Phase 1 Final Report

Reference: NMC2 293-1-A

Title Biodegradable Tree Guards

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Project Summary

To meet our COP26 targets the current government are putting plans in place to treble woodland creation rates by the end of this Parliament, reflecting England's contribution to meeting the UK's overall target of planting 30,000 hectares per year by the end of this Parliament. It is estimated that between 30%-70% of unprotected tree seedlings are destroyed by deer and squirrels in the UK. Forestry Commission Chair, Sir William Worsley estimated they cost the economy £1.8 billion a year. To protect the saplings tree guards are used, the majority of which are plastic. In the last 40 years 200,000,000 guards have been used in the UK the majority left to contaminate the environment (both land and sea) with micro plastics. Furthermore the current products have significant levels of carbon dioxide embedded in them which will contribute to the UK footprint

This project succeeded in developing prototype biodegradable tree guards that can protect saplings from wildlife. The prototype product has 80% less embedded carbon. Our aim in phase 2 is to reduce this to zero. We have also shown that there is a significant desire within the market for these products and there is no intellectual capital impediment for us to manufacture and sell these products in the UK. A 5 year forecast has been developed which shows the product has significant potential to create jobs in the UK, specifically in rural communities, and create significant value at the farm gate.

At the end of phase 1 the project will have moved from TRL4 to TRL5.

The delivery partners assembled for phase 2 include a number of those already working within the programme as well as organisations who are considered to be world class in their area of expertise.

1. Introduction and market need

As of 31 March 2020, around 13% of the UK (3.2 million hectares) was covered by woodland. In England, this was 10%, compared with 15% in Wales, 19% in Scotland and 8% in Northern Ireland[1]. To meet our COP26 targets the current government are putting plans in place to treble woodland creation rates by the end of this Parliament, reflecting England's contribution to meeting the UK's overall target of planting 30,000 hectares per year by the end of this parliament[2]. The other governments have set their own equally challenging targets[3][4][5].

It is estimated that between 30%-70% of unprotected tree seedlings are destroyed by deer and squirrels in the UK. Our own research in phase 1 of the project has shown that, even with protection, we are seeing failure rates of up to 90% in some planting. It should be noted that the cost of seedling, guard, stake and planting was estimated at £5 per tree with a planting density of 1,000-2,000 trees per hectare (£5,000-£10,000 per hectare). However, with the increase in materials costs post COVID-19 this is more like £10 per tree. Therefore losses of materials alone are estimated at between £10,000 to £20,000 per hectare, totalling circa £150-250million.

Recent published work has estimated that grey squirrel damage alone will cost in the order of £1.1 billion over the next 40 years due to lost carbon revenue and replacement of stock[6]. Defra estimated the cost of deer damage in 2003 to be £4.3m[7]. This does not include the carbon value and contribution to the UK's net zero target. It should be noted that the deer population has increased significantly since 2004 spreading to every county in England and timber value has increased >100% in the last year alone and therefore the actual value will be significantly above this. Forestry Commission Chair, Sir William Worsley estimated they cost the economy £1.8 billion a year.[8]

There are currently in excess of 2 million deer in the UK, with the population going up by 30% each summer[9]. Wild deer belong to no one until killed or captured and are part of the public domain to be managed to safeguard and promote the public interest or common good. The right to hunt wild deer generally goes with the ownership of land[10]. Grey squirrels once captured must be destroyed[11], however, very few are captured and the

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1 https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/woodlandnaturalcapitalaccountsuk/ecosystemservicesforenglandscotlandwalesandnorthernireland2020

2 https://www.gov.uk/government/news/tree-planting-rates-to-treble-by-end-of-this-parliament

3 https://forestry.gov.scot/news-releases/scotland-showing-leadership-on-climate-forests

4 https://naturalresources.wales/guidance-and-advice/business-sectors/forestry/woodland-creation/why-we-need-more-trees-the-benefits-of-new-woodland-creation/?lang=en

5 https://www.daera-ni.gov.uk/news/poots-planting-pledge

6 https://rfs.org.uk/wp-content/uploads/2021/03/grey-squirrel-impact-report-overview.pdf

7 https://www.parliament.uk/globalassets/documents/post/postpn325.pdf

8 https://deframedia.blog.gov.uk/2020/03/16/sir-william-worsley-first-interview-and/

9 https://wilderness-society.org/predator-problem-britains-burgeoning-deer-population/

10 https://www.thedeerinitiative.co.uk/uploads/guides/89.pdf

11 https://bpca.org.uk/a-z-of-pest-advice/squirrel-control-how-to-get-rid-of-squirrels-bpca-a-z-of-pests-/188983

population has increased by 28% since 1995 and is now standing at just over 2.5million[12]. With climate change making winters milder in the UK this figure is set to increase significantly.

In order to protect against deer and squirrels an estimated 7 million tree spirals or guards are sold each year[13] with an estimated 200 million used between 1980-2020[14]. This is set to increase significantly to between 60,000,000-90,000,000 as tree planting is ramped up. Until now the majority of these guards have been made of thermoplastic. There is increasing concern from all parties with regard to contamination of the environment caused by tree guards left in the countryside and blown into the sea[15]. Based on the increased planting this could be up to 35,000 tonnes a year.

2. Commercialisation

A competitor landscape, supply chain integration map and 5 year sales forecast have been developed and can be found in appendix 1 (fully redacted).

2.1 Competitor analysis

Our phase 1 project assessed the current products on the market and their costs (Appendix 2). It should be noted that prices very significantly but were accurate at the time of collection. The majority of the sales of tree guards are still made of plastic, which break down in the environment into micro plastics and if they are not removed from the tree can inhibit or stop growth. However, there are a number of so called biodegradable guards that have been launched that are made of bio polymers such as poly lactic acid (PLA) or avocado nut biopolymer. These products are variously claimed to be more sustainable due to being biopolymers or biodegradable. Our research, carried during phase 1 of the project, has shown that, for example, PLA is only biodegradable above 60°C (so called hot composted in an industrial process) and in normal environmental conditions can take up to 100 years to degrade. The growing of avocados is considered to be one of the most unsustainable fruits with extremely high embedded carbon.

Plastic spiral guards are the dominant, low-cost solution, retailing at £0.37 each (packs of 100 from China). UK-made versions of the spiral retail at £0.49. Estimated market share 40% [Sure Green and Ashridge]. The spiral is regarded as poor quality, UV unstable, and breaks down quickly in the environment, leaving fragments of the guard capable of harming wild animals, birds and pets. In areas where strimming is used as a way of stopping saplings being overgrown by vegetation, spirals provide no protection and shatter as described above. Market share of spirals is starting to decline.

Polypropylene guards are the next popular line, with 60cm and 75cm lengths, UK manufactured and retail at £1.46 and £1.71 respectively. Estimated market share 25% and growing as users shift from spirals to the better-quality so called Green plastic guards (green as they use recycled plastic not because they degrade in the environment any faster that virgin plastic). Pine stakes are commonly used to support these guards.

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[12] https://www.gwct.org.uk/research/long-term-monitoring/national-gamebag-census/mammal-bags-comprehensive-overviews/grey-squirrel/

[13] https://tubex.com/news/tubex-report-card-2021-6-5-million-trees-protected-and-150000-tree-shelters-recycled/

[14] https://www.kent.gov.uk/environment-waste-and-planning/nature-and-biodiversity/trees/case-study-biodegradable-tree-guards

[15] https://www.woodlandtrust.org.uk/about-us/what-we-do/research-and-evidence/plastic-tree-guards/

Thin metal wire guards are available in either pre-cut or rolls to cut. A typical mesh guard retails at between £1.36 and £3.40 (depending on the quality and grade of mesh). Pine stakes are used to secure the guards. Estimated market share 20% and growing.

Heavy duty metal mesh is the fourth category of incumbent products. These have specific uses in high value tree planting and are much more expensive. We identified a range of prices at £7.99, for imported products from the Far East, to £19.99. Market share is around 5%.

Currently we find that buyers look towards deals for either green plastic (which they think is environmentally friendly even though they are not clear about what it means) or mesh as alternatives to spirals. Budget is a driving factor and often users turn to spirals if budgets are tight despite poor quality and performance. Many, non professional users have no idea how their guard choice affects the loss rate of the trees they plant.

New market entrants are bio-based materials (PLA) and biodegradable cardboard. These insurgent products are becoming popular under the names of 'TreeBio' and 'Earthboard'. Market share is around 10%. 'TreeBio' typically cost £1.50 and the 'Earthboard' £3.00 (including pine stake). Our phase 1 research has shown that because the polymer is made in the Far East and South America out of sugar cane, when considering embedded carbon these materials emit even more carbon into the atmosphere than polypropylene. A key finding of phase 1 was that using PLA derived tree guards would lead to significant levels of carbon dioxide equivalent, (CO_2e) being emitted (up to 3750 tonnes per annum).

There are a number of other products due to come on the market made from, for example, sheep's wool held within a resin (using a moulded design). All of them claim to be made from natural materials but with no assessment of embedded carbon as yet published.

Based on the current costings of the raw materials and processing requirements the costs of our product will be priced in line with the current products. This will include profitability for all parts of the supply chain especially those before the farm gate where new markets will be created. In addition, the embedded carbon will be close to zero, significantly improving local and national emission reductions. Furthermore, it is anticipated that all the raw materials and manufacturing will be located in the UK. Finally, because of cradle to grave assessment of the process and materials used it is anticipated that there will also be significant benefits in increasing sustainable biomass supply, biodiversity and reduction in waste biomass.

2.2 Route to market

Tree guards are largely bought wholesale by silviculture companies planting significant numbers of trees on behalf of clients such as land owners, government agencies or charities like the Woodland Trust or Natural England. There are also sales to community groups, farmers and the general public in smaller numbers on line or from agricultural suppliers such as Mole Valley.

We have strong relationships with potential buyers and partners: Confor, Scottish Woodland and Natural England are keen to trial products as soon as they are available. The industry body, Confor (1500 business members), has considerable influence and has a plastics working group dedicated to removing plastic guards from the industry and replacing them with biodegradable, better performing products. Amey, who manage a significant area of National Highways Soft Estate, have also confirmed that they wish to remove plastic tree guards from their planting policy.

Once the results from our developments and trials are available, the product will be able to be sold directly to these larger customers by phone or over the internet or supplied directly to agricultural suppliers.

Using our existing relationships, initially selling direct to large silviculture businesses and charities will shorten the supply chain and ensure margins are maintained, certainly within the first few years. It will also allow for larger quantities of product to be shipped together reducing the transport costs and carbon footprint.

3. Phase 1 innovation

A key part of our phase 1 project was the development and characterisation of a biopolymer, which will be biodegradable, with Centre for Sustainable Chemistry at University of Bath. This was successfully achieved with prototype samples currently on test both for degradation (in the laboratory) and on a farm to see if they will guard against sheep (a test species as they have the same habit of damaging seedlings but can be easily controlled and their damage assessed on a farm). The reaction conditions have been extensively improved during the project to significantly reduce the levels of embedded carbon.

The actual formulation, ingredients and synthetic method are considered proprietary and can not be discussed within a report that will be circulated outside of any Non Disclosure Agreement because it would be considered a disclosure and make patenting of any innovation disallowed.

However, the basic formulation contains a multi functional compound which reacts with a derivatised natural oil to form a polymeric ester. Esters are well know to break down easily in the environment and the natural oil starting materials, which also break down in the environment, are non-toxic, food grade and used in a broad range of cosmetics.

The initial literature review and the full report are available in Appendices 3, 4. At the end of phase 1 the Technology Readiness Level had moved from TRL4 to TRL5

3.1 Characterisation of resins

Depending on the resin chosen and the curing process the materials themselves have a range of properties from highly flexible (elastomeric) to rigid films. (Diagram 1). In terms of the application, the current tree guard products on the market have a range of physical properties ranging from flexible to semi rigid depending on the material used and the manufacturing process. The key ability is to wrap around a seedling and provide protection from deer, squirrel etc. This gives us flexibility in the products' properties which will be helpful when developing the manufacturing process.

Diagram 1 - Flexibility dependent on curing Times

Once the resin was optimised, it was coated onto a range of organic filler materials. Given the timescale within the project, Commercial Off The Shelf (COTS)materials were used including hessian and flax linen scrim as specimen filler materials to create the composites (Diagram 2). These materials were then tested to get their physical properties and biodegradability accessed. A proxy test was then carried out as per the literature in water, soil and finally in dilute sodium hydroxide, where rapid degradation was seen in 5 days. It should be noted that there is currently no test for long term biodegradability (for example 3-5 years).

Diagram 2 - Filler materials and cured composites

3.2 Literature and intellectual capital review

Following an extensive scientific literature review, over 3,800 patents were flagged as potentially relevant. These were reduced to 35 relevant and in need of further review with 7 having the potential to interfere with our license to operate (that need Patent Attorney considered opinion). A follow up review with the Patent Attorney cleared these 7 with regard to the formulation and application (to protect trees from mammals). With regard to the chemistry, it has been well used in other applications (such as surface coatings) which has severely affected the breadth of any claims in recent (still active) patents. Appendix 5 confirms that there are no impediments or license to operate issues with regard to patents or other intellectual capital that would stop us commercialising the product

3.3 Life cycle assessment

As already stated the initial innovation aim of the project was to create a biodegradable tree guard to replace the thermoplastic guards which litter the environment and are causing such concern amongst all stakeholders[16]. We had naively assumed that biodegradability would be directly linked to low embedded carbon. Following the carbon and life cycle assessments carried out for the project (Appendix 6), our understanding of the issues regarding embedded carbon, rather than simply biodegradability, were enhanced. Furthermore, the consequences of this understanding for the UK's carbon reduction targets have affected the direction and scope of our phase 2 submission.

Diagram 3 shows the embedded carbon of Poly Propylene (PP) and Poly Lactic Acid (PLA) broken down by origin extracted from the original paper[17].

Diagram 3 - embedded carbon of range of alternative shelter scenarios

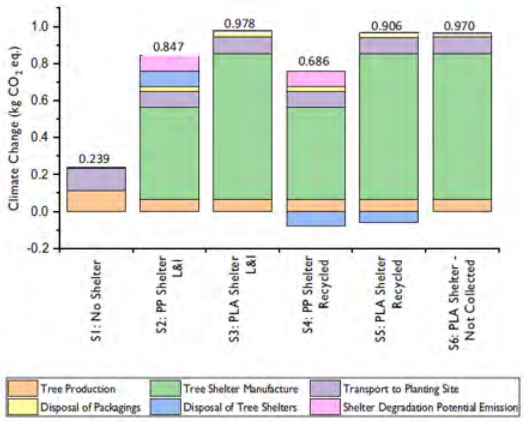


Fig. 2. Climate Change for scenario 1 (base case) and Current Scenarios for shelters-aided tree planting S2 to S6.

