WESTERN SYDNEY UNIVERSITY

CUMBERLAND COUNCIL

GUIDE TO

CLIMATE-SMART PLAYGROUNDS –

RESEARCH FINDINGS AND APPLICATION

2021

AUTHORS

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Warami wellamabamiyui, yura! We pay our respect to the Darug people, the traditional custodians of the land on which this work has taken place. For many thousands of years, the Darug have known about the importance of shade. This is indicated by at least three different phrases in their rich language to describe 'shadow' (*bawuwan, buwari buwa* and *gugubuwari*). Its linguistic brother 'shade' provides us with comfort and protection. We hope the present work on heat and UV in playgrounds – places for meeting and learning, of and for community – will help promote shadow and shade, comfort and protection. This will not only increase our resilience against increasing heat but demonstrate our respect and care for country and its people.

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LOCAL GOVERNMENT NSW

NSW GOVERNMENT

CUMBERLAND COUNCIL

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PRÉCIS

This report has two parts. Part 1 provides a systematic assessment of surface temperatures found in playgrounds during hot summer days. Part 2 applies the findings of Part 1 to design and build Australia's first dedicated *UV-smart Cool Playground*. Since October 2020, the playground is enjoyed by the local community of Merrylands in Western Sydney.

The following recommendations are the quintessence of physical measurements (Part 1) and lessons-learned (Part 2) during this exciting project.

1. **Prioritise interventions that mitigate heat and UV radiation** when designing new or upgrading existing playgrounds.
2. **Expand shade where it is absent**. Shade is the most important element to make playgrounds climate-smart. Shade will markedly cool surfaces and play equipment. It will reduce radiant heat loads and block harmful UV radiation.
3. **The most cost-effective and climate-responsible approach to improve playground microclimate is planting large canopy trees** that block midday and afternoon solar irradiance. Tree plantings will increase community resilience.
4. **Consider the thermal comfort of parents and carers** when introducing or expanding shade. If resting places for adults are unshaded, they will spend less time at a playground even if shade is provided over the play equipment.
5. **Avoid dark rubber softfall in unshaded playgrounds**. This material can lead to burn injuries. In direct sun, lighter colours (or light-coloured speckled mixes) will have lower surface temperatures, but higher quantities of reflected radiation will lead to lower human thermal comfort (*Trojan Effect*).
6. **Consider rubber softfall material** – cheaper products, even in lighter colours are likely to have higher surface temperatures when unshaded.
7. **Avoid synthetic turf in unshaded playgrounds**. Regardless of the light conditions, broader environmental impacts (i.e., capacity to recycle, escape of microplastic) should always be considered when selecting or replacing synthetic turf in playgrounds.
8. **Provide access to drinking water**. Keeping children and their parents and carers well hydrated during active outdoor play is key to prevent heat-related health issues.
9. **Educate parents and carers** about the risks associated with hot surfaces and exposure to UV radiation in your playground.
10. **Promote climate-smart playgrounds** to your community.

CONTENTS

PART 1

THERMAL ASSESSMENTS

Part 1 of this report documents surface, air and feels like temperatures in public playgrounds across the Cumberland Local Government Area. All playgrounds were visited repeatedly during warm and hot conditions in the summer of 2019/20 and 2020/21. While data collections were impacted by smoke haze from the Black Summer bushfires during the summer of 2019/20, they were not impacted by playground closures in response to COVID-19 safety measures in 2020.

1.1 **INTRODUCTION**

Outdoor play is vital for positive socialisation and development of children including cognitive, psychological, and physiological benefits (Brockman et al., 2011). Playing outdoors increases attention, creative thought processes and problem-solving skills as well as combating obesity, mental health problems and improving social skills of children (Bundy et al., 2011). Encouraging and supporting outdoor play is particularly important today, where the daily time interval children are engaging in physical activity is contracting (Ridgers et al., 2013).

The decline in time spent outdoors by children has several reasons. In short, these can be attributed to three main subject areas: (1) centre of life, (2) contemporary lifestyle, and (3) unsuitable outdoor environmental conditions. Across the world, the centre of life for humans is increasingly urban where overall access to green space can be limited. At our own doorstep, the metropolitan region of Sydney, the issue of limited access to green space, and the lack of it more broadly, has raised concerns in local and state government organisations. The issue was sufficiently severe to be captured in two of the 14 Premier's Priorities, *Greener Public Spaces* and *Greening our City*. To address the lack of urban green space, the State Government has committed substantial resources to plant 1 million new trees by 2022 and improve access to green space for 230,000 homes by 2023 across metropolitan Sydney. These actions reflect the importance of access to public green space, including playgrounds.

There is strong evidence that, as part of contemporary lifestyles, screen time of children has significantly increased (Chen and Adler, 2019). Without doubt, regular use of electronic screens has become an integral part of modern life. It is estimated that 95% of households in the United States and the United Kingdom have at least one television and one smart phone (Ribner and McHarg, 2021). Similar numbers can be expected for Australia where children will spend on average 3-4 hours in front of a television or mobile device by the time they are 12 years old (Yu and Baxter, 2016). As screen time of children is increasing, time spent outdoors in a park or playground is declining.

Even if the local park or playground is nearby and children are off screen, increasing summer heat is limiting the time available for safe outdoor play. Here we define summer heat as days with maximum air temperatures at or above 35°C. On average, Western Sydney experienced 11 days each summer where the mercury climbed past 35°C between 1981 and 2010 (Ogge et al., 2018). According to modelling from CSIRO (reported in Ogge et al., 2018), the number of days that this temperature threshold is reached in Western Sydney could increase to 60 or more per year by 2090. And even in the cooler coastal parts of Eastern Sydney, the number of intense summer heat could increase more than five-fold from 4 (mean of 1981-2010) to 22 days per year by 2090.

Increasing urban heat is not restricted to Sydney but impacts cities and their populations around the world. Urban expansion and densification lead to the loss of green spaces which reduces the cooling capacity inside our cities. More people in a city simply leads to more heat. The impacts of climate change further accelerate this effect. All internationally validated climate models indicate that planetary warming and localised urban heat phenomena will continue to intensify over the coming decades. These predictions demand adequate responses at all levels of intervention – from multilateral climate agreements down to cooling initiatives at the local street, park and playground.

Shade in the form of mature trees or other structures provides good protection against harmful ultraviolet (UV) radiation (Parisi and Turnbull, 2014), but is often missing in public playgrounds. A recent national survey in New Zealand found that 60% of all playgrounds had no shade at all and in many playgrounds shade it was inadequate (Gage et al., 2019). The lack of shade will leave children and their parents or carers exposed to direct solar radiation, which not only increases thermal discomfort and the risk of overheating but overexposes them to harmful UV radiation. High exposure to UV during childhood and adolescence seems to increase the risk of developing skin cancer later in life (Green, 2011; Whiteman et al., 2001). In Australia, where the intensity of solar and UV radiation is very high for most of the year, up to 95% of melanomas and 99% of keratinocyte carcinomas are likely the result of overexposure to UV (Gage et al., 2019). Hence, protection of children against UV is paramount to increase their chances of a life without skin cancer.

Shade in playgrounds will also result in lower temperatures of surfaces and play equipment. Reports of severe skin burns from children in playgrounds are documented in the scientific literature (e.g., Strong et al., 2007) and recent work in the United States and Canada has highlighted the health hazards that arise when playing in unshaded playgrounds (Vanos, 2016; Vanos et al., 2016, 2017; Kennedy et al., 2020). A central question in *Everyone Can Play*, the reference guide of the NSW Government on how to create world-class play spaces (NSW Government, 2019), is "Can I stay?". The answer to that question is "Only if good shade is provided".

1.1.1 **HEAT ACROSS CUMBERLAND CITY COUNCIL**

Prior to the formation of Cumberland City Council in 2016, most towns and suburbs of the region in the geographical centre of metropolitan Sydney were managed by the Cities of Holroyd and Auburn. The Climate Change Risk Assessments of both former local governments identified urban heat, heatwaves and/or extreme temperatures as important risks to local communities. Once Cumberland City Council became operational, the identified risks and associated mitigation approaches were reviewed. In 2018, the Western Sydney Regional Organisation of Councils released its *Turn Down the Heat Strategy* (WSROC, 2018) which provided local governments in Western Sydney Councils, including Cumberland, with a strategic framework and action plan around the issue of urban heat. Cumberland City Council adopted the framework and began planning and implementing initiatives to better understand the extend and variability of local heat across its jurisdiction.

Cumberland City Council engaged Western Sydney University to document and map air temperatures across the 72 km^2 of the Local Government Area (LGA), including commercial centres, industrial zones, residential streets, parks and other green spaces. The necessary field-based research took place in the summer of 2018/19, where air temperatures were recorded at very high frequency for more than two months in 97 locations inside and outside the boundary of the LGA of Cumberland.

Results of this research project revealed that heat across the council area was much more intense than previously known (Pfautsch and Rouillard, 2019). Measurements from the nearest official weather station at Sydney Olympic Park recorded 10 days with maximum daily air temperatures above 35°C during December 2018, January and February 2019. In contrast, analyses of the locally acquired measurements showed that maximum daily air temperatures at or above 35°C occurred on 41 days during the same time period. Summer daytime temperatures, the average air temperature between 10:00 and 18:00, differed by 6°C across the LGA and varied by more than 10°C during heatwaves.

Some of the 97 measurement locations of the project were at or near playgrounds where very high temperatures were recorded. Given the strategic recommendations in the *Turn Down the Heat Strategy* (WSROC, 2018), the importance of playgrounds as public green spaces and the need to prioritise heat mitigation actions gave rise to the work captured in this report. Public playgrounds across the LGA are important assets to Council as they represent a vital resource for learning, social coherence, and well-being of the community.

1.1.2 **PLAYGROUND MICROCLIMATE**

As emphasised by the work of Pfautsch and Rouillard (2019), microclimate across Cumberland varies markedly. This also applies to the playgrounds within the LGA. Their microclimates are influenced by the configuration of the surrounding landscape where distance to roads and buildings, air flows and the size, quality and hydration status of adjacent green space will influence site climate.

The thermal experience of humans spending time at a playground will largely depend on the configuration of the playground itself. The proportion of sunlit (or shaded) ground area as well as materials used for surfacing and play equipment will influence this experience. The combined effects of physical properties of surface and play equipment, especially their thermal mass, and the reflectance, absorbance and emission of solar irradiance will result in the 'thermal performance' of a playground. During clear summer days, these characteristics can result in gradients of surface temperatures of 50°C or more over short distances (Figure 1).

Playgrounds are predominately designed to stimulate safe play and learning experiences. To date, their thermal performance is not central to design considerations, which in increasingly hotter summers will lead to a reduction in time when playgrounds can be used safely. They will simply be too hot for children to use. A first step towards good thermal design of playgrounds is sound information about surface temperatures of widely used playground materials and how shade can reduce these temperatures and improve microclimate.

FIGURE 1: Normal (left) and infrared (right) views of the playground at Auburn Park, Auburn. The infrared image shows surface temperature by colour. The colour scale is provided on the right side of the image. Surface temperatures change nearly 50°C within a short distance from the lawn to the playground. Large differences in surface temperature of different materials exposed to the sun are visible (i.e., grass, concrete, different-coloured rubber softfall). The image was taken at 15:00 on 4 January 2020.

1.1.3 PROJECT AIMS

1. Systematically assess the effect of solar irradiance on surface temperatures of common materials used in the playgrounds of Cumberland.
2. Document the cooling capacity of shade and its impact on human thermal comfort.
3. Collate sound evidence that will inform climate-responsible design of playgrounds that mitigates heat and exposure to UV radiation.

1.2 METHODS

1.2.1 SELECTED PLAYGROUNDS

Cumberland City Council owns and manages 220 public playgrounds. They range in size from very small neighbourhood play spaces with a slide and a swing to large playgrounds with adjacent recreational and picnic facilities. In most of these playgrounds, the council uses bark mulch as surface material. The second most surface material is rubber softfall. Synthetic turf as a surface material is used in less than 10% of all playgrounds.

Six playgrounds were selected across the Cumberland City Council LGA. Selection criteria included geographic location, size, surface materials and shade status. Location was especially important, because the heat mapping across the LGA by Pfautsch and Rouillard (2019) showed that temperature regimes varied across the Cumberland LGA in summer. The selection of playgrounds aimed to incorporate this variation. The size criteria ensured that only neighbourhood playgrounds were included. These small to medium size playgrounds make up the majority of playgrounds across the LGA. Larger 'destination' playgrounds or splash parks were excluded. Lastly, it was imperative for the study to cover a large range of surface materials and colours to provide a wider overview of how summer conditions impact surface temperatures and thermal regimes in playgrounds.

At the end of the selection process, six playgrounds were identified in Auburn, Granville, South Granville, Greystanes, Merrylands and Toongabbie (Figure 2). Surface materials included bark mulch, rubber softfall and synthetic turf (Table 1). The shade status of playgrounds, especially if shade was cast over the play area during daytime hours where heat and UV radiation would be most intense, varied widely (Table 1).

FIGURE 2: Public playgrounds used in the research project. (A) Auburn Park, Auburn. (B) Bennelong Park, Granville. (C) Colquhoun Park, South Granville. (D) Kootingal Reserve, Greystanes. (E) Memorial Park, Merrylands. (F) The Portico Park, Toongabbie. Images shown in A and B were extracted from Google Street View.

TABLE 1: Selected playgrounds for thermal and environmental monitoring. Shade status was related to the presence or absence of shade during midday and afternoon where playground visitors would experience high air temperature and intense UV radiation.

NAME	STREET ADDRESS	SUBURB	PREDOMINANT SURFACE TYPE	SHADE STATUS
Auburn Park	Macquarie Road	Auburn	rubber softfall	some tree shade
Bennelong Park	William Street	Granville	synthetic turf	no shade
Colquhoun Park	Blaxce ll Street	South Granville	bark mulch	some tree shade
Kootingal Reserve	Kootingal Street	Greystanes	bark mulch	green shade sail
Memorial Park	Windsor Road	Merrylands	bark mulch	no shade
The Portico Park	Aurelia Street	Toongabbie	rubber softfall	some tree shade

Of the six playgrounds selected, only the playground at the Kootingal Reserve had a shade sail. The sail was lime green made from Architect 400® (Polyfab Australia, Carrum Downs, VIC, Australia). According to the manufacture, the shade cloth material had a cover factor of 95%, a mean UPF of 15 and a shade factor of 82%. As shown in Figure 3, the size of the sail was large enough to provide full coverage of the play equipment during midday.

FIGURE 3: Shade sail at Kootingal Reserve, Greystanes. The image was taken at noon on 04.01.2020. All play equipment is shaded.

1.2.2 ENVIRONMENTAL MONITORING

The playgrounds were visited on 18, 19 and 21 December 2019, 4 January, 28 November and 6 December 2020 and 10 and 16 January 2021. As a result of intensive smoke haze from bushfires burning in the Blue Mountains, the campaigns on 18 and 19 December 2019 were stopped during the early afternoon. At these times, the partial or total absence of direct solar radiation did not permit an objective assessment of cooling effects from shade on surface temperatures. Environmental conditions during all other days were sunny without cloud cover. Air temperature during these summer days ranged from 25°C to 48°C.

SURFACE TEMPERATURE

The temperature of surface materials and play equipment was measured using a radiometric infrared camera (T540, FLIR Systems, Wilsonville, OR, United States). Over the duration of the project, a total of 480 infrared images were collected. The camera simultaneously took RGB (red-blue-green) as well as infrared images, which supported very clear post-identification of objects, materials, colours, light conditions and locations. The FLIR Tools software was used to extract surface temperatures from individual images. In each image, five individual random spot measurements were recorded and averaged for each target surface. For the analyses of surface temperatures, we extracted 1055 individual measurements from 332 images collected at the six playgrounds. The images and resulting data covered a wide range of surface materials and play equipment in the full sun and under shade.

MICROCLIMATE

Air and black globe temperatures were measured at each playground. Two tripod-mounted portable weather stations (Model 5400, Kestrel Instruments, Melbourne, VIC, Australia) with integrated black globe thermometers (a 25 mm diameter copper sphere with a matt black surface) were used to record ambient environmental conditions in the sun and where possible in the shade over different surface materials. Accuracy of the air temperature sensors was ±0.5°C and ±1.4°C for the black globe thermometers. Each weather station was positioned 1 m above ground. Instruments were allowed to equilibrate to ambient conditions before data were recorded at 30-second intervals for 5 minutes. Data were stored on the instrument and downloaded for analyses. Measurements for each 5-minute interval were averaged and ±1 Standard Deviation (SD) was calculated. Microclimate measurements were recorded at the same time when surfaces were imaged.

The black globe thermometer was used to document a 'feels like' temperature that represents the thermal sensation of a human under the simultaneous influence of several important environmental factors. A black globe thermometer can capture these combined effects and is commonly used to track heat stress in work health and safety applications. The instrument is designed to represent the temperature of a seated adult human. It provides a composite measure of ambient air temperature, heat transfer by incident solar radiation and convection of heat between the globe and the environment, as well as wind speed (Olivera et al. 2019).

UV RADIATION

A portable spectroradiometer (Stellar Rad UV-VIS, Stellar Net Inc, Tampa, FL, United States) was used to estimate the reduction of UV radiation under shade sails. The effective bandwidth of the instrument captured ultraviolet light, starting at 250 nm through to near infrared, ending at 1150 nm. Data were recorded at 1 nm resolution. For this study, we defined UV-A radiation to cover wavelengths of light between 350 and 400 nm, and UV-B between 280-350 nm. Solar irradiance was recorded in W m^{-2}. Between three and five individual measurements were taken under different shade conditions at Kootingal Reserve and after the transformation of the playground at Memorial Park (see Part 2 of this report). These measurements were averaged and compared to the same number of measurements taken in full sunlight to estimate how much UV-radiation was blocked by the shade sails under field conditions. All measurements were collected during the early afternoon hours when the sky was clear and solar irradiance measurements in the full sun were unobstructed by clouds or other objects blocking light. Spectra were recorded on 6 December 2020, and on 10, 14 and 16 January 2021. A total of 20 spectra were recorded at Kootingal Reserve and 120 spectra were recorded at Memorial Park.

1.2.3 SYSTEMATIC TESTS

In addition to collection of field data, a systematic assessment of surface temperatures of common playground materials was done. Materials included styrene butadiene rubber (SBR), ethylene propylene diene polymer rubber (EPDM) and thermoplastic polyolefin (TOP), synthetic and real turf. All materials were provided as square tiles (30 cm x 30 cm). SBR, EPDM and TOP samples were 12-15 mm thick, mounted on a base layer (40 mm) of black rubber granules. All sides of the rubber tiles were covered with white fabric tape to prevent heating of the black rubber base from direct sunshine. Synthetic turf was placed on foam pads (15 mm thickness). Real turf (Kikuyu) was backed by a layer of soil and was standard material from a hardware store.

The assessment was done on 11 January 2021 in a special facility at the Solar Institute of Western Sydney University. The facility is a rectangular space with large glass windows and no sealing/roof to allow maximum solar exposure (Figure 4). Placing the samples in this room ensured that they were exposed to the same environmental conditions. The day of the experiment was sunny without clouds and maximum air temperature inside the room peaked early at 45°C around 10:00 and stabilised at 35°C at midday and during the afternoon. Outside the room, ambient air temperatures peaked at 36°C around 16:00. Solar radiation was 1000 W m^{-2} at midday and black globe (i.e., feels like) temperatures were between 47°C and 51°C inside and outside the room during the afternoon. Average windspeed was 0.1 m s^{-1} inside and 0.7 m s^{-1} outside the room.

FIGURE 4: Systematic assessment of playground surface materials. The images show a wide range of surface materials, including different rubber softfall materials and colours as well as synthetic turf samples with different pile heights. The materials were exposed to continuous sunshine in a testing facility of the Solar Institute at the Hawkesbury Campus, Western Sydney University, Richmond, NSW.

1.3 RESULTS

Surface temperatures in playgrounds can vary widely, depending on material, colour, orientation towards the sun, environmental conditions such as intensity of solar irradiance and air temperature. and other variables. Some of these variables can be controlled while others cannot. For environmental monitoring of playgrounds, we focussed on surface temperature, air temperature and feels like temperature measured in the sun and shade during warm and hot summer days in the suburbs of Auburn, Greystanes, Granville, Merrylands, South Granville and Toongabbie in Western Sydney.

