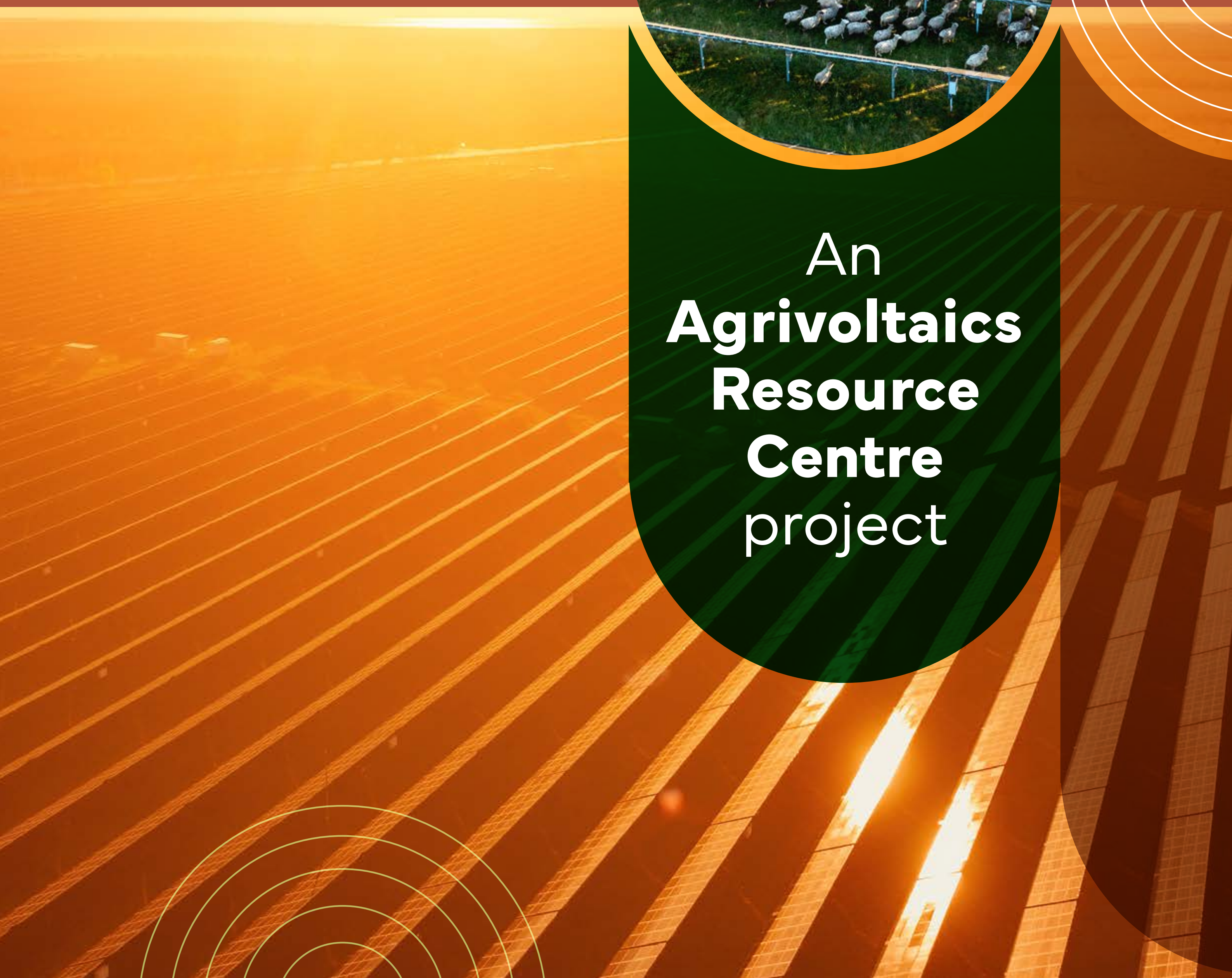
Pursuing an
Agrivoltaic future in Australia

An
Agrivoltaics Resource Centre
project



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Executive Summary

This report initiates an exploration of agrivoltaics, with an objective of promoting awareness and knowledge dissemination in this field. It presents findings from two workshops, which convened key stakeholders to achieve a multi-faceted understanding of known best industry practice, research needs, potential policy interventions, and the collection of feedback on the Agrivoltaic Resource Centre (ARC) concept.

Furthermore, this report articulates policy recommendations to encourage the widespread, successful adoption of agrivoltaic practices, thereby contributing to sustainable energy and agriculture integration.

Agrivoltaics (also referred to as 'agrisolar') refers to co-locating agricultural production systems with solar development. Australia's electricity system is transforming to one characterised by distributed solar, wind and storage. While critical for tackling climate change, replacing retiring coal fire power stations and meeting international commitments, there are both challenges and opportunities for regional communities and landholders that should be addressed in the transition.

In the first phase of this Agrivoltaics Resource Centre (ARC) project, stakeholders including farmers, government representatives, consultants, researchers, and solar developers, convened to explore the challenges and opportunities associated with the integration of agriculture and solar developments. Engagement occurred via two workshops, one on solar grazing and the other on horticulture and solar, as well as targeted consultation with key stakeholders. Participants also offered valuable insights for the development of an ARC website by reviewing a prototype homepage.

The second phase, yet to be funded, will be the creation and development of the ARC website.

The key partner for the two workshops held in October was EnergyCo, who are responsible for coordinating the development of the first five Renewable Energy Zones and two priority transmission projects across NSW.

Knowledge partners include Landcare NSW, NSW Farmers, Farmers for Climate Action, RE Alliance and Clean Energy Council.

