Final Version 2017

World Vegetable Center

REVIEW OF RESEARCH INFRASTRUCTURE AND DEVELOPMENT OF HEADQUARTERS CAMPUS MASTERPLAN
TAINAN, TAIWAN, NOVEMBER, 2016

CONTENTS

EXECUTIVE SUMMARY

A review of WorldVeg's research buildings and associated infrastructure was undertaken in November 2016. Facilities were inspected and evaluated with regards to utilisation, capability, condition and safety.

An Infrastructure Modernisation Master Plan for the Tainan research site has been formulated and this identifies a number of specific functional activity zones to provide a framework for the rationalisation, integration and modernisation of the research infrastructure and for future developments. The Infrastructure Master Plan aligns to WorldVeg's new strategic and operational plans, ensuring the enhancement of existing research capabilities and the development of new research platforms. The modernisation of the research infrastructure is critical to ensure that WorldVeg is equipped to deliver on its vision and maintain its position as a world leader in the development of vegetable crops for an increasingly growing world population.

The replacement of the research laboratories and the development of supporting research support buildings have been identified as high priorities. The creation of a research intensive research capability precinct co-locates modern research laboratories, dedicated research support buildings, supports and creates strong linkages to the unique Vegetable Resources Gene Bank, and enables the development of a new training, collaborator and staff amenity hub.

1. BACKGROUND AND SCOPE OF THE CONSULTANCY

The AVRDC- World Vegetable Center (WorldVeg) was established in the early 1970s as a non-profit institute focused on vegetable research and farming systems development with aims to increase production and consumption of a broad range of vegetable crops.

The headquarters of the Center is located in Tainan, Taiwan, and the majority of the buildings on the site are now over four decades old. Some additions, refurbishments and improvements have been undertaken, but there remains an urgent need to modernise the laboratories and other research facilities to ensure that WorldVeg can continue to be a significant international Center for vegetable science and research impact.

The focus of this consultancy was to undertake a review of Worldveg's existing infrastructure and develop a strategy and associated plans to create a framework for the modernisation of the infrastructure - encompassing modern research platforms, capabilities, work trends and evolving technologies. Significantly, with the development of WorldVeg's new Strategic and Operational Plans, this timely review of the infrastructure and the formulation of a strategic framework for improvements will ensure that the Center's requirements are clearly identified and are aligned to its organisational strategy.

2. VISIT, FAMILIARISATION TOUR AND STAFF CONSULTATIONS

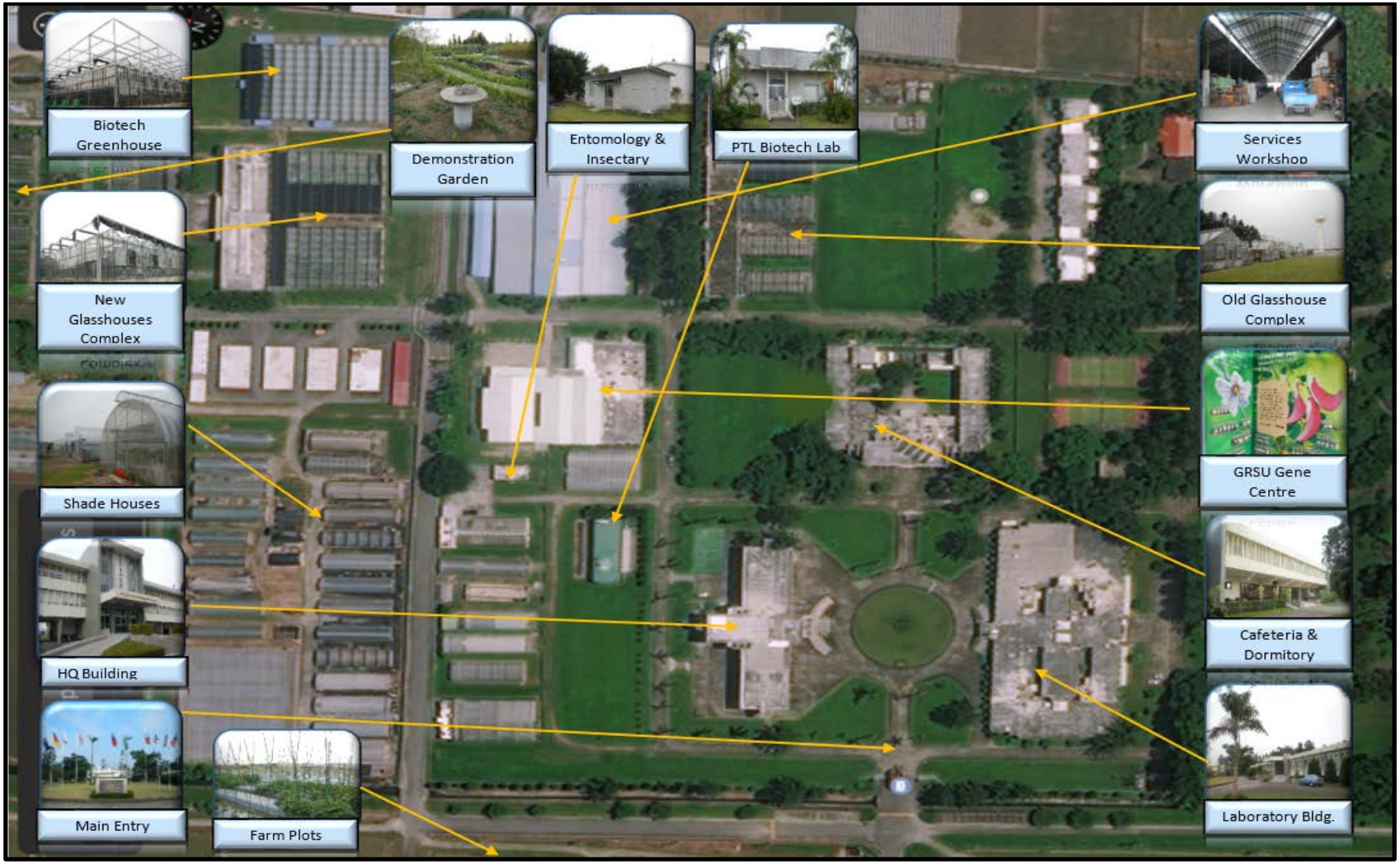
The consultancy was undertaken during a two-week period from the 19th November to the 2nd December 2016.