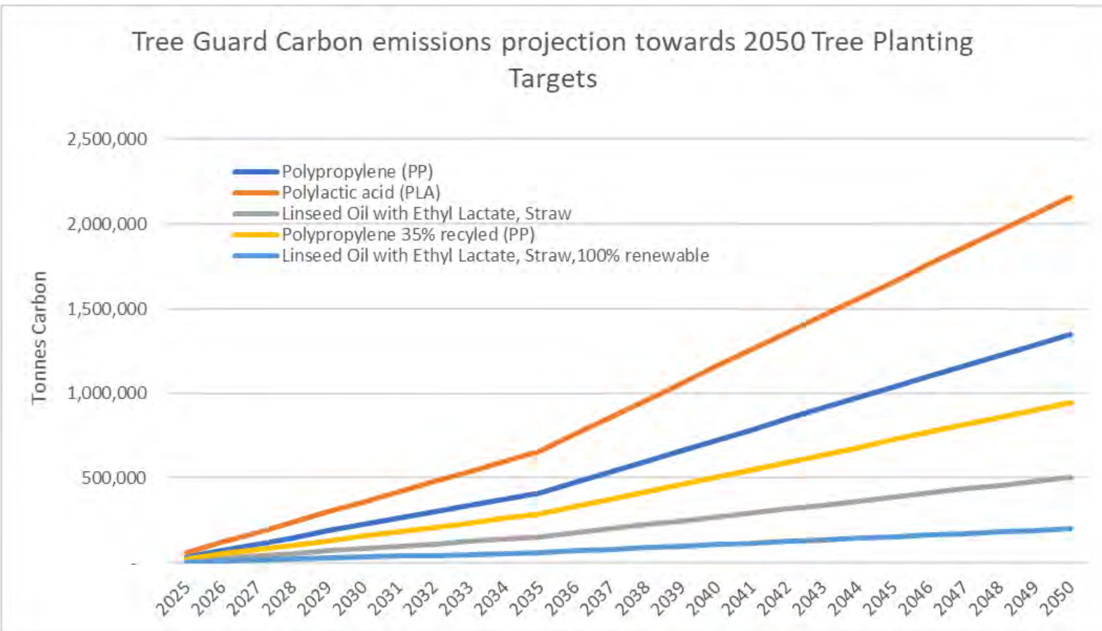
[16] https://phys.org/news/2021-08-plastic-free-alternatives-young-trees.html

[17] https://www.sciencedirect.com/science/article/abs/pii/S0048969721033106

As can be clearly seen, the PP tree guards release around 0.85kg of CO_2 equivalence per guard (if not recycled). The PLA guard releases in the order of 0.97kg of CO_2 equivalence per guard (if not recycled). This does not include the stake and ties that will be used with each guard. However, the carbon released (embedded carbon) for the innovative material developed by the project had a significantly lower foot print. Based on the initial methodology this is <0.2kg of CO_2 equivalence per guard. Further analysis showed that the foot print could be further reduced.

NOTE: Depending on the species it can 5 years or more for a tree to absorb the 0.5kg of carbon released during the manufacture of the PP or PLA tree guards .Diagram 4 shows the embedded carbon of Poly Propylene (PP), Poly Lactic Acid (PLA) and our phase 1 based on the 2050 planting target (assuming no losses).

Diagram 4 - Tree guard emissions projected to 2050



By 2050 if PP or PLA guards were used between 1.4 and 2.3 million tonnes of carbon would be emitted from their production. This compares with 200,000 tonnes with our current prototype process and potentially zero or less with the developments envisaged in phase 2.

3.4 Scalability manufacturing assessment

The vision of the team is to create a UK based manufacturing plant for production of bio-composite based tree guards. The types of facility that will be considered include assessment of a Build, Buy or Partner strategy, including but not limited to:

- A single static production facility developed either in
  1. Current distressed but purposeful building,
  2. A new facility built using sustainable construction techniques ideally at BREEAM rating of Outstanding and incorporating best of breed technology.
- Smaller, modular, mobile units which can be easily built sustainably at suitable locations on a project-by-project basis and moved to other locations as and when appropriate.
- Buy an available new construction assessed to achieve BREEAM rating of Outstanding to meet our sustainability goals.

- Outsourced partnership model with complete production line facilities which would meet our sustainability requirements.

The facility should have access to renewable power and heat, ideally much of it being generated locally in order to minimise the embedded carbon in the product.

The scalability assessment focused on three key elements:

Market scale and manufacturing process and scale of products required (>60,000,000)

Supply of materials

Embedded carbon

3.4.1 Market scale and manufacturing process

Filled resins can be manufactured by either a continuous process with the resin cured as it travels through either a convectional or microwave oven. Alternatively a moulding process can be used with the resin cured in a press such as seen with rubber processing. Given the scale of the requirements, (up do 60,000,000 a year to meet Government targets), we considered a continuous process as being the most appropriate, as seen with fabric, cardboard or glass production. As yet it is unclear as to whether we will need to manufacture the filler and then coat it in resin or whether the process can be completed in one stage, reducing processing.

We have therefore focused on finding partners for phase 2 who have experience and knowledge of continuous composite manufacture. Biotech are considered to be one of the UK's leaders in natural materials including fibres and waste to create bio based products such as biodegradable food packaging and many other bio-based products. Sheffield University - Advanced Manufacturing Research Centre (AMRC) is regarded as one of the most successful industrially focussed research centres in the UK. It has over 100 industrial partners. AMRC will use its design, automation, composite moulding, composite cutting and sustainability skills to develop a continuous net zero manufacturing technology for the project.

The AMRC will also work with Hoare Lea (UK's oldest Engineering Company) to create a Virtual Twin of the process or 3D Building Information Model (BIM) The BIM model is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. It can be shared with partner organisations as part of building a production facility.

3.4.2 Supply of materials

All the ingredients used in the resin manufacture are available on a large scale and are currently being used in food production and chemical processes. However, they are produced outside of the UK and have significant embedded carbon. In extending the scope (in phase 2) to a cradle to grave supply of material from the UK materials, needed to support tree guards will be sourced locally with improved control of the embedded carbon. This would include the stakes and derivatised natural oil.

3.4.3 Embedded carbon

The manufacturing process, including heat or microwave curing is a key source of embedded carbon. The manufacturing process will use renewable energy or waste heat from other processes such as waste to energy production. Furthermore, the use of bio based fillers, ideally from waste sources, will lock up carbon in the product (giving a negative value to the embedded carbon) as will the use of untreated stakes.

3.5 Stakeholder analysis

Over the period of the project we have spoken to multiple stakeholders including but not limited to Natural England, Highways England (Amey), Woodland Trust, Local and County Councils, such as Somerset and Wiltshire, multiple private estates and industry bodies such as Forestry Commission, CONFOR (1500 company members in Forestry Industry), and the Forestry Plastics Working Group. In addition we have spoken to key silviculture businesses who actually control the majority of the planting as well as many of the organisations actually contracted to plant the saplings such as Pryor & Rickett and Tilhill

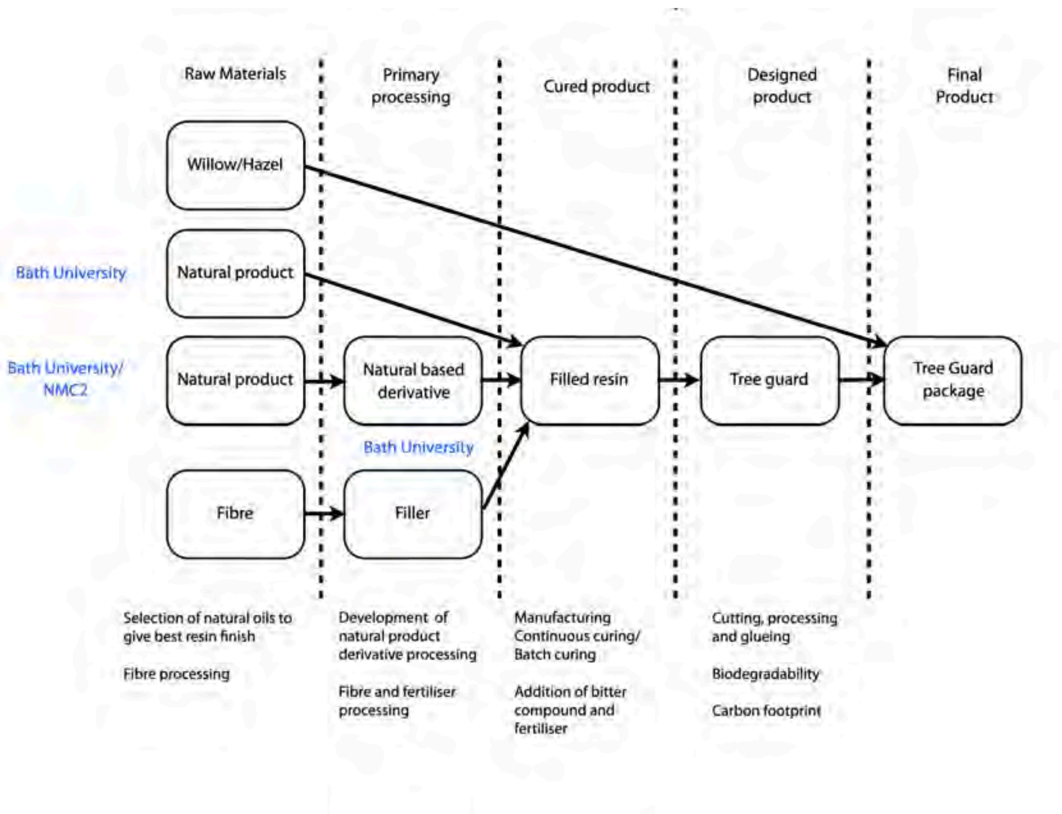
They have all echoed the comments from Lord Blencathra, the Vice Chair of Natural England; "We are desperate to see millions of trees planted but equally horrified to at millions of plastic tubes in the countryside".

Our main issue has been the inability to provide samples immediately. However, they have all given their support and are keen to start trialing as soon as samples are available.

Following the findings regarding embedded carbon, we have been focusing on building relationships with the current and potential supply chain stakeholders within the market to understand how we better support a sustainable biomass industry, improve the environmental benefits of the product still further as well as working with other projects within the programme to deliver a more sustainable UK supply chain. This has included addressing all aspects of the process not just the manufacture of the tree guard.

Diagram 5 shows the process flow for tree guard production including the supply of natural fibre, fertiliser (seaweed) and stakes to be incorporated into the product. This will bring all material production and manufacturing into the UK.

Diagram 5 - Phase 2 Process Flow



3.5.1 Stakes

Currently stakes for tree guards are either made from imported bamboo or machined pine often imported and treated. As the stakes need to last for only 3-5 years, there is no requirement for them to be treated or indeed machined (embedding more carbon).

It should be noted that at little as 7%[18] of native woodland is considered in good condition with more than 50% of all woodland unmanaged[19]. Managed woodland not only supports more biodiversity but also absorbs significantly more carbon. Bringing woodland back into management is a key target of the Government's Forestry Climate Action Plan[20].

Hazel has been used for millennia as a stake through the process of coppicing in woodland. Coppiced woodland and specifically hazel is a key requirement of the endangered hazel or common dormouse and other species that need the nuts to be close to the ground in order that they can reach them.

We have spoken to a number of estates who are keen to bring their woodland back into management and for coppiced hazel to become a woodland crop in the future with the potential of improving biodiversity, embedding carbon and generating income for woodland communities. We have also spoken to other projects including the ECCL2020 (Chestnut Capital) and Surrey University about the potential of breeding and delivering coppiced hazel as a fast growing crop that embeds significant carbon to support the tree guard industry, both of which are keen to work together in phase 2.

We have also spoken to the team at York University about using hemp fibre as a filler (as raised at the dissemination meeting). They have directed us to a number of partner organisations who are keen to work with us in phase 2 such as Rare Earth Global. The majority of hemp fibre is currently used for combustion in biomass facilities delivering low value to suppliers and releasing the embedded carbon back into the atmosphere. Using the fibre in tree guards will embed the material for up to 5 years and then allow it to be absorbed into the forest floor creating further carbon and biodiversity benefits.

NOTE that more than 50% of carbon stored by woodland is in the soil, litter and deadwood rather than the trees[21].

Finally, we are keen to further reduce the carbon associated with our guards by incorporating an organic fertiliser into the guard which is released, supporting tree growth, as the guard breaks down. We have spoken to the team at Seagrown who have confirmed that they wish to work with the project to develop the significant market for the seaweed farming they are being supported by BEIS to trial.

4. Environmental benefits, risks and trade offs

As stated throughout the report, there are significant environmental benefits with the development of carbon neutral and biodegradable tree guards. In extending the scope of the project to include the supply of the stakes these benefits are further increased. These benefits include:

- Increased forestation by reducing failure rate of seedlings, increasing UK biomass cultivation.

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[18] https://www.woodlandtrust.org.uk/state-of-uk-woods-and-trees

[19] https://www.forestresearch.gov.uk/tools-and-resources/statistics/statistics-by-topic/woodland-statistics/

[20] https://rfs.org.uk/wp-content/uploads/2021/03/action-plan-for-climate-change-adaptation.pdf

[21] https://www.fao.org/3/ac836e/AC836E03.htm

Reduction of plastics and micro plastics into the environment and sea by up to 30,000 tonnes a year.

Reduction of 3,750,000 tonnes of carbon dioxide released into the atmosphere per annum.

Capturing of >1,000 tonnes a year of carbon in hazel stakes.

Improve soil health through enrichment as guard breaks down but also as more planting is successful.

Bringing back significant areas of woodland into management with the benefits to biodiversity and carbon absorption that entails.

UK seen as leading circular economy and carbon neutral products (that can be potentially used in other global markets and applications).

NOTE: An estimated 1.9 billion trees are planted each year according to the United Nations.[22]

With regard to environmental risks and trade offs, because we are using waste materials as the filler we do not anticipate problems with supplies being diverted from other markets. Indeed we feel that the ability to move to UK sourced product should be considered as a benefit. Furthermore, because of the world shortage in soft timber and subsequent increase by >100% in prices, releasing timber for markets such as construction, where the carbon is locked up for >25 years can only considered to be a benefit.

In addition, moving waste biomass from combustion into a value added application will allow products such as short rotation hazel more market space to develop.

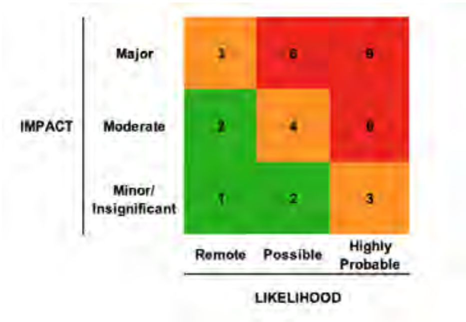
Finally, moving away from plastics may affect current suppliers but we are already in conversation with Confor's (Federation of Forest Industries), Forest Plastics Working Group members to ensure the industry stakeholders are informed and, as key stakeholders, can support the change from plastic to zero carbon biodegradable replacements.

[22] https://www.gotreequotes.com/how-many-trees-are-planted-each-year-month-day-minute-second/#Tree_Planting_by_Country

5. Risks and risk mitigation table

NC will be responsible for risk management and reporting. Each WP-lead will manage risks related to their deliverables. At the start of the project, each risk will be given a review schedule where it will assessed against impact and likelihood. For risks classed as amber or high a mitigation strategy will be put in place. Risks will be a standing agenda item in monthly meetings. We will use Agile approaches to de-escalate nay high impact risks. Our risk mitigation will be actively monitored and reviewed, and a live version will be circulated to sub-contractors. Risk is defined as shown in diagram 8. The redacted risk register is shown in appendix 7.