1.3.1 TEMPERATURES IN DIRECT SUN

In and around the playgrounds investigated, surface materials included pine bark mulch, rubber softfall, synthetic and real turf, concrete, bare soil and bricks for delineation of playground surfaces and pathways. When unshaded, these surface materials had very different temperatures and, depending on the materials, could differ by more than 30°C. General trends were observed for some surface materials in the sun and are summarised as:

(a). Bark mulch was always hotter than bricks or concrete (Fig. 5A, B)

(b). Old and new concrete was always cooler than red bricks (Fig. 5A, B)

(c). Synthetic turf was always hotter than real turf (Fig. 5C, D)

(d). Real turf was always cooler than concrete or bark mulch (Fig. 5E, F)

(e). Surface temperatures could change abrupt (Fig. 5A-D) or gradually (Fig. 5E, F)

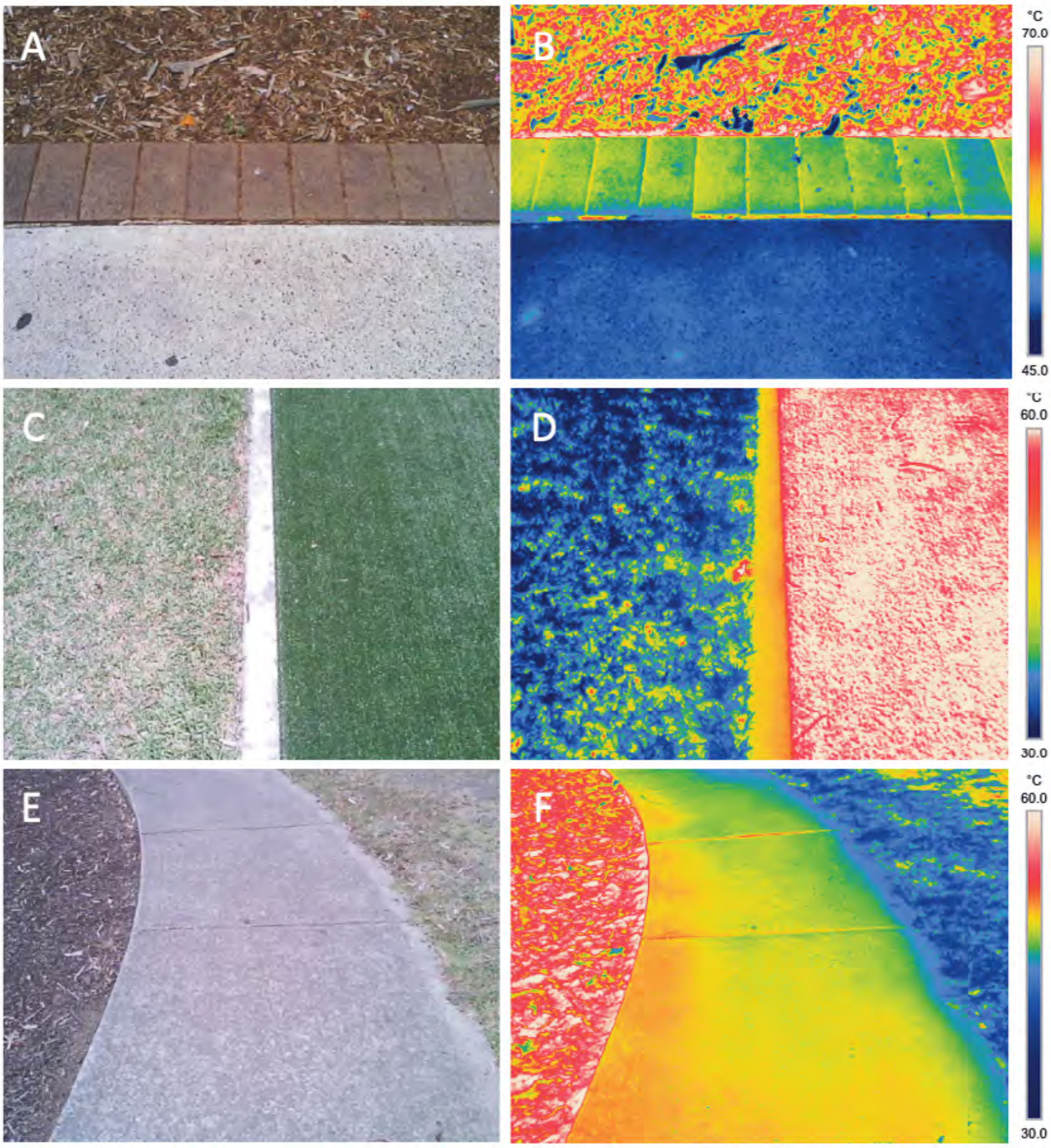

FIGURE 5: Surface temperatures of different unshaded materials in summer. Panels on the left show the normal view, while those on the right show the infrared view where temperature is represented by colour (see scale on the right of each panel). (A, B) Bark mulch (top), red bricks (middle) and new concrete (bottom). (C, D) Natural turf (left) and synthetic turf (right). (E, F) Bark mulch (left), old concrete (middle) and natural turf (right).

The absolute highest individual surface temperatures were measured on 4 January 2020, a day of extreme heat with air temperatures well above 40°C throughout Cumberland. The highest single air temperature measurement was 49.4°C, recorded at 13:33 in the playground of Bennelong Park. During that day, we measured a maximum surface temperature of 93.7°C on old synthetic turf in the same playground. The hottest surface temperature of play equipment was detected 30 minutes earlier in Memorial Park where the top of a blue rubber dolphin showed a surface temperature of 91.8°C. At the time these measurements were recorded, surfaces and play equipment of both playgrounds were unshaded. The combined effects of hot ambient air temperatures and additional radiant heat from the unshaded surfaces resulted in feels like temperatures (measured using black globe thermometers) of 64.1°C at Bennelong Park and 61.9°C at Memorial Park. Although the playgrounds were not being used by children during these temperature extremes, the measurements are important because they demonstrate the potential hazards in unshaded playgrounds during summer.

Very hot surface temperatures around 90°C were also measured on black rubber softfall. Rubber softfall surfaces and those covered with synthetic turf had the highest average surface temperature (70-75°C; Fig. 6). Side-by-side comparisons at the playground in Bennelong Park revealed that newer synthetic turf had always lower surface temperatures compared to older synthetic turf. The lowest average surface temperature of a material exposed to full sun was 37°C, measured on real turf (Fig. 6).

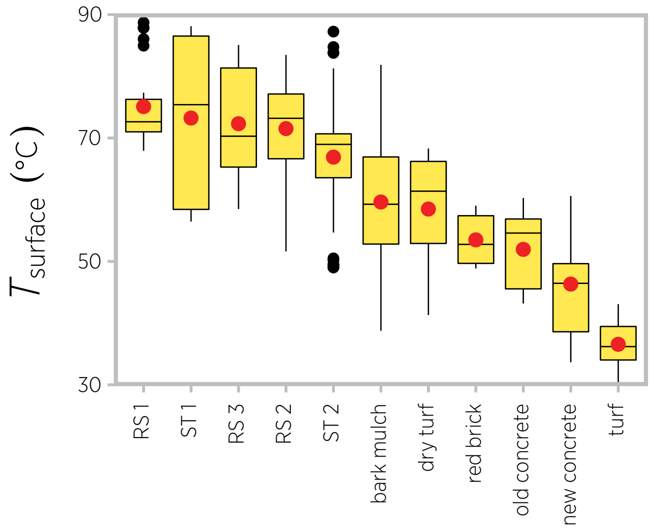

FIGURE 6: Surface temperatures ($T_{surface}$) in summer of a range of sunlit materials found in and around public playgrounds. RS 1 (black rubber softfall): n = 25. ST 1 (old synthetic turf): n = 15. RS 3 (dark blue rubber softfall at Memorial Park): n = 35. RS 2 (green, blue, red and dark-speckled rubber softfall): n = 110. ST 2 (new synthetic turf): n = 40. Bark mulch: n = 75. Dry turf (i.e., real turf that is yellow/brown): n = 40. Red brick: n = 10. Old concrete: n = 35. New concrete: n = 85. Turf (i.e., real turf that is green): n = 75. Red dots show the mean $T_{surface}$, black lines the median, top and bottom of the box represents 75th and 25th percentiles, whiskers show maximum and minimum values and black dots depict potential outliers. Data were collected during the early afternoon on clear days during the summer of 2019/20 and 2020/21. See Section 1.2 for more details about data collection.

When assessing natural surface materials in and around playgrounds, real turf, especially when irrigated, usually had the coolest surface temperatures in direct sunshine. When air temperatures increased above 40°C, unshaded real turf remained cool and its surface temperature mirrored air temperature (Fig. 7). However, when real turf was not irrigated, it yellowed and appeared dead (dry turf). This resulted in exposure of dry patches of bare soil, which dramatically increased surface temperature. With increasing air temperature, surface temperature of unshaded dry turf increased sharply. During very hot summer days, unshaded dry turf reached surface temperatures of 60°C and above (Fig. 7).

Regardless of warm or hot air temperatures, unshaded bark mulch had the highest surface temperatures of all three natural surface materials. On a clear day when the air temperature was 28°C, the surface of unshaded bark mulch was already 50-60°C. When air temperatures increased, the surface temperature of unshaded bark mulch increased to nearly 80°C (Fig. 7).

With increasing surface temperatures of the three natural materials, the associated feels like temperature (black globe temperature, T_{globe}) increased. While surface temperatures of irrigated turf rarely increased above 40°C, very high temperatures during the summer of 2019/20 resulted in feels like temperatures of more than 50°C over this material (Fig. 8). However, emission of heat from the hot surfaces of dry turf and bark mulch increased feels like temperatures even more, producing feels like temperatures of above 60°C (Fig. 8).

Rubber softfall and synthetic turf were generally the hottest surface materials to be found in playgrounds. When unshaded, and regardless of ambient temperatures, these surface materials always had very high mean temperatures and the highest absolute maximum temperatures. Examples of high surface temperatures of rubber softfall are provided in Figure 9. Large differences in surface temperatures as result of different materials, but not colour, were also visible when comparing red rubber softfall with red concrete pavers (Fig. 9D).

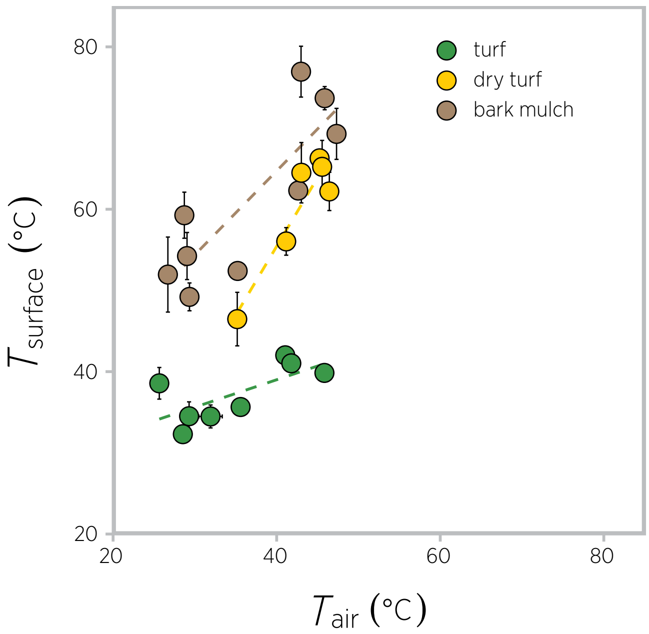

FIGURE 7: Relationship between ambient air temperature (T_{air}) and surface temperature ($T_{surface}$) on natural materials in full sunlight. Turf: n = 40. Dry turf: n = 30. Bark mulch: n = 45. Data were collected during the early afternoon on clear days during the summer of 2019/20 and 2020/21. See Section 1.2 for more details about data collection.

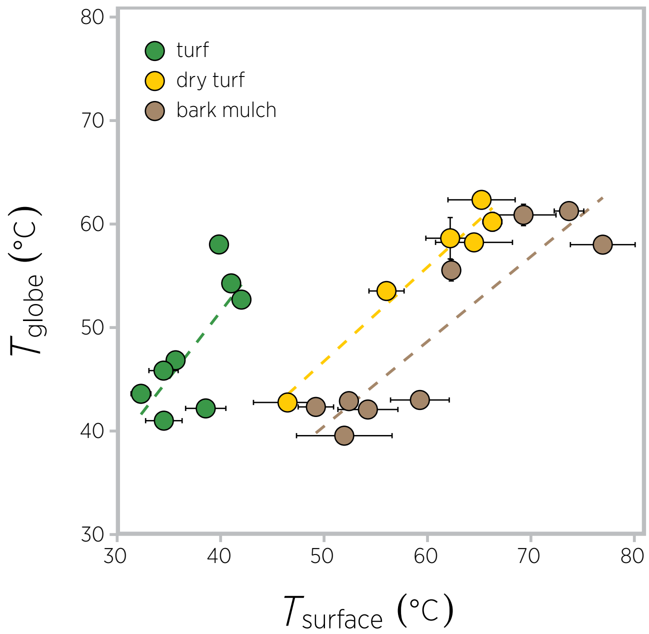

FIGURE 8: Relationship between surface temperature ($T_{surface}$) and black globe temperature (T_{globe}) on natural materials in full sunlight. Turf: n = 40. Dry turf: n = 30. Bark mulch: n = 45. Data were collected during the early afternoon on clear days during the summer of 2019/20 and 2020/21. See Section 1.2 for more details about data collection.

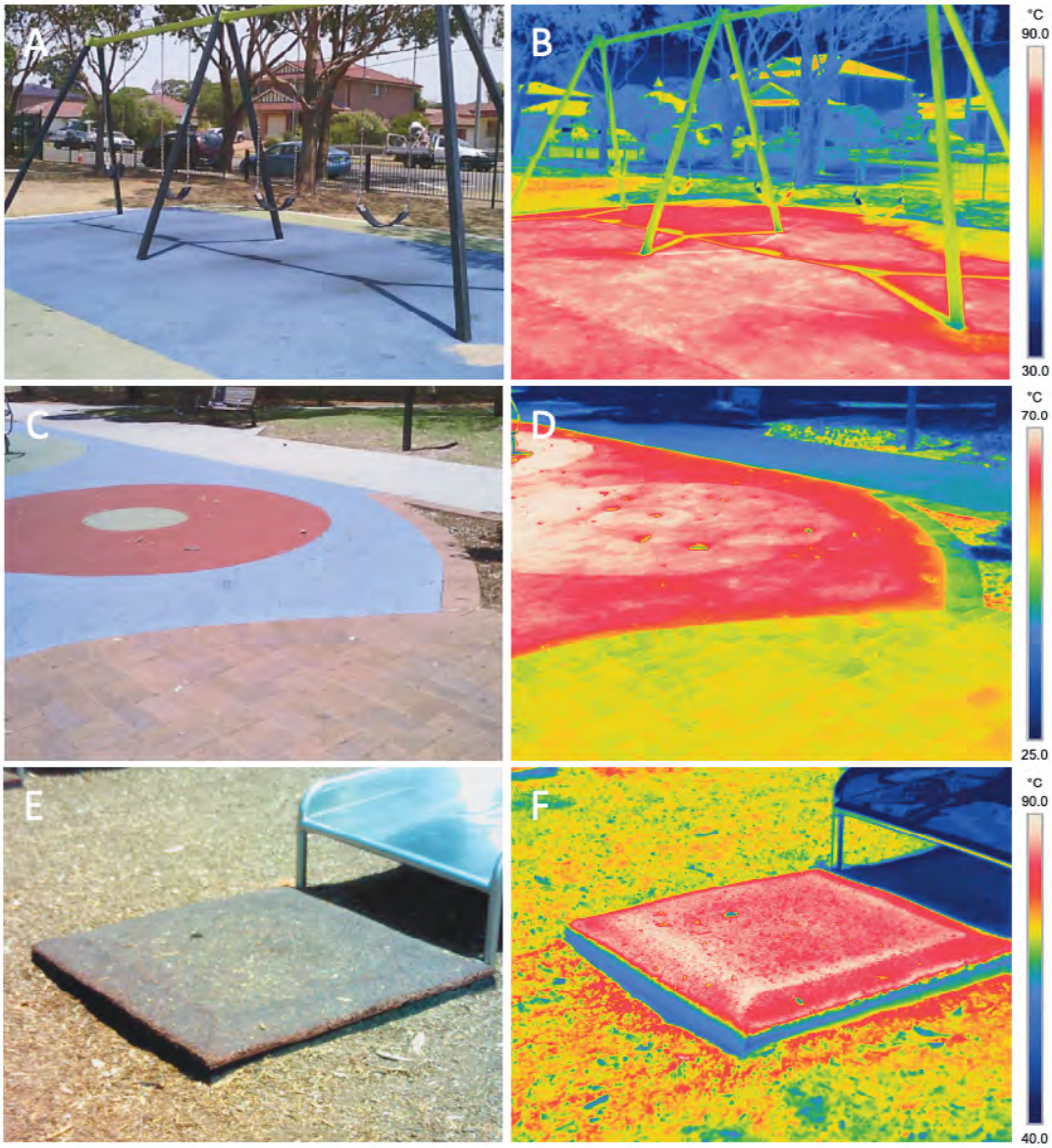

FIGURE 9: Surface temperatures of unshaded rubber softfall in summer. Panels on the left show the normal view, while those on the right show the infrared view where temperature is represented by colour (see scale on the right of each panel). (A, B) Blue and green rubber softfall in Memorial Park (4 January 2020). (C, D) Blue and red rubber softfall in Auburn Park (16 January 2021). (E, F) Black impact tile at the end of a slide in Holroyd Gardens (17 January 2019); this image is added for demonstration purpose only; surface temperatures shown in the image were not included in the analyses presented in this report, because the playground was not part of the monitoring program.

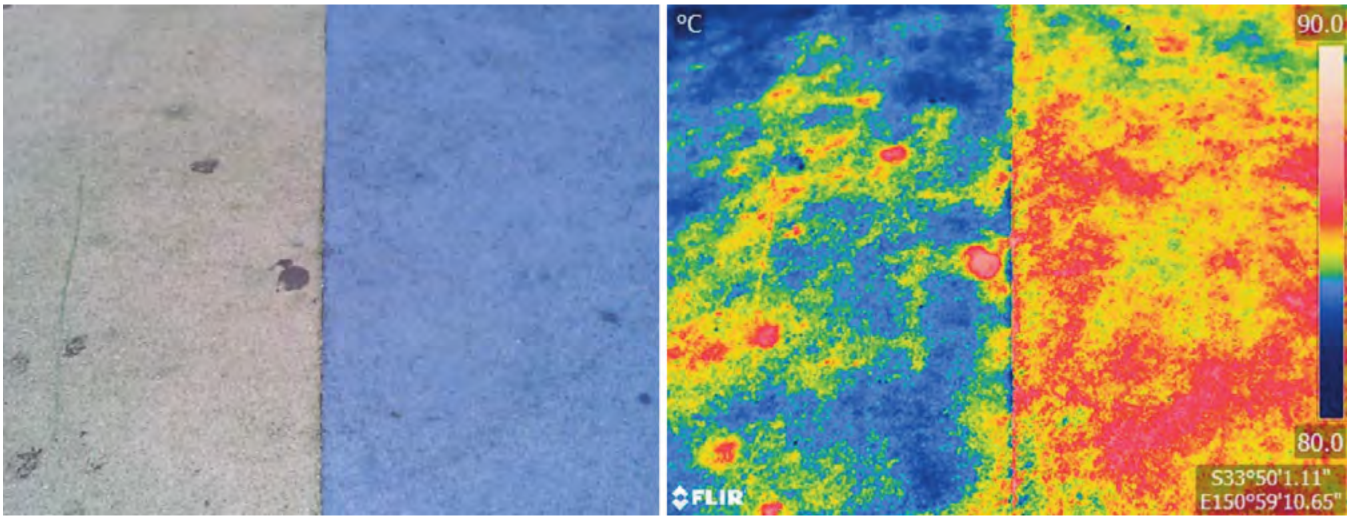

FIGURE 10: Example of the effect of colour on surface temperature of unshaded rubber softfall. The panel on the left shows the normal view, while the panel on the right shows the infrared view where surface temperature is represented by colour (see scale on the right side of the panel). The image was taken at Memorial Park, Merrylands on 4 January 2020.

As evident in Figure 9D, the colour of rubber softfall affects its surface temperature. According to the infrared image, the dark red and green rubber surface had a temperature of 70°C, while the surrounding light blue surface was up to 6°C cooler. A side-by-side comparison of blue and green rubber softfall from Memorial Park is used here to further demonstrate the effect of surface colour on surface temperature (Fig. 10). The darker blue surface had a mean surface temperature of 85°C, while the slightly lighter green surface had a mean surface temperature of 83°C, which was still very hot.

Different surface temperatures were also measured on speckled rubber softfall surfaces represented in the playground at Auburn Park. A surface with a mix of green, orange and red rubber granules was 5°C hotter (66°C) compared with a surface that had a mix of blue, beige and white granules (61°C). The surface temperature of the same mix of green, orange and red rubber granules was also up to 3°C hotter (81°C) compared to a surface made using predominately orange and light brown granules (78°C).

Unshaded, non-natural surface materials like synthetic turf and rubber softfall had very high temperatures, even when ambient temperatures were not particularly warm. Measurements from three different playgrounds showed that during clear summer days with ambient air temperatures below 30°C, surface temperatures of these materials were as high as 65-75°C (Fig. 11). With increasing air temperatures, surface temperatures of all non-natural materials rose further. This increase in surface temperature was least on new concrete, and the most on red coloured rubber softfall. Surface temperatures of all materials, except concrete, increased much faster compared to air temperatures.

