Powering a sporting nation:

Rooftop solar potential for AFL

AUSTRALIAN CONSERVATION FOUNDATION

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Contents

Cover. **Richmond AFLW team.**
Photo: **Wayne Ludbey**

Introduction

Australian Rules Football is Australia's most watched sport with an estimated TV audience of 7.8 million across the 2012-13 season[1], while over 1.7 million registered participants played the game in 2019 [1].

But the sport is already being impacted by climate change and its future is in jeopardy from rising global temperatures and increasing extreme weather events. According to the Australian Football League's (AFL) own community website, some AFL pitches have been made unusable by prolonged years of drought, while others have been put out of action for extended periods by regular flooding.[2] While reconstruction is ongoing at Kangaroo Island's Western Districts Sporting Club, completely destroyed by the 2019/20 bushfires, at least 262 AFL community clubs were sufficiently affected by the fires to need financial support from the AFL Community Relief Fund.[3]

Like other sports, playing Aussie rules in extreme heat can cause dizziness, headaches or collapse, and can even be life threatening [2]. With Australia experiencing increasing frequency, duration and intensity of heatwaves,[4] the interruptions, postponements and cancellations of AFL matches will become commonplace without decisive action to stop and reverse climate change through immediate and drastic reductions in carbon emissions across all sectors of society.

The response of the AFL – Australia's wealthiest sporting body – to this existential threat has been muted. In the risk management guidance given to AFL community clubs, climate change doesn't get a mention.[5] And while the AFL community raised $8 million for bushfire relief in 2020,[6] the sport's efforts to address the underlying causes are patchy. Although the AFL's Green Clubs initiative recognises the impacts of climate change on the sport and the need for community leadership, criteria for clubs to achieve Gold Level accreditation don't include specific energy or carbon emission reductions.[7]

However, some of the AFL's 18 clubs are taking a lead. Richmond FC is the first AFL club to join the United Nation's Sports for Climate Action initiative,[8] which commits them to reduce their own climate impact as well as using their community leadership position to promote sustainable consumption and educate and advocate for climate action.

Richmond FC, North Melbourne and St Kilda have installed substantial 100 kilowatt (kW) solar systems, while Carlton, Essendon, Fremantle, Gold Coast Suns and the West Coast Eagles also have some small systems on on their stadia or training facilities. However, the analysis in this report shows that there is significant potential for further deployment of solar on the stadia and other properties of AFL clubs across Australia.

1 http://www.roymorgan.com/findings/5488-sports-viewing-on-tv-201403140213

2 http://www.aflcommunityclub.com.au/index.php?id=62

3 https://aflvic.com.au/afl-community-raises-8-million-for-bushfire-relief/

4 https://www.climatechangeinaustralia.gov.au/en/climate-campus/climate-extremes/extreme-temperature/

5 http://www.aflcommunityclub.com.au/?id=215

6 https://aflvic.com.au/afl-community-raises-8-million-for-bushfire-relief/

7 http://www.aflcommunityclub.com.au/index.php?id=62

8 https://www.richmondfc.com.au/news/243150/richmond-partner-sports-for-climate-action-initiative

In general, the best financial returns for rooftop solar are achieved by consuming as much of the generated electricity as possible on site. In a football stadium, powering floodlights for evening matches is challenging without battery storage, but some venues have significant daytime consumption, including lighting, heating and cooling for offices, clubrooms and other facilities. Not all commercial electricity tariffs include a feed-in-tariff (FiT) – payment for electricity exported to the grid – so solar systems on commercial properties are often designed to avoid any export. However, large commercial customers are in a strong position to negotiate a tariff structure that enables them to enjoy the full value of their solar system, exporting during the day and offsetting the export payment against their evening consumption.

Australia's AFL venues include diverse building styles and ages. While solar photovoltaic (PV) installation on traditional pitched and flat roofs is relatively straightforward, deployment on modern sculptural roof forms may present challenges. However, solutions are emerging: technological advances in Building-Integrated Photovoltaics (BIPV) including lightweight, flexible modules[9] will enable PV installation on previously unviable structures.[10]

Ownership and governance arrangements for major stadia and headquarters vary. While some are owned and/or operated by the club, others are owned by government, private companies or other bodies. Moreover, many are used for multiple sports and other events, so the AFL club may be just one of several tenant organisations.

Nevertheless, AFL's massive following in Australia gives the clubs status that could be used to influence the owners and partners of the stadia.

The AFL national clubs are part of a network of hundreds of local AFL clubs that spans Australia, giving them an opportunity to communicate the risk posed by climate change to the sport, and to demonstrate one way of reducing the danger by installing rooftop solar to power their stadia.

This report explores the opportunity for deploying solar on the headquarters and stadia of the 18 national AFL clubs to generate clean energy, reduce carbon emissions and combat the causes of climate change.

Interruptions, postponements and cancellations of AFL matches will become commonplace **without decisive action to stop and reverse climate change**

[9] *"Australia invests $9.6m in 'revolutionary' Chinese solar company Sunman,"* David Chau

[10] The potential solar installations on stadium rooftops identified in this report are based on visual inspection of the sites using aerial imagery and do not take account of structural engineering issues.

Australian Football League

The headquarters of the Australian Football league (AFL) is at the multipurpose 53,359-capacity Marvel Stadium, also known as the Docklands Stadium.[11] The stadium is also home to five AFL clubs – Essendon, Carlton, North Melbourne, St Kilda and Western Bulldogs – and hosts various sports events including international rugby, international football world cup qualifiers, as well as concert events.

The headquarters of the AFL are located on the western side of the precinct, but the roof is overshadowed by the stadium itself. However, excluding areas heavily shaded by neighbouring buildings, there is space on the stadium's retractable roof for a potential 1553 kW solar system, subject to an engineering assessment. Figure 1 shows the Marvel Stadium as it is now (inset) and with the potential 1553 kW solar system on the roof space.

