✓ Enterprise scale
- ✓ Management horizon
- 6 Short term constraints

6 Short term constraints

What proportion of the target population is under conditions of severe short-term financial constraints?

○ Almost all currently have a severe short-term financial constraint
○ A majority currently have a severe short-term financial constraint
● About half currently have a severe short-term financial constraint
○ A minority currently have a severe short-term financial constraint
○ Almost none currently have a severe short-term financial constraint



Cold Plasma Disinfestation for Horticulture

Edit Project Settings >

✓ RELATIVE ADVANTAGE FOR THE POPULATION

LEARNABILITY CHARACTERISTICS OF THE INNOVATION

- 7 Trialable
- ✓ Innovation complexity
- ✓ Observability

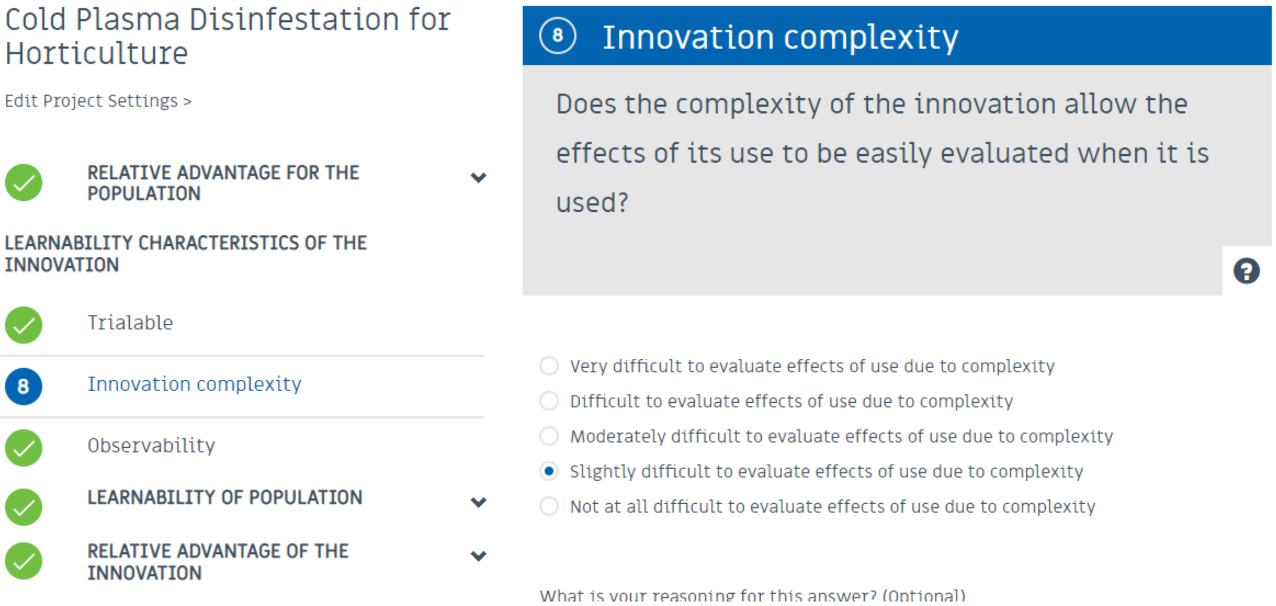
✓ LEARNABILITY OF POPULATION

✓ RELATIVE ADVANTAGE OF THE INNOVATION

7 Trialable

How easily can the innovation (or significant components of it) be trialled on a limited basis before a decision is made to adopt it on a larger scale?

○ Not trialable at all
○ Difficult to trial
● Moderately trialable
○ Easily trialable
○ Very easily trialable



Cold Plasma Disinfestation for Horticulture

Edit Project Settings >

✓ RELATIVE ADVANTAGE FOR THE POPULATION

LEARNABILITY CHARACTERISTICS OF THE INNOVATION

✓ Trialable

8 Innovation complexity

✓ Observability

✓ LEARNABILITY OF POPULATION

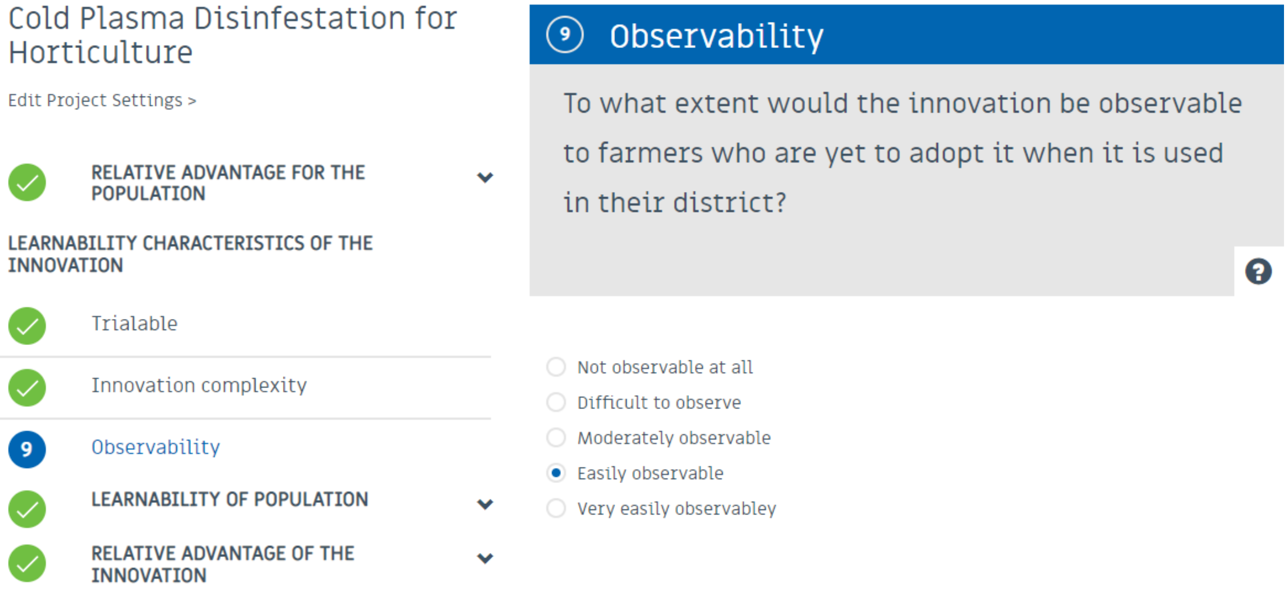
✓ RELATIVE ADVANTAGE OF THE INNOVATION

8 Innovation complexity

Does the complexity of the innovation allow the effects of its use to be easily evaluated when it is used?