The relationship between surface temperature and feels like temperature was positive for all non-natural materials (Figure 12). However, feels like temperature above materials that already had high surface temperatures tended to also be higher. This was particularly true for synthetic turf at Bennelong Park and blue rubber softfall at Memorial Park. For concrete, a small change in surface temperature (from 48 to 55°C, 7°C increase) resulted in a large change in feels like temperature (from 46 to 59°C, 13°C increase). The proportional increase in surface and feels like temperatures was reversed for synthetic turf and rubber softfall materials, showing a much smaller increase in feels like temperature compared to the measured increase in surface temperature.

The different responses of non-natural materials (concrete vs synthetic turf and rubber softfall) shed light on their thermal properties related to reflection and absorption of solar radiation. The high density of concrete caused this material to heat up slowly and its light surface colour allowed it to absorb less solar radiation. Instead, solar radiation was reflected which led to much warmer feels like temperatures. On the other hand, less dense synthetic turf and rubber softfall had less reflective surfaces. As consequence, solar radiation was absorbed more by these materials resulting in greater surface temperatures and, when days became hotter, the feels like temperature above these surfaces increased less compared to the more reflective concrete. A similar effect is illustrated in Figures 8 and 9 where the surface temperature of real turf was less compared to dry turf and bark mulch when air temperatures increase. However, feels like temperatures increase more steeply over warming real turf compared to the other two natural surfaces because they absorbed more solar radiation (resulting in higher surface temperatures) and reflected less (resulting in a smaller increase in feels like temperatures over warming surfaces).

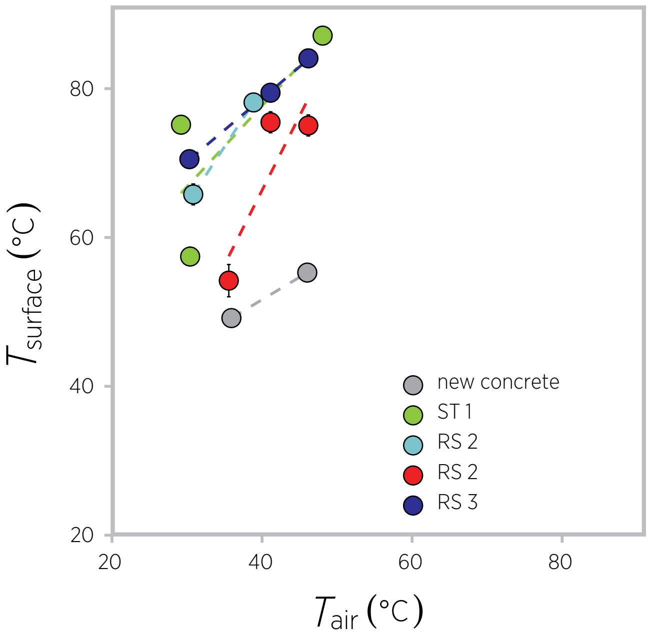

FIGURE 11: Relationship between ambient air temperature (T_{air}) and surface temperature ($T_{surface}$) on unshaded non-natural surface materials found in and around playgrounds. New concrete: n = 10. ST 1 (old synthetic turf): n = 15. RS 2 (blue rubber softfall only): n = 15. RS 2 (red rubber softfall only): n = 15. RS 3 (blue rubber softfall at Memorial Park): n = 15. Data were collected during the early afternoon on clear days during the summer of 2019/20 and 2020/21. See Section 1.2 for more details about data collection.

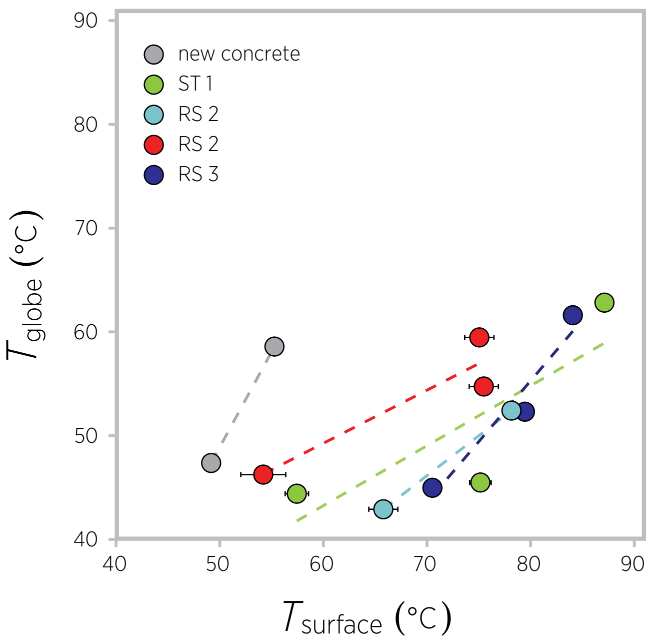

FIGURE 12: Relationship between surface temperature ($T_{surface}$) and black globe temperature (T_{globe}) on unshaded non-natural surface materials found in and around playgrounds. New concrete: n = 10. ST 1 (old synthetic turf): n = 15. RS 2 (blue rubber softfall only): n = 15. RS 2 (red rubber softfall only): n = 15. RS 3 (blue rubber softfall at Memorial Park): n = 15. Data were collected during the early afternoon on clear days during the summer of 2019/20 and 2020/21. See Section 1.2 for more details about data collection.

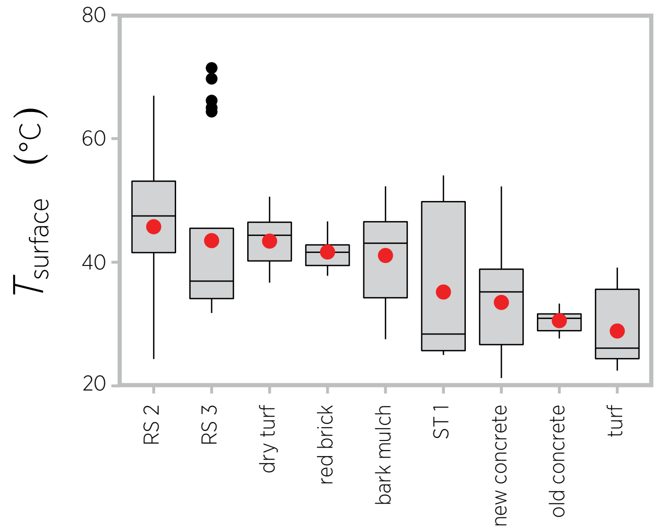

FIGURE 13: Surface temperatures ($T_{surface}$) in summer of a range of shaded materials found in and around public playgrounds. RS 2 (green, blue, red and dark-speckled rubber softfall): n = 60. RS 3 (dark blue rubber softfall at Memorial Park): n = 20. Dry turf: n = 40. Red brick: n = 5. Bark mulch: n = 55. ST 1 (old synthetic turf): n = 15. New concrete: n = 45. Old concrete: n = 10. Turf: n = 45. Red dots show the mean $T_{surface}$, black lines the median, top and bottom of the box represents 75th and 25th percentiles, whiskers show maximum and minimum values and black dots are potential outliers. Data were collected during the early afternoon on clear days during the summer of 2019/20 and 2020/21. See Section 1.2 for more details about data collection.

1.3.2 THE COOLING EFFECT OF SHADE

Shade markedly reduced the surface temperature of all materials. On average, across synthetic and natural surface materials, surface temperatures were 20°C cooler when measured in the shade. The cooling effect of shade was greater for surface materials that had high temperatures in the sun. Hence, shading synthetic turf reduced mean surface temperature of this material by nearly 40°C, from 73°C to 35°C (Fig. 13). Shading darker rubber softfall surfaces reduced mean surface temperatures between 26°C and 29°C. It is worth noting, that rubber softfall had high surface temperatures in the full sun and although reduced by shade, the mean surface temperatures of these materials remained the high in the shade (Fig. 13). The mean surface temperature of darker rubber softfall was 46°C in the shade.

Shading bark mulch reduced mean surface temperatures from 60°C to 41°C, and when bricks were shaded their mean surface temperature dropped by 12°C. As a result of having a relatively low surface temperature in the sun, shade reduced the mean surface temperature of real turf by 8°C from 37°C to 29°C.

In and around playgrounds, shade was provided by trees, play equipment and, in one playground, by a shade sail. Tree shade reduced the mean surface temperature of dry turf from 71°C to 45°C (Fig. 14A, B). In the same playground, tree shade reduced the surface temperature of real turf by 10°C and bark mulch from 58°C to 24°C (Fig. 14C, D). A similar cooling effect on surface temperatures was provided by shade cast from play equipment (Fig. 14E, F). Although shade from these solid objects was very effective and not as patchy as some tree shade (compare images in Fig. 15C and E for example), the resulting shaded areas were always small and often inaccessible.

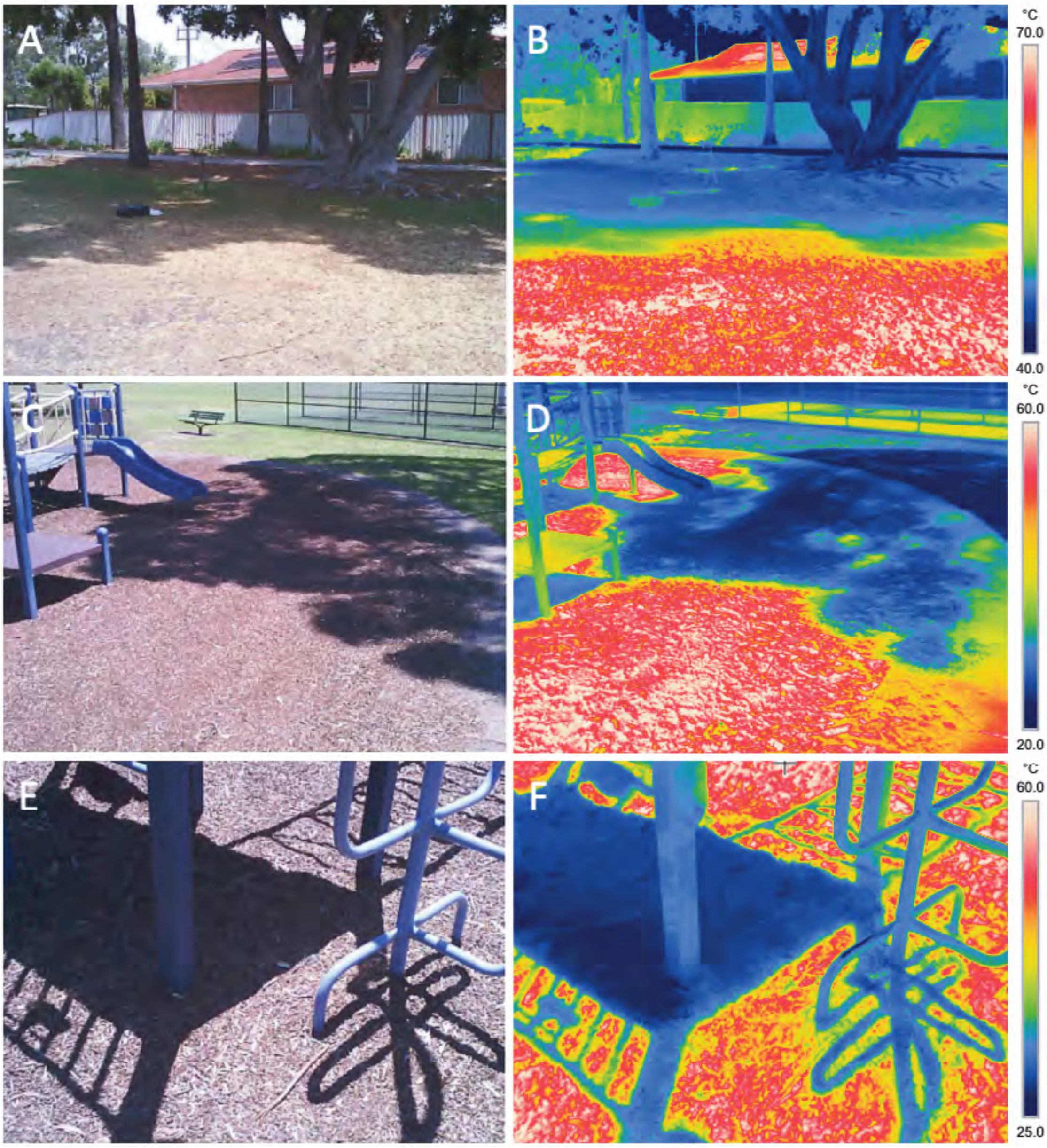

FIGURE 14: Cooling effect of shade on surface temperature of natural materials. Panels on the left show the normal view, while those on the right show the infrared view where temperature is represented by colour (see scale on the right of each panel). (A, B) Shade of a mature fig tree cooling the surface temperature of dry turf (Colquhoun Park, 4 January 2020). (C, D) Shade of a mature gum tree cooling the surface temperature of turf, concrete and bark mulch (Colquhoun Park, 16 January 2021). (E, F) Shade of play equipment cooling the surface temperature of bark mulch (Colquhoun Park, 16 January 2021).

Shading natural surface materials during summer was the most effective way of reducing surface temperatures on real turf. Surface temperatures on dry turf and bark mulch remained hotter compared to green grass even when shaded (Fig. 15). The difference in surface temperature between these materials was less than 10°C during days where air temperatures were below 30°C. Once air temperatures were very hot, the difference in surface temperatures increased to more than 12°C, demonstrating the natural cooling effect of green grass particularly during hot summer days.

The lower surface temperatures of shaded real turf did not translate to lower feels like temperatures. These temperatures were similar for all three natural materials during warm and hot summer days (Fig. 16). Regardless of surface temperature differences of more than 10°C between real turf and dry turf or bark mulch, feels like temperatures were the same. This result highlights that shading has a much larger cooling effect on a body compared to the warming effect of heat being emitted from a surface.

Shading rubber softfall and synthetic turf had the greatest cooling effect on surface temperatures (see Figs. 6 and 13). Some examples are used here to demonstrate the cooling effect of tree shade on non-natural surface materials. During a warm summer day (16 January 2021), tree shade in Auburn Park reduced surface temperatures of speckled light blue and a darker red rubber softfall by 51°C (from 74°C to 23°C; Fig. 17A, B). This remarkable cooling effect was realised within just 2 m of distance from full sunshine to dense tree shade provided by a fig tree. A young Chinese elm nearby effectively reduced the surface temperature of light-coloured concrete from 50°C to 25°C (Fig. 17C, D). On 4 January 2020, shade from play equipment in The Portico Park in Toongabbie cooled dark blue rubber softfall from 82°C to 43°C (Fig. 17E, F). The image at Portico Park was taken at 11:00, indicating that surface temperatures were elevated in full sun. The reduction of very high surface temperatures over incredibly short distance underlines the effectiveness of shade to reduce surface temperatures in playgrounds.

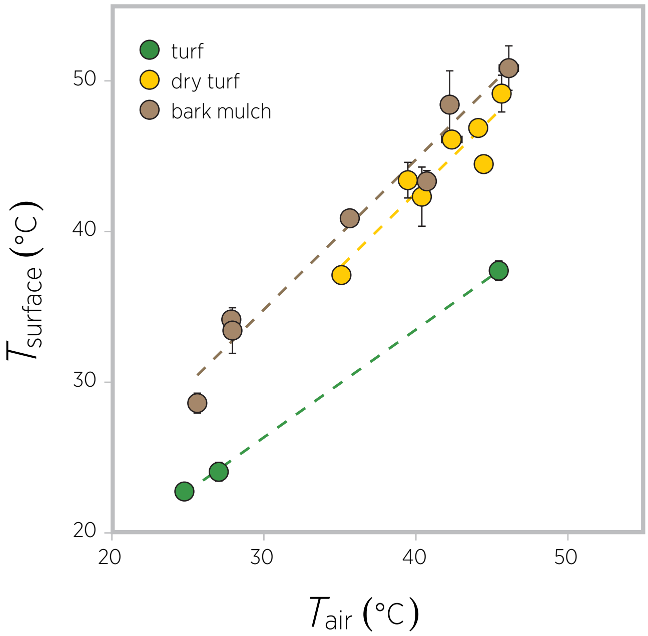

FIGURE 15: Relationship between ambient air temperature (T_{air}) and surface temperature ($T_{surface}$) on natural materials in the shade. Turf: n = 15. Dry turf: n = 35. Bark mulch: n = 35. Data were collected during the early afternoon on clear days during the summer of 2019/20 and 2020/21. See Section 1.2 for more details about data collection.

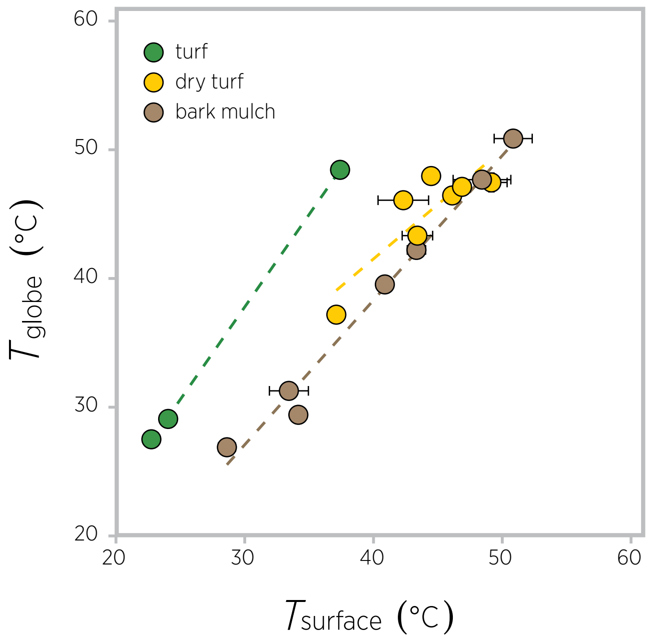

FIGURE 16: Relationship between surface temperature ($T_{surface}$) and black globe temperature (T_{globe}) on natural materials in the shade. Turf: n = 15. Dry turf: n = 35. Bark mulch: n = 35. Data were collected during the early afternoon on clear days during the summer of 2019/20 and 2020/21. See Section 1.2 for more details about data collection.

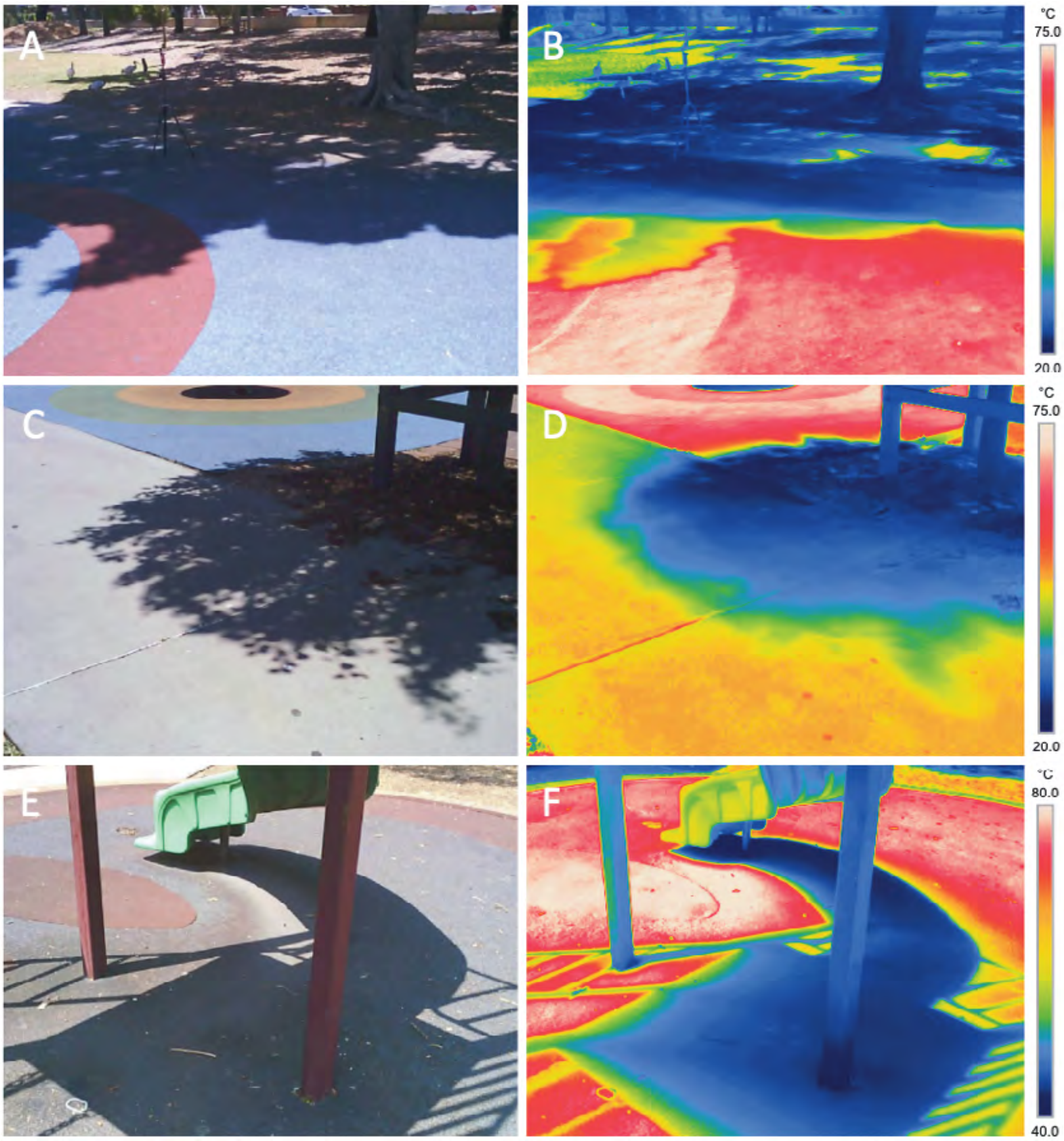

FIGURE 17: Cooling effect of shade on rubber softfall and concrete in summer. Panels on the left show the normal view, while those on the right show the infrared view where temperature is represented by colour (see scale on the right of each panel). (A, B) Shade of a mature gum tree cooling the surface temperature of blue and red rubber softfall and new concrete (Auburn Park, 16 January 2021). (C, D) Shade of a young Chinese elm cooling the surface temperature of new concrete (Auburn Park, 16 January 2021). (E, F) Shade of play equipment cooling the surface temperature of rubber softfall (The Portico Park, 4 January 2020).

