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The Embodied Biodiversity Impacts of Construction Materials

Research Report

November 2023

This report presents the results of a 2023 study carried out by Expedition Engineering, supported by the Institution of Civil Engineers (ICE) Research and Development Enabling Fund, into the embodied biodiversity impacts of construction materials.

The project aimed to equip those working in the built environment with a qualitative understanding of how biodiversity is impacted throughout the lifecycles of the materials used by the construction industry in the UK.

The work has been enabled and reviewed by the ICE's Research and Development group. We would like to thank the ICE for supporting this research and its dissemination.

This research has also been enabled by extensive engagement with the construction industry supply chain, including engineers, contractors, architects, infrasructure providers, and charities, as well as specialist biodiversity experts.

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This report is supported by an appended Evidence Base, available on request.

Executive summary

Executive summary

'Nature is our life-support system...and ultimately we are committing suicide by proxy, because the loss of nature and biodiversity comes with a steep human cost...it means the timber, chemicals, building and construction industries taking their impacts on nature into account in their business plans'

UN Secretary General António Guterres, remarks at the 2022 COP15 summit[1]:

Biodiversity is declining more quickly than at any time in human history, and the sixth 'mass extinction event' we have entered is the first primarily driven by human activity[2,3]. The crisis of biodiversity loss is deeply connected to climate change, and experts have suggested that the biodiversity crisis is 'as urgent' as the climate crisis[4]. The built environment is a significant contributor to this crisis: the WEF identified it as one of the three systems responsible for over 80% of global biodiversity loss, and threats from infrastructure and the built environment impact 29% of threatened and near-threatened species[5].

The UK committed to the Kunming-Montreal Framework to restore biodiversity at COP15, has committed to become nature positive by 2030, and will introduce Biodiversity Net Gain legislation in 2023 to prevent the net loss of habitats on new developments.

However, the site of a building or railway is not the only place its construction impacts biodiversity. All of the materials forming it must be extracted from mines, quarries and forests, manufactured, transported to sites, and eventually reused, recycled or disposed of. These processes can significantly impact biodiversity.

Built environment practitioners, including engineers, have great influence over the selection of materials used in construction, and have the power and responsibility to minimise the biodiversity impacts throughout the lifecycles of the materials specified in their designs. This behaviour change will only be possible when practitioners have the capability, opportunity and motivation to do so; these elements form the COM-B model for behaviour change.

One of those capabilities is knowledge of the impacts: an understanding of how, and to what extent, biodiversity is negatively impacted throughout the lifecycles of different materials. There is currently a lack of clear and understandable information to describe these impacts in a way to help practitioners in decision-making around materials.

This research is an initial scoping piece to start gathering information, help practitioners build an understanding of biodiversity impacts, and frame a way forwards for the industry.

Executive summary

Embodied biodiversity impacts

The concept of 'embodied biodiversity impacts' is proposed as a way for practitioners to describe these impacts.

Embodied biodiversity impacts are defined as the impacts on biodiversity as a result of all of the processes that take place throughout a material's lifecycle, which are not covered by other metrics such as Biodiversity Net Gain.

Embodied biodiversity impacts are analogous to embodied carbon, as the concept describes the impacts on biodiversity throughout the lifecycle of a material. However, these impacts depend on local factors to a greater extent than embodied carbon, including local habitats, species and environmental receptors. Unlike carbon, a multifaceted framework is required to truly understand embodied biodiversity impacts.

This research uses a framework based on four of the five 'key pressures' driving biodiversity loss, identified by the UN:


Land-use change


Direct exploitation of species


Pollution


Invasive species

This research makes a qualitative assessment of embodied biodiversity impacts through each of these four lenses.

Methodology for appraising impacts

The embodied biodiversity impacts of five key construction materials (concrete, steel, timber, earth and asphalt) are appraised using the 'key pressures' framework.

A four-stage methodology is used for this appraisal:

1. **Defining material assumptions**
2. **Mapping the high-level lifecycle processes**
3. **Identifying evidence of impacts on biodiversity**
4. **Rating the likely severity of impact**

Executive summary

Applying this methodology for the five materials, based on the UK supply chain, gives an insight into some of the most significant impacts and the maturity of the body of evidence for each:

Concrete

37.5 million m^3 of concrete is used in the UK every year. Most raw materials used for concrete are sourced from the UK and are subject to UK planning and environmental legislation. Quarrying for limestone requires land use, although rehabilitation is mandatory and can create long-term net gain where sites were previously on poor land. Cement production, mostly in the UK, causes air pollution, and aggregate mining and dredging in the UK can damage habitats.

