Annex 1

hemp-30

Phase 1 | BFI Project

Industrial Hemp 10-Year Roadmap

CONTENTS

Partners:

University of York

Biorenewables Development Centre

Lucid Insight

Kepier & Company Limited
Business and Management Consultants

VISION

Our vision is for a thriving ecosystem of hemp-based industries that adds 700 million pounds to the UK economy and sequesters or displaces a million tonnes of CO_2 each year.

Farmers will plant hemp on at least 80,000 hectares of UK arable land as a profitable and soil-friendly break crop in cereal rotations with many growers adding value through on-farm processing of the crop at regional hubs.

With excellent connectivity between growers, end users, researchers and regulators, the crop will be used as raw material in diverse markets to displace more carbon intensive resources within food, feed, construction, biofuel and bioenergy industries as well as textiles and high value health and wellbeing products.

Founded on a robust evidence base, UK hemp-based products will be sought after in voluntary carbon markets and will play an important role in decarbonising the construction industry.

The UK will be recognised world-wide both as a leader in fast-track breeding of optimised hemp cultivars and as innovator in hemp processing.

BACKGROUND AND CONTEXT

Industrial hemp is currently grown on a few hundred hectares in the UK. It has potential both as a low input break crop in cereal rotations and as a sustainable raw material for a range of industries, however, it faces a number of barriers:

- Growers suffer from limited availability and expense of certified seed together with poor evidence on the performance of different varieties under UK conditions. The effectiveness of hemp in rotation with cereals for suppression of weeds and disease as well as sequestering CO_2, improving soil organic carbon and enhancing biodiversity need demonstration and analysis so that growers can select the best variety for their purposes and access the opportunities arising from "carbon farming".
- Current use of hemp products is niche rather than industrial in scale. Potential large scale users will not invest in hemp as a raw material because supply is insecure with limited numbers of producers. Producers will not grow at scale until the markets for their product are secure - Catch 22.
- Connections are lacking between potential large scale users of hemp and the growing community as well as with research groups. Poor knowledge sharing means that opportunities for adding value before the farm gate are not adopted and innovation is slow.
- Whilst the industry agrees regulation is important, the current licensing process is unwieldy, untimely and expensive for growers as well as limiting opportunities for UK processing of high value extractives.
- The UK is world leading in the use of hemp in construction as well as the genetics of hemp secondary metabolism and seed oil composition but could lose this first mover advantage.

MARKET OPPORTUNITIES

Productive break crop
Hemp can meet a pressing need for new break crops in cereal rotations, reducing the need for pesticides, suppressing weeds and enhancing yields of cereal crops. A conservative estimate suggests production of 100kt seed and 600kt biomass from 80,000 ha in 2031.

Carbon farming
Hemp can fix up to 22t CO_2 per ha in above ground biomass whilst enhancing soil carbon and biodiversity. Hemp biochar for soil amendment or as co-feedstock for AD or heat and power can help farms achieve net zero and income from ELMS or VCMs.

Value before the farm gate
Processing of hemp at regional on-farm facilities for construction raw materials or food/feed/health products can capture value before the farm gate, enhancing farmer incomes and growing the rural economy across the UK.

Food & feed
The healthy profile of hempseed oil and protein is attractive for human and animal diets. Hempseed meal is well placed to meet exponentially growing UK markets for plant based 'meat' products, replacing imported soy as raw material.

Construction
Some 5% of the UK's carbon emissions arise from new construction and there is an urgent need to retrofit existing homes. Construction applications of hemp have been proven over twenty years and now need investment to scale up and fulfill their potential to decarbonise construction, displacing or sequestering over 0.5 mt CO_2 whilst adding over £200m to the UK economy by 2031.

Textiles
Hemp, with its strong but biodegradable fibre, is well positioned to replace plastics in non-woven products such as wipes. New technology to cottonise hemp fibre will open markets in woven textiles, avoiding the social and environmental drawbacks of cotton.

Composites
The excellent weight and elasticity of hemp fibre together with a strength comparable to carbon is driving the use of hemp in the body work of cars. With some technology development, the wind industry could use hemp fibre in turbine blades

Health & wellbeing
The UK is home to a thriving CBD industry generating sales worth £700m in 2021; oil from imported hempseed is already widely used in personal care products and pharmaceuticals founded in cannabis have UK markets of £1bn by 2025.

Bioenergy
Whilst a low value application, bioenergy supplied by pelletted hemp biomass can be an accessible market that will drive increased acreage of hemp cultivation whilst displacing or sequestering CO_2 from 2027.

Biofuel
Hemp offers an opportunity to establish 2G ethanol production in the UK for use in sustainable aviation fuel.

PROJECTIONS FOR HEMP 2022–31

80,000 ha

of arable land growing industrial hemp

Displacement or sequestration of

1 m

tonnes CO_2 pa

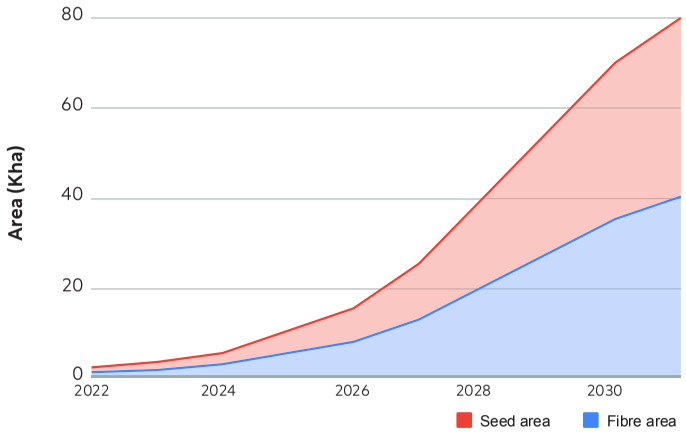
Contribute

£700 m

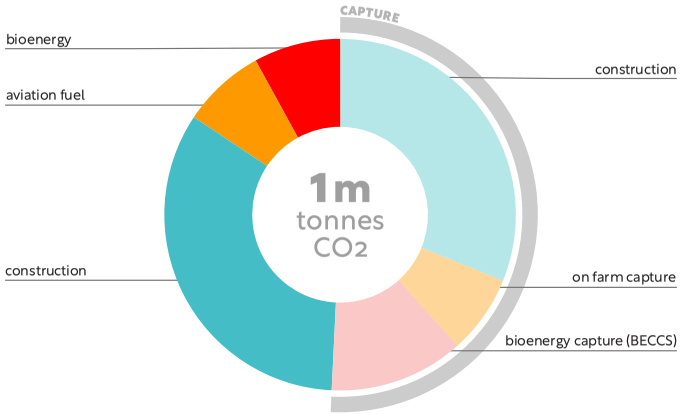
to the UK economy

See Annex 4 for commentary on projections.