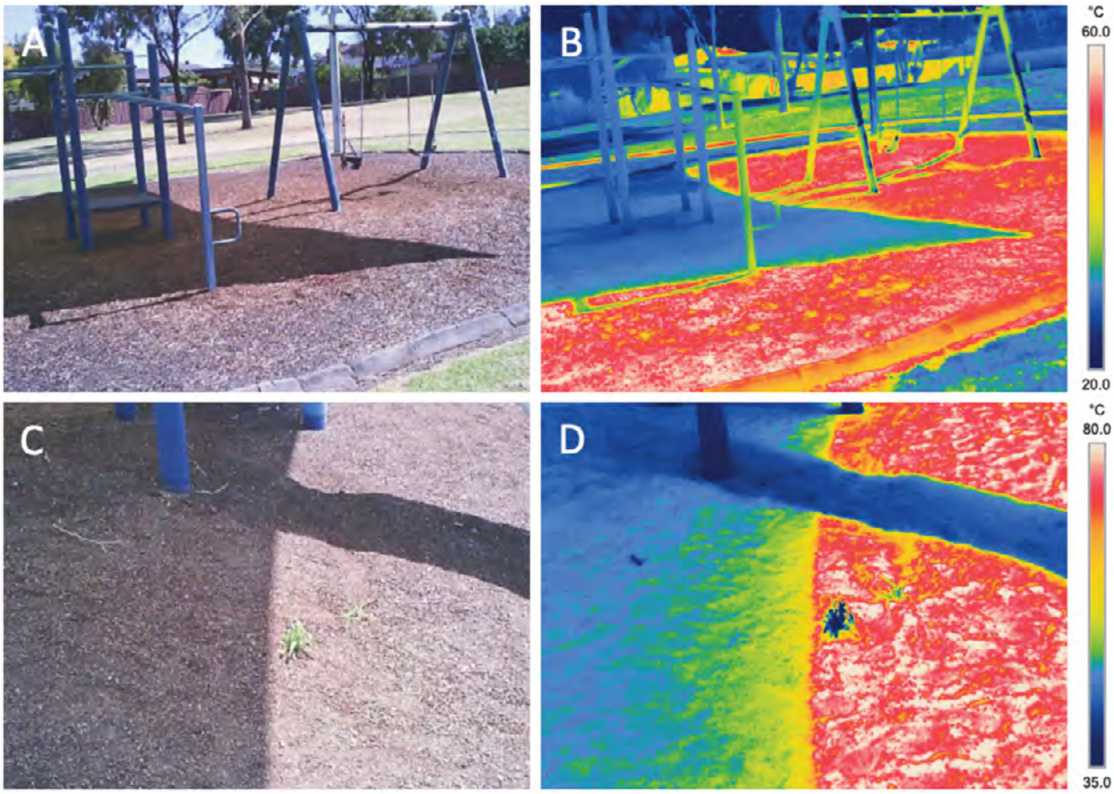

FIGURE 18: Cooling effect of the shade sail at Kootingal Reserve on (A, B) play equipment and (C, D) bark mulch surface temperatures of unshaded playground equipment in summer. Panels on the left show the normal view, while those on the right show the infrared view where temperature is represented by colour (see scale on the right of each panel). Images were taken on 16 January 2021 (A, B) and 4 January 2020 (C, D).

The rectangular shade sail at Kootingal Reserve in Greystanes covered most of the play space during the day. Shade was not cast on the swings at the western end of the playground only during the late afternoon (Fig. 18A, B). The surface of the playground was covered with bark mulch. Sections of the mulch that were unshaded reached surface temperatures between 60°C and 80°C and peaked with a maximum temperature of 86°C (12:00, 4 January 2020). Shade cast by the sail reduced the surface temperature of the bark mulch by 25-40°C (Fig. 18C, D). Surface cooling was particularly effective during very hot days.

The shade sail also influenced air and feels like temperatures in the playground. Simultaneous measurements on the sunlit and shaded bark mulch about 8 m apart showed that air temperatures were nearly 1°C cooler under the sail. During the afternoon of 16 January 2021, reduction of solar radiation under the sail reduced feels like temperatures from 43°C in the sun to 31°C in the shade. However, the shade sail did not provide greater cooling benefits for air and feels like temperatures during 40°C+ days. For example, on 4 January, air and feels like temperatures on unshaded mulch were 43°C and 58°C, while they were 42°C and 48°C on shaded mulch.

Total irradiance (i.e., the amount of power from sunshine received by a surface in per unit area) ranged between 917 and 1056 W m^{-2} during light measurements at the playground (Fig. 19A). Measurements using the portable spectrophotometer showed that only 13% of all light measured was transmitted through the lime green shade sail, effectively blocking 87%. Only 6% of UV-radiation was transmitted, indicating that 94% was blocked (Fig. 19B). Of the 46 W m^{-2} UV light in the full sun, 33 W m^{-2} was in the UV-A and 13 W m^{-2} was in the UV-B spectral range. Underneath the shade sail, the measured UV light intensity was reduced by 93% of full sun light and by 95% in the UV-A spectral range. These UV blocking levels equate to a ranking of 'moderate' to 'high' according to the guidelines provided by the Cancer Council NSW.

The manufacturer rated the sail fabric with an Ultraviolet Protection Factor (UPF) of 15. According to AS 4399:1996 (Australian Standards, 1996) a UPF rating between 15 and 24 is equivalent to 93.3-95.9% UV blockage. Hence, measurements from the playground at the Kootingal Reserve reflect the light transmission characteristics reported by the manufacturer of the fabric. We acknowledge

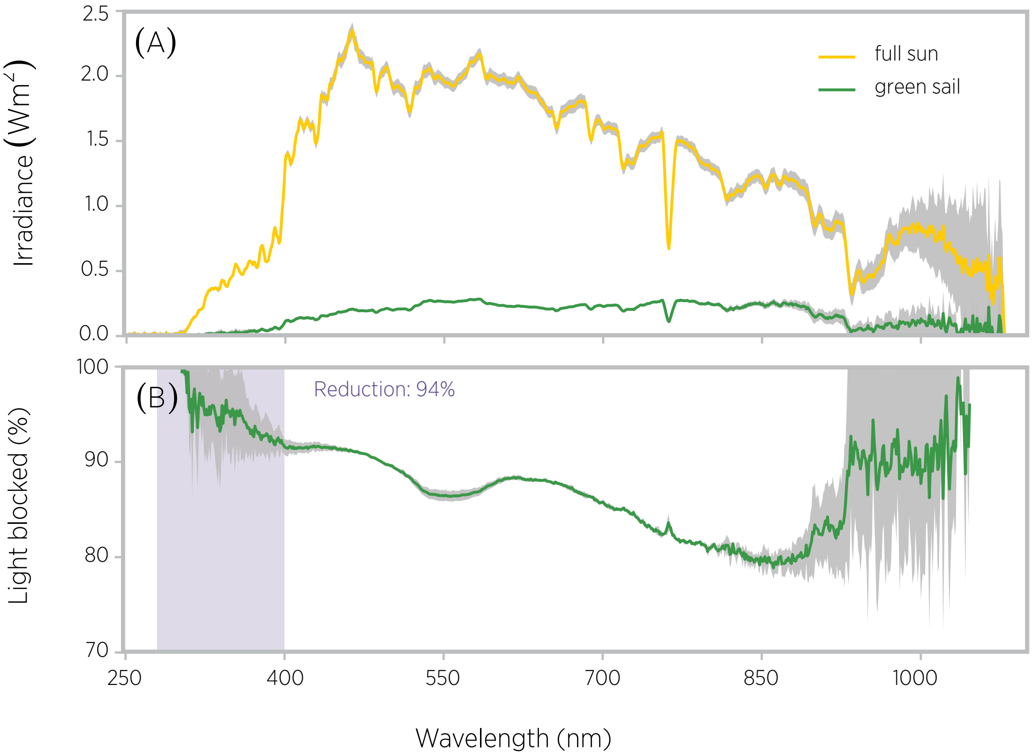

FIGURE 19: Effect of shade cloth on light conditions in a playground. Panels show irradiance (A) and light blocked (B) by the shade sail at Kootingal Reserve during the early afternoon on 16 January 2021. Light spectra are means of three individual measurements. The grey area in panels A and B indicate ±1 SD. The purple area in panel B indicates the spectrum of UV-B and UV-A radiation (280-400 nm). The reduction of 94% relates to UV-A + UV-B radiation only.

that the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) recommends using the Ultraviolet Effectiveness (UVE%) rating, based on the newer standard AS 4174:2018. However, this rating was not available from the manufacturer for the sail fabric used in the playground. If the UVE% would be applied, the fabric would fall into the 'very effective' and 'most effective' categories. ARPANSA recommends using only shade sail materials that fall into the highest UVE% category (i.e., greater than 97.5% UV block) for effective protection from UV radiation.

1.3.3 SURFACE REPAIRS AND AGING

Installation of non-natural surfaces in playgrounds requires highly trained professionals, not only to meet regulations for impact attenuation of surfaces according to fall height, but also to ensure the installation itself lasts many years of use. For several reasons (e.g., tree roots, vandalism, high impact use, UV breakdown) synthetic turf and rubber softfall surfaces can fail and need repair work. These tasks also require professional skills and a sound understanding how to restore the integrity of the playground surface. During visits to playgrounds in Cumberland, and other locations, we found examples of poor craftsmanship when repairing rubber softfall surfaces. Not only were these repairs visually and technically unsatisfactory, but they also added more surface heat to the playgrounds (Fig. 20A-D). For example, at the playground at Auburn Park, a hole in red rubber softfall was repaired using a coarse black rubber granulate which, on a sunny day in January 2021, was 8-15°C hotter compared to the original surface material. Similarly, at a playground in Ropes Crossing where a defect in light-coloured rubber softfall was repaired using black rubber, surface temperatures increased from 64°C to 77°C. The age of synthetic turf made a noticeable difference in surface temperatures at Bennelong Park (Fig. 20E, F). The surface temperature of old synthetic turf with a pile height less than 2 mm, was 6°C warmer compared to a newer synthetic turf patch that had a pile height of at least 4 mm. Throughout the playground, three different types of synthetic turf was used, and all had slightly different surface temperatures.

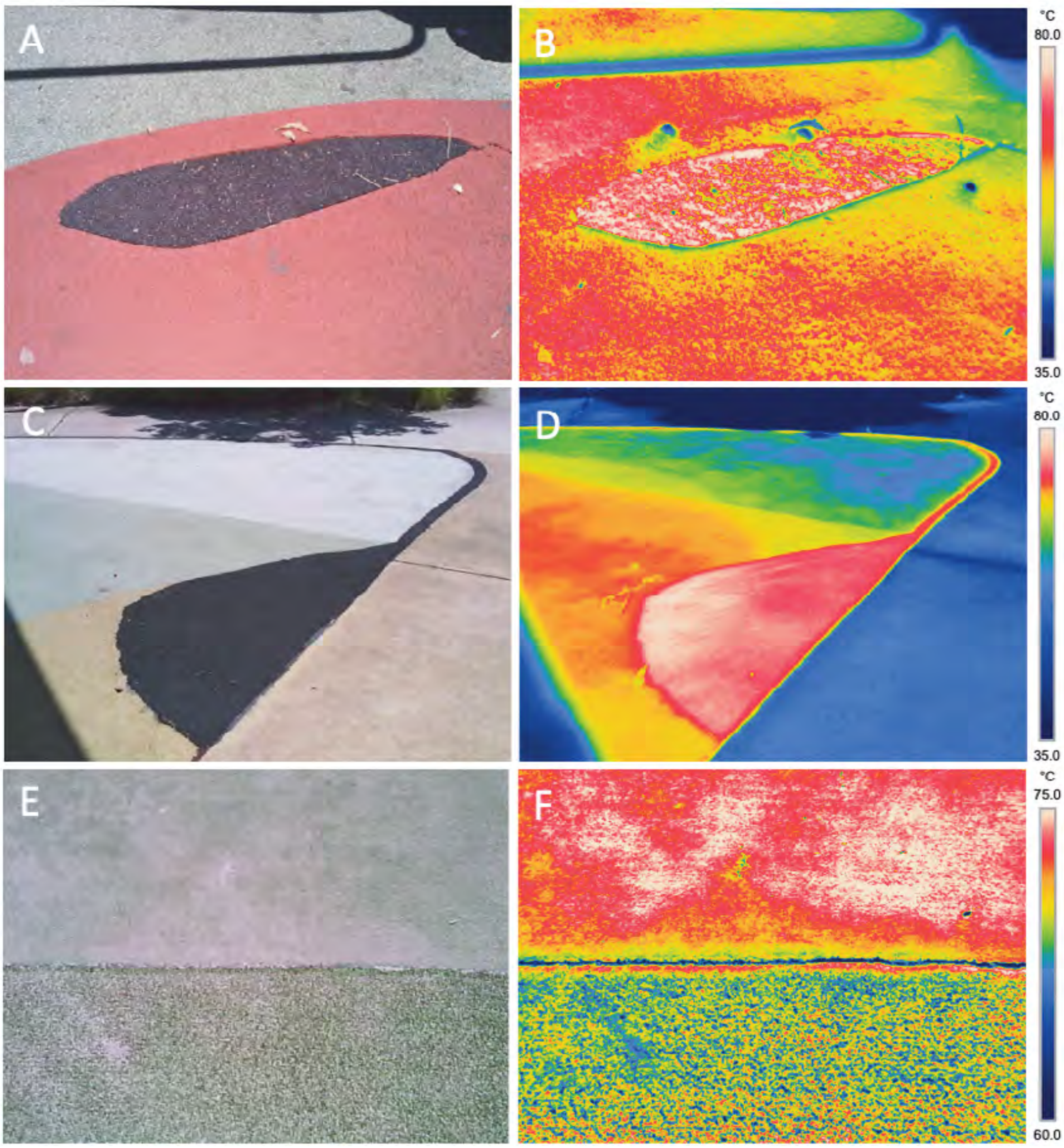

FIGURE 20: Effect of inappropriate patching of rubber softfall (A-D) and wear of synthetic turf (E, F) on surface temperatures. All depicted surfaces were unshaded. Panels on the left show the normal view, while those on the right show the infrared view where temperature is represented by colour (see scale on the right of each panel). (A, B) Patch at Auburn Park (Auburn Park, 16 January 2021). (C, D) Shade of a young Chinese elm cooling the surface temperature of new concrete (Barinya Park, Ropes Crossing, 20 March 2020); this image is added for demonstration purpose only; surface temperatures shown in the image were not included in the analyses presented in this report, because the playground was not part of the monitoring program. (E, F) Old (top) and new (bottom) synthetic turf at Bennelong Park (16 January 2021).

1.3.4 PLAY EQUIPMENT

High surface temperatures are not only an issue for unshaded ground surfaces, but also for unshaded play equipment. In the six playgrounds investigated, play equipment was made from coated and uncoated metal and were composed from a range of different types and colours of plastic. Surface temperatures of more than 90°C were recorded during this project.

The ISO Standard 13732-1 (2006) lists contact times and surface temperatures of burn thresholds for a range of materials commonly used in the manufacturing of playground equipment. Table 2 shows that these contact times and surface temperatures are much lower than the temperatures reported here for surfaces and play equipment. Contact times to avoid skin burns are very short and threshold temperatures especially for metal and plastics are relatively low. The differences in threshold temperatures and contact times are related to the thermal conductance of different materials.

TABLE 2: Burn thresholds of skin (modified from ISO 13732).

		BURN THRESHOLD (°C)		
MATERIAL	**MATERIAL CHARACTERISTICS**	Contact time: 3 seconds	Contact time: 5 seconds	Contact time: 1 minute
Metal	uncoated	60	57	51
Coated metal	Powder: 90 µm	65	60	51
Stone material	Concrete, granite, asphalt	73	60	56
Plastic	Polyamide, acryl, duroplastic	77	74	60
Wood	Bare, low moisture	99	93	60

Examples of surface temperatures of play equipment are provided in Figure 21. The infamous blue rubber dolphin (Fig. 21A, B) had a maximum surface temperature of 91.8°C (note: the transformation of the playground at Memorial Park resulted in shading the dolphin). High-density plastic materials can conduct heat well. The sun-exposed sidewall of the green plastic slide in the playground at Portico Park had a surface temperature of 73°C at 11:20 on 4 January 2020 (Fig. 21C, D). The part of the slide where a child would play was only slightly cooler (67°C). Touching this surface for three seconds caused great thermal discomfort. However, the reduction of surface temperature by 6°C demonstrates the high heat conductance capacity of this plastic material. While time spent on a slide is usually short, children are inclined to spend longer time intervals on swings. The modern black plastic bowl swing represents a great asset at Auburn Park and allows inclusive play (Fig. 21E, F). However, as it was unshaded, its surface temperature was up to 82°C, representing a potential burn hazard.

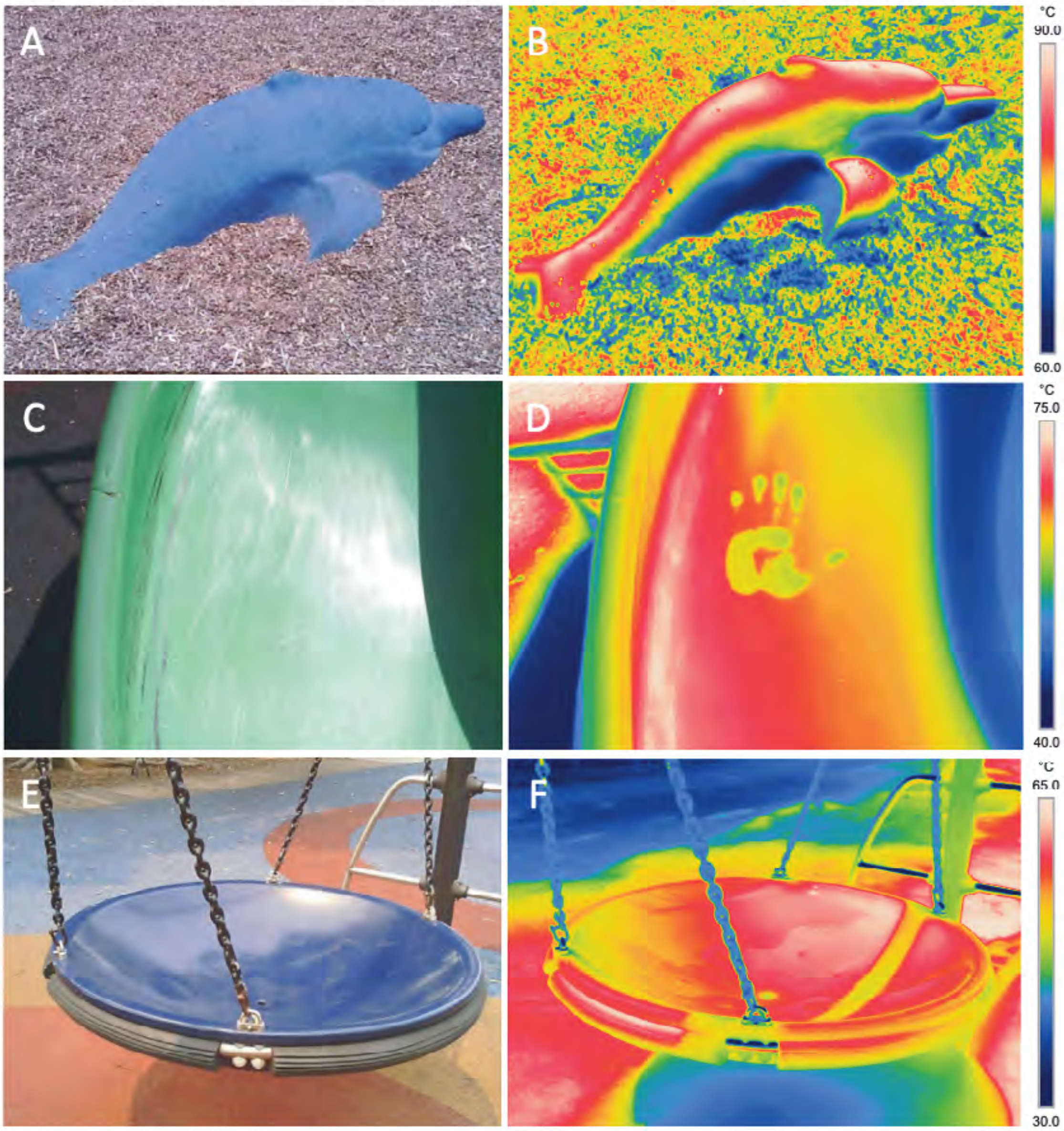

FIGURE 21: Surface temperatures of unshaded playground equipment in summer. Panels on the left show the normal view, while those on the right show the infrared view where temperature is represented by colour (see scale on the right of each panel). (A, B) Blue rubber dolphin at Memorial Park, Merrylands (4 January 2020). (C, D) Green plastic slide at The Portico Park, Toongabbie (4 January 2020); the palm print resulted from touching the surface for 3 seconds, indicating high heat conductance of the material. (E, F) Black rubber swing at Auburn Park, Auburn (21 December 2019).