Upon arrival at the site, a tour of the facilities at WorldVeg's site in Tainan was undertaken with Dr Marco Wopereis (Director General), Dr Yin-Fu Chang (Deputy Director General, Administration and Services) and Mr Rollen Shun-Chu Chang (Manager, Technical Services).

Following the tour and initial discussions, a staff presentation to staff was given to provide information on the intent and scope of the review of WorldVeg's research infrastructure. Discussions after the presentation provided an opportunity for staff to provide comments and suggestions pertaining to the process. A number of research, administrative and technical staff were individually consulted during the course of the review.

The diagram in Section 2.1, on the following page, provides an overview of key buildings and facilities at the WorldVeg headquarters site.

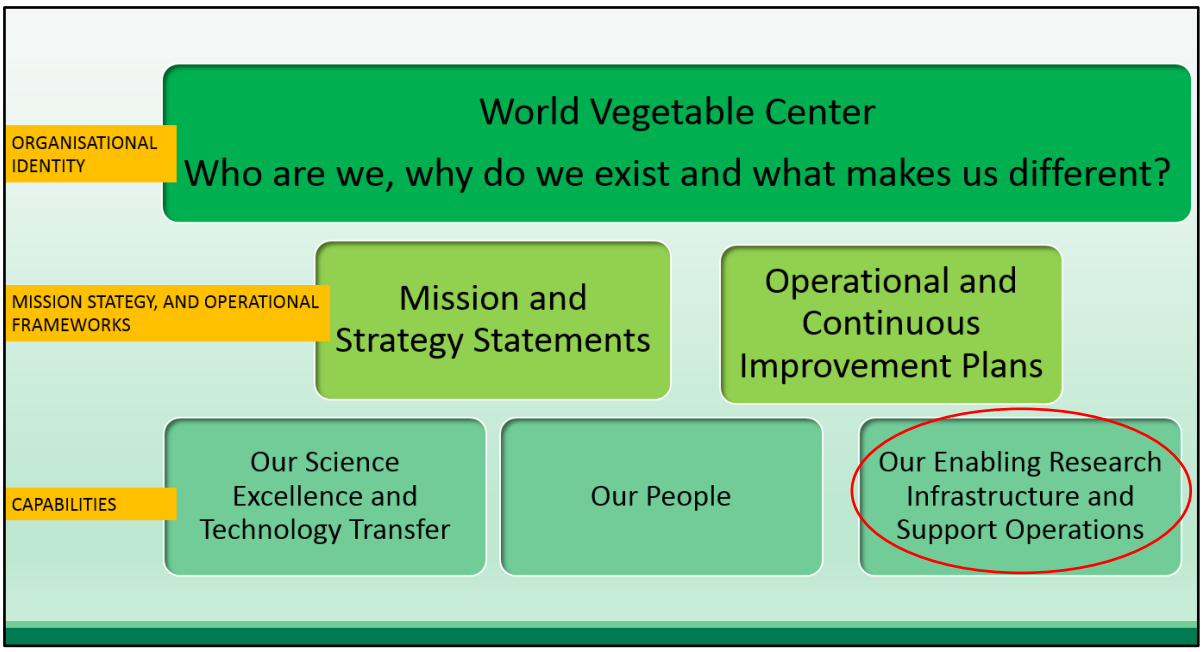
2.1 Graphic summary of Key buildings and Facilities at WorldVeg's Headquarters Site in Tainan.



3. OBSERVATIONS AND THE FRAMEWORK FOR THE REVIEW OF RESEARCH INFRASTRUCTURE AND THE DEVELOPMENT OF THE CAMPUS MASTERPLAN

After an initial review and inspection of the buildings and facilities at the WorldVeg headquarters site, the following summary of findings and ideas was developed. This information was shared with WorldVeg staff during a presentation on Tuesday 22nd November.

3.1: Relationship between Organisational Role, Capabilities and Infrastructure.



3.2: Drivers for WorldVeg's infrastructure review and master plan development

What are the key drivers for the WorldVeg infrastructure redevelopment master plan?

WorldVeg's future scientific success and the ability to attract excellent staff, donors, industry and community support will require access to fit-for-purpose modern research laboratories, specialist facilities and associated science support capabilities

- Consolidation: Maximise resource utilisation and generate efficiencies
- Modernisation: Adopt modern design principles and practices, capture evolving capabilities (new technologies, big data, geno/pheno-typing)
- Integration: Develop infrastructure that promotes common WorldVeg goals and creates opportunities for staff interactions and multidisciplinary collaboration.

Inward and Outward Looking

3.3: Observations and Issues for Consideration

Observations and Issues for Consideration:

- The majority of research laboratories and supporting research facilities are 40 years or older. These will increasingly limit WorldVeg's ability to develop work practices, team structures and capabilities that are required for modern plant science research
- Ageing buildings and associated infrastructure contribute significantly to WorldVeg's rising maintenance and energy costs
- Most buildings will increasingly fall behind in modern design, occupational health & safety and environmental standards
- The physical separation of WorldVeg's research group may be barrier for effective scientific workflows, optimal resource utilisation and team collaboration
- The physical and operational integration of research support buildings (glasshouses, head houses, processing areas, specialist instrumentation and storage area), may contribute to greater economies of scale, optimised resource utilisation and increased capability impact.

3.4: Benefits of consolidation, modernisation and integration of WorldVeg's Facilities

The benefits of consolidation, modernisation and integration of laboratories and research support

- Create modern "fit-for-purpose" buildings and supporting facilities that will optimise research workflows and promote staff interactions and collaboration.
- Promote and provide access to shared research facilities and capabilities.
- Provide significant improvements in workplace safety through contemporary safety design principles and adherence to modern building codes.
- Ensure compliance with statutory regulatory compliance (e.g., Quarantine, GMOs, Hazardous Materials) requirements.
- Significantly improve energy management through building design, materials and technologies.
- Reduce the building footprint and realise improved space utilisation / positioning / functional proximity of the key WorldVeg infrastructure components within the boundaries of the Headquarters site.

