Horticulture Innovation Australia Limited

Living turf fire benefits study - Literature review

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Table of contents

Table index

Figure index

1. Introduction

1.1 Purpose

This living turf fire benefits project includes a desktop study and a scientific evidence-based assessment of the fire protection benefit of living grass, with some comparison to synthetic grass. The purpose of this report is to articulate the benefits of living grass in firewise landscape design, and to provide the turf industry with information to develop and market sustainable products for use in reducing bushfire risk in bushfire-prone areas. This project contributes to the **Turf Industry Strategic Investment Plan –** Outcome 1 **– Strategy 4**, *i.e. Undertake review of existing literature to collate benefits and identify information gaps* and **Strategy 5***, i.e. Conduct research to address information gaps.*

1.2 Background

In bushfire-prone areas, the nature of vegetation surrounding houses and buildings has a very strong influence on the degree of bushfire damage/loss risk to which a building is exposed. The presence of flammable vegetation and combustible materials in close proximity to a house or building is a key factor which increases house/building ignition risk, whereas risk is reduced by vegetation and materials which are not conducive to being ignited by airborne embers or when exposed to high radiant heat levels. For these reasons planning regulations in most Australian States and Territories require new dwellings/extensions and other building types in bushfire-prone areas to be subject to *Bushfire Attack Level* (BAL) assessment (quantifying radiant heat exposure levels at the building being assessed). Based on such assessments, buildings are then required to be separated from bushfire-prone vegetation by a distance appropriate to their design and construction, and for the intervening space (variously referred to as Asset Protection Zones or Defendable Space) to be established and maintained in a condition which minimises the potential for fires to start and spread within such zones.

To this end, fire and emergency service agencies in the different states and territories have developed advisory materials providing guidance on firewise landscaping design and plant selection around houses, and providing standards for maintaining outdoor areas including vegetation around houses and buildings in a firewise condition. Well maintained lawns have the potential to resist ember attack by not sustaining ignitions during ember attacks, in contrast to some other ground covers used in landscaping. One of the more detailed publications currently available is *Landscaping for Bushfire* (CFA Victoria, 2011[1]) developed in response to Recommendation 44 of the Victorian Bushfires Royal Commission. The *Landscaping for Bushfire* guide promotes the use of gravel paths, non-flammable mulch, and mown grass in areas separating homes from bushfire-prone vegetation, and cautions against incorporating flammable materials and objects in such areas, particularly immovable ones. Live turf and lawns maintained in a short, green condition are promoted, and no mention is made of artificial turf or lawn products.

Synthetic turf, as a substitute to living turf, is increasingly being used in landscaping, particularly in backyards, sports fields and playgrounds. Synthetic turf is typically made of a mixture of polypropylene (PP), polyethylene (PE) or nylon fibres, some products also incorporating 'rubber crumb' often recycled from tyre rubber, and with base material variously comprised of materials including rubber and latex. Depending on the materials mix used, different synthetic turf products have different propensity for ignition by embers and radiant heat and different potential for sustaining fire spread across the laid synthetic turf product. Such materials when undergoing

[1] For Table of Contents and link to full online document, see https://www.cfa.vic.gov.au/plan-prepare/landscaping

combustion may generate health risks due to the release of toxic gases like dioxins, furans and other noxious emissions produced when they burn (Verma & Vinoda 2016).

Some synthetic grass manufacturers/suppliers subject their products to fire testing, very often using test methods applicable for carpet and indoor flooring products, and some provide on-line You-Tube clips of their products being flame tested with hand-held gas guns. Such tests typically are static tests, with no accounting for the effects of wind (or high fuel temperature), which is a major influence on fire spread in outdoor environments, but not relevant for testing of indoor flooring materials.

Given the lack of evidence-based bushfire-relevant information on the fire-resistant nature of living grass compared to synthetic grass, and the gap in guidance materials relating to choosing between living or synthetic grass products in bushfire-prone landscape design, this project has the potential to provide important evidence and information for the turf industry to develop and market sustainable bushfire-wise products for use in reducing bushfire risk in bushfire-prone areas.

1.3 Scope and limitations

This report has been prepared by GHD for Horticulture Innovation Australia Limited and may only be used and relied on by Horticulture Innovation Australia Limited for the purpose agreed between GHD and the Horticulture Innovation Australia Limited as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Horticulture Innovation Australia Limited arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer to section 1.4 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

1.4 Assumptions

In preparing this report, GHD has made the following assumptions:

- Turf species tested are limited to buffalo, kikuyu and couch on the assumption these are the main commercial turf species on the market in Australia – no inference is made as to whether the fire protection benefits attributable to these species also extend to other species;
- The peak bushfire season in southern Australia corresponds mostly to the summer months (December, January, February), however GHD notes that in sub-tropical areas the bushfire season is principally in spring (September, October, November), and in the tropics is in the late wet season (typically July to September). In all cases, it is assumed these periods are active growth periods for living turf/lawns.

2. Method

GHD undertook a literature review as a component of the project TU17008 *Conveying the benefits of living turf* – *A bushfire retardant*. This literature review has been divided into two main components, to assess the suitability of synthetic grass and subsequently living grass to be used as part of firewise landscaping.

The synthetic turf literature review has identified synthetic grass flammability attributes including:

- A typology of different synthetic turf types (materials/composition) available in the Australian market
- Melting points and ignition temperatures
- Flammability
- Key information from Material Safety Data Sheets (including combustion products if available)
- Types of damage caused to the product when subject to ignition, embers, radiant heat exposure etc.

