Hort Innovation

Final Report

National vegetable protected cropping centre

Project leader:

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Delivery partner:

Western Sydney University

Project code:

VG17003

Project:

National vegetable protected cropping centre (VG17003)

Disclaimer:

Funding statement:

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General project overview

In this project, Western Sydney University will address the jointly identified needs of the protected cropping sector by developing the newly completed glasshouse as the National Vegetable Protected Copping Centre for the next generation of protected cropping specialists. Blending research and training excellence, with access to a high-tech production system, offers opportunities for learning, training and education with broad possibilities for collaboration and industry engagement. The primary aim of the project will be to deliver vegetable protected cropping R&D through the proposed research Centre.

Summary

Research activities in the National Vegetable Protected Cropping Centre have fully utilized the facility capabilities over the period October 2019 to October 2020. Several experimental capsicum and eggplant crops have been grown to investigate the response of fruit crops to Smart Glass. Lettuce crops were also grown comparing the effect of Smart Glass and a new light shifting material (LLEAF) on leafy vegetable crops. The impact of SG and LLEAF was also trialed with cucumber cultivars. Pollination trials with the Australian native stingless bee species *Tetragonula carbonaria and T. hockingsi* have been conducted using strawberry crops to investigate crop yield, fruit size and quality. Stingless bees were introduced to capsicum crops to investigate pollination treatments on fruit yields. Initial trials were also started with flies as managed pollinators of strawberry crops.

Research activities in the Centre were negatively impacted by the COVID-19 pandemic during the period June 2021 to October 2021. Western Sydney University restricted access all its campuses from 5 July 2021 resulting in cessation of all research activities. The NVPCC facility was classified as essential WSU infrastructure requiring continued operational support for the facility; hence, the Facility Coordinator and Crop Manager continued to maintain and operate the facility. In addition, they assisted in essential maintenance of existing crops and continued to provide donations to Food Bank during the restricted access period.

Training activities continued with Protected Cropping courses developed and delivered in Autumn and Spring semesters during 2021. Although adversely affected by COVID-19, the Hort Innovation Emerging Leaders in Protected Cropping (LP18000) project delivered face to face workshops in April 2021 followed by online workshops in September 2021.

The Centre has hosted a number of school and industry engagement activities with visits and tours from industry stakeholders, research collaborators, government delegations, community groups, and importantly school groups through the Centre's training program up to June 2021. These engagement activities have highlighted the Centre's capabilities and capacity to investigate crop production under highly controlled environmental conditions, and to convey these ideas to a wide audience. Unfortunately, all visits to the facility were temporarily suspended from July 2021 due to COVID-19 restrictions.

The technical staff within the facility displayed extraordinary resilience during the WSU shutdown period. The stoppage of many research activities required them to prioritize essential facility operations and crop management, and assist with data collection for ongoing essential research elements. The Centre continued to donate significantly to Food Bank with marketable quality crops of capsicum, chilies, cucumber and eggplant harvested and packed for delivery by the technical staff.

Achievements

Outstanding Milestone 105 Achievements

MA4. Submit a succession plan to PRG for recommendation.

The succession plan (Appendix 1) was circulated and approved by the PRG on 2nd September 2021**.**

The translation plan (Appendix 2) was circulated to the PRG on 2nd September 2021, requested updates were made, and the translation plan was re-circulated, with the request that further feedback be received by the 19th October 2021. No further PRG feedback was received and therefore, the NVPCC translation plan (Appendix 2) was subsequently endorsed and approved.

Milestone 105 is achieved.

Outstanding Milestone 106 and 107 Achievements

MA3. Report on implementation of the succession plan in stages.

Details on current investments are provided below. The phasing of each investment is described in the succession plan (see Appendix 1) and action plan (Appendix 3). Each program was discussed in detail in the PRG meeting (see NVPCC PRG meeting minutes- Appendix 4 for discussion points).

1. CRC FFS funded acoustic pollination – Partners are Perfection Fresh, WSU, UNSW – using sound to induce pollination.
2. CRC funded LLEAF- testing of light shifting film with WSU and Sydney start-up company (LLEAF) – films also tested on berries in poly-tunnels in regional NSW.
3. CRC funded Internet of Things -IoT- Highly automated technological approach to monitoring & controlling the environment – 1.5 years into project. Partners are WBS, WSU and UNSW
4. CRC funded project in robotic pollination methods – QUT; eventually will be tested in glasshouse.
5. CRC funded Integrated disease management in broccolini- Partners are Perfection Fresh and WSU.
6. Hort Innovation funded - Emerging leaders in protected cropping. Education and training program that has been used to develop new courses at WSU. Difficult due to COVID, but still functioning via Zoom. Tertiary pathway in protected cropping.
7. Hort Innovation funded – Projects on stingless bees, blue banded bees, and flies for improving pollination efficiency in protected cropping.

Milestone 109 Achievements

MA1. Annual report submitted detailing research outputs and communication progress.

MA2. Information on shortlisted programs for the next cycle.

Shortlisted/Proposed programmes & partnerships for next cycle:

1. Testing automated pollination strategies against other pollination systems is in the pipeline.
2. CRC Foundation project – Hort Innovation, Rijk Zwaan, WSU & QUT.

Proposed project objectives for the CRC Foundation program:

- Develop and trial energy efficient new version of smart glass for protected cropping industry.
- Smart crops to develop nutritious varieties compatible with automated systems and robotic harvesting.
- Precision pollination - test and compare pollination effectiveness between native bees, drones, and other artificial pollinators, reducing labour costs.
- Automated crop management - using high tech control systems and sensors through the internet of things approach.
- Integrated pest & disease management -test novel technologies to reduce energy use and increase profitability. Important component of disseminating trained workers to industry.

Other projects submitted for funding from ARC:

- ARC Hub and Linkage projects developing next generation smart film. Interfocus Photonics, Swinburne, WSU – detailed analyses of HIA funded Smart Glass project results led to the development of this project to produce new films that allow more light to enter the glasshouse to increase productivity, while still retaining the heat blocking traits (see succession & translation plan). Testing all done in Australia, using new technology to design films, will be much cheaper and easier to apply.
- Linkage project in AI and ML techniques for studying pollinator efficiencies. Partners are Costa farms, WSU and Monash University.

MA3. PRG meeting with Hort Innovation was held on 25th February 2021 and 2nd September 2021. Please refer to Appendix 4 -PRG minutes for details on attendees, discussions, and approvals. PRG members discussed in detail the industry research gaps, importance of ongoing projects, individual project outputs, technology translation mechanisms and identified programs for the next cycle succession plan. The succession and translation plans have been updated accordingly and attached (Appendices 1 and 2).

MA4. Update M and E plan accordingly. The M and E plan is attached (see Appendix 6). M and E for identified projects will be updated and submitted along with the milestones of the respective programs.

Outputs

- The facility was visited by many groups since October 2020 (shown below), representing stakeholders spanning industry and other interest groups.
- COVID-19 restrictions at WSU required the Centre to temporally close to all visitors from July to October 2021.

Month	Organisation
October 2020	• Four representatives from Landcom visited with Ian Anderson on 16th October. • Alex Soeriyadi of LLEAF visited with 4 media students on the 30th October.
November 2020	• Robert Mullin from Syngenta visited 20th November to discuss lettuce crop and Smartglass project.
December 2020	• No engagements occurred for December 2020.
January 2021	• No engagements occurred for January 2021.
February 2021	• Kris Beazley, Principal of the Centre of Excellence in Agricultural Education -Richmond Agricultural College came with 5 students from Bomaderry Highschool to tour the facility on February 19th.
March 2021	• Freelance reporter Alexandra Morris and freelance photographer Zoe Lonegran visited to write article about the NVPCC.
April 2021	• Engagement (20th April) UWS Alumni from the Commonwealth Bank Specialised Agri Business Solutions team (30) toured the NVPCC, learning of current projects and possibilities of the Centre. • NVPCC hosted 50 students and teachers from the Kings School NSW in April 2021.
May 2021	• Alexandra Morris (freelance writer) and Zoe Lonergan (freelance photographer) visited again to interview Dr Michelle Mak and Dr Sunil Panchal for future article. • Marcus Van Heijst from Priva visited to discuss the integration of two new Priva functions: Workload monitoring and data storage on the cloud for easier access. • Simon Holloway from Vegepod, professional colleague of David Thompson visited. • Two representatives from LLEAF and two representatives from Australian Vanilla Plantations visited. • Eireanne Feeney from Catholic Education Diocese of Parramatta visited (she is a past student).
June 2021	• Bruce Cairns from AgriPower visited with Dr. Zhonghua Chen. • Group of 20 undergraduate students from Microbiology class visited the glasshouse with Instructors Michelle Moffitt and Oula Ghannoum. • Demi and Brad Sargent from CSIRO visited the glasshouse - Demi is a new postdoc with Rob Sharwood and David Tissue.
July 2021	• No visitors through the month of July because of COVID lockdown.
August 2021	• No visitors through the month of August because of COVID lockdown.
September 2021	• No visitors through the month of September because of COVID lockdown.

Refereed scientific publications

- Zhao, C**.,** Chavan, S., He, X., Zhou, M., Cazzonelli, C. I., Chen, Z.-H., Tissue, D. T., & Ghannoum, O. (2021). Smart Glass Impacts Stomatal Sensitivity of Greenhouse Capsicum Through Altered Light. *Journal of Experimental Botany*, erab028. https://doi.org/10.1093/jxb/erab028
- He, Xin, Chelsea Maier, Sachin G. Chavan, Chen-Chen Zhao, Yagiz Alagoz, Christopher Cazzonelli, Oula Ghannoum, David T. Tissue, and Zhong-Hua Chen. 2021. "Light-Altering Cover Materials and Sustainable Greenhouse Production of Vegetables: A Review." Plant Growth Regulation. doi: 10.1007/s10725-021-00723-7.
- Samaranayake, Premaratne, Chelsea Maier, Sachin Chavan, Weiguang Liang, Zhong-Hua Chen, David T. Tissue, and Yi-Chen Lan. 2021. "Energy Minimisation in a Protected Cropping Facility Using Multi-Temperature Acquisition Points and Control of Ventilation Settings." Energies 14(19):6014. doi: 10.3390/en14196014.