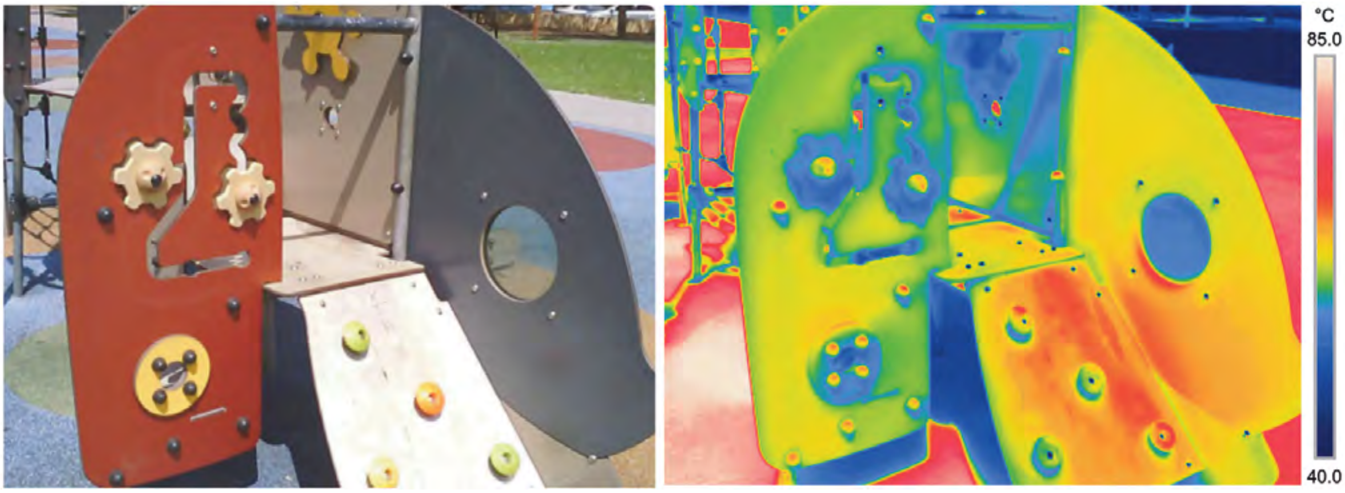

FIGURE 22: Example of the impact of surface orientation on surface temperature. The image was taken at Auburn Park, Auburn (4 January 2021). Normal (left) and infrared (right) views are shown, where the infrared image on the right shows surface temperature by colour (see scale on the right).

The orientation of surfaces of play equipment towards the sun can result in markedly different surface temperatures. Here, orientation is concerned with positioning of surfaces in the three-dimensional space. In the southern hemisphere, orientation of play equipment to the north and west (the azimuth) will generally receive the most solar radiation when unshaded. Besides the azimuth, the tilt angle towards the sun must also be considered because it influences the surface temperature of the surface. The combined effect of azimuth and tilt can lead to the situation where surfaces and play equipment designed to stay cool become undesirably hot. As shown in Figure 22, the west-facing white surface with a tilt angle of about 45° has a higher surface temperature compared to the dark brown panel to the left with a tilt angle of 0°. Even the black surface to the right had a lower surface temperature as result of no direct exposure to solar radiation. This example demonstrates how decisions about the design of play equipment and the positioning of this equipment at playgrounds can have unwanted effects related to surface heating and safety. Once adequate shade is provided, these considerations are negated.

1.3.5 **REST AREAS**

Provision of adequate shade also applies to rest areas. These areas are critical to allow parents and carers to supervise play from a distance and to help then enjoy the experience. Five of the six playgrounds investigated here did provided rest places, but not all had good quality shade. Surface temperatures of benches in the full sun easily reached 65°C. At The Portico Park in Toongabbie, a sunlit bench made from dark wooden slats reached a surface temperature of 73°C when the park was visited at 11:00 on 4 January 2020 (Fig. 23A, B). Metal and wooden benches and seats were shaded in Bennelong Park, Colquhoun Park, Portico Park and Memorial Park for all or part of the day. When shaded, their surface temperatures were generally equal to air temperatures. At Auburn Park, small picnic pavilions were available near the playground (Fig. 23C, D). These pavilions were erected on concrete slabs and the metal benches and tables were well shaded all day. Surface temperatures of the concrete ground were below air temperatures although radiant heat from the uninsulated corrugated iron roof slightly increased feels like temperatures. Dedicated rest places were absent from Kootingal Reserve.

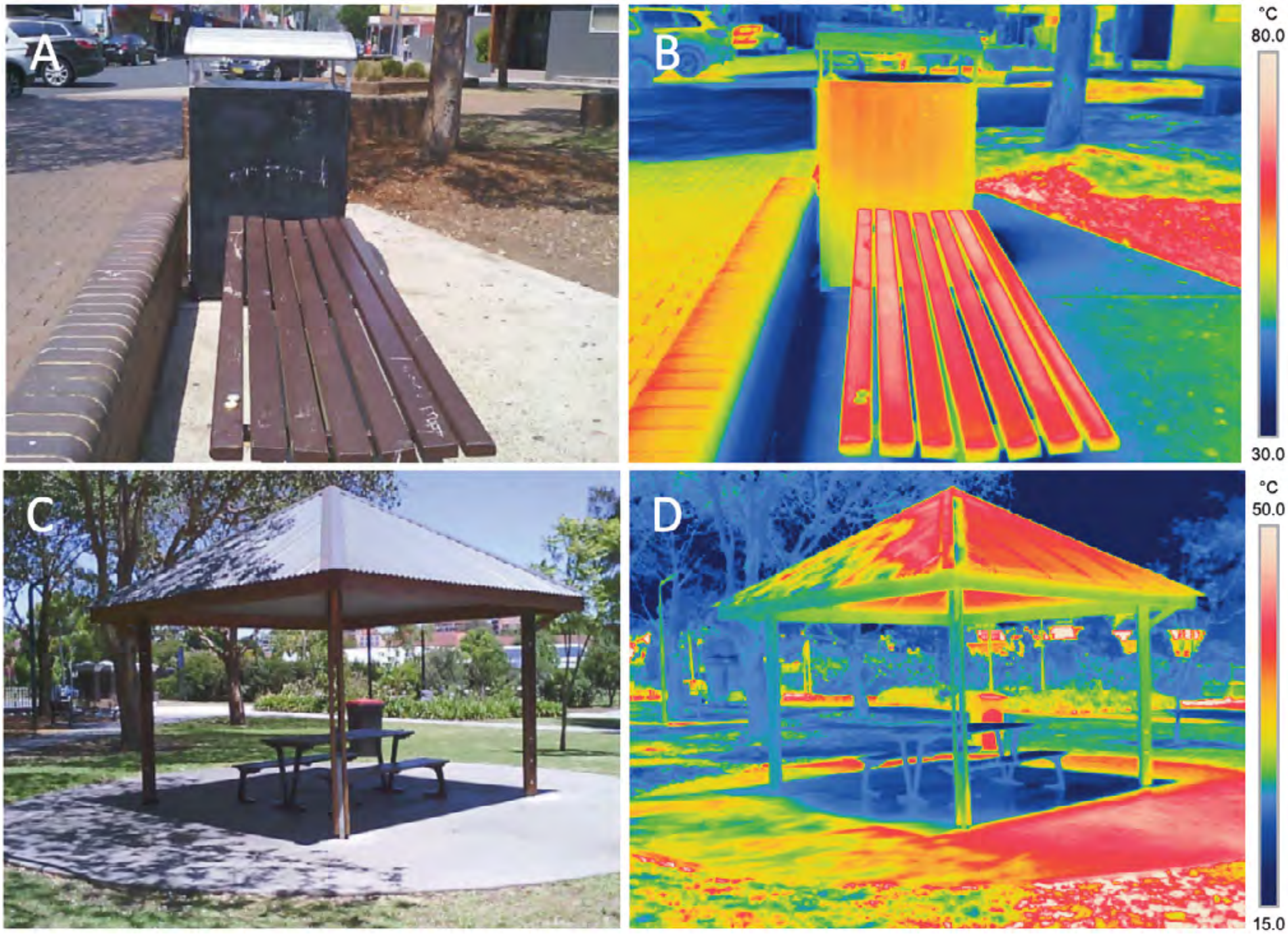

FIGURE 23: Examples of surface temperatures on unshaded (A, B) and shaded (C, D) rest areas at playgrounds in summer. Panels on the left show the normal view, while those on the right show the infrared view where temperature is represented by colour (see scale on the right of each panel). (A, B) Park bench at The Portico Park, Toongabbie (4 January 2020). (C, D) Pavilion at Auburn Park, Auburn (16 January 2021).

1.4 SYSTEMATIC TESTING OF SURFACE TEMPERATURE

For this report, the surface temperatures of 18 different samples are documented. Four of these samples were made from SBR, five were EPDM, five were TPO, three were synthetic and one was real turf (Fig. 24). Four samples were blue, five were green, and another five had earth-like or light colours. Two TPO samples were speckled, all other rubber materials were of single colour. The synthetic turf samples included three different pile heights (short: 13 mm, medium: 30 mm, long: 40 mm). All samples were placed on a linen tarp apart from the real turf which was placed on concrete to allow it to be moistened three times during the assessment period to prevent it from drying out.

Throughout a whole day, samples were randomly moved every 30 minutes to keep them fully exposed to sunshine. Infrared images (FLIR C3-X, FLIR Systems) were taken of each sample every 15 minutes from 07:00 until 19:30 resulting in 900 images. The FLIR Tools software was used to extract three random measurements of surface temperature from the centre of each tile at each timepoint. The three measurements were averaged to represent a mean surface temperature for each sample and timepoint.

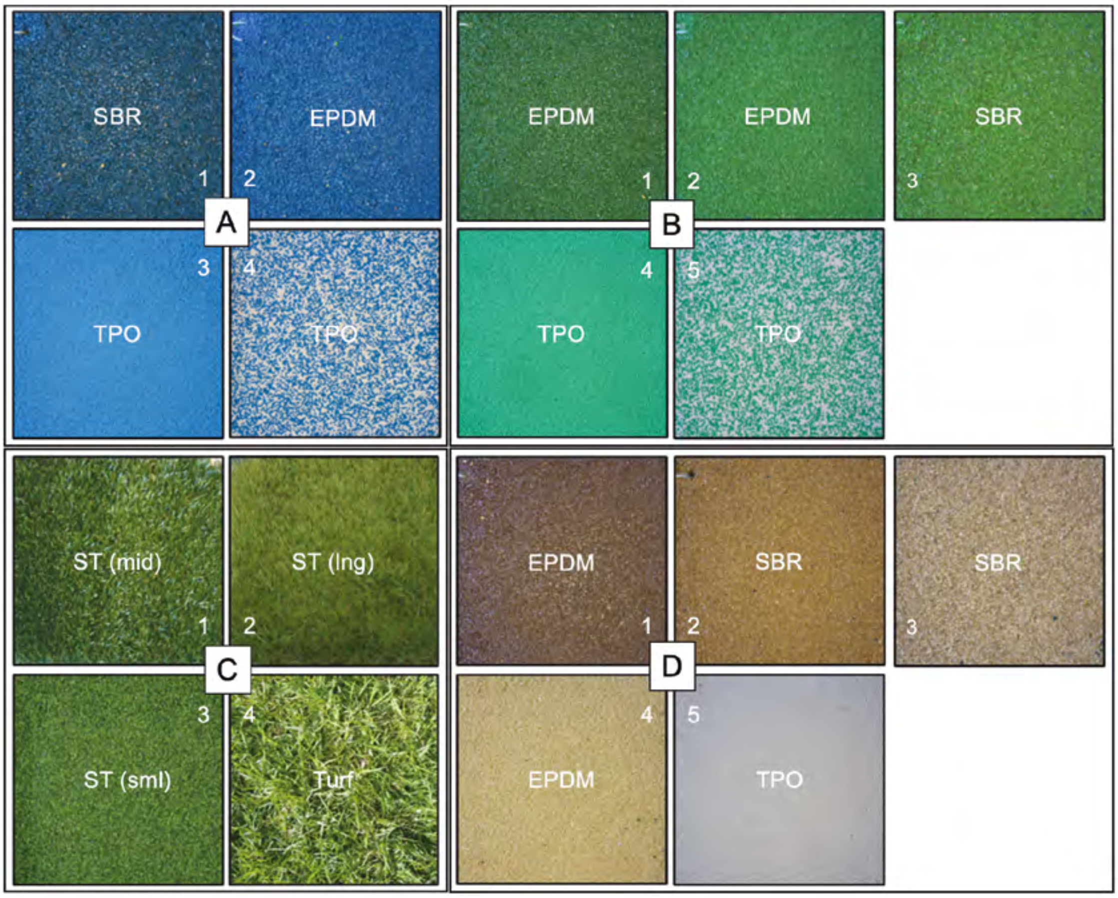

FIGURE 24: Representation of the surface materials tested under standardised environmental conditions. (A) blue and speckled-blue surfaces. (B) Green and speckled-green surfaces. (C) Synthetic and real turf. (D) Earth- and light-coloured rubber softfall materials. Abbreviations: SBR = styrene butadiene rubber; EPDM = ethylene propylene diene polymer rubber; TPO = thermoplastic polyolefin; ST = synthetic turf; lng = long pile height (40 mm); med = medium pile height (30 mm); sml = short pile height (13 mm).

The systematic tests, where surface temperatures of 18 different surface samples were tracked over a full day, revealed significant differences related to colour and material (Fig. 25). To track data shown in Fig. 25 and relate measurements of surface temperatures to the exact material and colour, we provide a reference to Figure 24 (letter = panel, number = sample tile).

For the group of blue rubber surface materials, the sample made from SBR (A1) had the highest surface temperatures (Fig. 25A). This material heated up quickly, reaching 64°C at 10:00 and maximum temperatures of 87°C at 13:45. In comparison, the blue surfaces made from EPDM (A2) and TPO (A3) heated up at a slower rate. At 10:00, their surface temperatures were 55°C (EPDM) and 57°C (TPO). Maximum surface temperatures were 75°C (EPDM) and 73°C (TPO) at 15:30. The coolest surface temperature in the group of blue surfaces was measured on the speckled blue-white TPO sample (A4). This sample heated up the least and was 24°C cooler at 13:45 compared to the SBR surface.

Like the blue SBR-type material, the leaf green SBR surface (B3) reached very high temperatures during midday (Fig. 25B). Similarly high surface temperatures were also measured on the darker moss green sample of EPDM (B1). In the group of green surface materials, surface colour of the EPDM sample (B2) was similar to the SBR sample (B3), but surface temperature differed markedly. At 15:30, the surface temperature of the EPDM (B2) material was 78°C, while that of the SBR sample (B3) was 10°C hotter. The speckled green-white TPO sample (B5) had the lowest maximum surface temperature (64°C at 15:45) of all green materials tested.

The overall hottest surface was synthetic turf with medium (C1) and long (C2) pile heights (Fig. 25C). In full sun during midday these materials reached average surface temperatures of 91°C. Synthetic turf with a

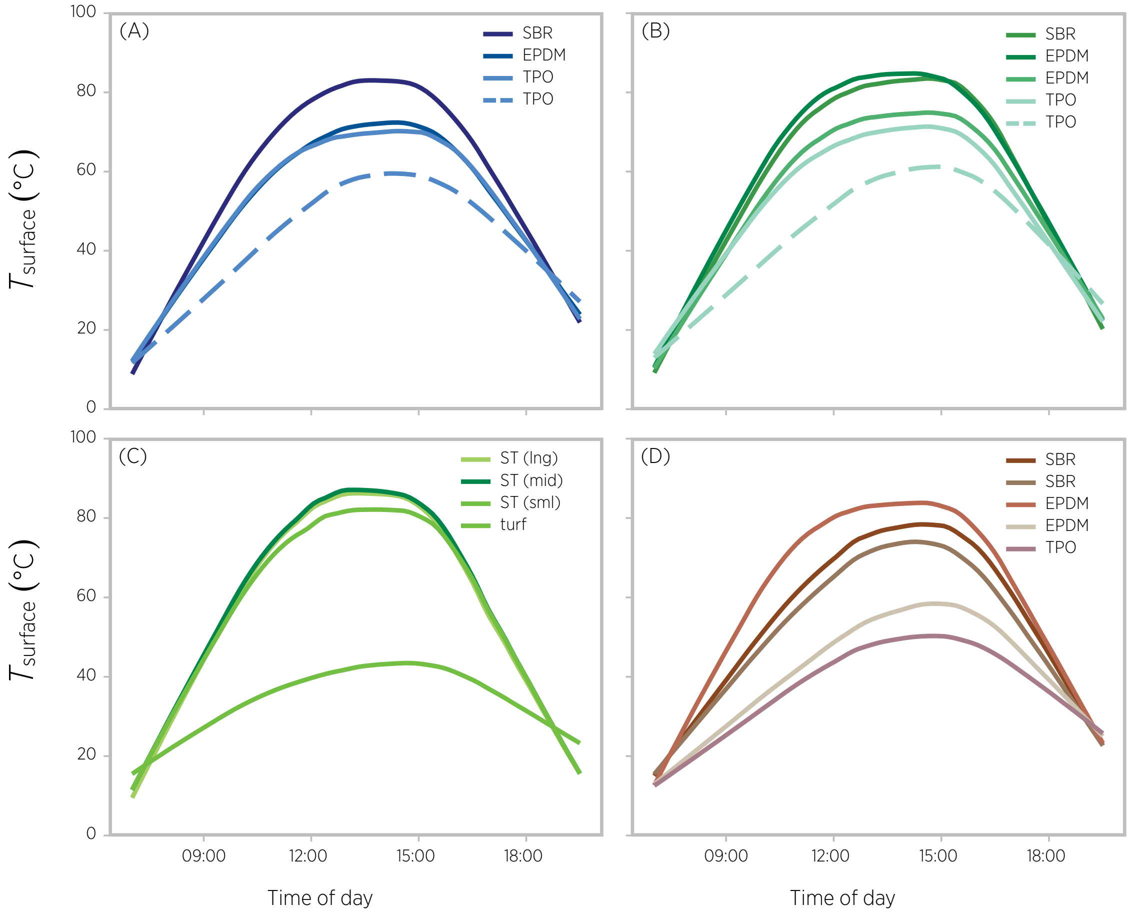

FIGURE 25: Pattern of surface temperature ($T_{surface}$) over a full solar day for a range of surface materials. Data are shown for (A) blue rubber softfall materials, (B) green rubber softfall materials, (C) synthetic and natural turf and (D) earth- and light-coloured rubber softfall materials. Solid lines represent single colours, dashed lines represent speckled materials (blue-white in A, green-white in B). Abbreviations: SBR = styrene butadiene rubber; EPDM = ethylene propylene diene polymer rubber; TPO = thermoplastic polyolefin; ST = synthetic turf; lng = long pile height (40 mm); med = medium pile height (30 mm); sml = short pile height (13 mm). Data were recorded during 11 January 2021.

short pile height (C3) was considerably cooler at 83°C. However, real turf (C4) as 48°C cooler than synthetic turf samples with medium and long pile height. Real turf also heated up and cooled down slower compared to synthetic turf samples. Notably, at the end of the collection period, real turf had a higher surface temperature compared to all three synthetic turf samples. This effect was most likely the result of the greater thermal mass of the real turf sample where energy stored during the day was retained for longer.

Earth-like coloured SBR and EPDM rubber softfall samples had cooler surface temperatures during midday compared to blue and green coloured samples of the same material types (Fig. 25D). In this group, the white TPO sample (D5) had the lowest and the dark brown EPDM sample (D1) had the highest surface temperatures around midday. The sand-coloured sample made from EPDM (D4) showed very similar heating and cooling dynamics compared to the ‘cool’ white TPO sample but was 8°C warmer at 13:45. Although similar in colour to the sand-coloured EPDM material, the beige SBR sample (D3) heated up much quicker and also reached markedly higher peak surface temperatures. At 10:00, the SBR sample (D3) had a surface temperature of 43°C, while the EPDM sample (D4) was 32°C. At 13:45, the difference between the two materials was 17°C.