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Co-locating our food and energy systems presents a promising pathway for farmers, solar developers and governments, provided it is executed with careful consideration and integrated thinking. Consultation during phase one of this project uncovered several major themes relevant to ensuring best practice adoption of agrivoltaics in Australia. These were:

- There is a community expectation that agricultural production be retained during the course of Australia's transition to renewable energy, and it presents good business opportunities for farmers.
- Agrivoltaics represents a feasible approach in the Australian context, but that co-locating agriculture and solar development comes with a series of challenges that require site-specific solutions.
- In the absence of comprehensive information and compulsion for large scale developers to adequately plan the implementation of agrivoltaics, adoption outcomes have been patchy and improvements are needed.
- There is an important role for government to partner with industry to ensure the right information and incentives are available to foster successful uptake of agrivoltaics.

The information gathering process for this project showed considerable optimism for the feasibility of agrivoltaics in Australia, but emphasised that change is required to ensure future solar developments are undertaken in a way that guarantees successful outcomes. Adoption has been slow in Australia, because knowledge gaps, technical and economic impediments, poor planning, and a lack of clear policy guidance at development stage have hindered uptake. This project has underscored the necessity for research and demonstration sites, supportive policy, and knowledge sharing to pave the way for adoption of agrivoltaics on a significant scale.

By delivering two workshops to canvass best practice, priorities and knowledge gaps, this Agrivoltaic Resource Centre (ARC) project aims to progress the co-existence of solar and farming in Australia, create policy recommendations for governments, shape an online ARC, and gather insights that will inform the development of best practice guidelines.

Compiled using insights and data gathered through the course of this project, the online ARC will be delivered once funding has been secured, and would represent the only dynamic and interactive agrivoltaics resource for the Australian context. It would operate as a centralised hub for farmers, developers, and researchers, and would provide useful information, case studies, research, links to international webinars and articles, and advertise demonstration days and ag friendly suppliers.

The policy recommendations arising from this project are discussed in a later sections of this report, and summarised here:

1. Where development is occurring on agricultural land, state planning instruments require development proposals to outline specific plans for co-locating agricultural production within large scale solar facilities as part of the EIS process.
2. In advance of impending large scale developments, the Australian government provide $200,000 to 1) develop initial best practice guidelines for developers, operators, and farmers for successful agrivoltaics adoption that includes standards for the different application cases and 2) facilitate knowledge transfer to stakeholders.
3. The Australian government collaborate with the renewables industry to co-invest in ongoing essential research into agrivoltaics in different areas marked for solar development, and for different farming systems such as grazing, viticulture and horticulture.
4. The Australian Government provide $215,000 to fund knowledge sharing through the development of the ARC including 0.1FTE to manage and update the resource over the subsequent three years
5. The Australian government develop a coherent framework of carbon and biodiversity incentives to maximise best practice agrivoltaics adoption, across both broadacre and horticultural systems.
6. There is an intergovernmental agreement between Commonwealth and State Governments to ensure consistent framework across Energy and Agricultural agencies for:
    a) Determinations of the extent to which agrivoltaics may be allowed to impair agricultural activity.
    b) Establishment of appropriate thresholds for land use, yield, soil, construction, water, synergies, system thinking, that may be referred to for receiving subsidies.
    c) The development of a framework that links agrivoltaic economic development with broader regional growth, decentralization and job creation.
7. The insurance sector co-operate to develop a workable and industry-wide grass height policy for solar facilities, recognising reduced risk during cooler months

Methodology

In the first phase of this Agrivoltaics Resource Centre (ARC) project, various stakeholders including farmers, government representatives, consultants, researchers, and solar developers, convened to explore the challenges and opportunities associated with the integration of agriculture and solar developments.

Engagement occurred via two workshops (attended by 30 people per workshop), one on solar grazing and the other on horticulture and solar, as well as targeted consultation with key stakeholders. Participants also offered valuable insights for the development of an ARC website by reviewing a prototype homepage.

The second phase, yet to be funded, will be the creation and development of the ARC online platform.

Photo courtesy of JR Howard

Background

Agrivoltaics (also referred to as 'agrisolar') refers to co-locating agricultural production systems with solar development.

Its adoption has been more prevalent in Europe and the United States over the past decade than Australia, primarily because of their dynamic of acute land use competition for productive agricultural land. While land use competition with renewables is not as statistically significant an issue here, community demand for maintaining broadacre agricultural activity within large scale solar developments has driven strong interest in agrivoltaics from the renewables sector and policy makers.

In Australia, solar grazing is the most common form of complementary land use for utility-scale solar farms. This reflects the baseline land use of large scale renewable sites in Australia, and the low feasibility of undertaking broadacre cropping or beef cattle enterprises among solar panels.

The task of co-locating solar and agriculture will become increasingly important to Australian policy makers and renewables companies. Looming deadlines to replace coal fired electricity generation has led to significant large scale solar development, and an impending burst of solar projects as new, strategic transmission infrastructure is built over the course of the 2020s.

State-based, large scale solar planning approval processes have increasingly taken into account concerns about loss of productive agricultural land, and developers are seeking to alleviate these concerns by proposing agrivoltaic systems to ensure developed land maintains agricultural output. For example, in NSW large scale solar developers are now generally required to undertake an agricultural impact assessment as part of their SEARS (streamlined secretary's environmental assessment requirements), quantifying the economic effects of lost agricultural production. To demonstrate a recognition of these effects and taking action to mitigate them, proponents are indicating an intent within their EIS to incorporate sheep grazing into their development.

Photo courtesy of BayWa r.e.

