Final Report

Sustainability, Cricket Gear, Clothing and Apparel: Report on Components, Materials, and Innovation Opportunities

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Disclaimer

This open access research has been conducted by the authors in order to raise awareness of sustainability issues relating to cricket gear which may impact on the sport. It should not be used for any other purpose.

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1. Introduction

This report is part of ongoing research initiated by PASIC (Platform for Accelerating Sustainable Innovation in Cricket) conducted by The Centre for Sustainable Design ® at UCA Business School that aims to broaden awareness and understanding of environmental and social sustainability impact associated with cricket equipment, clothing, and apparel, and identify innovation opportunities.

To increase awareness and understanding of cricket gear and apparel, and the materials and components used in production and the potential sustainable innovation opportunities, a mix of desk and primary research was undertaken. The focus of the research was chosen due to cricket being: one of the most intensive sports; played at various levels by 300 million people across the world (including 300,000 in England and Wales); and having complex supply chains with unknown end-of-life destinations.

The report provides an initial review of environmental impacts of 5 items of cricket equipment and apparel. The research focused on the material composition of 5 items of cricket equipment and apparel and has assessed opportunities to minimise the environmental impact of those components and materials. The findings are a result of web-based research and a review of articles, research papers coupled with online interviews with industry-related experts and manufacturers undertaken between June – August 2021, as well as the conclusions from a stakeholder forum organised on the 15th July 2021 which was documented in a report[1]. This report aims to raise awareness of the opportunities for further research into potential areas for sustainable material innovation in cricket equipment and apparel. Cricket clothing is not included in the report due to limited time and budget for this research, but clothing will be investigated by CfSD in future PASIC studies.

Annex A provides a non-exhaustive listing of 44 items of cricket equipment, clothing, and apparel. From the list, the following 5 products were selected as the focus of this report, with a section dedicated to each item. The budget and timescales for the initial research were restricted and the 5 items were chosen as being essential gear to play the game.

- Cricket Bats
- Cricket Balls
- Pads (Batting/Wicket-keeping)
- Gloves
- Helmets

2. Performance Equipment (Cricket Bats/ Cricket Balls)

2.1 Cricket Bats

BSI standards pertaining to protective equipment

There are no existing British standards and/or laws governing the design, production, and testing of cricket bats.

Existing MCC Standards

A cricket bat consists of two parts: a handle and a blade. Adhesives (usually woodwork glue Polyvinyl Alcohol (PVA)) and bindings are allowed and used to join the handle to the blade.

Law 5 and Appendix B of the MCC's *The Laws of Cricket 2017 Code* specifies that the blade of cricket bats should be solely made of a single piece of wood[2]; except for bats for junior players in junior cricket, where

[1] https://cfsd.org.uk/wp-content/uploads/2022/01/Final-Report-Sustainability-Cricket-Gear-Stakeholder-Workshop-18-1-22.pdf
[2] https://www.lords.org/mcc/about-the-laws-of-cricket

no more than 3 glued and laminated pieces of wood are allowed for the blade. The International Cricket Council (ICC) application of this code to the professional game means that – at present - wood is the only material that can be used to form the blade of bats used in the professional game[3]. To facilitate repair of the blade after damage, removal and insertion of wood with minimal adhesives is allowed. Repair may be needed due to cracking and chipping, typically along the edges and toe. For protection of the bat during its use, coating of non-solid materials (e.g. oil) and toe guards (e.g. from rubber, nylon) - to offer moisture control and resist moisture penetration are allowed - with cloth coverings on the blade face being allowed for recreational and junior cricket.

The handle is specified to be made principally of cane, wood or twine, with any other materials restricted to one-tenth or one-fifth of the total volume of the handle, depending on the grade of the cricket bat.

Cricket bats: components and materials

Initial findings related to the components and materials used in the production of cricket bats are highlighted below:

Component(s)	**Materials**
Cleft for the blade	• Willow - Main wood used in production of cricket bats that conform to the current MCC Laws of Cricket. - Harvested from "Cricket Bat Willow" (Salix alba var. caerulea, or "white willow"), most commonly found in England and the region of Kashmir (India). [4],[5] - Takes 12 to 18 years to mature ready for felling.[6] - Over 0.5 million willow clefts are produced in England annually, with 90% exported (mainly to Indian subcontinent) for bat manufacture. Kashmir and Australian willows are considered to be lower quality but are significantly cheaper with over 2 million bats produced from these materials annually. - Typically, the lighter colour sapwood (rather than the denser, drier, darker hardwood) of white willow is used for the blade of high-quality bats. (Transition from heartwood to sapwood took place over 20th Century; heartwood is at the central core of a trunk and