All ‘hot’ materials (A1, B1, C1, C2, D1) reached their maximum surface temperatures earlier (405 minutes of exposure to full solar radiation) compared to the ‘cool’ materials (A2, A3, B2, B4, D4, D5; 510 minutes of exposure to full solar radiation). This delay was most pronounced between dark synthetic turf (medium pile height, C1) reaching a maximum surface temperature of 91°C at 12:15 after 315 minutes, while white TPO (D5) reached a maximum surface temperature of 64°C at 15:45, after 525 minutes. At this time, surface temperatures of many ‘hot’ materials had already begun to cool down (Fig. 25).

1.5. EVIDENCE-BASED CLIMATE-RESPONSIVE PLAYGROUND DESIGN

The empirical measurements collected at playgrounds in Western Sydney document widespread hazardous surface temperatures. These temperatures can already be expected to occur on unshaded synthetic turf and rubber softfall during clear summer days when air temperatures are around 30°C. During hot and extremely hot days, the surface temperatures of these particular materials may be approaching the boiling point of water. Unshaded feels like temperatures can easily reach 50°C or more on these surfaces. For example, we have documented an incredible 64°C feels like temperature on unshaded synthetic turf. Shade can cool surface temperatures of rubber softfall by more than 50°C, and other non-natural surface materials by 25-40°C. Shade also reduced harmful UV radiation. **These results leave no doubt that the most important aspect of climate-responsive playground design must be the introduction of high-quality shade.**

When designing new climate-smart playgrounds, the following aspects will help keep play spaces cool with low UV exposure:

- Incorporate existing tree canopy in the design
- Plant trees to grow natural shade over time
- If no natural shade is present, provide man-made shade of very high quality
- Where shade cannot be provided use natural surface materials (e.g., bark mulch, light-coloured wood chips, sand)
- Avoid bare soil in sunlit areas
- Where natural surface materials cannot be used, use non-natural materials that have light colours (beware of the 'Trojan Effect' – Section 2.7.2)
- Speckled rubber softfall with high proportions of beige or white is a good alternative to light coloured surfaces made using a single colour
- Avoid using dark rubber softfall and synthetic turf in sunlit areas to prevent potential skin burn injuries
- When choosing rubber softfall materials, consider selecting a material that has a cooler surface temperature in a similar colour (SBR hotter than EPDM hotter than TPO)
- When unshaded, select play equipment made from materials that have low heat conductance (e.g., wood)
- Consider orientation of play equipment and its surfaces to avoid heating effects (azimuth and tilt angle)
- Provide high-quality shade for rest areas

When retrofitting/upgrading existing playgrounds, the following points should be considered to reduce the impacts of heat and UV radiation:

- Provide high-quality shade over the entire play area
- If shade is already provided, assess if it is of high quality and if it covers the entire play area at all times – if necessary, improve density of shade and/or add shade
- Provide high-quality shade for rest areas
- Avoid repairs that will increase heat loads inside the playground
- If shade cannot be provided, replace hot non-natural surfaces (e.g., rubber softfall, synthetic turf) with cooler natural surfaces (e.g., bark mulch, light-coloured wood chips, sand)
- If shade cannot be provided, introduce play equipment that has low heat conductance
- If shade cannot be provided, avoid introducing dark rubber softfall and synthetic turf to prevent skin burn injuries

The primary motivation for providing climate-smart public playgrounds is to increase resilience of local populations against increasingly hot climates. If done well, these spaces will deliver immediate benefits for its users. The time children can play outdoors will be extended which, in turn, will improve their physical health and support cognitive development. These play spaces will protect children from UV radiation, minimising the risk to develop skin cancer in their adult life. Parents can enjoy quality time with their offspring and gain new access points to social interactions with other parents, with the result of increased local social coherence. These playgrounds will become valuable assets for local governments to demonstrate how delivering strategic goals set out in planning policies and guidelines can look like in reality. The once neglected small neighbourhood playground can become a showpiece for progressive and responsible local development.

PART 2

AUSTRALIA'S FIRST UV-SMART COOL PLAYGROUND

The second part of this report describes the process, outputs and outcomes of the playground transformation at Memorial Park in Merrylands. The playground is in the Local Government Area of Cumberland City Council in the geographic centre of Sydney. With support from the NSW Government, Cumberland City Council, industry partners and inputs from a range of stakeholders, this integrative playground was used to demonstrate how a hot, unshaded neighbourhood playground can become a play space where surface and air temperatures are lower, and children are protected from exposure to harmful UV radiation.

2.1 INTRODUCTION

Outdoor play is important. In urban environments, playgrounds are often the only space where children can play outdoors. While playground safety has improved by implementing new standards for play equipment and use of engineered surface materials, the impacts of heat as a safety concern have largely been ignored. In Part 1 of this report, we have provided evidence that on a regular summer day, unshaded synthetic surfaces can heat up to 80°C. Such surface temperatures can become a health hazard and can cause burns of exposed and highly sensitive skin of children. In addition, overexposure to UV radiation remains a widespread concern of public health.

In the face of a changing climate, it is important to provide cooling strategies for public infrastructure, like playgrounds, that help reduce heat and UV loads. To date, high-quality shade is often absent in playgrounds due to budgetary constraints in organisations that own and manage these public spaces. This dilemma is not restricted to Cumberland City Council but can be observed across Australia.

In the Cumberland City Council LGA, UV levels are high enough to damage unprotected skin for at least 10 months of the year. It has been estimated that 95% of melanoma and 99% of non-melanoma skin cancers are caused by overexposure to UV from the sun. In Australia, 2 out of 3 people are diagnosed with skin cancer in their lifetime. Melanoma of the skin is the fifth most common cancer in Cumberland Council LGA (2011-2015) with a mortality rate of 3.3 per 100,000 citizens (data provided by Cancer Institute NSW). This situation is a burden on local health services and a preventable trauma for families.

Western Sydney University teamed up with Cumberland City Council, several other government organisations, industry partners and advocacy groups to demonstrate how a cool and UV-smart playground could look and function. The work aligned well with a range of objectives, goals and actions outlined in place-making and environmental strategies of Cumberland City Council, but also the Greater Sydney Commission, and other government institutions. Unifying among these documents was the aim to improve community resilience and adaptive capacity to the contemporary and ongoing effects of climate change.

The project was supported by three goals of the Cumberland Council Community Strategic Plan 2017-2027 (Cumberland Council, 2017): 1. *A Great Place to Live*, 2. *A Clean and Green Community* and 3. *A Resilient Built Environment*. 'Urban Heat Stress' is listed as key driver and emerging issue in the primary environmental strategy document of Cumberland Council, the Environmental Management Framework (EMF) (Cumberland Council, 2019a). Cumberland's Delivery Program 2017-2021 (Cumberland Council, 2019b) requires the adoption of the Biodiversity Strategy 2019 which identified the cooling aspect of urban canopy and green infrastructure. The project met Direction 2 of the Resilient Sydney (2018) 'Live with our Climate – Resilience Challenge: Pressure on our Health, the Environment and Economy'. Moreover, it aligned with actions 3, 4 and 13 set out the in Turn Down the Heat Strategy from the Western Sydney Regional Organisation of Councils (WSROC, 2018) and Objectives 36-38 of the Greater Sydney Commission's Central District City Plan's 'Adapting to the Impacts of Urban and Natural Hazards and Climate Change' (Greater Sydney Commission, 2018). Lastly, and importantly, the proposed playground transformation was in line with two of the NSW Premier's Priorities (*Greener Public Spaces* and *Greening our City*).

An existing integrative playground in Memorial Park, Merrylands was selected because the transformation would result in positive responses to all three central questions of the NSW Government strategy *Everyone Can Play*. Central to this strategy is the desire to create more integrative play spaces. Framing the delivery of better integrative play spaces are three questions. The question of "Can I Get There?" was easy to address, as the playground was close to the town centre at a major pedestrian route from residential precincts to the shopping mall. Level access to the playground was provided. The 2018 upgrade to integrative play equipment answered: "Can I play?". The upgrade included play equipment accessible for children with disabilities, including being wheelchair-bound. Prior to the transformation, however, a positive answer to the third question, "Can I stay?", was not possible due to the lack of shade and resulting hot surfaces and maximum exposure to UV. The project described here aimed at rectifying this situation.

A successful application for funding from the *Increasing Resilience to Climate Change* program of LG NSW marked the pivot point to make Australia's first dedicated *UV-smart Cool Playground* a reality. The proposed transformation included the following elements:

- Build high-quality shade for the entire playground to keep surface temperatures low and exclude UV radiation
- Replace bark mulch and dark blue rubber softfall with a cooler surface material to improve thermal comfort
- Plant additional trees to grow natural shade in strategic locations
- Provide a drinking water fountain to help children stay hydrated
- Include a sign that provides parents and children with education around being heat and UV-smart

2.2 SCIENCE TRANSLATION

In 2012, the United States Consumer Product Safety Commission published a fact sheet that warned consumers about the risk of 'thermal burns from playground equipment' (CPSC, 2021). In Australia and overseas, media articles described children suffering from skin burns as a result of playing on hot equipment in public playgrounds (e.g., Sawyer, 2013; Gold Coast Bulletin, 2016; Smith, 2017; Keegan, 2018). Yet worldwide only a single team of researchers, led by Dr Jenifer Vanos at Texas Tech University investigated and published systematic studies of heat in playgrounds before 2018 (Vanos, 2015; Vanos et al., 2016, 2017). No systematic studies were available from Australia. This is despite the impacts of summer heat on children's health already being well established (e.g., Bytomsky and Squire, 2003; Rowland, 2008; Xu et a., 2012). As explained in the Introduction of Part 1 of this report, overexposing children to UV radiation increases the risk of skin cancer later in life (Green 2011, Whiteman et al. 2001). However, in 2018 the link between unshaded playgrounds and an elevated risk of children being burnt or overexposed to UV radiation was not in the focus of the public, politicians or the scientific community in Australia.

The *Benchmarking Heat* study (Pfautsch and Rouillard, 2019) mapped air temperatures across the entire Cumberland City Council LGA during the summer of 2018/19. The study identified several playgrounds where maximum daily air temperatures were at or above 40°C for more than 10 days that summer. In contrast, the nearest official weather station at Sydney Olympic Park recorded air temperatures above 40°C only during a single day over the same time interval. This discrepancy highlighted that some playgrounds in the region had very hot microclimates and mitigating that heat would require highly local interventions.

To better understand the thermal dynamics of playgrounds, especially when unshaded, Western Sydney University designed a playground heat monitoring study for Cumberland City Council. Design, results and recommendations from that study form Part 1 of this report. Early results from this work revealed strong relationships of surface materials and surface temperatures when in the sun or shade. These results, together with the recommendation from the *Benchmarking Heat* work to plant trees for shading offered an evidence-based pathway that addressed local heat in playgrounds and could provide local surface and air-cooling benefits over time.

2.3 MEMORIAL PARK PLAYGROUND

The footprint of playground at Memorial Park was a combination of two overlapping circles, where the larger circle covered an area of 137 m^2 and the smaller circle had an area of 41 m^2 (Fig. 26). The floor of the larger circle was covered with bark mulch and was framed with a double bullnose brick edge and had two outer sections of a concrete walkway. A metal bench at the northern end of the walkway was provided as rest area. In the centre of the larger circle was a metal play frame with a maritime theme. The frame contained access stairs, metal platforms, two galvanised metal slides and a U-net ramp. In addition, and accessible from the ground, there was a net wall, a curved balancing bar, a monorail, a rubber dolphin and a Hulaa Sea-Saw. The smaller circle was covered in dark blue rubber softfall, edged with a narrow concrete band and contained a horizontal spinner (1.5 m diameter) with a mount to hold a wheelchair. Prior the transformation, there was no direct shade over the two circular play areas. During summer, trees on the eastern side of the playground provided limited shade and only during the morning. Two additional seating benches were located under the tree canopy to the east of the playground. Memorial Park also contained an asphalted area with a basketball ring to the north of the playground and a triple swing set to the west. The project focussed on transforming the main playground only.

FIGURE 26: Aerial overview of Memorial Park and the playground prior to the transformation. The image was taken in September 2019. Image credit: Nearmap.

2.4 PROJECT TEAM

A strong team of experts was assembled between May and August 2019 to guarantee the implementation of best practise and knowledge in the playground design and delivery of the transformation project. Ten organisations and companies joined the team (Table 3). All organisations and companies were represented on the Steering Committee of the project. Most of the partners offered their knowledge, services and products as in-kind to the project. Without these very generous contributions, it would have not been possible to deliver the excellent outputs and outcomes.

TABLE 3: List of partner organisations and their roles and contributions in the playground transformation project.

ORGANISATION	ROLES
Cumberland Council	» Project management » Integration of policies, regulations and limitations » Provision of site » Site planning and groundworks » Communication and media strategy
Western Sydney University	» Research lead » Environmental monitoring
Alfresco Shade – Intelligent Shade Solutions	» Provision of expert knowledge on playground shade structures » Development of a fully recyclable shade structure » Construction of shade structure at playground
Gale Pacific	» Provision of expert knowledge on shade sail materials » Provision of high-quality shade sail materials
Polysoft – Flexible Seamless Paving	» Provision of expert knowledge on impact attenuating rubber softfall surfaces » Provision of cool rubber play surfaces
Kidsafe	» Provision of expert knowledge on playground safety » Development of the UV and heat-smart 'user guide' for the prototype playground
Andreasens Green Wholesale Nurseries – Create Great Landscapes	» Provision of advanced trees for strategic shading
Cancer Council NSW	» Provision of expert knowledge for best practice to prevent exposure to UV radiation » Development of the UV and heat-smart 'user guide' for the prototype playground
Cancer Institute NSW	» Provision of expert knowledge for best practice to prevent exposure to UV radiation » Development of the UV and heat-smart 'user guide' for the prototype playground
NSW Government Health – Western Sydney Local Health District	» Provision of expert knowledge on improvements for public health
WSROC	» Provision of expert knowledge on urban heat mitigation practices » Disseminating information to Western Sydney councils

2.5 **PROJECT TIMELINE**

May 2019	Project inception
June-August 2019	Development of project application
August 2019	Submission of project application to LG NSW, Grant Program: *Increasing Resilience to Climate Change* (Round 2)
November 2019	Announcement of successful application
November 2019	First project meeting between Cumberland City Council and Western Sydney University
November 2019	Development of Comms Plan
December 2019	Draft plans for site transformation completed and distributed
February 2020	Mayor Steve Christou announces the project publicly in a media release from Cumberland City Council
February 2020	First Steering Committee meeting
March-April 2020	Final playground design
April 2020	Second Steering Committee meeting
June 2020	Project timelines confirmed
June-July 2020	Engagement of construction contactors
September 2020	Playground is fenced off for the public (Fig. 27A)
September 2020	Removal of bark mulch and laying of new subgrade (Fig. 27B)
September 2020	Planting of new trees
September 2020	Installation of drinking water fountain
September 2020	Installation of shade support structure and shade sails (Fig. 27C, D)
October 2020	Installation of new rubber surface materials (Fig. 27E)
23 October 2020	Opening of the playground to the public

FIGURE 27: Main stages of the playground transformation in September and October 2020. (A) Closing the playground to the public. (B) Ground works to remove old surface materials and new subgrade. (C) Installation of the steel frame for shade sails. (D) Mounting shade sails into the frame. (E) Pouring the new surface material.

2.6 IMPORTANT INNOVATIONS

During the consultation and design process, partners brought forward ideas how to improve the playground immediately and to implement long-term strategies at the same time. This process resulted in the development of several innovative techniques, developed exclusively for this playground to maximise benefits for the children and the wider community. For example, the modular design of the steel frame that supported the shade sails did not require a central support pole, creating a wide airy and unobstructed space under a dome-like structure (Fig. 28A). Applying the concept of sustainable use of materials, Alfresco Shade developed the modular structure sufficiently flexible to allow deconstruction and rebuilding at another playground. This idea was the response to the need for immediate high-quality shade, coupled with the long-term vision of growing additional natural tree shade around the playground that in 10-15 years will make the shade structure obsolete.

To make this vision a reality, trees were planted at strategic locations along the northern and western edge of the playground. Four advanced *Lophostemon confertus* (Brush Box) trees and four *Callistemon viminalis* cv 'Kings Park Special' (Bottlebrush) trees were selected. Several Brush Box trees were already growing in the park and the new additions would blend in well. At maturity, this species will be a medium-tall tree with a dense canopy. At maturity, the bottlebrushes will be of low-medium height with their vibrant red flowers adding colour to the park and food for local wildlife. Once these trees cast sufficient natural shade over the playground, the shade sail structure will be removed and used to provide shade in another playground where shade is missing.

Several innovations related to the selection of shade materials and their final position in the shade structure were realised in this project. First, the four large sails on the upper level of the structure were only made from very light-coloured materials to prevent absorbing and radiating heat into the play area (Fig. 28B). Second, most of the solar radiation (including UV) would heat up playground users, and equipment and surfaces during midday until late afternoon. For this reason, the top sails facing north and west were made from materials that blocked more direct light compared to those facing east and south.

FIGURE 28: View of the shade sails from (A) below and (B) above the playground in Memorial Park. Differences in colour, position and venting gaps are clearly visible. Please refer to text for more details.

The top sail facing north was made from a double layer of Commercial Heavy 430 shade cloth (Gale Pacific). Colour of this monofilament fabric was 'desert sand' which blocks 93% UV radiation (290-400 nm spectrum) in a single layer. The UV blocking capacity of the double layer was unknown (but see further below). Hiroaka HG 212 SHS (B) is a PVC material that provides 100% UV block and was used for the top west-facing sail. This material was waterproof and included heat shield technology on its top surface for greater reflection of incoming infrared radiation. The top sail on the eastern side of the playground was made from a single layer of 'natural' (92% UV block), and the south facing sail was made from a single layer of 'desert sand' Commercial Heavy 430 material.

Gaps were left between the top sails to allow venting of warmed air from underneath the sails and thus prevent accumulation of heat in the play space. A single layer of 'aquatic blue' (Commercial Heavy 430, 91% UV block) was used to shield solar radiation entering the playground through the gaps. These 'filling' sails were installed 60 cm underneath the top sails. In the south of the shade structure, a larger single layer of aquatic blue was installed underneath the single layer of desert sand. The purpose of this 'loose double layer' was to assess if light transmission would differ between a double layered shade sail that is open (south facing) or sown together (north facing).

The bark mulch and dark rubber softfall was replaced with speckled blue-white TPO in the large circle and speckled beige-white TPO in the smaller circle. These materials had lower surface temperatures compared to single colours of the same plastic material and were far cooler compared to single colour EPDM or SBR surfaces (see Section 1.4). By choosing these colours, any solar radiation entering the playground through the gaps in the sail structure should not result in hazardous surface temperatures. Lastly, a drinking water fountain was installed at the entrance of the playground.

2.7 'BEFORE-AFTER' ENVIRONMENTAL MONITORING

Data collection at the playground commenced in December 2019 and was finalised 13 months later in January 2021. In the following two sections, we provide information of the cooling effects that shading and changing the surface materials of the playground had on surface, microclimate, human thermal comfort and how effective the sails were in blocking UV radiation. Data were collected during four clear summer days (28 November 2020, 6 December 2020, 10 and 14 January 2021). As a result of the generally cooler summer in 2020/21 compared to 2019/20, mean and maximum air temperatures and maximum globe temperatures were slightly lower in 2020/21 (Table 4). However, surface temperatures of unshaded dark blue rubber under the swings in Memorial Park still reached nearly 80°C when average air temperature was 28°C, and maximum feels like temperatures remained high (Table 4), which indicates that intensity of solar radiation was still very high in summer 2020/21.

TABLE 4: Mean, maximum and minimum air and feels like (black globe) temperatures during data collections in the summer before (2019/20) and after the playground transformation. All measurements are in °C, one SD is shown in parenthesis.

SUMMER	MEAN T_{AIR}	MAX T_{AIR}	MIN T_{AIR}	MEAN T_{GLOBE}	MAX T_{GLOBE}	MIN T_{GLOBE}
2019/20	42.5 (0.7)	48.1	35.2	55.4 (0.5)	62.8	42.8
2020/21	32.0 (0.7)	42.6	25.7	46.4 (0.6)	57.4	39.6

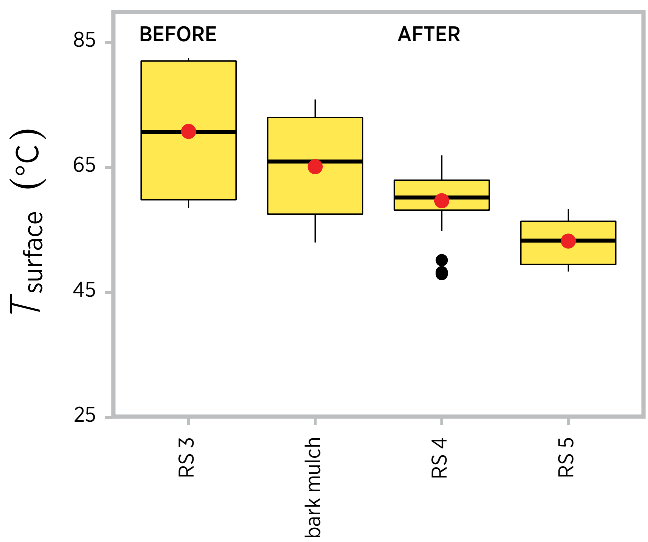

FIGURE 29: Surface temperatures of materials in full sunshine before and after the transformation. RS 3 (blue rubber softfall): n = 10. Bark mulch: n = 10. RS 4 (beige-white speckled rubber softfall): n = 20. RS 5 (blue-white speckled rubber softfall): n = 20. Red dots show the mean $T_{surface}$, black lines the median, top and bottom of the box represents 75th and 25th percentiles, whiskers show maximum and minimum values and black dots depict potential outliers.