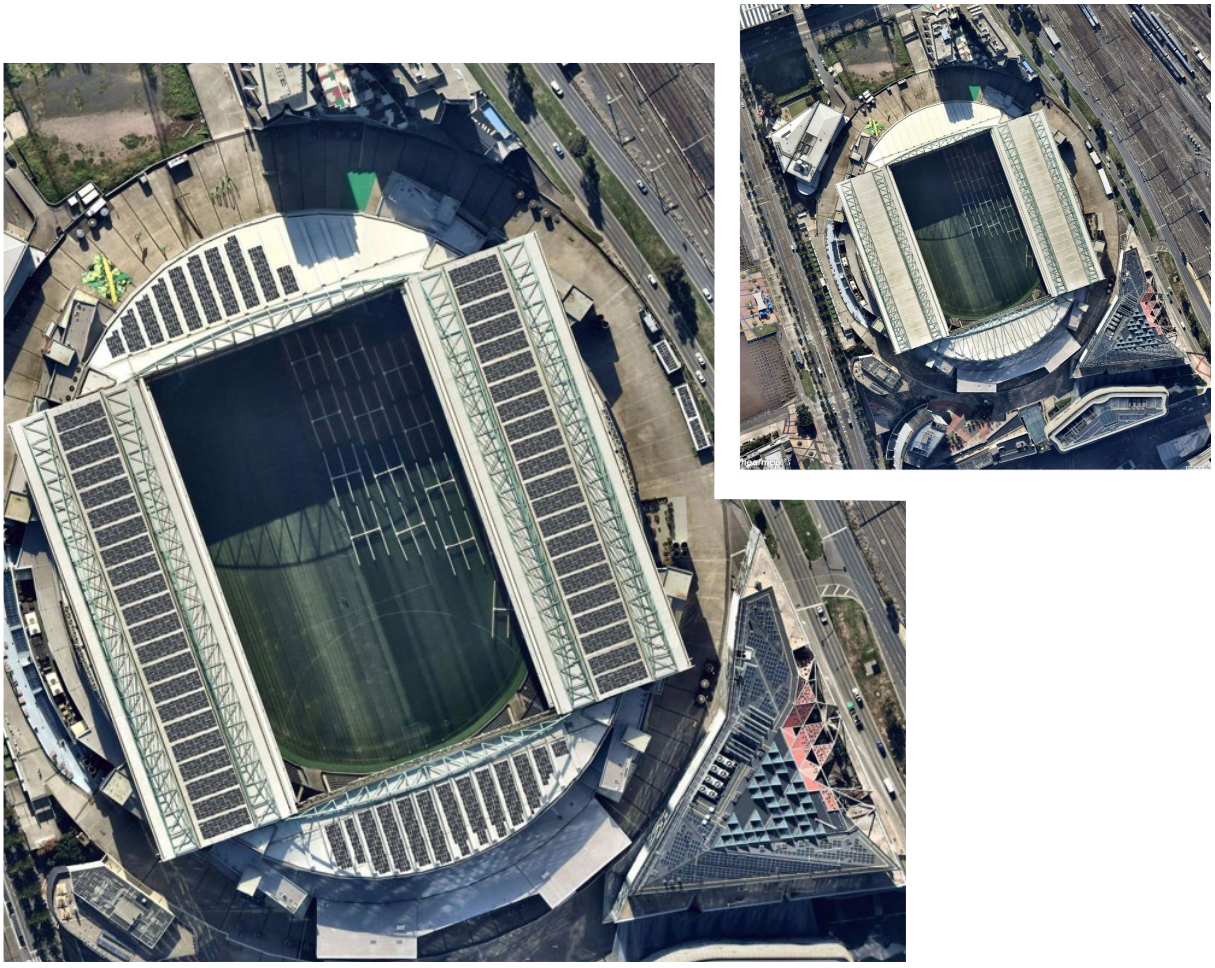


Figure 1: Marvel Stadium, now (inset) and with a potential 1553 kW solar array

[11] https://www.austadiums.com/stadiums/marvel-stadium

Australian Rules Football teams summary results

Analysis was carried out on the rooftops of the home grounds, training and administrative centres of each AFL team to determine the size of the potential solar system that could be installed.

Figure 2 shows a representation of the solar potential on these stadia rooftops.

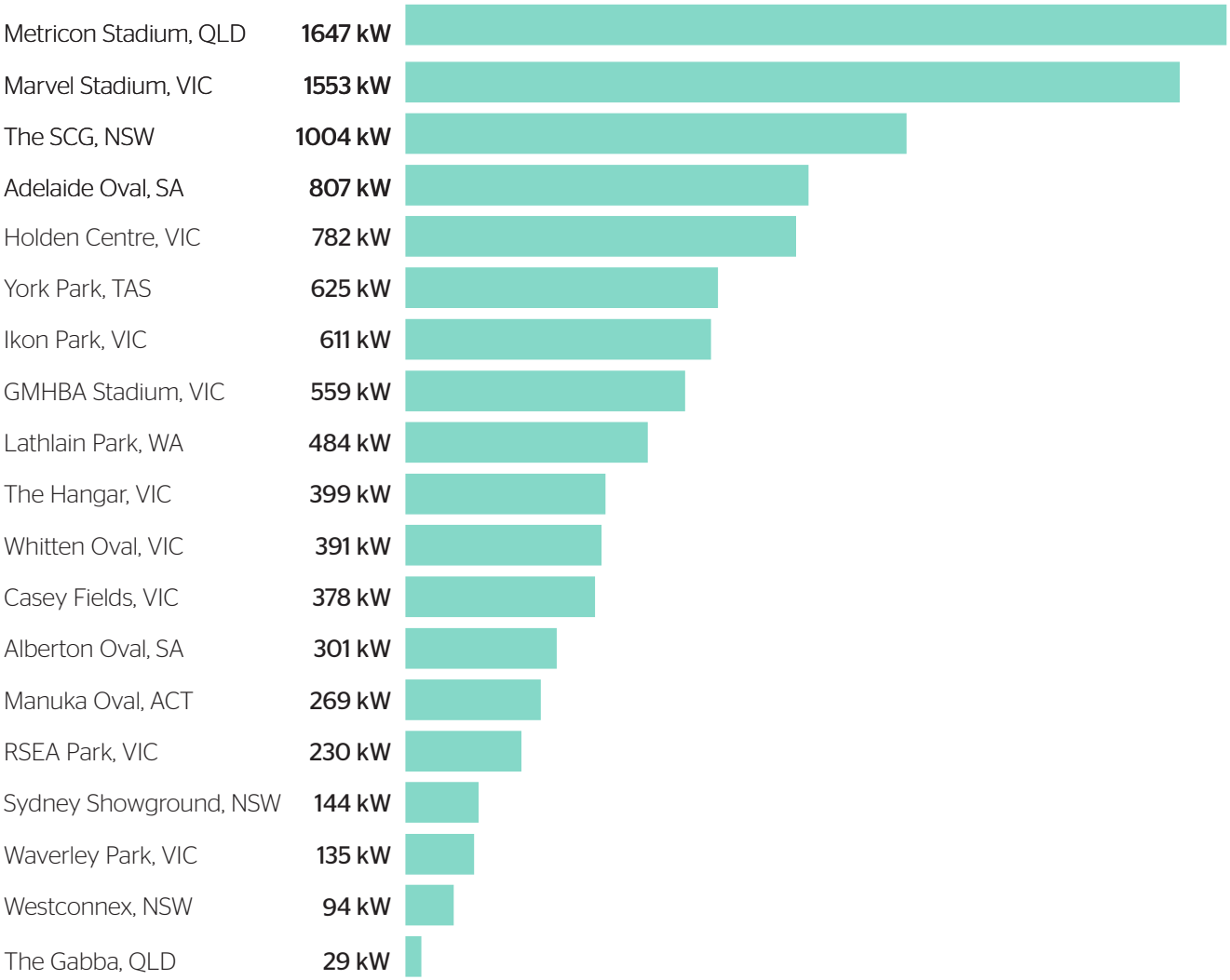


Figure 2: Potential rooftop solar capacity on AFL Team Stadia and headquarters

Table 1 shows the array area and maximum power output of these potential solar systems, along with the annual energy produced and estimates of their potential impacts, in terms of avoided CO_2 emissions over the typical 20-year life of the system and the equivalent number of trees planted. It also includes the number of typical households that could be powered by each array and the employment that could be generated through the installation.

Stadium	Seating capacity (1000's)	Array area (m^2)	PV capacity (kW peak)	Estimated energy production (MWh/year)	Estimated avoided emissions (kilo tonnes-CO_2-e / 20 years)	Equivalent # household energy supplied	Equivalent 1000's trees (over 20 yrs)	Estimated job-hours created	Estimated system cost ($1,000's)
Marvel Stadium, VIC	53	7,766	1,553	1,857	38	319	631	15,134	$1,661
Ikon Park, VIC	22	3,053	611	712	15	122	242	5,949	$653
Holden Centre, VIC	3	3,908	782	945	19	162	321	7,616	$836
The Hangar, VIC	7	1,993	399	451	9	77	153	3,883	$426
GMHBA Stadium, VIC	36	2,795	559	700	14	120	238	5,448	$598
Casey Fields, VIC	9	1,890	378	476	10	81	162	3,683	$404
RSEA Park, VIC	10	1,148	230	261	5	45	89	2,238	$245
Whitten Oval, VIC	10	1,957	391	478	10	82	162	3,813	$418
Metricon Stadium, QLD	40	8,237	1,647	2,494	38	324	640	16,052	$1,746
The Gabba, QLD	42	144	29	44	1	5	631	281	$31
Sydney Showground Stadium, NSW	24	720	144	179	3	24	48	1,403	$138
Westconnex Centre, NSW	3	472	94	121	2	16	33	919	$91
Manuka Oval, ACT	16	1,346	269	377	6	39	102	2,624	$258
York Park, TAS	21	3,127	625	684	2	63	34	6,093	$700
Waverlley Park, VIC	6	675	135	144	2	24	49	1,315	$144
Alberton Oval, SA	11	1,507	301	398	4	55	58	2,936	$310
Adelaide Oval, SA	54	4,035	807	1,068	9	150	157	7,863	$831
The SCG, NSW	49	5,020	1,004	1,293	21	176	349	9,783	$963
Lathlain Park, WA	6	2,421	484	733	10	141	169	4,718	$551
TOTALS	**422**	**52,214**	**10,442**	**13,415**	**218**	**2025**	**4,268**	**101,751**	**$11,004**