Outcomes

Broad Outcome:
Increased awareness on state-of-the-art vegetable protected-cropping production practices and technologies.
Continued employment of dedicated technical staff to ensure continuous operation of the NVPCC.

Smart Glass Project:

Fruit crop trials under SG: We conducted replicate trials on eggplant (published in *Food and Energy Security* journal, Chavan et al., 2020) and capsicum under Smart Glass (SG) to investigate the mechanism of SG impact on light, growth and productivity. In the second capsicum experiment, we also tested the effect of eCO_2 on physiological and growth response to SG.

SG saves energy required for cooling, water and nutrient use by blocking UV and light wavelengths > 700 nm, which contribute to heat generation. However, higher reduction of light under SG may reduce productivity. In one capsicum experiment there was no effect of SG on yield, but the replicate experiment exhibited a yield reduction in capsicum. The variable response of yield is associated with the seasonal variation in light transmission under SG.

In capsicum, stomatal responses to SG were affected by changes in light intensity rather than spectral quality, which was published in the *Journal Experimental Botany* (Zhao et al., 2021). Key findings for fruit quality (under review in *Postharvest Biology and Technology*) indicate that the effect of SG-altered light environment on postharvest traits is cultivar-specific, and changes in fruit development, morphology, colour, Brix, and shelf life remained within an acceptable range for commercial use. The decreased cuticle thickness and ascorbic acid levels in SG did not affect postharvest traits, and unlikely affected marketability or consumer preference. In conclusion, SG does have a subtle effect on specific biochemical traits in a cultivar specific manner.

In capsicum, SG and eCO_2 both reduced stomatal size and increased water loss in leaves in the red cultivar. However, only eCO_2 reduced stomatal size and increased water loss in leaves for orange cultivar. SG and eCO_2 both reduced stomatal density in orange cultivar, but eCO_2 increased stomatal density in red cultivar. We continue to analyse data and will write manuscripts detailing the impact of eCO_2 on physiology, yield and fruit quality.

Leafy vegetable crop trials under SG and new cover material luminescent light emitting agricultural film (LLEAF): First leafy vegetable crop trial under SG was conducted from November 2020 to May 2021 using three lettuce cultivars for three experiments. Colour, morphology, photosynthesis and yield parameters were measured during all three experiments. Colour was measured using a colorimeter at three canopy positions, including top, middle and bottom. Lightness parameter (L*) measured by colour varied with time and was significantly affected by SG. All cultivars showed highest lightness values at the end of third week and plants under SG showed significantly higher lightness values relative to control. Chroma value calculated using a* associated with red (+) and green (-) colour and b* associated with yellow (+) and blue (-) colour showed significant changes in response to SG and the differences were highest towards the end of growth period. Photosynthetic parameters measured using portable handheld device PhotosynQ showed significant increase in quantum yield of photosystem II (Phi2) and significant decrease in non-photochemical quenching (NPQ) under SG

relative to Control.

In the first lettuce experiment, SG significantly decreased the plant fresh weight only in green cos (13.5 %, $p < 0.001$). SG significantly decreased leaf number in green cos (10%, $p < 0.001$) and red cos (12%, $p = 0.001$) but not in butter head. In addition, SG slightly increased leaf water content in two of the three varieties.

During second lettuce trial, LLEAF was installed one week after transplanting lettuce. LLEAF shifted green light wavelengths to red which are more efficiently used by the plants for photosynthesis. The second and third lettuce experiments were conducted using SG and LLEAF. During second lettuce experiment, SG decreased the plant fresh weight in butter head (11%, $p = 0.002$) and Green cos (15%, $p < 0.001$), but LLEAF did not significantly affect the plant fresh weight. Interestingly, during third lettuce experiment SG did not affect plant fresh weight in the three cultivars, but LLEAF increased plant fresh weight only in butter head (27%) and Green cos (14%). Data collection from stored samples and analysis for lettuce experiments is underway.

Fruit crop trials under SG and LLEAF: Currently we are investigating the impact of SG and new cover material LLEAF on two cucumber cultivars (Lebanese and Continental). Because of the strict lockdown in greater Sydney, we could only measure basic crop traits like bud, flower fruit number and yield. We are planning to collect samples and more data once the campus is accessible in November (2021).

Overall Smart Glass project summary

Smart Glass (SG) trials were conducted for eggplant and capsicum in differential light conditions to understand the impact of seasonal light variation under SG on plant growth and productivity.

SG reduces yield more during high light conditions by reducing light available for photosynthesis without changing fruit quality.

Elevated CO_2 interaction with SG in capsicum will provide insights to understand impact of light changes on plant biochemistry and physiology.

Leafy vegetable crop lettuce response to SG varies according to the cultivar, growth season and SG significantly affects the color pigments.

New light shifting cover material LLEAF does not reduce the useful light, and effects of LLEAF on crop yield depends on season and cultivar.

Future Work

We need to trial another climbing vine (cucumber) to assess the effects of SG and LLEAF on the harvestable material (i.e. leaf or fruit) to confirm our findings for a range of vegetables.

Our goal is to find the least expensive glasshouse covering material that can generate the greatest benefit to fruit production and reduce energy, water and nutrient use without losses in fruit quality and nutritional value.

Pollination Program:

Glasshouse pollination – strawberry trials research update

We have completed a second glasshouse experiment to detail the effectiveness of *Tetragonula* stingless bees in improving the yield and especially the quality of strawberry fruits. Due to the relatively short flowering period of the crop in this second trial (we used a different plantlet supplier and received the last seasonal batch of plantlets), we focused this experiment on *T. hockingsi*, which was a slightly better pollinator than *T. carbonaria* in our first trial, although both were good. As in the first experiment, we used the following pollination treatments: 1) open pollination treatment (OP) where the strawberry flowers were accessible for unlimited stingless bee visits; 2) bagged pollination treatment (BP) where bees were prevented from visiting strawberry flowers; 3) hand-pollination treatment (HP) where the flowers were pollinated manually; 4) controlled, multiple visit treatments where the bees were allowed to visit the flowers for a specified number of times: one visit (1V), two visits (2V), five visits (5V), ten visits (10V), fifteen visits (15V), and twenty-five visits (25V). The last treatment was new to this experiment and was introduced to test the hypothesis that very high visitation may reduce fruit quality due to stigma damage.

Using the previous grading metrics, we found that fruit quality (grade extra and grade A) in fruits developing

from flowers with 10 or more bee visits was as good as fruits derived from hand pollination. Additionally, we counted the number of achenes (seeds) for each harvested fruit and found a strong positive correlation between fruit weight and the number of seeds [p<2.2e- 16, R=0.75] (Figure 3) and therefore between fruit weight and pollination intensity. We compared fruit weight between all treatments using analysis of covariance. We used seed number as a covariate because of the above-mentioned effect of seed number on fruit weight. After correcting for the number of seeds (a surrogate for the flower size), fruit size increased with number of bee visits up to 5 bee visits, but was not further improved by more bee visits, open pollination or hand pollination. We next assessed the effect of the different treatments on the total soluble solids (TSS, a measure of the sweetness) of the strawberry fruits, finding that TSS was significantly higher only in five visit and hand pollination treatments.

Recent stingless bee work, including COVID-19 impacts

In early June 2021, we introduced 3 stingless bee colonies to the education chamber in S40, where there are experiments on capsicum varieties grown under different conditions. We began assessing differences between bagged flowers (pollinator exclusion), open flowers (full pollinator access) and hand-pollinated treatments. We planned to assess fruit development, weight, number of seeds and Capsaicin levels. In addition, students began videoing the behaviour of bees on flowers and activity at the hive entrance, as well as recording mortality post-introduction to the facility, as bees learn to orient and navigate. However, due to the COVID-19 outbreak, the S40 glasshouse had to be closed to researchers in July, with activities retracting to crop and glasshouse maintenance by the core technical team. This has prevented any further experimental work on the pollination of the crops being grown from July onwards, but the technical team has maintained the crops successfully throughout the wider close down. In addition, we reintroduced hives of stingless bees to the chambers containing strawberries. While pollination experiments have not been possible since July, our first two trials had already shown the stingless bees to be good pollinators of strawberry and introduction of non-experimental hives has ensured good fruit production

Flies as managed pollinators, including COVID-19 impacts

Pollinating flies also made a recent appearance at the NVPCC. Flies have several significant differences from honeybees as managed pollinators, including being cheap to rear and ship and not exhibiting aggressive defensive behaviors. Flies can also carry and deliver large quantities of pollen. We are currently researching the potential use of flies as glasshouse pollinators as part of the **Flies as managed pollinators project (PH16002).** Two species of fly (*Calliphora stygia* and *Eristalis tenax)* are being trialed as glasshouse pollinators**,** using strawberry as a model crop**.** An initial trial of *C. styia* in the NVPCC was promising, with many fly pollinated fruits being of equal weight and quality to hand pollinated fruits. Furthermore, the flies seemed to cope well in glasshouse conditions with low levels of mortality. We planned to upscale the fly pollination trials in mid-2021 and potentially do a direct comparison between fly and stingless pollination of strawberry under glasshouse conditions. We established a good strawberry crop in two chambers but, unfortunately, the COVID-19 outbreak forced suspension of new experiments from July onwards. The glasshouse remains closed to researchers, but we expect to regain access in November. At this point, if the crop continues to flower well, we hope to resume fly pollination trials until mid-December. We also plan to again use 2 chambers for fly pollination trials in 2022 and will establish a new crop when the seasonally produced plantlets are available from commercial suppliers in March/April. **Blue-banded bees plans**

In June 2021 we signed a contract for a new project (PH19001) on "Development of Blue-banded bees (BBBs) as managed buzz pollinators". Importantly, BBBs are buzz pollinators and many plants including solanaceous crops require buzz pollinators to release pollen from their anthers and effect pollination. Honeybees and stingless bees are not buzz pollinators, so bumble bees are often used as managed buzz pollinators in protected cropping. However, Australia has no native bumble bees and introducing them would pose biosecurity and conservation risks. Hence, PH19001 will research the feasibility of using native BBBs as commercial glasshouse pollinators and explore the range of crops that they pollinate effectively. The first (current) phase of the project involves establishment of a captive population of the bees from wild-collected insects, and investigation of the nesting materials and diet required to keep them healthy and reproducing. Following this, we expect to move to glasshouse trails of their foraging behaviour and pollination efficiency in 2022.