Diagram 8 - Risk assessment matrix



6. Project collaborators and sub contractors (Phase 2)

NMC2 delivery team

Dr Neil Carpenter. Project Lead. WP1/6/9/10

Neil is Director and Founder of NMC2. Neil leads the strategic development of NMC2 and manages the delivery of environmental projects for customers as diverse as Highways England, The Beauty Council and Church of England. Neil is a member of Confor and attended the BEISr workshops organised by Ricardo. Neil previously worked as a COO for the METT Group, Neil started his career working with ICI becoming global head of innovation for Uniqema working across multiple market sectors globally.

Nick Kenyon WP10

Over 25 years experience in marketing and design, with responsibility for marketing strategy development, value proposition creation, branding and design support. Nick has extensive experience in the environmental sector previously being one of the lead suppliers for WRAP where he promoted the use of sustainable practises across all sectors.

Marion Liquorice WP10.4 /5

Marion has been a company and charity secretary for over 15 years responsible for finance as well as, GDPR, cyber security, document control, environmental and other policies.

The University of Bath delivery team

The University of Bath is established as a top UK university with a reputation for research and teaching excellence, The Centre for Sustainable and Circular Technologies applies biochemistry and green engineering to develop solutions for sustainable materials, recycling and waste reduction.

Prof Matthew G. Davidson (MD), WPs 2/3/4/6

Director of CSCT, the Research Centre for Sustainable and Circular Technologies at University of Bath and iCAST, the newly formed Innovation Centre for Applied Sustainable Technologies. Matthew Davidson is Whorrod Professor of Sustainable Chemical Technologies.

Dr Antoine Buchard WP 2/3/6

Royal Society Research Fellow at the University of Bath. Antoine has been a research fellow for 8 years. His research focuses on the synthesis of novel polymers from renewable resources, in particular sugars and bio-based materials.

Dr. Ullrich Hintermair WP4

RS URF and Reader in Chemistry. Developed process for the manufacture of triglyceride epoxides from natural product oils using supercritical carbon dioxide. Founder and Scientific Director of Dynamic Reaction Monitoring Facility, University of Bath. Winner of multiple chemistry prizes.

Subcontractors

P8 TECHNOLOGY (P8), Kate Lowes. WPs1, 10

P8 Technology has over 35 year experience in product innovation in the biomaterials space, agriculture and food. Director and Founder Kate Lowes has successfully supported the rigorous research and development, and then accelerated the scale-up of more than 500 products from concept stage through to commercial release.

ClearLead Consulting WP10.3

ClearLead Consulting is an international energy and sustainability consultancy. They specialise in helping clients reduce their energy costs, operate more sustainably and comply with complex environmental regulation, both in the UK and internationally.

BIOTECH Ltd WP 5 Steve Price

Biotech are considered to be UK leaders in natural materials including fibres and waste to create bio based products such as biodegradable food packaging and many other bio based products. The have supplied multiple super market chains as well as winning a Tesco Innovation Award.

Melior Engineering WP7 Dr Gareth Lucken

Melior Engineering and Advanced Growers Ltd delivering renewable packaging from green waste and soilless cultivation products. Their team have over 25 years experience in engineering and manufacturing plant design globally.

Hoare Lea WP7.4/7.8 Mike Jones

Hoare Lea are the world's oldest engineering company. Their world leading sustainability team works extensively from the earliest stages of a project to embed sustainable design and carbon neutrality. Mike is an assessor for Global Sustainability Assessment System (GSAS) and leads a specialist team working on digital twinning of facilities or Building Information Modelling (BIM)

AMRC WP7 Dr Anthony Stevenson

The University of Sheffield’s Advanced Manufacturing Research Centre (AMRC) is regarded as one of the most successful industrially focussed research centres in the UK. AMRC will use its design, automation, composite moulding, cutting and sustainability skills to develop continuous net zero manufacturing technology.

Chestnut Ltd WP8 Ian Brown

Chestnut Ltd. are specialists within forestry, biomass and sustainability for arboriculture and agroforestry. This includes the growth and management of hazel and willow and working with farming groups to develop successful business models for agroforestry production.

University of Surrey Professor Richard Murphy, Dr Zoe Harris

The Centre of Environment and Sustainability (CES) is an internationally-acclaimed centre of excellence on sustainable development. Their research includes development of rapid sapling production using soilless systems.

Whitfield Estate WP9 George Renny

Over 30 years experience in forestry and silviculture in the UK and internationally planting and managing forests and estates including planting over 500,000 trees per year, maintenance and care of saplings through first 5 years of growth and management and control of habitat including wildlife pests, invasive species and disease control.

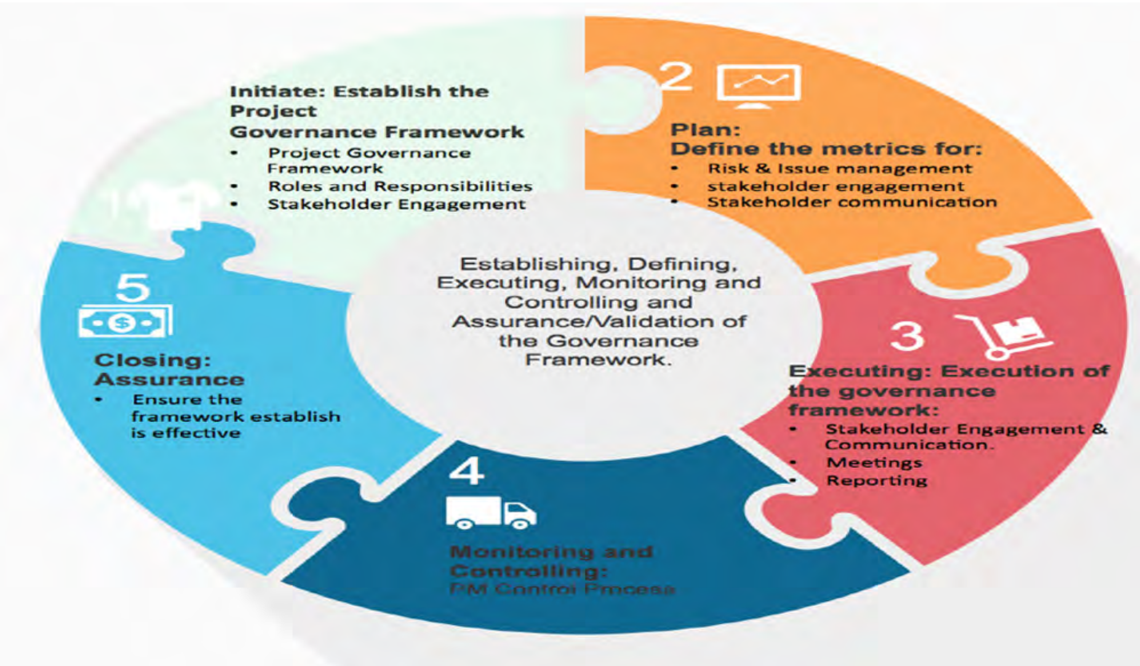
Bawden & Associates Ltd WP10.4 Stephen Geary

Intellectual Property as well as license to operate support.

7. Project controls and governance

Project controls and governance follow the cyclical project governance framework and eight underlying governance components as set out by Project Management Institute in diagram 8.

Diagram 8 - Cyclical Project Governance Framework



8. Quality assurance, financial control and document management

In both phase 1 and 2 of the project.

Financial control will be monitored through NMC2 using web based FreeAgent accounting software.

All computers and electronic records are encrypted and protected with up to date security software in line with Cyber Essentials Accreditation.

All Computers will be backed up weekly to ensure information is not lost.

Paper and electronic documents will be safely stored for 7 years.

9. Reporting plans

Phase 2 of the project will start off with a 2 day kick off meeting for all organisations working on the project. The event will be aimed at building positive relationships, understanding skills, agreeing delivery plan and working through the risk register to get everyone's buy-in and commitment.

Project Director and Manager will also share and get buy-in on how they plan to run the project, reporting requirements and expectations with regard to addressing any issues and problems early to manage risks. Agile and Prince project management techniques will be used.

There will then be monthly progress meetings by video (including Programme Monitoring Officer) as well as quarterly reviews in person.

Either the Project Director (Dr Neil Carpenter) or Manager (Kate Lowes) is also expected to visit the organisations involved every 6 months to confirm progress.

10. Phase 2 project plan

The Phase 2 project plan entitled NMC2-293-2-A is attached as Appendix 8. It is split into 10 work packages, 1 project management, 1 commercial and the rest technical. By splitting the technical development in phase 2 across 8 work packages we can address key elements concurrently, reducing the time taken and lowering the risks associated with the project. All work packages will have life cycle assessment and sustainability running parallel to the technical developments as well as continued assessments of the intellectual capital to see if any of the work infringes others' work or is patentable itself.

At the end of phase 2 the project will have moved from TRL5 to TRL7.

10.1 Dependencies

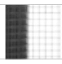
This project has many cross-linking dependencies. Including key dependencies between WP2, and WP3,WP4 and WP7. These are also all linked to WP6.3 (assess biodegradability) and WP's 10.3 (Carbon leadership and assessments) and 10.4 (IP and Freedom to operate). Finally products generated in WP, 2, 3, 7 and 8 will be tested in trials in multiple locations across the UK (WP9).

10.1 Critical path

The project plan clearly shows the critical path which ends with the ability to trial the products in the field (WP9.4). In order to achieve this we will need to manufacture guards at volume (WP 7.6, M10). The ability to manufacture is dependent on an agreed production process for both agreed filler (WP 5.4, M9) and 2nd generation binder (WP3.5).

Appendix 1 - Commercialisation - Fully Redacted

Tree guard competitor analysis

Product	Supplier	Description	Image	Cost	Notes	
Rainbow Treebio Biodegradable Spiral Guard	Greentech	Rainbow Treebio Biodegradable Spiral Guards are a new product in response to the growing desire to reduce the use of standard plastics, we are delighted to introduce our new TreeBio range – an environmentally friendly, weed and erosion control range of planting essentials.		£0.57-£1.26	Made of PLA	Weight 50g
gt GreenGuard Biodegradable Tree Shelter Guard	Greentech	The gtGreenGuard Biodegradable Tree Shelter is an eco-friendly tree guard for protecting newly planted trees. Manufactured from water-resistant kraft paper from sustainable forests, it can be composted after use. The guard will protect against small browsing animals such as rabbits and will provide weather protection from the elements. Our new gtGreenGuards Biodegradable Tree Shelters are perforated to assist ventilation and allow the newly planted tree to acclimatise. The gtGreenGuards Biodegradable Tree Shelter are a great alternative to traditional plastic tree shelters, their lifespan is dependent on planting conditions and their location, however they are simply replaced and can be disposed of by composting or through typical recycling facilities.		No price given	Available early 2022	Weight 100g with thicker version weighing 200g
Tubex Ecostart Tree Shelter Guard	Greentech	Tubex Ecostart tree shelters are an economical solution for protecting slender plants used in small scale landscaping and hedging. Tubex Ecostart tree shelters enhance the plant growth by improving the micro-climate around the plant. Tubex Ecostart tree shelters contain lower levels of UV stabiliser, compared to the Tubex Standard tree shelters, and will naturally begin to break down over a shorter period. Tubex Ecostart tree shelters are often used in hedging, tree planting and small scale landscaping projects, ideal for whip planting in the 20cm- 40cm range. The Ecostart Tree Shelter Guard will protect the plant, whip, hedge and tree from rabbits, voles and hares. The 60cm Tubex Ecostart tree shelter will protect the plant from rabbits and voles, and the 75cm tree shelter will protect the plant from hares.		£0.96	Not eco at all, made of plastic	Weight 500g
BIO-EARTH BIODEGRADABLE PLASTIC-FREE TREE SHELTER GUARD		The Bio-Earth Biodegradable Plastic Free Tree Shelter Guard has been developed by Green-tech over the last 2 years in light of the growing demand in the landscaping and forestry industry to reduce the use of plastic tree shelter tubes as protection during tree planting. The Bio-Earth Biodegradable Plastic Free Tree Shelter Guard and sapling protectors are made from a water-resistant board, which has been coated to give it additional protection to offer a longer lasting biodegradable tree tube guard and all made from natural biodegradable safe materials. They are designed to last, outside, for at least 3 years* - and then will eventually disintegrate safely into the ground. They are suitable for composting or recycling. The Bio-Earth Biodegradable Plastic Free Tree Shelter Guard is supplied flat pack. A 60cm tube guard will arrive 100mm x 1000mm x 600mm and will form a 100mm square section by 600mm high biodegradable tree shelter. Earthboard Biodegradable Plastic Free Tree Shelter Guard and Sapling protectors are an environmentally-friendly alternative to the traditional plastic products used to protect young trees and hedges. They are made from a special water-proof cardboard which is 100% Biodegradable,100% recyclable, and 100% compostable.		£1.65	4 week lead time as made to order	Weight 500g
Wire fencing	wirefence.co.uk	High-quality rolls of European made galvanised steel mesh. 13mm x 13mm holes will protect against medium-sized animals such as rabbits.		£79.99 /6metre roll (18 guards @£4.45 each plus stake	Need to cut each guard off and use a stake	
Weld mesh tree guards	Ultimate -one	Green PVC plastic coated galvanised welded mesh tree guards with a 2" x 2" (50mm x 50mm) square mesh aperture. These 1.2m x 300mm Dia. (48" inch x 12" inch diameter) green pvc plastic coated welded wire mesh tree protection guards protect trees from browsing animal damage in residential, plubic, country estates and gardens. Green tree guards protect saplings from browsing animals including sheep, cattle, livestock, hares and rabbits that can cause lasting damage to newly planted or established trees.		£22.50 each		
Biocycle	**Biocycle**	We are the ONLY manufacturer of a credible 100% Biodegradable Tree Shelter that is fit for purpose, designed to withstand all seasonal weather to protect saplings throughout their vulnerable early growing stages. Our biodegradable resin has been laboratory and field tested by PERA International (a UK Government approved Research Organisation) and Organic Waste Systems in Belgium.			Spoken to supplier and will not be launched for another 12-24 months	
Tree shelters	Biome Bioplastics	The Vigilis Bio tree shelters are the result of six years of extensive research and development, laboratory testing and successful initial field testing. Made from biodegradable biomaterials, the tree shelters have specifically been designed to guard and protect the first 5-7 years of a tree's life. They then slowly fragment into small pieces that completely biodegrade in the span of two years, leaving only CO2, water and a few naturally occurring minerals.			PLA polymer, Working with Aberystwyth university. Biome Bioplastics has secured £248,000 of further funding to support the commercialisation of its biodegradable tree shelters. This additional funding follows the successful completion of an initial feasibility study to develop and test a new generation of biodegradable tree shelters. The additional funding has come from the Government-backed Innovate UK agency as part of the Sustainable Innovation Fund. It will support a significant increase in project activity and facilitate further extensive laboratory testing of materials and UK-wide field trials of the novel biodegradable tree shelters.	
Tree shelters	NexGen	Our trees shelters have been designed to be biodegradable. NexGen Tree Shelters are made from British wool, together with some clever, innovative, bio-based chemistry.			NexGen has been working closely with foresters and landowners throughout 2020-2022 before going into production in readiness for the 2022–2023 planting season.	
	Chestnut Natural Capital	Spoken to Ian Edward-brown (Owner). Product developed over last 12 months with support funding.			Planned to have further discussion but product has not been launched	
	CPI	Spoken to Dan Noakes, Business Manager			They have been working for local company (assume Chestnut) to develop biodegradable tree guard. Follow up conversations underway as they want to support production process for phase II of our project.	