3.5: WorldVeg's Infrastructure Renewal: Some Opportunities

WorldVeg Infrastructure Renewal : Some Opportunities

- Consolidate WorldVeg's operations at within a smaller and integrated buildings footprint. Bring research groups, management, corporate support services, and related functions closer together to promote a unified WorldVeg identity and an environment of collaborative interactions.
- Leverage from and "celebrate " WorldVeg's unique Seed Bank Centre – housing over 60,000 vegetable accessions.
- Provide new and integrated research laboratories that are designed for modern plant biology and plant breeding research.
- Provide purpose-built facilities supporting WorldVeg's research operations including specialist instrumentation laboratories, bulk seed storage facilities, phenomics, analytical services, microscopy, bioinformatics, hazardous materials handling areas.
- Attract staff, collaborators, research students, industry, farmers and the general community by creating a international "centre of excellence" for vegetable science research and technology transfer.
- Leverage from the WorldVeg's capability and expertise to provide training opportunities to an international audience – specialised scientific and technical training, training in vegetable farming and production systems, training targeted at government, industry and public engagement. (The availability of on-site accommodation and facilities is a significant resource).
- Create a clearer and distinctive WorldVeg "front door" that more readily showcases WorldVeg's goals, capabilities and achievements.

3.6: Identified Infrastructure Components

Identified Infrastructure Components

Infrastructure Components	Notes
Modernisation of WorldVeg's research laboratories : Address workflows; create enhanced collaboration opportunities; shared services – instruments, facilities and stores; address health, safety and environmental issues; and better utilisation of building footprint (more in less).	Refurbished or New Laboratories?
Continued enhancements to the Gene Bank – e.g. Fit-for-purpose seed processing facilities	Capabilities and workflows to support Gene Bank – Relationship to support services – quarantine, seed health and inspection, seed processing and cleaning, specialist growth facilities e.g. germination and CE's for "difficult to grow " materials
Consolidation, refurbishment and integration of plant growth facilities – glasshouses, head houses, controlled environment facilities, screen houses, plant drying and processing, centralised bulk storage facilities etc.	Condition audit of glasshouse infrastructure and other research support facilities, Consider: location; demand; facility specialisation; user access; shared services models; maintenance; and cost information financial management
Environmental Sustainability • Solar Power Generation Capability : Generation to reduce dependence on grid power • Rain Water collection and use: Reduce dependence on town water supplies- optimise water usage	• Roof-top panels, Solar Farm – Industry engagement • Rain water collection from rooftops, storage and dedicated usage
WorldVeg's "Front Door", training opportunities and broader research/industry/public engagement	Create Impact on arrival: Interpretation and Display Pavilion; Demonstration/Teaching/Production Garden; Training Facilities; Co-hosted Collaborators/Partners; Public interaction spaces
Demolish outdated and surplus buildings	Remove "liabilities" - avoid safety and maintenance issues

3.7: Frameworks for Decision Making and Time Frames

4. SURVEY OF EXISTING BUILDINGS – UTILISATION AND CONDITION AUDIT

A Survey of the major buildings at WorldVeg's Tainan Headquarters site is summarised in the table below. Recommendations and opportunities are also indicated in the table.

Building	Age (yrs.)	Area (m^2)	Condition	Issues for consideration	Opportunities
Administration Building	**42**	**1180**	**Very good**	• **Refurbished in 2007 to modern standards. Executive and Administration Accommodation. Lecture Theatre, Conference and Meeting Rooms.** • **Internal fit-out is to a high standard and requires no changes.**	• **Potential utilisation of under croft (carpark) area for future expansion – offices, exhibition, display etc.**
Laboratories	**42**	**3959**	**Poor**	• **Original laboratory building with some partial refurbishment.** • **Library area underutilised** • **Ageing services (air-conditioning, electrical, hydraulics).** • **Internal location of building power transformers.** • **Multiple corridor areas and fragmented distribution of laboratories, instrumentation rooms and office areas contribute to poor overall space utilisation within the**	• **Laboratory design and facilities are over 42 years old and do not comply with modern design principles, health, safety & environmental standards and contemporary laboratory workflows. The construction of new modern laboratories is recommended and these should follow international laboratory design principles that encourage open plan workplaces, shared equipment zones and other opportunities that create staff interactions and collaboration.** • **Safety issues were identified in a number technical support rooms within the**

				building footprint. • Building design with separate work areas for each department (entomology, nutrition, genetics etc.) does not encourage collaboration between research and support staff. • Given the age of the building there are some significant health, safety and environmental compliance issues. These include: ➢ Poor air circulation in some laboratories and toxic chemical storage rooms. ➢ The need to store large quantities of gases (including liquid nitrogen) in instrumentation rooms creating significant risks. ➢ Poor ergonomics of some laboratory benching particularly around fume – cupboards, laminar flow hoods and other areas where staff are required to undertake time-intensive processes. ➢ The location of some support staff in technical support rooms (e.g. RO water treatment room). Poor air quality and noise from equipment may present hazards. ➢ Tiled flooring not ideal in laboratory environment. Higher potential for	laboratory area. In particular, the following issues are noted: *Presence of significant quantities of gases in rooms without adequate ventilation systems to handle inadvertent release of significant quantities of gas. Risks include toxicity and potential for asphyxiation due to oxygen depletion (especially the case with liquid nitrogen); *The storage and handling of toxic chemicals in rooms not specifically designed for the management of hazardous material. Poor air extraction and non-compliant hazardous chemical storage present toxicity and other risks; *Poor ergonomic design within the laboratory and office areas that could lead to body stressing injuries; *The placement of larger heat generating equipment items (ovens,-80^{o}C freezers, growth chambers) creating heat and poor air quality issues within the laboratory area; *The internal placement of the main power transformers (located near the building entrance) is not ideal as the ageing equipment and wiring presents potential fire risks and electro-magnetic interference problems. • The buildings age and design makes it inefficient with regards to energy utilisation. The lack of a modern centralised air conditioning and air handling capability