[3] Ibid.
[4] https://www.forestresearch.gov.uk/publications/archive-the-cultivation-of-the-cricket-bat-willow/
[5] http://www.cricketbatwillow.com/trees-required/
[6] http://www.cricketbatwillow.com/blades-grading/

	sapwood the outward periphery of the trunk) [7] Positives - Traditional material with cultural heritage, small-scale family-business, and craftsmanship built around its use. - Home-grown product (from an English perspective), with significant export value. UK is the world's second largest net importer of timber, and yet the world's largest exporter of cricket bat willow. [8] - Good combination of density (light), stiffness (rigidity), coefficient of restitution (energy transfer)[9], tough and resistant to splintering on impact. - Sustainable management practice around its harvest, with tree replenishment schemes run by private companies (i.e. willow suppliers). [6, 10] Some producers have re-generation programmes, re-planting 3 times as many trees that are cut down. [9] Negatives: - 25% of clefts are unusable due to defects (e.g. knots, blemishes, poor weight distribution[11], narrow grain structure).[7] - There is limited supply as willow is only grown and harvested in specific regions, and can be prone to climate challenges e.g. diseases and pests, as well as natural disasters such as floods in Kashmir valley in 2014 led to halving of the global supply of premium-grade willow that year[12] - Willow grows slowly. It takes 12-18 years to mature, and as harvesters

[7] https://www.forestresearch.gov.uk/publications/archive-the-cultivation-of-the-cricket-bat-willow/
[8] https://journals.sagepub.com/doi/pdf/10.1177/17543371211016592
[9] Proportion of energy transferred from bat onto ball, typically measured as a ratio of the velocity of the ball before impact and immediately after impact on a cricket bat.
[10] http://www.cricketbatwillow.com/tree-information/
[11] Weight distribution of a bat is an important criterion that influences handling of the bat. If the wood microstructure is significantly distorted making the top section of a cleft heavier/lighter in comparison to the bottom section, this would affect handling.
[12] https://www.bbc.co.uk/news/blogs-news-from-elsewhere-29205686

	want quick returns on investments, trees are planted and managed to grow quickly (e.g. site, spacing between trees, pruning, etc). This trend is leading to less desirable (technically and visually) narrower grain structures. - It is to be noted that a natural cleft of willow is too soft to be used in *play* and would be indented by a cricket ball, if not for the significant repeated pressing and thereafter hand-knocking with a wooden mallet for several hours. The manufacturing process for willow bats has co-evolved with the willow material to make it more effective as a bat material.
Handle	• Rattan - Mainly consists of Manau Cane (from Indonesia) and Sarawak Cane (from Malaysia). • Cork or Rubber - Spliced, laminated and glued into a cane handle to facilitate shock absorption of energy transfer from bat to ball. The construction of the handle by varying the laminations (e.g. 9 or 12 piece handle with 2 or 3 rubber spring inserts) is an area of current innovation. • Twine (binding) - Binds the handle together, and adds strength and grip to the handle - Mainly derived from cotton, flax, hemp, rayon (viscose), or nylon yarn • Rubber - Grips are made from high quality synthetic or natural rubber and provide greater control over movement of the bat. - Natural rubber is produced from the rubber tree, typically in Malaysia, Thailand and India. - Synthetic rubber is preferred to natural rubber due to its improved

	thermal stability and resistance to chemical degradation[13]. - Synthetic rubber is derived from oil and manufactured from petroleum by-products.

Potential sustainable innovation opportunities

Bamboo Bat

- A prototype bat was produced by researchers at Cambridge University working with a local cricket manufacturer. The prototype uses culms of Moso bamboo, laminated with a standard polyurethane and a soy-based resin (Purbond HB S3309).[14] Adhesives account for up to 5% in weight content, typically 2-3%, and PVA (woodworking glue, also used in handles) is also proposed as a working alternative. The laminated bamboo had undergone preservative treatment either though caramelisation (steam pressure treatment) or bleaching (hydrogen peroxide treatment) to increase product life. The form of preservative treatment alongside the thickness and orientation of the rectangular bamboo strips in the lamination (edgewise or facewise) are expected to influence bat performance (from the material perspective).
- Design rights for this innovation have been registered in UK ((#6170095-98) and Australia (#4163-1975-9160). The fact that bamboo is classified as a grass (rather than a wood), and as the bat is laminated, are two principal reasons this bamboo bat does not meet the current MCC Laws of Cricket (see 2.1).

Properties:

- 30-40% higher density than English cricket bat willow owing to the inherent dense composite structure of the laminated bamboo, with oriented vascular fibre bundles.
- Strong/durable.

Comparable natural frequency of vibration (sound of 'thwack' of the ball on the bat) to willow.