The synthetic turf literature review is presented in section 3.

GHD has also undertaken a literature review of garden and landscaping advisory material produced by Australian fire and emergency services (and relevant material from other countries) to identify:

- Turf species on the Australian market; their attributes and maintenance requirements
- The flammability of living turf
- The extent to which living turf is highlighted as a component of firewise garden/landscape design
- The extent to which there are opportunities to improve the specifying of living turf as a fire retardant feature in garden/landscape design.

The living turf bushfire protection benefits review is presented in section 4.

3. Synthetic turf review

3.1 Overview of artificial turf development and composition

Synthetic turf, initially termed Chemgrass, was developed and first installed in 1964 at Moses Brown School in Providence, Rhode Island, USA. This was followed by a larger installation at Houston Astrodome, from which it derived its colloquial label 'Astroturf' (Turf Australia n.d.).

Over the past 50 years synthetic turf has undergone three major generations of product development. The first generation was made of short, 10-12 mm, high-density nylon yarn which, unless used wet, caused severe friction burns on exposed skin in situations where a person fell and slid on the synthetic grass (Turf Australian n.d., Victoria State Government 2017).

Second generation synthetic turf products were principally made of polypropylene and were designed with a longer blade length, 20-35 mm, and comprised a lower density of blades. To give the required support and stability, rounded sand was used as an infill (Turf Australia n.d.).

The third generation of synthetic turf has been in use since the late 1990s, being the generation of synthetic turf products in most common use today. It is made using a softer polyethylene fibre, with a longer blade design than previous versions, of around 40-65 mm (Technical Textiles & Nonwoven Association 2013). To give the rigidity and support required for the turf, rubber or plastic granules are often used as infill. Many third generation synthetic turf products feature synthetic 'thatch' between the taller synthetic grass blades, giving a less uniform appearance better imitating the variability of colour found in natural lawn systems. The third generation synthetic turf products have increased both the popularity and use of synthetic turf in Australia, increasingly expanding markets from sporting and commercial applications into residential/landscaping uses (Artificial Turf 2019).

A fourth generation of artificial turf products seeks to dispense with infill components through providing a dense structure (web) of twisted synthetic fibres to provide support to the synthetic grass blades. The web is most frequently made of polypropylene (PP), polyethylene (PE), PE and PP copolymer, polyamide (PA) or nylon (PA6) and may also consist of a mixture of polyethylene, polypropylene or nylon fibres (Kukfisz 2018).

Over recent years, synthetic turf has increasingly been taken up in residential and commercial landscaping settings with clients perceiving that synthetic turf will have lower maintenance requirements than natural turf (Victoria State Government 2017).

As synthetic turf products have become more common, a range of concerns regarding their safety and utility, relative to natural turf, have emerged with comparative studies typically following after product take-up by the market. One of the more studied areas of synthetic turf – natural turf comparative studies is in relation to sporting injury occurrence (Department of Local Government, Sport and Cultural Industries). A wide range of studies covering different sports and injury types have been undertaken with variable results, however many of the studies indicate higher injury rates on synthetic turf surfaces.

Another field of comparative study is in relation to the surface temperatures in outdoor environments (Department of Local Government, Sport and Cultural Industries). Live turf has been found to sustain substantially cooler surface temperatures than synthetic turf surfaces, with some studies showing synthetic surface temperatures up to three times hotter than natural turf. An American study by Williams and Pulley (2009) recorded temperatures as high as 93ºC. In Australian summer conditions, synthetic lawns have been recorded to reach 80°C. Accordingly, it has become necessary for high volume water sprinkler systems to be installed and operated periodically on synthetic turf sporting fields in warm climates, to temporarily cool the surface temperatures and reduce heat-stress health risk (Department of Local Government, Sport and Cultural Industries). Synthetic turf flammability has also been studied in recent years (although not nearly as extensively as the aforementioned fields) with findings summarised in this report.

3.2 Materials and properties

Synthetic turf is created using methods similar to those used in carpet manufacturing. The turf comprises three components including a backing material that serves to hold the plastic blades of the synthetic grass, and infill which maintains the turf structure (Victoria State Government 2017). The backing material is typically a combination of polypropylene, polyethylene or nylon, and will be coated in a latex or other adhesive to hold the materials together. The plastic blades are usually polyethylene (in third generation products) and the infill material varies, depending whether the turf is for commercial or private use; either silica sand, rubber, cord or envirofill is used. The rubber infill (also referred to as 'rubber crumb') is often applied in commercial and/or sporting field use, and is made of old tyres, crushed down to create the supportive particles. Recent studies have raised the potential issue of the toxins released from the rubber crumb (refer Bleyer 2017).

The principal components of installed synthetic turf products (Victoria State Government 2017, TenCate Grass n.d.) are:

- Synthetic grass blades which can be:
  - Polyethylene group polymers
  - Polypropylene group polymers
  - Nylon group polymers
- Infill material which can be:
  - Polypropylene and/or Polyethylene group polymers
  - 'Rubber crumb' (principally vulcanised tyre rubber)
  - Silica sand (non-combustible)
- Backing material
  - Typically polypropylene and/or latex rubber
- Adhesive (typically all-weather solvent-based adhesive containing a blend of polymers, solvents and additives)

With the exception of silica sand infill components used in some products, all components are combustible.

