Appendix D

Site Management and Integration of Agriculture

NEOEN GOORAMBAT EAST SOLAR FARM

SITE MANAGEMENT AND INTEGRATION OF AGRICULTURE

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Executive summary:

The placement of large solar installations in agricultural regions of Australia provides *an opportunity to develop an integrated approach, whereby the land can be sustainably used for both food/fibre and energy production.*

A review of scientific literature has demonstrated that such integration, referred to as 'agrivoltaic systems', is certainly feasible. However, the specific means of integration needs to be tailored according to site and the design of the photovoltaic arrays.

The key aspect of investing in an agrivoltaic approach is that *land stewardship becomes a key aspect of site management*, which means that site issues such as groundcover and dust suppression, weed and pest management are managed proactively and cost-effectively within a productive, sustainable system. Furthermore, responsible land management under a solar farm can maintain the value of the natural capital and sequester soil carbon, which in the event of the solar panels being decommissioned after 30 years, means that this land can be returned to highly productive agricultural land.

A range of options for agrivoltaic trials are presented, with all options providing both agricultural and land management benefits. Importantly, the specific land management option adopted is actually less important than the fact that by committing to actively manage the land within the envelope of the solar farm, Neoen would be demonstrating an explicit commitment to responsible land stewardship.

Neoen already uses grazing as a site management at several solar farms and are committed to investing in further trials of agrivoltaic systems at the Goorambat East Solar Farm. Such investment will be guided by quantitative benchmarks in the Operational Environmental Management Plan, to be prepared at a later date, which demonstrates a commitment to responsible land stewardship.

If Neoen were to commit to developing an agrivoltaic system at the Goorambat East solar farm, it would surely be a 'triple win' for all involved:

1. Provision of solar power
2. Economic benefit to landholders and community through secure investment in the region
3. Environmental benefit through maintaining natural capital and increased soil carbon, which would further mitigate any Greenhouse Gas emissions of the Goorambat site (including manufacture of construction materials and panels).

The following report provides a review of relevant peer-reviewed literature, key issues to be considered in responsible land management, and a range of options for the provision of integrated solar and agricultural production.

Review of current published knowledge – Integration of solar and agriculture

The placement of large solar installations in regional areas of Australia has significant benefits in regard to alternative energy production, economic growth and alternative income sources in areas which are predominantly dependent upon agricultural production. With an increase in the number of large solar installations in highly productive agricultural areas, there is an opportunity to explore avenues for dual purpose land use, whereby the land can be productively used for both food and energy production.

The interaction between agriculture and alternative energy sources, especially photovoltaic (PV) systems has received a lot of attention in the local and international scientific community over the past five years, with a new term coined in 2011 of 'agrivoltaic' systems (Dupraz et al, 2011a). The concept behind agrivoltaic systems is the co-location of solar and agricultural systems for mutual benefit. This co-location concept has been applied in a variety of research environments, in which solar and agricultural production has been combined. The variance in interpretation of this approach around solar panel placement and density means that there are no clear conclusions around the impact of solar panels on the associated plant-soil environment. However, some key examples from the available literature are given below.

Example 1.

Dupraz et al (2011a), was one of the first to develop an agrivoltaic system at Montpellier, using PV panels mounted 4m above the ground, placed in rows 44.8m long, which resulted in a 59% vertical projected cover of the ground area. The system was then split into two parts with different densities of PV panels (full- described above, and half). Yield of durum wheat was reduced under the full density panel arrangement due to reduced light, with no yield penalty measured under half density arrangements.

Dupraz et al (2011a, 2011b) used Land Equivalent Ratios to compare conventional systems of separation of agriculture and energy production, to the combined agrivoltaic system at different densities of PV panels. Modelling of light transmission and crop productivity indicated that combining the two systems into an agrivoltaic system may increase total productivity by 35-73%.

As a concept, the elevation of PV above farming land (4m height) provides the maximum potential for mutual benefit, due to the PV panels being placed beyond the influence of farming operations, with farming operations and machinery access being relatively unimpeded by the presence of the PV array. However, the trade off in such a system is the cost of infrastructure and maintenance access, which is likely to increase as the scale of the PV installation increases.

The reduction in plant growth due to shading is dependent upon plant choice, with different plants being able to deal with different shading levels, due to varying levels of radiation use efficiency. For example, wheat may not be able to respond well in reduced light conditions, whereas shade tolerant crops like lucerne, clovers and pasture species may thrive under those conditions (Dinesh and Pearce 2016). This was also found by Marrou et al (2013), who found that solar panels only reduced plant growth rates of vegetables and durum wheat during early growth stages, with no growth penalty once crops were established.

Example 2.