Appendix 3

Biodegradable Tree Guards (BEIS-funded project)

Preliminary review of the academic literature

General reviews:

<u>On the use of renewable resources in the field resins:</u>

[redacted].

<u>Specifically on vegetable-oil based resin and their composites:</u>

4. [redacted]

<u>On bio-hardener for those resins:</u>

8. *Recent Developments on Biobased Curing Agents: A Review of Their Preparation and Use.* Ding, C.; Matharu, A. S. *ACS Sustainable Chemistry & Engineering* **2014,** *2*, 2217-2236.

Peer-reviewed original scientific articles

<u>Miscellaneous:</u>

9. *Anhydride Cured Bio-Based Epoxy Resin: Effect of Moisture on Thermal and Mechanical Properties.* Anusic, A.; Resch-Fauster, K.; Mahendran, A. R.; Wuzella, G. *Macromolecular Materials and Engineering* **2019,** *304*.
10. [redacted]

13. [redacted].
14. [redacted]
15. *Biodegradation Behavior of Some Vegetable Oil-Based Polymers.* Shogren, R. L.; Petrovic, Z.; Liu, Z.; Erhan, S. Z. *Journal of Polymers and the Environment* **2004,** *12*, 173-178.
16. *Chemical and mechanical reprocessed resins and bio-composites based on five epoxidized* [redacted]
17. *Composites with hemp reinforcement and bio-based epoxy matrix.* Di Landro, L.; Janszen, G. *Composites Part B: Engineering* **2014,** *67*, 220-226.
18. [redacted]
19. [redacted]
[redacted].
22. *Eutectic hardener from food-based chemicals to obtain fully bio-based and durable thermosets.* Tellers, J.; Willems, P.; Tjeerdsma, B.; Guigo, N.; Sbirrazzuoli, N. *Green Chemistry* **2020,** *22*, 3104-3110.
23. [redacted]
24. [redacted]
[redacted]
30. *Recyclable, Repairable, and Reshapable (3R) Thermoset Materials with Shape Memory Properties from Bio-Based Epoxidized Vegetable Oils.* Di Mauro, C.; Malburet, S.; Graillot, A.; Mija, A. *ACS Applied Bio Materials* **2020,** *3*, 8094-8104.
31. [redacted]

[redacted]

34. [redacted]

Specific articles mentioning (bio)degradability:

39. *Accelerated weathering behavior of castor oil bio-based thermosets.* Echeverri, D. A.; Pérez, W. A.; Inciarte, H. C.; Rios, L. A. *Journal of Applied Polymer Science* **2020,** *137*, 49509.
40. *Environmentally Degradable Bio-Based Polymeric Blends and Composites.* Chiellini, E.; Cinelli, P.; Chiellini, F.; Imam, S. H. *Macromolecular Bioscience* **2004,** *4*, 218-231.

Appendix 4

Phase 1: UK Sourced Bio-based Tree Guards

University of Bath

Summary

We have met the overall objective of identifying and demonstrating feasible materials for sustainable manufacture of UK-sourced bio-based tree guards with a low carbon footprint and environmental impact.

- We successfully made tree guard prototypes from a composite of natural material and a biobased, degradable resin made from low-cost starting materials.
- The resin and composite materials synthesised demonstrated physical properties suited for tree guards.
- Two formulations were optimised to move toward large-scale manufacturing.
- Non or low toxic bio-based starting materials were used, therefore minimising the danger to wildlife. In addition, a bitter compound was incorporated in the formulation of our tree guards prototypes to reduce the likelihood of ingestion of the tree guard by wildlife.
- Initial degradation studies found that the materials were resistant to short term (>1 month) water and soil degradation. The resin showed degradation under strong basic conditions, which is a good indication of long-term degradation by hydrolysis.
- Formulations avoid emitting nitrous oxide that has a high carbon dioxide equivalent value of 298.

Introduction

On average 50% of trees planted in newly established woodlands across the UK are damaged or destroyed by wildlife, predominantly by deer, rabbits, and hares (Forest-Research). New biomass projects are beginning to plant a larger quotient of tree saplings or secondary species to prevent natural wildlife damaging the young plants, and to prolong the maturation of trees so they are established before they are destroyed. This is an expensive approach. To plant a new broadleaf woodland in the UK averages at £4,800/ha (Forestry-Commission). However, based on inflation seen during last 2 years this has increased to £10,000. Increasing the quotient of planting by 50% to compensate for destruction from natural wildlife creates an additional overhead of £5,000/ha planted. Deer cause the most prolific destruction from bark stripping and browsing (Gill-1992).

In 2020, the UK Government set a target to establish 30,000ha of new woodland in England every year by 2025, increasing UK woodland cover from 13% to 17% (Woodland Trust). Wildlife can destroy up to 50% of new planted tree saplings, meaning the UK would have to plant 42,000ha a year to compensate for deer damage to reach its target, that equates to an additional cost of £150m annually on tree planting. Since the UK Government's 2012 Bioenergy Strategy, biomass has played a prominent role in the efforts to decarbonise the economy. Transitioning to sustainable biomass is crucial to meet the UK's Net Zero target.

The Forestry Commission recommends tree shelters and guards as the primary form of protection for young trees. Tree shelters are used to stop damage to young trees, but majority made from petrochemical based feedstocks and do not degrade. On the assumption that 50% new trees are planted with a tree shelter to reduce damage by wildlife, this creates substantial waste, equivalent to 30,000 tonnes of plastic and metal waste per year based on target planting figures.

Tree shelters are typically made from fossil fuel derived non-biodegradable virgin plastics. They are difficult to recycle and as a result often litter the landscape, including our waterways, leading to an estimated 30,000 tonnes of microplastic pollution a year (Biome) based on future growth plans. There is an urgent need to find a sustainable, bio-based alternative to single-use plastic tree guards.

There are key problems with current tree shelters:

- Single-use plastic shelters creating a waste problem.
- Metal mesh shelters causing damage to wildlife.
- Cardboard shelters use a bioplastic coating and so not easy to biodegrade.
- Biodegradable alternatives not commercially available.
- Research underway into use of organic materials.

Petrochemical based tree guard waste

Petrochemical based tree guards

Research demonstrates that vegetable oil-based resins compare like-for-like to synthetic polymers on mechanical strength and thermal moldability, meaning bio-based tree shelters will perform as well as plastic alternatives. Studies have also proven the sustainable qualities of bio-based resins in comparison to synthetic polymer resins, with environmental assessments evidencing that they use less energy and generate less waste generated in production (Llevot *et al.*, 2016).

This technical research was a collaboration between NMC2 and the University of Bath's Centre for Sustainable and Circular Technologies. We aimed to develop a resin composite, using novel techniques to identify compounds which have the qualities to:

- Biodegrade in the natural environment
- Deliver nutrients to the soil upon degradation
- Avoid omitting nitrous oxides, which contribute to global warming
- Taste bitter, to prevent destructive consumption by wildlife
- Resist short term environmental degradation (rain or soil degradation)
- Not harm wildlife
- Be injected into a mould or continuously manufactured to achieve high scalability and low-cost production.

We identified modified triglycerides as the base compound, such as soya and linseed oil, both of which can be grown in the UK. We aimed to cross-link and cure these with readily available and bio-based hardeners to achieve a high performance and durable resin. More widely grown oil derivatives in the UK such as rape and soya were not available.

There were two processes that stood out in our literature review detailed below:

Redacted

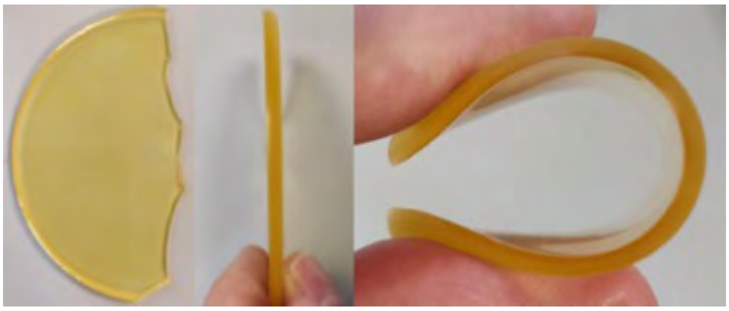
W e aimed to test different fillers to form the structural material and their potential to reinforce the mechanical and/or biodegradable properties of the tree guards. We aimed to look at using UK waste sources, such as waste paper pulp or wool wood chips. In addition, we will identify and test different fertiliser and/or bitter compounds that can be integrated into the resin to, respectively, slowly release during biodegradation and prevent animal-biting.

Results and findings

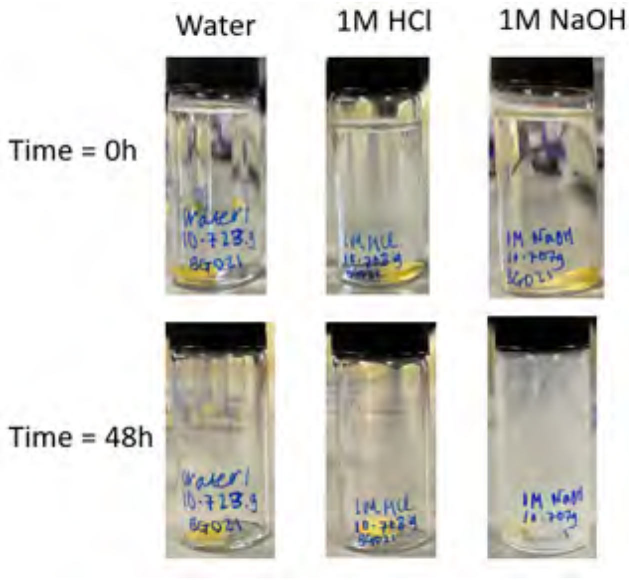
Material formulation, optimisation, and degradation studies

Redacted

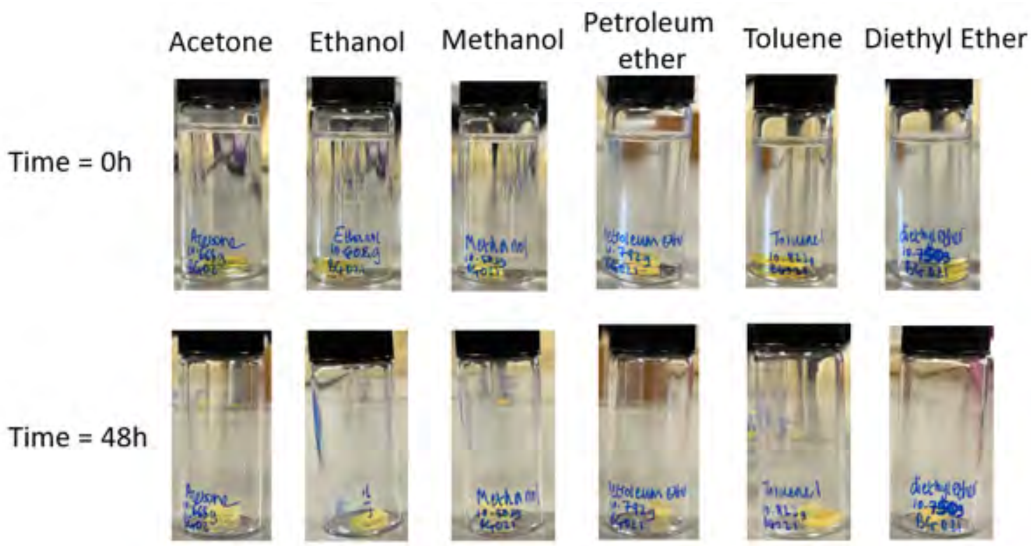
I n i ti a l impressions from the material were positive with a transparent yellow resin obtained, see photos below. The material was flexible and felt tough, a great starting point.



Stability and degradation of the material was important to identify for the material. Therefore, samples were left in neutral, acidic, and basic aqueous media.



The resin showed resistance stability in water and 1M HCl aq. with degradation visible under basic conditions after 48 hours. Such test under basic conditions is often used in the literature as a proxy for long-term hydrolytic degradation in the natural environment.. This will hopefully lead to the eventual degradation of tree guards after protecting young trees. Additionally, the resin was found to be stable in most solvents such as Acetone, Ethanol, Methanol, Petroleum ether, Toluene and Diethyl ether.



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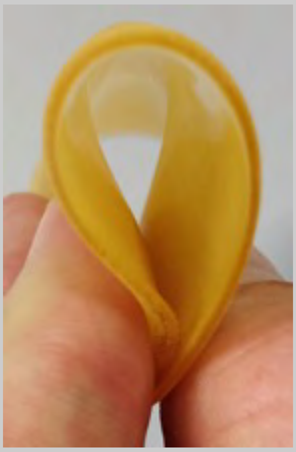
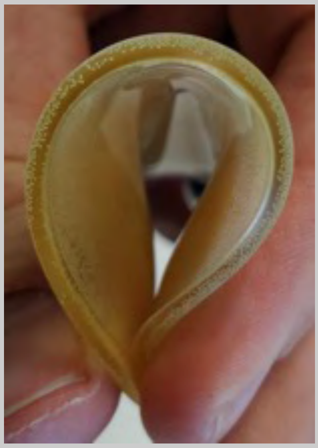
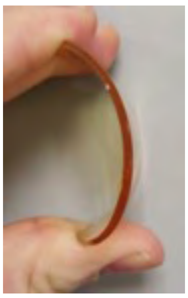
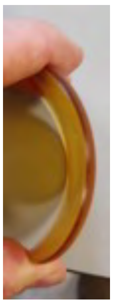
We found that the resins obtained had similar physical properties independent of the ratio of the ingredients. However, resins with a higher ratio R shown a darker colour.

R = 1	R = 0.8	R = 0.5
		

.

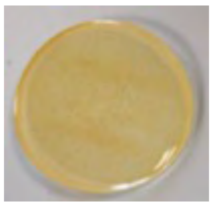
R = 0.5	R = 0.8	R = 1.0
		
		

Small scale reactions were undertaken on a 9 g scale and we successfully scaled up the reaction to a 30 g scale with relative ease.

30g, 18 x 8 cm		80g, 19 cm^2
		

Liquefactor Investigation

A range of compounds were tested, and successful mixtures, that were liquid at 60 °C were used to make resins by curing in the oven. In the following table the current solvent was directly replaced with liquefactor **X**. Compounds were selected, as they have previously reported been, to form eutectic mixtures and easily accessible from bio-based feedstocks.

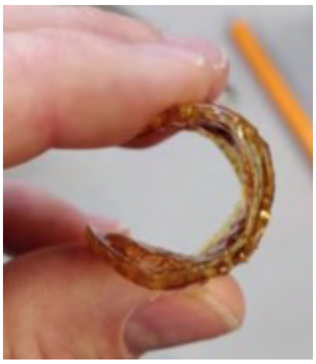
Entry	Liquefactor (X)	Ratio (X:CA)	Liquid when cooled to 60 °C?	Resin
1		1:1	Yes	
2		1:2	Yes	
3		1:1	Yes	
4		1:1	No	-

5		1:1	Yes	
6		1:2	Yes	
7		1:2	Yes	
8		1:2	No	-

Mixtures were heated in a vial to 140 °C for up to 5 minutes before cooling to 60 °C.