3.3 Susceptibility of artificial turf to fire ignition

As synthetic turf comprises a mixture of combustible plastics, when exposed to an ignition source it is predisposed to melting and ignition. The flammability of plastics varies greatly between the different types of plastic and the additives used.

The combustible polymers in artificial turf have relatively low melting points (see Table 3.1). The most widely used (third generation) artificial turf products are comprised of polyethylene and have a melting point in the range of 110 to 130°C. Further heating volatilises the polyethylene into hydrocarbon vapours, with ignition occurring from its flashpoint of around 330°C (comparable to the flashpoint of the organic polymer cellulose from which dead, dry grass and paper is principally comprised, noting that live green grass is principally comprised of water). Glowing embers, as are commonly blown in front of an advancing bushfire, have a temperature of around 700-800°C, and the flame of a burning leaf has a temperature of around 700°C. Strips of polyethylene can be ignited with the flame of a match which has a temperature of around 700°C.

Ignition testing undertaken by Kukfisz (2018) established that all polyethylene and polypropylene turf products tested ignited when exposed to radiant heat flux of less than 3 kW/m^2, which is considered ‘easily flammable’ (flammability class E_{fl}).

Table 3.1 Synthetic turf combustion properties

Material	Melting point (°C)	Ignition temperature (°C)	Combustion products (toxins)	Usage trends	Other information (risks/ease of damage)
Nylon	Highest melting point 160 – 260[3] 160 – 275[4]	485 – 575[3] 424 – 532[4]	Carbon monoxide and dioxide Smoke (particulates)	Stronger, more expensive[5]	May be more prone to high extractable lead concentrations Attracts water[6]
Polyethylene (PE)	109 – 123[7] 85 – 140[8] 126[9] 107 – 137[4]	349[4] 330 – 410[8]	Carbon monoxide and dioxide Smoke (particulates)	Softness[10] makes it appropriate grass material – looks more natural	UV stable Unable to absorb moisture[10]
Polypropylene (PP)	Higher melting point than PE 165[9] 158 – 168[4]	570[4] >357[11]	Carbon monoxide and dioxide Smoke (particulates)	Prevalent, inexpensive, but less durable Typically a backing (matrix) material	Doesn't maintain colour well Prone to UV breakdown[12]
Rubber	The melting point of crumb rubber is typically not reported.	260 – 316[4]	Carbon monoxide and dioxide Sulfur dioxide Zinc oxides Smoke (particulates)	Small particles provide support to turf blades	The EPA have identified several ingredients in tyres including: benzene, mercury, styrene-butadiene, polycyclic aromatic hydrocarbons, and arsenic, among several other chemicals, heavy metals and carcinogens. Tyre rubber combustion emissions are estimated to be 16 times more mutagenic than residential wood combustion in a fire place.[13]

Table References

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8 ILO & WHO (2017). Polyethylene, http://www.inchem.org/documents/icsc/icsc/eics1488.htm

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11 Rompetrol (2008). MSDS-01: - Polypropylene – Material Safety Data Sheet, https://www.petrobul-bg.com/files/MSDS%20PP%20eng.pdf

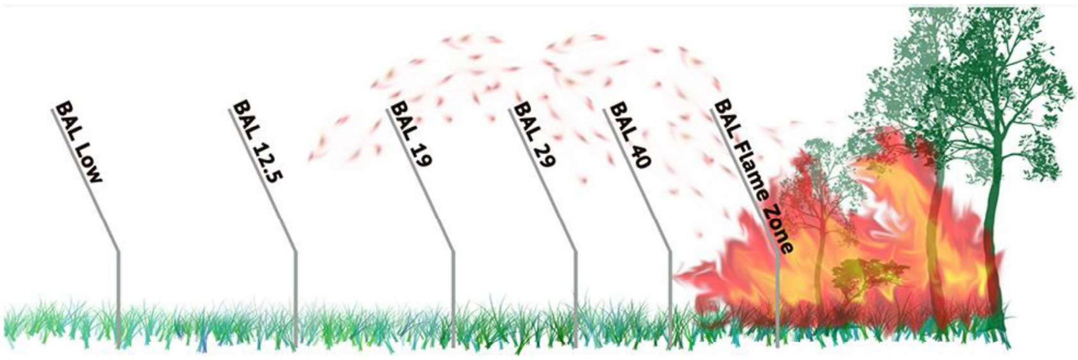
12 Zande, S. (2015). The UV resistance of polypropylene and polyester explained, https://www.servicethread.com/blog/the-uv-resistance-of-polypropylene-and-polyester-explained

13 Reisman, J.I. (1997). *Air emissions from scrap tire combustion*. Published by EPA's Office of Research and Development, EPA – 600/R-97-115

When polypropylene or polyethylene turf is installed in an external landscaping setting around homes in bushfire prone areas, it may be subject to an approaching bushfire. There are three forms of bushfire attack which the artificial turf may be subject to:

- **Ember attack –** low to high volumes of glowing embers blown ahead of the approaching fire by the wind, and continuing to be blown in from nearby areas of burnt, smouldering vegetation after the fire front has passed, potentially for several hours afterwards.
- **Radiant heat –** radiates directly from the flame front of the approaching fire. Assuming the standard design fire for a forest fire as used in AS3959:2018 *Construction of Buildings in Bushfire Prone Areas* (Forest fire on level ground, with a surface fuel load of 25 tonnes per hectare, burning under a Forest Fire Danger Index (FFDI) of 100, with a flame front width of 100 metres) the forest fire flame front will generate a modelled radiant heat flux (RHF) of >3 kW/m^2 at a distance of 110 metres ahead of the fire. At a distance of 50 metres the RHF will have increased to 11.65 kW/m^2, at 20 metres the RHF is over 38 kW/m^2, and at 10 metres away it will be 76 kW/m^2. Note that the radiant heat flux generated in 'reaction to fire testing' of floor coverings has a maximum RHF exposure of around 11 kW/m^2 at the point closest to the radiant heat source.
- **Flame contact –** as the bushfire front approaches the synthetic turf landscaped area, flames from the fire front can directly impact the turf. The modelled flame length for the FFDI 100 design forest fire assumed in AS3959 is 23.7 metres.

The modelled radiant heat flux calculations referred to above are made using the detailed AS3959 Method 2 (normative) for determining the Bushfire Attack Level (BAL).



Source: NSW RFS

Figure 1 Mechanisms of bushfire attack

The Bushfire Attack Level (BAL) values referred to in Figure 1 refer to radiant heat flux (in units of kW/m^2). Embers lofted forward of the fire front (or blown from burning/smouldering areas after passage of the fire front) can land in combustible material and ignite them. Radiant heat decays with increasing distance from the fire, however it can still be sufficient to ignite combustible materials at BALs exceeding 12.5 (and in the case of PE and PP, less than this). The flame front is the third key mechanism of bushfire attack.

Claims that synthetic turf will not sustain fire spread are misleading. It may be true that in a wind-free environment, a synthetic turf product exposed to a point ignition source such as a match or hand-held gas burner may result in melting and localised flaming combustion at the point of ignition, with fire not spreading from the ignition point if the flame source is removed. Such a test cannot be taken to validly simulate conditions in a vigorous bushfire attack scenario. Polyethylene and polypropylene have the potential to sustain fire spread. In the case of polyethylene this has been illustrated in a number of recent catastrophic building fires which involved flammable composite cladding (typically a composite comprised of a polyethylene core, sandwiched between two aluminium sheets). Fires spreading via combustible cladding containing a polyethylene core have quickly spread floor-to-floor or engulfed multi-storey buildings, such as occurred in the 20 storey Grenfell Tower fire in London, UK in 2017, and the Neo200 building in Melbourne in 2019.

3.4 Synthetic turf flammability testing standards

The burning behaviour of synthetic grass is technically difficult to test and evaluate. Presently, there is no common international standard ignition or fire testing for outdoor application of artificial turf.

Some artificial turf manufacturers may have fire or burning testing undertaken, however in the absence of fit-for-purpose outdoor environment burn testing methodologies, typically such testing is undertaken using testing methodologies designed for indoor floor coverings, as may be required for indoor floor coverings such as broadloom carpet, carpet tiles and other internal flooring products. These tests do not heat the test samples to the high temperatures attainable in exposed sunny outdoor settings on hot adverse fire danger days, nor do they apply any wind during the tests, noting that wind is a critical contributing factor which influences bushfire spread and intensity.

For indoor 'reaction to fire' testing for building products, test samples conditioned for testing in accordance with BSEN 13238:2010 are conditioned at a temperature of 23±2^{o}C and a relative humidity of 50±5%. These test conditions may be relevant for many indoor conditions, however they are not relevant for outdoor installed synthetic turf exposed to direct sun and adverse fire danger conditions. Synthetic turf surface temperatures have been measured at more than three times the test conditioning temperature, and relative humidity below 10% (less than one fifth of the test conditioning relative humidity) has been observed in a number of high-consequence bushfire events. Adverse bushfire weather is commonly associated with hot, dry winds. Bushfire spread modelling incorporated in the *Australian Standard for Construction in Bushfire Prone Areas* (AS3959:2018) applies a wind speed of 45 km/hr. The conditions used for fire testing of indoor floor coverings are not representative of realistic outdoor environmental conditions to which synthetic turf products would be exposed during adverse fire weather conditions.

In Australia, Flammability/Flame Resistance testing for indoor floor coverings is undertaken using two test methods:

a) AS/NZS 2111.18:1997 for determination of fire propagation properties – a small ignition source (Methenamine Pill) is applied to the surface of the floor covering and ignited. No wind is present and the tests are carried out in an atmosphere with a temperature between 10 - 30°C, and 20-65% relative humidity.

b) AS/ISO 9239-1:2003 for determination of burning behaviour (Critical Radiant Flux) using a radiant heat source. The test involves a floor covering product being placed horizontally under the influence of a radiant heat source at one end – the test sample is ignited at the heat source end and the radiant heat flux at which combustion ceases is determined. The radiant heat received by the test sample is about 11kW/m^2 at the end closest to the heat panel, reducing down to 1 kW/m^2 at the end furthest away. The amount of smoke generated is also determined. This test may be relevant for indoor testing scenarios simulating the potential of radiating heaters to cause ignition, but for outdoor radiant heat flux in a bushfire scenario the test is not fit-for-purpose. AS 3959 (*Construction in Bushfire Prone Areas)* considers that at radiant heat flux of 12.5 kW/m^2 or less, building materials have a low likelihood of ignition such that the principle ignition source of concern is ember attack. The radiant heat flux levels of concern in bushfire situations are from 12.5 to 40+ kW/m^2. Again, the testing does not involve any exposure to wind.