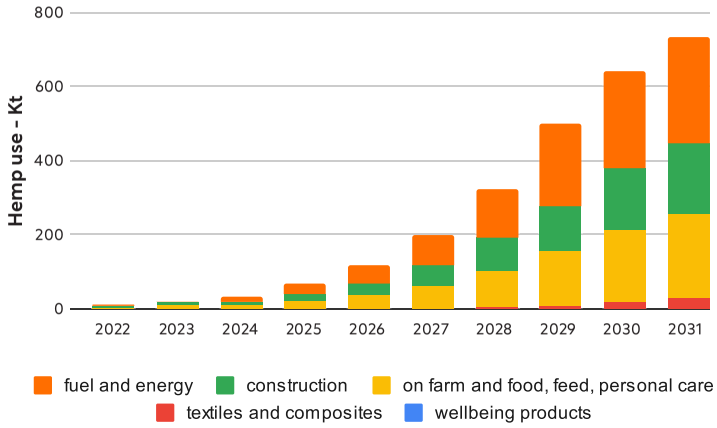
80,000 ha under hemp in the UK by 2031



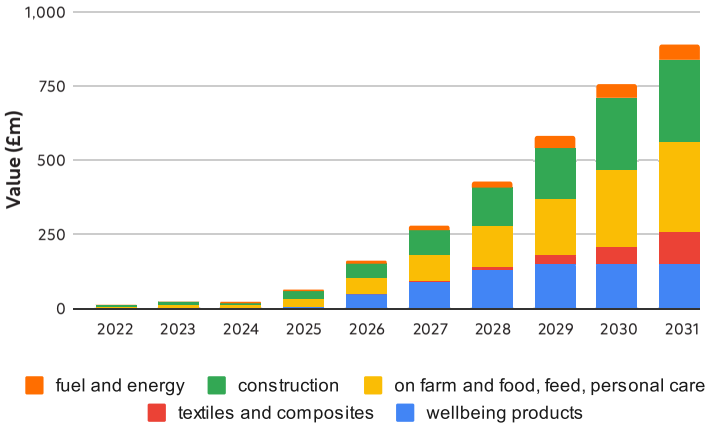
1 mt CO_2 displaced or sequestered by hemp products by 2031



Mass of hemp used in different markets 2022–31



Value of hemp in different markets 2022–31



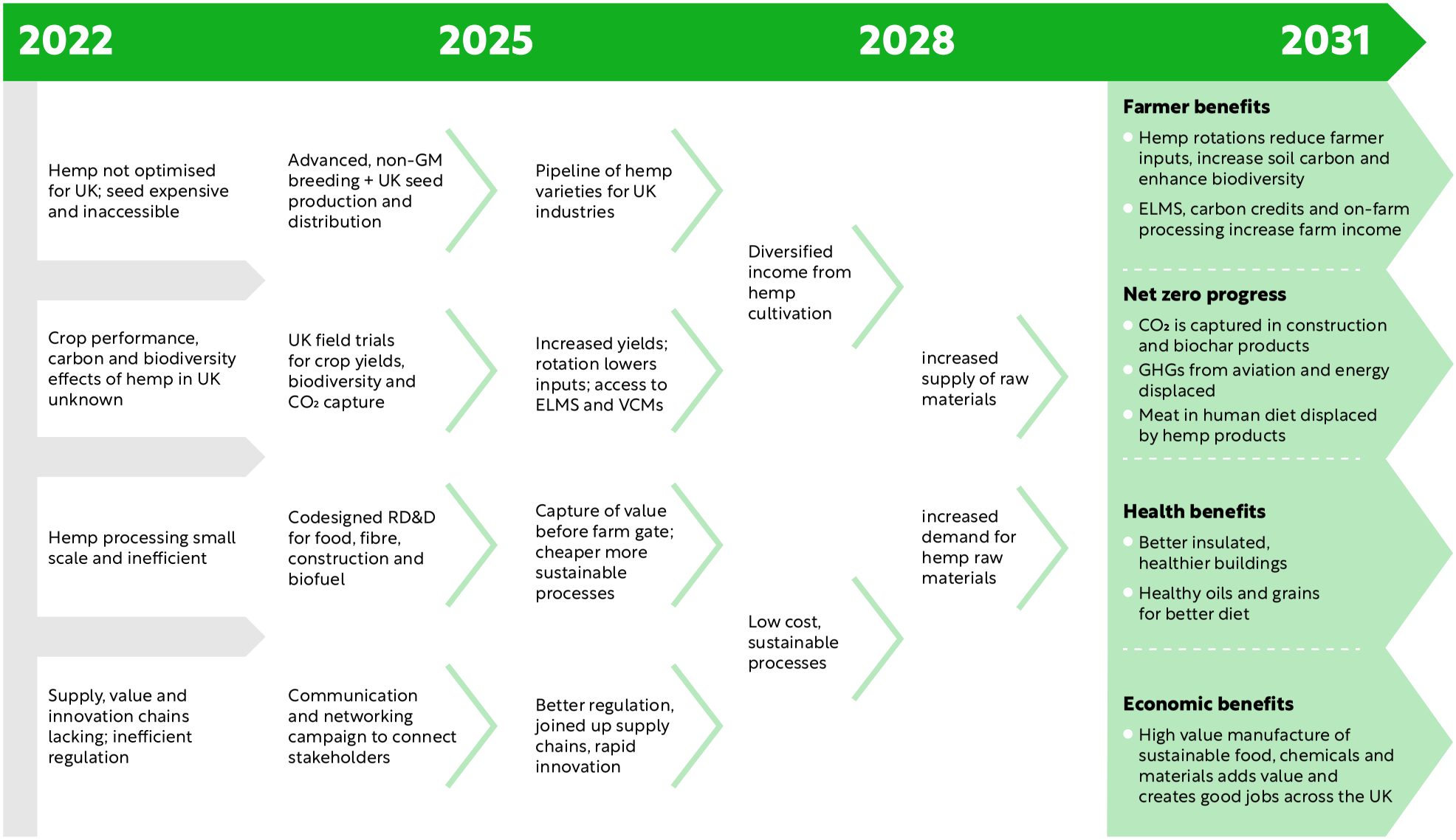
PRIORITIES FOR UK HEMP

Develop hemp varieties for a range of markets for instance dual purpose food & fibre crops to increase income for farmers; hempseed oil that is more stable and suitable for more food industry applications; reduce losses that arise from retting in the field; optimise levels of various secondary metabolites including THC and CBD; address emerging threats of pests and disease. **Farmers need reliable access to affordable seed** for existing varieties and sources of seed for new varieties as they are developed.