○ Very difficult to evaluate effects of use due to complexity
○ Difficult to evaluate effects of use due to complexity
○ Moderately difficult to evaluate effects of use due to complexity
● Slightly difficult to evaluate effects of use due to complexity
○ Not at all difficult to evaluate effects of use due to complexity

What is your reasoning for this answer? (Optional)



Cold Plasma Disinfestation for Horticulture

Edit Project Settings >

✓ RELATIVE ADVANTAGE FOR THE POPULATION

LEARNABILITY CHARACTERISTICS OF THE INNOVATION

✓ Trialable

✓ Innovation complexity

9 Observability

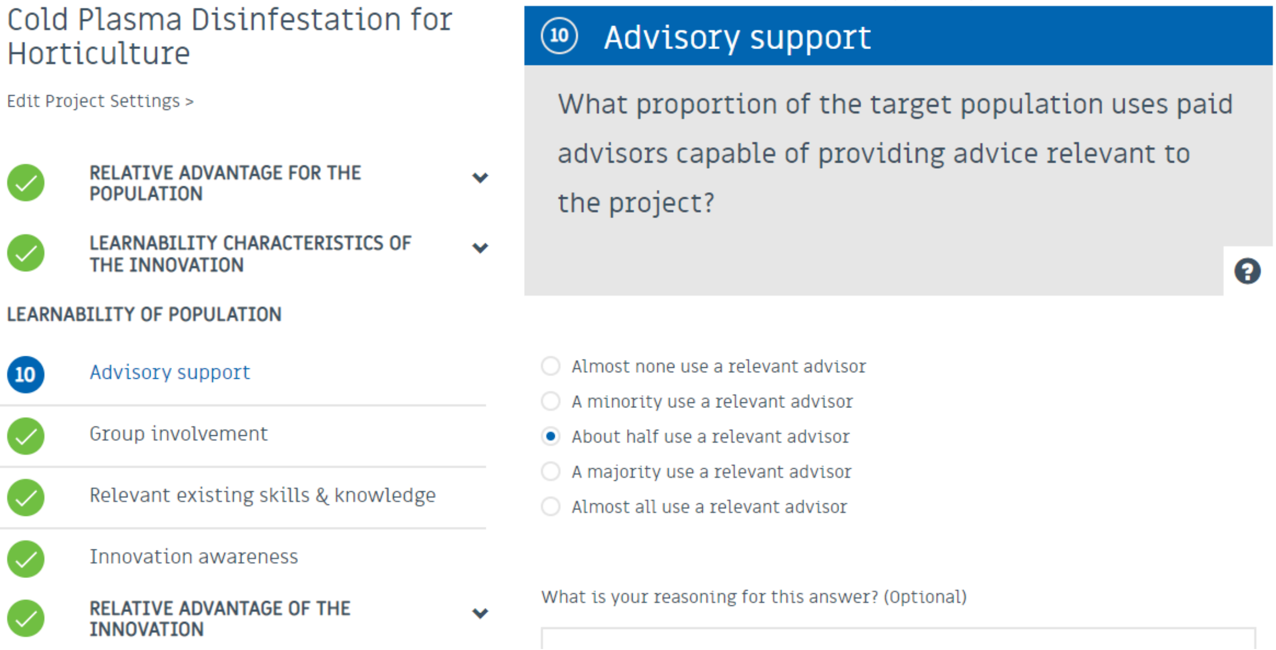
✓ LEARNABILITY OF POPULATION

✓ RELATIVE ADVANTAGE OF THE INNOVATION

9 Observability

To what extent would the innovation be observable to farmers who are yet to adopt it when it is used in their district?

○ Not observable at all
○ Difficult to observe
○ Moderately observable
● Easily observable
○ Very easily observabley



Cold Plasma Disinfestation for Horticulture

Edit Project Settings >

✓ RELATIVE ADVANTAGE FOR THE POPULATION

✓ LEARNABILITY CHARACTERISTICS OF THE INNOVATION

LEARNABILITY OF POPULATION

10 Advisory support

✓ Group involvement

✓ Relevant existing skills & knowledge

✓ Innovation awareness

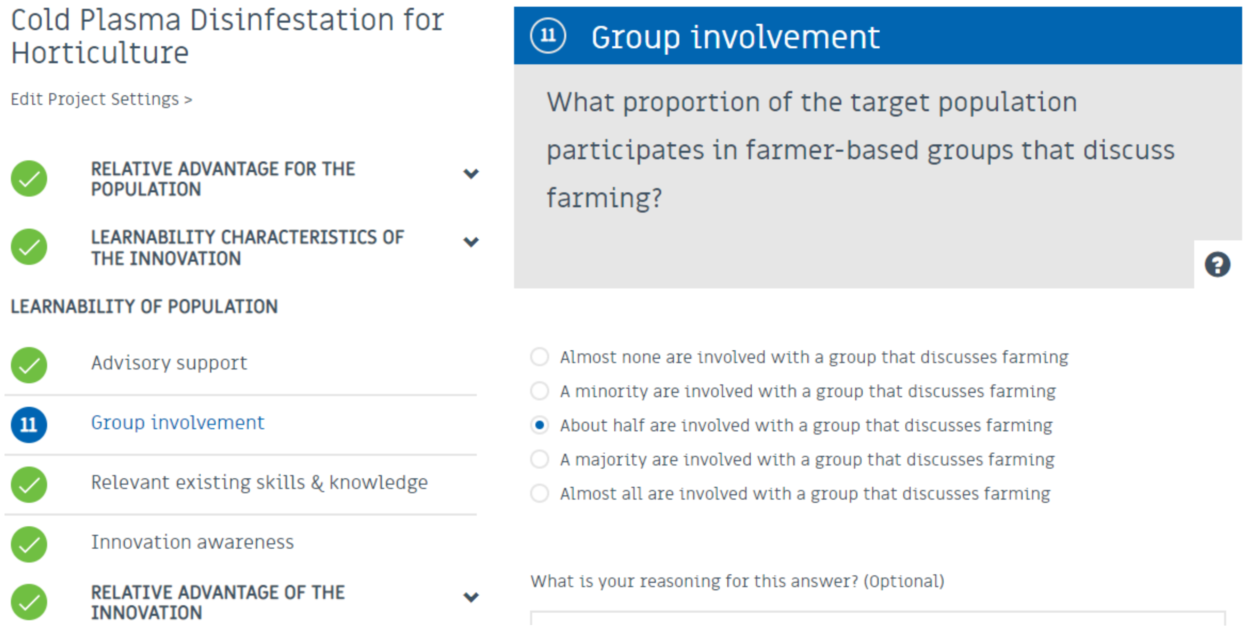
✓ RELATIVE ADVANTAGE OF THE INNOVATION

10 Advisory support

What proportion of the target population uses paid advisors capable of providing advice relevant to the project?