The testing which is currently used for synthetic turf occurs in environmental conditions which are very much less extreme than those likely to be experienced during exposure to a bushfire during adverse fire weather. While synthetic turf samples may be able to pass flammability testing designed for indoor flooring materials, great care should be taken not to infer that fire-tested synthetic turf products are safe or fire resistant in a realistic bushfire scenario.

3.5 Smoke and combustion products

Polyethylene – PE (C_2H_4) and polypropylene – PP (CH_3) are both hydrocarbons. Combustion products of hydrocarbons are principally carbon monoxide and carbon dioxide and soot (particulates). Material Safety Data Sheets for PE and PP identify that fires involving these materials may produce irritating gases and dense smoke. Carbon monoxide (CO) toxicity occurs from breathing in CO at excessive levels. Carbon monoxide primarily causes adverse effects by combining with haemoglobin to form carboxyhemoglobin (HbCO) preventing the blood from carrying oxygen.

Accordingly, environments contaminated by smoke from PE or PP are considered toxic environments – firefighters will only enter structures containing smoke from burning PE and PP wearing self-contained breathing apparatus, to rescue occupants who are otherwise likely to die from smoke inhalation and/or carbon monoxide toxicity. The vast majority of bushfire fighters typically operate without self-contained breathing apparatus and are not able or allowed to operate in environments contaminated by dense smoke and irritating gases emanating from synthetic materials.

3.6 Fire damage

Due to the low melting point of synthetic grass surfaces, and their susceptibility to spot ignitions from embers, synthetic turf areas are vulnerable to permanent damage from embers during a nearby bushfire, and from other heat sources including cigarette butts and embers from barbeques or fire places/pits.

Figure 2 Example of melted synthetic turf from point ignition source

4. Living turf review

4.1 Overview of the live turf industry

History

The living turf industry in Australia began with planting imported Kikuyu Grass at the Hawkesbury Agricultural College in the 1920s and 1930s. The region's climate and fertile soils created the perfect environment for quick establishment and rapid growth of the grass. The region soon became a production zone of Kikuyu grass and people were able to cut and transplant the runners (Turf Australia n.d.).The primary use for Kikuyu in the 1930s was for establishing livestock pasture. However, due to the ease in transplanting and establishing the grass, it soon became a common feature in gardens.

The initial transplanting method involved long battens being laid on the turf, using an axe to cut along the edge of the batten. A shovel would then be used to cut under the strip of turf, then the turf would be rolled ready for transportation (Turf Australia n.d). The principals of turf cutting have remained the same over the past 80 years. However, improvements have been made as new technologies have been developed. In the 1960s the 'Ryan' Turfcutter was introduced, which was followed by the Brouwer Turfcutter in the 1980s. The 'sod' planter was invented later in the 1990s, and served to advance the turf industry, and increase the overall efficiency of the process.

Turf species

Over the past 90 years biological improvements have also been made in the turf industry. Additional turf grass species have been introduced and cultivated for specific lawn use. These include Buffalo Grass, Couch, Zoysia, Tall Fescue and Tif Turf, a Hybrid Bermuda grass. The addition of these species means living turf is a viable option for a range of Australian regions and climates. A variation of grass species also means a differing management requirements, some grass species require a higher level of maintenance. Species such as Kikuyu and Couch are fast growing and often invade undesirable areas, and therefore require mowing maintenance. Fescue is slow growing, however requires copious amounts of water particularly in summer, and is prone to fungal and pest diseases (Lawn Solutions Australia n.d.). Currently the most popular grass species is Buffalo Grass, as it can handle full sun to 70% shade, is highly drought tolerant, and has low maintenance costs (The Turf Farm n.d.). Specifically the brand Sir Walter Buffalo Grass is recognised as Australia's most popular turf and is supported by most industry experts as the best buffalo grass.

Turf industry

In 2017-18 the value of cultivated turf production in Australia was almost $250 million (ABS 2019). NSW is the state with the highest gross value for cultivated turf in 2017-18 (at $127 mil) followed by Queensland and Victoria with $47 mil and $41 mil respectively (ABS 2019). Turf Australia, the peak body for the turf industry, reported 176 Australian turf growers in 2017/18 (Turf Australia 2018). The Australian turf market in is dominated by the three species of Buffalo, Couch/Hybrid Couch and Kikuyu, which collectively represent around 90 per cent of total turf production volume in Australia, and 87 per cent of the value of the industry (Turf Australia 2018). Turf producers usually deliver the turf to the customer (67% direct delivery) with a small proportion having a contractor in between (14%) or being picked up directly by the customer (18%) (Turf Australia 2018).

Turfing methods

A variety of lawn species are available through specialised turf companies as well as general house and hardware stores. The easy access to a variety of turf species and the quick installation of the 'instant green carpet' gives landowners confidence in installing turf themselves. Industry experts suggest one of the most important steps in turf installation is the preparation of the soil before laying out the roll, and is key to maintaining healthy turf. In particular, having at least 75-100mm of topsoil helps the grass form a deep root system (Centenary Landscaping n.d.). Consequently in dry periods or drought, the turf is effective at finding water and will remain greener for longer (Centenary Landscaping n.d.).

Whilst rolls of lawn are the most common choice, seeding a lawn is another viable option and can save on cost (Centenary Landscaping n.d.). However due to the time and effort required in establishing a healthy lawn by seed, it is usually not the preferred option.