				contamination and difficulty cleaning. Continuous vinyl flooring is preferred. • Poor space utilisation, fragmentation of work groups, older design does not meet contemporary health, safety and environmental standards.	results in poor air quality in many areas of the laboratory and office areas. The building design with numerous corridors lead to poor space utilisation. Single glazed windows, older lighting systems and dated electrical systems also contribute to the buildings poor energy utilisation ratings. • There is an urgent need to update WorldVeg's laboratory facilities. Given the age and poor condition of the existing building the recommendation is for the construction of a new fit-for-purpose laboratory building utilising modern design and safety compliance principles. This may be more cost effective and create greater opportunities for the integration of facilities at the Tainan research site.
Cafeteria & Dormitory	41	1080 (Cafeteria-Dining - Meeting Rooms) 1360 (Dormitory)	Good	• Cafeteria, dining and meeting rooms. Recently modernised and in good condition. • Dormitory block for students and visitors in good condition. • Cafeteria is an excellent facility that encourages interaction between staff and visitors.	• The refurbishment of the second level space (above the cafeteria) will provide excellent facilities for meetings, conferences, training and staff functions. • The dormitory rooms are in good condition. The corridor areas leading to the rooms appear dated and could be updated to improve the presentation.
GRSU Office Building GRSU Storage	32 15-32	1056 780	Good Good	• Office, labs, seed handling and storage rooms • Some recent modernisation of processing, packing and storage	• Facilities within the Gene Bank Building are generally in good condition. • Some minor work to improve the visibility and entrance areas to the building would

				facilities. • Currently there is a program of migrating stored materials into modernised cold room and other storage facilities. • External presentation of the GRSU Building could be improved to draw greater attention to this important germplasm collection and the research capability/opportunities that it creates.	significantly enhance its presence and draw attention to the important role that this facility plays in WorldVeg's research capability.
PTL - Transgenic Facility	**32**	**297**	**Poor**	• Laboratory and Greenhouse for transgenic work • Building currently underutilised and future use will be dependent on the extent of GM related work within WorldVeg. • The cladding system (polycarbonate sheeting) on the attached glasshouses is in poor condition. If the cladding is to be replaced careful consideration of the replacement materials should be undertaken. Modern trends in glasshouses seek to utilise materials that are transparent to ultraviolet light to ensure that plants are grown in (as close to) natural light conditions. Polycarbonate attenuates the transmission of ultraviolet light and	• Need for the Transgenic Facility should be reviewed. Significant maintenance work will be required to ensure the on-going viability of this facility.

				discoloration over time also contributes to a shift in the spectral quality with adverse effects on plant growth.	
Entomology Building & Insectary Greenhouse	**32**	**885**	**Poor**	• **Insectary and screen house for entomology.** • **Insectary building should be modernised to ensure improved work flows and to improve the management of the risks associated with work involving insects.** • **The associated greenhouses should also be modernised and designed to better manage associated risks.**	• **The existing Entomology and supporting Insectary Screen House are in poor condition and should be replaced with a modern facilities that better manage workflows and contain the risks associated with work involving insects.** • **In creating the new facility for this work, the opportunity will be present to also incorporate new quarantine facilities for assessing seed health, testing and screening.**
Quarantine (Virology) Screen house	**32**	**608**	**Moderate**	**Greenhouse used by Virology.**	• **The facility should be maintained and requires maintenance works to ensure that it continues to operate to specifications. A schedule of maintenance should be developed.**
Services Building	**41**	**4004**	**Moderate**	• **Technical Services office and working areas.** • **A number of research related facilities – e.g. pepper, tomato breeding working and storage rooms are located in the TSO facility.** • **Significant number of older drying ovens that should be inspected for safety and the possible presence of asbestos fibres in the door seals.**	• **The facility is in moderate condition but is fit for purpose. The roof of the Services Building needs replacement and this and other regular maintenance works should be scheduled to ensure the on-going functionality of the building.** • **The old ovens and material storage rooms should be updated. The location of these facilities should be reviewed to ensure that they are more centrally located to support research activities.**

Old Greenhouse Complex	**41**	**966 (Head house)** **1808 (Green house)**	**Poor**	• **Head house, working and preparation areas.** • **Greenhouses in poor condition. Glazing stained, rusting framework, bare earth floors.**	• **The glasshouses are in poor condition and require significant maintenance and recladding.** • **Given the age of these facilities, it is recommended that, as opportunities arise, glasshouse work should be relocated to the new glasshouse complex. The old glasshouse complex should be decommissioned and demolished to make way for new research buildings and facilities in this area.**
New Greenhouse Complex / Farm Operations (Head house)	**24**	**1427 (Green house)** **860 (Farm Operations / Head House)**	**Good**	• **Good quality glasshouse space.** • **TSO Farm Office and working area.** • **TSO storage.** • **Cucurbit working room.**	• **The greenhouses are in good condition.** • **The Farm Operations / Head house areas require some maintenance to improve functionality and appearances.** • **There is potential to build additional glasshouses within this area to leverage of the centralised services provided by the Farm Operations and Head House support buildings.**
Biotechnology Greenhouse Complex	**12**	**1532**	**Good**	• **Very good glasshouse complex which is currently underutilised – mainly because the glasshouse space is certified for work with GM plants.** • **Utilisation of the glasshouses should be reviewed and the certification changed to reflect the decreased demand for space to work with GM plants.** • **Potential to alter the glasshouse**	• **The certification status of Biotechnology Glasshouse Complex should be reviewed.** • **Opportunities for better utilisation of this space should be explored and promoted.**

				space to reduce operating costs. • The availability of the smaller glasshouse compartments may present opportunities for disease related work or other applications where greater levels of control are required.	
Screen Houses	**1-15**	**6960 (Combined area for multiple units)**	**Good to Poor**	• Numerous screen houses with some in very good condition whilst others requiring significant maintenance. • Utilisation of space within screen houses highly variable. • Significant potential for rationalisation of screen houses to ensure that a uniform standard is applied and that the space is utilised more effectively. • Significant amounts of surplus building materials, rubbish, waste and other materials located in this area should be removed to improve the amenity around these facilities and to improve overall presentation, hygiene and effectiveness of this area.	• The condition and utilisation of screen houses in this area should be assessed with the aim of providing more uniform standards and to ensure that the available space is being utilised effectively. • Screen houses in poor condition should be repaired or demolished once the on-going requirements/needs are established. • Space allocation within these facilities should be reviewed and a system to ensure effective utilisation should be developed. • The areas around the screen houses should be cleaned of surplus materials and waste to improve the safety, functionality and appearance of this area.