Expand the area of land used for hemp cultivation which is held back by lack of evidence for performance of hemp under UK conditions, its nutritional needs & effectiveness as a break crop as well as data on its carbon and biodiversity impacts; crop establishment also requires optimisation. Key to expansion of hemp as a break crop is streamlining regulation of its cultivation.

Develop supply chains and processes for hemp products On-farm process development is needed for retting and decortication to release fibre and for fibre cottonisation as well as pelletting of biomass for bioenergy and use of biomass in AD & biochar. Lack of reliable carbon accounting is hindering access to the opportunities offered by Voluntary Carbon Markets (VCMs)and Environmental Land Management Scheme (ELMS). Poor connectivity between stakeholders leads to small scale supply, value & and innovation chains together with inefficient regulation.

Overview of hemp industries 2022–2031



Timeline for hemp cultivation and use

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Barriers	**Hemp30 Phase 2 activity**									
Varieties	**Priority 1: Develop hemp varieties for a range of markets**									
• Need for dual purpose food & fibre variety • Seed oil unsuitable for many food industry applications • Losses from poor retting, establishment & seed scatter • THC, CBD & 2°ry metabolites not optimised • Emerging threats of pests & disease	• **WP 2:** UK-bred varieties with seed oil suitable for broad food industry applications registered • Building on York's existing advanced genetics platform, develop hemp germplasm with variation in genes controlling key traits (disease resistance, dual purpose crop, retting, THC/CBD, seed oil & protein)			• Hemp lines with variation in key traits identified; initial trials to pick best performers to take forward to registration • Varieties with new seed oil profiles registered				• Registration trials for varieties with enhancements in key traits (eg dual purpose, disease resistant, Zero-THC &/or high CBD, ease of retting)	
• Insecure seed supply with reliance on imported seed • No hemp seed multiplication in the UK • No route to market for new varieties bred in the UK	• **WP3:** Establish hemp seed production in UK • Multiply seed for UK-bred variety with oil suitable for new uses in food industry • Improve seed supply of existing varieties with best traits for UK growers			• Certified seed from UK-bred varieties with novel seed oil profiles available to farmers • Availability within UK of varieties with best traits for UK growers & end users				• UK-bred seed available to farmers for new varieties with enhancements in key traits • More varieties suited to UK become part of the program to multiply seed in UK	
Low acreage	**Priority 2: Expand the area of land used for hemp cultivation**									
• Hemp is a niche crop, unfamiliar to many farmers & limited information available on agronomy • Evidence is lacking for performance of hemp under UK conditions, its nutritional needs & effectiveness as a break crop • Inefficient regulation inhibits hemp cultivation	• **WP4:** Field trial existing varieties in UK • Characterise hemp as a break crop for cereals • **WP8** Collaborate widely to disseminate results; engage with regulators to improve regulation			• Variety selection and agronomy guidance is available to growers • Mainstream farmers adopt hemp as a break crop • Experience of growers increases yield of seed and biomass				• Widespread optimised cultivation of hemp for a range of food, feed, materials and energy markets	
• Crop establishment not optimised • Carbon sequestration & biodiversity effects under UK conditions not characterised, limiting access to ELMS support and voluntary carbon markets	• **WP5:** Evaluate novel seed and plant treatments to maximise yield and minimise inputs • **WP4&7** Characterise soil carbon sequestration and biodiversity effects of hemp			• New agronomic methods increase yields and decrease inputs. • Evidence base for biodiversity and carbon sequestration offers new sources on income to growers from VCM & ELMS				• Increased yields, optimised inputs and VCM or ELMS income enhance returns to farmers whilst enabling soil carbon and biodiversity gains	

Timeline for hemp cultivation and use (cont...)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Barriers	**Hemp30 Phase 2 activity**									
Supply chains	**Priority 3: Develop supply chains and processes for hemp products**									
• Retting inefficient and unreliable • Decortication to separate fibre and fibre cottonisation suboptimal. • Pelleting of biomass & its use in AD and biochar require optimisation	• **WP6** Collaborative research, development and demonstration to deliver new processes for retting and on-farm decortication, fibre cottonisation, use in AD, biochar and on farm pelleting of biomass			• New regional on-farm processing hubs scale up hemp supply. • Capture of value before the farm gate delivering new sources of income and carbon savings for farmers • Use of innovations later in supply chain delivers more sustainable products				• Technology and knowledge for processing hemp on farm is being exported world-wide • Farms are well integrated into supply chains and capture value with multiple end-markets	
• Evidence base lacking for carbon & biodiversity impacts of hemp in UK, hindering access to ELMS and VCMs • Environmental, economic and social impacts of hemp not understood	• **WP7** Develop evidence base for use of hemp in VCMs and ELMS and guidance on best practice to maximise carbon sequestration and biodiversity impacts of hemp on farm and in products • Evidence base allows agreement on criteria for sustainability reporting in hemp products and business case releases investment			• Income from VCMs and ELMS improves price competitiveness of hemp in construction & other markets • Agreed sustainability criteria accelerate adoption of the best innovations • Investment is released in sustainable processing creating value and jobs • Policy makers and regulators use analysis for better policy and regulation				• Demand for UK hemp products drives up value through the whole supply chain. • Reputation of UK hemp products for reliable sustainability claims increases demand in export markets • Improved soil carbon, biodiversity and carbon negative products accelerate UK progress to net zero • Good jobs in the net zero economy	
• Supply, value & and innovation chains are lacking / small scale • Inefficient regulation inhibits hemp cultivation and processing • Poor connectivity between stakeholders • Seed is expensive and difficult to obtain • Low international awareness of UK expertise in hemp technology • Perception of industrial hemp as marijuana	• **WP8** Works as an "honest broker" connecting stakeholders (regulators, investors, growers, end users) to initiate and strengthen hemp supply and innovation chains, collaborating with stakeholders to co-design and disseminate research, connecting with regulators, supporting farmers in seed buying co-operatives, promoting UK hemp internationally & raising awareness with large scale end-users.			• Industrial hemp trade association established • Industrial hemp 'normalised' as a UK crop and in products • Improved connectivity & knowledge sharing enables supply chains, investment, accelerated innovation before and after the farm gate and regulation that is responsive to the needs of different sectors				• Vibrant hemp ecosystem with established supply and value chains responsive to market demand in the UK and internationally; rapid innovation arising from excellent knowledge sharing; policy makers and regulators support sustainable development of the hemp-based industries	

ACTIVITIES TO DEVELOP UK HEMP

WP1 PROJECT MANAGEMENT

Management team to include all delivery partners and advisory board reflecting primary producers and end users, existing and potential.