Improvements:

a) Performance

- 22% stiffer than willow bats[15].
- Larger "Sweet Spot" than willow bat, extending closer to the toe of the bat.
- Sweeter sweet spot than willow bat, with higher coefficient of restitution e.g. 18.9% bouncier[16].

b) Manufacturing

- As the laminated bamboo material is pre-compressed during the strip lamination process, it does not require pressing or extended knock-in. Both of the latter processes are vital, but time consuming, in willow bat manufacture to densify and harden the cellular structure at the face of the blade.

[13] https://onlinelibrary.wiley.com/doi/abs/10.1002/14356007.a23_239.pub5
[14] https://journals.sagepub.com/doi/pdf/10.1177/17543371211016592
[15] Ibid.
[16] Ibid.

- As laminated bamboo is a relatively homogenous material (coefficient of variance between samples of <15%), this reduces waste related to defect willow clefts (which can be as much as a quarter) and helps standardise bat performance.

c) Sustainability

- There are over 1000 species of bamboo (of which 20 are identified as priority species for those wishing to start a bamboo plantation) [17]. Moso bamboo (grown predominantly in China, Philippines, Japan) and Guadua bamboo (grown in Colombia, Peru) are structural varieties with large thickness culms, that may be suitable for cricket bats.
- Bamboo is a renewable material, growing up to 1 metre a day or 1 millimetre every 90 seconds. Found in warm temperate to warm tropical climates and commercially grown throughout South Asia/Southeast Asia and East Asia[18].
- Bamboo matures quicker than willow and competing timbers. New plantations can begin harvesting after 5 years, compared to 15 years for willow.
- Bamboo plantations can operate productively for over 50 years[19], without replanting.
- Moso bamboo (used in Cambridge University prototype), like willow, is a renewable material, and as bamboo would be transported to the Indian subcontinent (where bat manufacture typically takes place) from China and Taiwan, rather than willow being transported from England to India, a reduction in embedded carbon relating to the transportation process is expected[20].
- It would be difficult to establish commercial farming of Moso bamboo in the UK. Temperate conditions are ill-suited to growth of bamboo except for ornamental purposes[21].
- Similar bamboo species are classified as invasive/hostile to competing wildlife and would be likely have a detrimental effect on the biodiversity of the UK[22].

Next Steps

- The Cambridge University researchers are presently exploring design strategies to reduce the weight of the prototype bat as it is 40% heavier than existing bats[23].
- Current efforts are also exploring the role of digital fabrication (CNC machining and robotic fabrication) to improve bat quality and homogeneity.
- A change in the MCC Laws of the Game (see 2.1) would be required to facilitate commercial production of the bamboo bat. Laws specifying wood as the only material for cricket bats would need to be reformed to include other natural materials, such as grasses, like bamboo[24], and laws around lamination would need to be changed.
- The properties of other bamboo species and other woods might be researched to determine the suitability for cricket bat production.

2.2 Cricket Balls

BSI standards pertaining to cricket balls

- BS 5993:1994. Specification for cricket balls.

[17] https://www.bambooimport.com/en/facts-about-bamboo
[18] Ibid.
[19] https://www.plantationsinternational.com/bamboo/
[20] https://bambubatu.com/moso-bamboo-the-king-of-grasses/
[21] https://theecologist.org/2007/apr/01/house-bamboo
[22] https://www.researchgate.net/publication/332232677_Growing_Bamboo_for_Commercial_Purposes_in_the_Southeastern_US_FAQs
[23] https://www.cam.ac.uk/stories/bamboo-cricket-bats
[24] Ibid.

- Published Date: 15/01/1995
- Status: Current

- BS 5993:1987. Specification for leather-covered cricket balls.
  - Published Date: 31/03/1987
  - Status: Withdrawn

- BS 5993: 1980 - Specification for leather-covered cricket balls.
  - Published Date: 29/08/1980
  - Status: Withdrawn

The BSI standard mainly specifies the construction and manufacture of the different grades of cricket balls. Notably, while the standards do specify that the cover of the ball needs to be constructed from "two or four pieces of aluminium-tanned leather enclosing a core", the material for the core is not specified. Typically, the core is constructed from cork or rubber (or a moulded core from granulated cork and rubber) [25], as well as twine (e.g. wool). In terms of performance characteristics, the BSI standard specifies the mass and dimensions/shape of the ball – the latter is actively regulated by umpires in the professional game when deciding whether a ball change is necessary during a game – as well as hardness, impact and wear resistance.