Steel

The UK construction industry uses over 803,000 tonnes of steel every year. The raw material supply chain is varied, with imports from across the world, making it difficult to paint a single picture of impacts. Iron ore and coal mining in the UK supply chain has been shown to damage marine and land habitats and pollute groundwater; steel production, which takes place mostly in the UK, can cause air and water pollution, as can preparing steel for recycling or reuse.

Timber

The UK construction industry uses 5 million m^3 of softwood timber every year. The greatest area for impact on biodiversity is in the management of forests, which can provide rich habitats. Most timber is from FSC and PEFC certified sources, which require ecologically sensitive management, do not allow the development of monocultures, and prevent the use of pesticides. The impacts of sawn softwood timber are likely to be lower than other timber products.

Asphalt

20 million tonnes of asphalt are produced every year in the UK. The most significant impacts are from the sourcing and production of bitumen. The extraction and transportation of crude oil in order to produce bitumen can have significant negative impacts on biodiversity, despite regulation controlling the release of chemicals. The transportation of crude oil through pipelines has been shown to significantly impact marine biodiversity by generating pollution.

Earth

The UK produces 250 million tonnes of aggregate material every year. In addition to these aggregates being used as fill, the production of manufactured topsoil can have impacts on biodiversity as a result of removing natural topsoil. However, the available information presents limited evidence of the extent of these impacts and suggests further investigation is needed into the impacts from the manufacture of topsoil in particular.

Executive summary

Actions for practitioners

The findings of the research were reflected on in an **industry roundtable** with infrastructure clients, consultants, engineers and others in the construction industry. Four initial actions are proposed, for built environment practitioners to take to reduce the embodied biodiversity impacts of the materials they use in their designs.

These actions largely complement those that might be taken to reduce carbon, and strengthen the carbon driver to move to a circular economy.

1 Minimise the amount of materials needed

2 Prioritise reused materials

3 Utilise existing responsible sourcing and certification schemes

4 Understand where materials have been sourced from

Research challenges

Three key reflections emerged in the process of the research:

- a lack of available, credible, detailed, and unbiased data about biodiversity impacts.
- the challenge of enabling comparison between materials while maintaining a nuanced understanding of impacts
- the need to consider systemic impacts.

A routemap to action

Further work is needed to enable those working in the built environment to reduce the embodied biodiversity impacts of the materials they select, and ultimately enable the industry to address its contribution to the biodiversity crisis.

It is recognised that there is a need to develop a strategic routemap to provide practitioners with the capability, opportunity and motivation to make this change.

A framework for this routemap is proposed according to the COM-B model. This research provides a springboard to give practitioners the capability to understand, articulate and compare biodiversity impacts. Three key themes of work are set out to further develop the insights gathered in this report and transform them into useful tools for practitioners:

Giving built environment practitioners the **capability** to understand and improve the embodied biodiversity impacts of the materials they specify

Mapping complex global systems

Establishing clear boundaries

Defining an approach to quantification

Creating the **opportunity** for practitioners to improve those impacts

Developing **motivation** for practitioners to improve those impacts.

1 / Introduction

1.1 What is biodiversity and why is it important?

Biodiversity, or biological diversity, refers to the variety of life and the interactions between living things on earth. Biodiversity is a characteristic of ecosystems; ecosystems with a greater amount and variety of life and interactions have greater biodiversity. There are many ways to describe and quantify aspects of biodiversity, including numbers of species, lifeforms and habitats.

Biodiversity is essential to supporting all life on earth, including humanity: pollinators are responsible for one third of the world's crop production; plants absorb rainfall, reducing the risk of flooding; coral reefs and mangroves protect coastlines from storms; and invertebrates maintain the health of the soil in which we grow our food[6].

Biodiversity is critical to humanity, because it underpins the resilience of the ecosystems we ultimately depend on. According to the International Union for Conservation of Nature (IUCN), the monetary value of the goods and services provided by ecosystems is estimated to amount to around $33 trillion every year[7].

