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Planning Panels Victoria

Expert Witness Report

Solar Farm Planning

Permit Application Nos 2017-162, 2017-274, 2017-301 and

2017-344

for Solar Farms at

Tatura East, Tallygaroopna, Lemnos and Congupna

Report prepared for

City of Greater Shepparton

7 May 2018

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Date of Report: 7 May 2018

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Prepared by Ken Guthrie

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Introduction

1. My name is Kenneth Ian Guthrie and I am the Director of Sustainable Energy Transformation Pty Ltd.

2. I have been requested by Holding Redlich on behalf of the City of Greater Shepparton to provide my opinion in relation to certain aspects of the proposed Solar Farms at Tatura East, Tallygaroopna, Lemnos and Congupna

My Qualifications and Experience

3. I am the Chair of the International Energy Agency's Solar Heating and Cooling Program and until the end of 2017 also Chairman of the ISO Standards Committee on Solar Energy.

4. Until August 2012 I was the General Manager, Sustainable Environs at Sustainability Victoria, Australia, where I oversaw programs to increase the deployment of sustainable energy technologies.

5. I have Engineering qualifications from Melbourne University, and postgraduate business qualifications.

My area of expertise to make the report

6. I have worked in the area of renewable energy since 1978.

7. In August 2017, I provided a report to the City of Greater Shepparton regarding the Tatura East solar farm that reviews some of the objections made to that planning application.

8. In January 2018 I provided a presentation to the Council of the City of Greater Shepparton on the potential impact of solar farms on local temperatures and also provided some background on the electricity grid in relation to the four solar farm proposals that were before council at that time.

The application

9. The planning applications have been made to the City of Greater Shepparton by the proponents listed below:

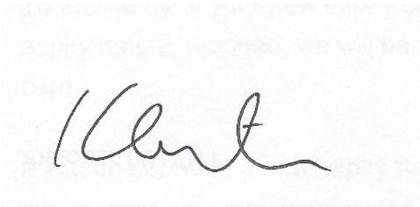
    - For the proposed 45 MW solar farm at Tatura East by Clean Gen on 5 June 2017;
    - For the proposed 30 MW solar farm at Tallygaroopna by X-Elio on 15 September 2017
    - For the proposed 100 MW solar farm at Lemnos by Neoen on 13 October 2017: and
    - For the proposed 68 MW solar farm at Congupna by X-Elio on 3 November 2017:

10. My opinion of the proposal has been informed having regard to:

- Planning application documents
- Council officer's reports, objections made and other documents in the Panel Books.
- Review of relevant studies in scientific literature as well as additional information regarding the studied sites included from online maps and specific questions to an author of one of the studies.
- Inspection of the sites of these planning applications
- Previous work that I have undertaken for the City of Greater Shepparton with respect to these applications.

11. The modelling to illustrate the solar energy available to solar photovoltaics installed in tracking versus fixed format used in this analysis was undertaken using the TRNSYS[1] modelling package by Alastair McDowell of EnergyAE Pty Ltd under my instructions and review.

12. I declare that I have made all the inquiries that I believe are desirable and appropriate and that no matters of significance which I regard as relevant, have to my knowledge, been withheld from the Panel.

13. Signed:  7 May 2018

[1] TRNSYS is a transient system simulation modelling environment developed by the University of Wisconsin that is used widely for modelling of solar and other energy systems. This work used the solar radiation analysis modules.

Instructions that define the scope of the report

14. The instructions were received by email from Joseph Monaghan of Holding Redlich representing the City of Greater Shepparton on 29 March 2018 which included a general brief. This outlined the role of the expert witness and asked for confirmation that I would be available for a hearing that would begin on 14 May and take 5-8 days.

15. I responded that I would be willing and able to provide an expert witness report as long as the questions to be formulated were appropriate and that I would not be available on 28 or 29 May.

16. On April 9, I received an email setting out 12 questions to be covered in the report

    1. *Describe the relevant particulars of the applications*
    2. *Describe the electricity grid*
    3. *Describe the renewable energy policy context for solar farms in Victoria*
    4. *Describe the suitability or otherwise of the Shepparton region from the perspective of the development of solar farms*
    5. *What is your view in relation to whether there is a heat island effect?*
    6. *What is your view in relation to technical measures to address heat island effects?*
    7. *Describe any effects of PV arrays on local climate*
    8. *Describe any temperature change effects on neighbouring orchards*
    9. *Describe any insect effects from the solar farms?*
    10. *Are there any other effects from the solar farms?*
    11. *What can be done to mitigate any possible effects?*
    12. *Inform the panel as to your views in relation to the conditions*

17. I subsequently responded by email that Question 9 was outside my area of expertise and was informed by Holding Redlich by email that I should not include that question in my report.

18. On Wednesday 18 April I was instructed by Holding Redlich to prepare a letter to the Horticultural Expert witness regarding my opinion on the temperatures likely to be encountered in and surrounding the solar farm. That letter was delivered to Holding Redlich by email on 23 April 2018.