Cricket balls: components and materials

Initial findings related to the components and materials used in the production of cricket balls are highlighted below:

Component(s)	**Materials**
Core	• Cork - Harvested from bark of Portuguese cork oak (Quercus suber) trees, typically of higher densities. - Chosen for ability to absorb impacts whilst maintaining its shape. - Cork is lightweight and 'springy' due to its viscoelastic properties, leading to good bounce. Positives: - Trees absorb up to 3 times more CO2 when regrowing their bark after harvesting. [26] Negatives: - Takes 25 to 30 years for trees to mature. Thereafter, the tree bark can be harvested every decade, for up to 150 years. Although the first two extractions almost always produce inferior quality cork.

[25] https://onlinelibrary.wiley.com/doi/full/10.1002/jst.8
[26] https://www.tinyecohomelife.com/is-cork-environmentally-friendly

	- Climate change poses a serious threat to cork oak forest conservation and the future supply of cork. [27] • Rubber and cork-rubber composites [28] - Moulded rubber and granulated cork-rubber composites are also used as alternatives to cork cores. - Rubber is primarily produced in Malaysia, typically synthetic rubber. Positives: - High durability/shape retention, and bounce/springiness - Granulation of cork for moulding with rubber may enable the use of lower-quality/cheaper cork or opportunities for cascading uses of cork. Negatives: - Synthetic rubber is derived from oil and manufactured from petroleum by-products.
Casing	• Leather - Tanned with aluminium salts, binders, and proteins to increase materials durability and resistance (e.g. moisture). - Leather thickness 4mm and 4.5 mm (Duke balls), which is then dried and compressed to a thickness of 3.5mm. - The leather encases and protects the core, and offers a smooth, shiny surface and defined seam to demonstrate bowling craft. Negatives: - High levels of greenhouse gases produced through commercial cattle farming. - Tanning processes release pollutants. • Worsted Yarn - High quality, lightweight type of wool from English and New Zealand breeds. - Multiple (3 to 6) layers quilted between layers of cork, wrapped around a cork

[27] https://ec.europa.eu/eip/agriculture/en/find-connect/projects/adapt-your-cork-oak-forests-resist-forest-fires
[28] https://onlinelibrary.wiley.com/doi/full/10.1002/jst.8

	core inside leather casing, with or without tension. - Ductile, able to be tightly wound around the cork core. • Thread (Seams) - Thread can be made from natural fibres (cotton, wool, silk, linen) or synthetic fibres (rayon, polyester, nylon). - The seam can be either hand stitched or machine stitched. - Hand stitched balls are held in place with 6 lines of stitching, offering greater integrity. Machine stitched balls are held together by the two centre rows, while the outer 4 rows are purely decorative, which awards limited overs/lower-level use. - A test match ball will usually have between 78 – 82 stitches around the centre, whereas training balls and balls used in lower levels of the game will have around 55. - The stitching is essential for 'seam bowling'. • Nitrocellulose lacquer - Organic compound consisting of naturally occurring polymers. - Protects leather against harm from fertiliser chemicals that maybe present on grounds/playing fields. - Improves resistance to abrasion. - Gives (lasting) shine enabling bowler to potentially 'swing the ball'

Potential sustainable innovation opportunities

- Vegan Leathers
  - Various organic, plant-based alternatives to animal leather have been developed. Manufacture of vegan leathers are potentially less polluting than the production of animal-based leathers. However, many vegan leathers include plastics as binders (such as polylactic acid (PLA)) and some incorporate Polyurethane (PU)/ Polyvinyl Chloride (PVC).
  - Leather from cows is three times more harmful to the environment than PU based vegan leathers according to Ananas Anam – the producer of Pinatex vegan leather[29].

[29] https://www.huffingtonpost.co.uk/entry/vegan-leather-explained-truth-sustainable-fashion_uk_5e314b41c5b6e8375f652471

- So far, such vegan leathers are primarily used in fashion products and accessories, ranging from bags to footwear.

Major Alternatives

- Pinatex® - made from waste pineapple leaf fibres[30].
- Desserto® - made from Mexican cactus leaves[31].
- Bananatex® - made from Banana leaves cultivated in the Philippines[32].
- Mycelium leather – mushroom-based alternative with multiple existing producers such as MycoWorks who produce Fine Mycellium™ [33] under controlled conditions to ensure predictable/uniform growth[34].
- BarkTex® - made from the fibrous tree bark e.g. of the Mutuba East African fig tree

Drawbacks associated with vegan leathers

Research into nine leather alternatives, entitled '*Comparison of the Technical Performance of Leather, Artificial Leather and Trendy Alternatives'*[35] found that none of the alternatives matched the universal performance of animal leather in regard to 5 key properties: tensile strength, tear resistance, flex resistance, water vapor permeability and water vapor absorption[36].