Living turf can be significantly cheaper than other options for outdoor surfaces such as artificial turf, concrete or pavers (Lawn Solutions Australia n.d.).

4.2 Turf types and biological attributes

Different grass species are likely to have different bushfire mitigation properties due to their particular biological attributes. Three grass types have been selected for this project which are common and popular turf species in Australia: Buffalo, Couch and Kikuyu. These species are described in further detail in the following sections and summarised in Table 4.1 below.

4.2.1 Buffalo grass

Buffalo grass is the common name for the popular turf species *Stenotaphrum secundatum* 'Sir Walter' which arrived in Australia in the 1840s. The reported origin of the species is the Indian Ocean region, which lends the plant to growing well in tropical, subtropical and warm temperate climates (OGTR 2018).

Buffalo grass is a perennial species which grows via branching stolons. When mowed or grazed this biology results in a dense thatch structure which excludes weeds. Buffalo grass grows best with partial or full shade. The stoloniferous growth means that although it is liable to spread, it is less invasive than other species that also spread via underground rhizomes (OGTR 2018).

Buffalo grass is distributed throughout the Australian turf industry, but is particularly common in Queensland and New South Wales. The turf is propagated by planting stolon cuttings or runners. Typically, when rolls are harvested a strip of grass is left behind which allows the Buffalo grass to revegetate the area.

The grass growth slows in autumn and in winter Buffalo grass becomes dormant in temperate environments. In tropical environments it will grow all year (OGTR 2018). This means that in summer, Buffalo grass is typically green which reduces bushfire risk and makes it a good choice for a lawn species in bushfire prone areas (CFA 2011).

4.2.2 Kikuyu

Kikuyu (*Pennisetum clandestinum*) is a grass species used for turf in Australia which was originally brought to the country from Kenya as a pasture species (Atlas Turf 2019). Kikuyu is a perennial grass with the key growth period in spring, summer and autumn. It is a drought tolerant species which is highly competitive and forms a dense mat which supresses weeds (DPI).

It can be highly invasive and therefore is likely to spread from wherever it is planted, due to the presence of both branching stolons and underground stems called rhizomes (Pastures Australia

2007). Kikuyu is the main turf species grown in South Australia, but is also grown in most turf regions other than Queensland and the Northern Territory (Turf Australia 2018).

4.2.3 Couch

Couch grass is widespread across Australia, and it is unclear whether it is indigenous to Australia or was an early coloniser. Couch is a perennial grass with stolons and rhizomes that forms into a mat (DJPR 2019). It can produce toxins that inhibit the growth of other species (known as allelopathy) and is not particularly shade tolerant (Western Australian Herbarium 1998).

The growth of Couch slows in cooler seasons (Western Australian Herbarium 1998). It is a resilient species that is able to tolerate changes in moisture including moderate flooding, and some salinity (AWI & CRC Salinity 2006).

Queensland and the Northern Territory are by far the largest Couch producers in Australia. Couch is the most commonly grown turf species in Australia (Turf Australia 2018).

4.2.4 Maintenance

Appropriate maintenance of these turf types includes regular mowing and watering. All of these grass species should be irrigated over summer to maintain moisture content which reduces bushfire risk (CFA 2011).

Mowing should use sharp blades, not cut more than a third of the blade height and leave 4 cm or more to reduce stress to the plant (Turf Australia 2016). Grass turf should be maintained in a state less than 100 mm in length to provide bushfire protection to property (NSW RFS 2019).

Good management such as allowing proper establishment, and watering at particular times of day (e.g. before 10 a.m.) can minimise water use (Turf Australia 2016). Buffalo, Couch and Kikuyu are all warm season species and as such require on average 20 per cent less water than cool season species such as Fescue (Turf Australia 2016). Watering for longer but less frequently encourages plants to develop deeper roots which also increases their resilience to drought (CFA 2011).

The ideal watering regime varies across different parts of Australia. A turf lawn that is well-established or has partial shade is likely to require less water. During summer, lawns in full sun of Couch, Buffalo or Kikuyu would require watering from 1 (East coast) to 3 times (Adelaide/Perth) per week (Turf Australia 2016).

It is worth noting that with a warm climate prone to drought, regions of Australia may be subject to water restrictions which can impact a householder's ability to water outdoor spaces. However, water restrictions are unlikely to impact water use in such a way that green turf cannot be maintained. Restrictions often promote watering of grasses at a time when the water may be more beneficially used by the grass (rather than evaporating) such as before 10 a.m. For example, in Victoria, Stage 3 water restrictions allow watering of residential lawns between 6 a.m. and 8 a.m. on alternate days (DELWP 2019) which is easily enough to allow maintenance of a green lawn. Even if watering is completely prohibited, greywater and rainwater may be collected and used to water lawns and gardens, which are common practice in periods of extreme drought.

In addition, many Australian turf species are able to recover rapidly from periods of complete drought (3-4 weeks) and associated dormancy when they are watered by rain or irrigated (Lawn Solutions n.d.).