However, within their EIS as part of the planning approval process, developers have previously only stated an intent to adopt solar grazing, without providing information supporting meaningful planning to execute this intent. The consequence has been that existing solar facilities are poorly suited to agricultural production, because solar grazing production systems have been retrofitted to operate within the constraints of the constructed array.

This is an important issue to resolve if agrivoltaics is to be successful in the Australian landscape, and will require better information, planning, design, and construction outcomes to achieve best practice.

Although the application of agrivoltaics in horticulture is typically at a smaller (non-utility) scale, this project has also demonstrated substantial interest from developers and producers in Australia. For farmers, agrivoltaics represents an opportunity to generate power for export and secure a secondary income, to use behind the meter energy production for energy intensive horticultural production systems, and to utilise physical infrastructure to improve production outcomes. This could include enabling production of certain crops in regions where climatic factors limit production, but could be mitigated by solar infrastructure (for the shade they provide and improved water conservation).

In addition, Australia's urgent need to replace fossil fuels in the electricity network means small to mid-scale solar developments need to be considered more seriously. The strategic siting of solar above horticultural crops not only expands the available geographical choices for developers but also frequently positions these projects in closer proximity to urban centres and major load centres, resulting in reduced energy losses during transmission. Understanding where on the distribution network there exists capacity for more mid-scale renewables will be an important step in progressing agrivoltaics.

There are some important lessons that can be learned from overseas, particularly European experiences with horticultural production under solar panels. However, research and demonstration is required for climatic conditions and crops that are suitable for Australian producers to adopt. For an Australian context, the Clean Energy Council's guide to agrisolar for large scale solar contains useful information gathered from stakeholder consultation with proponents, graziers, and horticulturalists, and should be read in conjunction with the information gathered as part of this project, and outlined below.


Photo courtesy of JR Howard

Solar grazing

The task of successfully integrating solar production and agriculture in the Australian landscape is highly feasible.

Solar grazing can have clear economic benefits for both solar developers and graziers, and play an important role in achieving community support for solar development in rural areas. The following key objectives were identified during project consultations:

- Meet community expectations to maintain agricultural production on developed land.
- Achieve a sustainable farming system, i.e. optimal animal health and soil health outcomes.
- Provide cost effective grass management for solar developers.

There are several major challenges that need addressing to ensure this is achieved, which will require important knowledge gaps be filled, the availability of best practice information for proponents and graziers, and adequate planning and co-operation between sectors.

These issues are summarised below.

Challenges

1. Farming and solar production are very different activities
2. Minimal research and demonstrated success
3. Bespoke approaches are necessary
4. Misaligned incentives
5. Insurance-driven management

Insights

1. Grazing and solar can be co-located
2. Early design is better than retrofitting
3. Early design needs to be compelled
4. Best practice guidelines for all parties are needed
5. Current insurance requirements need to change
6. Biodiversity should be prioritised in low rainfall zones
7. Government policy will be a key driver of success

Challenges

When seeking to co-locate two land use activities with very different characteristics, challenges have inevitably arisen. When assessing previous efforts at solar grazing, it is apparent that solar developments have focussed on efficient and timely electricity generation, and not typically prioritised integration of agricultural systems central in planning, design, and construction.

The following is a summary of the nature of the challenges encountered so far, as evident from input from workshop participants and discussion with developers and graziers.

1. Farming and solar production are very different activities

The most obvious challenge associated with co-locating solar and sheep grazing is the very different nature of each enterprise, and their potential incompatibilities. These include:

- Knowledge: solar companies have little knowledge or experience of agriculture, and don't typically have this expertise readily at hand. This can limit the likelihood of successfully implementing a sheep production system, which is more technically complex than may be realised.
- Culture: cultural differences can affect effective day to day site management. Farmers often prefer to manage working relationships on the basis of trust and phone communication, and are averse to procedure and extensive paperwork. Contrastingly, developers' risk management processes require documentation of process and longer lead times for decisions. This is not always practical when managing sheep and can lead to frustration.
- Operations: the practicalities of mixing farming activities within an industrial site can be complex. This includes mustering sheep around panels, limited hours of access, the need for swift animal health interventions, managing pastures and weed control by concentrating sheep grazing, chemical withholding periods, and providing adequate water sources for stock.
- Co-ordination: bringing in another business entity can create co-ordination challenges, particularly when there are often separate facility owner and management businesses already needing to co-ordinate solar operations. Farmers grazing sheep may be unclear about opportunities to access the site, decisions about altering stock numbers, mowing requirements and chemical applications, and decisions about infrastructure improvements.

2. Minimal research and demonstrated success

There is limited prior research or real world experience in Australia where solar grazing is being attempted.

Information shared with the authors of this report include:

- Preliminary (unpublished) research undertaken by Agriculture Victoria on suitable pasture species for solar grazing in Northern Victoria.
- Various consultant reports for solar proponents on incorporating sheep grazing into solar.
- Project scope and methodology for a CSU research project recently commenced at Bomen Solar Farm, near Wagga Wagga.
- Various farmers that have experimented with grazing sheep and pasture management within solar facilities.
- Clean Energy Council guide to agrisolar for large scale solar.

While the work undertaken in real world operational environments by several farmers has provided valuable insights into the opportunities and challenges of solar grazing, there has been minimal investment in undertaking thorough research into, and demonstration of, best practice solar grazing systems.

Important questions remain unresolved to establish a comprehensive best practice framework for use by developers, facility managers, and graziers. These issues are outlined in a summary of research needs below.