The above indicates that further research and development is required into the suitability of vegan leathers for use in performance and recreational cricket equipment e.g. gloves and balls.

Lifecycle assessments (LCAs) determining the environmental impacts of alternate leathers are not readily available (or likely to be representative due to lack of economies of scale). Therefore, an objective comparison of sustainability with traditional leather is not possible at present.

The cost and supply-chain of vegan leathers needs further clarity, both of which impact the feasibility of manufacture.

One can also consider alternatives to virgin cork and rubber as the core materials in cricket balls. For example, the use of low-grade materials (e.g. granulated and moulded cork/rubber composites) may present opportunities to use recycled materials.

2.3 Pads (Batting/Wicket-keeping)

There are a range of protective equipment that is used to play the game. A series of BSI standards have been published related to protective equipment excluding gloves and helmets (see other sections below).

- BS 6183-3:2000. Protective equipment for cricketers. Leg protectors for batsmen, wicketkeepers and fielders, and thigh, arm and chest protectors for batsmen.
  - Published Date: 15/05/2000
  - Status: Current

- BS 6183-1:2000. Protective equipment for cricketers. General requirements.
  - Published Date: 15/02/2000

[30] https://www.ananas-anam.com/about-us/
[31] https://desserto.com.mx/why-desserto%3F
[32] https://www.bananatex.info/
[33] https://www.mycoworks.com/
[34] https://www.forbes.com/sites/brookerobertsislam/2021/04/01/mushroom-leather-is-now-a--scalable-alternative-to-animal-leathers-poised-for-market-disruption/
[35] https://www.mdpi.com/2079-6412/11/2/226
[36] Ibid.

- Status: Current

• BS 6183-2:2000. Protective equipment for cricketers. Genital protectors.
  - Published Date: 15/02/2000
  - Status: Current

• BS 6183-1:1981. Protective equipment for cricketers. Specification for batting gloves, leg guards and boxes.
  - Published Date: 31/12/1981.
  - Status: Withdrawn

The BSI standards principally specify the dimensions and norms for different types of protectors depending on the player's characteristics (e.g. sex, height), the effectiveness of the restraint system (to ensure it is in designed to remain in place during normal play and impacts), as well as impact performance.

Pads (Batting/Wicket Keeping): components and materials

Initial findings related to the components and materials used in the production of pads (batting/wicket keeping) are highlighted below. Further research is needed into the components and materials used in other forms of protective equipment.

Component(s)	**Materials**
Outer	• Polyurethane (PU)/Polyvinyl Chloride (PVC) facing
Padding	• High-Density Foam (HDF) Pad - Foam element of a foam-sandwich used to form the main skeleton of modern pads - Consists of primarily polyurethane foam. - Includes polymer-based fixings, such a Velcro fastening straps. Positives: - Lightweight - Manufacture tightly governed by existing regulations. - The chemistry of polymer foam materials is highly tailorable – this enables the production of a range of foam materials that can meet diverse specifications and criteria for the various protective pad applications. Negatives: - Synthetic material derived from non-renewable natural resources e.g., oil, which contribute to global warming and has limited end-of-life disposal routes. - Volatility in prices of oil-based polymers

	- Production of such polymers comes under REACH regulations – e.g. isocyanates (critical to the manufacture of PUs) are toxic, classified as CMR (Carcinogen, Mutagen and Reprotoxic), and are already regulated by Environment Protection Agencies and Occupational Safety and Health Administration; this may tighten further.[37] • Cane - Traditionally used as the skeleton for cricket pads. In modern equipment, cane has been replaced by HDF and is now largely found in cheaper, lower quality pads.

Potential sustainable innovation opportunities

- Use of vegan leather might be considered for the production of pads (see above)
- Use of polymer foams (e.g. Non-isocyanate Polyurethanes (NIPUs) [38] [39], e.g. Green Polyurethane™) that present reduced health risks to factory workers during the foam production process, and use of bio-based polymer foams (such as PLA-based, or bio-PUs [40]) in place of current facing and foam padding materials is an area for potential innovation.
- There are a number of examples of bio-based rigid and flexible polyurethane (PU) foams, such as Baymer®, Desmodur®, Elastoflex® E by Bayer, SPF, SIP and Boardstock from Huntsman, and WALLTITE and Elastospray from BASF, and Eurowall®+ insulation from Recticel BiOH® and Agrol® soybean oil-based polyols for foams from Cargill, Elmira's ExaPhen Polyols based on Cardanol (cashew nut seed liquid). So far, these have found applications in construction (insulation), automotive (instrument panels, headliners, hoodliners, front panels and interior door panels, as well as seating), furniture and bedding, and footwear (sports shoes)