Training Program:

Emerging Leaders in Protected Cropping (LP18000)

1. Development of the Protected Cropping courses completed and delivered in Autumn and Spring 2021.

2. A total of 39 students have been enrolled across three courses (up to the 30 June 2021): Graduate Certificate in Protected Cropping, Graduate Diploma in Protected Cropping, and Master of Science (Greenhouse Horticulture). All courses utilize the protected cropping specific units, which have been created from the Emerging Leaders in Protected Cropping project.
3. However, our promotional activities to entice students has been hampered due to the Covid-19 travel restrictions and border closures, which has generated a reluctance by some prospective students to enroll in the course. Although adversely affected by COVID-19, some remarkable achievements have been achieved during the reporting period. To date we have completed the following tasks for the Emerging Leaders in Protected Cropping (LP18000):
    - Delivery of two online workshops in the Spring Semester (September 2021) following on from two face to face workshops delivered in the Autumn semester (April 2021).
    - Scholarship awards to students who need funding to support their study.
4. Our teaching team has grown in the second teaching session and continues to work collaboratively to develop and deliver a complete postgraduate offering with flexible options for studying, work integrated learning opportunities, hand-on best practice skills building and avenues for continuing onto higher levels of education, if desired. WSU has also employed two new positions which will teach into these units, one lecturer and one senior lecturer, who bring a wealth of new expertise to our team and enrich the learning and applicability for students. To further support student networking and career success, we have engaged additional industry experts through the second delivery of workshops, taking our students industry exposure from seven in the first half to eleven by the end of the first year.
5. Two Project Reference Group (PRG) meetings were successfully hosted by WSU.

School and industry engagement

1. NVPCC hosted 50 students and teachers from the Kings School NSW in April 2021.
2. The NVPCC Education Team delivered an online lecture to potential future students at Flavorite VIC in March 2021.
3. The education team received an Award of Merit for their contribution to Australian horticultural education and training. The ceremony was hosted by the Australian Institute of Horticulture in Sydney on 16 April 2021.
4. Significant course promotion through industry publications, targeted emails to allied industry companies and growers and follow-up (email and phone calls) of prospective students identified through these processes.
5. Additionally, we have circulated information to other tertiary institutions to attempt to capture their new graduates.
6. The NVPCC is scheduled to host the Masterclass in Protected Cropping by Graeme Smith (Former Chair of Protected Cropping Australia) in November.

Intellectual property, commercialisation and confidentiality

No project IP, project outputs, commercialisation or confidentiality issues to report.

Issues and risks

Project Risk Register has been circulated and approved in the PRG meeting held on 2nd September 2021 (see appendix 5).

Other information

Research articles being prepared based on data generated from Centre research crops include:

- Xin He, Sachin G. Chavan, Ziad Hamoui, Chelsea Maier, Oula Ghannoum, Zhong-Hua Chen, David T. Tissue, Christopher I. Cazzonelli. *"An energy saving smart glasshouse film reduces ascorbic acid and does not impact postharvest shelf-life quality in red or orange capsicum cultivars. In review "Postharvest Biology and Technology".*

- Chavan, S.G., Cazzonelli, C.I., Chen, Z., Ghannoum, O., Tissue, D. *"Current Technologies and Target Crops in Protected Cropping"* (Review). (In preparation).

- Chavan, S.G., Xin He, Maier, C., Alagoz, Y., Cazzonelli, C.I., Chen, Z., Ghannoum, O., Tissue, D. “Seasonal light variation under energy saving Smart Glass affects capsicum growth, photosynthesis and yield”. (In preparation).

- Chavan, S.G., Zhao, C; Vandegeer, R; Maier, C., Cazzonelli, C.I., Chen, Z., Ghannoum, O., Tissue, D. “Interactive effects of elevated CO_2 and Smart Glass on Capsicum growth, photosynthesis, yield, fruit quality and resource use”. (In preparation).

- Samaranayake P, W Liang, ZH Chen, DT Tissue and YC Lan. Sustainable protected cropping in Australia: energy consumption and crop yield analyses of greenhouse capsicum production. (in preparation).

- Terry Lin, Mark Goldsworthy, Sachin Chavan, Weiguang Liang, Chelsea Maier, David Tissue, Yi-Chen Lan, Subbu Sethuvenkatraman, Zhong-Hua Chen. A Novel Cover Material Improves Cooling Energy and Fertigation Efficiency for Greenhouse Eggplant Production. (in preparation).

Appendices:

Appendix 1: NVPCC Succession Plan

Appendix 2: NVPCC Translational Plan

Appendix 3: NVPCC Action Plan

Appendix 4: NVPCC PRG minutes (Feb 2020 meeting and Sep 2021 meeting)

Appendix 5: NVPCC Risk register

Appendix 6: NVPCC M&E plan and program logic.

Appendix 1: NVPCC Succession Plan

Table 1: Proposed Succession Plan (projects beginning in 2016 and ending in 2030)

	Name	Funding agencies and Project values	2016 - 2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Translational Model Will be tailored to each project as per the proposed plan
Proposed Investments at NVPCC **Partners and Budgets to be confirmed** **Potential Funding and collaborating agencies-** WSU Hort Innovation CRC & partners Rijk Zwaan Syngenta Perfection Fresh Phillips Lighting Costa Flavorite Australian Fresh Green Camel PRIVA Bosch BASF Aldi Woolworths	Affordable smart & automated technology to monitor and control crop production, quality and health													Steering committee, Co-designing trials Industry presentations Industry Newsletters
	Adopt and standardise energy efficiency growing strategy for improving productivity													Steering committee, Co-designing trials Industry presentations Industry Newsletters
	Develop novel integrated pest and disease management strategies suitable for crop production under protected cropping													Steering committee, Co-designing trials Industry presentations Industry Newsletters Conducting on farm trials
	Test and breed suitable nutritious crop varieties for automation													Steering committee, Co-designing trials Industry presentations Industry Newsletters Conducting on farm trials

	Improved pollination strategies													Steering committee, Co-designing trials Industry presentations Industry Newsletters
	Continued program on skill development													Industry training, Student internships
Current Investment														
	Name	**Funding agencies & Project values**	**2016 - 2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	
Current Investment	PH19001 Development of Blue-banded bees as managed buzz pollinators	WSU-$4.27M PFR-$1.16M Hort Innovation-$2.15M												Steering Committee, Masterclass, Industry workshops, Field days, Multimedia, Industry presentations Industry Newsletters
	PH16002 Managing flies for crop pollination	WSU-$1.9M Hort Innovation-$538K					Improved pollination strategies- To be continued with funding from CRC, Hort Innovation and partners like Perfection Fresh, Green Camel etc.							Steering Committee, Masterclass, Master farms, Industry workshops, Field day, Multimedia, Industry presentations Industry Newsletters

	P2-013 Smart Glass film impacts on energy and productivity in greenhouse lettuce	WSU - $200K Commonwe-alth (CRC) and Lleaf Pty Ltd- $40K			Projects on energy saving mechanisms, e.g., photovoltaics to be continued with funding from CRC, WSU and partners.			Steering Committee, Industry workshops, Field days, Industry presentations Industry Newsletters
	VG 16070 Research and Operations to trial Innovative glass technology	Hort Innovation- $799K			Project already extended with funding from CRC and Lleaf Pty Ltd. To be continued with funding from CRC and other industry partners.			Steering Committee, Industry workshops, Field days, Industry presentations Industry Newsletters
	LP18000 Emerging Leaders in Protected Cropping	WSU-$748K Hort Innovation- $698K Other partners- 552K				Project to be continued with funding from WSU and industry partners. Continued funding will involve programs in Master of Science in protected cropping for training next generation professionals and Graduate Diploma for training industry professionals.		In house training of industry professionals
	VG 17003- National vegetable Protected Cropping Centre WSU-$3.5M (Towards Construction)	Hort Innovation- $3M			Facility operational costs funded through individual projects with continued funding from WSU to support the facility manager and coordinator.			

Appendix 2: NVPCC Translational Plan

NVPCC RESEARCH PROJECTS- TRANSLATION PLAN

The drivers of research transformation in protected cropping are multidimensional, interrelated, and can change over time with novel research outcomes. The readiness and success of any research transformation strategy will therefore depend on the flexibility of the translational framework to address prioritised and different requirements of the participating industries. The NVPCC translation plan has been drafted considering the importance of bespoke delivery and governing mechanisms for selected industries. We propose to adopt the framework given below to influence the likelihood of accelerating industry transformation resulting in on-the-ground impact. The proposed framework has been tested successfully for rolling out research, extension and translation program in pollination (see details- Appendix 1).

Stage 1: Research Knowledge User Groups/Target Audiences **Need and Suitability Assessment**	**Stage 2:Involvement of Research Users in the Project** **Define Governance Model**	**Stage 3: Implementation, Evaluation, Knowledge Translation** (forms and types of communication) and **Feedback Model**	**Stage 4: Explain how Users will Benefit from the Research** **Impact**
Activities: **Need Assessment:** Defining research questions, knowledge gaps, constraints, and potential solutions. **Suitability Assessment-** The research is important to industry XXX and possible solutions to test are YYY. **Stage 1 output:** Trial objectives confirmed with industry partner**.** **Stage 1 outcome:** Industry XXX has identified the need for project and are a part of the broader research team	**Activities:** **Planning of program:** Develop a governance structure. Conduct research (participatory). **Stage 2 output:** **Design and implement the trial** Trial design developed with partners. Roles and responsibilities of each collaborating partner assigned**.** **Stage 2 outcome:** The users involved in the planning and implementation of the project right from the beginning. On farm trials to initiate in parallel with research program.	**Activities:** **M&E and Communication Strategy:** M&E will be undertaken during the program. **Stage 3 output:** **Communication channel established** Knowledge transfer through information exchange meetings, workshops, presentations and Q&A, publications in plain language and participation in theme-based research highlight days` etc. **Stage 3 Outcome:** Collaborative trials planned and tested in commercial facilities	**Activities accomplished will include:** Actions taken or work performed through identified inputs, technical assistance and other types of resources are mobilised with the intention of achieving specific outputs (e.g. technology development, education, engagement). **Stage 4 outputs will include:** Research solutions, services, and/or capacities that result from the completion of activities within a research portfolio or project (e.g. publications, patents, prototypes, training packages, students trained, reports). **Stage 4 outcome will include:** New knowledge identified from on farm trials and participatory learning will be adopted by growers to inform their decision making. Besides adoption of techniques, this will also include process and behavioural changes, new products, licenses/IP sold. Grower to grower extension- Influence peers and initiate diffusion of proven technologies across the sector. **Impact:** New knowledge gained will bring direct benefit to grower crop management and production practices, resulting in an increase in crop quality, yield and a greater economic return on investment. Develop successful case studies. Develop subsequent business plans based on the knowledge gained.