Table 4.1 Summary of three main turf Species in Australia

Turf attribute	Buffalo	Couch	Kikuyu
Scientific name	*Stenotaphrum secundatum*	*Cynodon dactylon*	*Pennisetum clandestinum* (syn. *Cenchrus clandestinus*)
Image *(Source: Turf Australia)*			
Production	All regions, mainly NSW and QLD/NT	All states, mainly QLD /NT	Most states (very little in QLD/NT), mainly NSW/ACT
Growth form	Branching stolons	Branching stolons and rhizomes	Branching stolons and rhizomes
Position	High tolerance to shade	Full sun	Full sun (tolerates some shade)
Lifespan	Perennial	Perennial	Perennial
Growth season	Summer and autumn (warm temperate) All year (tropical)	Spring/summer	Spring/summer
Benefits	Drought tolerant Tight cover excludes weeds Less invasive than Couch and Kikuyu Suitable for stabilising sandy soils Can withstand high wear	Drought tolerant Low maintenance Can withstand very high wear	Drought tolerant Supresses weed growth Stabilises soils Fast growing Can withstand high wear
Maintenance	Low maintenance requirements Low water demand	Requires frequent mowing Low water demand	Requires frequent mowing (every 5 to 7 days in peak growth) Low water demand

4.3 Live turf physical properties for fire resistance

Live turf, kept in a short green condition, is highly resistant to ignition by bushfire. This is due to the high moisture content in the live green leaf blades. The leaf blades will not ignite until the moisture contained within the blades has been driven-off by the heat source. Embers typically have insufficient heat energy to do this, and radiant heat exposure sufficient to reduce moisture levels to a combustible state take prolonged exposure to high levels of radiant heat.

The peak growth period of Buffalo, Couch and Kikuyu in summer means that they are likely to be actively growing and therefore more able to retain their green, moisture-rich nature during the highest period of bushfire risk (OTGR 2018).

4.4 Live turf benefits in a bushfire context

The Australian Standard 3959 -2018 *Construction of Buildings in Bushfire-prone areas* considers maintained turf to be a low threat vegetation (low likelihood of supporting bushfire spread). This standard cites grasslands managed in a minimal fuel condition including maintained lawns, golf courses, maintained public reserves, parklands and sporting fields as examples of low threat vegetation (Clause 2.2.3.2). Accordingly, live turf is a key component (and mitigation strategy) for the implementation of asset protection zones, and providing defendable space.

The following specific guidance is provided in relation to garden/landscape design scenarios for a Victorian context.

TURF

The lawn areas are planted with *Stenotaphrum secundatum* 'Sir Walter' (Sir Walter Buffalo Grass), a soft-leaf, hard-wearing turf species. It can be managed to a low height and will be irrigated over summer. This maintenance helps create a defendable space.

LAWN

The lawn species is *Pennisetum clandestinum* (Kikuyu Grass). It is tough, hard wearing and able to be managed at a low height. These lawns will be irrigated over summer to assist in maintaining a green, defendable space.

Figure 3 Excerpts from Landscaping for bushfire protection (CFA 2011)

4.4.1 Asset protection zones

Asset Protection Zones (APZs) are designed provide a low fuel buffer zone between a bushfire and a potentially fire-vulnerable asset. The NSW RFS (2005) identifies that APZs provide an area of reduced bush fire fuel that allows suppression of fire, and also provide an area from which backburning (for property protection) may be conducted. The APZ provides "an area which allows emergency services access and provides a relatively safe area for fire fighters and home owners to defend their property" (source: Standards for Asset Protection Zones; NSW Rural Fire Service; 2005).

APZ dimensions vary depending upon the surrounding type of vegetation, slope, regional fire weather factors, and the design/construction standard of the structure. Any APZ is to be maintained regularly during the locally declared bushfire season, by reducing fuel loads and minimising potential radiant heat levels (New South Wales Rural Fire Service 2019). Planting and maintaining live turf around a structure is encouraged on the basis it will not support surface fire spread to the adjacent dwelling/building, and will not be ignited by embers.

4.4.2 Defendable space

Conceptually a “defendable space” (terminology used in Victoria) is the equivalent of an Asset Protection Zone. The Victorian Country Fire Authority define Defendable Space as:

> *Defendable space is an area of land around a building where vegetation (fuel) is modified and managed to reduce the effects of flame contact and radiant heat associated with a bushfire. It usually comprises an inner zone and outer zone. Defendable space is one of the most effective ways of reducing the impact of bushfire on a building.*

Two key requirements of a defendable space are:

- A 10 metre zone immediately around a building within which CFA recommends to “avoid flammable objects near vulnerable parts of the building”; and
- An “Inner Zone” being “an area immediately around the house. It provides separation from fuel sources, radiant heat, eliminates direct flame contact and reduces ember attack. Vegetation needs significant and intense management. Fuel is managed to a minimum in this zone” (source: “Landscaping for Bushfire”; Country Fire Authority; 2011).

Maintained lawns are one of a number of ‘low fuel’ types the CFA encourages home owners and occupiers to maintain within a Defendable Space – others specifically identified are ponds, pools and tennis courts. Maintained lawn areas around houses provide defendable space for fire and emergency services to operate and defend homes.

Figure 4 below shows an example of how a defendable space operates in practice, in this case for Rural Fire Service crews provided by well-maintained turf lawns from the Tathra bushfires in 2018, with a high intensity bushfire approaching. Such locations, where maintained lawn and non-combustible surfaces (such as roads, driveways, footpaths and paved areas) not compromised by areas of flammable vegetation, are sought by emergency crews as locations from which to defend life and property. Such areas provide relatively safe areas around fire appliances where firefighters can remain safe while they respond to bushfire attack in the form of falling embers and tolerable levels of radiant heat.