Several combinations were tested with most forming an eutectic mixture that could be mixed to form a resin. Several compounds failed to form a eutectic mixture. Resins obtained from curing in the oven varied greatly showing the importance of a good liquefactor in this formulation.

This method was attempted three times with different resins obtained each time. The resins had to be cured overnight to ensure a material that was not sticky to the touch.

Attempt 1	Attempt 2	Attempt 3
		
		

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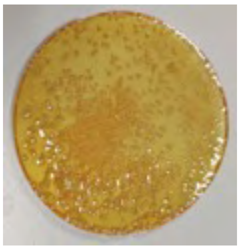
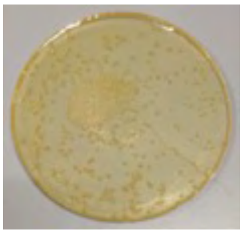
The resins obtained in attempts 2 and 3 show promise with a tough material that would not break on bending. However, further optimisation of the method is required to improve material consistent material outcomes.

Redacted

Entry	Curing method	Resin
1	60 °C 1h then 160 °C 20 mins	
2	90 °C 1h then 120 °C 2h	
3	90 °C 18h	

4	60 °C 18h	

Although the ingredient allowed for effective mixing of starting materials upon curing under different times and temperatures, the resins obtained were unsatisfactory with bubbles trapped in the resin and the resulting discs were brittle on bending.

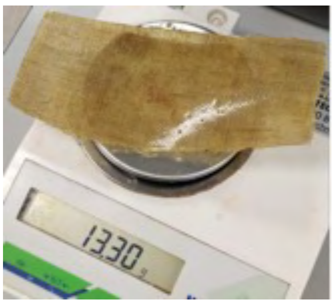
<u>Composites</u>

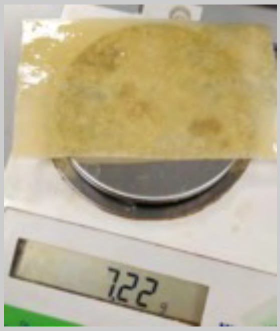
Alongside the investigation for exploring the resin formulation we investigated the formulation of composite materials with natural materials.

Redacted

Composite resins with natural fillers

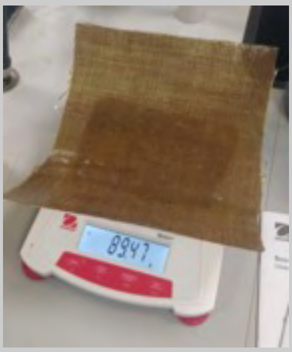
Entry		**Filler**	**Composite**	**Resin loading (% mass)**
1		Linen 1 		80%

2		Cellulose filter paper 		84%
3		Recycled paper 		66%
4		Woven fabric 		84%
5		Linen 1 		79%
6		Linen 2 		84%

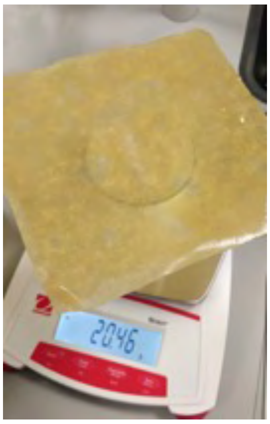
7		Cellulose filter paper 		88%
8		Recycled paper 		73%

Excellent materials were made by painting the filler with precured resin using a silicone pastry brush. As with the resins before the based composites were more flexible than the ELO based materials.

Having ascertained a method for composite production we made prototype tree guards using filler linen 1, cellulose filter paper and printer paper.

Linen prototypes	
	

Paper prototypes		
Filter paper	Printer paper A3	Printer paper A4



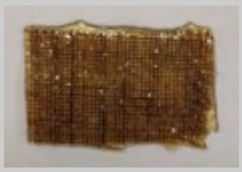
All composites appear viable for potential tree guards however the linen based materials seem to be the best as a hard, strong material that could be bent into a cylinder as a tree guard.

<u>A bitter taste</u>

We investigated the integration of a bitter compound, to the formulation. The synthesis and resulting resin appeared not to change with the addition of bitter material to the formulation. We successfully produced tree guard prototypes using resins with no visible change to physical properties or ease of synthesis.

Preliminary soil degradation study

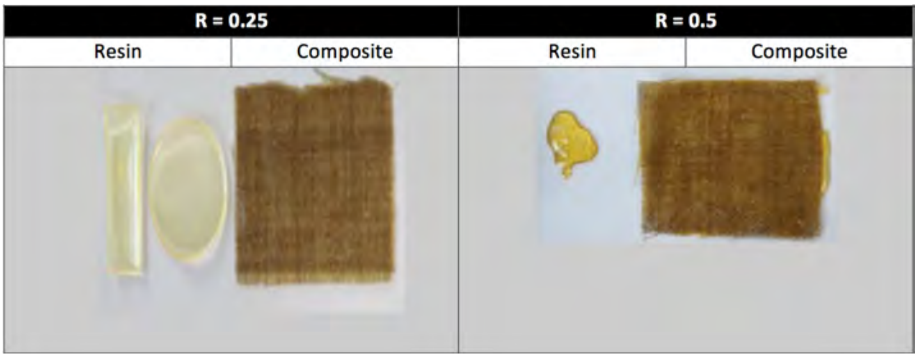
With the resins and composites synthesised previously we investigated materials in the environment. Samples of resin and composite were placed in a container of soil at outside for 33 days and the materials showed no signs of degradation, only slight mass increases from water absorption were observed. See table below, for more details see experimental. Longer degradation and stability studies will be undertaken in Phase 2.

Sample	Weight (before)	Photo (before)	Weight (after)	Photo (after)
ELO + linen	1.65g		1.78g	

Different formulation

Redacted

The resulting resins were similar to those obtained previously with transparent yellow discs that appeared tough and did not easily break on bending, see below.



In conclusion, using water as a liqufactor appears to be a suitable alternative to the use and show excellent promise for the large-scale manufacturing of tree guard prototypes.

<u>Characterisation</u>

Redacted

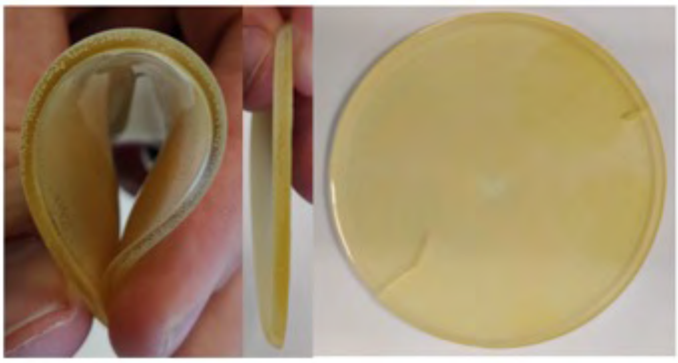
Conclusions

We have investigated numerous variables and methods for the formulation of a bio-based tree guard material. Two formulations are ready to take forward to Phase 2 of the project.
Formulation 2.

Experimental

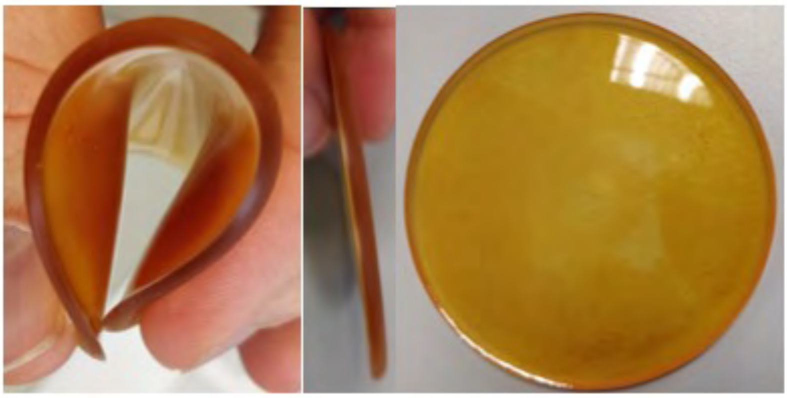
Following General Procedure 1

Experiment 2
Following General Procedure 1,



Experiment 3

Following General Procedure 1,



Experiment 4

Following General Procedure 1,

Experiment 5

Following General Procedure 1,

Experiment 7

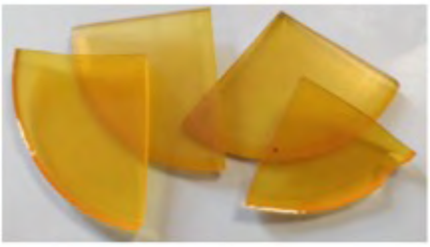
Following General Procedure 1, 30g used to synthesis a resin.

Experiment 8

Following General Procedure 1,

Experiment 9

Following General Procedure 2, used to synthesis a resin.

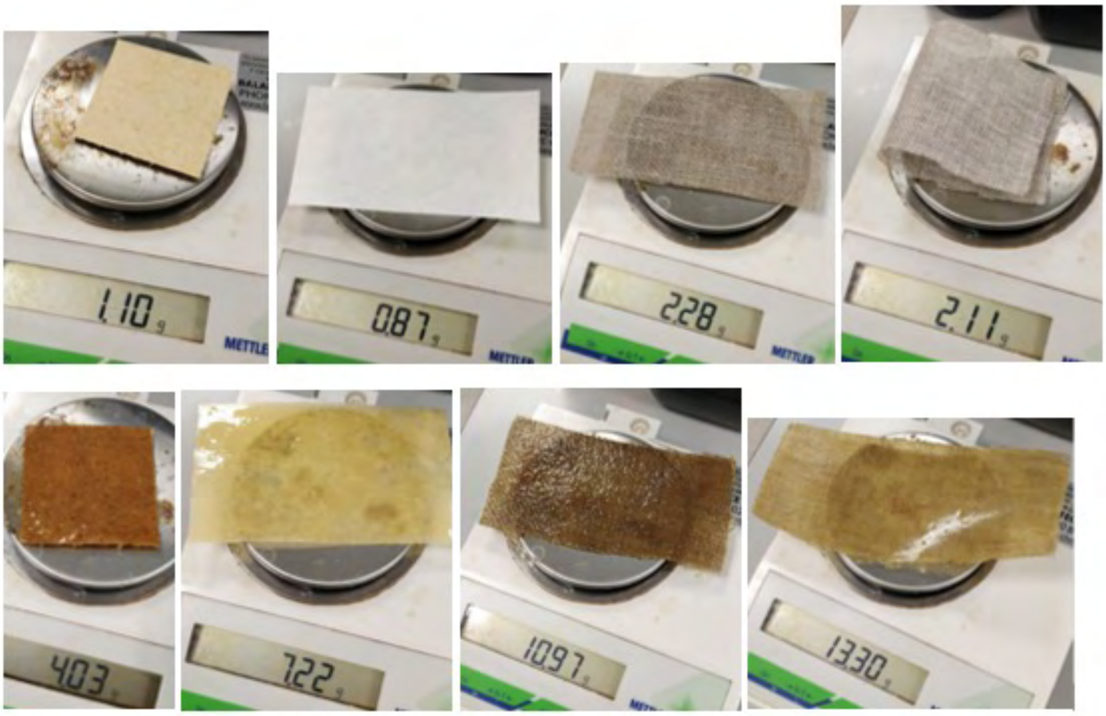
 

Redacted

Experiment 30-33

Following General Procedure 5, 40g used to make composites 30-33.

33 32 30 31



Experiment 34

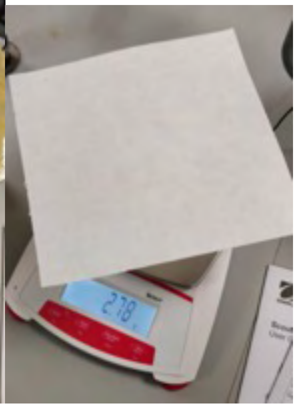
Following General Procedure 5, 80g was used to synthesise a tree guard prototype.

Experiment 35

Following General Procedure 5, 80g was used to synthesise a tree guard prototype. Linen 1 was the filler.

Experiment 36

Following General Procedure 5, 40g used to make a composite. Cellulose filter paper was the filler.

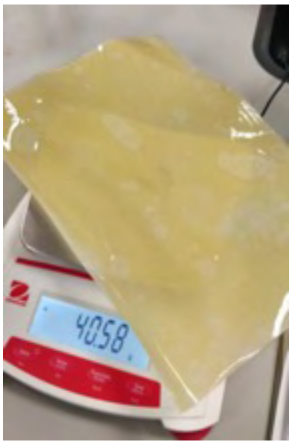


Experiment 37

Following General Procedure 5, was used to synthesise a tree guard prototype. A3 printer paper was the filler.

Experiment 38

Following General Procedure 5, 40g was used to make a composite. A4 printer paper was the filler.



Experiment 39 – Bitter material

Following General Procedure 1, was used to synthesis a resin.

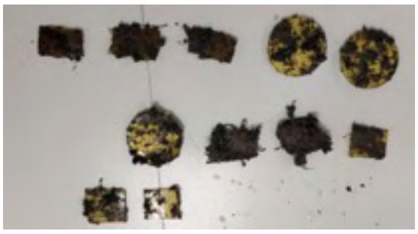
Experiment 40 - Soil

On the 23rd December 2021 samples of, linen and composites were placed in soil dug up from a vegetable patch in my garden. The vessel was a plastic storage box with holes drilled into the top and bottom to allow water and air in and out. To start the experiment, I added water to the soil. See photos below. The vessel was left on my deck for 33 days before being bought to the lab to remove the samples. Each sample was washed with water and dried on the bench before being weighed.

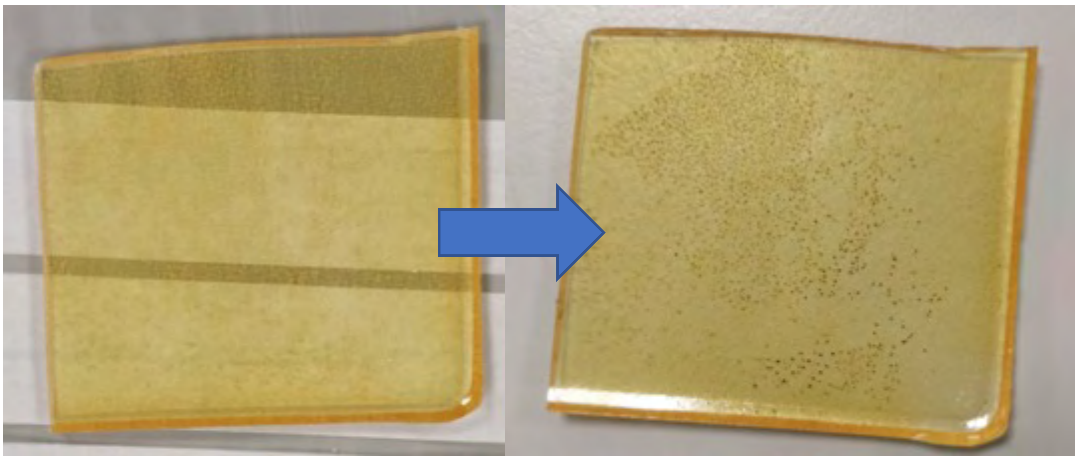
The summary of the experiment is that all samples appeared similar to the original with no/minimal degradation. Samples which had small air pockets on one surface seem to have soil in those spaces that could not be removed by washing with water after the study.