○ Almost none use a relevant advisor
○ A minority use a relevant advisor
● About half use a relevant advisor
○ A majority use a relevant advisor
○ Almost all use a relevant advisor

What is your reasoning for this answer? (Optional)



Cold Plasma Disinfestation for Horticulture

Edit Project Settings >

- ✓ RELATIVE ADVANTAGE FOR THE POPULATION
- ✓ LEARNABILITY CHARACTERISTICS OF THE INNOVATION

LEARNABILITY OF POPULATION

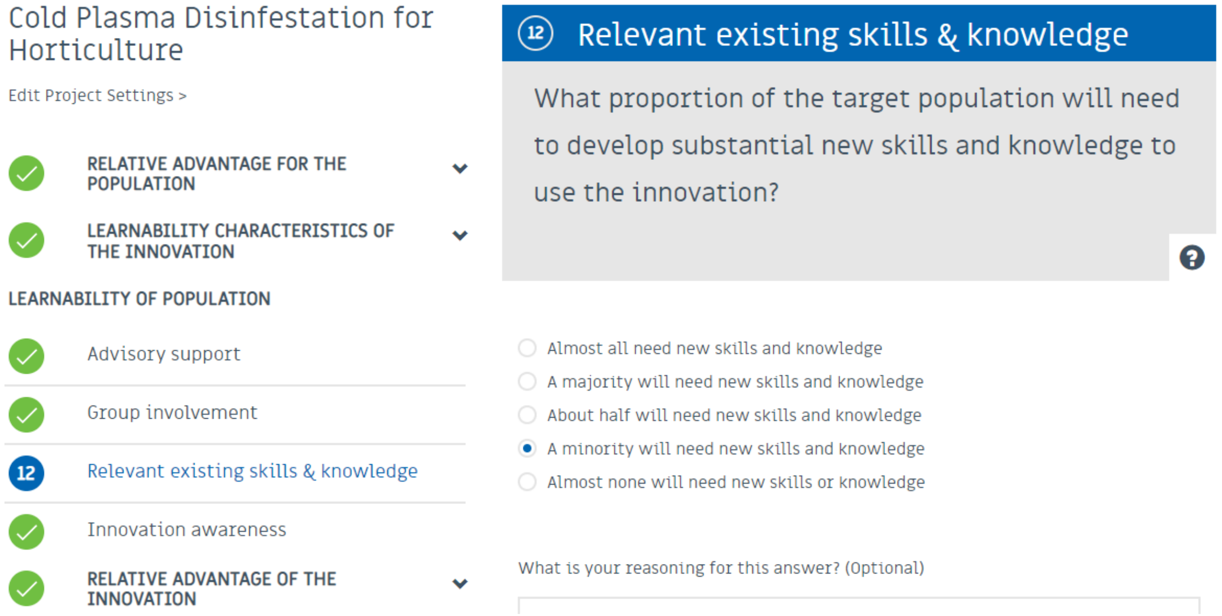
- ✓ Advisory support
- 11 Group involvement
- ✓ Relevant existing skills & knowledge
- ✓ Innovation awareness
- ✓ RELATIVE ADVANTAGE OF THE INNOVATION

⑪ Group involvement

What proportion of the target population participates in farmer-based groups that discuss farming?

○ Almost none are involved with a group that discusses farming
○ A minority are involved with a group that discusses farming
● About half are involved with a group that discusses farming
○ A majority are involved with a group that discusses farming
○ Almost all are involved with a group that discusses farming

What is your reasoning for this answer? (Optional)



Cold Plasma Disinfestation for Horticulture

Edit Project Settings >

- ✓ RELATIVE ADVANTAGE FOR THE POPULATION
- ✓ LEARNABILITY CHARACTERISTICS OF THE INNOVATION

LEARNABILITY OF POPULATION

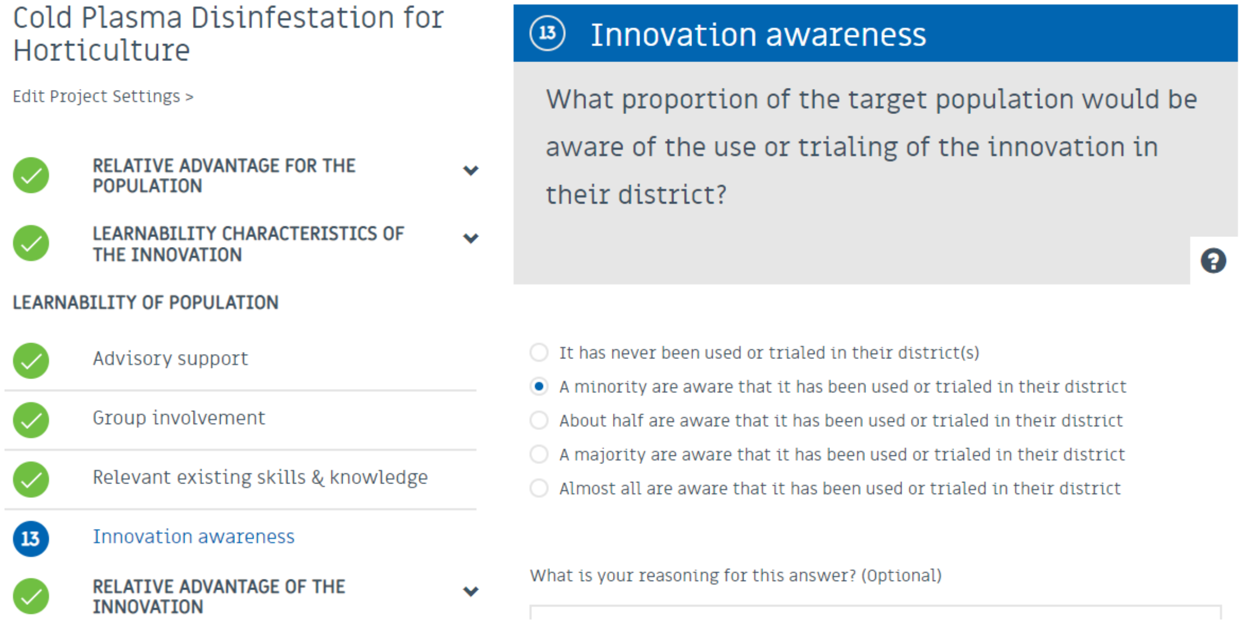
- ✓ Advisory support
- ✓ Group involvement
- 12 Relevant existing skills & knowledge
- ✓ Innovation awareness
- ✓ RELATIVE ADVANTAGE OF THE INNOVATION

⑫ Relevant existing skills & knowledge

What proportion of the target population will need to develop substantial new skills and knowledge to use the innovation?