My Evidence

19. The Questions to be answered are:

1. Describe the relevant particulars of the applications
2. Describe the electricity grid
3. Describe the renewable energy policy context for solar farms in Victoria
4. Describe the suitability or otherwise of the Shepparton region from the perspective of the development of solar farms
5. What is your view in relation to whether there is a heat island effect?
6. What is your view in relation to technical measures to address heat island effects?
7. Describe any effects of PV arrays on local climate
8. Describe any temperature change effects on neighbouring orchards
9. Are there any other effects from the solar farms?
10. What can be done to mitigate any possible effects?
11. Inform the panel as to your views in relation to the conditions

Question 1: Describe the relevant particulars of the applications

20. The applications are for Solar Photovoltaic Farms. The number of Solar Photovoltaic Panels and capacity of alternating current (AC) electrical power produced when operating at peak solar input is shown in the table below, with other information provided in the relevant Panel Books.

Solar farm proposed location	**Congupna**	**Lemnos**	**Tallygaroopna**	**Tatura East**
Applicant	X-Elio	Neoen	X-Elio	CleanGen
Application Number	2017-344	2017-301	2017-274	2017-162
Solar farm capacity … MW	68	100	30	45
Estimated size of the PV array. (sq. m.)	380,464	737,365	176,378	316,083
Total Area of the farm (ha)	160	475	96	98
Type of solar array	tracking	tracking	tracking	tracking
number of panels	196,080	380,016	90,900	162,900
highest point of panels (m)	3.03	3.03	3.03	3
Mounting height (m)	1.7	1.7	1.7	
Total panel width (m)	2.996	2.996	2.996	2[2]
Pitch (m)	Not specified	7	Not specified	4.5

21. All applications include a buffer along the boundary of the solar arrays and include vegetation within that buffer. This is to provide a visual screen as stated in some applications. The application for the Lemnos solar farm does not include vegetation on all sides of the solar farm. It is not common practice to have vegetation screening along the boundary of solar farms in Australia and overseas.

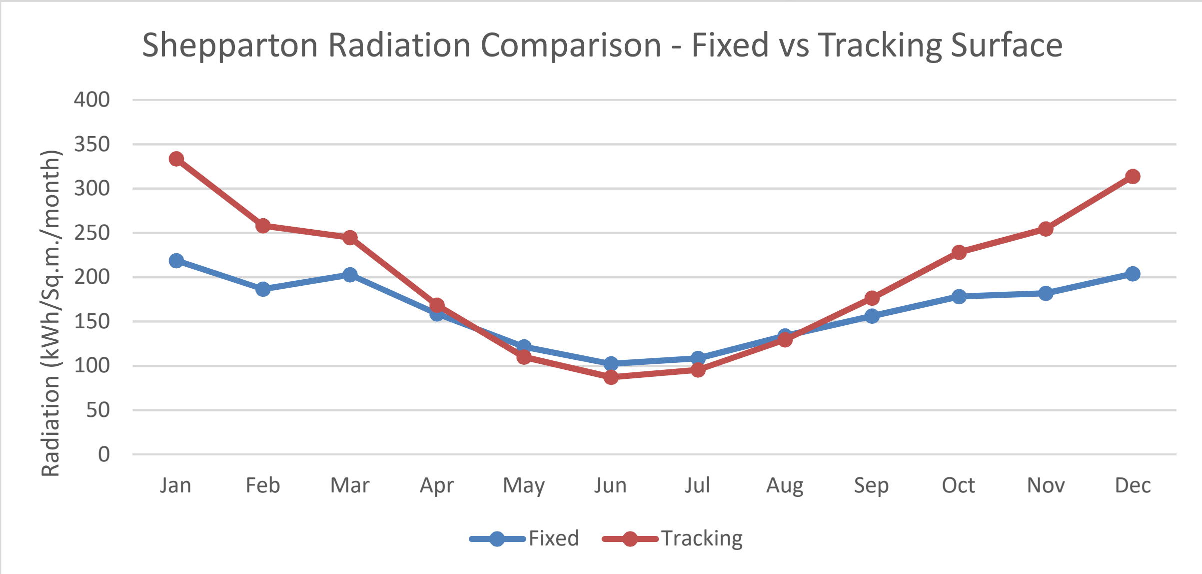
22. Solar PV panels are flat, thin, light weight and robust devices that convert light into electricity by using semiconductor materials. The panels will be placed in arrays on single axis trackers that rotate from facing Easterly in the morning through horizontal at midday to facing Westerly in the afternoon. Note that Neoen have stated that they may have some or all panels fixed. However, current practice in large solar farms in Australia is to have all panels mounted on single axis trackers.

23. From calculations using the TRNSYS modelling package, panels placed on a tracker of this type in the Shepparton area will allow the panels to intercept approximately 23%