4.1: WorldVeg Facilities: Some Identified Health and Safety Issues

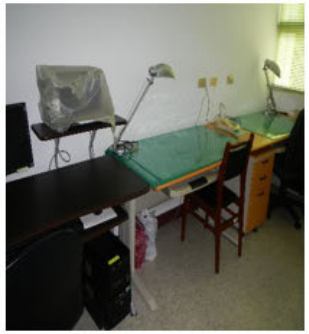
WorldVeg: Some Identified Health & Safety Issues

Laboratories: Gas Storage in poorly ventilated instrumentation rooms – toxicity and asphyxiation hazards (especially liquid nitrogen).

Laboratories: Hazardous Chemical Handling in poorly ventilated rooms – toxicity and contamination hazards.

Laboratories: Numerous rooms used for handling and storage of hazardous chemicals – poor ventilation, inappropriate storage and work areas.

Technical Services Building: Old drying ovens with exposed electrical connections, rusting and possible asbestos in door seals.



Laboratories: Offices and work stations with poor ergonomic design. Poor ventilation and air quality.

Laboratories: Poor ergonomic design around fume cupboards and other major equipment.

Laboratories: Heat generating equipment located in corridors and in rooms without appropriate ventilation to disperse heat load.

Laboratories: Power substation located in corridor area – fire hazard, old electrical wiring and potential electromagnetic interference.

Screen house Area: unsecured structure used for storage of used chemical reagent bottle – toxicity and contamination hazards.

Experiment Farm Area: Storm damaged/collapsed screen house structures – potential for injury staff and others accessing the area.

5. DEVELOPMENT OF CONCEPT MASTER PLAN

A concept masterplan is presented diagrammatically in Section 5.1. Key points pertaining to the master plan are:

- Creation of four distinct functional zones supporting key activities and enhancing capability, collaboration, workflows and interactions. The four activity zones are:

    - Research Capability: This zone brings together the new research laboratories, the administration building and the gene bank. Other research intensive buildings include the new seed extraction and treatment building, quarantine, entomology and a new seed health and screening center. The concentration of these research functions into a smaller area, with inter-connected buildings, will create an enhanced environment for staff interactions and provide a more visible "*front-door*" demonstrating WorldVeg's research capability.
    - Training, Collaboration and Community Hub: Overlapping with the Research Capability Zone, this zone creates opportunities for Worldveg's education and training programs, space for co-location of potential industry collaborators, exhibition space and associated areas that promote WorldVeg's activities to the broader research community and the general public. Central to this space is the role of the cafeteria and meeting rooms that create a hub for everyday staff interactions and a focal point for high profile functions. The relocation of the demonstration garden to areas next to the cafeteria, administration, the new laboratories and the gene bank will create a critical focal point for demonstrating the mission, capability and achievements of WorldVeg.
    - Plant Growth, Farm and Technical Support: This zone encompasses the critical plant growth facilities including greenhouses, screen houses, head house and farm support buildings, farm operation and other facilities important for the propagation of experimental materials from WorldVeg's research programs.
    - Staff Housing: The staff housing zone provide residential and recreational facilities for WorldVeg staff and visitors based at the Tainan headquarters site.

- A centrally located demonstration, teaching and production vegetable garden will showcase WorldVeg's research activities, the role of the gene bank in maintaining genetic diversity, and create a strong link to the plants grown within the garden and their dietary use and consumption within the cafeteria.

The garden will also provide enhanced amenities for staff and visitors and create a focal point for meetings, social activities and other gatherings.

- Enhanced energy and environmental sustainability for the headquarters site. These include:
    - Solar farm and the use of rooftop solar panels to offset reliance on grid power for the operations of the buildings and facilities on the headquarters site. The possibility of support, within the context of "proof-of-concept" and social stewardship and responsibility, from solar energy panel manufacturers and/or energy supply companies should be investigated.
    - Capture of rainwater for garden irrigation, cleaning and wash down of facilities, glasshouse watering and other opportunities to reduce the reliance on mains water supply.
    - Planting lower maintenance gardens that provide points of interest, shade and other amenity for staff whilst reducing the need for mechanical mowing and other energy intensive inputs.