○ Almost all need new skills and knowledge
○ A majority will need new skills and knowledge
○ About half will need new skills and knowledge
● A minority will need new skills and knowledge
○ Almost none will need new skills or knowledge

What is your reasoning for this answer? (Optional)



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LEARNABILITY OF POPULATION

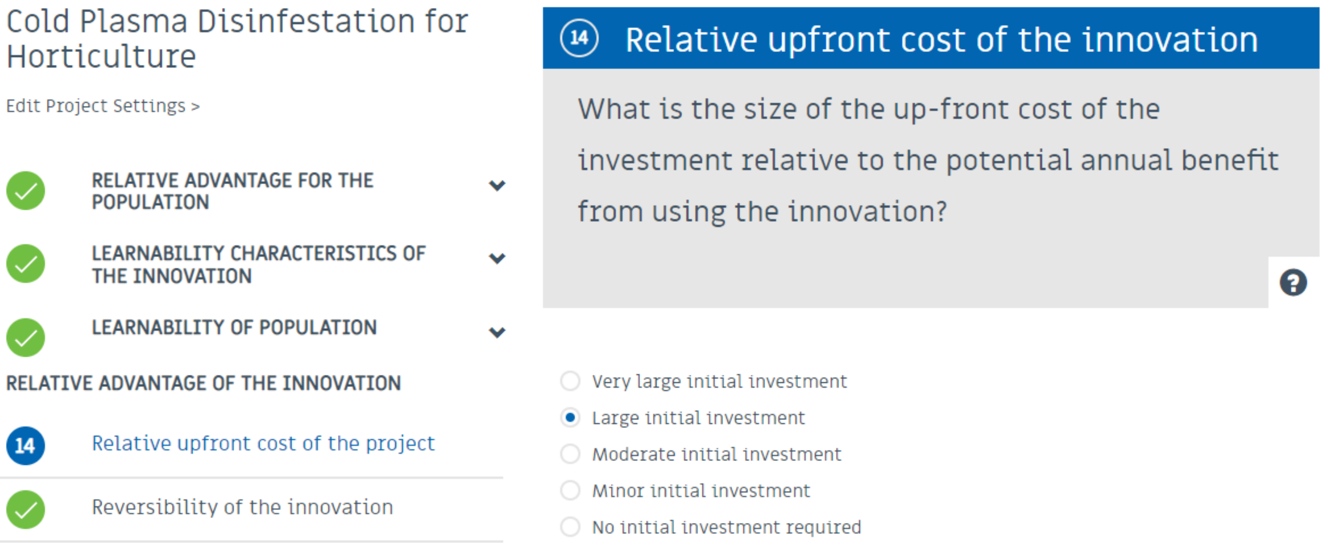
- ✓ Advisory support
- ✓ Group involvement
- ✓ Relevant existing skills & knowledge
- 13 Innovation awareness
- ✓ RELATIVE ADVANTAGE OF THE INNOVATION

⑬ Innovation awareness

What proportion of the target population would be aware of the use or trialing of the innovation in their district?

○ It has never been used or trialed in their district(s)
● A minority are aware that it has been used or trialed in their district
○ About half are aware that it has been used or trialed in their district
○ A majority are aware that it has been used or trialed in their district
○ Almost all are aware that it has been used or trialed in their district

What is your reasoning for this answer? (Optional)



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✓ LEARNABILITY OF POPULATION

RELATIVE ADVANTAGE OF THE INNOVATION

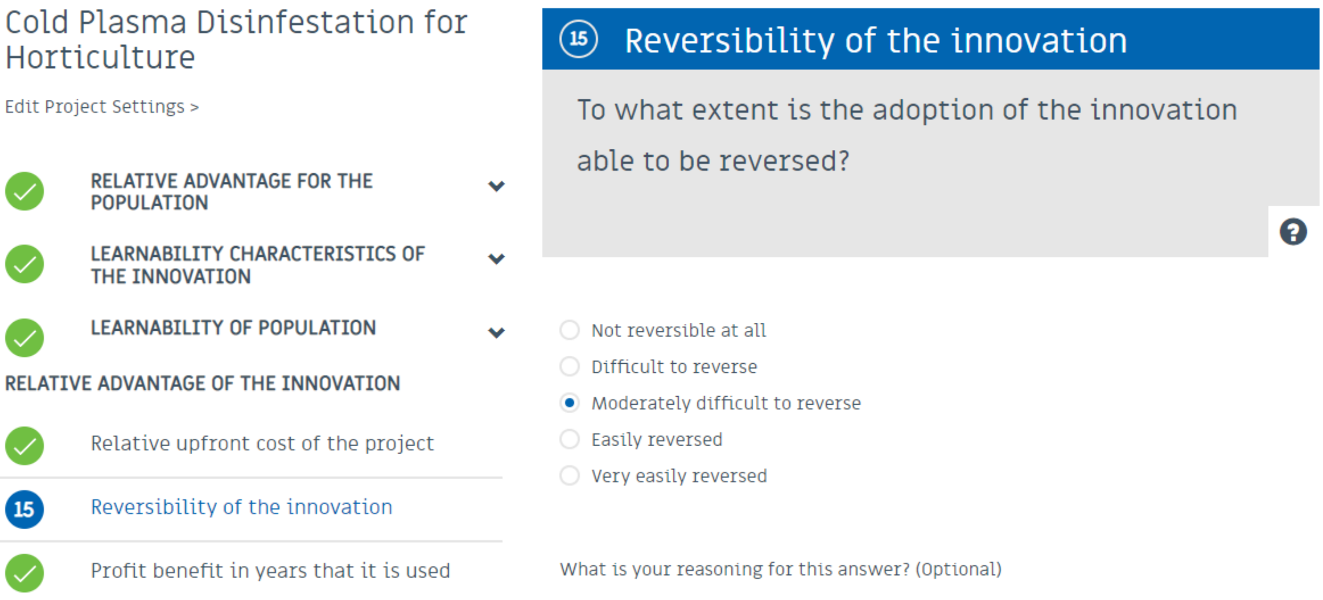
14 Relative upfront cost of the project

✓ Reversibility of the innovation

14 Relative upfront cost of the innovation

What is the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation?