Table 1: Potential solar generation and equivalent metrics for case studies completed on AFL stadia rooftops

Prices paid by commercial customers for electricity from the grid are negotiated with their retailer and vary between states, networks and customers, depending on the generation costs of the electricity, charges for transmission and distribution, and retail margins. According to the ACCC, the median price paid by small and medium enterprises in 2019 was 32.3 c/kWh [ACCC 2020). Inquiry into the National Electricity Market – September 2020 report]. It its likely that some of the estimated 13,000 MWh that could be generated annually by solar systems on the AFL club headquarters described in this report would be exported to the grid, and while some commercial customers negotiate to receive a feed-in tariff, others receive nothing for the export. Using a conservative assumption that half the generated energy is consumed within the facilities and that half of the exported energy attracts a typical FiT of 9.5c/kWh, the annual solar generation could save the organisations up to $2.4 million annually.

Above. **MCG.**
Photo: **Scottt13/Shutterstock.com**

Adelaide Football Club

Adelaide Football Club (FC) and Port Adelaide FC share the Adelaide Oval with the South Australian Cricket Association and South Australian National Football League (NFL). The multipurpose venue has a seating capacity of 55,317[12] and was redeveloped in 2014 with the expansion of the east and south stands. The stretched, flexible, Teflon-coated fibreglass roofing material installed by Fabritecture[13] on these stands would not allow a solar installation, but the more rigid roof structure of the west stand may be able to support a system, subject to detailed engineering assessment. Additionally, there is roof capacity on the Favell/Dansie indoor cricket centre in the south-west corner of the precinct, as shown in Figure 3, giving a possible total capacity of 807 kW.

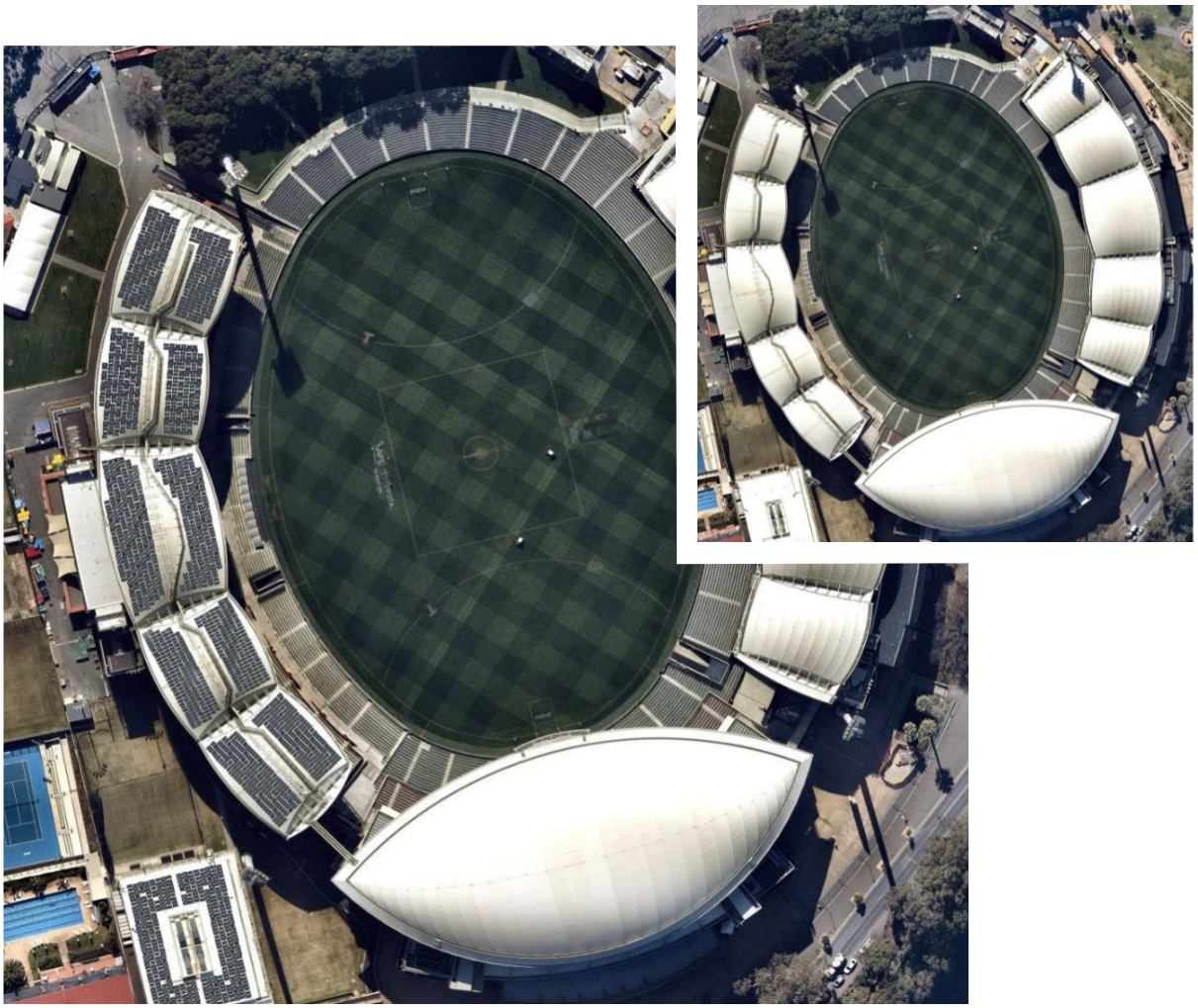


Figure 3: Adelaide Oval, now (inset) and with a potential 807 kW solar array

[12] Adelaide Oval | Austadiums (https://www.austadiums.com/)

[13] "*Fabritecture Lands $4M Contract for the Adelaide Oval Stadium Redevelopment*" News Wire press release

Brisbane Lions Football Club

The Brisbane Lions are based at the Gabba in the heart of Brisbane, sharing the 42,000-seater stadium with the Brisbane Heat and Queensland Bulls cricket teams. The roof structure of the main stadium comprises flexible material stretched over a steel frame, making a traditional solar installation unfeasible, although there may be future opportunities using lightweight, flexible solar technology.[14]

However, there is potential for a modest 28.8 kW solar system on the roof at the south-west edge of the stadium. As shown in Figure 4, the potential system is limited to small open areas available on the rooftop and is capable of producing 44 megawatt-hour (MWh) of electricity per year.

Due to the multiple demands on the Gabba, the Lions are planning a new, purpose-built stadium – The Reserve in Springfield – which is still in the early stages of development. This could provide an opportunity to install an extensive solar system to supply energy to the new facility.