Many valuations of ecosystems such as this are based on 'ecosystem services', or Natural Capital, but the value of biodiverse ecosystems goes beyond this in many ways. The landmark Dasgupta Review, published in 2021, drew out five sources of value provided by biodiversity[8]:

1 Human existence: ecosystems can help to control local climates, reducing the impacts from extreme weather events and protecting human life.

2 Human health: we harvest an estimated 50,000 plant species for traditional and modern medicine worldwide.

3 Human enjoyment and amenity: ecosystems allow us to derive joy from the natural world, generating economic value through ecotourism.

4 Natural goods and services: ecosystems maintain soil quality, pollinate crops and provide value as a resource. This is often the basis for Natural Capital valuations.

5 Its own existence and its moral worth: humanity values the existence of biodiversity, usually ascribed to specific species, even where it provides no direct value to us.

1.2 The global biodiversity crisis

Species are disappearing at the fastest rate recorded in human history, and it is widely agreed that global biodiversity is at risk of collapse[2]. Experts agree we have entered the sixth 'Mass Extinction Event', and the first one driven primarily by human activity[3]. Earlier mass extinctions wiped out up to 95% of all species, and it takes ecosystems millions of years to recover from such an event[9]. Humanity is heavily dependent on the biodiversity of the planet's ecosystems in many ways and is unlikely to survive millions of years without them.

One million of the world's eight million species of plants and animals are threatened with extinction; this figure does not include the millions of species of fungi, bacteria, and other organisms[10]. Since 1970, there has been an overall 70 percent loss in abundance of animal species[11]. The nature of biodiversity is not only in individual living things, but also in the interactions between them: those connections make cascading extinctions more likely[12].

Experts agree that the primary driver of this crisis is human activity. The UN identifies five key 'pressures' driving biodiversity loss[13]:

- land-use change (resulting in habitat loss)
- pollution
- the introduction of invasive species
- the direct exploitation of species
- climate change

The biodiversity crisis is deeply connected to other global crises; the UN defines it as one of the three Triple Planetary Crises, in addition to the climate crisis and global air pollution[14]. Multiple studies also link biodiversity loss to socioeconomic inequality. These crises are all interlinked: the climate crisis increases the frequency and severity of habitat destruction, biodiversity loss impacts access to food and clean water, and the deposition of air pollutants changes the chemical composition of our freshwater systems, disrupting ecosystems and driving biodiversity loss.

1.3 Biodiversity in the UK

The UK in particular is one of the most biodiversity-depleted countries in the world. A 2020 report from the Natural History Museum suggested that it has 'led the world' in biodiversity destruction, accelerated by the advent of large-scale farming and the Industrial Revolution[15].

The UK is a signatory to the Convention on Biological Diversity, which sets objectives to preserve biodiversity, use natural resources sustainably, and ensure the benefits of those resources are shared fairly and equitably.

In 2010, the UK government committed to the Aichi Biodiversity Targets, all of which were due to be met by 2020. Despite this, a UN report in 2020 indicated that the UK (and the world) had missed the majority of these targets[16].

At COP15 in 2022, the UK signed the Kunming-Montreal Global Biodiversity Framework, which succeeds the Aichi Targets and sets four goals to minimise biodiversity loss[17].

1.4 Biodiversity and the construction sector

There is a need for action to reverse the continuing loss of biodiversity, and the construction industry has a part to play. Threats from infrastructure systems and the built environment impact 29% of IUCN-designated threatened and near-threatened species[5], as buildings and infrastructure assets require land-use change, generate noise and air pollution, and can leach toxic materials in surface water run-off.

In the UK, Biodiversity Net Gain calculations will be implemented in November 2023 to begin to address these effects, initially on large developments. Developers will be required to demonstrate a net increase in on-site biodiversity of at least 10 per cent on completion of a development, compared with a pre-development baseline. This increase is calculated based on a series of metrics developed by Defra, principally concerned with the suitability of available habitats on the site.

The UK Government has introduced Biodiversity Net Gain credits for developers: these are all based on the presence of habitats, either as land area, hedgerows or watercourses, and can be

bought to compensate for biodiversity loss on site. These credits range in cost from £42,000 to compensate for a unit area of wetland or traditional orchard grassland, and from £650,000 to compensate for a unit of lake habitat. Purchasing these credits to compensate for on-site biodiversity net loss also incurs a double multiplier, incentivising developers to prioritise on-site net gain.

The government has also pledged funding to help meet these targets: in 2023, £9.6 million was pledged to help councils hire specialists for nature-positive developments[18].