Priority 1 – New variety development

WP2 HEMP BREEDING PROGRAMME

- Development of varieties adapted to UK conditions with characteristics needed by end users. In the first instance this will build on the York advanced breeding platform to develop varieties of hemp with desirable characteristics in their seed oil. Longer term targets will include a range of additional industrial hemp traits such as disease resistance, retting time, seed scattering, and secondary metabolite profile. This WP will take target traits from idea through to field trials and registration of new varieties.

WP3 SEED MULTIPLICATION

- Key to successful deployment of new varieties is timely, reliable and resilient bulking of seed.

Priority 2 – Expand area of land used for hemp cultivation

WP4 HEMP CROP CHARACTERISATION PROGRAMME

- Field trials of existing varieties under UK conditions
- Characterisation of hemp as a break crop for cereals.

WP5 HEMP YIELD MAXIMISATION PROGRAMME

- Evaluation of the use of novel seed and plant treatments to maximise biomass and specific plant components such as fibre, seed, shiv and leaf quantities.
- Characterisation of carbon sequestration above and below ground and biodiversity effects of hemp.

Priority 3 – Develop supply chains and processes for hemp products

WP6 HEMP PROCESSING INNOVATION PROGRAMME

- Evaluation of before the farm gate innovation opportunities including decortication, fibre cottonisation technology, use of on farm anaerobic digestion, biochar production and on farm pelleting of biomass.

WP7 ENVIRONMENTAL, ECONOMIC AND SOCIAL IMPACT ASSESSMENT

- Analysis of the sustainability (economic, environmental and social) of products and processes that rely on hemp as a raw material eg for construction, textiles, biofuels. This WP will include establishing hemp and its products for carbon credits.

WP8 SUPPLY CHAIN DEVELOPMENT PROGRAMME

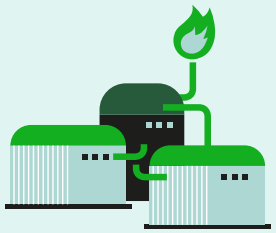
- This will focus on building supply, value and innovation chains for hemp through connecting end users with the primary producers and research providers.

Breakdown of actor roles

Stakeholder	Role
Phase 2 project participants	
University of York	Project Lead, Plant Breeding, Field Trial Studies
The Biorenewables Development Centre Ltd	Hemp processing development / Stakeholder engagement / Project Management
Lucid Insight Ltd	Stakeholder Engagement
Kepier & Company Limited	Commercialisation
K J Voase & Son	Hemp Growing Trials
Seff Fibre Limited	Fibre Production
UK Hempcrete Ltd	Construction Materials Production
Azotic Technologies Ltd	Yield Development
Elsoms Seeds Limited	Seed Production
Stockbridge Technology Centre Limited	Growth Trials
University of Nottingham	Life Cycle Analysis
Tatham Limited	Processing Equipment Design
Simpson (York) Limited	Construction Industry
NNFCC Ltd	Biomass Feedstock Trends and Bio-based Product Development Advice
Game and Wildlife Conservation Trading	Biodiversity surveying
Phase 2 Industrial Advisory Group	
DRAX Group	Bioenergy
NFU	UK Farmers
IndiNature	Hemp-based insulation
Rowett Institute	Nutrition and Human Health
Nestle	Food and Drink
Industrial participants from Hemp-30 Phase 2 project	Textiles / Construction / Seed production / New Variety Development / Bioenergy

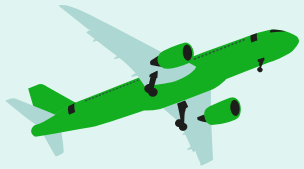
Stakeholders beyond phase 2	
Defra	Farming support policy, ELMS support for hemp
Home Office	Regulation & licensing of hemp cultivation and processing
BEIS	Use of hemp to reduce GHG emissions & grow the economy
UKRI	Funding innovation in use of hemp
	Promotion of UK hemp industries to export markets
Farmers	Cultivation and on-farm processing of hemp; use to decarbonise agriculture
Investors	Funding scale up of hemp industries and use in VCMs
RD&D community	Development and demonstration of hemp technology
Construction industry	Use of hemp to decarbonise & construct healthy buildings
Bioenergy industries	Use of hemp to make sustainable energy
Aviation	Using hemp biofuels to deliver sustainable aviation fuels
Personal care industries	Use of hemp products in personal and wellbeing products
Food industry	Use of hemp oils and protein in healthy low carbon food
Animal feed	Integration of hemp into pet food, aquaculture & farm animal diets
Textile industry	Integration of hemp into woven and non-wovens to replace plastics and cotton

Industrial hemp by 2030: industry vision



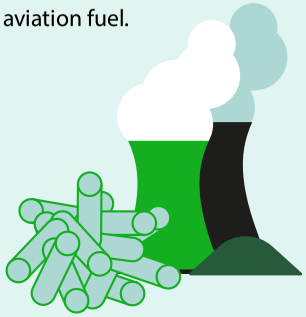
Biogas

Hemp biochar as a co-feedstock for anaerobic digestion can help farms achieve net zero and earn extra income.



Biofuels

Opportunities to establish 2G ethanol production in the UK for use in sustainable aviation fuel.