2.7.1 COOLING ACROSS THE PLAYGROUND

The playground transformation resulted in lower surface temperatures of unshaded materials (Fig. 29). In the summer 2019/20, unshaded bark mulch in the playground had average surface temperatures of 65°C. During hot, clear days, maximum surface temperature of this material reached 86°C (Fig. 30). During these hot summer days, the dark blue rubber softfall covering the small circle heated up to 82°C (Fig. 31). When replaced with TPO, maximum and average surface temperatures in the sun declined. On the large circle where speckled blue-white TPO replaced bark mulch, maximum surface temperatures in 2020/21 were 57°C and mean surface temperatures were 52°C (Fig. 29).

On 28 November 2020, playground surface temperatures were measured at Memorial Park and, shortly after, at Colquhoun Park which allowed a direct comparison of sunlit TPO with sunlit bark mulch. Measurements showed that the average surface temperature on blue-white TPO was 11°C cooler than bark mulch. In addition to this temperature difference, only a very small proportion of the blue-white TPO surface was exposed to direct sunshine after the transformation (Fig. 30). However, to demonstrate the real cooling effect of the playground transformation, it was necessary to calculate surface temperature differences between sunlit bark mulch and shaded blue-white TPO. This comparison revealed a combined surface cooling effect from shading and changing the surface material of 34°C. Mean air temperature over the shaded blue-white TPO was 1°C cooler (i.e., 42°C in the sun, 41°C in the shade) and feels like temperature was 9°C less (i.e., 54°C in the sun, 45°C in the shade) compared to measurements collected on the sunlit turf next to the playground on 28 November 2020. Across all four measurement dates in summer 2020/21, air temperatures were 3°C cooler and feels like temperatures were 11°C cooler under the shade sails compared to full sun on the turf next to the playground.

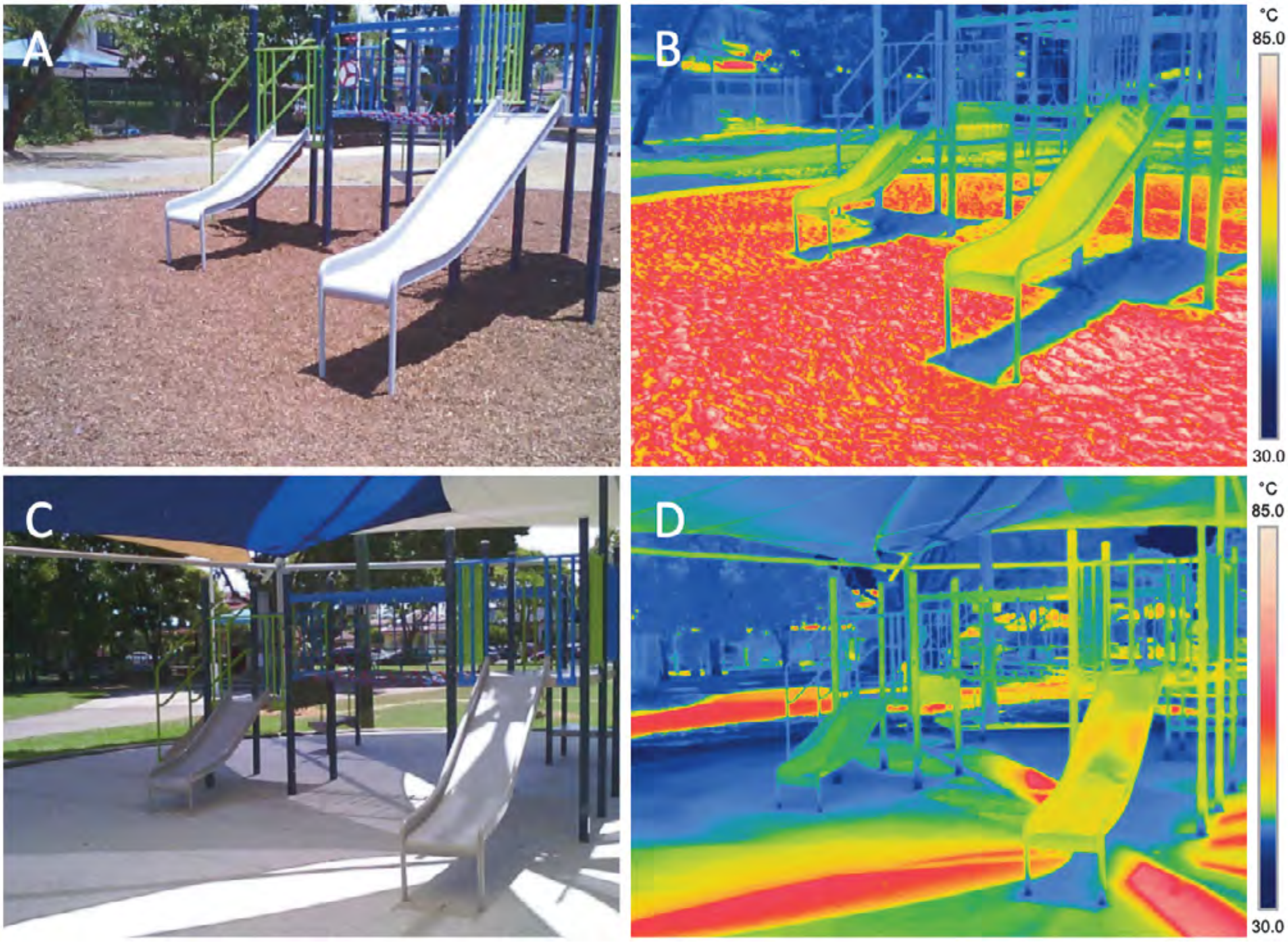

FIGURE 30: Temperatures of surface material and play equipment before (4 January 2020) and after (28 November 2020) transformation of the playground. Panels on the left show the normal view, while those on the right show the infrared view where temperature is represented by colour (see scale on the right of each panel).

As depicted in Figure 29, the beige-white TPO material had a slightly higher average surface temperature compared to the blue-white TPO. Based on the positioning of the two surfaces, it is reasonable to assume that the temperature differences resulted from longer exposure time of the beige-white material to solar radiation, compared to the blue-white material. Under the shade sails, small patches of direct solar radiation (visible in Fig. 30D) move relatively fast over the blue-white surface as a combined result of the narrow gaps in the top sails and the change in angle of incoming light. In contrast, the sunlit section of beige-white TPO is exposed to direct sunshine for several hours. The longer exposure will lead to higher surface temperature of the beige-white TPO surface. Regardless of this, the combined effects of changing the surface material around the spinner from a dark to a light-coloured surface material and introducing shade resulted in a surface cooling effect of 25.1°C on shaded beige-white TPO (Fig. 31).

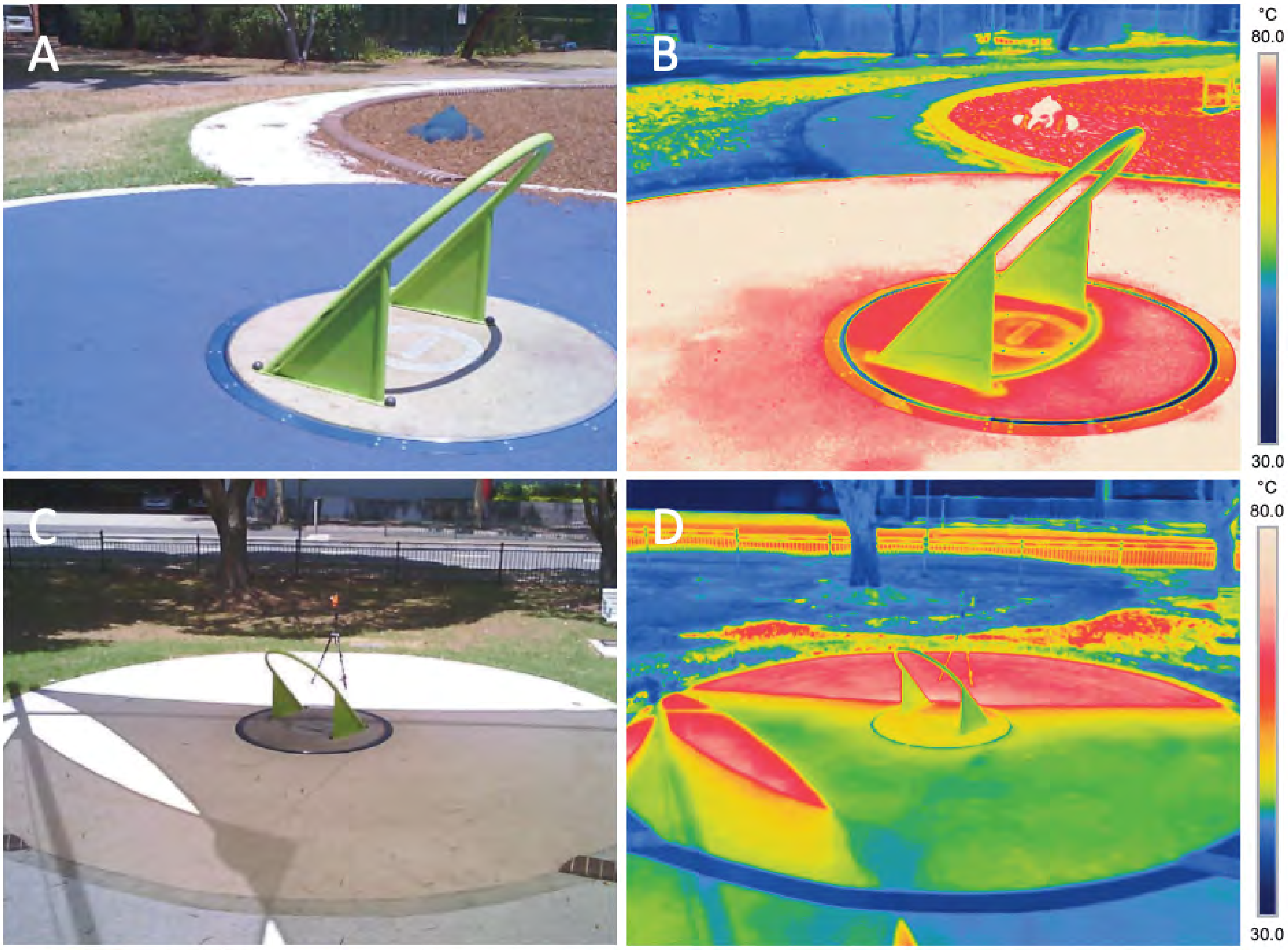

FIGURE 31: Temperatures of surface material and play equipment before (4 January 2020) and after (28 November 2020) transformation of the playground. Panels on the left show the normal view, while those on the right show the infrared view where temperature is represented by colour (see scale on the right of each panel).

Shade also cooled other surface materials (Table 5). Comprehensive measurements were collected to compare surface temperatures of sunlit and shaded surface materials on 28 November. During that day, afternoon air temperatures were just above 40°C, feels like temperature was 53°C in the sun and 45°C under the shade structure. Shade effectively provided by the new sails reduced surface temperatures between 6°C and 29°C. It is also worth mentioning that shade reduced the surface temperature on real turf even more (6°C degrees cooler) compared to natural shade from nearby Brush Box canopies (3°C degrees cooler).

TABLE 5: Surface temperatures of materials in the full sun and shade at the transformed playground at Memorial Park. Measurements were collected between 14:10-15:40 on 28 November 2020, a hot, clear summer day. Each temperature represents the mean of five individual measurements, extracted from high-resolution infrared images.

MATERIAL	SURFACE TEMPERATURE IN THE SUN (°C)	SURFACE TEMPERATURE IN THE SHADE (°C)	COOLING EFFECT OF THE SAILS (°C)
Real turf	43	37	6
Concrete walkway	49	36	13
Dark bricks	52	38	14
White metal slides	53	45	8
U-net ramp	58	44	14
Blue rubber dolphin	77	48	29

2.7.2 THE *TROJAN EFFECT*

Cooling and UV blocking effects of shade are critical to provide safer playgrounds. However, when shade is absent, using light-coloured materials to keep surface temperatures down will produce an unwanted 'Trojan Effect' that should not be overlooked. This effect refers to the observation that surface with high reflectivity will have lower surface temperatures but will lead to a reduction in human thermal comfort as reflected radiation increases feels like temperatures. This phenomenon was already described for sunlit concrete in Part 1 (see Figs. 12 and 13 and associated text).

At the transformed playground at Memorial Park, this effect was detected on sunlit beige-white TPO. A direct comparison of surface, air and feels like temperatures between sunlit beige-white TPO with sunlit dark blue rubber softfall clearly demonstrated the effect. A direct comparison of the two materials was possible because the dark blue rubber softfall material was still in use under the swings in the west of the park (see Fig. 26).

Measurements of surface, air and feels like temperatures for both surfaces were collected on 28 November 2020 and 10 January 2021. During these clear summer days, the mean surface temperature on the beige-white TPO was 11°C lower compared to the dark blue rubber softfall. The average air temperature over the two surfaces was 1°C warmer over the TPO (36°C) compared to the dark blue rubber softfall (35°C). The real difference was in feels like temperature above the two materials. While this temperature was 49°C for the darker surface, it was 54°C for the lighter coloured TPO. A difference of 5°C represents a significant warming effect that would lead lower human thermal comfort.

The warming effect of reflected solar radiation, especially longwave infrared radiation (the part of the light spectrum that causes intensive warming) is also apparent when comparing the sunlit beige-white TPO with sunlit turf next to the playground. As shown in Part 1 of this report, real turf had the lowest surface temperature of all surface materials investigated, but was not linked with the highest feels like temperature. This is the result of converting a proportion of energy contained in solar radiation into biochemical energy that helps the plant to assimilate carbon during the process of photosynthesis. This capacity to convert incoming energy is absent in other surfaces. When compared to the real turf next to the playground, feels like temperatures were constantly higher on sunlit beige-white TPO (Fig. 32). The blocking of solar radiation by the shade structure on the other hand resulted in up to 10°C lower feels like temperatures on the shaded blue-white TPO compared to measurements over real turf (Fig. 32). These observations highlight the overruling importance of shade on thermal comfort in playgrounds once more – the *Trojan Effect*.

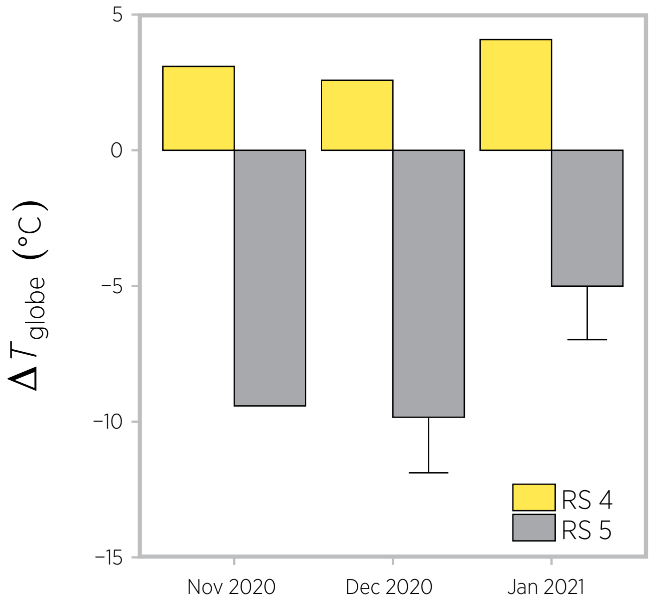

FIGURE 32: Differentials of feels like temperatures (approximated using black globe temperature, T_{globe}) measured over sunlit beige-white TPO in the sun and shaded blue-white TPO in the shade of the playground at Memorial Park. Differentials were calculated by subtracting simultaneous measurements of T_{globe} over sunlit real turf next to the playground from those measured over TPO surfaces. The yellow colour indicates measurements made in the sun, and grey indicates that measurements were made in the shade.

2.7.3 REDUCTION OF UV RADIATION

Implementation of shade at the playground reduced the exposure of surfaces to direct sunlight and UV radiation significantly. For the four days when measurements were collected, average total irradiance was 1035 W m^{-2}, with maximum irradiance of 1109 W m^{-2} on 10 January 2021. Typical light spectra of full sunlight were recorded between 280 nm and 1150 nm (Fig. 33). The amount of light block varied among the sails. The double-layered sails blocked most of the light. The open double-layered sail, made from Desert Sand (top) and Aquatic Blue (bottom) blocked 98.5% of solar irradiance. The closed double-layered sail blocked 97.4% of solar irradiance. The PVC sail blocked 95.4% and the light-coloured single layer sails blocked 89.2% (Natural) and 88.3% (Aquatic Blue) of the incoming sunlight.

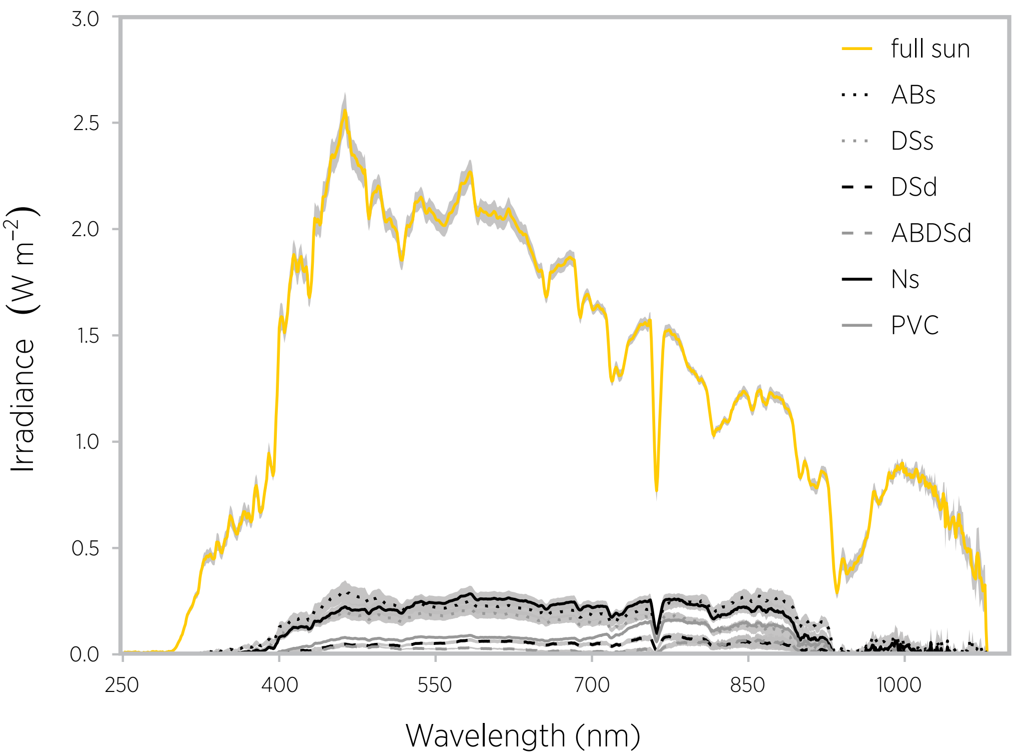

FIGURE 33: Full light spectra measured in full sun and underneath the shade sails introduced at the playground in Memorial Park. Measurements represent means (n = 5 per day and sail type or sun) collected during the early afternoon of four days in the summer of 2020/21. Abbreviations: ABs = Aquatic Blue single layer; DSs = Desert Sand single layer; DSd = Desert Sand double layer (closed); ABDSd = Aquatic Blue Desert Sand double layer (open); Ns = Natural single layer. Data were collected at 1 nm increments; dark grey shading indicates 1SD.

The surface temperatures of the blue-white TPO material differed depending on the shade sail directly above it. For example, measurements on 16 January 2021 showed that surface temperatures were highest (33.8°C) under the single layer of Aquatic Blue material that blocked 92.1% total irradiance. In contrast, the double-layered open sail, made from Desert Sand (top) and Aquatic Blue (bottom) material, obstructed 99.3% total irradiance. The surface temperature of TPO below these shade sails was more than 4°C cooler (29.6°C). The relationship between light blockage and surface temperature was negative and strong (R^2 = 0.69). The relationship remained significant when using block rates for infrared radiation only (i.e., 750-1100 nm band), although it was less strong (R^2 = 0.45).