○ Very large initial investment
● Large initial investment
○ Moderate initial investment
○ Minor initial investment
○ No initial investment required



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RELATIVE ADVANTAGE OF THE INNOVATION

✓ Relative upfront cost of the project

15 Reversibility of the innovation

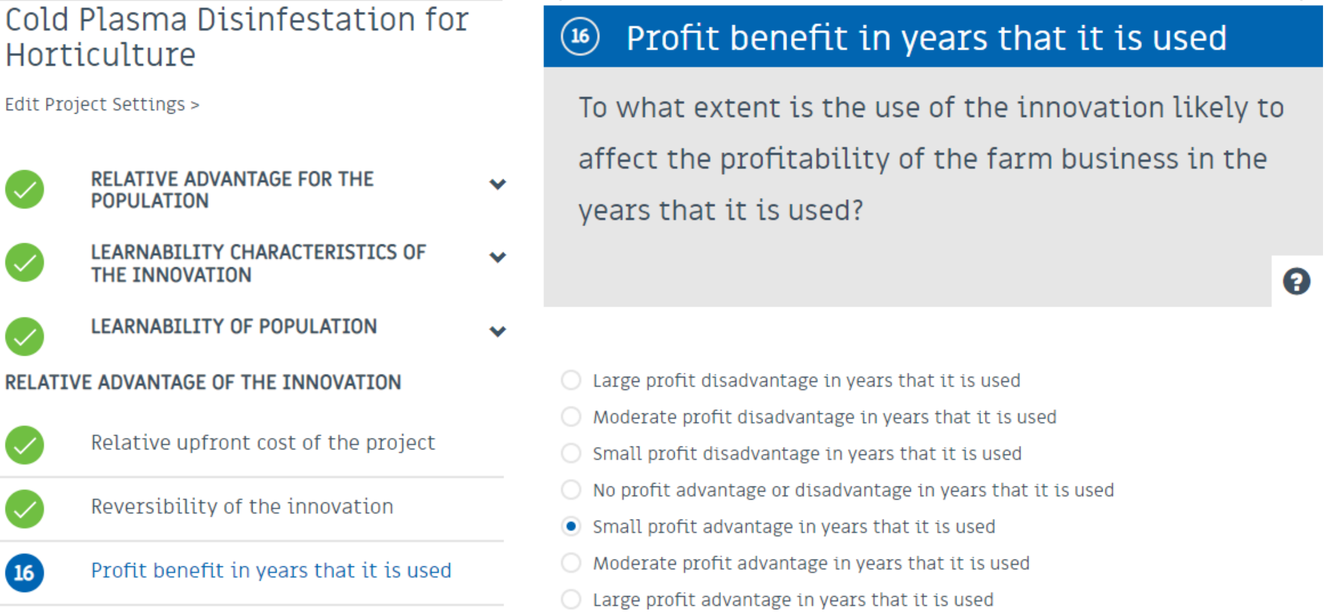
✓ Profit benefit in years that it is used

15 Reversibility of the innovation

To what extent is the adoption of the innovation able to be reversed?

○ Not reversible at all
○ Difficult to reverse
● Moderately difficult to reverse
○ Easily reversed
○ Very easily reversed

What is your reasoning for this answer? (Optional)



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✓ LEARNABILITY OF POPULATION

RELATIVE ADVANTAGE OF THE INNOVATION

✓ Relative upfront cost of the project

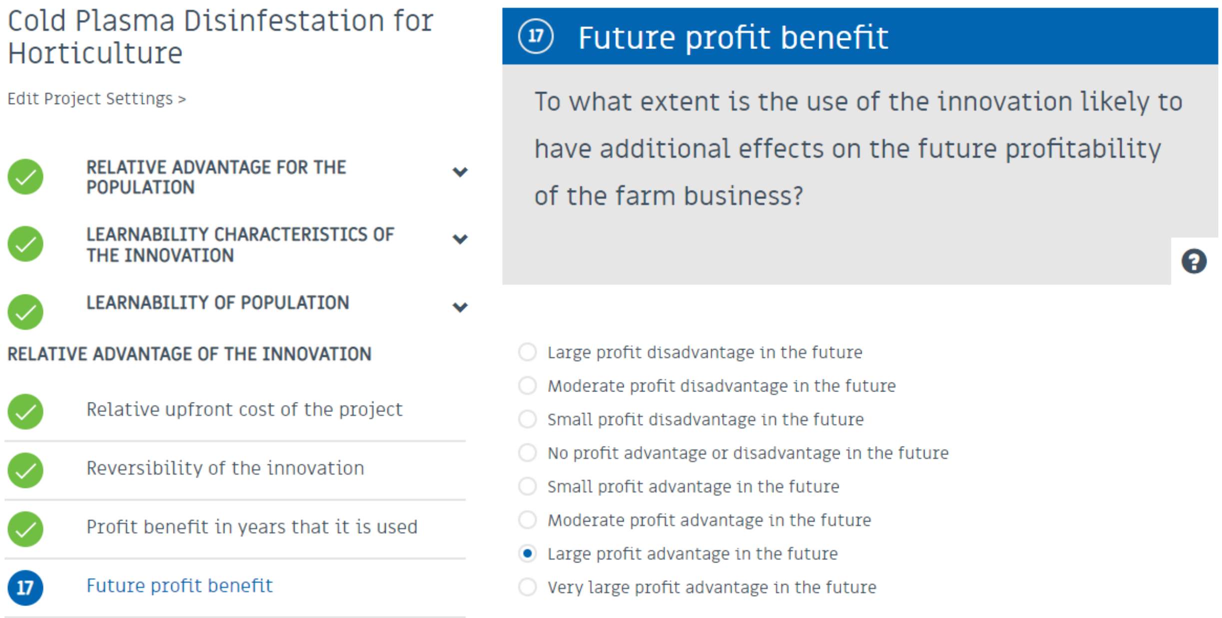
✓ Reversibility of the innovation

16 Profit benefit in years that it is used

16 Profit benefit in years that it is used

To what extent is the use of the innovation likely to affect the profitability of the farm business in the years that it is used?