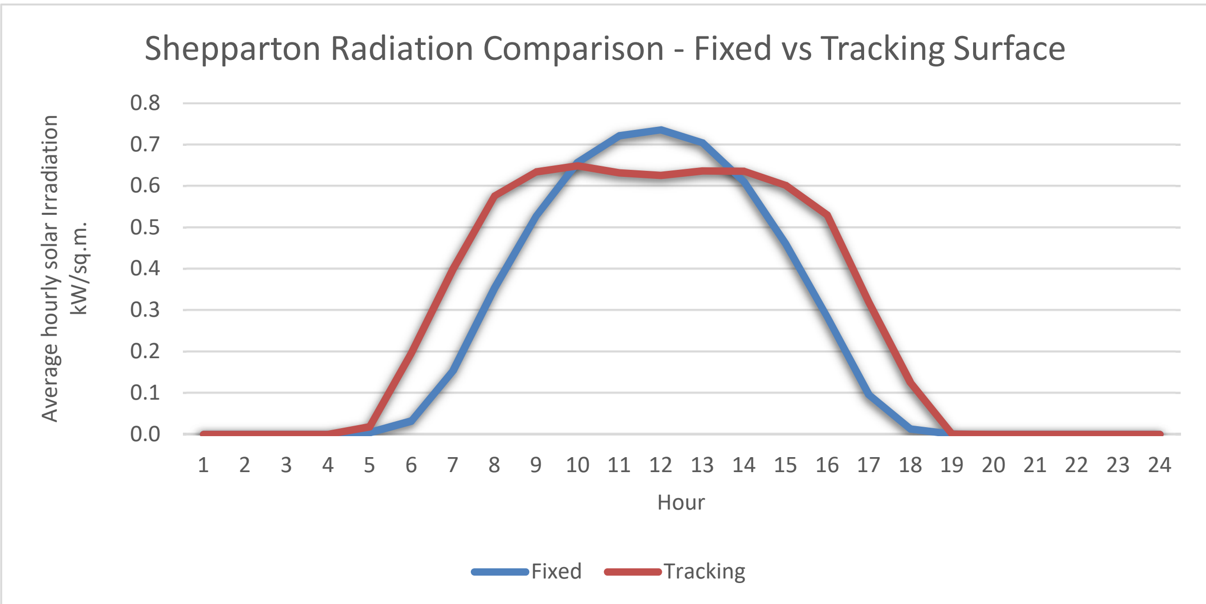
[2] The application is unclear of the pitch and the width of the array being proposed. In the notes on page 347 of the Panel book it states 4.5m pitch and implies that there will be one panel in portrait ie approximately 2 m wide. In the panel book on page 305, Figure 14 indicates that the pitch is 7.8 m and that there will be 2 panels (in portrait) wide ie approximately 4m. I have used the former figures as the second figures will be unlikely to fit within the 3m height proposed.

more solar radiation than a fixed panel placed facing True North inclined at an angle equal to the latitude (approximately 36.5°).

24. The solar irradiance intercepted by the tracking panels will be higher in Summer and lower in winter than a fixed installation. As shown in the figure below:



25. Apart from the increased solar radiation available to the panels, tracking will also allow the panels to intercept more solar radiation earlier in the morning and later into the afternoon, providing a less variable output. The following Figure illustrates that comparison for an average day.



Question 2: Describe the electricity grid

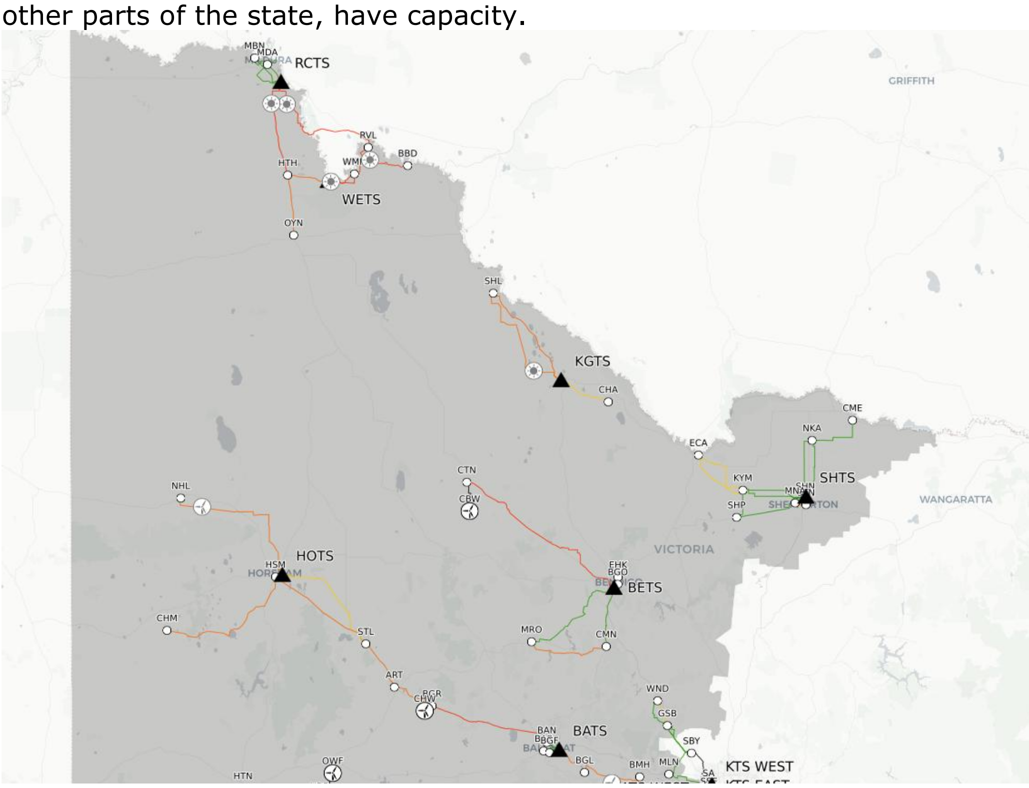
26. The electricity grid is made up of transmission and distribution lines that carry electricity from large generators to the end users that consume electricity. The transmission network operates at extra high voltage 220 – 500 kV. The distribution system takes electricity from the transmission system and delivers it at an appropriate voltage level for users.