Using a 4m high agrivoltaic system, Amaducci et al (2018) found that the shading under agrivoltaic systems in North Italy reduced radiation which affected mean soil temperature, reduced evapotranspiration and associated water usage of maize, providing more favourable conditions for plant growth than in full light. Under rainfed conditions, average grain yield was higher and more stable with varying rainfall under the agrivoltaic system than under full light. The advantage of growing maize in the shade increased proportionally in with low water availability, which indicates that agrivoltaic systems could increase crop resilience to climate change.

While the previous examples have been using 4m high fixed PV arrays, a small amount of work integrating solar and agriculture has also been reported using more traditional arrays of PV panels closer to the ground (1-2m height).

Example 3.

Adeh et al (2018) describe a 6ha agrivoltaic solar farm and sheep pasture was established at Oregon State University. The site consisted of PV panels arranged in east-west orientated strips, 1.65m wide, held at 1.1m above ground at the lowest point and inclined southward with a tilt angle of 18°. A pasture was established prior to panel construction, which was not irrigated, and experienced water stress.

Micrometeorological, soil moisture and plant growth measurements were conducted between full, partial and non-shaded areas. Significant differences in mean air temperature, relative humidity, wind speed, wind direction and soil moisture were observed. Areas under PV solar panels also maintained higher soil moisture throughout the period of observation, due to increased water use efficiency in the shaded areas. A significant increase in late season plant biomass was also observed under the PV panels (90% more biomass), and areas under PV panels were significantly more water efficient (328% more efficient).

This suggests that plant growth may be sustained longer in the presence of PV panels in water-limited systems, which applies to most of the Australian agricultural dryland systems.

Example 4.

A similar system has been developed in India (Patel et al, 2019), whereby small scale, labour intensive agricultural production has been developed around a conventional array, to demonstrate the value of maintaining the productivity of a solar installation in an agricultural zone. In addition to the benefits inherent in producing food from an area otherwise non-productive, improvements in soil health were noted due to consistent vegetation cover over the soil surface, preventing soil erosion. It was suggested that the vegetation might have a cooling effect, keeping the temperature of the panels 1-2 degrees lower than ambient, but no results were presented.

Key findings from review:

1. An exhaustive search of Australian literature suggested that while there are some articles in newsletters, popular press and on websites discussing the potential for agrivoltaic type systems to add value to large solar farm installations, there is a dearth of peer-reviewed published research from Australian systems investigating the interactions between PV panels and the soil-plant environment and microclimate. All available peer-reviewed literature was from international research groups.
2. Popular press articles in Australian media support the use of sheep for opportunistic grazing under solar panels.
3. Agrivoltaic systems generally refer to PV panel arrays mounted at 4m above the ground to allow uninterrupted plant production and machinery operations but can be adapted to any design and configuration.

4. The effect of panels on plant growth, soil moisture and microclimate can be negative, positive or neutral, subject to plant species, climate and solar panel placement, angle and height from the ground.
5. Integration of best-practice agricultural activity with large scale solar farm installations will reduce the tension of conflicting land use for food/fibre and energy.

Key areas to be considered for site management and agricultural activities

In addition to the specific agricultural activities to be considered, there are a range of items to be considered in site design for responsible and sustainable land management.

1. *Fire management*

Proactive fire management at the minimum will require the following and should be considered in consultation with the Victorian Country Fire Authority (CFA):

a. Accessible water supply

A large reliable water supply needs to be established on site (in addition to any wetlands and seasonal watercourses). This water supply may be either as a large earth tank, or large water tanks with gutters (to catch all water which falls on it). This water will be needed to support fire suppression. A fire may start as either a grassfire from surrounding paddocks, or as an electrical fire from within the solar farm. Either way, a response from the local fire brigade will require access to the site for asset protection. Ready access to water may increase the effectiveness of the responding brigades.

This water supply may also be used if required for watering points for any stock on site.

b. Familiarisation of site by local volunteer fire brigades

As the first responders to any fire activity on or near the site, providing the local brigades with an understanding of the site and the specific issues associated with fire fighting in a power generating site will increase the effectiveness of fire suppression.

c. Fire breaks around the site.

During the summer fire danger period there needs to be fire breaks maintained around the site, as cultivated areas devoid of vegetation. To avoid generating large amounts of dust, this cultivation could be done soon after rainfall while the soil is still slightly moist. An alternative approach may be to establish a permanent gravel road around the site.

2. *Tree breaks*

Placement of tree breaks could be done to align with the direction of strong winds. By reducing the velocity of winds coming onto the site, the amount of dust that is likely to come onto the site may also be reduced.

While species selection should be largely done to connect with those tree/shrub species which may be indigenous to the region, and so have a higher chance of thriving, consideration should also be given to the degree to which those species may support fire movement. As all trees and shrubs vary in their flammability, a selection of tree breaks should be considered from the list of plants that are considered to be less flammable, and so provide less energy to a fast moving grassfire. Examples of these plants include some species of saltbush and acacia, while Eucalypts are among the most flammable species due to the high levels of volatile oils in the leaves.