NVPCC RESEARCH PROJECTS- TRANSLATION PLAN

Appendix 1: Research and Translation Model Adopted for Pollination

Research Knowledge User Groups/Target Audiences Need and Suitability Assessment	**Involvement of Research Users in the Project** **Define Governance Model**	**Implementation, Evaluation, Knowledge Translation** (forms and types of communication) and **Feedback Model**	**Explain how Users will Benefit from the Research** **Impact**
Need Assessment: A detailed assessment with relevant industries, grower associations, individual growers and Hort innovation officials was conducted to identify research, knowledge and technology gaps. **Suitability Assessment-** There was significant research and knowledge gap on causes for pollinator decline, impact of declining floral resources and climate change on pollinators, bee disease etc. **Output:** Selected industries partnered with the research team in delivering, monitoring, evaluating and diffusing project outcomes through various platforms. **Outcome** **Alignment with industry:** The proposed research and extension program was supported by industries listed below. (For more details refer section 1 in appendix 2).	**Planning of program:** Participatory action research and learning method was adopted for designing on farm trials and data collection. A steering committee was developed with representatives from key industries and representatives from other participating organisations. **Output:** **Design and implement the trial:** Project team which included key industry representatives designed the program methodology. Team implemented the program through on farm trials, collaborative surveys, sampling and data collection along with educating and training peers. **Outcome:** A partnership initiative adopted and trialled for better adoption and diffusion. (For more details refer section 2 in appendix 2).	**M&E and Communication Strategy:** M&E was undertaken regularly and reported in the steering committee meetings. Recommendations and suggestions from the members were adopted. **Output:** An ongoing knowledge transfer mechanism was adopted in this program through various platforms like information exchange meetings, workshops, presentation, Q&A session, study tours, informal round table discussions, publications in plain language, field days` etc. (see details in the appendix 2). **Outcome:** The program outcome was communicated through various platforms. (For more details refer section 4 in appendix 2).	**Benefits and Impact:** Increase in grower understanding of the importance and value of diverse pollinator species - beyond the well-known Honeybee - and key aspects of bee biology. Increased understanding by growers of current best practices for floral plantings, pest management and chemical use to encourage healthy pollinator populations at a local level**.** **Output:** Online web information for growers providing information on pollinators and recommendations on optimising farm-level practices to sustain pollinators. Printed materials for growers providing information on pollinators and recommendations on optimising farm-level practices to sustain pollinators. **Outcome & application of knowledge:** M**a**king decisions and taking future actions informed by findings from on farm trials or knowledge gained. Developed subsequent planting strategy based on the knowledge gained. Grower to grower extension- Influence peers and initiate diffusion of proven technologies across the sector. Impact:Successful case studies with Almond, Macadamia, Avocado, Apple, and Mango industries. (For more details refer section 3 in appendix 2).

Industry partners

- Nut industry (Almonds, Macadamia), Fruit industry (Avocado, Apple, Pear and Mango) and Vegetables

Appendix 2

Section 1: Research Knowledge User Groups/Target Audiences Need and Suitability Assessment

User groups (Industries)- Apple, Pear, Almonds, Macadamia, Avocado, Vegetables and Mango

Need assessment:

To identify research, knowledge and technology gaps a detailed need assessment was conducted across selected industries, grower associations, individual growers, Hort innovation officials etc. Methods adopted to gather information included one on one interviews, field visits, rapid screening of pollinators with growers, transect walks across farms to spot pollinator diversity, question and answer sessions, workshops, landscape mapping to understand vegetation diversity around farms etc. (Details of all these activities are documented and reported).

Outcome: Through detailed interaction with the industry, grower priority issues related to pollination and pollinator health were identified. This includes significant knowledge and information gap on pollinator decline, impact of declining floral resources and climate change on pollinators, bee diseases. Further issues included knowledge gaps on seasonal patterns of floral resource use by bees, the value of floral species for bees, the effects of targeted floral enhancements in cropping environments, impact of climate variations on the quality, quantity and seasonality of nectar and pollen resources and other threats largely unknown.

Significant knowledge gap on role of alternate pollinators like stingless bees as managed pollinator was also noted.

Suitability Assessment-
Possible solutions identified with industry partners to address the gaps include:

- Understand which insects (both wild and managed) are providing pollination services in different crops and regions
- Identify solutions to better support these pollinators through adequate floral resources
- Better understanding of diseases and other threats to pollinator populations
- Educate growers about pollinator biology and crop pollination services.
- Develop on farm trials with participating industries and encourage on-farm practices that promote, or at least limit harm to, beneficial pollinators.
- Develop planting schemes with selected industries that help sustain local pollinator populations
- Undertake exploratory study tour to selected cities in India to get first-hand information on stingless bees as effective managed pollinators.

Section 2: Involvement of Research Users in the Project and Defining Governance Model

Various extension approaches particularly participatory action research and learning method was adopted to include industry in this program. This method is a tested and proven extension strategy for increased involvement of growers leading to improved learning and adoption of trial outcomes. On farm trials with relevant industries was designed, which included educating and training of industry participants on bee population health, floral resources, diseases and pest management - and appropriate actions needed as project participants for maximising bee health and pollination services in their own horticultural context.

On farm programs were categorised based on the research

1. Crop pollination: Identifying pollinator species present on farms and which species visit and pollinate horticultural crops in field situations. Pollinator surveys involving industry was undertaken at a large scale in apple and cherry production areas in NSW, across regions with contrasting degrees of human disturbance surrounding orchards.
2. Floral resources --- Understanding on how bees use different floral resources across seasons and devising and testing appropriate farm-level floral enhancement schemes. To assess non-crop floral resources in cropping landscapes, series of survey plots both on-farm and in adjacent habitat was set up. On-farm surveys were undertaken in collaboration with participating industries for 2 full years.
3. Bee health --- Collecting samples with research team for determining microbial diseases and insects in Australian pollinator communities.

Study tour:
Detailed assessment on stingless pollinators and relevance for Australian Hort sector was undertaken through an exploratory study tour with industry representatives in April 2017. As part of this planned activity, 12 horticultural growers and HIA representatives, along with WSU researchers visited various farms in India were stingless bees were managed for better crop pollination. The Indian study tour involved two components – a south Indian tour focused on stingless bees and tropical crops, and a north Indian tour focused on apple and pear pollination.

The study tour (full report submitted to Hort Innovation) also provided opportunities for presentations, question and answer sessions, interaction with researchers from different institutions, roundtable discussions of existing Australian and Indian pollination research programs and stingless bees. In addition, there were both formal and informal discussions between WSU researchers, Australian growers / beekeeper and HIA staff on the potential of stingless bees in Australian crop pollination, and the need for targeted research and extension program to address open questions in this area.
Significant outputs stemming from this study tour include the subsequent project PH16000 “Stingless bees as effective managed pollinators for Australian horticulture” and the establishment of two ongoing dual PhDs between WSU and different Indian Universities. These student projects are focused on almond pollination in Kashmir (Kashmir University of Agriculture, Science & Technology) and the role of non-crop floral

resources in cropping landscapes (Haryana Agricultural University). This program was useful in understanding the relevance of additional floral resources in almond plantation specifically for improving bee health and attracting native pollinators. This led to establishment of large scale on farm trials with Olam Orchards which is a successful case study outcome.

Section 3: Output - working with Industry:

In collaboration with industry partners, new knowledge was generated on the diversity of insect pollinators visiting selected orchard crops in horticultural production areas in NSW and the role of these various insect in crop pollination. Project team which included industry representatives found that a combination of Honeybees and native bees are the key species providing pollination services, but native bee species vary between regions (Reported to Hort Innovation and relevant industries).

A method was developed collaboratively with the industries to assess the contribution of rented beehives to pollination services on a farm. A question many growers asked was whether it is worthwhile to rent Honeybee hives for pollination of their crops. While most of our (and many other) studies have made good assessments of the role of Honeybees versus other pollinators in a given situation, the relative role of wild bees versus those from rented hives was almost never known. In collaboration with relevant industry partners, a technique was developed which involves fitting on-farm hives with marking blocks that deposit coloured dusts on bees leaving the hive and then conducting surveys of marked (from farm hives) versus unmarked bees (not from farm hives) visiting crop flowers. This allowed a test of the relative contribution of the rented hives in the farms.

Evaluation of a range of plant species for use as floral resource enhancements at the farm scale. A series of collaborative surveys and trials were conducted to investigate the suitability of a large number of native floral species for supporting pollinators. The data collected provide the evidence for selecting sets of flowering plants that can support particular types of pollinators, and provide floral resources at particular times of year, including times that may represent floral resource shortages for resident bees and other pollinators.

Native plant on-farm floral enhancements support a wider range of wild pollinators compared to commercially available exotic seed mixes. Our collaborative study and successful case study with almond industry show that low-maintenance long-lived perennial native floral strips can provide diverse and persistent floral resources for a wide range of insect groups, other than just bees. Exotic and native plant mixes can provide complementary benefits (Figure 1), with exotics boosting Honey bee numbers during crop flowering, while natives act to support pollinators throughout the year.

Native (left) and exotic (right) floral strips planted within horticultural areas to provide alternative floral resources for pollinators. Photo – Lena Schmidt.

On farm demonstration that non-crop floral diversity around farms can increase pollinator diversity and/or crop flower visitation by pollinators. Our industry partners found that co-flowering floral resources available within and surrounding apple and cherry orchards support pollinators with vital nutrition during and outside the crop flowering period and can enhance pollinator visitation during crop flowering.