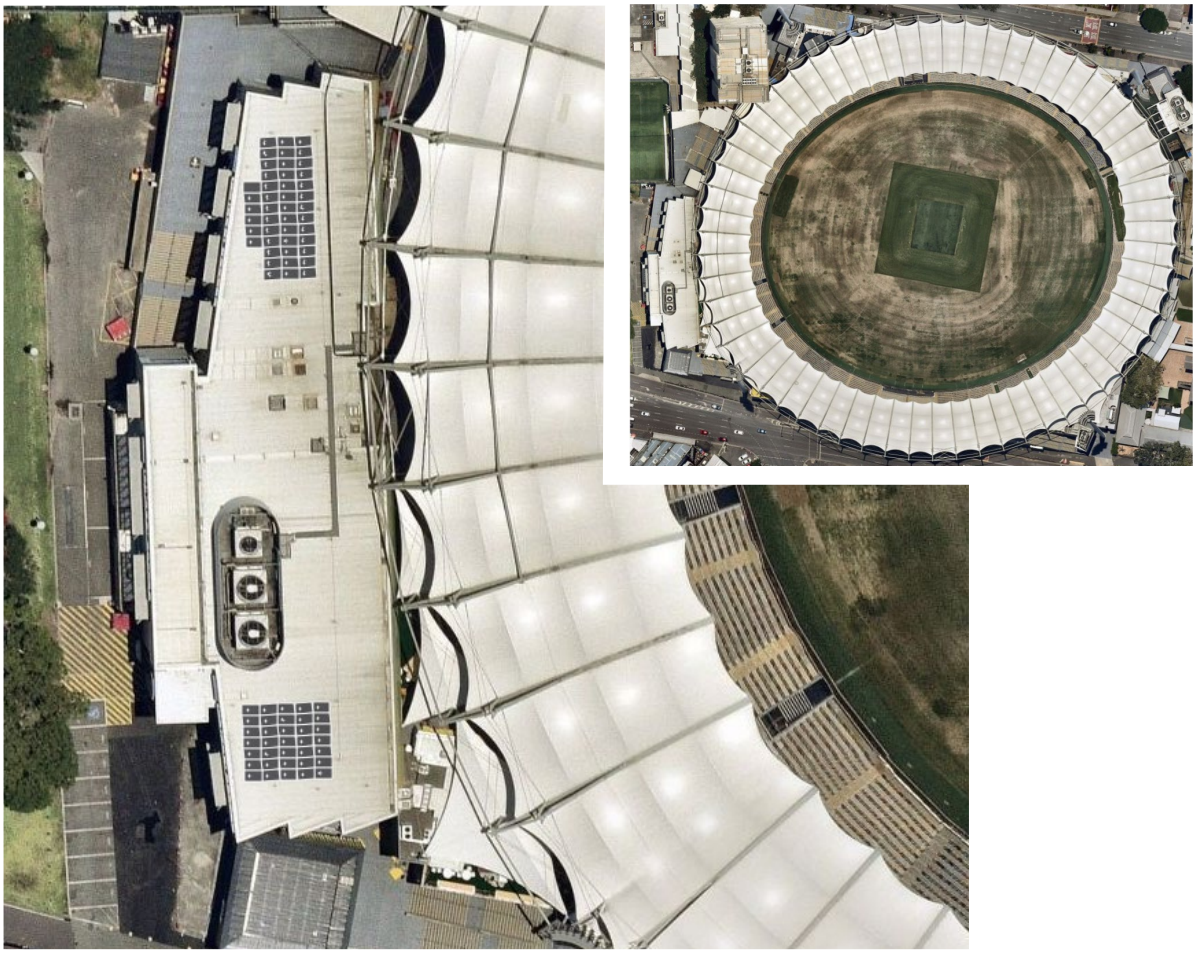


Figure 4: The Gabba, now (inset) and with a potential 28.8 kW solar array

[14] https://reneweconomy.com.au/sun-king-returns-to-solar-market-with-ultra-light-panels-on-maritime-museum-28176/

Carlton Football Club

While Carlton FC play their home games at the Marvel Stadium, their headquarters and training facility remains at their traditional home, formerly Princes Park and now called Ikon Park, with a modest 22,000-spectator capacity.[15]

There is already a significant solar system installed on the roof of the western stand, as shown in Figure 5 (inset). However, our analysis shows potential on the remaining roof areas for a further 611 kW of solar PV, despite some rooftop obstructions on parts of the stadium (see Figure 5).

The club has initiated a $40 million redevelopment of Ikon Park, making it the centre for women's AFL in Victoria. This could present a perfect opportunity for expanding the total installed solar capacity to utilise the full potential of the site.

Figure 5: Ikon Park, with existing solar system (inset) and with a potential additional 611 kW solar array

[15] https://www.austadiums.com/stadiums/princes-park

Collingwood Football Club

The Collingwood Football Club (The Magpies) uses the Melbourne Cricket Ground (MCG) for their home games but train at the Olympic Park Oval, while their administrative headquarters are located in the adjacent Holden Centre. Originally constructed for the 1956 Melbourne Olympic Games, the Holden Centre was redeveloped in 2013 and now hosts an array of athletic equipment and services including hydrotherapy and swimming pools, as well as a 3,000-seater training ground.[16]

The large rooftop of the centre has an appropriate 10° slope (Figure 6, inset) allowing for a flush solar system design, while the flatter roofs of other buildings would require a tilt design and appropriate spacing between the rows to avoid self-shading. Collectively, the Holden Centre rooftops could house a substantial 782 kW solar system (Figure 6), capable of generating 945 MWh of electricity per year.