27. Local generation can be fed into the distribution system where there is capacity to absorb the amount of power produced.

28. For generators of the capacity proposed in these four sites the electricity produced must be fed into the transmission system at or above 66KV.

29. The distribution system in and around Shepparton is owned and operated by Powercor. Powercor distributes electricity to the western side of Victoria which includes much of the state's good solar resource, being the north and west of Victoria.

30. Powercor provides the generation capacity available on their 66kV Sub-Transmission lines on their website at https://www.powercor.com.au/our-services/electricity-connections/solar-and-other-generation/connecting-larger-embedded-generator-systems/. The following figure is copied from that website. The colours indicate available generation capacity on that 66kV line. Green indicates that between 50 – 135 MW can be fed into that line. Red indicates less than 10 MW capacity is available. It can be seen that many of the 66kv lines around Shepparton, but not many lines in other parts of the state, have capacity.



31. The following figure shows more detail from the Powecor website of the area around Shepparton. The website shows that the following capacity is available on those 66kV sub-transmission lines.

- Shepparton Terminal Station to Numurkah 1 (SHTS - NKA 1) has indicative generation capacity of 92 MW,
- Shepparton Terminal Station to Numurkah 2 (SHTS – NKA 2) has indicative generation capacity of 86MW,
- Numurkah to Cobram East (NKA-CME) has indicative generation capacity of 63 MW,
- Shepparton Terminal Station to Kyabram 1 (SHTS-KYM1) has indicative generation capacity of 76MW,
- Shepparton Terminal Station to Stanhope (SHTS-SHP) has indicative generation capacity of 96MW.

32. The proposals are that

- Clean Gen plan for the Tatura East site to connect into the Stanhope – Shepparton 66kV line (SHTS-SHP) which has capacity to accept this amount of power.
- X-Elio sites at Tallygaroopna (30MW) and Congupna (68MW) plan to connect in to the Numurkah – Shepparton 66kV line (SHTS-NKA No 1) which has 'indicative' capacity to accept 92 MW.

- Neoen propose to pay to build a line to the Shepparton Terminal station to connect the 100MW solar farm at Lemnos.

33. A solar farm builder is responsible to pay for a power line and switching station to take the electricity from their installation to a part of the grid that has capacity available to accept the amount of electricity they will generate. From the Powercor website it can be seen that the cost of the switching station is $5.0 million each and that a 66kV line will cost $300,000 per km installed overhead or $1.2 Million per kilometre installed underground. The lines and switching station are installed and owned by Powercor who will be responsible for the operation and maintenance.

Question 3: Describe the renewable energy policy context for solar farms in Victoria

34. The Victorian government has strong policy supporting renewable electricity deployment in Victoria.

35. The Climate Change Act 2017 establishes a target for Victoria to have net zero greenhouse gas emissions by 2050 The preamble to the Act states "The Parliament of Victoria recognises that the community wants and expects Victoria to play its part in global mitigation efforts and in preparing the community for unavoidable climatic impacts"

36. The Victorian Renewable Energy Action Plan states "Victoria's Climate Change Framework makes it clear that moving to a clean energy supply by increasing renewable energy generation is a key pillar of the state's approach to emissions reduction". It also aims to "create jobs, attract investment and grow our economy through boosting the new energy technologies sector." And states " In the northwest of our state, solar PV is beginning to be rolled out at utility-scale. Planned grid augmentation will help unlock our abundant natural resources well into the future."

37. The Victorian Government is also purchasing electricity from a solar PV farm at Wunghnu to offset the electricity consumed by the Melbourne tram system.

The Victorian Renewable Energy Target.

38. The Victorian Renewable Energy Target is complementary to, and operates in a similar manner to, the Commonwealth's Renewable Energy Target. However, it will cover only limited technologies to supply electricity into the Victorian electricity grid, initially wind and solar.

39. The Victorian Renewable Energy Target is defined in the Renewable Energy (Jobs and Investment) Act 2017.

The Act defines "**renewable energy** source means any of the following energy sources—

(a) solar;
(b) wind;
(c) an energy source declared by the Minister …"

It also sets targets "The renewable energy targets are—

(a) by 2020, for 25% of electricity generated in Victoria to be generated by means of facilities that generate electricity by utilising renewable energy sources or converting renewable energy sources into electricity;

and

(b) by 2025, for 40% of electricity generated in Victoria to be generated by means of facilities that generate electricity by utilising renewable energy sources or converting renewable energy sources into electricity"

Question 4; Describe the suitability or otherwise of the Shepparton region from the perspective of the development of solar farms

Solar availability

40. Availability of solar energy is one important criteria for a financially viable solar site. The solar resource available is measured in terms of average Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI).

41. GHI is the solar power falling on a horizontal surface. It is often given in $MJ/m^2/day$ averaged over a year. It illustrates the total amount of energy likely to be available, however a tilted surface facing toward the equator will intercept more irradiation as it will face more directly toward the sun.