Increase in grower understanding of the importance and value of diverse pollinator species - beyond the well-known Honeybee - and key aspects of bee biology.

Increased understanding by growers of current best practices for floral plantings, pest management and chemical use, to encourage healthy pollinator populations at a local level.

Section 4: Communication pathways

Throughout the program, we generated information and materials targeted primarily at horticultural growers, but also beekeepers and the wider public. This involved using a wide range of media, including online fact sheets, videos and podcasts, in person workshops and field visits, as well as online Q&A sessions, printed grower magazine articles, and radio and TV appearances to discuss key issues. Few activities are listed below and full range has been documented and provided to Hort Innovation and industry partners.

Field days, workshops and orchard visits.

1) India Study Tour, April 2017 (MS104).

The India Study Tour was undertaken in April 2017 and involved 12 horticultural growers and HIA representatives, along with HIE researchers, travelled through either Himachal Pradesh (north India) or Kerala (south) to investigate how stingless bees and crop pollination are managed in India. The Indian study tour involved two components – a south Indian tour focused on stingless bees and tropical crops, and a north Indian tour focused on Apple & Pear pollination.

2) Grower advice field days

Multiple discussion group meetings were held with growers involved in the *HIA Healthy Bees* project, research fellows from *Western Sydney University*, along with research and development staff from *NSW Department of Primary Industries* for planning methods of data collection (pollinator & floral resources surveys) and an update on progress thus far updated.

3) Visits to OLAM orchards in Griffith region, NSW for pollinator diversity assessment.
4) Presentation to Syngenta and tour of apple & cherry orchards, Nashdale & Canobolas NSW
5) Pollinator survey at Ed Fagan's vegetable farm in Cowra, NSW by project team.
6) Visit of two WSU team members and one Bayer staff member to apple and pear growers in Shepparton (VIC) to discuss crop pollination issues and training for collaborative surveys in the next flowering season, May 2018.
7) Pollinator surveys undertaken in Griffith and Mildura on almonds in collaboration with OLAM. Other almond growers also visited to discuss project, Aug–Sep 2018
8) Pollinator surveys on and off-crop in Young, Bilpin and Orange on cherry and apple varieties. On farm meetings and discussions with 18 growers across these sites, Sep–Oct 2018
9) Regular workshops with growers across selected industries.

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Grower / beekeeper articles.

Lead researcher / student	**Title of output**	**Output type**
Amy-Marie Gilpin	Native vegetation and weedy flowers could support successful fruit crop pollination	Australian Tree Crop
James Cook	Plan Bee	Future Makers (WSU publication)
Olivia Bernauer	It's good to "bee" aware.	Australian Tree crop (grower magazine)
Laura Brettell	Are honey bee diseases a threat to Australia's native pollinators?	The Australasian Beekeeper (beekeeper magazine)
Lena Schmidt	Restoration of native wildflower patches in agronomic settings for diverse and healthy pollinator populations.	Australasian Plant Conservation (plant conservation magazine)
Laura Brettell	Are native pollinators at risk from honey bee diseases?	The Cross Pollinator (native beekeeper magazine)
Lena Schmidt	Keeping our native pollinators buzzing.	Australian Fruit Grower (grower magazine)
Olivia Bernauer	If honeybees decline, Australian native bees can secure apple pollination in NSW	The Cross Pollinator (native beekeeper magazine)
Amy-Marie Gilpin	Honey, here's a sweet spot for bees.	Sydney Morning Herald

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Fact sheets.

A series of three fact-sheets were developed for project stakeholders including growers. These factsheets are available from the Hawkesbury Institute for the Environment website and can be accessed using this link:
https://www.westernsydney.edu.au/hie/topics/supporting_healthy_bees_and_healthy_crops

Simon Tierney	Bee biodiversity: safeguards for pollination services.	Published on HIE website
Laura Brettell	Are honey bee diseases shared amongst Australian pollinators?	Published on HIE website
Amy-Marie Gilpin	Encouraging wild pollinators to your orchard.	Published on HIE website

Media including online videos.

Earth IQ pollinator video: https://www.youtube.com/watch?v=6LisdC7zc-I on pollination and bee hotels with Amy-Marie Gilpin

Oct 2018. Simon Tierney presented research in a video diary for Cherry magazine: https://youtu.be/kNOs1QidwuU

Amy Gilpin was interviewed on ABC television about bees and pollination ABC broadcast featuring Amy Gilpin: http://bit.ly/ABCAMY

James Cook recorded an interview on bees and pollination for ABC Radio Sydney Evenings Show for broadcast on 17 December 2017. https://www.westernsydney.edu.au/hie/stories/surprising_pollinators

Meet The Pollinator Researcher videos were made: Amy Gilpin's introducer received 825 views: https://www.facebook.com/EarthIQ/videos/vb.839054086466466/257898051504704/?type=2&theater . Amy conducted a Reddit Ask Me Anything session where she took questions from the public about her career and pollination that generated more than 3000 reactions https://www.reddit.com/r/IAmA/comments/9wjie6/i_am_amy_gilpin_a_researcher_looking_into/

Jan 2019. Sydney Scoop article entitled "Five surprising Sydney pollinators" featuring James Cook. http://sydneyscoop.com/the-five/five-surprising-sydney-pollinators/

Jan 2019. James Cook was interviewed by ABC radio and this interview was broadcast across their network on the 21st January 2019.

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March 2019. Scott Nacko's mud wasp article in the Hawkesbury Gazette: Wasp season brings native mud wasps into urban Hawkesbury to build nests. https://www.hawkesburygazette.com.au/story/5912065/wasp-season-brings-native-mud-wasps-into-urban-hawkesbury/

May 2019. Article in the Venture Magazine entitled: "What the buzz is about" with input from James Cook. https://www.theventuremag.com/native-bees/

Release of the Hort Innovation podcast – Abuzz with pollination: https://www.horticulture.com.au/growers/help-your-business-grow/news-media/2019/podcasts/

Pollinator week article in the Sydney Morning Herald, Gardening with Amy-Marie Gilpin: Honey here's a sweet spot for bees.

James Cook worked with Ashley Zamek and other Hort Frontiers pollination project leaders to produce a YouTube video for world bee day: https://www.youtube.com/watch?v=gjYRMifZ7RM and
https://www.linkedin.com/posts/horticulture-australia-ltd_worldbeeday-activity-6668642140022800384-1Ac2

ABC National radio interview with James Cook and Hort Innovation about the need to support alternative pollinators. Several linked articles from this have been published:

- ABC article "Alternative pollinators to help farmers as bee populations suffer in drought and bushfires" https://www.abc.net.au/news/rural/2020-02-06/bee-populations-die-alternative-pollinators-to-help-farmers/11928080
- https://www.weatherzone.com.au/news/alternative-pollinators-to-help-farmers-as-bee-populations-suffer-in-drought-and-bushfires/531037
- https://www.hortidaily.com/article/9186702/australia-looks-to-alternative-pollinators-to-support-apiarists-and-industry/
- https://www.nationaltribune.com.au/looking-to-alternative-pollinators-to-support-apiarists-and-industry/
- https://www.msn.com/en-au/news/other/alternative-pollinators-to-help-farmers-as-bee-populations-suffer-in-drought-and-bushfires/ar-BBZGOWW
- https://www.floraldaily.com/article/9186850/australia-looks-to-alternative-pollinators-to-support-apiarists-and-industry/

Article published in The Conversation related to locating native and exotic bees across Australia, written by Manu Saunders, Callum McKercher, Mark Hall, Tanya Latty and Tobias Smith,

- https://theconversation.com/aussie-scientists-need-your-help-keeping-track-of-bees-please-128932
- https://tagg.com.au/aussie-scientists-need-your-help-keeping-track-of-bees-please/
- https://thenextweb.com/science/2020/01/09/australian-scientists-need-your-help-keeping-track-of-exotic-bees-please/

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Press release by WSU titled “Combining crops and native forests increases the diversity of pollinators” featuring Dr Amy-Marie Gilpin: https://www.westernsydney.edu.au/newscentre/news_centre/more_news_stories/crops_native_forests_diversity_pollinators

Article published in the Guardian, featuring commentary from Megan Halcroft during almond pollination: https://www.theguardian.com/australia-news/2020/oct/18/meet-the-beebrokers-you-never-stop-learning-about-bees-theyre-just-incredible

Bayer article and video release outlining the Healthy Bee research program:

- https://www.crop.bayer.com.au/news-and-insights/news/newscontainer/2020/09/02/06/35/sustainable-pollination
- https://www.youtube.com/watch?v=CRPIIqWwT9U&feature=youtu.be

News story titled: Sustainable pollination project protects pollinator biodiversity, featuring Dr Amy-Marie Gilpin was published in Good Fruit and Vegetables, The North Queensland Register, Stock and Land, Queensland Country Life and The Land.

Appendix 3: NVPCC Action Plan

Current projects and potential future projects

Established Project Reference Group for the glass house in collaboration with Hort Innovation.
Given this 'non-traditional' funding directed to supporting the costs of establishment and wider operations of the NVPCC, the annual work plan is significantly tied to the plans for each of the individual projects being delivered within the facility. WSU has provided milestone reports to Hort Innovation for the Pollination and Smartglass pro details on ongoing projects.

Ongoing projects-

On-going projects	**Start and end date**	**Milestone report submitted**	**Research Bays occupied during project duration**	**Planned activity**
Smart Glass Films- LLIEF	01/01/2021-31/12/2021	Submitted Milestone to CRC	6	Industry meetings in Dec 2021.
Stingless bees	15/11/2017-30/08/22	Submitted Milestone report number 102	2 (project is being implemented in the smart glass bays)	PRG meeting Dec 2021
Blue banded bees	26/06/21-25/09/26	1st Milestone report 102 due 25/03/22	2 from 2022	First Milestone report (102) 25/03/22
Flies as pollinators	1/4/2018-31/03/23	Submitted Milestone report number 107	2	PRG meeting Nov 2021 Miletone 108 Dec 2021

Future plan of action:

Further to those projects, it is anticipated that significant ongoing work will be aligned to delivery of Future Farming Systems CRC. Specific projects to be performed in association with the CRC will be negotiated with the PRG and Hort Innovation. Meanwhile, short -medium term industry projects are also being developed to maximise the use of bays.