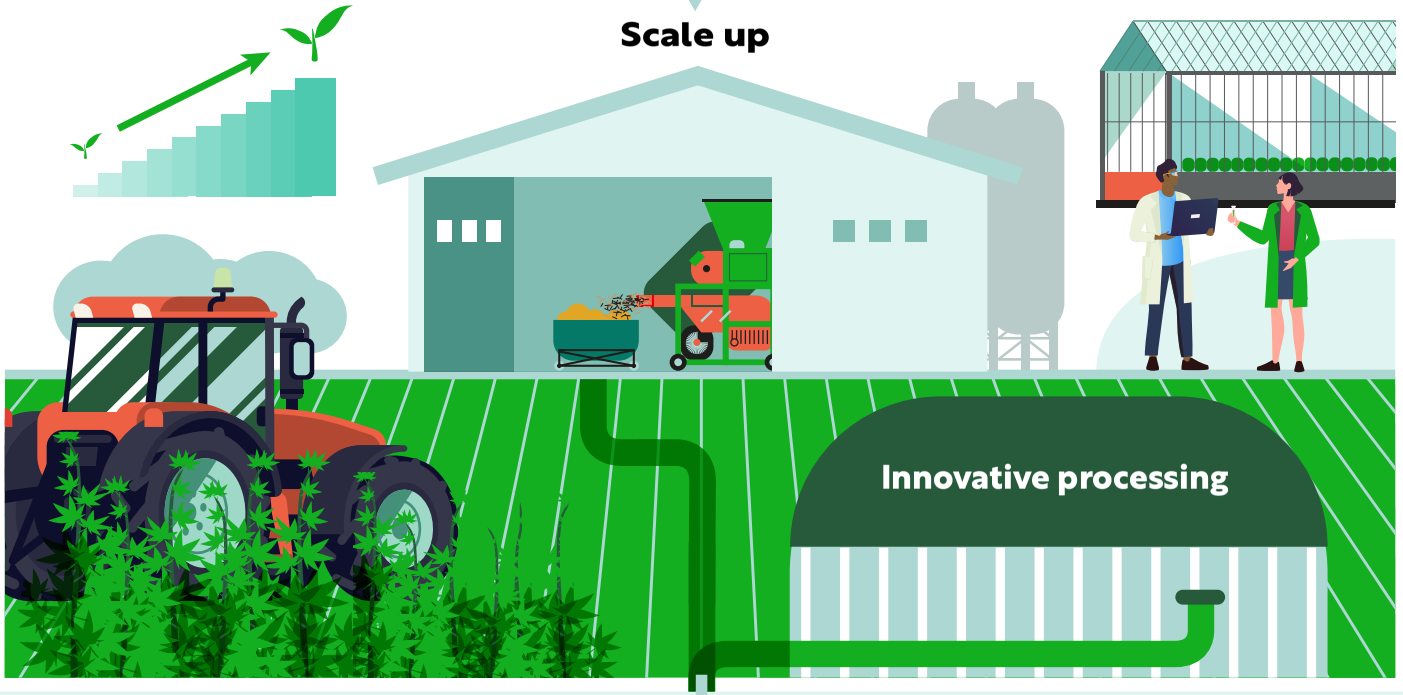


Bioenergy

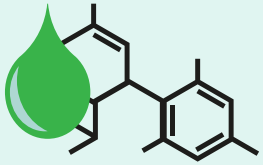
Pelleted hemp biomass will drive increased acreage of hemp cultivation whilst displacing 200 kt CO_2 from 2027.

Growth trials ⟷ **Plant breeding**

Scale up



Increase products on the market

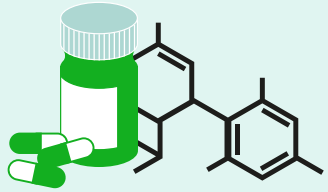


Oils and Proteins

Novel food products using hemp proteins and oils are displacing a range of high carbon food products.

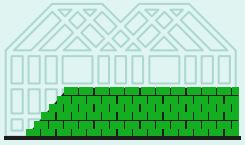
Textiles

New technology to cottonise hemp fibre will open markets in woven textiles, avoiding the social and environmental drawbacks of cotton.



CBD and Medicines

Oil from imported hempseed is already widely used in personal care products and pharmaceuticals, the UK market is estimated to be worth £1bn by 2025.



Construction

Hemp building products are predicted to have a value of >£200m and displace 1.3m tonnes of CO_2.

Automotive

The weight and elasticity of hemp fibre together with a strength comparable to carbon is driving the use of hemp in the body work of cars.

Annex 1:

Priority 1 – New variety roadmap

Date seed from HEMP-30 breeding programme available to farmers	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Seed oil profile			●		○		●		◆	
Varieties with no THC and/or high CBD available										■
Range of disease resistant seed and fibre varieties available										■
Rettability										■
Seed scattering										■

● HOH in Finola background ○ HGLA in Finola Background ● HOH in new background suitable for evolving UK markets ◆ Other novel oilseed profiles

Priority 1 – New variety roadmap

Trait	Present day	2024	2028	2031
Germplasm	• Finola widely cultivated seed variety, suitable for UK; short life cycle and height • UK bred high oleic variety approved for UK National Listing in 2021, and gaining traction internationally for its utility in the food industry • No UK commercial hemp seed production • Limited understanding of performance of hemp varieties under UK conditions • Hemp populations with increased genetic variation being developed for trait improvement using established fast-track breeding pipeline	• UK hemp certified seed production established • Better understanding of the performance of a range of varieties under UK growing conditions • New backgrounds suitable for breeding for UK conditions identified • Germplasm with variation in genes controlling key traits available	• Additional UK-bred varieties which perform better around a range of key traits undergoing registration trials • New traits being introgressed into a range of hemp backgrounds suitable for cultivation in the UK	• UK-bred varieties which perform better on a range of key traits available for farmers to grow in the UK
Oil profile	• Hemp oil profile attractive but unstable and unsuitable for use in many food industry applications • High Oleic Hemp (HOH) registered and ready for bulking • High GLA variety ready to enter registration trials	• HOH seed bulked and ready to be cultivated by UK farmers for use in the UK food industry • High GLA variety registered and ready for bulking • Germplasm with novel oil profiles available for development as the market demands • Introgression of HOH trait into other desirable hemp varietal backgrounds in progress	• High GLA certified seed bulked and ready to be cultivated by UK farmers for use in personal care & food industries • Seed available for farmers for HOH trait in different hemp backgrounds	• Seed for hemp varieties with a range of seed oils suitable for a different dietary and processing requirements
Disease resistance	• Evidence for disease problems (Sclerotina and downy mildew) emerging in Canada • Genes for broad spectrum disease resistance known	• Lines altered in disease susceptibility genes characterised • Laboratory assays for disease resistance in progress • Row trials starting	• Disease resistant varieties undergoing registration field trials	• Seed for disease resistant varieties available
Secondary metabolite profile	• Genes controlling CBD and THC well understood. • Entourage effects poorly understood but focus of research • Track record at York in manipulating biochemicals in range of species • Levels of THC and CBD not ideal for use of industrial hemp in a range of markets	• Zero THC and high CBD lines identified • Research starts to uncover effects of hemp metabolites beyond CBD and THC	• Zero-THC &/or high CBD varieties undergoing registration field trials	• THC-free seed and fibre varieties available
Rettability	• Some genes affecting rettability characterised	• Lines altered in genes controlling rettability characterised and assessment initiated	• Easy retting varieties undergoing registration field trials	• Easy retting varieties on the market
Seed scattering	• Inconsistent maturation leads to loss of seed in soil and through bird attack • Some genes known to control seed loss known in other species	• Lines altered in candidate genes controlling seed scatter identified • Assessment of lines initiated	• Reduced seed scatter trait introduced into elite varieties	• Reduced seed scatter trait available to the market in elite variety background