3. Control of pest animals

Rabbits, hares, foxes and kangaroos need to be controlled. While kangaroos can only be controlled through effective exclusion fencing (ensuring no holes at base of fencing), if rabbits, hares and foxes are found on the site they need to be effectively managed through baiting programs if needed. Not only will rabbits destabilise the ground through building warrens, rabbits, hares and kangaroos will eat all available vegetation in the dry summer months. Bare earth will lead to increased erosion potential, dust issues and increased opportunity for weeds to colonise the site.

Moreover, effective management of rabbits, hares and foxes all contribute to responsible land stewardship, and being a responsible neighbour – rabbits who breed up on site will move to neighbouring properties, decimating pastures and destabilising soil.

4. Weed control

The most important component of good land stewardship and being a responsible farming neighbour is to manage weeds.

If problematic and noxious weeds are permitted to thrive on site, they will spread seeds over adjacent properties via wind dispersal and water movement, increasing their weed burden and cost of management. In addition, it is the legal responsibility of the land manager to eradicate all declared noxious weeds from their land and ensure that all machinery moving from their land does not contain any seeds from noxious weeds.

The most important aspect of weed control is that every weed plant disperses lots of seeds every year, even thousands of seeds per plant. While some of these seeds germinate the following year, some stay dormant in the soil for many years. If weeds are not effectively managed before they set seed, a significant bank of weed seeds can accumulate in that soil, continuing to support ongoing weed populations over many years into the future. Therefore, if weeds are not effectively managed on solar farms, the massive weed bank which will accumulate on that land over 25-30 years means that the future productivity of that land will be significantly diminished for many years to come. This may potentially impact on the long-term value of that land, due to the high future cost of weed management and control.

An indirect impact from poor weed control is fouling of wool (sheep's wool picking up weed seeds, thorns and thistles). This means that farmers may refuse to bring sheep on site for strategic grazing, further reducing options for site management.

Effective weed control can be achieved through timely application of herbicide products that are not only effective against the target weed species, but also unlikely to lead to herbicide resistance issues, whereby the weeds become immune to the chemical, a significant industry issue which is reducing the number of herbicides available for problematic weeds.

However, in conjunction with good chemical control, the best and most sustainable control of weeds is through the establishment of vigorous and competitive pasture or crop plants.

Potential agricultural activities to be conducted at the Goorambat East Solar Farm, as per an 'agrivoltaic system'

Context:

A range of agricultural activities may be conducted on the site of the solar farm. While a more detailed description of these proposed activities will be listed below, the key driver behind all proposed activities is to support the expectation that all land within the envelope of the solar farm is managed in a way such that **at the end of the lease period it is returned to full agricultural production in a better state than it was at the start of that lease period**.

Opportunity:

It appears that the general current status of solar farms in Australia is predominantly that the land is managed to low expectations. While plant growth is managed as needed through sheep grazing or slashing, the predominance of weedy species and earth exposure means that soil nutrient status, soil organic matter, biological health and physical structure is degraded. Upon eventual decommissioning of the solar farm this land will have a lower capacity for production and higher cost of management with potentially a decreased land value.

The alternative approach is to use plant-based strategies to manage the land under and surrounding the solar arrays in a way that maintains the value of the natural capital and sequesters soil carbon. This needs to consider:

1. Managing any soil constraints to plant growth, with a key constraint being soil acidification. The addition of a large amount of lime prior to solar installation should ameliorate this constraint to a degree that it does not have to be addressed for at least 5 years.
2. Maintaining good quality ground cover with species that are strongly competitive against weeds, suit the geography, climate and soil type, while suiting the required agricultural activities.
3. Choose plant species which will contribute to building soil organic matter through effective cycling of dead plant litter and extensive root systems, thus building soil carbon stocks into the future.
4. Appropriate management of plant species to support optimal growth, including fertiliser as required.
5. Management of pest weeds and animals
6. Use of direct drill seeding operations where possible by planting new species into an existing sward, to reduce site disturbance and limit the amount of dust.

Potential agricultural practices:

While the specific trials which might be conducted at this site cannot be confirmed until land management arrangements have been confirmed, a range of potential alternate or complementary agricultural activities is listed below, along with the key benefits to be derived from each activity.

1. Perennial grass/legume pasture

The mix of grass and legume means that the growing period will be extended through the year, although they still may dry off over summer. As the legume provides a nitrogen benefit to the grass, the need for fertiliser is reduced. A vigorous pasture will reduce weeds while ensuring good groundcover all year, with timely selective weed control through herbicides also used for weed control if needed. A good groundcover all year means that trafficability will be maintained and dust will be minimal. A highly productive pasture will need to be well managed, either through slashing, hay production or through grazing. It is assumed that these species can thrive under a variable shade environment.