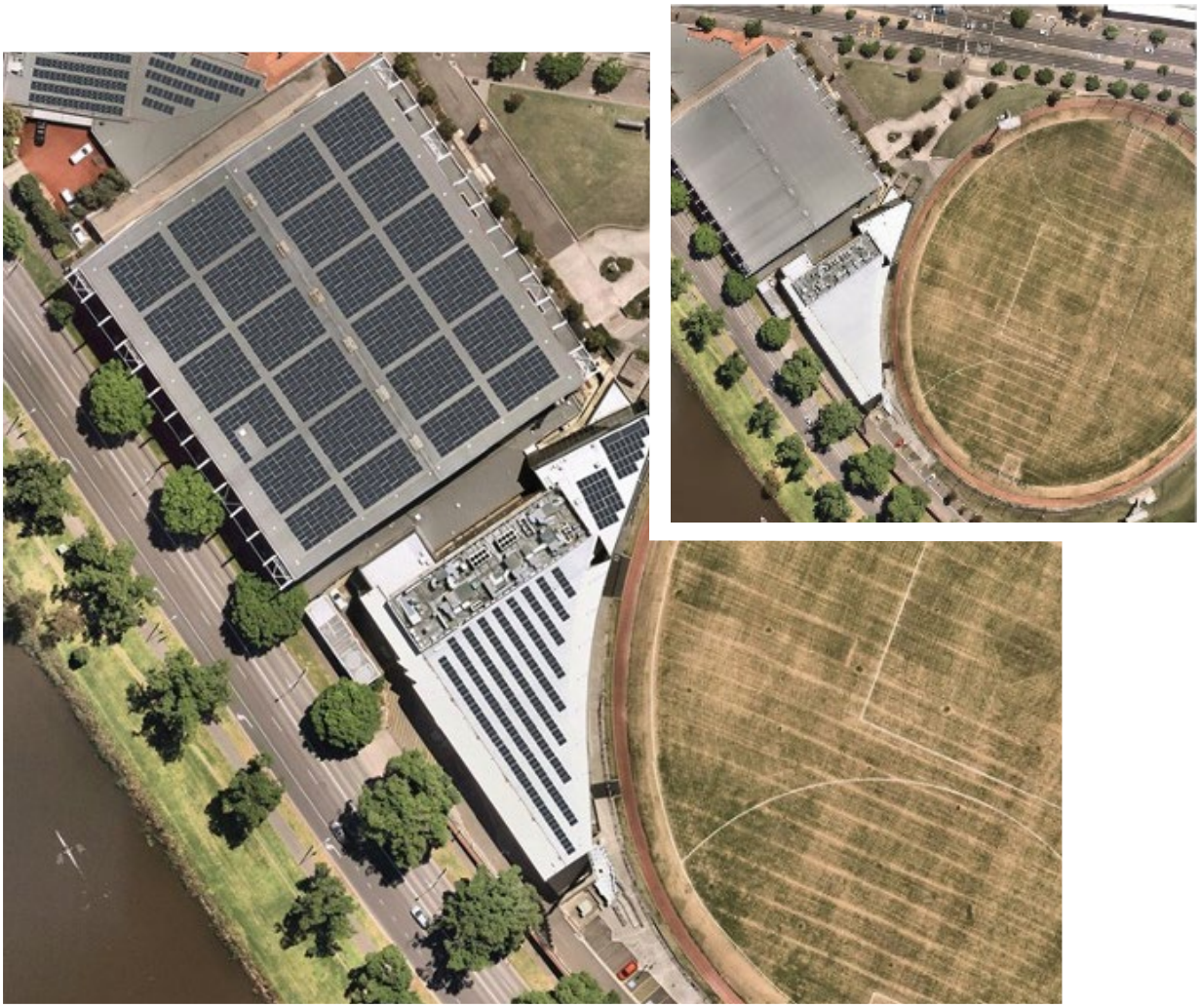


Figure 6: Holden Centre, now (inset) and with a potential 782 kW solar array

[16] https://www.austadiums.com/stadiums/olympic-park-oval

Essendon Football Club

Essendon FC (the Bombers) play home games at either the Marvel Stadium or the MCG, but the club's administrative and training base is at The Hangar, near Melbourne airport, which they share with the Australian Paralympic Committee. The $27 million stadium includes two ovals, an indoor aquatic centre, a running track, gymnasium and administration offices.[17]

The stadium opened in 2013 as the True Value Solar Centre under a sponsorship deal that included installation of a substantial solar system on the main building. Our analysis reveals sufficient roof space for an additional 399 kW array, generating a potential 451 MWh of electricity per year. The venue is shown in Figure 7 with the existing system (inset) and with the whole roof used for solar.

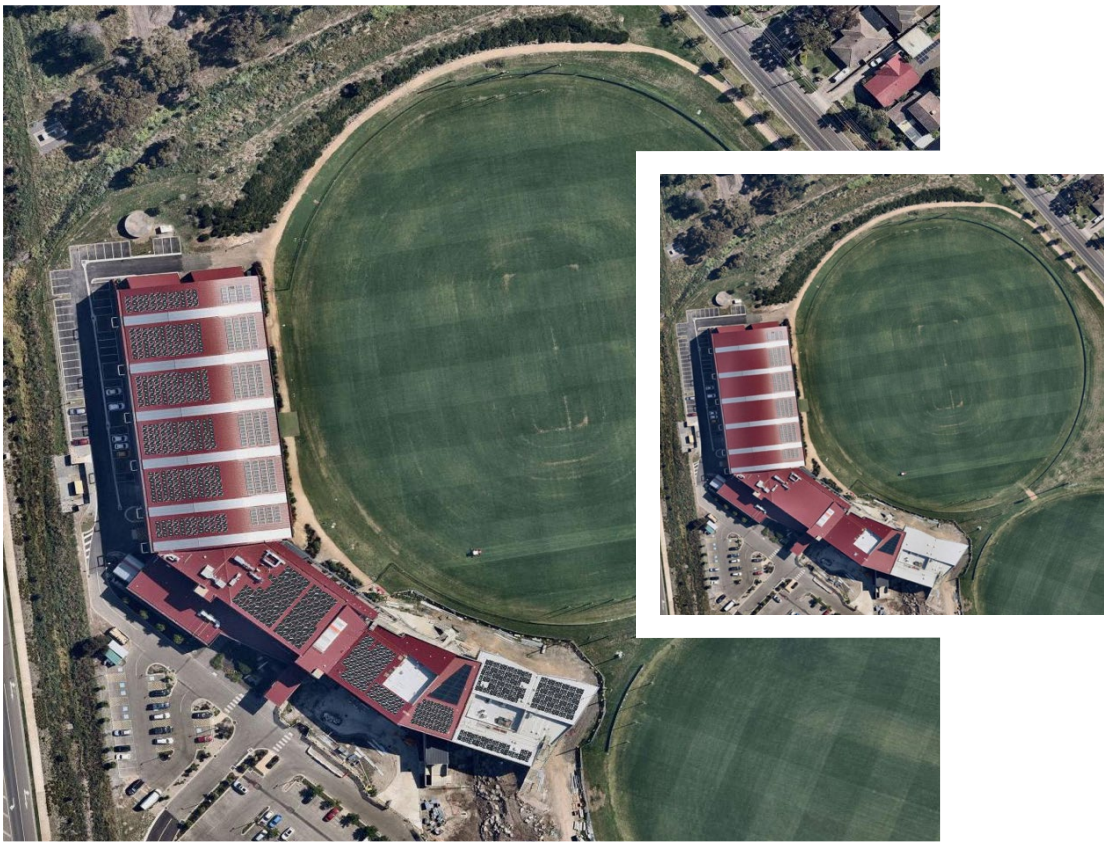


Figure 7: The Hanger, now (inset) and with a potential 399 kW solar array

[17] https://en.wikipedia.org/wiki/The_Hangar

Fremantle Football Club

The training and administrative headquarters of Fremantle FC (the Freo Dockers) is at the Cockburn Aquatic and Recreation Centre (Cockburn ARC), while the club play their home games at Perth Stadium, also known as Optus stadium. The extensive roof of Perth Stadium is covered in a flexible material unlikely to support a traditional solar PV array, although there may be future opportunities with next generation lightweight, flexible PV modules.[18] However, the Cockburn ARC has a more suitable roof and a massive 1 MW system has been installed, covering most of the available roof space. 100 kW of this was installed by the Dockers' sponsor Solargain[19] and supplies power to their training facility.

Figure 8: Cockburn ARC, showing the existing 1 MW solar system

[18] https://reneweconomy.com.au/sun-king-returns-to-solar-market-with-ultra-light-panels-on-maritime-museum-28176/

[19] https://arena.gov.au/blog/sustainability-in-sports-stadiums-powering-the-afl-scoreboard/

Geelong Football Club

The Geelong Football Club (Geelong Cats) is one the oldest football clubs in Melbourne, formed in 1859.[20] The Cats play their home games at the GMHBA stadium (previously known as Kardinia Park), one of the largest in regional Victoria with a seating capacity of 36,000.[21] The team's administrative headquarters are also located on site.

The stands of the stadium surround the grounds with the majority of them under sawtooth shaped rooftops with an approximate 22° slope, so that only north-west- and east-facing slopes are suitable for solar installation, with space for 20 flush panels per face. Figure 9 shows the GMHBA with a potential 559 kW array, capable of generating 700 MWh of electricity per year. The lighting towers would partially shade the system but modelling has shown that its effect on the energy output is negligible.

Figure 9: GMHBA Stadium, now (inset) and with a potential 559 kW solar array

[20] https://www.geelongcats.com.au/

[21] https://www.austadiums.com/stadiums/gmhba-stadium

Gold Coast Suns

The Gold Coast Suns play their home matches at the Metricon Stadium (also called the Carrara Stadium), with their training and administrative headquarters located in the nearby Gold Coast Sports and Leisure Centre. The Metricon Stadium, Gold Coast Sports and Leisure Centre and adjacent Carrara Indoor Stadium together form the Gold Coast Sports Precinct.[22]

The Metricon Stadium had a 200 kW "solar halo" installed in 2011[23] (Figure 10), while additional future deployment may depend on development of lightweight, flexible modules.

Figure 10: Existing 200 kW "solar halo" at Metricon stadium

[22] https://www.goldcoast.qld.gov.au/thegoldcoast/gold-coast-sports-precinct-30125.html

[23] https://arena.gov.au/blog/sustainability-in-sports-stadiums-powering-the-afl-scoreboard/

Gold Coast Suns *continued*

The rooftop of the Sports and Leisure Centre has a relatively small existing system (Figure 11) and our analysis shows the whole Precinct has the potential for an additional 1,647 kW array, which would produce 2,494 MWh of electricity annually to power the precinct's significant daytime use. Figure 11 and Figure 12 show the potential solar array installed across multiple rooftops.