3. Bespoke approaches are necessary

Any new agricultural enterprise needs to account for local rainfall, topography, soil types, and other environmental conditions that influence production outcomes. The need for a bespoke approach to production systems is even more acute when adding the significant variable of a solar array above pastures. This means that location specific planning and design is necessary, defying any preference (either knowledge deficit or economic) to take off-the-shelf agrivoltaics methods and apply them to any given solar proposal in any given landscape.

Location-specific decisions will be required about pastures that combine optimal biomass accumulation and quality of feed for producers, with grass height limitations, weed control, and panel height cost aspects for developers. The unique characteristics of each site will need to be accounted for in developing best practice systems.

A major challenge will be to encourage developers to incorporate the additional task of agricultural planning, into what is primarily viewed by proponents as an electrical engineering and construction exercise.

4. Misaligned incentives

A significant risk for successful adoption of solar grazing is misaligned incentives between developers, site managers, and graziers. If any of these parties are motivated to undertake their role to the detriment of the others, economic and production outcomes will suffer.

For developers, objectives are focussed on lowest cost construction and maximum output per dollar invested, avoiding unnecessary infrastructure construction costs, maintaining regulatory and insurance compliance, and obtaining community support for developments. Site managers (operations and maintenance) need to reduce OHS risk and damage to infrastructure, ensure ease of trafficability, maintain maximum grass height at lowest possible cost, and reduce dust creation. Graziers are driven by achieving feed quality, mustering ease, and maintaining sheep health.

There are currently issues affecting meeting each party's objectives. There will inevitably be trade-offs between multiple economic incentives, though competing objectives can be addressed by good planning. These potentially competing motivations include:

- A grazier's feed production objectives may conflict with developer and operator requirements to limit grass height. Certain varieties of taller grasses may benefit graziers, but increase the cost of maintenance to the operator, and create insurance risk to developers.
- Additional investment in production-friendly infrastructure (less dense panel spacing for mustering, providing handling yards, etc) occurs at the expense of the developer, yet the beneficiary of this investment is often the site manager, by achieving lower cost grass height management under contract.
- Contractual incentives to manage economic, regulatory and workplace safety risk may conflict with the economic imperative of immediate production decisions.

5. Insurance-driven management

Insurance companies have taken an extremely risk averse approach to fire risk within solar facilities, by imposing rigid and often unnecessary restrictions on grass height under solar infrastructure.

A common requirement from insurance companies is to enforce a 100mm grass height at all times, though there may be some flexibility applied during periods outside fire season.

This policy imposes excessive mowing/slashing activities that are counterproductive to achieving good ecological outcomes via germinating seed, maintaining agricultural production across seasons, and limiting herbicide use. It encourages poor pasture management, the proliferation of invasive weed species, dust and erosion, could potentially make grazing uneconomic.

Insights

A solar grazing workshop and direct discussions with stakeholders as part of this project provided excellent insights into how best practice solar grazing can be achieved. This input came from solar developers, researchers, and farmers with direct experience in implementing this system in the Australian context.

The key observations are as follows.

1. Grazing and solar can be co-located

There is widespread agreement from livestock producers and industry experts that sheep production is feasible within solar facilities. Graziers can gain access to an inexpensive feed source and operators and owners access to inexpensive vegetation management.

Reported benefits of solar grazing have included the following:

- Free or low cost agistment for graziers with sedate sheep breeds being sold into the trade market.
- Provision of livestock shade and shelter.
- Improved seasonal pasture quality/duration from shade and water runoff from panels.
- Enhanced wool quality.
- Protection from predators via perimeter fencing.
- Reduced cost of mechanical grass mowing.
- Incentive to maintain ground cover and reduce dust.
- Increased land productivity and community support for solar development.

Optimism about the potential benefits needs to be put in context. There are notable differences of opinion about the extent of likely losses or gains in production within this environment. This depends on assumptions about partially shaded feed production relative to baseline (non-solar) conditions, the positive and negative effects of solar infrastructure on animal health and handling, and the potential inefficiencies associated with managing co-located enterprises.

Past experience has not been optimal. In its March 2021 report on solar grazing, the Clean Energy Council claimed that over a dozen farms across Australia have implemented this system, though anecdotal reports suggest that it is not currently being utilised at all the farms identified in that report. More importantly, the current examples were overwhelmingly not subject to sound design and planning for solar grazing, and the developers and graziers spoken with for this project say their system could be much improved.

2. Early design is better than retrofitting

A key insight from industry consultation is that solar grazing systems require adequate planning and design prior to construction to avoid major problems later. Planning is required to ensure the following:

- Pastures are managed to a) avoid overgrazing and selective grazing and b) better manage grass heights and mowing maintenance via crash grazing.
- Sites require adequate trafficability and holding areas to enable effective mustering and application of animal health treatments.

Attempting to manage pasture and sheep handling is challenging in a single large paddock co-located with solar panels. Furthermore, retrofitting farm layouts with additional fencing, water points and handling yards/holding paddocks once the solar array has been installed is expensive and logistically challenging. It also carries risk that separate owners and operators are misaligned on capital investment and economic returns.

Solar developers need to be seeking advice from agronomists, livestock experts and graziers early in the design process. This will inform the following:

- Soil and climatic characteristics to inform pasture selection and preparation.
- Farm layout for pasture management, animal health and trafficability.

Pastures need to be established well in advance of construction to ensure their establishment and continuing viability, or existing improved pastures on site should be managed with minimal disturbance during the construction period. In the context of native pastures, minimal disturbance should be the primary objective.

3. Early design needs to be compelled

Previous experience of proposed solar developments is that construction design has been focussed on engineering, cost, and meeting planning approval requirements. To ensure that agricultural systems thinking is included in the design process, project proponents should, as part of the Environmental Impact Statement (EIS) process, be required to include specific plans for co-locating agricultural enterprises or biodiversity measures within the solar array.