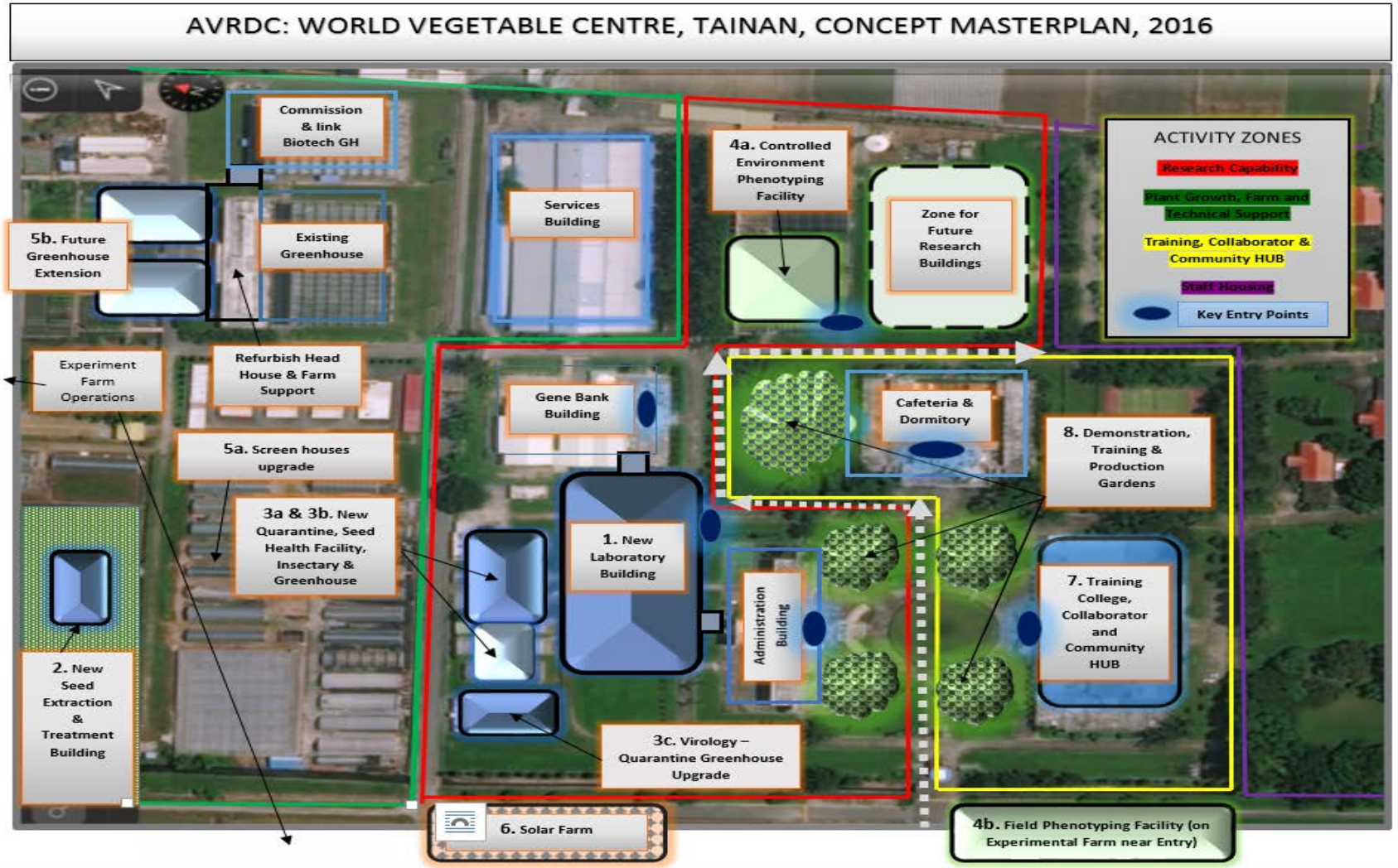
- Create opportunities for greater educational, public, partner and collaborator interactions by developing a training college, display areas, teaching farms, student interactive activities, public lectures and other opportunities to showcase and promote WorldVeg's vision, strategy and capability to a broad audience.

- Adopt open plan laboratory design principles as illustrated in the diagram 5.2. The tripartite model of laboratory design, with distinct areas for staff accommodation, open plan laboratories with centralised shared equipment areas, and dedicated technical and instrumentation rooms, is a model of laboratory design that is being adopted internationally. The open plan nature of the office accommodation, laboratories and other areas encourage staff interactions and promote the centralised provision and utilisation of increasingly expensive research equipment and instrumentation.

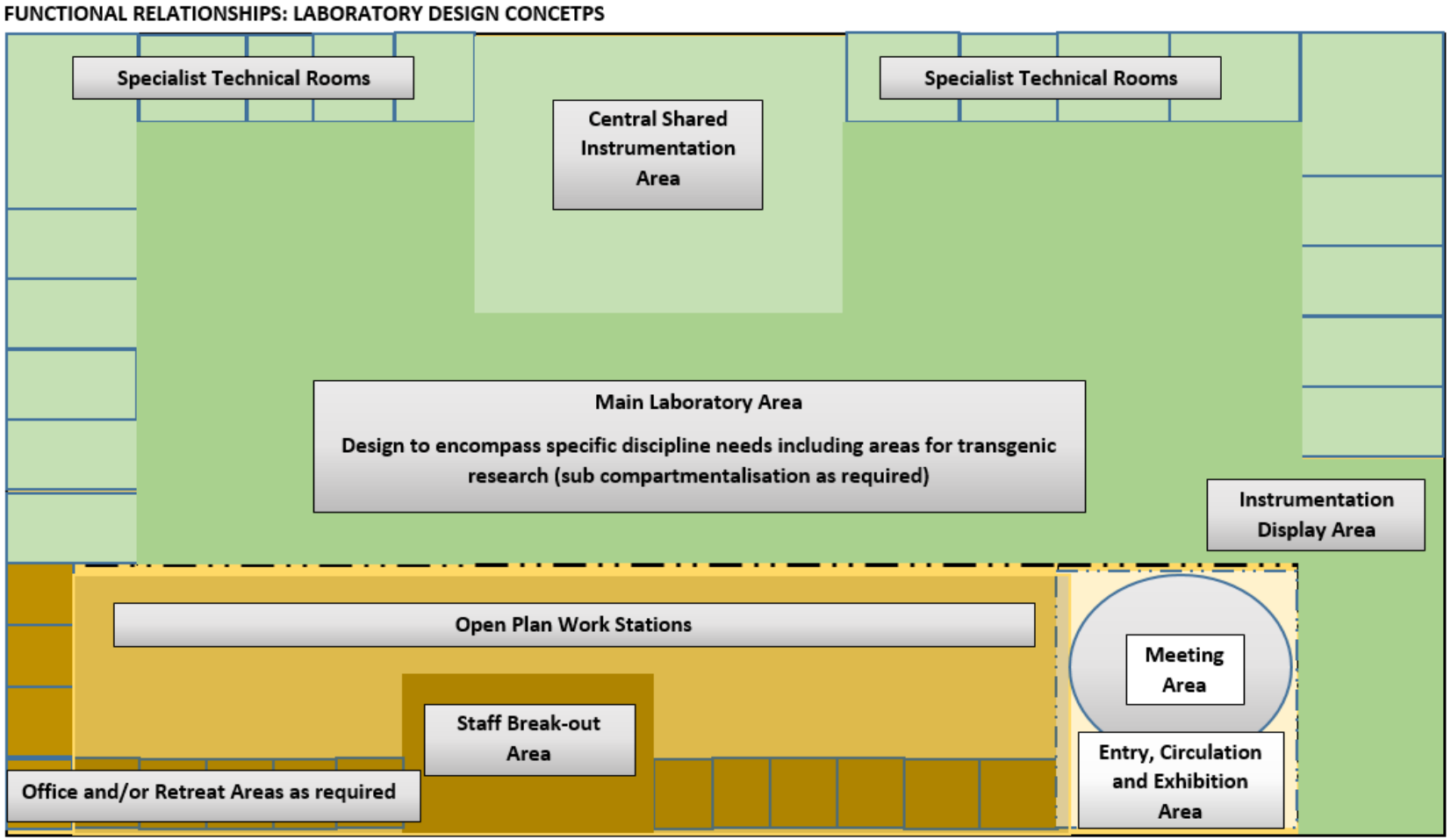
Further development of Concept Master Plan