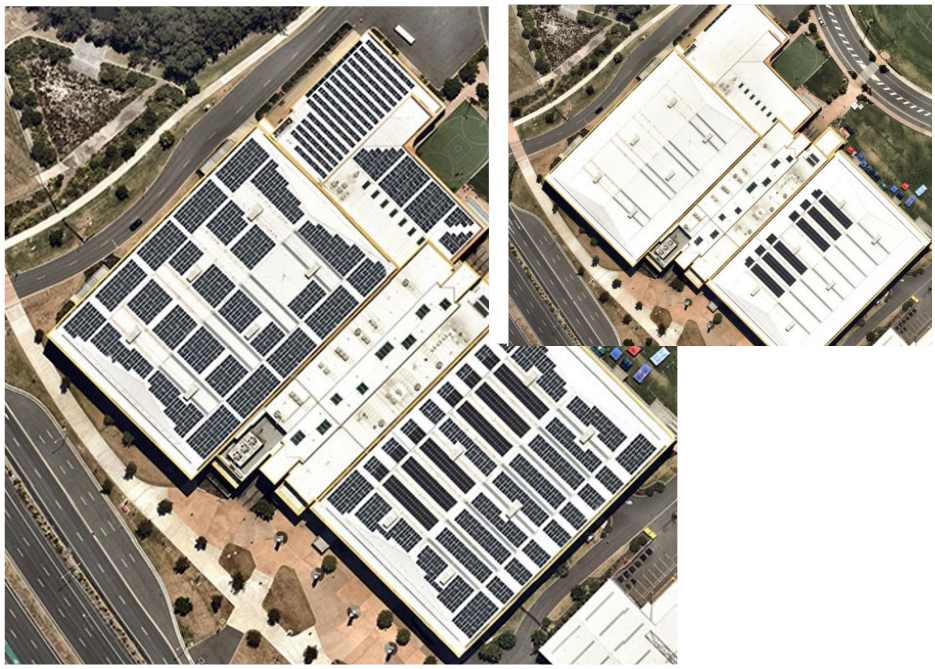


Figure 11: The Gold Coast Leisure Centre, with existing solar system (inset) and with potential additional solar arrays

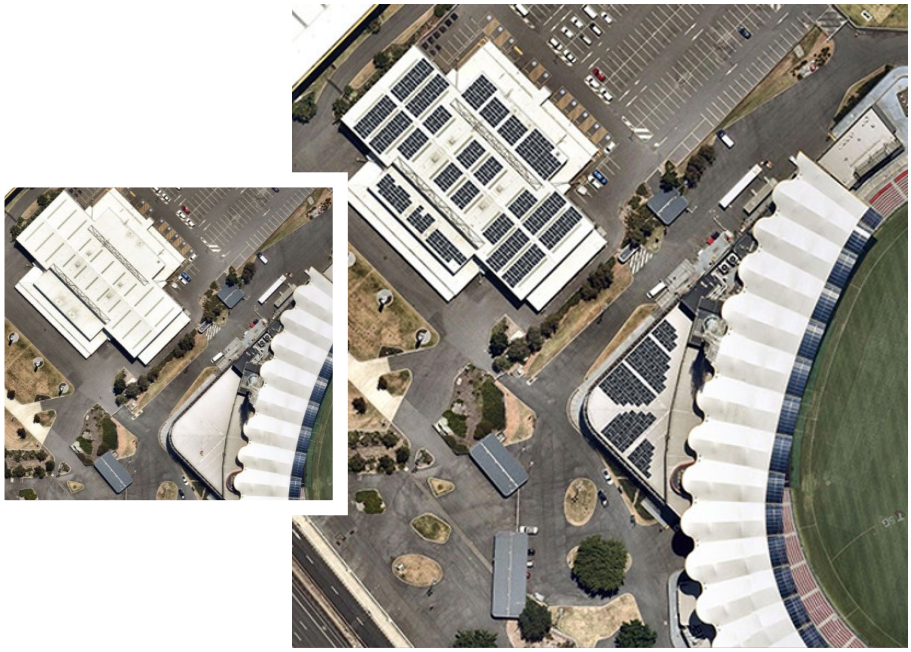


Figure 12: Carrara Indoor Stadium and Southwest Metricon Stadium, now (inset) and with potential additional solar arrays

Greater Western Sydney Giants

The Greater Western Sydney Giants football team plays home games at the 24,000-seater Sydney Showground Stadium in Sydney Olympic Park.[24] Much of the roof area is obstructed by metal trusses and supporting cables, as shown in Figure 13, which could prevent solar installation. However, some sections of the roof are more suitable, with potential for a 144 kW solar system, capable of generating 179 MWh of clean energy per year.

Figure 13: Sydney Showground Stadium, now (inset) and with a potential 144 kW solar array

[24] https://www.austadiums.com/stadiums/sydney-showground

Greater Western Sydney Giants *continued*

Although the Giants' home ground has less solar potential than other sites analysed in this report, their training and administrative headquarters are located about 1.2 km away at the Westconnex Centre,[25] where a significant solar system already occupies much of the roof space. However, there is potential for an additional deployment of 94 kW (Figure 14), capable of generating 121 MWh of electricity per year. The potential solar system shown follows a similar design to the existing system, requiring row spacing due to module tilting used to avoid self-shading.

Figure 14: The Westconnex Centre, with existing solar system (inset) and with an additional 94 kW solar array

[25] https://populous.com/project/gws-giants-hq

Greater Western Sydney Giants *continued*

The Giants also play four additional home games per season at the Manuka Oval in the Australian Capital Territory.[26] Including the grass embankments, Manuka Oval has capacity for 16,000 spectators[27] and hosts international sporting events such as cricket Test matches. Figure 15 shows the Manuka Oval rooftops with a potential 269 kW solar array installed on the roofs of the stands and associated buildings. Through this secondary home ground, the Sydney Giants team could generate a further 377 MWh of electricity per year. In combination with the Sydney Showground Stadium and Westconnex Centre, the facilities used by the Giants have the potential for 507 kW of solar, generating 677 MWh per year.

Figure 15: Manuka Oval, now (inset) and with a potential 269 kW solar array

[26] https://www.gwsgiants.com.au/matches/venues

[27] https://www.austadiums.com/stadiums/manuka-oval

Hawthorn Football Club

Hawthorn FC (the mighty Hawks) has its headquarters at Waverley Park but the stadium is no longer used for AFL matches so the club's home games are split between the MCG and York Park, officially known as University of Tasmania Stadium.

Waverley Park stadium is surrounded by houses but has a small grandstand with potential for a modest solar installation of 135 kW on the roof as shown in Figure 16. This system would have an annual output of 144 MWh.

Figure 16: Waverly Park with existing solar installation (inset) and with a potential additional 135 kW solar array

Hawthorn Football Club *continued*

As described in our companion cricket report, in 2017 the Australian Photovotaic Institute (APVI) identified potential roof space for a massive 2.2 MW solar array on the MCG [1]. However, an engineering assessment of the roof structure, subsequently determined that much of the stadium roof would not support the weight of a traditional solar array. A smaller 99.4 kW[28] solar system has now been installed on parts of the north stand.[29]

York Park is one of the largest stadia in Tasmania with a capacity of 19,500 people. York Park is an additional facility that is used for four home games per year. The stadium already has a solar system installed on the south-west stand and a smaller system at the north of the site (Figure 17, inset). However, use of the remaining roof space would enable installation of a further 625 kW of solar, with the potential to generate 684 MWh of energy each year. The cantilever structure of the roof would require engineering assessment prior to installation, but the existing solar system suggests that installation would be possible. The protruding trusses and cross-bracing would cause some shading, but the impact would be relatively minor and has been allowed for in our analysis.