Figure 4 Defendable space in use at the Tathra bushfire 2018 (source: news.com.au 2018)

4.4.3 Evidence of fire protection benefit

It is common in post-bushfire impacted areas to observe green lawns remaining largely undamaged by fire surrounding either unburnt houses, or burnt houses where airborne ember attack has directly impacted the house but the surrounding lawn remains unburnt.

Live turf is known operationally to both mitigate fire spread, and to provide defendable space to allow safe defence of properties. Lawns and walkways create firebreaks which interrupt the path of surface fire spread. Well-maintained lawns have low flammability and risk of ignition, and have been shown to remain intact even in the context of extreme bushfires which have occurred in Australia.

The following figures demonstrate the low chance of ignition of managed turf even under severe Australian bushfire conditions and ember attack.

Figure 5 Yarloop damage following Waroona bushfire (source: ABC News 2016)

The Waroona bushfire which burnt through Yarloop in Western Australia in 2016 destroyed 181 houses. Figure 5 above shows the green lawns around destroyed houses which reduced fire spread. Airborne ember attack direct to vulnerable housing, and house-to-house ignition, and ignition of garden trees/shrubs were the leading causes of fire loss and damage.

Figure 6 Tathra (NSW) following bushfires in 2018 (source: Clubs NSW 2019)

In 2018, Tathra (NSW) was subjected to a high intensity bushfire which approached from the west through forest, but as shown in Figure 6 above, has not spread across maintained lawns. Rather, airborne embers landing in pockets of fire-prone vegetation have resulted in the burning of some isolated garden beds, while maintained lawns remain largely intact.

4.5 Live turf as a component of firewise landscape design

Landscaping to reduce the impact of fire is known as 'firewise design'. Firewise design considers an asset at the centre of an area which should be situated so that it is increasingly protected from fire as you get closer to the asset. Firewise design is a well-established concept in American literature, where extreme wildfires are experienced in many states. The 'entire home ignition zone' is the zone surrounding a property or assert and can be up to a 60 metre radius (NFPA 2014). This zone is broken into a number of smaller zones. In general, the zones closest to the structure should comprise low to the ground vegetation, and be well irrigated to maximise their moisture content, while minimising fuels.

The Victorian Country Fire Authority's Landscaping for bushfire (CFA 2011) is one of the few resources in Australia which describes good landscaping practices to mitigate bushfire risk to property, including the choice of appropriate plant species based on their flammability.

There are four main principles of landscaping for bushfire, or firewise design, described as follows (CFA 2011):

1. **Create defendable space –** grass should be no more than 10 cm tall. Lawn space is identified as an area of low fuel to provide defendable space.
2. **Remove flammable objects from around the house –** the inner zone of defence around a house should have grass maintained to 5 cm height. Plants and materials that are flammable should be avoided within a 10 metre radius from the building.
3. **Break up the fuel continuity –** breaking up areas of flammable vegetation reduces the likelihood of fire spreading. Mown grass is identified as a barrier that can be used between groups of plants to create a break in fuels.
4. **Carefully select, locate and maintain trees –** maintaining trees reduces the chance of fire spread, the type of tree, location and pruning regime all influence the risk. Trees should be maintained so that they do not overhang roofs or have continuous canopies, but may be used as a windbreak.

The flammability of a plant relates to whether it will ignite, continue to burn, and how much fuel there is to burn through (CFA 2011). The CFA's Plant Selection Key rates grasses as Moderately Firewise (from Not Firewise, At-risk Firewise, Moderately Firewise to Firewise). This means that this type of vegetation may be used in the garden but must be maintained to ensure their less flammable condition is maintained. In the case of grasses this includes regular watering, mowing, and adequate disposal of cutting debris. If turf does turn brown from drought, it is best to cut it short, and dispose of litter immediately (CFA 2011; NFPA 2014).

Live grasses have oven dry weight ranging from 30% to 260% (CFA 2014). Scientific research into grass fires in field conditions (Cheney & Sullivan 2011) has identified that in dead grass fuels, in light winds, at fuel moisture contents above 20% (of oven dry weight), fires will not spread. In well maintained live lawns, and even drought-stressed live lawns, fuel moisture content is typically many times higher than the 20% fuel moisture threshold for fire spread in dead grass – as demonstrated in Figure 5 and Figure 6, areas of live lawn do not support fire spread.

4.6 Opportunities for the turf industry

Currently there are very few Australian resources that recognise the benefits of living turf to mitigate bushfire risk to property, by providing a defendable space, and an area of low flammability which reduces the risk of radiant heat and direct flame contact. These typically do not have much focus on turf, are confined to particular states or territories, and are largely silent on the maintenance strategies to maintain turf in a state that provides bushfire protection benefits.

Typically, fact sheets promoting the live turf industry compare aspects such as cost, maintenance, longevity, surface temperature and environmental impacts. However it is uncommon to find resources with information on the bushfire risk mitigation benefits conferred by turf which is maintained in a short, green condition.

This literature review, along with the accompanying scientific report and fact sheets to this report aim to begin to fill this gap, to provide turf producers with information which can be used for marketing purposes to demonstrate the value of living turf in firewise landscaping, or landscaping for bushfire.

Refer to the following resources for further reading:

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- GHD (2020). *Bushfire protection benefits of couch turf*
- GHD (2020). *Bushfire protection benefits of kikuyu turf*

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