2.4 Gloves

BSI standards pertaining to gloves

• BS 6183-4:2001. Protective equipment for cricketers. Gloves for batsmen.
- Published Date: 15/03/2001
- Status: Current

[37] Rokicki, G., P.G. Parzuchowski, and M. Mazurek, Non-isocyanate polyurethanes: synthesis, properties, and applications. Polymers for Advanced Technologies, 2015. 26(7): p. 707-761.
[38] Kathalewar, M.S., P.B. Joshi, A.S. Sabnis, et al., Non-isocyanate polyurethanes: from chemistry to applications. Rsc Advances, 2013. 3(13): p. 4110-4129.
[39] O. Figovsky, A. Leykin, L. Shapovalov. Non-isocyanate polyurethanes – Yesterday, today and tomorrow. O. Figovsky, A. Leykin, L. Shapovalov. International Scientific Journal for Alternative Energy and Ecology, 2016. 03-04(191-192); p.95-108.
[40] Bio-Based Polyurethane (PU) Market Analysis By Product (Rigid Foams, Flexible Foams, CASE), By End-Use (Furniture & Interiors, Construction, Automotive, Footwear) And Segment Forecasts To 2020. 2015; Available from: https://www.grandviewresearch.com/industry-analysis/bio-based-polyurethane-industry

Gloves: components and materials

Initial findings related to the components and materials used in the production of gloves are highlighted below:

Component(s)	Materials
Palm	• Leather - "Pittards® Leather" - Specialist performance leather brand named after Charles Pittard, who founded the company in 1826[41]. - Treated with special water repellent to protect fibre structure against perspiration and maintain softness of leather over time[42].
Back	• Polyurethane (PU)
Fingers	• Poron XRD (Performance PU) - Comfortable, flexible, and lightweight. - Synthetic material that absorbs more than 90% of impact from the ball. - Soft material normally, becomes firm/ energy-absorbent upon impact. • High Density Foams (HDF) - Equipped with reinforced fibre inserts. - Dissipates force. - Inserts protect fingers at the end of the fingers.
Lining	• Cotton
Gusset	• Airflow Mesh - Used to increase breathability of gloves/ reduce discomfort. - Estimated to consist of 60% recycled and 40% new materials.

Potential sustainable innovation opportunities

- Use of vegan leather might be considered (see above)
- Use of polymer foams (e.g. non-isocyanate polyurethanes NIPUs) that present reduced health risks to factory workers during the foam production process, and bio-based polymer foams might be further researched (see above)
- Use of recycled materials in gloves

[41] https://pittards.com/pages/our-heritage
[42] https://www.pryzmcricket.co.uk/blogs/news/tagged/what-is-pittards-leather

Upcycling: Gray Nicolls developed Off-Cut Batting Gloves

- Launched in 2019.
- The gloves incorporate upcycled pieces of material to form a multi-coloured glove. To avoid substantial reprocessing (e.g. to remove colour) of off-cuts, and therefore avoid embedding more carbon and additional costs, the use of unsorted (by colour) off-cuts is critical – which leads to this multi-coloured product.
- Retailing at £45: cheaper than many comparable gloves[43]
- The gloves breached ICC *Clothing and Equipment Rules and Regulations* specifying that the colour of gloves should be more than 50% white and colour match the team's uniform[44] [45]. The gloves were banned from being used at a professional level. However, the upcycled gloves are being sold for use in the recreational game.
- This may also encourage end-of-life product return schemes where producers may re-use elements of their own gloves for future products, particularly as branding is likely to be retained.

Next Steps

- ICC perhaps should consider the reform of the present ICC rules to facilitate the greater inclusion of upcycled or recycled materials within performance cricket equipment, clothing and apparel.

2.5 Helmets

BSI standards pertaining to head protectors. The ICC Clothing and Equipment Regulations that was made effective on 1st January 2017, do not make it compulsory to wear a helmet when batting, but when a batsman elects to wear a helmet, it must be compliant with the British Standard BS7928. Sanctions will be applied to batsmen who wear non-compliant helmets after 1st February 2017. [46]

• BS 7928:2013+A1:2019 - TC. Specification for head protectors for cricketers.
  - Published Date: 12/11/2020
  - Status: Current

• BS 7928-2:2009. Head and face protection for cricketers. Face protectors for cricket wicketkeepers.
  - Published Date: 31/12/2009
  - Status: Current

• BS 7928:1998. Specification for head protectors for cricketers.
  - Published Date: 15/11/1998
  - Status: Withdrawn

Helmets: components and materials

Initial findings related to the components and materials used in the production of helmets are highlighted below:

Component(s)	Materials
Outer Shell	Produced using a mix of materials possessing specific properties.