Figure 17: York Park with existing solar installation (inset) and with a potential additional 625 kW solar array

[28] https://www.linkedin.com/posts/cherry-energy-solutions_power-play-mcg-goes-solar-in-climate-change-activity-6746916066280271872-TFl8

[29] https://www.smh.com.au/sport/cricket/power-play-mcg-goes-solar-in-climate-change-fight-20201218-p56om7.html

Melbourne Football Club

The Melbourne Demons play their home games at the MCG, which has a modest solar system installed but has a roof structure unsuitable for installation of traditional solar technology, as described above. The club's administrative and training headquarters is at AAMI park (Melbourne Rectangular Stadium), which has an innovative geodesic structure supporting its roof. This is also likely to present engineering challenges to solar installation, but developments in lightweight and flexible solar modules may present opportunities for future deployment.

The club's women's team plays at the 10,000-capacity VFL Oval at Casey Fields,[30] a multi-sport facility that is also used as a training ground by the men's team. The roof of the grandstand and the newly completed community football facility to the north of the oval has capacity for a 378 kW solar system (see Figure 18) with potential to generate 476 MWh of electricity each year.

Figure 18: Casey Fields, now (inset) and with a potential 378 kW solar array

[30] https://www.austadiums.com/stadiums/casey-fields

North Melbourne Football Club

North Melbourne Kangaroos play their home games at the Marvel Stadium, but the administrative and training headquarters of North Melbourne FC is at Arden Street in North Melbourne. A 100 kW solar system covers most of the stadium roof while another 100 kW system occupies the neighbouring North Melbourne Recreation Centre. The 269 MWh generated each year by the club's solar system means it uses 22% less electricity from the grid. The system was installed through a partnership between the Kangaroos and north Melbourne council, partially financed by the Clean Energy Finance Corporation.[31]

Figure 19: Arden Street Stadium and North Melbourne Recreation Centre, showing the existing 200 kW solar systems

[31] https://greenmagazine.com.au/north-melbourne-scores-solar/

Port Adelaide Football Club

The Port Adelaide Football Club competes in both the AFL and the South Australian National Football League (SANFL). Its AFL team plays home games at the Adelaide Oval (previous case study), while Alberton Oval is the home ground for the SANFL team.[32] The administrative headquarters and both AFL and SANFL training facilities are also located at the Alberton Oval site, which has a seated and standing capacity of 11,000.[33]

As shown in Figure 20, the rooftops of the stands and office building have the potential for a 301 kW solar system, capable of generating 398 MWh of electricity per year. This would be installed on tilt-frames to allow self-cleaning, and therefore require spacing between each row of panels, as shown, to avoid self-shading.

Figure 20: Alberton Oval, now (inset) and with a potential 301 kW solar array

[32] https://www.portadelaidefc.com.au/matches/sanfl-fixture

[33] https://www.austadiums.com/stadiums/alberton-oval

Richmond Football Club

The Richmond Tigers play home games at the MCG, described above, but the club's training and administrative headquarters is next door at the Punt Road Oval. The club installed a 100 kW solar system on the grandstand roof in 2014, to supply the significant daytime electricity load of their gym, treatment and recovery clinic, education spaces and offices.[34]

As well as reducing its own carbon emissions, membership of the United Nation's Sports for Climate Action initiative[35] commits the club to use its community leadership position to promote sustainable consumption and to educate and advocate for climate action.

Figure 21: MCG and Punt Road Oval, showing existing 100 kW solar system at Punt Road (inset)

[34] https://arena.gov.au/blog/sustainability-in-sports-stadiums-powering-the-afl-scoreboard/

[35] https://www.richmondfc.com.au/news/243150/richmond-partner-sports-for-climate-action-initiative

St Kilda Football Club

The St Kilda Saints is another team that plays home games at the Marvel Stadium, but its administrative and training headquarters is at Moorabbin Oval, formally known as RSEA Safety Park, which also hosts the AFLW team.[36] The 10,000-seater stadium, which recently underwent a $20 million redevelopment, has a 100 kW solar system already installed on the roof, providing much of the power for the club's gym, café and lighting.[37] Unusually for commercial systems, the PV modules have been mounted on frames with a significant tilt. This maximises the energy generated by each module but requires large separation between the rows of panels to avoid shading, and therefore reduces the total capacity that can be installed on the roof.

Nevertheless, there is still room to increase the solar generation capacity of Moorabbin Oval. Installing another 700 solar panels on the unused roof area (modelled here with a minimal tilt and closer spacing) could boost the total capacity to 329 kW. Figure 22 shows this potential solar system, and (inset) the existing 100 kW system.

Figure 22: Moorabbin Oval, with existing 100 kW solar array (inset) and with potential additional 229 kW solar array

[36] https://www.austadiums.com/stadiums/moorabbin-oval

[37] https://easybeinggreen.com.au/st-kilda-football-club-solar-pv-system/

Sydney Swans

The Sydney Swans play at the 48,601-seater[38] Sydney Cricket Ground (SCG), where they also have their administrative and training headquarters. Figure 23 shows the potential 1,004 kW solar system that could be hosted on the stadium rooftops. The slope of the roof is approximately 10° and relatively clear of fixtures and obstructions, allowing for flush mounting. There are no major sources of shading other than the grounds' floodlights, but modelling shows that these would cause little reduction to the annual output of the system.

Figure 23: Sydney Cricket Ground, now (inset) and with a potential 1,004 kW solar array

[38] Sydney Cricket Ground (SCG) | Austadiums (https://www.austadiums.com/)

West Coast Eagles

The West Coast Eagles' AFL team plays home games at the Optus Stadium, where the rooftops of the stands consist of a lightweight fabric material, unsuitable for conventional solar panels. Future solar system deployment may be possible with further development of lightweight, flexible modules. However, the West Coast Eagles' AFL women's team and the Western Australia National Football League (WANFL) play home games at the 6,500-capacity Mineral Resources Park (traditionally Lathlain Park), where the club's administration headquarters are also located.

As shown in Figure 24, the main building already has a substantial solar array built flush onto the flat eastern rooftop, but our analysis suggests potential for an additional 484 kW solar system, which has been modelled with a 10° tilt to allow for self-cleaning. This additional system alone could generate 733 MWh of electricity per year.

Figure 24: Mineral Resources Park, with existing solar system (inset) and with a potential additional 484 kW solar array

Western Bulldogs

The Western Bulldogs play home games at the Marvel Stadium, but their training and administrative headquarters is at the 10,000-seater VU Whitten Oval, where the club's AFLW & VFL teams also play.[39] Figure 25 shows the potential 391 kW solar system that could be hosted on the stadium rooftops. The slope of the roof is approximately 10° and relatively clear of fixtures and obstructions, allowing for flush mounting. There are no major sources of shading other than the grounds' floodlights, but modelling shows that this would cause little reduction to the annual output of the system. The system has a potential to generate an annual energy of 478 MWh.

Figure 25: Whitten Oval, now (inset) and with a potential 391 kW solar array

[39] https://www.austadiums.com/stadiums/whitten-oval

Regional and community AFL

As well as the 18 national clubs, there are 57 state-level AFL clubs organised into six state leagues, and over 1,490 AFL clubs playing in local leagues across the country. [40]

The range of playing fields and facilities available to these clubs is wide. While some have covered grandstands, function facilities and indoor training areas, others have more basic amenities. Moreover, much of this infrastructure is multi-use, shared with other sports clubs, schools, markets, country shows and diverse community activities. Ownership and responsibility for electricity supply may rest with the club, the state or local AFL or football association, local council, state government, or be shared between multiple parties.

Nevertheless, at a minimum each of these community clubs has access to toilet and changing facilities, while most state-level clubs will have some covered seating. Using only half the roof area of a minimal 100m^2 building, each of the community clubs could install a 10 kW solar system, while 20 kW would represent a reasonable lower limit for the state level clubs. Combining these gives a conservative estimate of a minimum of 15.5 MW solar capacity on Australia's state and local community AFL clubs, with an approximate investment cost of $18 million.

As well as reducing electricity costs for community clubs (with bill savings likely to repay installation costs within a few years, particularly if a feed-in-tariff is available), these systems would contribute to the decarbonisation of the energy system and help reduce emissions.