4. Best practice guidelines for all parties are needed

Project contributors highlighted a lack of comprehensive information about implementing solar grazing, and the need for user-friendly best practice guidelines to provide necessary decision making frameworks.

Components of these guidelines would include:

- Suitable pasture mixes for various climatic environments and soil types.
- The economics of combining sheep grass and weed control with mechanical mowing/slashing and herbicide control.
- Optimal layouts for pasture management and animal handling, and their cost implications.
- Suitable sheep breeds and commercial flock management.
- Frameworks for contractual arrangements between owner/operators and graziers to ensure incentives are aligned.
- How regenerative practices can be incorporated.

5. Current insurance requirements need to change

The current insurance requirements for site management (especially grass height) are both restrictive and subject to unexpected policy change. These factors are a major impediment to encouraging agricultural production and an ecologically friendly sheep management system, instead incentivising excessive mechanical and chemical intervention to control grass, with the consequence of weed infestation, dust, and erosion.

Unfortunately, highly restrictive grass height policies during low fire risk periods do little to reduce material risk of fire, yet can have a significant effect on the economic and agronomic feasibility of grazing sheep on solar farms.

6. Biodiversity should be prioritised in low rainfall zones

In arid and semi-arid areas characterized by an annual rainfall of less than 250 millimetres, an ecologically sensitive option is to employ rollers instead of graders during construction and to incorporate the seeding of native plants beneath solar panels. This approach offers numerous advantages, primarily centred around the conservation of soil structure and the promotion of low-growing plant growth for biodiversity enhancement.

One significant benefit is the substantial reduction in dust and maintaining lower temperatures beneath the solar panels, contributing to enhanced panel efficiency. Furthermore, the sequestration of soil carbon becomes a valuable mechanism for attracting carbon credits. Emphasizing biodiversity as a foundational element in solar developments not only positively influences adjoining properties but also has broader implications for the entire landscape.

7. Government policy will be a key driver of success

Successful implementation of best practice solar grazing will require government intervention, or current ad hoc approaches will continue as the impending burst of solar development takes place. Key focus areas for the government should be:

- Compelling planning for best practice via state-based planning instruments.
- Incentivising uptake of solar grazing via ESG incentives, including carbon and biodiversity frameworks.
- Funding research and knowledge transfer to foster the implementation of best practice agrivoltaic systems.


Photo courtesy of BayWa r.e.

Research needs

Until now, solar grazing uptake has occurred on the basis of developers and graziers solving localised issues on an ad hoc basis, with variable outcomes. Decisions are being made using limited information from anecdotal experiences in different locations.

Little formal research or landscape-scale analysis has been done to fill key information gaps confronted by developers and graziers planning new developments and partnerships. While there are emerging efforts to quantify variables across pasture species and local agronomic conditions, significant gaps remain to inform best practice across the renewables sector.

The following issues require a formal process of investigation and knowledge transfer prior to the construction of major new developments commencing in the next 18-24 months. These include:

- Pasture options for various climatic environments and soil types.
- The economics of combining sheep grass and weed control with mechanical mowing/slashing and herbicide control.
- Regional solar grazing feasibility - Investigate the viability of grazing cattle under solar panels in regionally specific areas, such as Central Queensland.
- Optimizing solar farm layouts - Research best practice for incorporating cell grazing fencing to maximize animal production and their cost implications. Explore different grazing methods, such as annual strip grazing and seasonal heavy campaigns, to reduce fire risk.

These research and knowledge transfer efforts should be focussed on potential grazing systems in climatic and soil environments prevalent in regions (e.g. NSW REZ) where large scale development is about to occur.


Photo courtesy of Fraunhofer ISE

Horticulture

In contrast to established practices abroad where solar integration with horticulture and broadacre cropping has proven successful, this remains an emerging field in Australia, with limited examples to showcase best practices and suitable technologies. One of these examples is Agriculture Victoria's trial of solar panels over part of a pear orchard based at the Tatura SmartFarm.

International studies have highlighted several benefits associated with this approach, such as enhanced crop yields in the case of certain produce like berries, fruit trees (apples, pears and soft fruits), asparagus, garlic, hops and leafy greens. Solar over vineyards has also demonstrated benefits to the sugar and alcohol content of grapes given the fruit's sensitivity to hot weather. Additionally, overseas research has indicated advantages including increased soil moisture, reduced irrigation demands, protection from excessive heat, and safeguarding against frost and hail damage.

In Australia, enabling more farmers to contribute renewable energy into the distribution network not only diversifies their income base but also grants them a stake in shaping the evolving energy landscape. The opportunity for horticulture or cropping under solar, lies in the sub-5MW solar developments connected to the distribution network, ideally providing behind the meter power when needed by the farm business and exporting for the remaining time.

Challenges

Given the integration of solar panels and horticulture is still in its nascent stage within the Australian context, there exists a significant need to gather data, assess technical feasibility, understand economic aspects, and embark on research efforts in order to unlock its full potential. The following is a summary of the nature of the challenges encountered so far, or foreseeable in the future as evident from input from workshop participants.