Proposed projects	Long /Short term	Proposed years	Number of bays occupied	Potential Partners besides Hort Innovation
CRC (Projects to be developed on vegetables)	Long term	7 years	6-8	Hort Innvation

HIA WSU National Vegetable Protected Cropping Centre (NVPCC; VG17003) Program Reference Group Meeting Minutes

Meeting 1: Held from 11.00 -12:00 pm on Thursday 25 February 2021, by Zoom

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Attendees:
NVPCC Group Members or delegates: Ian Anderson: IA (HIE Director; Chair), David Tissue: DT (HIE Professor/Chief Investigator Program 2 FFS), Zhonghua Chen: ZC (HIE Prof /Chief Investigator Emerging Leaders), Adrian Hunt: AH (HIA, R&D Manager),Byron de Kock: BdK (HIA, Head R&D), Michael Simonetta: MS (Perfection Fresh CEO), Adam Steel: AS (Green Camel Founder & Executive Chairman), Matthew Plunkett: MP (PCA Deputy Chair), Chris Millis: CM (Flavorite Group COO), Nisha Rakhesh: NR (HIE Research Development Advisor), Jessica Armstrong-Kearns: JAK (HIE Snr Admin Industry & Engagement).

Apologies:

Absent: Christian Parsons (Costa Group)

1. Welcome and introductions

   The Chair welcomed the attendees. The members of the reference group introduced themselves, noting their positions and roles.

2. Conflict of interest statement

   No conflicts of interest were declared. The Chair asked members to raise any conflicts of interest at any point during meetings should they arise.

3. Terms of Reference

   MP (PCA) queried TOR item 4.a (i.e. will NVPCC PRG membership cease in end 2022). Chair reiterated the plan is for NVPCC to continue past 2022 but in a different funding format and engagement of industry is crucial for the NVPCC for the long term. The Chair noted 3 meetings are planned until the VG17003 project end date but additional meetings can be arranged as required by contacting Jessica. No other queries on the TOR were raised.

4. Overview of NVPCC

   The Chair presented the history and purpose of the NVPCC which is for R&D, education & training that will produce outcomes for industry. Looking for industry partners to come on board in next couple of years.

   Research

   Prof David Tissue presented the aligned Smart Glass Project (VG16070). The Smart Glass (SG) project is investigating the potential use of an energy saving film (ULR-80) in reducing the cooling costs inside protected cropping facilities. In a detailed analysis in the first few years of the project, it was observed that there were reductions in heat load (53%), cooling energy (8%), and nutrient and water use (18%),

due to reductions in far-red light. In tests on three different crops, it was observed that yields were reduced in eggplant (21-25%), capsicum (2-3%) and lettuce (3-10%), but that there was no change in crop quality. Reductions in yield were due to lower rates of photosynthesis (carbon gain) due to reduced light penetration in the film, but also included some reductions in water and nutrient use. The greatest negative impact on yield was in eggplant, which has a very large fruit which requires substantial carbon to develop fully. In plants with smaller fruits or leafy edible material, SG may be very useful in reducing energy use without substantial yield penalty. A new film (LLEAF), which shifts green light to red, is now being trialled in lettuce in the NVPCC as a potential benefit to yield production. Overall, six bays are now being used to assess potential solutions to reducing energy cost and increasing yield.

Education & Training

Prof Zhonghua Chen presented on the aligned Education & Training project - 'Emerging Leaders' (LP18000)**.** ZC explained the 'Emerging Leaders in Protected Cropping' program which focusses on training the next generation of protected cropping professionals. The program was co-developed with industry and includes Post Grad, Grad Dip and Masters of Science (Green house major). There are fifty-five industry supported scholarships and internships in this program. He also mentioned the details of the ongoing collaboration with the NSW Dept of Education. As a part of this, four scholarships have been funded, a three-unit undergraduate short course has been developed and twenty students completed the program. He highlighted the interest from schools in educating students. As a result, the WSU team is currently designing programs for school kids through engaging schools and growers.

5. Update on VG17003 milestones

Milestone Progress: Chair went through the project milestones including those completed and those in progress/pending. AH (HIA) asked members of the PRG to raise any issues associated with milestones. No issues were raised.

6. Monitoring & Evaluation Plan (MEP) and Risk Register discussion

The MEP and Risk Register were included in the PRG briefing papers. An overview of these documents was given by the Chair and feedback was requested from the PRG so that these two documents could be finalised. MP (PCA) would like to see the inclusion of alignment to other relevant industry plans including the Vegetable industry and PCA strategies. MS (PF) had to leave the meeting early so it was agreed that the MEP and Risk Register would be updated and circulated to PRG members for their approval**.**

BdK (HIA) requested the members to identify research priorities for industry and provide feedback on the presentation and VG17003 documents. He further suggested to include the feedback in the SIP for the protected cropping industry.

MS (PF) highlighted the importance of the smart glass program for Australian growers and discussed future R&D priorities for the industry. He pointed out the need for well-developed research programs in pollination and automation particularly for addressing labour shortage issues, which is expected to be exacerbated in the coming years.

AS (Green Camel) backed the priorities and issues raised by MS (PF). He also emphasied the need and importance of skilled work force in this sector.

CM (Flavorite) discussed the issues the industry is facing due to lack of skilled workforce in the protected cropping sector and highlighted the importance of WSU's Emerging leaders' program.

AS (Green Camel) raised concerns on the productivity decline with the smart glass films. However, DT explained the importance of research in this sector and the need for testing the technology for

different crops in different seasons. He explained how the impact of smart glass technology can vary between crops, e.g., the yield decline in capsicum was far less compared to egg plants. The results from the smart glass program demonstrate the need for crop specific R&D.

Research translation models for VG17003
The Chair articulated the importance and the need for involving industry in identifying research gaps, prioritising research programs and finalising plans for future programs in the facility. He further requested members to suggest mechanisms for engaging, communicating and translating research outputs to industry.
MP (PCA) stressed the importance of aligning the NVPCC program with PCA objectives and recommended the use of PCA platform for outreach and extension. He suggested a few mechanisms for research translation such as presenting and advertising at the PCA conference, publishing in industry magazines, giving talks to industry groups etc.

Action:

- **JAK to add aligned industry plans into the Risk Register & circulate along with the Monitoring & Evaluation plan for final confirmation of acceptance by PRG members via email.**

7. Any other business

ZC shared an example of recent industry contact with Family Fresh Farms who would like to do some R&D (disease management) with the NVPCC. The chair thanked PRG members for their participation. JAK will be in contact to organise date of next proposed meeting in September 2021.

- **Action – confirm next meeting date with PRG members**

Actions Table

Action Number	Date	Action	Responsible	Update	Status
1	**25/02/2021**	**Update aligned industry plans onto NVPC Risk Register**	**JAK**		**Complete**
2	**25/02/2021**	**Circulate M&E plan & updated Risk Register**	**JAK**		**Circulated 5/3/2021**
3	**25/02/2021**	**Confirm next meeting date for September 2021**	**JAK**		

HIA WSU National Vegetable Protected Cropping Centre (NVPCC; VG17003) Program Reference Group Meeting Minutes

Meeting 2: Held from 10.00 -12:05 pm on Thursday 2nd September 2021, by Zoom

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Attendees:
NVPCC Group Members or delegates: David Tissue: DT (HIE Professor/Chief Investigator Program 2 FFS), Zhonghua Chen: ZC (HIE Prof /Chief Investigator Emerging Leaders), Adrian Hunt: AH (HIA, R&D Manager), Michael Simonetta: MS (Perfection Fresh CEO), Adam Steel: AS (Green Camel Founder & Executive Chairman), Matthew Plunkett: MP (PCA Deputy Chair), Maurizio Rocchetti (Costa), Nisha Rakhesh: NR (HIE Research Development Advisor), Jessica Armstrong-Kearns: JAK (HIE Snr Admin Industry & Engagement/Chair).

Apologies: Chris Millis, Byron de Kock, Joseph Cartisono, Ian Anderson

Absent:

1. Welcome and introductions & approval of February meeting minutes

   The Chair welcomed new attendee, Maurizio Rocchetti Plant Supply Manager, Berry category from Costa. Minutes from February 2021 Meeting were supported as being accurate.

2. Update on VG17003 program and timeline

David Tissue presented an overview of VG17003 to date - Centre established 2017, operational funding & smart glass project began. 2018 steering committee and emerging leaders project funded 2019. 2020 - 2021 going through succession & translation planning and funding from CRC Future Food systems, a 10-year program with 4 key interweaved projects provides a substantial succession plan along with other projects e.g. extension of smart glass with LLEAF through CRC, Blue banded Bee pollination with HIA. Industry partners have been identified for the proposed programs, currently prioritising gaps & succession projects.
Milestones 101-106 complete, 107 & 108 approved, funding received; however, listed as in progress because the succession & translation plans presented today still require approval. Milestone 109 due in October and final report in June 2022.

3. Update on ongoing projects in the NVPCC & future projects

David Tissue presented an update on projects in NVPCC including smart glass, pollination (stingless bees and blue banded bees) and Emerging leaders in protected cropping - education and training program & future projects included in the succession plan (See NVPCC Succession plan).

Smart glass project - worked with Swinburne using a building film, which eliminates UV and reduces far red light and theoretically heat, in 4 large trials conducted over 3 years with eggplant & capsicum, during different seasons. Overall, there were some energy savings due to reduction of heat-trapping radiation, and crops used less nutrients and water, but maintained the same fruit quality. However, the crop penalty

yield was high due to lower rates of photosynthesis due to lower light availability. The recommendation was that SG was not appropriate for growers due to the loss of yield. Although SG was not appropriate for crop production, the information gained from the project was incredibly valuable because it highlighted the regions of light that should be altered by the new film to increase productivity, yet maintain fruit quality and reduce energy, water, and nutrient use.

A new collaboration has been developed with a new Australian, Sydney-based start-up company(LLEAF), investigating light shifting films that shift non-optimal light (green, yellow) to optimal light (red) to increase photosynthesis. Trials comparing SG and LLEAF were initiated on lettuce with additional funding from CRC. SG did not improve lettuce production, but LLEAF showed promise by increasing lettuce production in one of the trials. SG and LLEAF are now being compared in new cucumber trials with completion in December 2021.