Timeline for introgression of novel trait into a new variety

	-9	-8	-7	-6	-5	-4	-3	-2	-1	0
Establishment of M2 hemp population with variation in key target genes										
Screening and crossing for lesions in target genes										
Four generations of crossing between variant and (new) parental background										
Row trials of promising hemp lines										
Small scale bulking of seed for use in field trials										
Field trials benchmarked against parental varieties										
Distinctiveness, Uniformity & Stability (DUS) field trials for UK variety registration										
Value Cultivation and Use (VCU) field trials for UK National Listing										
Bulking of seed for use by farmers										
Seed enters market										

Annex 2:

Priority 2 - Roadmap hemp cultivation

Parameter	Present day	2024	2028	2031
Hemp cultivation	• 800 ha under cultivation • Niche crop grown at a small scale by innovative enthusiasts • A few mainstream farmers testing hemp on a limited acreage • Seed is difficult to get hold of, almost all imported and expensive	• 5,000 ha under cultivation • Some farmers are adopting hemp as a break crop • More mainstream farmers testing hemp on a larger acreage • New varieties with different seed oil expand markets for hemp seed products • Growers can access UK sources of certified seed & best practice for hemp cultivation	• 30,000 ha under cultivation • New dual purpose varieties and better fibre varieties enter the market • Hemp is widely grown by forward looking farmers as a break crop • Up to half UK growers are buying UK sources of certified seed	• 80,000 ha under cultivation • Hemp is seen widely as a viable alternative to OSR as a break crop • Cultivation is still mainly to-contract but spot markets for hemp are emerging • Majority of UK growers are buying UK sources of certified seed
Crop performance	• Nutritional requirements for UK conditions not characterised • Performance as break crop poorly understood • Varietal performance under UK conditions poorly understood • No UK adapted varieties available	• Multi-site field trials provide evidence base for performance and nutritional requirements of several hemp varieties under UK conditions • Trials demonstrate effectiveness of hemp as a break crop in rotations of cereals	• Experience with hemp cultivation increases yields of both seed and biomass • Risk of development of disease and pest problems are mitigated through diversified rotations, breeding and monitoring • New agronomic methods eg seed coating, decrease inputs and increase yields	• Increased yields and optimised inputs enhance returns to farmers whilst maintaining soil carbon and biodiversity • New varieties with UK adapted traits eg maturity, yield, establishment, pest/disease resistance start to become available
Carbon performance	• Carbon sequestration under UK conditions not characterised • Potential in soil carbon enhancement not well understood	• Trials have demonstrated performance of hemp in sequestering CO_2 both above and below ground • ELMS and Voluntary Carbon Markets (VCM) view hemp as an element in decarbonisation strategies • Farmers testing technology for hemp in anaerobic digestion, bioenergy and biochar	• Widespread use of hemp cultivation and hemp products in VCMs increases markets for hemp and reduces their cost • ELMS supports hemp as a means to mitigate agricultural emissions and improve soil health • All farmers can access biomass processing facilities for shiv and/or fibre markets, leading to long term sequestration in products	• Hemp is a key contributor to decarbonisation of UK agriculture

Priority 2 - Roadmap hemp cultivation (cont...)

Parameter	Present day	2024	2028	2031
Harvesting	• Harvesting machinery available but requires optimisation and skills development • Retting inefficient and unreliable • Seed processing facilities (drying and pressing) not easily available	• Several standardised robust fibre and stalk harvesters become available • Farmers collaborate/contract-out to source specialist equipment locally • Novel efficient retting options are developed, which are tailored for specific end uses • Easy-retting varieties are trialled	• Widespread availability of robust harvesting machinery • Easy-retting varieties become available • Novel retting options are in use • Specialist hemp harvesting contractors are established	• Novel harvesting options are emerging eg that allow harvest of seed and fibre, reducing costs and losses • New varieties with limited seed scatter become available reducing losses and increasing yields
Communication	• Information on variety performance is not widely available • Connections between hemp growers and end users ad hoc and insecure	• Results from field trials widely disseminated and partnerships established with key trade, networking and levy boards • Growing network of hemp users contract directly with growers • Growers can easily find out what specifications are required by buyers for different applications	• Up-to-date information on varieties and best agronomic practice is available to growers • Vibrant networks connect growers to their end markets • UK seed is widely available • Growing international connections enhance markets for hemp growers	• UK is seen internationally as a key source of agronomic innovation and best practice for hemp cultivation • The market supports an effective network supporting hemp growers
Regulation	• Regulatory regime is slow, expensive and not aligned with growers needs	• Licensing administration has transferred to Defra and streamlining prevents delays • Review of THC limit is undertaken and decision made on whether to change the limit	• Home Office and DEFRA maintain regular contact with growers and processors to ensure effective oversight that is responsive to industry needs	

Annex 3:

Priority 3 – Roadmap for hemp industries

Sector	Present day	2024	2028	2031
Food, beverage, pet and animal feed	• Raw materials mainly imported • Excellent science base for optimisation of seed oil • Connections between primary producers and end users are poor • Seed oil profile attractive but unsuitable for some food industry applications	• Facilities for processing hemp seed available • Speciality markets for hemp oil have expanded • Mainstream food manufacturing initiates use of the stable hemp oils produced from new varieties bred and grown in the UK • Protein from hemp meal starts to be incorporated into vegan meat and be used in mainstream food & beverage • Residual meal used as desirable ingredient in pet, animal & fish feed	• The stable hemp oils produced from new UK varieties are in widespread use in food manufacturing • UK hemp oil is in demand internationally because of its quality, provenance and sustainability • Protein from hemp meal is widely used in vegan meat and as an ingredient by mainstream food & beverage manufacturers • Residual meal displaces soy & animal protein as high quality ingredient in pet, animal & fish feed	• High value hemp oils with novel fatty acid profiles designed for different dietary requirements are entering the market • Export markets for UK hemp oil are well established and growing • Novel food products using hemp proteins and oils are displacing a range of high carbon foodstuffs • Hemp seed residues command high prices in animal feed sectors
Construction	• Hemp construction products are proven and demand market is huge but investment needed for scale up • UK is a global leader in hemp construction but risks losing this first mover advantage • Awareness is low amongst mainstream companies and consumers • UK manufacturing is small scale and products are expensive because carbon and other benefits are not accounted for • Artificially inflated prices of imported hemp construction products & post-brexit supply chain problems	• One large construction company has taken on hemp products as a means to reduce the emissions from construction • Widespread workforce training in hemp-based construction established • Architects further engaged in specifying hemp products in their designs • Investors engaged to develop scale processing of hemp for UK construction, lowering costs	• Large scale processing of hemp for construction in place; potential integration with production of aviation fuel and speciality chemicals • Hemp insulation and hemcrete are widely used across the construction industry and benefit from carbon credits	• Range of novel, carbon negative building products that use hemp are on the market • UK has built on its leading position to become the go-to place for expertise and innovation in hemp-based construction • Innovation, economies of scale, integration with production of materials, chemicals and fuels together with carbon credits make hemp-based construction low cost and high performance

Priority 3 – Roadmap for hemp industries (cont...)