To further develop the masterplan concept plans discussions were undertaken with Mr Alex Kuo, from AlexArch, Architects. AlexArch have considerable experience with the buildings at WorldVeg's Tainan headquarters site and were involved in the redesign of the Administration Building and a number of partial refurbishments in the laboratories and other facilities. AlexArch have created a number of conceptual drawings that are attached as a PowerPoint presentation alongside this report

5.1 AVRDC: WORLD VEGETABLE CENTER, TAINAN, CONCEPT MASTERPLAN, 2016



5.2 FUNCTIONAL RELATIONSHIPS: LABORATORY DESIGN CONCEPTS



6. IDENTIFIED INFRASTRUCTURE COMPONENTS, PRIORITY AND STAGING.

The key components in the infrastructure plan are identified in the table below.

Priority and Staging of Developments: Priority ratings are based on the need for WorldVeg to develop new research capabilities and address operational, safety, compliance and reputational risks. Three stages of infrastructure renewal and development are identified.

Infrastructure Component	Indicative Size	Notes	Priority and Staging
1.New Laboratory Building	4000m^2	Operational, Safety, Compliance and Reputational Risks. Explore funding opportunities and develop plans.	Priority 1 : Stage 1
2.Seed Extraction and Treatment Facility	900m^2	Operational, Safety, Compliance and Reputational Risks. Design of the facility is well advanced. Needed to address viroid contamination problems.	Priority 1 : Stage 1
3a. Quarantine and Seed Health/ Seed Sorting Unit	600m^2	Operational, Safety, Compliance and Reputational Risks. Explore funding opportunities and develop plans.	Priority 2 : Stage 2
3b. Quarantine Insectary and dedicated Greenhouse Facilities	Insectary 600m^2 : Greenhouses 800m^2	Operational, Safety, Compliance and Reputational Risks. Explore funding opportunities and develop plan.	Priority 2 : Stage 2
3c. Virology-Quarantine Greenhouse (Renovation)	Existing Building 608m^2	Renovation of existing building – incorporate into normal WorldVeg building maintenance program.	Normal Maintenance upgrade

4a. Controlled Environment Phenotyping	Medium through-put glasshouse / growth cabinets based system (800m^2 including glasshouse space and automation.	Enhanced Research Capability. Need to scope available technologies and establish suitability of systems for a variety of vegetable crops.	Priority 2 : Stage 2
4b. Field Phenotyping Facility	Based on Phenospex system scoping studies	Enhanced Research Capability. High throughput field phenotyping will significantly accelerate WorldVeg's trait identification, selection and plant breeding programs.	Priority 1 : Stage 1
5a. Screen / Net Houses: Rationalisation and Upgrades	Existing Buildings Combined area: 6960m^2	Optimise current screen house utilisation. Upgrade existing facilities and develop additional space as required.	Normal Maintenance Upgrade
5b. New Greenhouse Extension	500m^2	Future greenhouse development in exiting greenhouse zone. Improve / modify existing Biotechnology Greenhouse.	Normal Maintenance Upgrade
6. Solar Farm	TBD	Improved Energy Efficiency and Sustainability. Explore Sponsorship / Partnership opportunities with power suppliers, local industry solar panel manufacturers.	Priority 2 : Stage 2
7. Training College, Collaborator, Partner, Public Exchange Hub	Use of Existing Laboratory Building	Enhanced WorldVeg Role, Collaborative, Industry and Public Interactions. Explore funding	Priority 3: Stage 3

	3959m^2	opportunities and develop plans. Building could be refurbished in stages reflecting needs, funding opportunities and priorities.	
8. Demonstration, Teaching and Production Garden	Landscaping components	Research, Training, Demonstration and Staff Amenity. Creates focal point for the site to showcase WorldVeg's purpose/role and facilitate staff, collaborator, industry and public interactions. Provide enhanced staff amenities.	Normal Maintenance Upgrade or other funding opportunities.

9. SUMMARY OF KEY ISSUES, RECOMMENDATIONS AND NEXT STEPS

The following table summarises the Key Issues/Findings, Recommendations and Actions.

Issue/Findings	Recommendations
1. Further development of infrastructure zones and development of Infrastructure Master Plan.	➢ High quality concept diagrams and a prospectus to be further developed to assist with fund raising and engagement with potential donors.
2. Location and Construction of Seed Extraction and Treatment Building.	➢ Revised facility (with footprint 21mx42m) should be constructed in location indicated on the concept masterplan. Consider use of evaporation pit for waste chemicals rather than collection in underwater tank. ➢ The construction of the Seed Extraction and Treatment Building is the highest priority so as to address viroid contamination problems.
3. Development of new Laboratory Building.	➢ Work should be undertaken to design new 4000m2 laboratory building. Open plan tripartite laboratory planning principles should be applied - i.e. separation of staff accommodation in open plan office area; separate open plan shared laboratories; provision of specialist laboratory instrumentation rooms and zones for shared equipment. ➢ The laboratory design should incorporate any requirements for transgenic work. An area meeting GM regulatory requirements (with dedicated laboratories, services rooms, tissue culture and other related functions) would be incorporated into the laboratory design. ➢ The design of the laboratory should be undertaken in full