○ Large profit disadvantage in years that it is used
○ Moderate profit disadvantage in years that it is used
○ Small profit disadvantage in years that it is used
○ No profit advantage or disadvantage in years that it is used
● Small profit advantage in years that it is used
○ Moderate profit advantage in years that it is used
○ Large profit advantage in years that it is used



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RELATIVE ADVANTAGE OF THE INNOVATION

✓ Relative upfront cost of the project

✓ Reversibility of the innovation

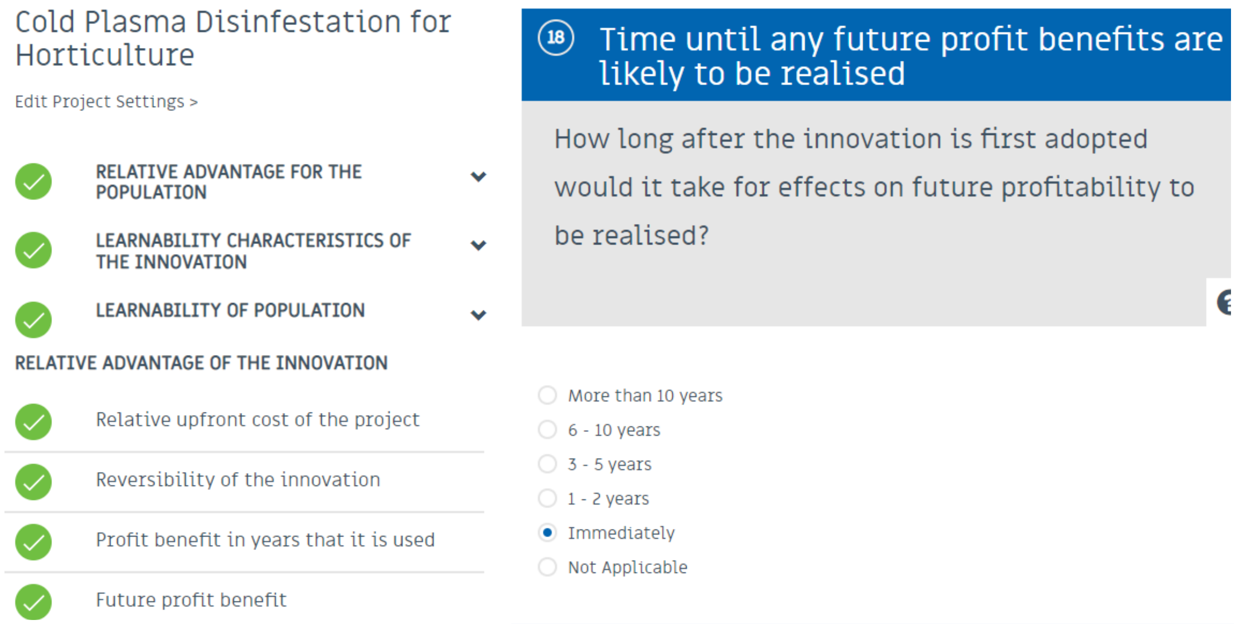
✓ Profit benefit in years that it is used

17 Future profit benefit

⑰ Future profit benefit

To what extent is the use of the innovation likely to have additional effects on the future profitability of the farm business?

○ Large profit disadvantage in the future
○ Moderate profit disadvantage in the future
○ Small profit disadvantage in the future
○ No profit advantage or disadvantage in the future
○ Small profit advantage in the future
○ Moderate profit advantage in the future
● Large profit advantage in the future
○ Very large profit advantage in the future



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✓ Relative upfront cost of the project

✓ Reversibility of the innovation

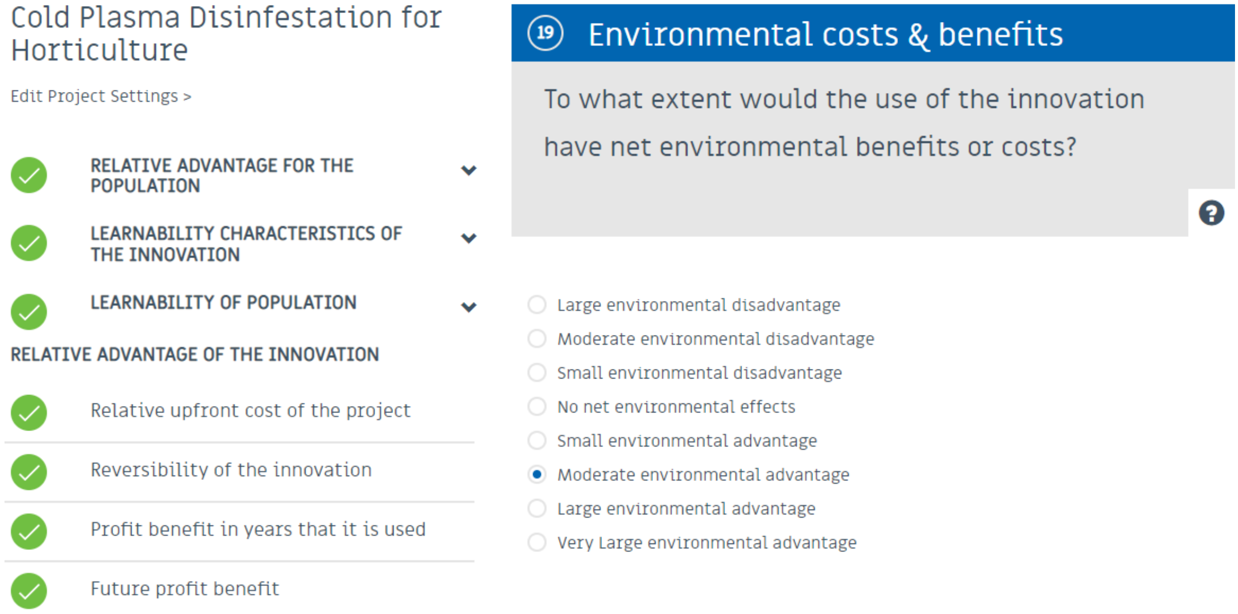
✓ Profit benefit in years that it is used

✓ Future profit benefit

⑱ Time until any future profit benefits are likely to be realised

How long after the innovation is first adopted would it take for effects on future profitability to be realised?

○ More than 10 years
○ 6 - 10 years
○ 3 - 5 years
○ 1 - 2 years
● Immediately
○ Not Applicable



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RELATIVE ADVANTAGE OF THE INNOVATION

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✓ Reversibility of the innovation