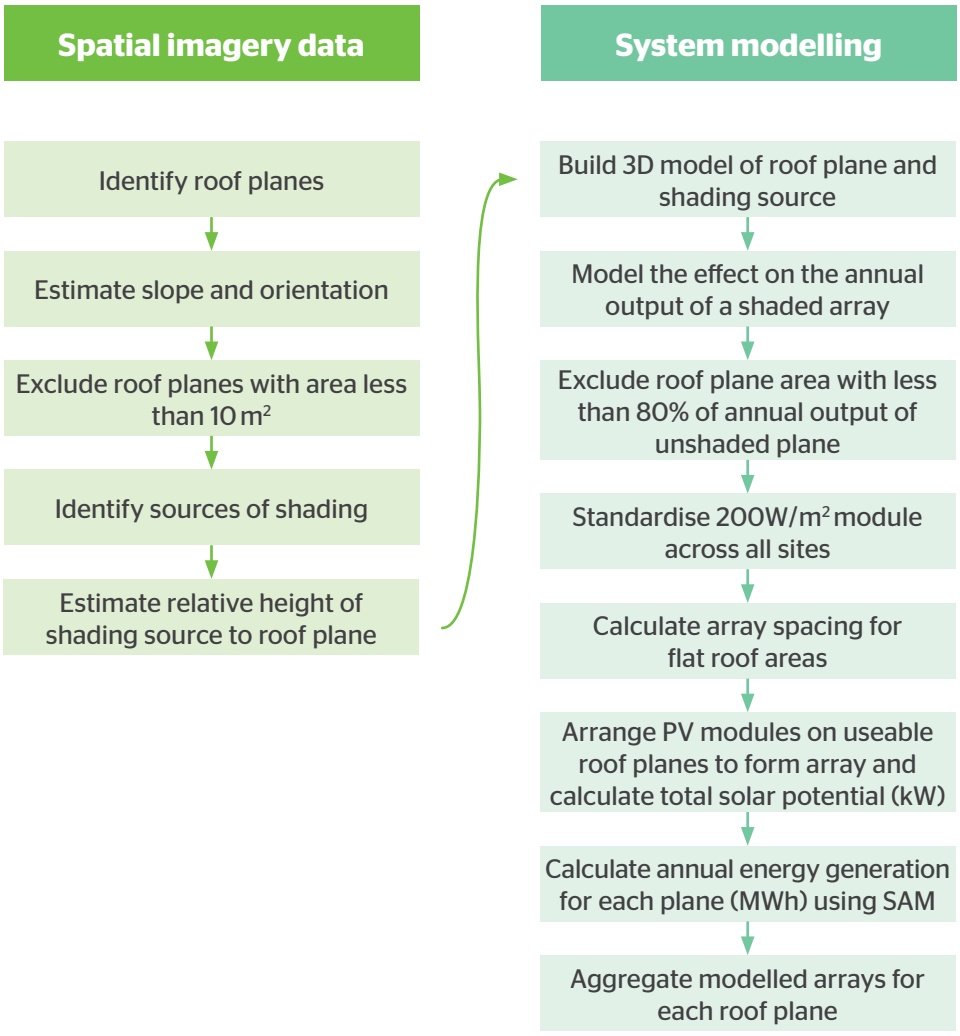
Above. **Community football match.**
Photo: **Allan Castle**

[40] https://en.wikipedia.org/wiki/List_of_Australian_rules_football_clubs_in_Australia

Methodology

This section describes the method used to estimate the rooftop solar potential of the AFL stadia and associated buildings. The steps in the methodology are illustrated in Figure 26.

Figure 26: Major steps in the estimation of rooftop solar potential using visual analysis



Analysis of **solar potential and energy generation**

The potential solar capacity of the case study buildings were assessed visually, using multiple viewpoint aerial imagery from Nearmap [2]. Unsuitable surfaces and obstructions were identified and excluded from the usable roof area. Roof slope was estimated using the measuring tools in Nearmap's Oblique View imagery, and small rooftop obstructions and perimeter walls were also identified and their height estimated. The shading on a PV module at a range of distances from obstructions of different heights was modelled using the 3D shading calculator in NREL's System Advisor Model (SAM) and the impact on annual output for a horizontal PV panel was calculated. Using this data, additional roof area proximate to rooftop obstructions was excluded if estimated annual output was less than 80% of an unshaded horizontal panel.

Nearmap's Solar Tool was then used to arrange 1.7m x 1.06m PV panels on the usable roof space. On all usable roof areas with greater than 10° slope, PV arrays were assumed to be installed flush to the roof, while 'flat' roofs were assumed to have rack-mounted arrays installed at a tilt of 10°. The rack-mounted arrays were spaced to avoid self-shading. The PV capacity was calculated assuming modules of 360 watts (and a consequent DC size factor of 200 W/m2), and the annual energy output was calculated using NREL's System Advisor Model [3] and an 'ERMY' weather file [4] for the nearest Bureau of Meteorology (BOM) weather station.

As the assessment was carried out remotely, there may be additional physical constraints on the available roof area as well as structural restrictions on the potential array size that have not been considered here. The systems described represent the available rooftop solar potential, not a design proposal.

Carbon and equivalency metrics

The annual energy produced by potential rooftop solar PV has been compared to the average annual household energy consumption in each state (Table 2 derived from [5-7]), using data for a four-person household in the climate zone of each stadium.

Potential CO_2-e emissions reductions from rooftop solar were calculated by multiplying the indirect (Scope 2) emissions factor for consumption of electricity purchased from the grid in each state (see Table 3) by the expected annual energy generation from the system over the 20-year module lifetime, and subtracting the estimated embodied carbon emissions from the manufacture, installation, operation and decommissioning of the PV system (0.045kg CO_2-e /kW[8]).

Since solar is very low-maintenance, jobs created in Australia through solar deployment are predominantly in sales and installation, at an estimated 5.8 job-years (assumed equivalent to 9,744 job-hours) per MW of commercial solar installed [10].

The carbon uptake of trees is highly variable, depending on species and growing conditions. For our estimate of the number of planted trees that would avoid an equivalent amount of carbon emissions as the potential PV installations, we used a figure of 0.06 tonnes CO_2-e per urban tree planted and allowed to grow for ten years [11]. This was divided into the estimated 20-year lifetime generation of the potential solar PV.

Table 2: Annual household energy consumption by state and climate zone

State	Zone	kWh/ year
NSW	5	7,311
QLD	2	7,682
SA	5	7,121
TAS	7	10,820
VIC	6	5,805
WA	5	5,198
NT	1	10,074
ACT	7	9,542

Table 3: Scope 2 emissions factors by state [9]

State	Emissions factor ($kg\text{-}CO_2/kWh$)
NSW	0.81
QLD	0.77
SA	0.44
TAS	0.15
VIC	1.02
WA	0.69
NT	0.63
ACT	0.81

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The School of Photovoltaic and Renewable Energy Engineering (SPREE) at the University of New South Wales (UNSW) has an international reputation for solar energy research. The SunSPoT Solar Potential Tool, which is the technical basis for the solar potential estimates in this report and a series of Solar Potential assessments published by the Australian PV Institute (APVI) for major Australian Cities, was developed and validated at SPREE for APVI to help inform and facilitate ongoing investment in solar photovoltaic (PV) systems in Australia. This work is part of a broader renewable energy systems research program at SPREE, including renewable energy resource assessment, performance analysis, modelling and mapping, renewable and distributed energy integration, and building energy modelling.

The Australian PV Institute (APVI) is a not-for-profit, member-based organisation providing data analysis, reliable and objective information, and collaborative research to support the uptake of solar photovoltaics and related technologies. APVI promotes PV through its live solar mapping platform (http://pv-map.apvi.org.au), organises Australia's national solar research conference, and coordinates Australia's participation in two International Energy Agency programs: Photovoltaic Power Systems and Solar Heating and Cooling.

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Images

Satellite imagery is sourced from nearmap.com.au

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