42. DNI is a measure of the energy coming directly from the sun to the collecting surface that is tracking in two dimensions so that it is always facing directly toward the sun. Clear sky conditions provide higher DNI. A high level of DNI is necessary to obtain the increased performance for tracking collectors required to offset the additional costs and complexity.

43. Solar energy available at Shepparton is relatively high on an international basis. From the Australian Renewable Energy Mapping Infrastructure (AREMI) data found at http://nationalmap.gov.au/renewables/ the solar radiation at Shepparton is average GHI 17.6 $MJ/m^2/day$ and average DNI 20.7 $MJ/m^2/day$. For comparison Shepparton figures are similar to Wangaratta and Albury and:
    - 7% less GHI and 8%less DNI than Mildura;
    - 3% less GHI and DNI Kerang;
    - 14% more GHI and 26% more DNI than Melbourne;
    - 2% more GHI and 6% more DNI than Bendigo; and
    - 30% less GHI and 27% less DNI than Alice Springs.

44. On the criteria of availability of solar energy, the Shepparton region has a good solar resource, similar to other sunny regions of Victoria, Northwest of the Great Dividing Range.

Proximity to a grid connection point

45. Apart from the level of solar energy available, the proximity to a suitable connection point with available capacity is often the most critical element when selecting a viable solar site. To the proponent of a solar farm, proximity to the electricity grid is a key criterion as construction of distribution and/or transmission lines can significantly add to project cost. See earlier section on Question 2

46. As outlined in that section (Question 2) of this report, the Shepparton region has good access to connections in to powerlines with available capacity, better than much of the rest of the state with good solar resource.

47. Therefore, on these two critical elements of financial viability, the Shepparton area is highly suitable for deployment of strategically placed solar farms and is a more suitable location than most other areas of Victoria.

Question 5 What is your view in relation to whether there is a heat island effect?

What is a "Heat Island"?

48. The heat island effect is the term that is generally used to describe increased temperatures in urban areas compared to surrounding rural areas. The American Meteorological Society – Glossary of Meteorology defines the term Urban Heat Island (Or heat island.) as "*Closed isotherms indicating an area of the surface that is relatively warm; most commonly associated with areas of human disturbance such as towns and cities. The physiographic analogy derives from the similarity between the pattern of isotherms and height contours of an island on a topographic map. Heat islands commonly also possess "cliffs" at the urban–rural fringe and a "peak" in the most built-up core of the city. The annual mean temperature of a large city (say 1 million inhabitants) may be 1°–2°C warmer than before development, and on individual calm, clear nights may be up to 12°C warmer. The warmth extends vertically to form an urban heat dome in near calm, and an urban heat plume in more windy conditions"*. This question relates to whether there is a similar effect for PV farms, the photovoltaic heat island (PVHI) effect.

49. Barron-Gafford et al (2016)[3] simultaneously monitored temperatures 2.5 m above the soil at three sites in Arizona. The sites represented a natural desert ecosystem, the traditional built environment (parking lot surrounded by commercial buildings), and a PV power plant. They found that "*temperatures over a PV plant were regularly 3–4 °C warmer than wildlands at night*". This effect was greater in warmer months than in cooler seasons. They claimed this to "*…demonstrate that the PVHI effect is real and can significantly increase temperatures over PV power plant installations relative to nearby wildland*". They also postulated that the PVHI "*may be due to heat trapping of re-radiated sensible heat flux under PV arrays at night*".

50. Fthenakis and Yu (2013)[4] measured temperatures at a height of 2.5 m at a solar farm in Canada within the PV field and at a number of points for a distance of up to 800m from the outside of the PV array. They found that "b*oth the field data and the simulations show that the annual average of air temperatures in the center of PV field can reach up to 1.9°C above the ambient temperature, and that this thermal energy completely dissipates to the environment at heights of 5 to 18 m." …*and*… "analysis of 18 months of detailed data showed that in most days, the solar array was completely cooled at night, and, thus, it is unlikely that a heat island effect could occur."*

51. These two papers indicate that temperatures within the solar farm will be higher than in the surrounding areas for at least part of the time. Whether that constitutes a "Heat Island" depends on whether the definition used requires it to be at an elevated temperature all the time or on average. However, Fthenakis and Yu also indicate that the PV farms also exhibits another of the characteristics of a heat island, which is the temperature "cliffs" at the fringe of the PV farm where temperatures drop quickly into the surrounding area.

Will there be an increased temperature in the solar farm?