Pollination

Trialled stingless bees as strawberry pollinators in smart glass, bees could navigate with films, 5 visits of bee gave 60% chance of grade A fruit, 10 gives 80% chance Grade A. James's group working on increasing stocking rates & investigating if stingless bees equally good at pollinating other crops?

Glasshouse pollination service – Bees do good for several weeks but lose weight inside, however, regain when released. Current work is looking at improving diet and sustaining them in glasshouse.

HIA funding on blue banded bees as buzz pollinators, using egg plant, tomato etc to access benefit. Current project exploring key knowledge gaps on keeping these bees in captivity, mass rearing & investigating effective crop range.

Presented Program Logic for CRC foundation project – Is a 7.5 year project with 7.8 M cash investment of which 2M is from HIA and 5.5.-6M from CRC and other partners. This program aims to increase profitability of glasshouses by reducing labour costs, increasing energy efficiency & maintaining/increasing productivity and increasing global competitiveness by generating greater skill development.

CRC Foundation Project objectives

1. Smart crops to develop nutritious varieties compatible with automatic systems and robotic harvesting.

2. Precision pollination - test and compare pollination effectiveness between native bees, drones, and other artificial pollinators, reducing labour costs.

3. Automated crop management - using high tech control systems and sensors through the internet of things approach.

4. Integrated pest & disease management -test novel technologies to reduce energy use and increase profitability – interplays with training for these systems and disseminating trained workers to industry.

List of current & future projects & partnerships

- CRC FFS funded acoustic pollination Perfection Fresh, WSU, UNSW – using sound to create pollination in tomatoes.
- LEAf light shifting Sydney company – films also tested in poly tunnels in regional NSW.
- Internet of things -IoT- Highly automated technological approach to monitoring & controlling the environment – 1.5 years into project
- Linkage project (in review) to develop next generation smart film based on the 3-yr SG trials in the WSU glasshouse. Interfocus Photonics, Swinburne, WSU – detailed analyses of Smart Glass with

significant industry funding ($300K) to produce new film using previous findings (see succession & translation plan). Testing all done in Oz, using new technology to design films, will be much cheaper and easier to apply.

- CRC Foundation project – HIA, Rijkzwaan WSU & QUT.
- Broccolini – PF & WSU -Integrated pest disease management program in Broccollini-768K
- root pathogens, using microbiome as pest disease management program, funding bio-science & WSU, $700K industry, $700K industry & remainder CRC.
- Robotic program Perpetual & QUT -Perpetual has own pollination method, like to put onto robotic system -eventually tested in glasshouse.
- Drone pollination program in the pipeline, polly bee like to apply and test against other systems. Syngenta conversations, they also have a pollination system their interested in.
- Developing Emerging leaders in protected cropping – Education and training program – Substantial important program – given rise to new courses at uni. Difficult due to covid, however still carrying on by zoom. Tertiary pathway in protected cropping.

Member discussion on presentation.

AH : How are we managing and maintain facility during current lockdown challenge?

DT: Constant contact with NVPCC facticity manager, needed to hire people who live in local area as some key personnel are in LGA lock down areas. Have maintained facility but not able to do the same depth of measurements i.e. physiology in way we would like to, but major core measurements of greatest interest to industry are still moving forward. Yield data maintained and crop system and quality ok, difficult to get underlying biological processes that are driving these. Until can get more people into the facility are struggling. AH: better than many other HIA providers are doing, good keeping wheels turning even slowly is progress.

AS asked how LEAf and smart glass films are applied – film has adhesive can be directly applied to glass, if poly tunnel can use film as poly tunnel or apply it to. Previous film used clip on system to ensure film was adhering to glass with grommets, are developing new film which will be much easier to apply.

DT: Aim -these films will be retrofitted to current glasshouses

4. <u>Succession Plan discussion for VG17003</u>

Chair shared Succession plan that had been circulated prior to meeting. DT asked if there was anything members thought should be added or altered in the plan.

MS: These are all important projects however need to deal with more pressing issues in industry now if we are to last in business to 2030 – pressing issues are availability of labour, to harvest product, it's not going to get easier for next couple of years even though Ag visas recently approved. Farm labour shortages across all of horticulture not just glasshouses. For MS research need be across projects that help minimise labour in glasshouses around pollination, precision pollination, bees, whatever method of pollination works needs to be a priority. Also all things automation to minimise and reduce labour across the glasshouses and finding varieties that are more grower friendly, a lot of work going on with commercial breeders all around the world particularly Holland & Israel to find those varieties so don't think we should be spending any of our time finding varieties as world leading companies that are miles ahead of where we are in this area. All about finding substitutes to replace people or won't be in business till 2030.

DT: agreed, not interested in new varieties, but we'd like to tailor the environmental conditions to the

particular crop, important component to use sensing technology to control environment but also to detect what environment impact is having on crop, early detection systems, what Internet of things project hopes to achieve. If we use high tech approach can control and alter environment through developmental stages of the crop, we can know quality of crop early on, is ideal – this is what QUT is trying to do e.g. trialling system to look through a watermelon to see if its ripe, controlled by Robot system (50% of watermelons don't make it to market). We have projects looking at robotic harvesters and pollination which I introduced earlier & pest and disease management, trying to save a huge amount of labour costs. Pollination is also key. No idea who will win the race, natural pollinators, drones, robots or acoustics? Will compare all of these under same crop and environmental conditions. Poly Bee, Syngenta, Perpetual, companies on board willing to put systems in the race – will be part of our translation program.

MP- shared perspective from National peak industry bodies – there is so much fantastic work going on, from their perspective good to have a discussion around –

1.Fantastic projects being developed and how we can share this info with industry in Oz

2. How do these priorities align with protected cropping 2030 strategy (plan not released yet) but prisonisation around that for investment. How 2 are working in alignment and how we as peak industry body can take growers on a journey around what's being learnt rather than have projects communicated through some forums but not all forums.

DT : please let us know other outlets we can be involved in, currently we conduct tours of NVPCC, industry outlets, magazines, CRC Future Food systems, try disseminate to different organisations too, develop industry fact sheets, interviews with BBC. MP welcome opportunity for these projects to present on webinar series, PCA conference in March next year and Soiless magazine, significant opportunity to talk about projects and findings throughout the whole R&D process rather than just at the end in a more targeted way. DT: if MP like to be Involved in our NVPCC communication strategy, we can run things through PCA. AH confirms is a good idea. AH is important translation plan have some blocks of funding that are existing and those we foresee in the future is funding that isn't single source dependant, lots of different people involved is important in maintaining the utilisation of facility for grower outcomes.

Succession plan was moved as supported

Action: JAK inform Project leads of PCA Conference next year for abstract submissions (interim presentations) & contribution of projects to Soiless magazine.

5. <u>Translation Plan discussion for VG17003</u>

Chair shared Translation plan asked for feedback from industry for comment and thoughts on how these things can be translated well. MP said is fine, logical sequence, well thought through.

AH: could check with NR offline later as there are a couple of parts where outputs and outcomes and activities and line between those is a bit blurred. AH to send supporting resources to make clear the difference between output & outcome. AH reminder translational model needs to be produced early on in projects, models constructed early and remember are working documents. Strongly recommend is a framework of the basics of how we think and how that will impact on growers' businesses and translate that into a grower relevant situation. The model exists upfront when the research is underway. Overall is fine as is, can move from good to great if update these.

DT: Are doing on farm trials, translating from our Research program – smart glass project good example of translation into new potential film and drove us to reach out to other film companies – has been done within this time.

MR: Trying to understand how costa can fit in here and participate, aware of pollination projects, very much interested in what we are doing. Definitely people from Ciara are interested in participating in this group, are providers of hydroponic berries, so highly interested in greenhouses and hydroponics and robotics and anything that can help minimise labour. Pollination is just one focus at the end of the day, we

have no control over success, as we look for technology out there…we only find out our crop has not been pollinated at the end of day when you can't do anything about it.

Action: Update AH's suggestions –Output/outcome descriptions to be made clearer in Translation plan and circulated to members for final confirmation of acceptance.

6. Finalisation of M&E Strategy & Risk Register

M&E Plan & Risk Register was supported by members. AH: keep updating and checking risk, managing and dealing with risks, when see something coming deal with it, we don't want surprises, if there is a challenge, deal with as proactively as you can.

7. Any other business

The chair thanked PRG members for their participation. JAK will be in contact to organise the date of the next meeting to be held in March 2022.

Action – confirm next meeting date with PRG members

Actions Table

Action Number	Date	Action	Meeting	Responsible	Update	Status
1	25/02/2021	Update aligned industry plans onto NVPC Risk Register	NVPCC	JAK		Complete
2	25/02/2021	Circulate M&E plan & updated Risk Register	NVPCC	JAK		Complete
3	02/09/2021	JAK inform Project Leads PCA conference March 2022 & investigate other avenues of knowledge translation	NVPCC	JAK		In progress
4	02/09/2021	Update output vs outcome in NVPCC Transitional plan and circulate to members for final approval	NVPCC	JAK		Complete
5	02/09/2021	Confirm next meeting date in March	NVPCC	JAK		In progress