1. Developers often lack a comprehensive understanding of the diversity of farming systems and commodities when considering solar sites. It is important to recognize that different renewable solutions are suited to different farming systems. For example, extensive farms may benefit from taller solar structures that offer shade and shelter for dairy operations, while flexible solar film may be more suitable for berry production that relies on polytunnels.
2. Farmers are dealing with the complex challenge of balancing competing demands on their land for carbon, food and energy generation. Finding the optimal equilibrium among these demands will be critical for addressing future food security and climate change.
3. A tension exists between developer and farmer needs and objectives. Increasing the height of panel structures can be more expensive acting as a disincentive to developers but is useful for farmers wanting to use tractors and equipment beneath panels. Government intervention may be necessary to mediate and find solutions that align the interests of both parties.
4. The economics of agrivoltaic systems are still unknown in Australia making working with equity partners challenging as well as managing risks to other enterprises. It is expected there will be difficulty in meeting return on investment (ROI) expectations of capital partners given the lack of examples and data in this field.

Insights

1. Understanding the economics of agrivoltaics in Australian horticulture is largely unknown

Given agrivoltaics over horticultural crops is new in Australia, there are existing challenges with understanding financing systems and cost-benefit ratios and subsequently selling this to stakeholders. The working capital requirements and payback periods are unknown for agrivoltaic systems as well as determining the optimal financing models, including debt verses equity.

Furthermore, it can be difficult to predict crop and energy values for a site, as prices fluctuate significantly for produce, and predicting yield becomes challenging in variable climates.

2. The distribution network could play an important role in locating agrivoltaic systems in the regions

The electricity network is physically constrained in many regional areas, however understanding where spare capacity exists on the network, will enable the export of power into the grid, opening up opportunities for siting new mid-scale solar projects in farming/horticultural regions that were otherwise inaccessible. The CEO of Essential Energy, the Distribution Network Service Provider in NSW, recently stated that its network could host 2.5GW of additional capacity with no augmentation to the grid.

3. Planning tools can either discourage or encourage innovation when combining solar and farming

Renewables and agricultural land assessments are treated differently in different State Planning processes. If agrivoltaics is to thrive and goals around food security and net zero are to be achieved, these planning instruments must be much more integrated in their approach and encourage innovation and dual use land.

International insights from the Fraunhofer ISE

4. Land scarcity and energy laws have driven regulatory reform in Europe

Land scarcity has driven legislation and regulatory reform supporting agrivoltaics in European countries.

Agrivoltaics interacts with many laws such as Safety, Energy, Agriculture, Constructions and Tax so these all need to be considered. Most incentives and changes in regulations came initially from Energy Laws with the other areas following.

The Fraunhofer ISE created specifications for defining agrivoltaics in Germany that included limiting the loss of agricultural yield, limiting soil erosion and damage and that guarantees decommissioning without further damage to soils and construction residuals. These specifications were created to provide a base for regulation.

5. The economics of agrivoltaics can be competitive when considering the system holistically

Shared knowledge and economies of scale are yet to be realised in the new application of agrivoltaics but they still have to compete with established technologies. Agrivoltaics can be competitive with ground mounted and rooftop PV but it does depend on the set up. Investment costs are usually higher with agrivoltaics due to construction and infrastructure being more complex having to fit with the farming context. Construction timeframes can be constrained in that it must take place during low agricultural activity and companies must take care to not damage the soil.

However as the maintenance of land is an existing farming activity, this lowers operating costs for developers. In addition, often fencing is not required when solar is placed over horticulture (as it is with ground mounted) further reducing costs.

Increased community acceptance for solar developments can result in less delays and opposition, positively impacting a project's budget.

Various business models for agrivoltaics exist in Germany, however generally farmers wouldn't own or operate the solar system but rather get paid for electricity generated or from leasing their land. The table below taken from Fraunhofer ISE's presentation slides illustrates different owner/operator models.

Overview of Agrivoltaics
Business models

Configurations of different agrivoltaic business models (based on Schindele et al. 2019)

Business model	Function			
	Providing land	Agricultural management	Providing the PV system	Operating the PV system
1. Base case	Farm			
2. External land ownership	Land owners	Farm		
3. External PV investment	Farm		PV investors	Farm
4. Cultivation and operation only	Land owners	Farm	PV investors	Farm
5. Cultivation only	Land owners	Farm	PV investors	PV operators

What should a farm ideally bring to the table?

Beneficial factors for the economical implementation of agrivoltaics:

- A good connection to the grid in terms of proximity and capacity
- Row cultivation
- Permanent crops
- Protected cultivation
- Low employment of machines/low clearance height
- A large, contiguous area (> 1 hectare)
- A low slope
- High and flexible energy consumption (e.g. cooling, drying, processing)
- A willingness to invest

In Australia, to address the higher costs of agrivoltaic systems, Governments could encourage market value by offering small premiums for corporate Power Purchase Agreements (PPAs) with ESG/SDG values.

6. Microclimates created under solar are generally positive for farming, but at times can be negative so must be considered carefully

The Fraunhofer ISE, 'APV Guidelines for Germany' describes the microclimates that can be created by the addition of solar panels over crops. These are listed below and are important considerations for agriculture.

- The solar radiation available to the plants can vary depending on the technical design (e.g., distance and orientation of PV modules). Reducing the radiation by about one third is considered an acceptable benchmark for Germany.
- The lower the height of the supports, the more pronounced the microclimatic changes.
- The soil temperature and to a lesser extent also the air temperature is reduced on particularly hot days.
- The wind speed can decrease or increase depending on the orientation and design of the system. This means that wind tunnel effects and their impact on plant growth should be taken into account during system planning.
- Soil moisture losses are reduced under agrivoltaics, while the air moisture level can simultaneously increase.

Photo courtesy of BayWa r.e.

Research needs

The use of solar panels over crops is a new application in Australia, so significant research and data is required to inform best practice. Below is a summary of the research needs highlighted by workshop participants and with input from the Fraunhofer ISE in Germany.