1.5 The missing piece

Importantly, the site of a completed building, railway or dam is not the only place where its construction impacts biodiversity. All the materials that make up those assets – the concrete, steel, timber, earth and everything else – typically require raw materials to be extracted, manufactured, transported to site and eventually disposed of.

Those processes also impact biodiversity: the quarrying of cement materials can destroy valuable limestone habitats, previous approaches to managing forests for timber have historically introduced biodiversity-poor monocultures, and the noise generated by transporting materials can affect wildlife near to transport corridors. These methods of extraction, manufacture and disposal have been significant contributors to biodiversity decline in the UK and elsewhere, and would not be captured in the Net Gain calculations of a new asset.

The construction industry uses a significant amount of materials, accounting for 55 per cent of all the materials used in the UK[19]. Civil engineers therefore have great leverage over the potential reduction in biodiversity loss, through their material choices.

Sustainable specification of materials is an area in which the profession has the power and the responsibility to take action on reducing biodiversity loss associated with our projects.

1.6 The role and power of the built environment professional

Practitioners working in the built environment, including civil engineers, can have great influence in decisions about which materials are used in construction (and how), from early stage conceptual design decisions through to specification of materials.

Considering the environmental impacts of materials throughout their lifecycles, and factoring those impacts into decision-making, is not a wholly new concept. In recent years, civil and structural engineers have increasingly recognised the importance of embodied carbon, and its comparatively significant contribution to the whole-life carbon of buildings.

At an industry level, significant work has enabled embodied carbon to be considered and quantified: carbon data has been gathered to enable effective decision-making, standards such as PAS2080 have been published to set best practice approaches for managing carbon, and a new proposed Part Z of the building regulations, which would regulate and mandate whole-life carbon management in buildings, has the support of government and is currently in consultation.

The construction industry has responded to the carbon challenge and has the responsibility and power to do the same with biodiversity challenge.

Critically, although it is anticipated that the impacts of material supply chains on biodiversity are likely to be significant, there is currently very little accessible and understandable information to help material specifiers make those decisions. Material lifecycle impacts are currently not covered by Net Gain requirements, and there is little incentive for civil engineers to spend time finding that information, or indeed to prioritise it in decision-making. A 2022 study on the use of digital tools in the built environment showed that fewer than 10 per cent of respondents considered using tools to measure biodiversity impact[20].

There is a need to enable practitioners working in the built environment to understand, analyse and prioritise the biodiversity impacts of the materials they choose for construction.