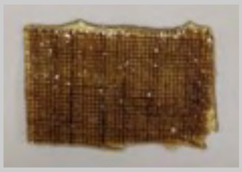
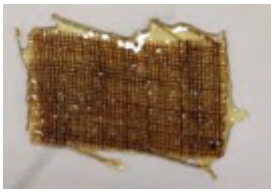


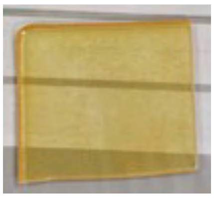
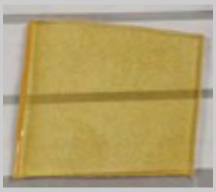


<u>Sample J before and after</u>



Before and after

Sample	Weight (before)	Photo (before)	Weight (after)	Photo (after)	
A	1.65g		1.78g		
B	1.65g		1.76g		
C	1.60g		1.71g		
D	4.32g		4.44g		
E	5.07g		5.21g		
F	8.03g		8.18g		
G	0.42g		0.61g		

H	0.42g		0.43g		
I	2.29g		2.34g		
J	2.62g		2.64g		
K	2.67g		2.70g		
L	3.54g		3.74g		
M	1.97g		2.07g		
N	1.68g		1.77g		

Appendix 5 -Freedom to operate

THIRD PARTY PATENT RIGHTS REPORT:

BIODEGRADABLE TREE GUARDS CONTAINING

[redacted]

1. Summary

- Approximately 20 searches were carried out using different combinations of keywords and international classification codes. These searches identified a very large number of hits and were used to identify hits of relevance and to filter out material of no or little relevance. This process gave a final list for review of about 3800 hits

- Of the 3800 hits, 18 were identified as of “amber” or “red” relevance and were reviewed individually

- The red hits are as follows:
    - [redacted]
    - [redacted]
    - [redacted]
    - [redacted]

- The amber hits are as follows:
    - [redacted]
    - [redacted]
    - [redacted]
    - [redacted]
    - [redacted]
    - [redacted]
    - [redacted]

- [redacted]

- In addition, the following pending applications are considered to be of relevance/ interest. Further searching with modifications to the search terms in the original searches were made and identified these applications:
  - [redacted]

2. Scope of Search and Sources

We have been instructed to carry out a “freedom to operate” (FTO) search for third party patent rights which may be of relevance to the NMC2 project for the development of biodegradable tree supports produced from renewable materials, particularly vegetable oil- [redacted]
The particular class or species of cross-linking agents and overall formulation are not yet settled so the FTO search is necessarily of broad scope to identify patent rights of potential interest/relevance rather than to provide specific clearance for a settled formulation. Further FTO work will be required as the options for the composition are narrowed to defined “windows” of components and quantities.

Scope of Search

Geographical: Patent rights in the UK ie including GB, EP and WO, and US were searched to identify live rights which may cover the technical scope of the project.

Time: As patents have a maximum life of 20 years from filing, rights were searched which were filed up to 20 years before the date of the search ie from September 2001 onwards.

Technical Scope: Based on several discussions with NMC2 and documents provided on the project, a search strategy was devised, as set out below to identify rights using truncated stems and alternative spellings and concepts (using international patent classification terms (IPCs) of the following keywords in various combinations:

- [redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- glyceride, glycerol
- cure/curing agent
- mould, coating substrate
- bands/coatings for trees
- biodegradable

<u>Sources</u>

Searches were carried out using the following databases to identify third party rights which may present an obstacle to NMC2 interests in this project :

i) LexisNexis TotalPatent – a commercial database of published patent rights to which we subscribe. Searching is carried out using a wide range of variables including keywords and international patent classification codes (IPC codes);

ii) European Patent Office (Espacenet) – a publicly available database of published patent rights administered by the European Patent Office searchable by bibliographic data appearing on the front page of patent documents, such as IPC codes, owner, limited keywords;

iii) WIPO PatentScope – a publicly available database of published patent rights searchable by bibliographic data appearing on the front page of patent documents, such as IPC codes, owner, limited keywords.

3. Search Strategy

The searches were carried out between 10 and 31 October 2021.

The searches were carried out using the truncated keyword and truncated keywords in combination with International Patent Classification (IPC) codes as set out below:

- IPC classifications:
  - A01, A01G, A01M - AGRICULTURE; FORESTRY including A01M1/18 - bands or coatings for trees;
  - C07 - ORGANIC CHEMISTRY;

- [redacted]
- [redacted]
- [redacted]
  - [redacted]
  - [redacted]
- [redacted]
- [redacted]
- [redacted]
  - [redacted]
  - [redacted]
  - [redacted]
  - [redacted]
- C11 - ANIMAL OR VEGETABLE OILS, FATS, FATTY SUBSTANCES OR WAXES; FATTY ACIDS THEREFROM;

Searches: All searches cover WO/PCT, EP, GB and US for patent rights filed from September 2001 onwards unless otherwise stated:

[redacted] **8180 Hits**

[redacted] **491503 Hits**

[redacted] **6058 hits**

[redacted] AND **IPC:(**C08G59 OR C08J3 OR C08L63 OR C09D**)** **53868 Hits**

[redacted]

[redacted]

[redacted]

[redacted]AND **IPC:(**C08G59 OR C08J3 OR C08L63 OR C09D**)**
32151 Hits

The above searches were then combined in various combinations to identify common "hits" and to sift out less relevant material. The optimal combination of searches, ie reasonably covering the desired subject matter whilst keeping the volume to (relatively) manageable quantities was as follows:

[redacted](*gly* OR resin OR fatty)**)** AND ((cross* OR cur*) NEAR20 carboxylic) AND **IPC:(**C08G59 OR C08J3 OR C08L63 OR C09D**)** **3814 Hits**

The search results from this search were provided to NMC2 for assessment as to relevance/ interest. A short list of "hits" was identified for further assessment/consideration, set out in Section 4 below.

4. Results/Hits of Potential Relevance

The following patent rights were identified from the searching as particularly of interest/ relevance:

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]

[redacted]

[redacted]

[redacted]

i) [redacted]

ii) [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted] a coating for coating a substrate, comprising i) an epoxy resin derived from an oil and cured using a curing agent comprising a mixture of iia) a carboxylic acid having at least two acid functionalities and iib). an ester [redacted] curing agent for curing a resin, containing a mixture of an organic acid containing at least two acid functionalities and an ester. A product comprising a resin with the curing agent, a method of making the curing agent and use of the acid and ester mixture for curing a resin is also claimed. [redacted]

5. Limitations on Searching

(i) The patent searches conducted on the various aspects of this project were carried out by us using publicly available databases, and LexisNexis TotalPatent, a commercial database to which we subscribe. Errors or omissions in the databases used for the searches, for example due to misclassification, categorising based on different information.

(ii) The scope of the project, the chemical components and the different ways of describing them meant that, by necessity, the search strategy in some elements of the overall exercise, was limited in certain respects due to high volumes of initial “hits” so as to narrow down the “hits” to more manageable numbers. Where such limitations were employed, alternative search strategies were used to seek to provide a “matrix” to provide a greater chance that prospective “hits” which might be missed would be picked up in alternative overlapping searches. Whilst we endeavoured o cover the full scope of the project,

(iii) No patent freedom to operate (FTO) clearance search can be certain to identify all potential risks due to the inherent nature of searching where one has to use limited classification codes, keywords and combinations of these to encompass concepts, materials and components which may be defined in different ways.

(iv) Unpublished patent rights effective in the UK may exist but which have not been published as at the date the searches were carried out. There is no way of detecting such rights and we therefore recommend an ongoing or periodic FTO exercise to “top-up” the search results from this initial and historical exercise to cover the period from the date of this exercise to the time at which such future FTO searches are carried out.

Stephen Geary

Bawden and Associates

21 February 2022

Appendix 6

BEIS – Low Carbon Biodegradable Tree Guards

Carbon Footprint Summary Report

Date: 17/01/2022

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Quality Management

Issue/revision	Issue 1	Revision 1	Revision 2	Revision 3
Report Status	Issue 1	Final		
Date	23/12/2021	17/01/2021		
Prepared by	George Bryant	George Bryant		
Signature				
Checked by	Neil Carpenter	Neil Carpenter		
Signature				
Project number	C0311	C0311		

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ISOQAR REGISTERED

UKAS MANAGEMENT SYSTEMS 0026

ISO 9001

ISO 14001

ISO 45001

Certificate Number. 16135

Table of Contents

Executive Summary

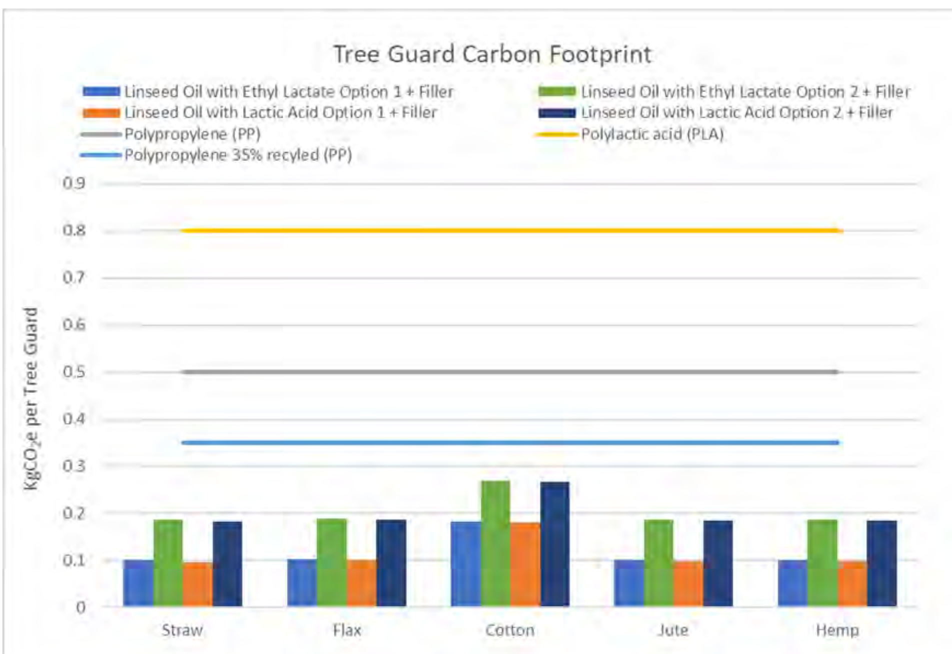
This report contains the results of a carbon footprinting study carried out on behalf of BEIS for the production of sustainable, biodegradable tree guards.

The report is a technical summary of the calculations and methodologies undertaken, with presentation of the results and analysis to help BEIS understand the carbon impacts of the production of biodegradable low carbon tree guards and to ascertain the lowest impact methods and materials currently available.

In total, twenty prototype products were assessed, a combination of four binders and five fillers. Comparisons between the two biodegradable binder materials used in the prototypes is considered minimal in terms of carbon impact, however the manufacturing process chosen appears to play the significant role in the overall carbon footprint.

Overall the data and analysis indicates that the prototype tree guard Linseed Oil with Lactic Acid option 1 with a straw filler has the lowest carbon footprint, which at 0.0974kgCO_2/tree guard, is around 70% lower carbon than a standard Polylactic Acid (PLA) and 30% lower carbon than a standard Polypropylene (PP) tree guard product.

When considering the large numbers of tree guards likely to be required over the next 30 years to meet UK government tree planting targets the potential cumulative carbon savings from a switch to a biodegradable low carbon tree guard are significant.



1. Introduction and Background

1.1. Life Cycle Assessment (LCA) and Carbon Footprints (CF)

Everything we buy, produce, use and throw away has an impact on the environment. Increasing awareness of environmental issues, especially climate change, has led to many initiatives that aim to decrease the environmental impact of consumer goods and services. Understanding and effectively communicating the environmental impact of products has resulted in carbon footprints and Life Cycle Assessments (LCAs) increasingly being used to assess the impact of products and by-products.

There are certain aspects of assessment that are common to life cycle assessments and carbon footprints, for both you must be clear on the limits or boundaries of the data and transparency of calculation is critical for both. Understanding what is and is not included in an assessment is critical in establishing whether the analysis is representative of a process.

LCA is a tool for evaluating the environmental burdens associated with a product (process or activity) over its entire life cycle as demonstrated in Figure 1. This diagram presents a typical life cycle and shows that a life cycle assessment focuses on all inputs in terms of materials and energy resource consumption plus any associated land use and the outputs in terms of emission to air, water and land are characterised in terms of acidification, toxicity, abiotic depletion etc. It is a complicated process with specialist software to help manage the process in terms of collecting the impact from each element of the raw materials and energy utilised through to the characterisation stage. The process starts with data collection on the different life cycle stages, an inventory is then pulled together that includes all the chemicals and process flows for a given product. Finally the characterisation information is presented.

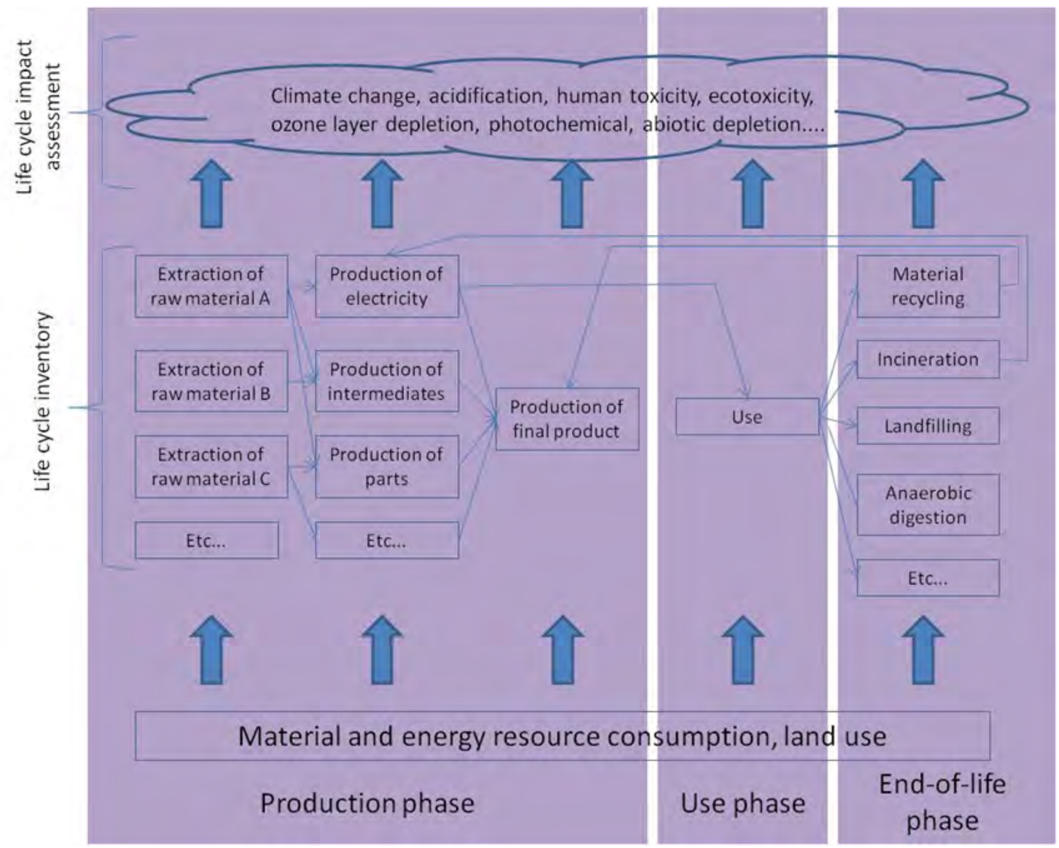


Figure 1: Life Cycle Assessment Process

A carbon footprint (CF) is a form of LCA in which the analysis is limited to assessing the impact of emissions that have an effect on climate change (carbon dioxide, methane etc.). This simpler scope makes it easier to undertake such studies, as reduced data needs to be collected for each part of the life cycle process. Carbon footprints can be certified to a separate standard - PAS2050, which is largely derived from the LCA standard ISO14044. The main difference between the two standards is that PAS2050 focuses on carbon impacts, or global warming potential, and ignores other environmental impacts. In this respect, PAS2050 represents a limited or streamlined application of ISO14044.