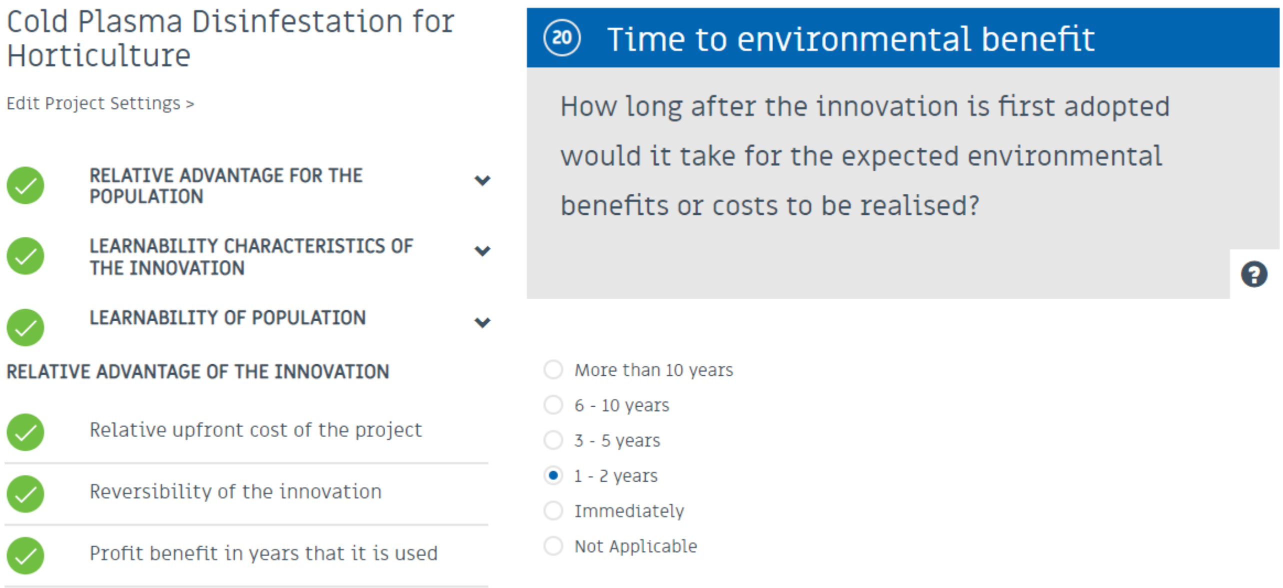
✓ Profit benefit in years that it is used

✓ Future profit benefit

⑲ Environmental costs & benefits

To what extent would the use of the innovation have net environmental benefits or costs?

○ Large environmental disadvantage
○ Moderate environmental disadvantage
○ Small environmental disadvantage
○ No net environmental effects
○ Small environmental advantage
● Moderate environmental advantage
○ Large environmental advantage
○ Very Large environmental advantage



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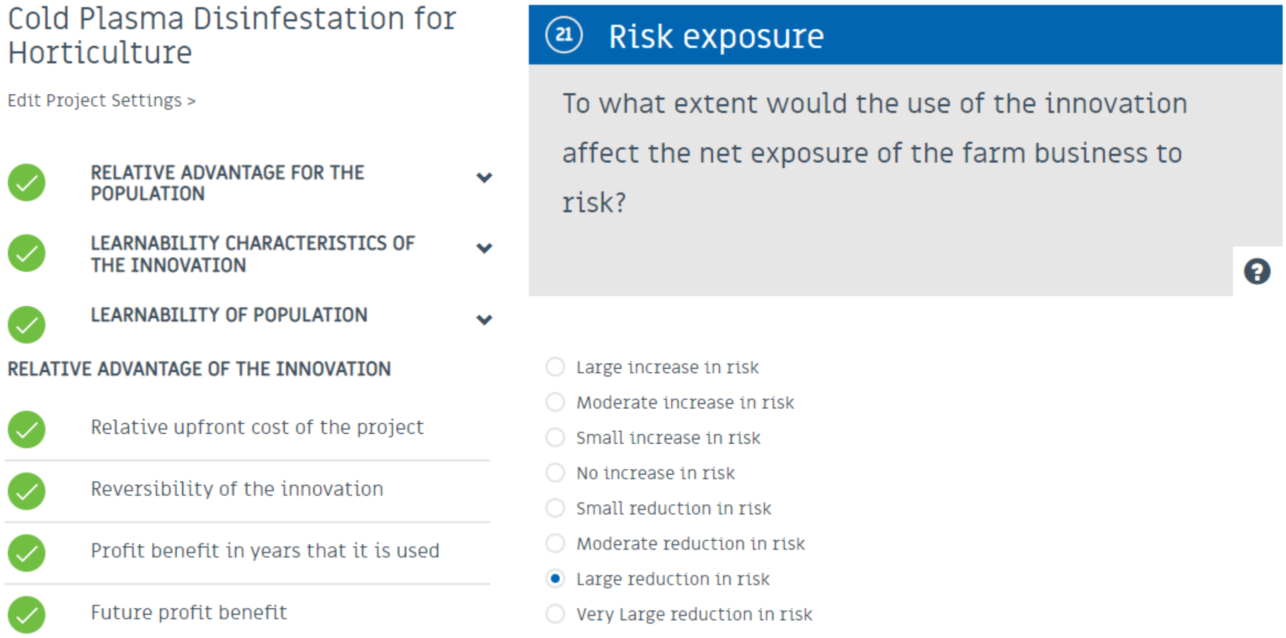
RELATIVE ADVANTAGE OF THE INNOVATION

- ✓ Relative upfront cost of the project
- ✓ Reversibility of the innovation
- ✓ Profit benefit in years that it is used

⑳ Time to environmental benefit

How long after the innovation is first adopted would it take for the expected environmental benefits or costs to be realised?

- ○ More than 10 years
- ○ 6 - 10 years
- ○ 3 - 5 years
- ● 1 - 2 years
- ○ Immediately
- ○ Not Applicable



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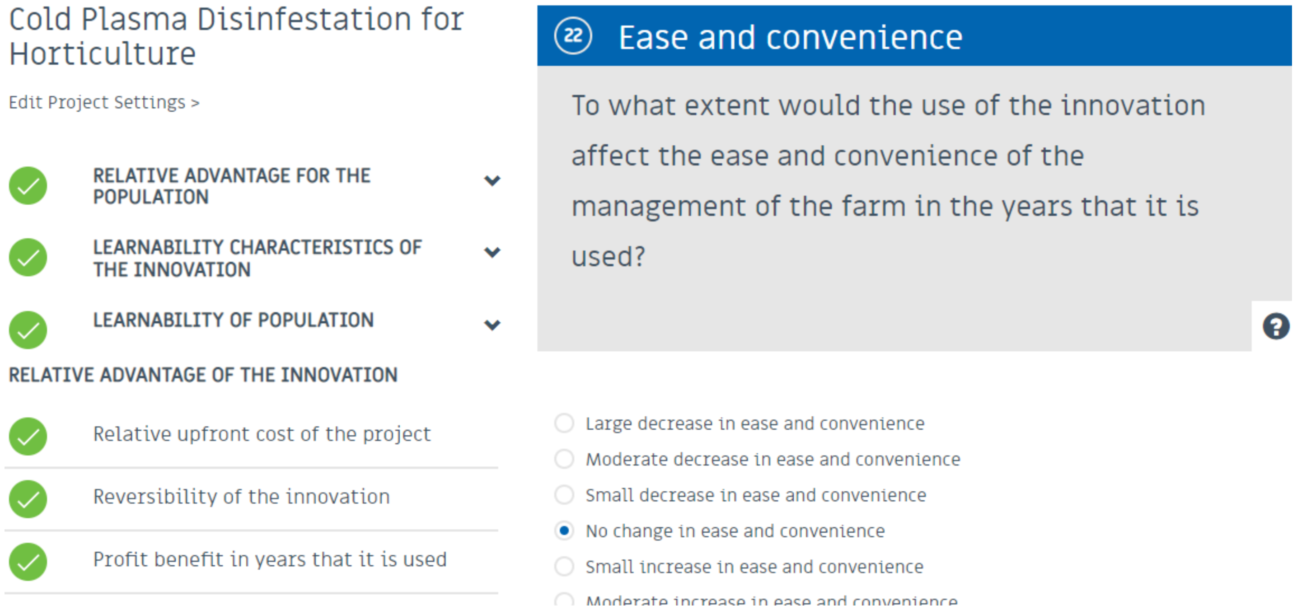
RELATIVE ADVANTAGE OF THE INNOVATION