2 / *Methodology*

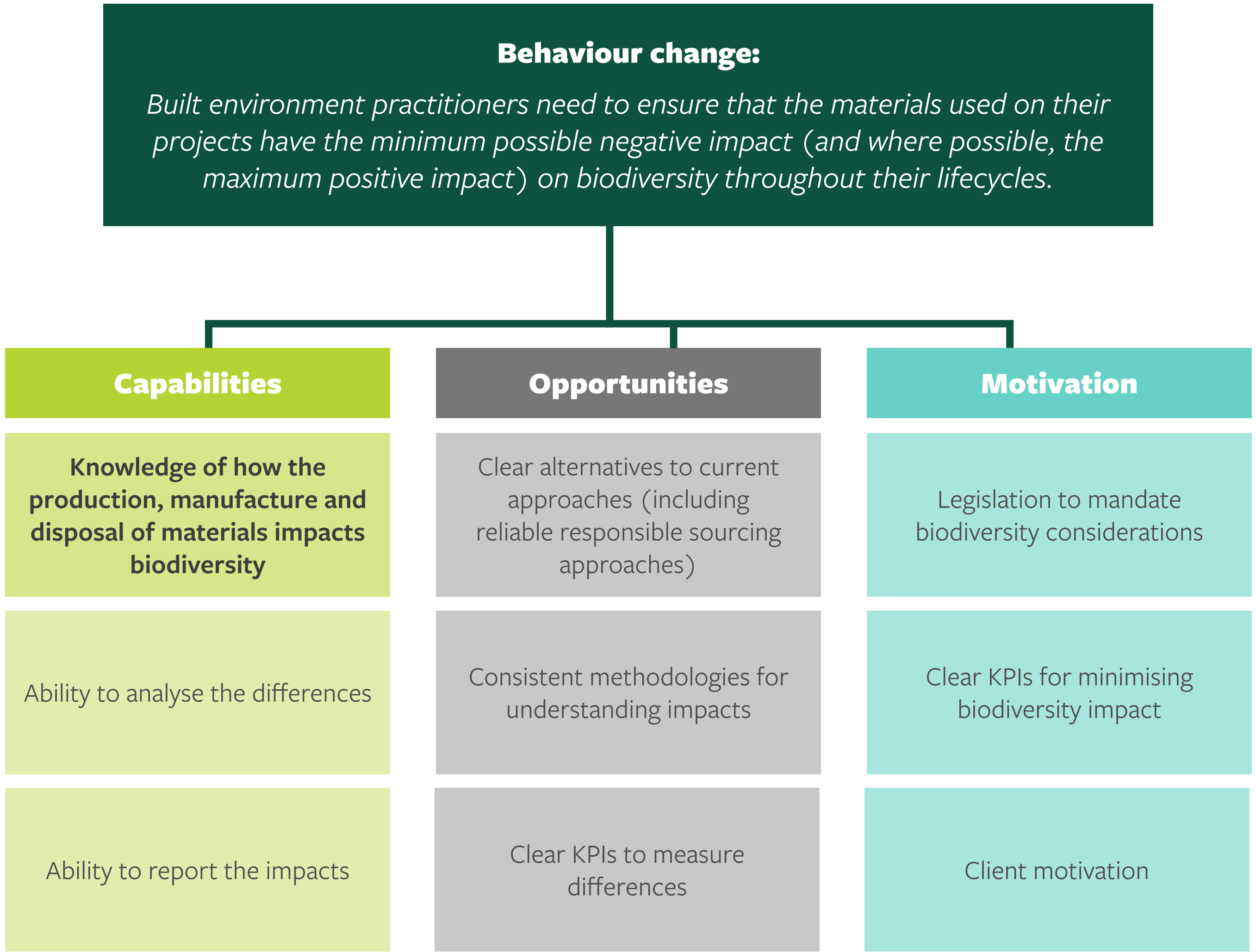
2.1 Research focus

Expedition propose that a behaviour change is needed, to reduce the contribution made by the construction industry towards biodiversity loss.

Built environment practitioners need to ensure that the materials used on their projects have the minimum possible negative impact (and where possible, the maximum possible positive impact) on biodiversity throughout their lifecycles.

The COM-B model for behaviour change is used to propose that practitioners will need the capabilities, opportunities and motivation to change their behaviour. This research focuses on developing a key **capability**: knowledge of how the production, manufacture and disposal of materials impacts biodiversity, and comparison of the differences between those impacts.

This research is a first step: to make this behaviour change effective, practitioners will also need opportunities to specify the right materials, and will need motivation to prioritise biodiversity among existing drivers such as cost, programme, and carbon. This behaviour change will require cross-industry collaboration and further work.



2.2 Research aims

This research has two aims:

1 To illustrate to **practitioners specifying materials for UK construction projects:**

- **how biodiversity might be impacted** throughout the lifecycles of the materials they might specify (these impacts are defined as the embodied biodiversity Impacts of those materials)
- **how severe those impacts are likely to be**, based on the UK's supply chain (and without knowing the exact supplier or origin of a material)
- **what factors influence the potential impacts** of that material, and how they can act to minimise the impact when sourcing and specifying materials later on in a project.

2 To communicate to the **wider industry**:

- what else needs to happen to develop this capability further
- potential future challenges in developing this knowledge
- other ways to develop capabilities, opportunities and motivation.

Embodied biodiversity impacts are:

the impacts on biodiversity due to all of the processes that take place throughout a material's lifecycle, which are not covered by other metrics such as Biodiversity Net Gain.