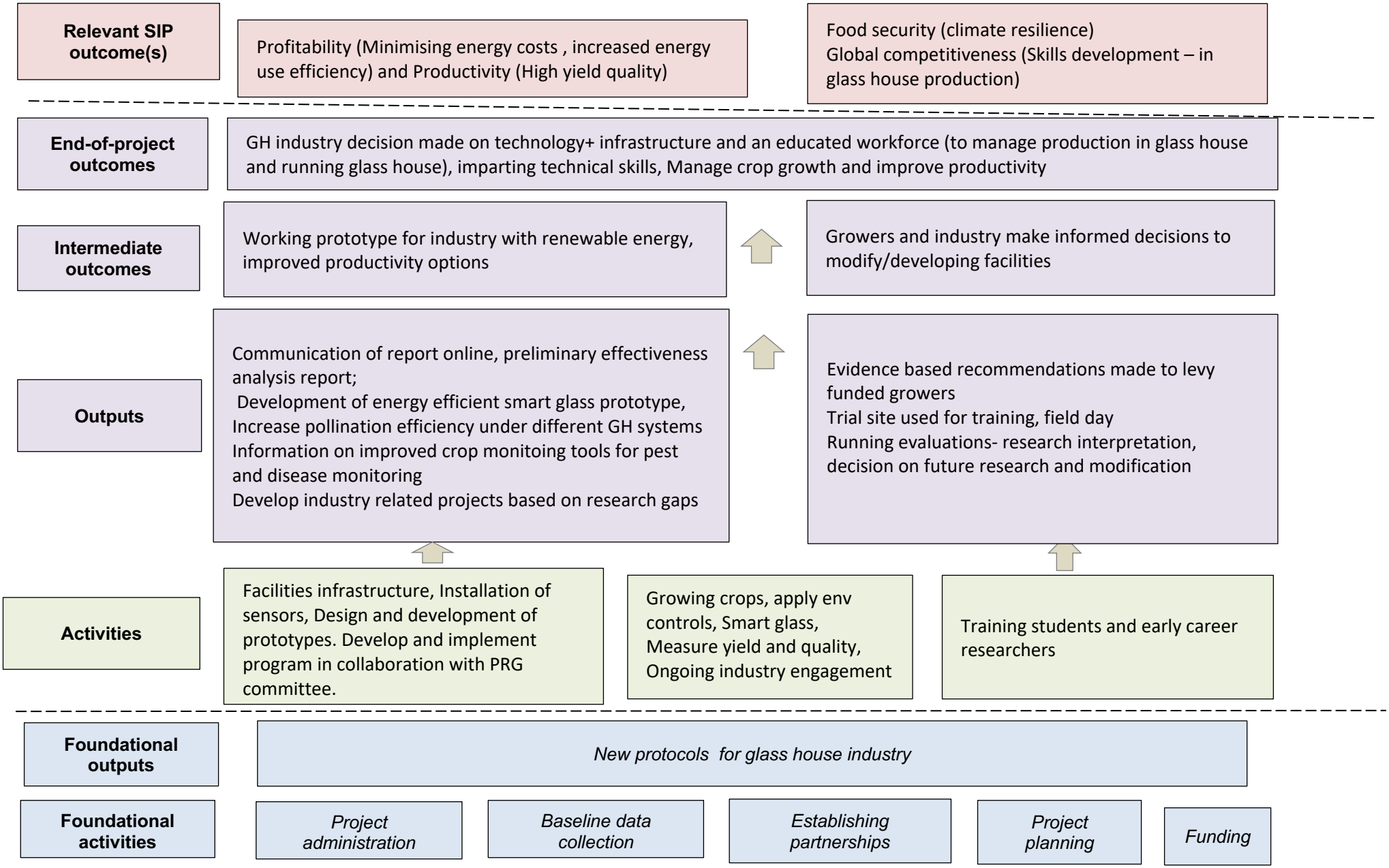
Appendix 5: NVPCC Risk register

Risk	Management Strategy	Likelihood (1-5)	Consequences (1-5)	Rating (Extreme, High, Medium, Low, Negligible)
Key operational staff depart	- Staff are well managed and provided appropriate training and development opportunities - Industry networks managed to support recruitment of potential replacements - Emerging support staff are actively identified and cultivated	2	4	Low to Medium
Failure to attract project funding leads to underutilisation	Proactive business development approach, spanning a number of project models such as long-term flagship consortium-based projects (FFS CRC, ARC ITRH); medium-term experiments (Smartglass, Pollination, FFS CRC); short-term lease and variety trials (developing discussions with BASF and other potential funders);	3	4	Medium
Insufficient industry engagement	WSU is making a significant investment to develop a Horticulture Futures strategy, of which the glasshouse will be a central pillar, to amplify the engagement and impact of research, teaching and training	3	5	Medium to High
Failure to align with other relevant industry strategies	Ensure alignment of the NVPCC activities and future plans with other relevant industry strategies including the Vegetable Industry Strategic Investment Plan and PCA's strategic initiatives	2	4	Low to Medium
Project Management leads to reporting challenges	Recruitment of a senior Central Facilities Manager is underway. WSU existing controls around grant management.	1	1	Low
Environment or economic impact within partner organisations	The level at which participating enterprises are prepared to abide by cooperation agreements when these become unfavourable due to changes in market conditions. Ensure institutional processes for example, realistic and clear goals, transparency in equity and inclusiveness, facilitate participation & consensus building at critical stages of development, develop a responsive system to deal with issues as they arise.	3	4	Medium

COVID-19 Risks to the Operation of the NVPCC	NVPCC facility classified as essential WSU infrastructure requiring continued operational support to the facility. Facility staff identified as essential staff and access to the campus provided. Students and visitors not permitted to access the NVPCC due to COVID-19 restrictions. Strict Standard Operating Procedures for all essential staff accessing the NVPCC to ensure physical distancing, hygiene practices and health status monitoring to reduce the risk of COVID-19 contamination or community transmission.	4	5	High to Extreme

Western Sydney Glass House Programme

Figure 1 Program logic model for the Western Sydney Glass House projects



1. Project M&E scope

a) Audience

Table 1: M&E audience and their information needs

Audience	Information need
Primary	
Project team (Primary) WSU research and management team	Learn and adapt, modify as we move and also provide accountability to funders and levy payers
Hort Innovation and PRG (Primary)	Feedback to stakeholder Justification for levy payers Feedback into HIA plan
Secondary	
Glass house industry	Energy/cost savings Water savings Better management practices for pest, disease and pollinator monitoring Drive to have food production closer to urban cities Decisions for future investment.
Dept of Agriculture	Return on investment
University	Public interest
General public	Food produced sustainably.
Private partners	Potential for commercialisation

b) Key Evaluation questions

Table 2: Project key evaluation questions

Key evaluation questions	Relevant?	Project-specific questions
Effectiveness		
1. To what extent has the projects in GH achieved its expected outcomes?		Have the projects developed new technology that is now available for industry uptake?
Relevance		
2. How relevant are the projects to the needs of intended beneficiaries?		To what the projects have met the needs of Glass house/Protected cropping and veg levy payers?
Process appropriateness		
3. How well have intended beneficiaries been engaged in different projects?		Have regular project updates been provided? How accessible were extension events to industry levy payers?
Efficiency		
5. What efforts did the projects make to improve efficiency?		How projects has adapted to maximise benefits? What influence is this having on profitability and productivity?

Performance expectations, data collection and analysis

Table 3 Project monitoring plan

Logic level	What to monitor (see logic)	Performance expectation (KPIs) and/or monitoring questions	How to monitor (suggested methods)	Data collection – method and source	When	Responsibility (who is responsible for the monitoring and how will results be reported)

Foundational activities (list)	***Project planning*** Baseline data collection Glass house committee establishment	Baseline data without plants in the glass house collected and analysed Steering committeee established	Record keeping	Glass house facility	Before experiment start	Six months after project intiation
Activities and outputs (list)	• Installation of sensors • Design and development of prototypes. • Growing crops • Apply environmental controls • Measure yield and quality • Training students and early career researchers • Ongoing industry engagement through Workshops; Publications; Training;	On going data collection and analysis Extension participation (number of growers and other stakeholders)	Record keeping Observation	On going experiments	On going As required for evaluation	Project team member Milestone Reports Final Reports Industry reports/publications

Intermediate outcomes (list)	Working prototype for industry with renewable energy and advanced technologies Interim report on project outputs	Increased percentage of growers make informed decisions to modify/developing facilities.	Group discussions during event days and field site visits	• Growers • Advisors	As required for evaluation	Intermittent (Project Team member) Independent reviewer Milestone Reports Final Reports Industry reports/publications
End-or-project outcomes (list)	GH industry decision made on technology+ infrastructure and an educated workforce (to manage production in glass house and running glass house), Manage crop growth with improved technology	Savings in energy without impacting productivity Evidence based information on crop management practices like pest and disease monitoring, effective pollination strategies etc. Better understanding on imporved technologies Growing interest in practice change An educated workforce (to manage production in glass house and running glass house) Global competitiveness (Skills development – in protected cropping production, commercialisation of proven technologies)	Data on crop growth collected and analysed at regular intervals Interactivediscussions during event days and field site visits	Experiments • Growers • Advisors	As required for evaluation	Organisation/specific project team member Independent reviewer Final Report Evaluation Report

Evaluation

Table 4 Additional evaluation data requirements

KEQ	Data collection requirement	Source and method
To what extent has the project achieved its expected outcomes?	Our hypothesis here is improving productivity, knowledge and skilss. • Data is collected on an ongoing basis from individual projects and reported.	
How relevant was the programme to the needs of intended beneficiaries?	Data on • Profitability (like increased energy use efficiency, minimised energy costs). • Productivity (like high yield and improved quality). • Global competitiveness (like skill development in improved crop production and monitoring) • Increased knowledge and improved understanding on the best practice	
How well have intended beneficiaries been engaged in the project?	Study the quality of engagement through extension and training programmes	Information collected through group discussions and using questionnaires during workshops and trainings Number of quality science and communication articles published in high impact factor journals and industry magazines.
What efforts did the project make to improve efficiency?	Identify measures to adapt to maximise benefits. How best resources are used to deliver the best? How flexible the project is made to suit levy payers needs?	How many times information from steering committee and other industry committess have been taken on board and the project modified accordingly?

Reporting, learning and improvement

Table5: Project progress reporting

Report type	To whom	Timing
Milestone Reports	Hort Innovation	Six-monthly

Final Reports	Hort Innovation	At end of project
Articles	Industry magazine	Annually
Written and verbal update	Project Reference Group	Six-monthly
Financial reports	Project Partners	Annually

Table 6 Project continuous improvement activities

Continuous improvement process	Details	Timing
Reflection meeting with Hort Innovation R&D Manager	Meeting between R&D Manager, Committee membersT and WSU researchers to discuss progress to-date and what's working well/not, and agree any follow up actions	Six-monthly
Team meetings	Meeting between project team members in WSU to discuss project trials and their timing. Meeting between project team members to discuss feedback from extension event participants to determine gaps in adoption and preferred learning styles for incorporation into project	Quarterly
Project Reference Group meetings	Meetings between project team members, Hort Innovation and industry representatives to gain feedback on project activities and refine methodology	Six monthly