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[3] "The Photovoltaic Heat Island Effect: Larger solar power plants increase local temperatures" https://www.nature.com/articles/srep35070

[4] "Analysis of the Potential for a Heat Island Effect in Large Solar Farms" Photovoltaic Specialists Conference (PVSC), 2013 IEEE 39th DOI: 10.1109/PVSC.2013.6745171

52. Liwei Yang et al (2017)[5] measured temperatures within and outside a PV farm in Golmud, China in the Gobi Desert. "*The results show that the air temperature at a height of 2 m at the two sites is essentially the same during winter daytime, but in the other seasons, the daytime air temperature at the PV farm is higher than that in the region without PV. The maximum difference appears during the summer daytime, with a value of 0.7°C (the summer daytime averaged value). …… The night time air temperature at a height of 2m during the four seasons at the solar farm was higher than that in the region without PV arrays, since the solar panels have a heat preservation effect near the ground. The differences in values between the two sites were 0.1, 0.3, 0.2, and 0.1°C in summer, autumn, winter and spring, respectively.*" and "*The results show that the daily range of soil temperature at a depth of 5–10 cm at the solar farm is lower than that in the region without PV farm.*"

53. The sites studied by Liwei Yang et al, and Barron-Gafford et al have similar solar radiation levels both higher than in Shepparton. The IRENA Global Atlas for Renewable Energy shows GHI of 20.3 MJ/m^2/day in Golmud and 20.9 MJ/ m$^{2/}$day in Arizona. The GHI at the site studied by Fthenakis and Yu is 13.1 MJ/m^2/day.

54. It is surprising to see the range of temperatures between the studies of Liwei Yang et al, and Barron-Gafford et al as they have very similar solar climates. This may be due to other differences such as ground cover.

55. Two of these studies were conducted on solar farms that had fixed PV panels rather than tracking panels as planned in the four solar farms proposed for the Shepparton Municipality. Tracking panels are generally spread wider apart than stationary panels. Wider spacing and, if parked overnight nearer to vertical, will allow more radiant heat loss to the sky, so in my opinion the temperatures in a tracking PV field can, if managed appropriately, be lower compared to those in a stationary PV field.

56. Based on these three papers it is my view that there will be an elevated temperature <u>within</u> the PV farm compared to the same site in current use and that the increased temperature will be of the range:
    - In winter, night time air temperatures above the panels will be 0.2 – 3.0 °C above temperatures outside the PV farm,
    - In summer, temperatures will be 0.1 – 4 °C higher above the panels than outside the PV field and:
    - In the soil under the PV panels, temperatures are cooler during the day and warmer at night, than outside the PV field.

57. It should be noted that temperature changes of this order are often encountered with changes in land use. For example, de Vries and Birch (1961)[6] observed 1-2 °C differences in temperatures at 1.25 metres above the ground in irrigated areas compared to dryland in the area near Rochester, approximately 75 km west of Shepparton.

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[5] "Study on the local climatic effects of large photovoltaic solar farms in desert areas" Solar Energy 144, 244–253 (2017)

[6] The modification of climate near the ground by irrigation for pastures on the riverine plain" Vries D A de and J W Birch 1961 *Australian Journal of Agricultural Research* 12(2) 260 – 272 http://www.publish.csiro.au/cp/AR9610260

Question 6: What is your view in relation to technical measures to address heat island effects?

58. PV installations shade a portion of the ground and therefore reduce heat absorption in surface soils. Tracking collectors intercept more solar irradiance than fixed arrays, therefore provide shade to the ground under the array.

59. Electricity supplied from the PV power station will remove energy. This will reduce the amount of energy that remains as heat in the local area. Commercial PV panels are becoming incrementally more efficient, meaning that more energy will be removed from the PV farm. It is likely that the developers of solar farms will already plan to use commercially available high efficiency panels as that will maximise the income available from the PV farm.

60. PV panels are thin and relatively lightweight therefore, have little heat retention capacity per unit area. Consequently, the array temperature will quickly reduce once the sun goes down. PV modules emit thermal radiation both up and down, and this is particularly significant during the day when PV modules are often 20 °C warmer than ambient temperatures.

61. Barron – Gafford et al postulated that the PVHI "*may be due to heat trapping of re-radiated sensible heat flux under PV arrays at night*". Consequently, increasing the amount of radiation heat loss from the ground under the PV panels will reduce the temperatures in the PV field overnight. This can be achieved by turning the PV arrays toward the vertical position overnight to open up the view to the cold night sky to facilitate radiant cooling.

62. To indicate the radiative cooling benefit available when 'parking' the array at different angles to the horizontal overnight, I have calculated the area of the ground 'covered' by the array at a range of different angles for the Lemnos site. If the panels are horizontal, they will shield approximately 43% of the sky. When completely vertical they will shield less than 5% of the sky, depending on the bulk of the tracking mechanism. At 45°, 60°, 70° and 80° to horizontal the array will shield approximately 31%, 22%, 15% and 8% of the sky.

63. Natural convection will also be facilitated by PV arrays not being held horizontal overnight so that the air near the panels will rise naturally if the panels are hotter than surrounding air. Open spaces under the panels, will facilitate this flow and as the cooler night air is drawn in to replace air that has warmed and risen, the ground will also be cooled. Fixed collectors often have little space left under the panels for air flow. The proposals allow approximately 500 mm of space which will facilitate natural convection cooling.

64. Vegetation is often removed from PV power plants. If retained, or replanted, vegetation under the panels will provide an extra heat removal mechanism through transpiration, however, this may require high levels of maintenance that could be impractical. Vegetation surrounding the solar farm will also contribute to cooling through transpiration.

Question 7: Describe any effects of PV arrays on local climate

65. The localised climate within the solar farm has been discussed in answering Question 5. In answering this question, I will cover impacts that may occur in areas surrounding a solar farm.

66. Temperature measurement in the localised area surrounding a solar farm has been reported in the literature only by Fthenakis and Yu[7].