Sector	Present day	2024	2028	2031
Textiles	• Most hemp textile grade fibre is imported and expensive • Low awareness of advantages of hemp vs cotton & synthetics • Innovation is needed for adoption of hemp into mainstream products	• Technology for cottonisation of fibre from UK-grown hemp commercialised • Hemp starts to replace plastics in non-woven products eg wipes • UK woven and non-woven companies and designers engaged.	• Technology for production of high quality, sustainable textile fibre established in the UK and being exported • Sustainable textile brands founded on UK hemp are establishing	• Improved varieties and technology development make fibre cheaper and improve quality • UK hemp brands known internationally
Composites for automotive and wind energy	• Connections with UK automotive manufacturing absent • Potential in wind turbines appreciated but innovation needed to overcome technical barriers	• Fibre from UK-grown hemp being incorporated into UK-manufactured automotive panels • Collaboration on development of hemp fibre in high performance composites for a range of applications	• Fibre from UK hemp widely used in UK automotive manufacturing • Commercialisation of hemp fibre in high performance composites for automotive and other sectors	• Light weight, strong hemp-based biorenewable composites contribute to efficient, low impact aviation, automotive and wind energy industries
Speciality chemicals	• No UK production of CBD because of regulatory hurdles; international competitors ahead in technology and commercialisation • CBD markets overheated and volatile • Excellent science base in plant biochemicals able to optimise balance of metabolites • UK is second largest market for CBD in the world	• More appropriate regulation of hemp allows processing of leaves and flowers and establishment of industries using hemp 2°ry metabolites • CBD products being manufactured from UK-grown hemp • Characterisation of the effects of new hemp 2°ry metabolites	• Hemp varieties with zero THC simplify regulatory status of hemp speciality chemicals • New products on the market from hemp metabolites based on CBD and other molecules • Better understanding of the effects of multi-component pharmaceuticals increases demand for whole hemp products and products with defined profiles	• Thriving high value UK industry based on hemp secondary metabolites exporting products worldwide
Biofuel	• Innovation needed to allow use of biomass in on-farm AD • Supply chains and investment absent in the UK for hemp-based aviation fuels	• Hemp biomass in use as a feedstock for on farm AD • Collaboration to demonstrate hemp as an aviation fuel feedstock	• Commercial production of hemp aviation fuel started, potentially integrated with manufacture of construction materials and speciality chemicals	• Commercial production of hemp aviation fuel established, supply chains integrated with manufacture of construction materials, bioenergy and speciality chemicals
Bioenergy	• Small scale briquette manufacture from hemp dust for domestic heating fuel	• On farm or regional facilities for large scale manufacturing of pellets for heat and power generation that are aligned with bioenergy sustainability criteria	• Hemp for bioenergy production has stable markets with ongoing monitoring of sustainability, acting as an "insurance policy" for use of hemp biomass	• Stable UK bioenergy markets supplied by sustainably produced hemp raw materials
Carbon credits	• Evidence base inadequate for use of hemp products in carbon credit markets	• Carbon credits on construction products and biochar from UK-grown hemp available on well regulated and respected platforms	• Further expansion of the carbon credit market for construction and biochar • Reputation of UK hemp based carbon credits drives demand by companies aiming for net zero by 2030	• Steady markets for carbon credits from construction and biochar products • Novel composites and building materials benefitting from carbon credits.

Priority 3 – Roadmap for hemp industries (cont...)

Sector	Present day	2024	2028	2031
Cross cutting support from the Hemp 30 innovation programme that catalyses product development and growth				
Hemp on-farm processing innovation programme	• Hemp30 WP5 supports RD&D to deliver new process for on-farm decortication & fibre cottonisation, use in AD, biochar, on farm pelleting of biomass	• Innovation programme enables capture of value before the farm gate delivering new sources of income and carbon savings • Innovations are used further up the hemp supply chain to deliver sustainable products	• Hemp processing and use on farm is an established part of the agricultural economy delivering value and carbon savings • Ongoing innovation, knowledge sharing	• Technology and knowledge for processing hemp on farm is being exported world-wide • Farms are well integrated into supply chains and capture value
Supply, value & and innovation chain development	• Hemp30 WP7 communication programme connects end users with primary producers, research providers & policy makers to initiate and strengthen hemp supply chains	• Connections established between primary producers and the end users in different sectors enabling integration of supply chains and investment in large scale facilities • New connections established between researchers and policy makers with the hemp supply chains accelerating innovation • Industrial hemp trade association established and servicing a wide range of industries and primary producers	• Hemp supply and value chains are established and responsive to market demand in the UK and internationally • rapid innovation arising from excellent knowledge sharing • Regulation that is responsive to the needs of different sectors	• Vibrant hemp ecosystem where businesses are aware of the complementary or competing interests in adjacent sectors, researchers are accessible and engaged in hemp product development, policy makers and regulators are aware and support sustainable development of the hemp-based industries
Environmental, economic and social impact assessment	• Hemp30 WP8 provides evidence base for use of hemp for carbon credits and sustainability in food, fuel and material markets	• Markets in carbon credits, food, construction, energy, materials and fuel use the sound evidence base to guide their product development and marketing • Policy makers and regulators use the social environmental and economic analysis to make better policy and regulation • Uses of hemp for applications that are not sustainable are avoided	• UK hemp products have an excellent reputation for reliable sustainability claims, which increases demand for UK products in export markets • Criteria for sustainability reporting in hemp products are agreed • UK perceived internationally as the go-to place for understanding of sustainability in hemp supply chains	• Demand for UK hemp products drives up value from hemp to farmers, manufacturers and the UK more widely. • Innovations are rapidly assessed according agreed criteria for the sustainability impact accelerating adoption of those that have a positive impact

Annex 4:

Commentary on projections

1. Area under cultivation of hemp

- 250ha of seed crop being grown, accounting for >30% of the estimated 800ha hemp cultivated currently. Interviews suggest plans 1,000 ha for seed in 2022 with licenses for 3* this area
- 2024 Increase *4 as HEMP30 field trial results come out, availability of seed increases and the High Oleic Acid variety becomes commercial available
- 2025, doubles again to 10 kha as farmers who have dipped their toe in 2024 increase their planting, knowledge on the effects on the soil emerges and markets for hemp increase and diversify
- 2026 - 2030 15kha added each year driven by increasing markets for hemp and carbon markets.