- ✓ Relative upfront cost of the project
- ✓ Reversibility of the innovation
- ✓ Profit benefit in years that it is used
- ✓ Future profit benefit

㉑ Risk exposure

To what extent would the use of the innovation affect the net exposure of the farm business to risk?

- ○ Large increase in risk
- ○ Moderate increase in risk
- ○ Small increase in risk
- ○ No increase in risk
- ○ Small reduction in risk
- ○ Moderate reduction in risk
- ● Large reduction in risk
- ○ Very Large reduction in risk



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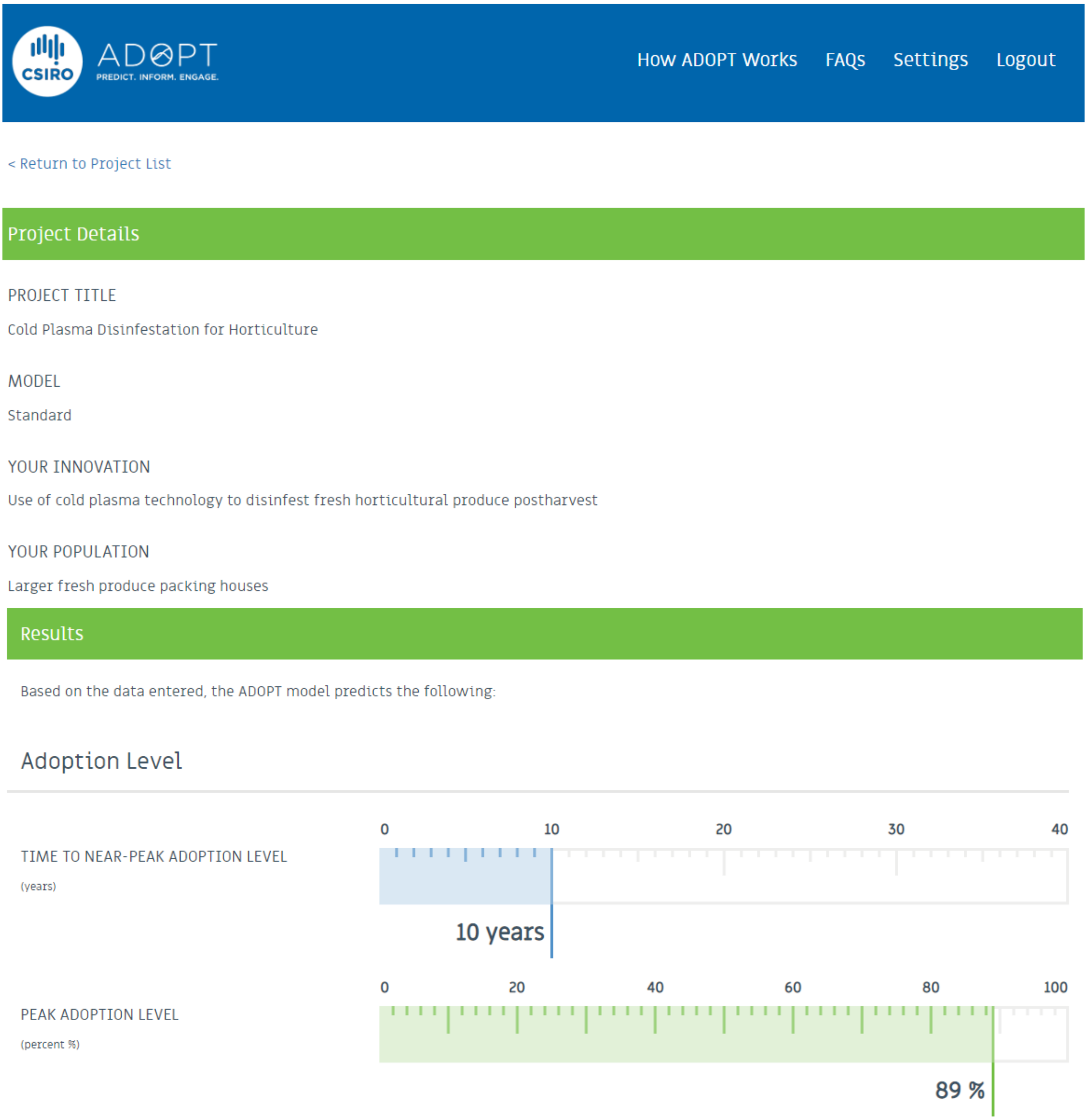
RELATIVE ADVANTAGE OF THE INNOVATION

- ✓ Relative upfront cost of the project
- ✓ Reversibility of the innovation
- ✓ Profit benefit in years that it is used

㉒ Ease and convenience

To what extent would the use of the innovation affect the ease and convenience of the management of the farm in the years that it is used?

- ○ Large decrease in ease and convenience
- ○ Moderate decrease in ease and convenience
- ○ Small decrease in ease and convenience
- ● No change in ease and convenience
- ○ Small increase in ease and convenience
- ○ Moderate increase in ease and convenience



Project Details

PROJECT TITLE

Cold Plasma Disinfestation for Horticulture

MODEL

Standard

YOUR INNOVATION

Use of cold plasma technology to disinfest fresh horticultural produce postharvest

YOUR POPULATION

Larger fresh produce packing houses

Results

Based on the data entered, the ADOPT model predicts the following:

Adoption Level

TIME TO NEAR-PEAK ADOPTION LEVEL (years): 10 years

PEAK ADOPTION LEVEL (percent %): 89 %