67. Fthenakis and Yu measured temperatures at a height of 2.5 m at a solar farm in Canada within the PV field and at a number of points for a distance of up to 800m from the outside of the PV array. They found that "*…air temperatures in the center of PV field can reach up to 1.9°C above the ambient temperature, and that this thermal energy completely dissipates to the environment at heights of 5 to 18 m. The data also show a prompt dissipation of thermal energy with distance from the solar farm, with the air temperatures approaching (within 0.3 °C) the ambient at about 300 m away of the perimeter of the solar farm.*"

68. The following figure is from Fthenakis and Yu. It indicates that the temperature drops quickly within the first 100 metres from the perimeter of the solar farm.

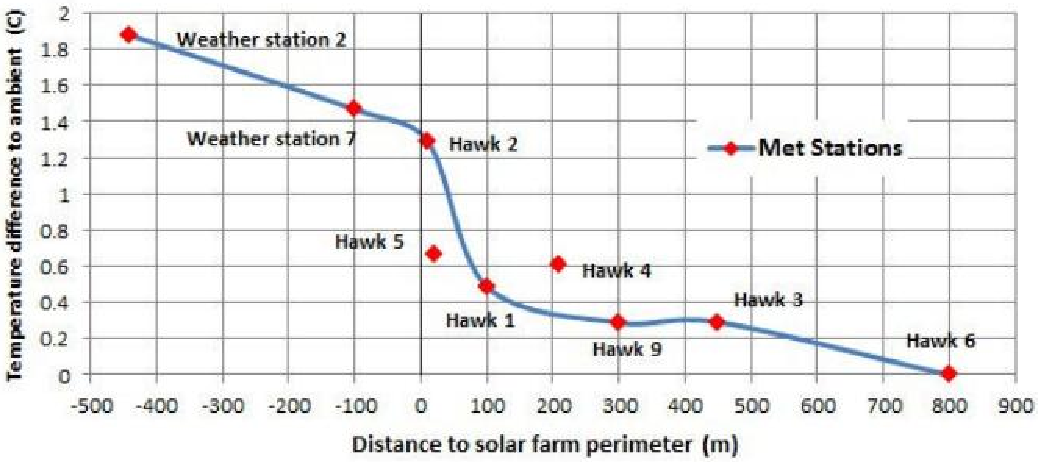

Fig. 8. Air temperature difference as a function of distance from the perimeter of the solar farm. Negative distances indicate locations within the solar farm.

69. The solar farm studied by Fthenakis and Yu was open to the surrounding area with no screening between the PV array and surrounding sites.

[7] "Analysis of the Potential for a Heat Island Effect in Large Solar Farms" Photovoltaic Specialists Conference (PVSC), 2013 IEEE 39th DOI: 10.1109/PVSC.2013.6745171

70. Heat flow from the solar farm to adjacent properties could take place by radiation or by convection. Radiation will transfer heat through empty space where there is a clear view from the hot body to a cooler body. Convection is the movement of a hot fluid to cooler region. It can be natural convection (hot air rising) or forced convection due to air moving across the surfaces by wind or similar.

71. Heat flow both by radiation and convection from the PV farm to the surrounding area can be substantially reduced by suitable screening.

Question 8: Describe any temperature change effects on neighbouring orchards

72. There are orchards that are near some boundaries of the proposed solar farm sites.

73. At Tallygaroopna an irrigation channel is between the solar farm and an orchard. In some other sites the orchards are across rural roads from the solar farm sites.   In these cases, the channel will provide a cooling effect and the road reserve will provide an additional setback to mitigate any increase in air temperature.

74. The study by Fthenakis and Yu, indicates that temperatures drop very quickly away from the perimeter of the solar farm studied. That solar farm was open to the surrounding area with no screening between the PV array and surrounding sites.

75. Natural convection will take the warm air upward, so it will not spread heat into neighbouring properties. Forced convection could move heat from the PV farm to surrounding areas if there is no barrier to reduce air flow. In a mild breeze the influence of natural convection will quickly lift the warm plume upward and in a stronger wind the heat may be spread wider, but temperatures will dissipate quickly as the air is mixed more quickly, diluting the heated air with unheated air. A dense vegetation screen will effectively block air flowing from the solar farm to a neighbouring orchard, thereby reducing the temperature impact from the solar farm.

76. Radiation from one surface to a nearby area can be effectively eliminated by ‘shading’ the cooler area from the hotter one. The vegetation buffers or hedges, proposed in most applications and required in the proposed conditions, will, if higher than the panels, screen the warm panels from radiating to adjacent orchards.

77. In my opinion a suitable screen would lead to a substantial reduction of the heat flow both by radiation and convection from the PV farm to the surrounding area.

Question 9: Are there any other effects from the solar farms?

78. There are a number of other effects that could occur in a development that requires earth moving during construction, installation of low profile equipment and construction or placement of buildings and power infrastructure.

79. **Noise** Tracking solar PV arrays move at an unobtrusive and slow rate, producing minimal noise. Solar PV farms are generally silent during the operational phase. The only noise emitted from an operational solar farm would be from the substation and inverters, which can be inaudible if appropriate buffer distances to sensitive receivers or equipment housing are used. There is no noise from inverters at night due to daytime operation of solar panels.