Southern hemisphere and Australia-specific data is needed due to varying soils and climates. Specifics that need investigation include:

- Funding demonstration sites in diverse climates/regions.
- Encouraging collaborative trials by CSIRO, Hort Innovations and Agrifutures.
- Establishing a Cooperative Research Centre (CRC) focused on agrivoltaics.
- Setting up a network/open database for data sharing.
- Establishing consistency in research methodology.
- Develop modular standard monitoring for agrivoltaic systems to ensure the research gaps in Australia are addressed. (Which parameters are a 'must-have' or optional? Where do the sensors need to be installed? How many (at least) sensors are needed? How often should be measured?)

The identification and prioritizing of relevant synergies of agrivoltaics in Australia and quantifying their potential will assist in understanding where best to target adoption. The following questions need investigation:

- Where are the land-scarce regions?
- Where are the hot, dry environments?
- Which regions will be most affected by climate change and/or solar farms?
- Where are the areas on the distribution network where capacity aligns with suitable horticultural/cropping zones for agrivoltaics.
- Considering Australia's high solar resource, identify areas with highest drought attenuation potential (Schweiger and Pataczek 2023) and where water availability can be improved by agrivoltaics.

The identification of investment risks and business opportunities, plus developing strategies and policy recommendations to address these will progress agrivoltaic uptake. Specifically:

- Determining which crops are suitable for agrivoltaics, e.g., garlic, berries, leafy greens, cut flowers, melons, and pumpkins.
  - Investigate with simple shade experiments: What crops, and horticultural crops would grow best in part shade in the Australian climate?
  - Undertake market analysis: What crops and horticultural crops are relevant in the Australian market?
- Studying the impact of microclimate changes on crops, including heat/frost risk and light intensity on yield and quality.
- Valuing crop loss mitigation due to hail, wind, excessive temperature stress, and frost, including data on extreme weather events in the face of climate change.
- Valuing potential savings due to the elimination of necessary recurring or continuous operational expenses, e.g. hail nets, foils, electricity (for water collection and treatment or for post-harvest processes, such as cleaning, packing and refrigeration), land lease.
- Assessing additional soil carbon from agrivoltaics/shading.
- Supporting CSIRO's 'responsible innovation' model.
- Identifying in which cases intercropping or overhead agrivoltaics can be a solution to operational/local/climatic/economic problems.
- An analysis of Australia's PV market and developments (solar panels, substructures, integration of water management) will enable a better understanding of designs that assist water conservation and capture and effectiveness of novel configurations of solar cells and panels (bifacial, semi-transparent, chequerboard pattern etc.)

It is essential that industry and legal partners are included in R&D projects to aid faster dissemination and knowledge transfer to private markets and to influence policies as well as the development of innovative agrivoltaic system designs.

As with solar grazing research, methodologies should include technical scientific research at university and departmental level, analysis of industry best practice by industry professionals, and a coherent method for knowledge transfer to stakeholders.

Questions posed by the Fraunhofer ISE for Australia to consider re: horticulture and solar.

1. Where is the highest potential in Australia – feasibility/GIS based study? Which region and which applications are best? This will help prioritise research, demonstration sites and also identify research gaps.
2. What are the barriers including legal barriers to address?
3. Are all stakeholders involved throughout the process? Frequent webinars and roundtables could involve and consider perspectives of all stakeholders
4. To develop local skills and knowledge, are Governments interested in becoming pioneers through 'model regions'?
5. Continuing monitoring – pilot projects dedicated to agriculture, technical, economic and social studies. What data is the most promising for the market uptake of agrivoltaics in Australia?

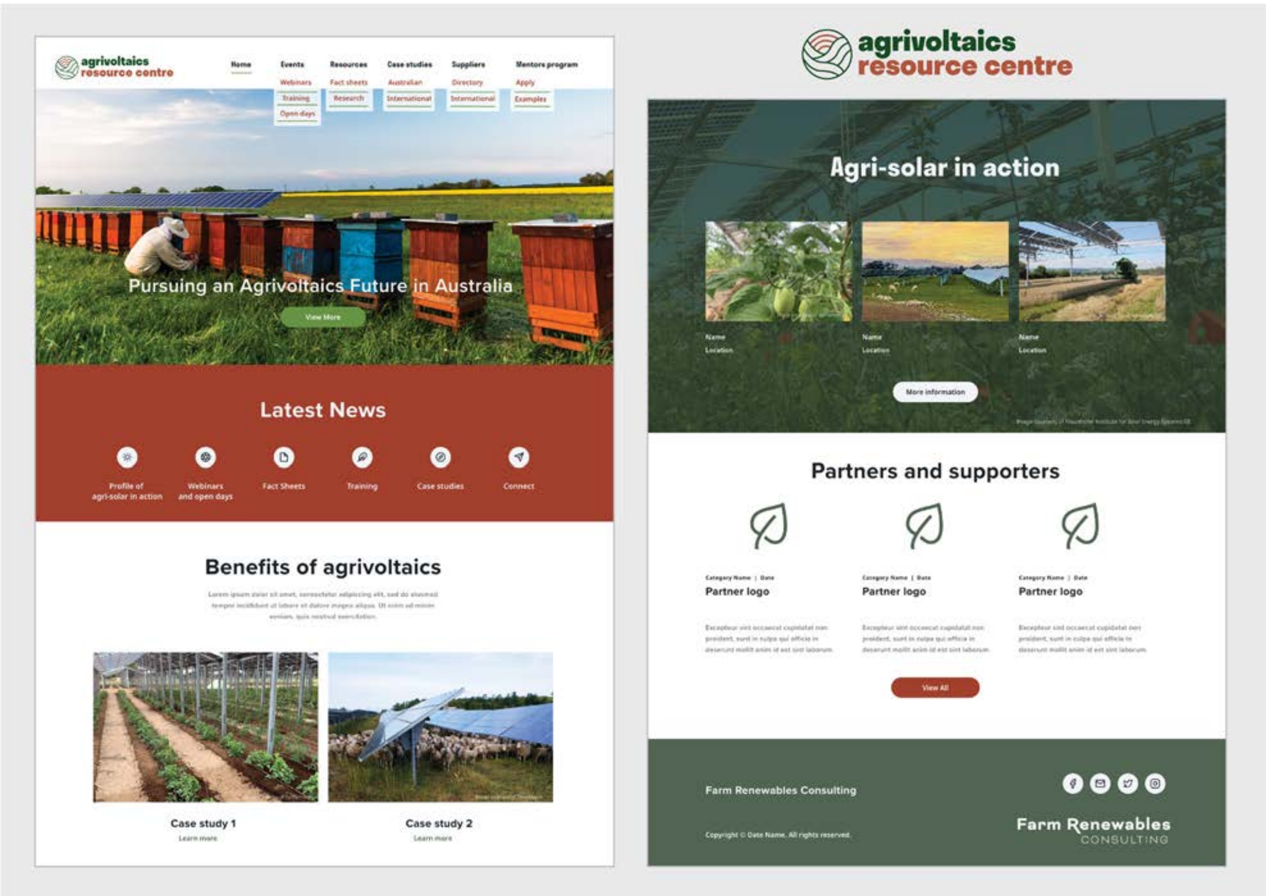
Knowledge Sharing And The Agrivolatics Resource Centre