[43] https://www.gray-nicolls.co.uk/products/off-cuts-pro-batting-gloves
[44] https://www.cricket365.com/gear/is-this-the-worst-thing-the-icc-has-ever-done/
[45] https://icc-live.s3.amazonaws.com/cms/media/about_docs/57d2c4c0b2222-19_Clothing%20Regulations_22%20Sep_2016.pdf
[46] https://www.espncricinfo.com/story/icc-announces-new-regulations-for-helmet-safety-1077774

	• ABS Plastic - Lightweight moulded thermoplastic. - Considered less robust when used on its own, more suited to recreational cricket. • Fibreglass - Incorporated into the shell to strengthen helmet's protective qualities. - High quality material, suitable for the professional level. - Aside from glass fibre, carbon and aramid fibres can also be used for the helmet, with carbon providing a significantly better strength to weight ratio, though at significantly higher costs. • Carbon Steel - Excellent protective qualities – suitable for international level cricket. - Heavy, uncomfortable if worn for extended periods of time.
Grill	• Steel/Titanium - Forms the protective grill. - Titanium considered the more lightweight/ comfortable option, although it is a more expensive material
Padding	• High Density Foam (HDF) - Lightweight, shape conforming and offering comfort to player
Strap	• Nylon - Offers strength, durability, and smooth contact with players' skin.
Chin guard	• Initial indications are the use of foam with fabric lining. However, further research is needed.
Neck protector	• Closed Cell Synthetic Rubber - Provides impact cushioning to prevent trauma to wearer • Polyester (fabric sleeve) • Nylon and Polyester Velcro fastening system

Potential sustainable innovation opportunities

No specific opportunities identified due to the safety critical nature of the equipment.

There may be opportunities to use natural fibre (e.g. flax, silk) reinforcements for the moulded composite outer shell of the helmets. There are examples of equestrian and professional cycling/activity helmets made from flax (linen) and silk fibre composites. [47]

As highlighted in previous sections, there may be opportunities to use more bio-based plastics and foams.

3. Conclusions

- **Further research**
  Initial research has indicated that there are few published papers on the sustainability impacts associated with cricket equipment, apparel and clothing. Due to limited budget and time, the research focussed on 5 items of gear used to play cricket, these were selected from the initial list of 44 items identified through initial analysis (see Annex A). The research provides an initial review of components and materials used to produce the 5 items and provides some initial thoughts in terms of sustainability implications. It is recommended that more detailed follow up research is completed into the 5 products and new research is initiated into the products not covered. For example, cricket clothing is a large product category that was not explored due to the time constraints involved in this project.

- **Further investment in R&D needed to explore sustainable alternatives to traditional materials (e.g. willow, leather, etc).**
  - There are conservative attitudes towards innovation within cricket that have contributed to the preservation of traditional materials: such as willow for cricket bats and animal leather for cricket balls. Research has indicated that there has been limited consideration of the environmental implications of the cricket equipment and/or the materials used, in spite of the emerging development of alternative materials in other sectors (e.g., bamboo, vegan leathers, etc).
  - Research has shown that many willow clefts are transported to India for finishing, and then after assembly and finishing, the finished bats are transported to final markets including the UK.
  - There is a need for further research into the overall embedded carbon associated with the production of a final willow bat that is sold and used, for example, in the UK. Due to the improbability of commencing commercial bamboo farming in the UK, it would be useful to complete an Lifecycle Analysis (LCA) of a bamboo cricket bat in order to assess the carbon embedded through transportation, assuming, for example, direct delivery to the market of bamboo cricket bats from China or another major bamboo producer.
  - Moso bamboo was used in the production of the Cambridge University cricket bat prototype and, at present, there has been no further research into other bamboo species that might be more suited to cricket bat production, though Central/South American Guadua bamboo may be a good contender.
  - There is a similar lack of research into the potential for vegan leathers and other sustainable, bio-based materials to be used in performance and/or recreational cricket equipment and apparel.
  - Research by the Heritage Crafts Association highlighted that the domestic production of cricket bats in the UK is under threat and the production of cricket balls is extinct in the UK. Therefore, further research might be completed into how sustainable alternative materials might be used to either revive domestic production in the UK or be used in the production of equipment and apparel in other countries, such as India.