80. Noise impacts would largely be restricted to the construction phase and these could be managed through mitigation measures.

81. During plant operations, other minor sources of noise would be from a small number of vehicles accessing the site per day, aeolian and/or corona noise from transmission lines and any intermittent noise from maintenance activities.

82. **Dust** The proposals have the potential to generate dust during construction from minor earthworks, construction vehicles driving on unsealed access road and wind blowing over stockpiles and exposed surfaces during construction and decommissioning.

83. Impacts due to the generation of dust would be short term. A dust management plan should be prepared as part of the Environmental Management Plan to identify mitigation measures, primarily aiming to suppress dust for each phase of development.

84. **Glare** In general, modern PV panels are designed to absorb as much sunlight as possible to convert it into electricity. Studies of PV modules with anti-reflective coating indicate they reflect around 2% of incoming sunlight[8]. The panels are single axis tracking aligned North/South. Consequently, they rotate from facing toward the East in the morning across the sky to facing West at sunset. Under the proposals, the maximum tilt of the panels is 60°. This would not allow reflection onto neighbouring properties under normal operating conditions, as when the sun is at the lowest point any light reflected would be upwards.

85. There will be a trade-off between the potential for glare and the desire to have an unimpeded view from the ground to the sky for night cooling. A suitable compromise would be to have the array park at 60 - 70° overnight.

86. **Light spill** In Australia, night lighting on solar farms is limited to the substation and support buildings. Light spill from solar farms at night has not been raised as a widespread issue in Australia.

87. It is likely that night time lighting will be installed around the operation and maintenance facilities, carpark and substation. The lighting used should be low-level

[8] Planning and Development Guidance Recommendations for Utility Scale Solar Photovoltaic Schemes in Ireland, p11.

and directional to minimise potential for light spill. Possible management strategies would be to include, design to *AS4282 Control of the obtrusive effects of outdoor lighting* or, include requirement that lights be shaded so that no light will spill on any surface above 3 metres. This would ensure that any otherwise obtrusive light would be shaded by the vegetation around the boundary.

Question 10: What can be done to mitigate any possible effects?

88. The possible effects of noise, dust, glare and light spill have been discussed with mitigating strategies under Question 9.

89. There are a number of options to reduce heat build up within the solar farm and reduce transmission of any heat that is retained into neighbouring properties.

90. Heat build up within the solar farm will be minimised by installation of efficient PV panels to transmit more of the incident solar energy out if the site as electricity and by tracking which will intercept more solar irradiation.

91. Any impact of heat that may build up during daylight hours can be mitigated by facilitating overnight radiative cooling of the ground by turning the PV array to maximum tilt overnight so that heat can be radiated to the cold night sky from the warmer ground.

92. A vegetation buffer may assist with cooling of the solar farm due to transpiration, however it may also reduce cooling winds across the panels during the day. On balance the impact on heat build up within the array will vary from a tendency to increase or decrease depending on the particular conditions at a particular time. However, a vegetation buffer will reduce impacts of radiation to the surrounding area in all conditions.

93. Whilst decreasing heat build up will be important to the operator of the solar farm, as PV output reduces as temperature of the panels increase, for neighbours the major issue will be to reduce the potential for heat transmission out of the solar farm into neighbouring properties.

94. An effective strategy to mitigate heat transmission out of the solar farm is to provide a buffer of dense vegetation surrounding the solar farm. The vegetation should be visually dense from the ground to higher than the top of the PV array at its highest point.

95. In my opinion a dense vegetation buffer will effectively stop heat transmission to neighbouring properties. There will be minimal effect on temperatures more than 100m from the outside of the vegetation.

Question 11: Inform the panel as to your views in relation to the conditions

96. The conditions set out in the draft proposed by the City of Greater Shepparton include conditions covering, screening vegetation, setback and the angle of tilt at which the PV array will be held overnight.

Vegetation screen

97. The recommended conditions include that "the landscape plan must include details of permanent screening trees and shrubs with a minimum of six rows using a mixture of local tress and understorey species." and "Once the landscaping planting is carried out the landscaping must be maintained including the replacement of any dead or diseased plants to the satisfaction of the responsible authority."

98. In my view this does not adequately define the requirement as there is no specification of the height. The height of the vegetation should be added to the condition so that the screen is in excess of three metres once the plants are grown.

99. The conditions should also require that the vegetation screen be planted and maintained along all boundaries of the solar farm.

Setback

100. The recommended conditions include that "the solar arrays are set back at least 50 metres from the lands boundary".

101. Whilst there is limited data upon which to make a definitive recommendation, in my opinion, if the screening is adequately defined and maintained, then that will provide an adequate buffer to heat flow so that there will not need to be a large setback. In my view this condition could be reduced to a setback of 20 metres from the vegetation screen, or approximately 30 metres from the boundary.

Overnight Array tilt

102. The recommended conditions include "The photovoltaic arrays (solar panels) must be orientated so that panels are perpendicular to the ground within 30 minutes of sunset until within 30 minutes of sunrise to facilitate night radiant cooling"

103. In my opinion requiring the array to be perpendicular will not be necessary as the vegetation screening will mitigate against heat flow to neighbouring properties if there is heat retained overnight. A tilt angle of approximately 60-70° from the vertical will still facilitate radiant cooling of the array.