The following insights were provided by workshop participants;

1. Farmers need to assess what they currently have, and what they could do under solar.
    - Exploring the possibility of implementing agrivoltaics with novel crops adapted to projected local, climatic conditions, to local communities' needs and/or to increase food resilience.
    - Fitting the infrastructure necessary for agrivoltaics around the existing growing, harvesting and maintenance equipment requirements.
2. Ensure farmers are aware of their options and can continue farming to some extent and that they engage with developers early to express agrivoltaics intentions.
3. Document approval processes and contractual arrangements for different projects from the beginning and provide organised information as future guidelines for interested parties.
4. Develop business models based on experiences/case studies.
5. Educate consultants (electricity production and use on farms) for farmers about agrivoltaics for faster dissemination.
6. Educate consumers about agrivoltaics so produce can attract a premium.
7. Improve community awareness about the co-location of solar and farming.
8. Combine interdisciplinary research capacities/skills and encourage collaborative research.

Feedback provided at the workshops regarding the mocked-up home page of the ARC included;

- Adding an interactive map to see where agrivoltaic projects are located around Australia.
- Including a list of research bodies and research projects (to reduce repetition and aid collaboration).
- A directory of people/ working in the agrivoltaics field as well as services specializing in ag and energy such as lawyers, accountants, financiers etc.
- A page on regulations and policy including how State /REZ planning processes interact with agrivoltaics.
- Include Guidelines for farmers, developers, planners (when developed).
- Create a decision tree to assist with early planning for agrivoltaics.
- Testimonials from farmers.
- Facilitate a Community of Practice, linked to Energy Smart Farms.



Policy Recommendations

Consultations as part of this project have informed the following policy recommendations:

1.

Where development is occurring on agricultural land, state planning instruments require **development proposals** to outline specific plans for co-locating agricultural production within large scale solar facilities as part of the EIS process.

2.

In advance of impending large scale developments, the Australian government **provide $200,000** to 1) develop initial best practice guidelines for developers, operators, and farmers for successful agrivoltaics adoption that includes standards for the different application cases and 2) facilitate knowledge transfer to stakeholders.

3.

The Australian government collaborate with the renewables industry to **co-invest in ongoing essential research** into agrivoltaics in different areas marked for solar development, and for different farming systems such as grazing, viticulture and horticulture.

4.

The Australian Government **provide $215,000** to fund knowledge sharing through the development of the ARC including 0.1FTE to manage and update the resource over the subsequent three years.

5.

The Australian government develop a coherent **framework of carbon and biodiversity incentives** to maximise best practice agrivoltaics adoption, across both broadacre and horticultural systems.

6.

There is an **intergovernmental agreement** between Commonwealth and State Governments to ensure consistent framework across Energy and Agricultural agencies for:

a) Determinations of the extent to which agrivoltaics may be allowed to impair agricultural activity.

b) Establishment of appropriate thresholds for land use, yield, soil, construction, water, synergies, system thinking, that may be referred to for receiving subsidies.

c) The development of a framework that links agrivoltaic economic development with broader regional growth, decentralization and job creation.

7.

The **insurance sector** co-operate to develop a workable and industry-wide grass height policy for solar facilities, recognising reduced risk during cooler months.

For more information please contact Karin Stark, hello@renewablesinagconference.com.au

Photo courtesy of BayWa r.e.

Appendix

Other comments recorded as part of the ARC workshops below.

Operational

1. Conduct comprehensive soil tests to assess soil nutrition and balance soil before solar construction. Enhance organic matter and microbial activity pre-construction while minimizing disturbances during construction.
2. Plan for end-of-life scenarios, including decommissioning, renewal, or rehabilitation of assets.
3. Address farmer requirements, such as crop selection, crop management, incorporation of regenerative agriculture, and the compatibility of existing agricultural equipment with agrivoltaic crops.

An **Agrivoltaics Resource Centre** project