2. Yield – biomass

- 2022 stakeholders estimated average retted straw yield of 5.5t/ha. This is conservative because a substantial proportion of the biomass is lost during retting.
- 2023 -24 added a small yield increase of 0.5t/ha based on increasing experience of farmers combined with better knowledge and evidence from field trials
- 2025–30 increases of biomass yield of 1t every 3 years, getting 8t/ha in 2030. This might seem ambitious, but there are several reports of yield of >15t/ha now. Set against this, however, I'm estimating that 50% of the crop is dedicated to oilseed and biomass yield from the seed crop will be lower and of lower quality.

3. Yield – seed

- 2022 - 23: estimate oilseed yield average of 1.5t/ha. This year growers in the North East of the UK have achieved 2t/ha so the estimate is conservative
- 2024 - 30 assumed yield increases of 0.2/ha every two years achieving 2.4 t in 2030 through a combination of improved agricultural practice and new varieties entering the market

4. Area cultivated fibre vs oilseed %

- 2021 30% of 800ha is cultivated for oilseed
- 2022 - Lukie's interviews suggest 1,000 ha hemp planned for 2022 will be harvested for oil.
- 2023 This increases to 50% as markets for hemp food and feed products increase sharply - for instance, if good hemp sourced their seed from the UK, that would create an instantaneous market. And new HOA oilseed variety is available for farmers
- 2025 onwards, 50% of the are under hemp is cultivated for oil with the residual biomass being used for lower value applications such as biochar, biogas, bioenergy and biofuel
- 50% of the area cultivated is fibre crop used in construction textiles and composites

5. Yield of oil, protein, fibre and shiv

- Seed - assume 30% of the dry weight is oil, 30% protein, 30% carbohydrate, 10% insoluble fibre-
- Fibre represents 25% of the dry weight of biomass (estimates in the literature vary and this is a conservative estimate)
- Shiv represents 60% of the biomass
- Dust from processing is 10%

6. Hemp used in food, feed and personal care

- Assumed that 100% of the oilseed is used in food and feed markets. Note that seed products may also be used in non-food markets - eg as drying oil or in personal care.

7. Hemp used in bioenergy

- 2022–23 assumed that just the dust is used in bioenergy ie 15% of the biomass available
- 2024–27 50% of available biomass is used for bioenergy because this is a readily available market which requires little technical innovation to satisfy
- 2028 - 31 this reduces to 25% of the available biomass as higher value applications become available. Note that the total amount of biomass used in bioenergy continues to rise gently, it is only the that % reduces

8. Hemp used to manufacture bioethanol to be used in aviation fuel

- This does not start until 2027 when a small amount is used for demonstration purposes. This rises to 25–30% from 2029 as a small biorefinery becomes operational. This is based on the beta renewables plant in crescentino, Northern Italy, which produced 40,000 t ethanol from 200,000 t biomass (mainly grass). You would expect a hemp based biorefinery to produce more ethanol per ton because it is richer in cellulose and hemi-cellulose and lower in lignin. Note that the plant will produce a range of byproducts - biogas, bioenergy and CO_2.

9. Hemp in used in construction

- Insulation and hempcrete are being manufactured at a small scale already. Based on industry estimates, 40% of the hemp that is grown is going into construction and will continue to do so until 2023. From 2024 the absolute mass of hemp used in construction will grow steadily but it will drop as a proportion of the biomass available. This is because bioenergy, which will have shorter lead times for deployment, will take up a large proportion of the biomass that is available from 2024. Construction will pick up to remain steady at around 30% of biomass from 2025 onwards
- It was estimated that 20% of the hemp that is used in construction is insulation batts/boards and 80% is hempcrete - this is because around 25% of the biomass is bast fibre and 60% shiv. The fibre will have other higher value uses, at least in the long term.
- Commercial figures, were used to calculate the mass of hemp needed to deliver the current insulation requirements.

10. Hemp used on farm

- Estimate that about half of the hemp biomass that is produced in 2021 is used on farm, mainly for animal bedding.
- This % drops until 2025 (but the absolute tonnage grows gently), where it stabilises at 20% of the crop.
- Three main uses for hemp on farm are envisaged from 2025 - anaerobic digestion (AD) (35%) animal bedding (30%) and conversion to biochar for carbon markets and soil improvement(35%).

11. Hemp used in textiles

- Estimate that it will take five years to fully commercialise cottonised yarn production from hemp so production will start in 2027. Yield of yarn is likely to be low but the residues can be used for other purposes. Therefore the % of biomass used in yarn is quite low growing from 0.5% in 2027 to 2.5% in 2031.

12. Hemp used in high performance composites

- Use of hemp in high performance composites requires innovation which will take time. A similar growth trajectory and amount used as for textiles has been projected.

13. Hemp used in wellbeing products

- Based on FSA and industry data on quantities and numbers of people using CBD, UK consumption has been estimated at approx 150t pa
- Using CBD as a typical wellbeing product
  - assume regulation allows processing of UK grown hemp in 2024
  - it takes three years to ramp up production to this level

14. Calculations of value of products in different markets

- The price of products from hemp were estimated from interviews and prices advertised on the internet eg spot market prices and value calculated from the mass of hemp used in each market.
- Where a product is made entirely from hemp - eg seed oil, the whole value of the product has been used. Where the product contains only a percentage of hemp, the value was multiplied by the % of hemp in the product on a mass basis eg hempcrete, is approx 30% hemp by weight so the value of hempcrete was multiplied by 0.3
- Where products sequester CO_2, eg building markets, an extra £100 was added for each ton of hemp used from 2025 onwards.

15. Displacement and sequestration of CO_2

- The basis of these calculations is very simple and needs the attention of a proper carbon accountant in Phase 2
- For displacement,
  - the carbon footprint of the hemp product is subtracted from the carbon footprint of the existing product for a given functional unit (eg an amount of energy or a square metre of insulation). Where no figures are available for hemp, a similar material is used as a proxy eg flax for hemp insulation. The mass of hemp used for that functional unit is worked out and the CO_2 saved through use of the hemp product rather than the competing product calculated.
- For sequestration
  - 1 ton Biomass typically contains 0.4 t carbon and 1 ton carbon represents 4 ton CO_2 so each ton of biomass sequesters approximately 1.6 ton CO_2
  - The mass of hemp that is used in the building product is multiplied by 1.6 to give the tons of CO_2 that are sequestered
  - Note that this does not take account of GHGs that are emitted during cultivation and processing of the hemp

Abbreviations

AD	anaerobic digestion
CBD	cannabidiol
ELMS	Environmental Land Management Scheme
GHG	Greenhous Gas Emission
GLA	gamma linlolenic acid
HOH	High Oleic Acid Hemp
THC	Tetrahydrocannabinol
VCM	Voluntary carbon market