Using the classification system for human shade protection provided by knitted and woven fabrics (Standards Australia, 2018), all materials used to shade the playground were 'Most Effective' as their mean UVE% was greater than 95%. According to the shade rating system endorsed by the Cancer Council NSW (2013), most sails provided 'Excellent' (i.e., Ultraviolet Protection Factor (UPF) 40-50+) or 'Very Good' (i.e., UPF 25-39) protection from UV radiation. Only the single layer Aquatic Blue was rated lower than this on three of the four measurement days. The lowest UPF of 93% was measured for this shade cloth material on 10 January 2021.

The most effective materials for blocking 100% UV-A and UV-B radiation were the double-layered shade sails and the sail made from PVC (Fig. 34). This excellent characteristic was consistent for both materials on all four measurement days. The sail made from a single layer of the Natural coloured material was less effective, blocking 98.1% UV radiation on average. Slightly less UV radiation (97.6%) was blocked by the single layer of Desert Sand coloured fabric. The lowest UV block was provided by the single layer of Aquatic Blue (95.2%) (Fig. 34).

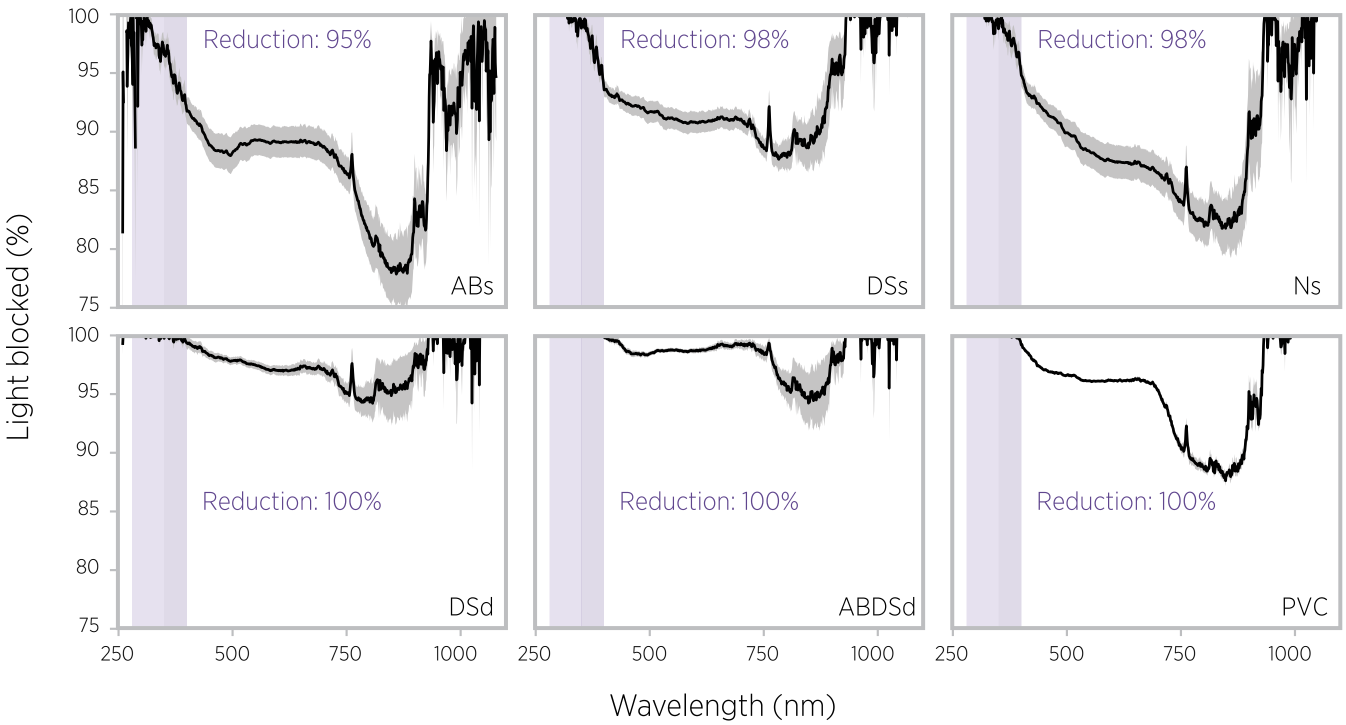

FIGURE 34: Differential spectra of blocked light for the six different sail types at the playground in Memorial Park. Abbreviations: ABs = Aquatic Blue single layer; DSs = Desert Sand single layer; Ns = Natural single layer; DSd = Desert Sand double layer (closed); ABDSd = Aquatic Blue Desert Sand double layer (open). The purple bars represent the UV-A (350-400 nm) and UV-B (280-350 nm) range of solar irradiance; dark grey shading indicates 1SD.

Measurements of ultraviolet light were separated into UV-A (350-400 nm) and UV-B (280-350 nm) bands. On average, UV-A in the full sun provided 54.8 W m^{-2} of energy, whereas UV-B had 16.4 W m^{-2}. This separation was used to investigate if the capacity of the sail materials to block UV radiation applied to both bands equally. The PVC and double-layered sails were most effective in blocking radiation in both UV bands (Table 6). As the UV-B band contained less total energy, the single sail fabrics were more effective in blocking UV-B than UV-A radiation.

All shade sail materials used as a single layer at Memorial Park blocked more UV light than specified by the manufacturer. In contrast, the lime green shade sail at Kootingal Reserve blocked less UV light than specified. The origin of this difference will be subject of additional investigation. It is unclear how results using standard laboratory testing methods can differ by the margins measured here. It could be speculated that the planar orientation of the sail fabric at Kootingal Reserve allowed perpendicular transmission of sunlight, which would be closer to laboratory testing conditions. The shade sails at Memorial Park were angled suggesting that transmission characteristics may differ from those used in standardised laboratory tests.

TABLE 6: Mean values for blocked UV light (%) of all sail types tested for this report. Measurements were collected using a hand-held spectroradiometer oriented towards the sun. Data are means of 20 individual scans during the early afternoon of two clear, warm summer days (five scans made on 6 December 2020 and 10, 14 and 16 January 2021), except the lime green sail at Kootingal Reserve (16 January 2021). At each day and site, at least five additional scans were taken in full sun to calculate relative UV block. Total UV = 280-400 nm band; UV-A = 350-400 nm band; UV-B = 280-350 nm band.

SHADE SAIL TYPE	MATERIAL	UV BLOCK (MANUFACTURER) (%)	LAYERING	ORIENTATION	TOTAL UV (%)	UV-A (%)	UV-B (%)
Aquatic Blue	Commercial 430 (Gale Pacific)	87.3	Single	NW	95.2	94.1	97.7
Desert Sand	Commercial 430 (Gale Pacific)	85.9	Single	S	97.6	96.7	99.5
Desert Sand	Commercial 430 (Gale Pacific)	N/A	Double (closed)	N	99.9	99.7	99.9
Aquatic Blue/ Desert Sand	Commercial 430 (Gale Pacific)	N/A	Double (open)	S	100	100	100
Natural	Commercial 430 (Gale Pacific)	87.9	Single	E	98.1	97.5	99.5
Coated PVC	HG 212 SHS (B) (Hiroaka)		Single	W	99.9	99.9	100
Lime Green	Architect 400 (Polyfab)	95.3	Single	Planar	93.7	93.0	95.5

2.8 **COMMUNICATION OF THE PROJECT**

The first coverage of the topic of heat in playgrounds was on ABC television show *Weekend Breakfast* in January 2019 and the Ten News Network in February 2019 in response to a media release from Western Sydney University. This media release reported surface temperatures above 100°C had been documented in several playgrounds across Western Sydney. Several online and newspaper articles and radio programs were produced towards the end of summer 2019, indicating broader public interest in the issue of heat in playgrounds.

An integral part of the project was a communication strategy to engage with the public. Cumberland City Council, Western Sydney University, Kidsafe NSW, and WSROC developed information materials and media releases. Western Sydney University coordinated interviews for TV and radio as well as producing content for social media networks. With the announcement of the project by the Mayor of Cumberland, Steve Christou, in early February 2020, the ABC *Weekend Breakfast* show covered the story again, reporting on the positive outcomes for the local community. Throughout September and October 2020, Western Sydney University had increased activity on social media sites. These posts passed into the networks of the partner organisations to reach a much wide audience.

The public opening of the transformed playground on 23 October 2020 was documented by several media teams (ABC, LG NSW, Cumberland City Council). Additional media releases from Cumberland City Council and Western Sydney University, as well as social media posts were prepared. Positive news about the playground as practical example to help communities adapt to a changing climate was reported nationally (Climate Council, 2021) and internationally (IFAI, 2021). The highly visual character of the project, the striking before-after effect (Fig. 35) has certainly helped to showcase the playground. The wide distribution of stories and images of the playground has resulted in an impressive online presence for Cumberland City Council. At the time this report was published, a Google search using the phrase “Cumberland Council Cool Playground” produced 750,000 hits. We can only speculate that without a well-executed media strategy, this number would have been drastically lower.

Apart from communicating the project to media and the wider public, it was essential to also report the ‘good news story’ to the local community. The steering committee of the project decided that a sign next to the footpath that passes the playground would be an ideal tool to inform the public. The messaging used was around the issues of heat and UV overexposure in playgrounds more broadly, and how this problem was resolved in their own local playground. A metal sign (450 x 300 mm) was designed to provide a short educational text with simple instructions for how to stay cool and be UV-smart (Fig. 36). In addition, it explained the project, listed the partners and LG NSW as the main funding agency.


A


B

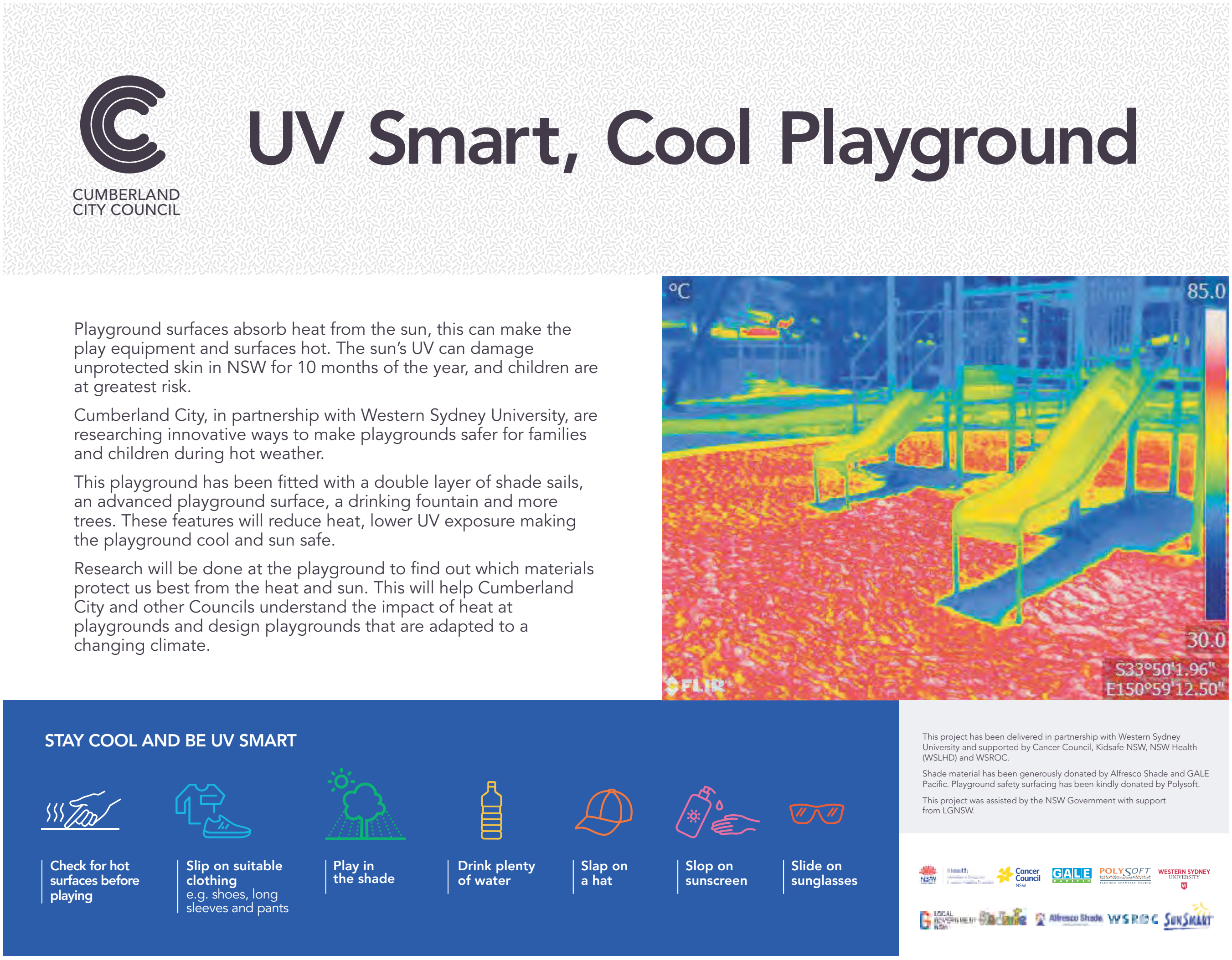

FIGURE 36: *UV-smart Cool Playground* sign for Memorial Park. The sign was installed to the left side of the entry to the playground and is easily accessible from the central walkway through the park. It provides a problem statement, research background and problem solutions. The infrared image shows the playground before it was transformed where unshaded bark mulch heated to more than 80°C surface temperature.

FIGURE 35 (previous page): The Memorial Park playground before (August 2020) and after (October 2020) the transformation into Australia's fist dedicated UV-smart Cool Playground. Image credit: S. Tsoutas, Western Sydney University.

2.9 ADDITIONAL PROJECT BENEFITS

Using research to design and construct a *UV-smart Cool Playground* is a stunning example of best practice. Councils are risk averse organisations and can be hesitant to incorporate the latest industry technologies without seeing prior application. The aim of this study was to pave the way for this type of 'design and build' to be embedded into the culture of capital works procedures in councils across Western Sydney.

The design principles and underlying research were readily available through reports from Cumberland City Council, WSROC, and Western Sydney University (Fig. 37). Project partners and funders agreed that it was important to provide evidence-based information to shift industry standards for playground design and planning that better include climate resilience factors. The experience gained through the construction of the prototype at Memorial Park will allow adaptation of innovative playground design based on thermal and UV performance. Cumberland City Council fosters a good working relationship with Western Sydney University and together will design and deliver more innovative projects that benefit local communities.

As direct outcome of the *Benchmarking Heat across Cumberland Council* project (Pfautsch and Rouillard, 2019), Cumberland City Council has formed new partnerships around urban heat mitigation with City of Parramatta, Blacktown City Council, City of Canterbury Bankstown, Fairfield City Council, Campbelltown City Council and Bayside Council.

The main funding body of this work, LG NSW, has developed information materials that are publicly available from their website. Cumberland City Council has also developed a compact description of the work in the form of a case study (attached at the end of this report). This document is also available through LG NSW and will be distributed to all local governments in NSW. The project has already been presented to the members of Play Australia (national peak body of playground managers and designers, located in Melbourne) and was used by Playscape Creations, Darra, Queensland, to bring thermal comfort and surface temperatures to the attention of playground users. The project team will continue to communicate the work and its key findings to national and international audiences through presentations at work meetings and conferences. Applications to a range of award programs are in preparation.

FIGURE 37: Project partners (from left to right): Richard Lao (Polysoft), Ben Westcott (Alfresco Shade), Sebastian Pfautsch (Western Sydney University), Tom Westcott (Alfresco Shade), Charles Casuscelli (Western Sydney Regional Organisation of Councils), Kim Cooke (Kidsafe NSW), Ahmed Meio (Cumberland City Council), Mark Cook (Gale Pacific), Liz King (NSW Cancer Council), Tim Nguyen (Cumberland City Council), Kostan Banos (fmr. Cumberland City Council), Joshua Hayden (Cumberland City Council). The image was taken at the opening of the playground in Memorial Park on 23 October 2020.

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4. LINKS TO PROJECT-RELEVANT INFORMATION

CUMBERLAND CITY COUNCIL

https://www.cumberland.nsw.gov.au/uv-smart-cool-playground-project

https://www.cumberland.nsw.gov.au/news/first-its-kind-uv-smart-cool-playground-ready-play

https://www.cumberland.nsw.gov.au/playgrounds-cumberland-city

https://www.facebook.com/cumberlandcitycouncilsydney/videos/come-and-play-at-the-uv-smart-cool-playground/1191100211284308/

LOCAL GOVERNMENT NSW

https://lgnsw.org.au/Public/Public/Policy/Case-Studies_-_Climate-Change-videos.aspx

https://www.youtube.com/watch?v=eQAIV2cuyH0&t=5s

WESTERN SYDNEY REGIONAL ORGANISATION OF COUNCILS (WSROC)

https://wsroc.com.au/media-a-resources/wsroc-news-stories/uv-smart-cool-playground-ready-for-play

WESTERN SYDNEY UNIVERSITY

https://www.westernsydney.edu.au/newscentre/news_centre/more_news_stories/research-backed_uv_smart_cool_playground_open_for_play

https://www.facebook.com/westernsydneyu/videos/dr-sebastian-pfautsch-playground-retrofit-update-video-1mp4/333175434596649/

5. UV-SMART COOL

UV Smart Cool Playground

Case Study

In March 2020, Cumberland City Council partnered with Western Sydney University (WSU) to research and develop innovative ways to make playgrounds safer for families and children during hot weather. It involved retrofitting Memorial Park Playground at Merrylands to improve thermal comfort and reduce ultraviolet radiation (UV). The project demonstrates a cost-effective method to retrofit existing playgrounds to be UV safe and heat smart. Cost savings will be realised through the modular construction of the shade structure that can be relocated to and adjusted for the next playground once the newly planted trees provide shade.

Surface temperatures dropped as much as **40°C** and thermal comfort by **20°C** after retrofitting the playground with shade

Heat as a hazard

Outdoor play is an important activity that improves physical and mental health. However, high ambient temperatures pose a risk for children as their capacity to self-observe and self-regulate their behaviour is underdeveloped. As a consequence, outdoor play on hot days can result in dehydration, heat exhaustion, heat rashes and other conditions that can pose serious health risks. Additionally, play equipment exposed to direct sunshine can reach extreme temperatures especially when surfaces are made of synthetic grass, rubber, plastic or metal which may result in severe burn injuries to feet, legs and hands.

UV exposure and safety

Children and adolescents are particularly vulnerable to solar UV as their skin is more vulnerable. Minimising exposure to UV radiation in the first fifteen years of life is key to reducing skin cancer risk later in life.

Well-designed shade can reduce exposure to UV by up to 75%, and we know that when shade is provided in parks and schools, young people will use it. However, the key problem is access to shade.

The Cancer Council NSW's Guidelines to Shade provides best-practice information for designing and constructing good quality and well positioned shade in outdoor public spaces.

PLAYGROUND CASE STUDY

Implementation

This playground builds on Cumberland City's heat mapping study which identified several playgrounds recording 10 or more 40°C+ days. The retrofit included installation of four key elements which will help to improve thermal comfort and reduce heat and UV exposure at the playground.
The elements were:

Cool materials

An advanced thermal resistant shade sail was installed over the playground. The new shade sail comprised of four quadrants, each with a different design and material, which will be tested to determine its thermal and UV performance in an outdoor environment. In addition, the existing mulch surface was removed and replaced with a new advanced polyolefin plastomer surface which has a lower heat conductivity.

Water

A drinking water fountain was installed to provide playground users access to water to stay hydrated during play. Water plays an important role in reducing heat associated risk.

Tree canopy

A shade analysis was completed to help strategically plant eight native trees around the playground to provide long term natural shade to the playground once they reach maturity. Plantings were concentrated at the northern and western side of the playground to shield intensive midday and afternoon sunshine. The trees not only provide optimal shade and improve microclimate, but they enhance the aesthetic of the playground and support local biodiversity.

Education

A sign was installed at the playground to educate users about the ongoing research on heat and UV in playgrounds, and how to stay UV-smart and cool. Providing information about safe and responsible outdoor play was imperative to achieve community awareness.

Outcomes

Photo credit: Sally Tsoutas

Today, the new surface materials and shaded play equipment rarely display surface temperatures of more than 35-40°C. In summer, "feels-like" temperatures of up to 62°C had been documented on site. At the new UV Smart Cool Playground, these temperatures have been cooled down to equal ambient air temperature.

Empirical evidence collected before and after the transformation shows that the main objective – extending the time to safely use a playground in increasingly hot summers – has been achieved. While prior to this work UV exposure was 100% due to the absence of shade, now UV exposure ranges from 0-2 %.

When exposed to the sun, surface materials and play equipment heated up to more than 80°C. As a result, this playground can now be used safely for more hours during summer.

The project demonstrated that through strategic planning and design, Councils are able to retrofit unshaded playgrounds with elements that help to reduce UV exposure and improve thermal comfort through a variety of ways, from low cost options such as planting trees, to more expensive options such as installing artificial shade structures.

This project has been delivered in partnership with Western Sydney University and supported by Cancer Council NSW, Kidsafe NSW, NSW Health (WSLHD), ARPANSA and WSROC. Shade material has been generously donated by Alfresco Shade and GALE Pacific. Playground safety surfacing has been kindly donated by Polysoft. This project was assisted by the NSW Government with support from LGNSW.

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