The key benefits from this practice would be to maintain a productive farm enterprise through either hay or sheep production, while supporting a vigorous root system that will capture large amounts of carbon over time.

2. Prostrate, low biomass pasture/groundcover

If agricultural productivity was of less importance, grass species could be selected that are less vigorous, but provide an effective groundcover while competing against weed species. A legume species could be sown into this existing groundcover to increase organic cycling and carbon accumulation. While this pasture could be grazed, it would not require a high level of management. If a summer active species was selected, it would also assist in maintaining a 'green' cover in the landscape over summer, assuming adequate rainfall.

In addition, the value of introducing native species into this system as a groundcover would also be considered. However, as most native species are not highly vigorous, competition against weeds would have to be evaluated.

The key benefits from this practice would be to provide perennial, low maintenance groundcover which would contribute to carbon storage through root activity and litter deposition.

3. Specific carbon farming

This activity would focus around growing plants for the primary objective of increasing soil carbon, with benefits to be realised through receiving carbon credits under international standards. The specific plants to be selected would be chosen based on their ability to produce leaf and root matter which can be readily decomposed and converted into soil organic matter, of which soil carbon is a key component.

As with all options, soil sampling to IPCC (Intergovernmental Panel on Climate Change) standards will be done before initiating the trial, to provide initial soil carbon levels from which to measure increases in soil carbon sequestration over time.

4. Strategic placement of lucerne or equivalent in larger non-utilised areas of the site

Lucerne is a deep-rooted perennial pasture plant, with roots down to 3m in some soil types which produces a high quality feed for hay or grazing. While lucerne may not be a suitable plant for sowing between rows of trackers, it may be well suited to filling out any empty land throughout the solar farm. Its deep-rooted nature means that it can assist in maintaining a dry soil profile to depth, which may assist with the integrity of electrical cabling that is trenched underground (assumption that immersing cables in saturated soil conditions is not conducive to longevity or performance). The ability of lucerne to dry out soil also means that the site is more likely to maintain trafficability. As lucerne will respond to summer rainfall, aesthetics of the site would also be improved by maintaining a 'green' cover over summer.

The key benefits from this practice would be to profitably utilise unused areas of the site with a high-quality feed source, while accumulating carbon to depth through deep root penetration.

5. Cropping

Conventional cropping operations, growing wheat, barley, canola or other broadacre crops, may still be considered as a management option. However, the need for specialist small scale equipment, high traffic use over the crop area (if sown between rows of trackers) and variable growth due to shading, means that there would be significant challenges. However, if this is something of key interest, it can be explored and scoped.

6. Novel plant species

Outside of the scope of conventional agricultural systems, there may be an opportunity to trial the establishment and growth of other plant species which may generate high value products into alternative food or health sectors. Examples of plants which might be worth investigating are alkaloid poppies (of interest as the site is already under security), cannabis (medicinal or industrial hemp), chia or other high value species for plant-based nutraceuticals.

Planting of any alternative plant species would involve a crop rotation with other species to increase soil health and maintain the sustainable production of the crop of interest.

7. Amenity planting of wildflowers or other flowering plants for pollinators

While this practice would not be practical across the whole site, selected areas of the site could be allocated as 'pollinator avenues', with a high-density planting of plants selected for their quantity or quality of flowers. Such an avenue would provide a refuge for pollinator insects including native bees, which would provide value to surrounding properties for increased pollination of agricultural crops.

An addition to this practice could be the commercial production of honey through the location of honey bee hives on site, which could be managed through an arrangement with a professional apiarist.

Summary:

There is evidence in the literature that co-location of solar and agricultural production can be beneficial. However, the specific agricultural activities to be adopted needs to be in considered in the context of specific panel arrangements, site design, location and soil type. There is also minimal information on the effect of shading on the growth of the types of plants which would be considered for agricultural production in this region.

A range of activities have been proposed, from which land management plans and agrivoltaic trial plans can be developed to provide a strategy for integration of agriculture with solar panels, which will have multiple land benefits, both now and into the future.

Good agricultural stewardship under a solar farm can maintain the value of the natural capital and sequester soil carbon, which in the event of the solar panels being decommissioned after 30 years, means that this land can be returned to highly productive agricultural land.

Therefore, demonstration of how the co-location of agricultural activities and solar energy generation can produce multiple benefits in the Australian context is an area in which Neoen can provide some strong direction and example.

Neoen has already demonstrated interest in integrating solar and agricultural production, using grazing as a site management strategy at several solar farms, and are keen to invest in further trials of agrivoltaic systems at the Goorambat East solar farm. Such investment will include soil quality testing and pre-construction activities, and provision of quantitative benchmarking records in the Operational Environmental Management Plan, to be prepared at a later date. Establishing quantitative benchmarks will clearly demonstrate accountability and commitment to responsible land stewardship.

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