	consultation with research user groups to ensure that all needs and workflows are captured. ➢ The design of the open plan office areas need to reflect WorldVeg's philosophy and approach to staff accommodation. The development of "accommodation principles" may assist in providing guidelines to assist with the design of the new laboratories and other facilities. ➢ The construction of the new laboratory building is a very high priority.
4. Development of new Quarantine, Entomology and Seed Health Facility.	➢ The existing Entomology Quarantine Building and supporting Greenhouse should be replaced with modern facility that allows for enhanced workflows and risk management. The new facility should also incorporate a separate Plant Health and Seed Sorting Laboratory. These combined facilities will consolidate the higher risk quarantine activities. ➢ Depending on funding availability and building/operational logistics issues, these facilities will be critical to ensure the secure, effective and compliant management of all germplasm within WorldVeg. ➢ There is merit in the co-development of the Quarantine/Seed Health Facility and the Quarantine Insectary facilities. The development of these facilities are of high priority. ➢ International collaborators / multi-national companies may be a good target audience for funding, given the benefits afforded to them through their access to WorldVeg's Gene Bank. These facilities are critical to ensuring genetic integrity of the materials and facilitating their exchange

	internationally.
5. Improvements to Seed Bank Building.	➢ The entrance area to the Seed Bank Building should be improved to give the facility a greater presence for visitors and collaborators. Improved external signage and banners should could be used to highlight the facility. The new laboratory building should make provision for a direct connection to the Seed Bank building.
6. Rationalisation of green houses and screen house facilities.	➢ The utilisation of glasshouse and greenhouse space should be reviewed to ensure effective space utilisation. The process of space allocation across these facilities should be considered at the "whole-of-institute" level and not directly at the project level. The utilisation of the biotechnology greenhouse should be reviewed and, if appropriate, the GM certification removed or reduced to a smaller area. This glasshouse should be made more widely accessible. ➢ The old greenhouse complex should be decommissioned over time and activities transferred to the new greenhouse/biotechnology greenhouse complex. The old facility should be demolished to make way for new science support buildings in this zone. The development of controlled environment facilities (growth cabinets and walk-in rooms) in combination with high/medium through-put phenotyping systems would be a good development for this area.
7. Relocation of Demonstration, Training and Production Vegetable Garden.	➢ The Demonstration, Training and Production Vegetable Garden should be relocated to the more central locations as indicated on the concept masterplan. The central placement

	of this garden provides strong messaging around the role and activities of WorldVeg. The proximity of the garden to the laboratories, the Seed Bank, the Cafeteria and the Training/Collaborator/Public Hub will create a strong focal point, interest and provide good amenities for the staff and visitors. ➢ Given that demonstration gardens can create significant maintenance issues, careful selection of plants and co-planting with other plants of interest should be considered. Further development of the Masterplan will establish the most suitable location for the gardens. Other gardens may be planted that create points of interest and staff amenity, which can be achieved through a thematic approach -e.g. plants endemic to Taiwan and plants of commercial or cultural interest.
8. Development of Training, Collaborator and Public interaction HUB.	➢ The old laboratory building should be decommissioned and opportunities for redeveloped include: a training facility; demonstration/exhibition areas; office space for the co-location of collaborators, industry and research partners; and a space for public interaction (e.g. engagement of school, university students and talks and demonstrations for the general public and other stakeholders). ➢ The refurbishment of the old laboratory building may be staged depending on needs and funding opportunities. The building can also be used to accommodate WorldVeg staff, contractors and casual workers who are currently located in other facilities on the Tainan site.
9. Development of Plant Phenotyping Capability.	➢ The development of plant phenotyping will greatly enhance

	WorldVeg's research capability. As required, both controlled environment and field phenotyping systems should be deployed. Work on the selection of the field phenotyping platform should continue and the facility should be located in a prominent location (e.g. in field leading up to the main entry) to showcase these facilities. ➢ Special consideration needs to be given to the selection of phenotyping technologies to ensure the suitability for the plants of interest. Technologies in this area are evolving rapidly and the selection of data analysis platforms needs to be fully scoped to ensure that these systems can add value to research and breeding programs. A number of specialised international plant phenotyping facilities have been established over the last decade and consultation with these organisations can assist in identifying and evaluating available/developing technologies so that the most suitable systems are selected.
10. Review of major research equipment capability and development of a strategic replacement plan,	➢ The condition and provision of major equipment items (e.g. HPLC, Mass Spectrometry, Imaging systems, molecular biology instrumentation etc.) should be reviewed and a program for prioritisation and replacement should be developed. ➢ Once the new WorldVeg Strategic and Operation plans are completed, a CAPEX priority list should be developed in consultation with research group leaders to develop a program to replace dated equipment or to secure new types of instrumentation. A rolling annual process for the identification, prioritisation, funding and replacement of equipment should be developed and run centrally by

	WorldVeg management. ➢ Safety considerations should be an important factor in making to decisions around the prioritisation of research equipment.
11. Review of research infrastructure utilisation and development of a centralised system for the management, allocation and monitoring of space utilisation – especially greenhouse, screen house and farm operations.	➢ A centralised model to allocate and monitor the deployment and use of major research infrastructure (particularly, greenhouse, shade house, farm plots and major equipment items) should be developed. These facilities should be allocated and managed at the "whole-of-institute level' and not at the individual project level.
12. Implementation of a risk assessment-based Health and Safety Management System for laboratories, facilities, farm operations and related workplaces.	➢ A health and safety management system should be developed for the laboratories, research facilities and other workplaces that allow staff/management to: identify and document risks; develop and document control strategies, Standard Operating Procedures and Work Instructions; develop effective training programs; develop a system for the reporting and investigation of hazards and incidents; develop a system for incident documentation and record keeping; and develop on-going continuous improvement programs.
13. Development of an Environmental Management System to optimise energy and resource utilisation, manage and reduce waste.	➢ An environmental management system should be developed to promote and encourage efficient power, water and other resource utilisation. The management of waste streams should encourage on-going recycling of materials and address the handling of hazardous materials. Environmental improvements on the research site and on the experimental farm should be on-going to promote environmental sustainability principles. The development of

	a solar farm and/or the utilisation of rooftop solar panels for electricity generation should be investigated and co-investment opportunities with power companies or solar panel manufactures explored.
14. Demolition of severely damaged structures.	➢ A number of badly damaged screen houses and other structures located across the site should be removed. These present hazards but also may reflect poorly on the public image that the institute presents.

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