The table below presents an overview of the difference between carbon footprints and life cycle assessment.

Carbon Footprint (CF)	Life Cycle Assessment (LCA)
Carbon footprints provide a simple measure of global warming impact	LCA is a holistic technique – avoids the problems of burden shifting
Simple process – easy to understand and interpret	Complicated process – requires an expert to conduct and assess
Can be conducted relatively quickly	Time-consuming
PAS2050 standard	ISO14040 & ISO14044 standards

1.2. Methodology

An initial carbon footprint assessment of the biodegradable tree shelter materials was conducted by ClearLead Consulting Ltd, the objective was to establish the possible carbon impact of each potential bio-based material shelter.

The methodology followed standard procedures for establishing product carbon footprints using the WRI Green House Gas (GHG) protocols. The scope of the footprint includes the use of established emission factors to assess the key raw materials plus any scope 1&2 emissions generated during the manufacturing process.

For clarity scope 1,2 & 3 are defined as; Scope 1 covers direct emissions from owned or controlled sources. Scope 2 covers indirect emissions from the generation of purchased electricity, steam, heating and cooling consumed by the reporting company. Scope 3 includes all other indirect emissions that occur in a company's value chain.

Emission factors have been obtained from dependable sources such as from the IPCC methodology and DEFRA emission factors database that presents organisation factors (updated every year). We have also used Ecoinvent, which contains datasets on agriculture, energy supply, transport, biofuels and biomaterials, bulk and specialty chemicals, construction, and packaging materials etc. and is one of the most comprehensive life cycle assessment databases.

2. Data and Analysis

2.1. Data sources and references

Details of the production process and material inputs was provided by the research team at Bath University for each of the potential tree guard materials.

Two key binder products have been tested and manufactured, each with two processing options that give variation to the quality of the finished product.

Five filler products were also tested, hemp straw, cotton, flax and jute. The five fillers were mixed with each binder option to create the tree guard construction material.

The product materials and manufacturing process are illustrated in the table below.

Product Name	Binder materials	Filler Materials	Process
[redacted]	[redacted]	One of the following; Straw Flax Cotton Jute Hemp	[redacted]
[redacted]			[redacted]
[redacted]	[redacted]		[redacted]
[redacted]			[redacted]

2.1.1. Emissions factors

Emission factors have been selected for base materials and energy inputs and are displayed in the table below.

Category	Material	Emission factor		Source
Binder	[redacted]	4.19321	kg CO_2e per kg	Ecoinvent
	[redacted]	4.19321	kg CO_2e per kg	Ecoinvent

Binder	[redacted]	2.80433	kg CO_2e per kg	Ecoinvent
	[redacted]	1.33313	kg CO_2e per kg	Ecoinvent
Process Energy	Electricity	0.2913	kg CO_2e per kWh	Defra 2021 (Inc. WTT & T&D)
Filler	Straw	0.09586	kg CO_2e per kg	Ecoinvent
	Flax	0.14215	kg CO_2e per kg	Ecoinvent
	Cotton	1.28513	kg CO_2e per kg	Ecoinvent
	Jute	0.1117	kg CO_2e per kg	Ecoinvent
	Hemp	0.10548	kg CO_2e per kg	Ecoinvent

2.2. Carbon Footprint

The carbon footprint for each of the products was calculated, including the materials and process energy. The footprint for each product is shown in the table below (kg CO_2e/tree guard) and shown graphically in figure 2.

	Straw	Flax	Cotton	Jute	Hemp
[redacted]	0.0998	0.1031	0.1831	0.1009	0.1005
[redacted]	0.1858	0.1890	0.2690	0.1869	0.1864
[redacted]	0.0974	0.1007	0.1807	0.0985	0.0981
[redacted]	0.1834	0.1866	0.2666	0.1845	0.1840

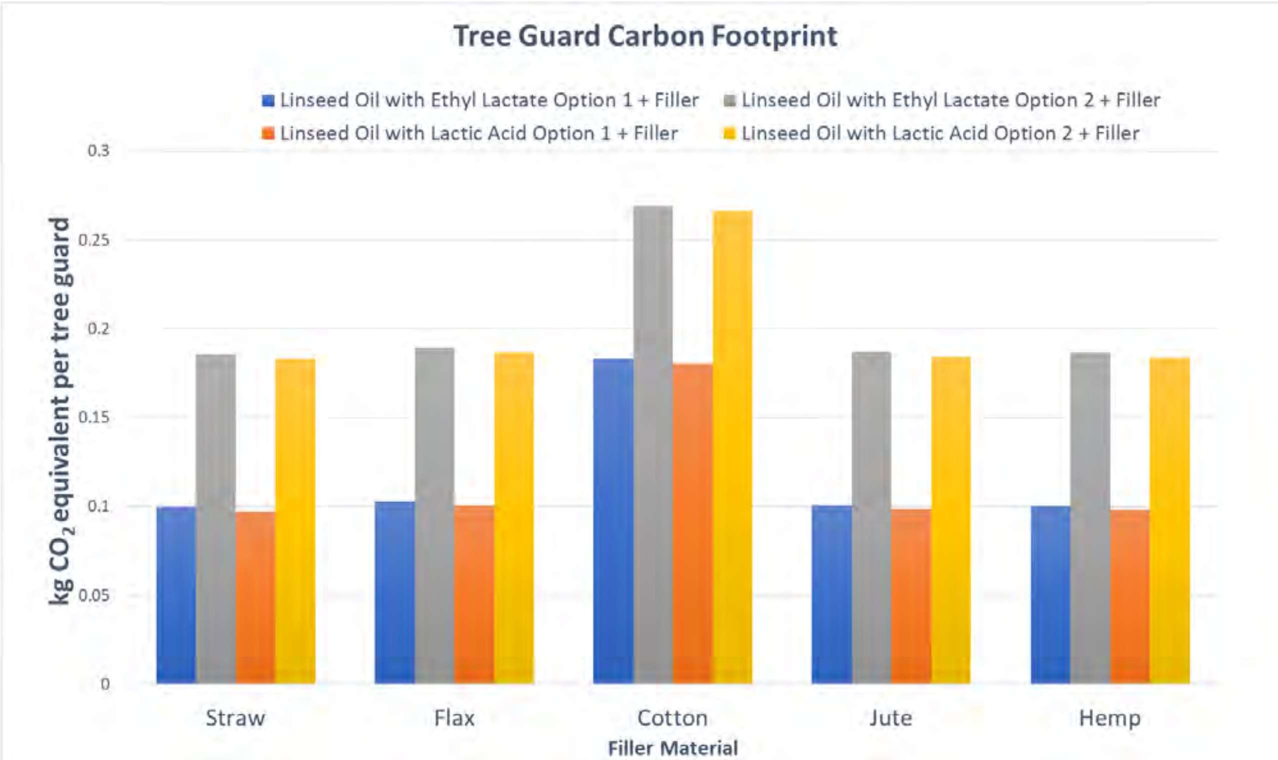


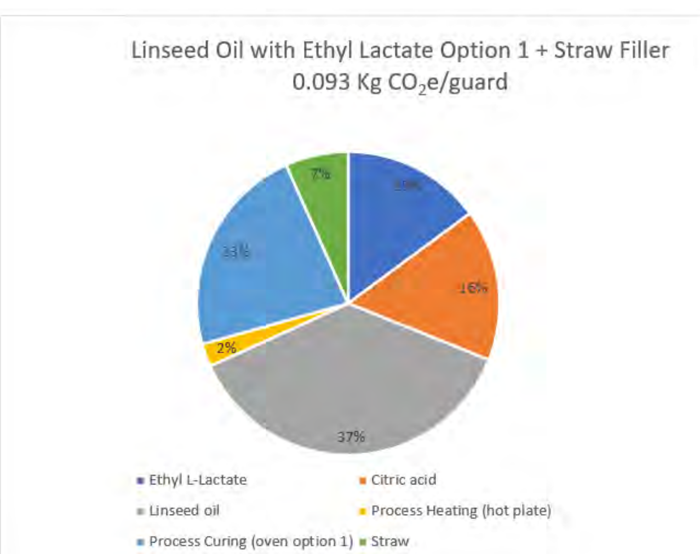
Figure 2: Carbon Footprint per Tree Guard

As can be seen the carbon impact between the two variations of binder materials (Ethyl Lactate and Lactic Acid) is minimal, with both mixtures of materials giving a similar result. The main difference occurs between option 1 and 2 which is a process change. Option 1 curing is for a much shorter time (2 hours) whereas option 2 is for 16 hours. Option 2 almost doubles the carbon impact of the product.

The choice of filler material, with the exception of cotton, is negligible between the five filler options, although Straw gives a marginally lower overall carbon footprint.

2.3. Carbon Breakdown

The breakdown of the carbon footprint is illustrated in figures 3 and 4 below to highlight the significant carbon impacts of the product, depending on the material selection or processing method. The breakdown has been completed for the products containing straw as a filler, but is representative for the other fillers as well, due to the similar overall carbon footprint.



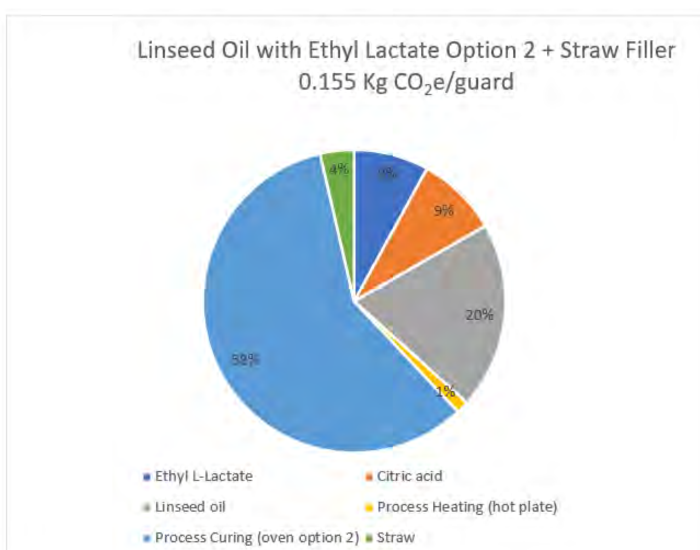


Figure 3: Carbon Breakdown Ethyl Lactate Option 1 & 2

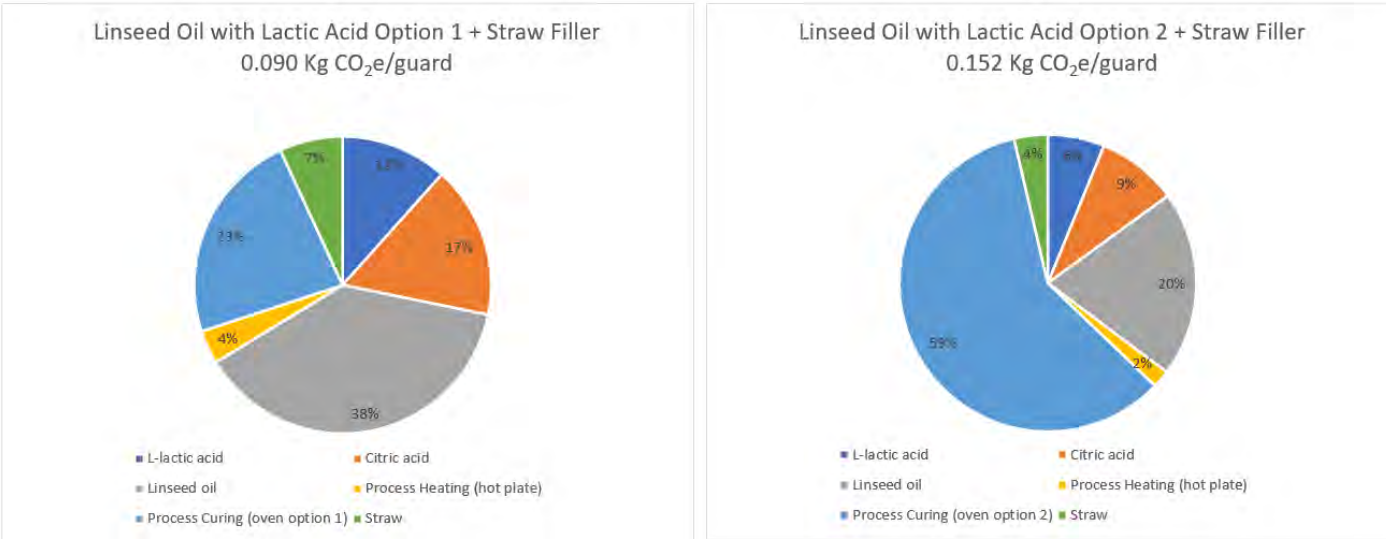


Figure 4: Carbon Breakdown Lactic Acid Option 1 & 2

For both the Ethyl Lactate and Lactic Acid binder using option 1 processing the most significant carbon impact of the product is the Linseed Oil material at 37 and 38% respectively. The manufacturing process itself (heating and curing) only makes up 25-27%.

The breakdown for option 2 is significantly different to option 1, with the significant carbon impact coming from the manufacturing processing, 59% for Ethyl Lactate and 61% for Lactic Acid.

The main reason for the variation in carbon impact during the manufacturing process is the extension of the curing time the product receives during option 2.

3. Discussion

The data and analysis from section 2 indicates that Linseed Oil with Lactic Acid option 1 with a straw filler has the lowest carbon footprint at 0.0974kgCO_2/tree guard.

Comparisons between the two binder materials used are very minimal in terms of carbon impact, however the manufacturing process chosen appears to play a significant role in the overall carbon footprint. Option 1 has a reduced curing time which significantly reduces the energy consumption per tree guard, and therefore has less impact on the carbon footprint when compared to option 2, which has an extended curing time.