[47] https://casco-shop.eu/en/599/champ-3-flachsfaser-whitegrey
https://www.vitalmtb.com/news/press-release/Urge-Announces-Brand-New-Archi-Enduro-R-R-Full-Face-Helmet,1284
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- **Need to evaluate regulatory and standards that may be acting as a barrier to innovation.**
  - Existing International Cricket Council (ICC guidelines) on the use of logos are perhaps acting as a barrier to innovation in cricket equipment, apparel and clothing. There is a need to more clearly understand how the requirements of rights holders and advertisers influence these kinds of decisions
  - ICC uniform guidelines ruled out the use of Gray-Nicolls Off-Cut Batting glove in the professional game. This shows how the current guidelines acted as barrier to the initiation of sustainable innovation in cricket equipment e.g. gloves, despite the gloves passing performance requirements and still be sold for use in the recreational game.
  - The reform of existing laws specifying e.g., that bats be made solely from wood, is a pre-requisite of any commercial efforts to develop existing prototypes for a bamboo cricket bat. Notably, materials for 'softs' (gloves, pads), helmets, and cricket balls (except for leather casing) are not regulated, and consequently have been subject of development work and innovation over the past decades. For example, the use of rubber and granulated cork-rubber composite cores for cricket balls transitioned from solely cork, and today's rigid polymer inserts, caps and foams transition from cotton infills for gloves and pads.
- **Promote materials development that reduces environmental impact especially the substitution plastics**
  - This report highlights that a lot of key materials used in the manufacture of cricket equipment are oil-derived polymers. For example, materials such as high-density foam (HDF) and synthetic rubber are made from polyurethane (PU) and polyvinyl chlorides (PVC) derived from petroleum by-products.
  - There is a need for further research into the environmental impact of the plastics industry in the production of cricket equipment, apparel, and clothing sector.
  - Further research should be conducted into
    - the technical feasibility and commercial viability of the use of sustainable materials that might substitute plastics used in the production of cricket equipment, apparel, and clothing, including bio-based plastics.
    - how to promote the adoption of international environmental standards amongst manufacturers producing cricket equipment, apparel and clothing and the components and materials used, and how cricket's governing bodies could support companies in improving their environmental and social performance.

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Appendix 1: Cricket equipment, clothing and apparel

Initial non-exhaustive analysis of 44 items used for the playing of cricket equipment, clothing, and apparel

Item
Cricket bat- willow
Cricket bat – plastic
Cricket bat – other
Cricket bat – facings
Cricket bat – toe protector
Cricket bat – grips
Cricket bat – leather
Cricket ball – rubber
Cricket ball – composition
Wicket keeping – face mask
Helmets
Caps
Hats – floppy
Gloves – batting
Gloves – wicket keeping
Gloves – inners
Abdo guard
Jock strap
Pads – batting
Pads – wicket keeping
Pads – shin guards – fielders
Pads – thigh
Pads – inner thigh
Chest – guard
Chest – protector
Guard – arm
Boots
Shoes
Jumpers – long sleeve
Jumpers – short sleeve
Socks – cotton
Socks – synthetic
Socks – blended
Trousers – synthetic
Shirt – long sleeve – cotton
Shirt – long sleeve - synthetic
Shirt – short sleeve – cotton
Shirt – short sleeve – synthetic
Wrist band
Head band
Glasses – sunglasses
Glasses – light enhancing glasses
Cricket bag – soft

Appendix 2: PASIC (Platform for Accelerating Sustainable Innovation Cricket)

The Centre for Sustainable Design ® (CfSD)[48] have partnered with British Association for Sustainable Sports (BASIS)[49] to launch a new initiative to open discussions around sustainability, innovation, cricket equipment, clothing, and apparel. PASIC (Platform for Accelerating Sustainable Innovation in Cricket)[50] is an online platform that aims to stimulate discussions, facilitate connections/networking and complete R&D projects related to sustainable innovation in cricket equipment, clothing and apparel. PASIC is a neutral, research-based platform that focuses specifically on cricket.

CfSD is based at the University of Creative Arts' (UCA)[51], Business School for the Creative Industries (BSCI)[52] and was established in 1995. CfSD focuses on research and knowledge transfer related to sustainable innovation and product circularity and completes research, training, and consultancy projects worldwide. The Centre has organised over a thousand conferences, workshops and webinars for businesses, policymakers and academia and participated in numerous UK and European funded projects. Further details of research, projects and events can be found on the Research and Projects pages of the CfSD website.

BASIS exists to help develop best practice strategies and integrate sustainability into the sports sector primarily focused on venues, facilities, and grounds. Its membership spans a variety of sports including cricket and members including MCC, ECB and county cricket clubs. Through webinars, workshops, and forums, BASIS encourage an open dialogue between leading academics, sustainability professionals and professional sports people, with the aim of inspiring systematic sustainable change within their organisations.

[48] www.cfsd.org.uk
[49] https://basis.org.uk/
[50] www.cfsd.org.uk/projects/cricket
[51] www.uca.ac.uk
[52] www.uca.ac.uk/business-school