The product resulting from option 1 tends to have harder/firmer properties whereas option 2 produces a slightly flexible product. From a carbon perspective option 1 is likely to have a lower carbon impact when produced on scale. However, the benefits of the physical properties of both products need to be evaluated as well.

As part of the carbon footprinting exercise current plastic alternative tree guard products have been reviewed as a comparison. Carbon footprints for the materials and manufacturing stage of Polypropylene (PP) and Polylactic Acid (PLA) tree guards* have been reviewed and are shown in figure 5 below for comparison.

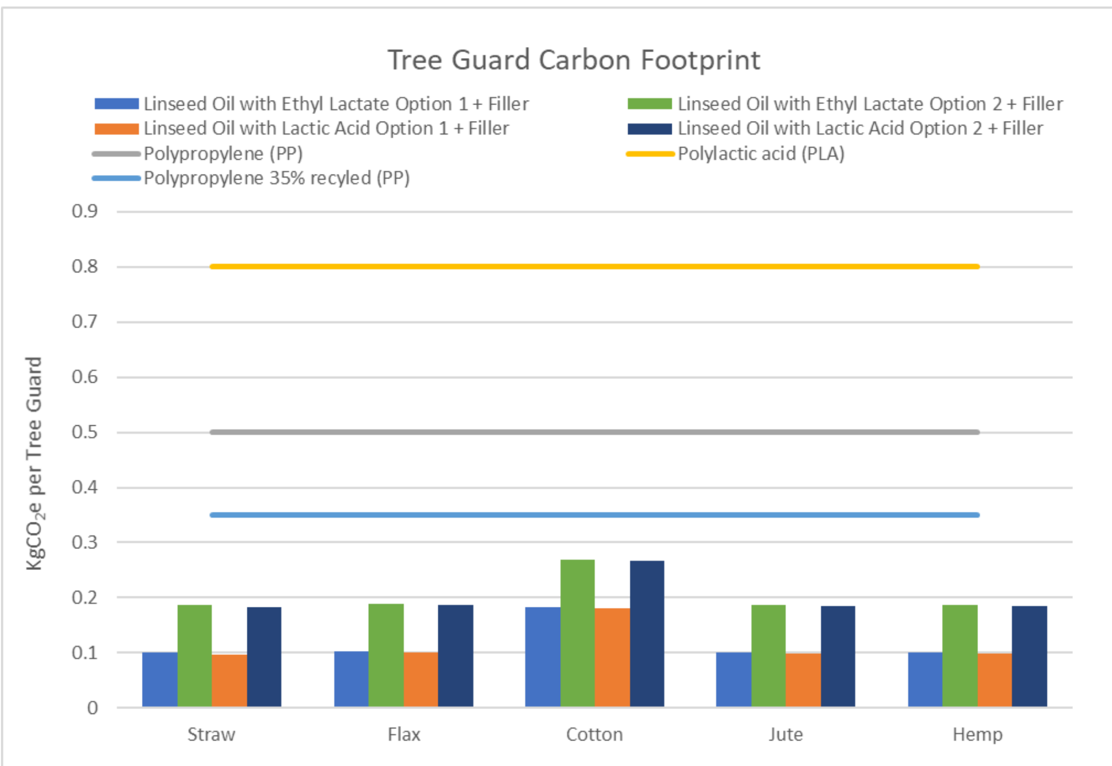


Figure 5: Tree guard carbon footprints

The comparison against current plastic alternatives indicates that the prototype biodegradable products have a significantly lower carbon impact, with the best performing product being around 68% lower impact per tree guard than standard PLA tree guards.

More than 7 million tree guards are sold in the UK each year, and this is forecast to increase significantly. The House of commons report (June 2021) states government targets for tree planting is 30K hectares per year from 2025 and 50k hectares per year from 2035. At roughly 2,500 trees per hectare the UK will plant between 2-3 billion trees before 2050.

At present in the UK the overwhelming majority of tree guards sold are petrochemical polymers (Polyethylene, Polypropylene). Therefore the potential carbon reduction impact from a switch to biodegradable low carbon tree guards is significant. Figure 6 shows projected carbon emissions of tree guards in line with tree planting targets.

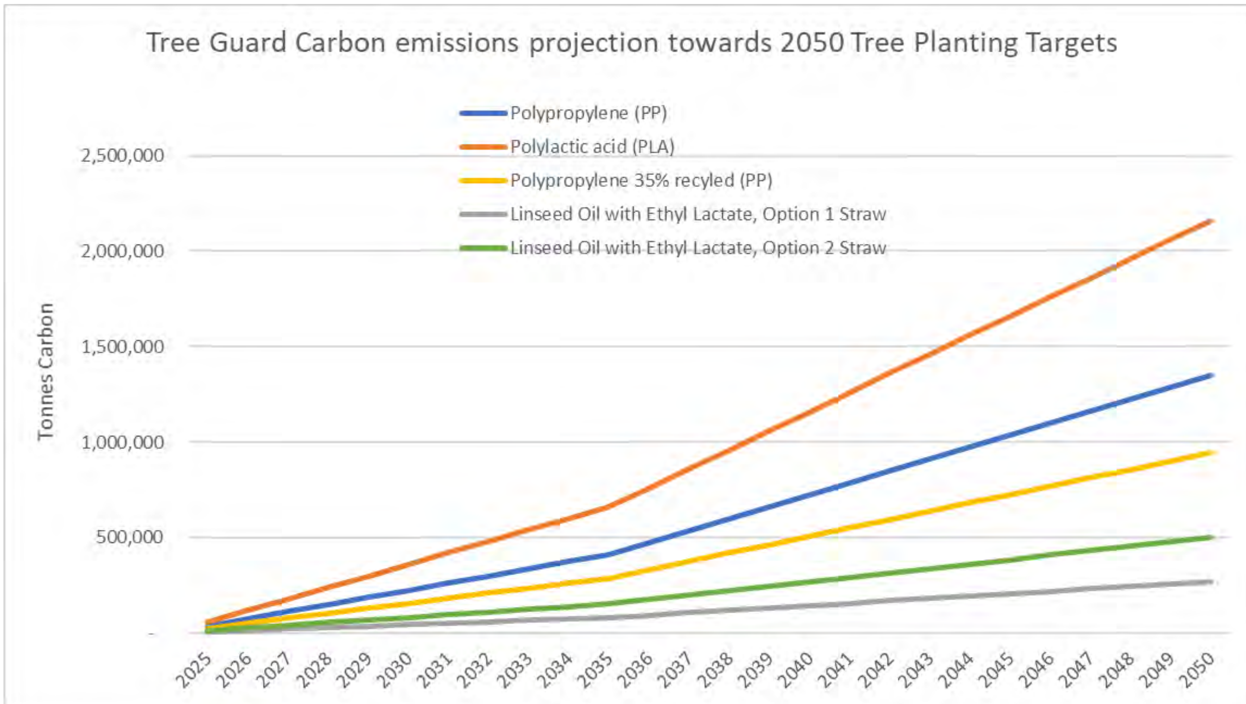


Figure 6: Tree guard carbon impact projection

The Carbon forecast is based on the 2050 requirements for tree planting and plots the cumulative year on year carbon emissions associated with material use and manufacture of tree guards. The carbon projections have not been adjusted at this point for any decarbonisation of electricity grid networks (which is generally expected to rapidly decarbonise in the UK from 2030 to 2050). This has been done purposefully as the mix of energy sources in the manufacturing of the PP and PLA products is unknown. Due to the large scale of production and heat requirements it is expected that the energy input is likely from combustion of natural gas or oil and decarbonisation plans for this sector are not yet clear enough to predict how these sources of heat are to be replaced. Therefore although the projection has a timeline up to 2050, certainty of the numbers is less confident beyond 2030.

Irrespective of future decarbonisation of electricity grids or industrial processes what the projection does show is there is potential to reduce the carbon emissions associated with tree guards by around 70% by switching to biodegradable low carbon tree guards.

In the upscaling of manufacturing there maybe potential to specify renewable electricity generation as the power source for the manufacturing process. This would lower the potential carbon impact of the processing portion of the product footprint. The overall benefit would be lower in Option 1 as the energy input is already relatively low. However, if the properties of option 2 were more favourable and this product was put into manufacturing, using renewable energy as the main power source would have a greater impact on the overall carbon footprint. It should be noted that with expected UK electricity grid decarbonisation over the next 30 years the carbon benefit of purchasing renewable energy rather than grid electricity will diminish over time.

* *Charnett Chau, Andrea Paulillo, Nancy Lu, Mark Miodownik, Paola Lettieri, 2021. The environmental performance of protecting seedlings with plastic tree shelters for afforestation in temperate oceanic regions: A UK case study. Science of the Total Environment 791 (2021) 148239.*

4. Conclusion & Next Steps

4.1. Conclusion

Comparisons between the two biodegradable binder materials used in the prototypes is considered minimal in terms of carbon impact, however the manufacturing process chosen appears to play a significant role in the overall carbon footprint. Careful consideration needs to be given to the process methodology when upscaling to mass manufacturing to ensure the tree guards remain a low energy/low carbon product.

Changes in the manufacturing process (option 1 or 2) also result in different physical properties for the finished tree guard. The benefits of the physical properties needs to be evaluated along with the manufacturing carbon footprint. As it maybe in the long term the product with a slightly higher carbon footprint but stronger physical properties is more likely to result in a tree reaching maturity.

Overall the data and analysis indicates that the prototype tree guard Linseed Oil with Lactic Acid option 1 with a straw filler has the lowest carbon footprint. At 0.0974kgCO_2/tree guard, this option is around 70% lower carbon than standard PLA and 30% lower carbon than standard PP tree guard products.

When considering the large numbers of tree guards likely to be required over the next 30 years to meet UK government tree planting targets the potential cumulative carbon savings from a switch to a biodegradable low carbon tree guard are significant.

4.2. Next steps

- Assess the physical properties from the prototypes option 1 and 2.
- Select the favoured prototypes to take forward into Phase 2, and assess upscaling potential
- Based on selected product and upscaling plans gather data to produce a full LCA assessment
- Develop a full LCA of the selected tree guard product

5. Phase 2

5.1. Phase 2 Budget

The key work package to be delivered in phase 2 is to develop a full life cycle analysis of the final tree guard product. The scope of work is to include;

- Collection of input data for the LCA tool based on upscaled product materials, energy inputs, transport, packaging and end of life scenarios
- Development of the full LCA carbon footprint of the tree guard
- Consultancy advice and recommendations on all phases shown in phase 2 work package process flow chart
- Attendance (virtually and in person quarterly) of project meetings to support process development (with carbon/environmental management).
- Support in product trials and development of marketing materials were appropriate.

The budget for phase 2 will be £64,800 invoiced quarterly over the 3 year project period, VAT will be added at the prevailing rate.

The budget is broken down as follows

- 100 days of consultant time at £600 a day (day rate is fixed for the 3 year project term)
- £4,800 expenses allowance for attendance at quarterly project meetings

Appendix 7 - NMC2 BEIS Biomass Feedstocks Phase 2 Risk register

RISK MANAGEMENT STRATEGY
NC will be responsible for risk management and reporting. Each WP-lead will manage risks related to their deliverables. At the start of the project, each risk will be given a review schedule. Risks will be a standing agenda item in monthly meetings. We will use Agile approaches to de-escalate any high impact risks. Our risk mitigation will be actively monitored and reviewed, and a live version will be circulated to sub-contractors.

IMPACT				
	Major	3	6	9
	Moderate	2	4	6
	Minor/ Insignificant	1	2	3
		Remote	Possible	Highly Probable
			LIKELIHOOD	

Risk	Lead	Rating pre-mitigation	Mitigation actions	Rating post-mitigation
Technical risks				
Material fails key test (performance or durability)	NMC2	4	Product has performed well in laboratory and team of developed good understanding of properties	1
[redacted]	Bath	6	[redacted]	3
[redacted]	Bath	6	[redacted]	3
[redacted]	NMC2	3	[redacted]	2
[redacted]	NMC2	4	[redacted]	2
Cost of capital equipment increased	NMC2	6	Order on confirmation of funding. New quotations should be valid for 3 months (note: will need BEIS to release funds)	3
Delivery of capital equipment delayed	NMC2	6	Order on confirmation of funding (note: will need BEIS to release funds). Quotes should include lead time	3
H&S risk due to chemical and biological lab work	Bath	2	COSHH assessments already completed. Materials low toxicity/food grade. As part of the application, full ethical approval for tasks have been given.	1
Tree shelters unable to withstand deer grazing	NMC2	4	[redacted]	2
[redacted]	NMC2	3		2
Financial/Commercial risks				
[redacted]	NMC2	6	Materials have been costed realistically based on experience from phase 1	2
[redacted]	NMC2	4	[redacted]	2
[redacted]	NMC2	4	[redacted]	2
[redacted]	NMC2	4	[redacted]	2
[redacted]	NMC2	6	[redacted]	4
[redacted]	NMC2	2	[redacted]	1
[redacted]	NMC2	4	[redacted]	1
Supply chain risks				
[redacted]	NMC2	4	[redacted]	2
Delays in delivery of materials and procurement	NMC2	4	We will order services and goods with time contingency	2
Environmental Risks				
[redacted]	NMC2	6	[redacted]	2
[redacted]	NMC2	6	[redacted]	2
[redacted]	NMC2	3	[redacted]	1
[redacted]	NMC2	3	[redacted]	1
Managerial risks				
[redacted]	NMC2	6	[redacted]	3
Project management systems are insufficient to deliver the project	NMC2	4	[redacted]	2
Sub-contractors lateness in delivery	NMC2	4	[redacted]	2
Contractors costs increase	NMC2	6	[redacted]	2
Regulatory risks				
[redacted]	Bath	6	[redacted]	2
COVID-19 risk				
Closure of labs prevents project development	Bath	2	Laboratory has continued to work throughout lockdowns. As we come to end of this phase of COVID risks are reduced but this will be addressed in terms of contractors risk mitigation at project kick off meeting	2

COVID-19 impacts supply chains	NMC2	**4**	We will order materials with time contingency	**2**

Appendix 8 - Project Plan - NMC2 - Redacted

WP #	Work Package and Tasks	Dependency	WP Lead and Teams	Q2-22	Q3-22	Q4-22	Q1-23	Q2-23	Q3-23	Q4-23	Q1-24	Q2-24	Q3-24	Q4-24	Q1-25
WP01	Project Direction, Management & Reporting		[redacted]												
1.1	Project Direction, Lead and Consortium Management, Financial & Cyber		NMC2												
M1	**Kick off Meeting**		**NMC2**												
1.2	Project Management, Work Package supervision and WP lead Communications		P8												
1.3	Project Reporting administration		NMC2												
1.4	Consortium and stakeholder kickoff event, quarterly meetings at UO Bath and EOP meeting.		NMC2												
1.5	Quarterly Project Reports		NMC2												
M2	**End of project report**		**NMC2**												

[redacted]

[redacted]			
[redacted]	[redacted]		[redacted]
10.1	Commercialisation & Exploitation Report		NMC2
M15	Business Plan		NMC2
10.2	Customer Engagement and Marketing Strategy		NMC2/P8
10.3	Carbon Report		ClearLead
10.4	IP and Freedom to operate		Bawdins
10.5	Financial control		NMC2
10.6	Cyber /records control		NMC2
10.7	Dissemination Events		NMC2
			Total cost: £2,662,768