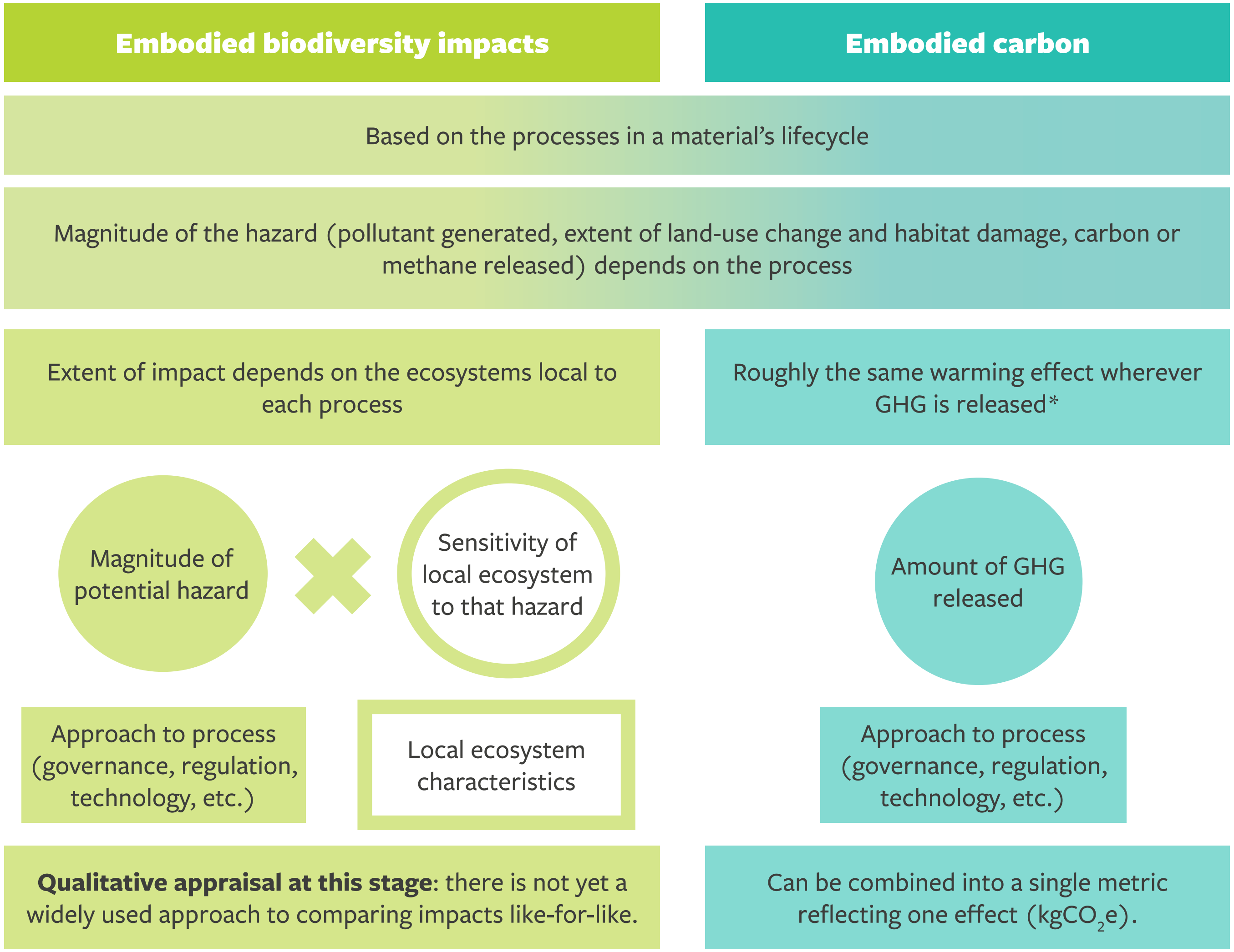
2.3 Comparison with embodied carbon

An approach is needed to enable practitioners to talk about and understand these impacts in a familiar language. '**Embodied biodiversity impacts**' as a concept is outlined as analogous to 'embodied carbon' with some key differences.

One difference is that many biodiversity impacts are heavily dependent on the nature of local ecosystems, whereas greenhouse gases have a very similar impact on warming regardless of where they are released. For example, quarrying limestone in a tropical location might risk damage to the habitat of a specific critical species, which may not be present in other quarrying areas.

This introduced an additional challenge in understanding biodiversity impacts, as there is a need to understand the processes within a material's lifecycle, and where they take place.

Understanding local habitats and species in detail was outside the scope of this initial research. This research provides a qualitative appraisal of embodied biodiversity impacts, as opposed to the use of a single metric as is used in the appraisal of embodied carbon.



2.4 The complexity of biodiversity impacts

Ecosystems are complex systems by nature: there is complexity in the numbers and kinds of living organisms, the interactions and dependencies between those organisms, the environmental conditions affecting those organisms, and the variety of processes that occur within those systems.

There are many dimensions needed to fully define how biodiversity is impacted as a result of human activity. Taking a factory as an example:

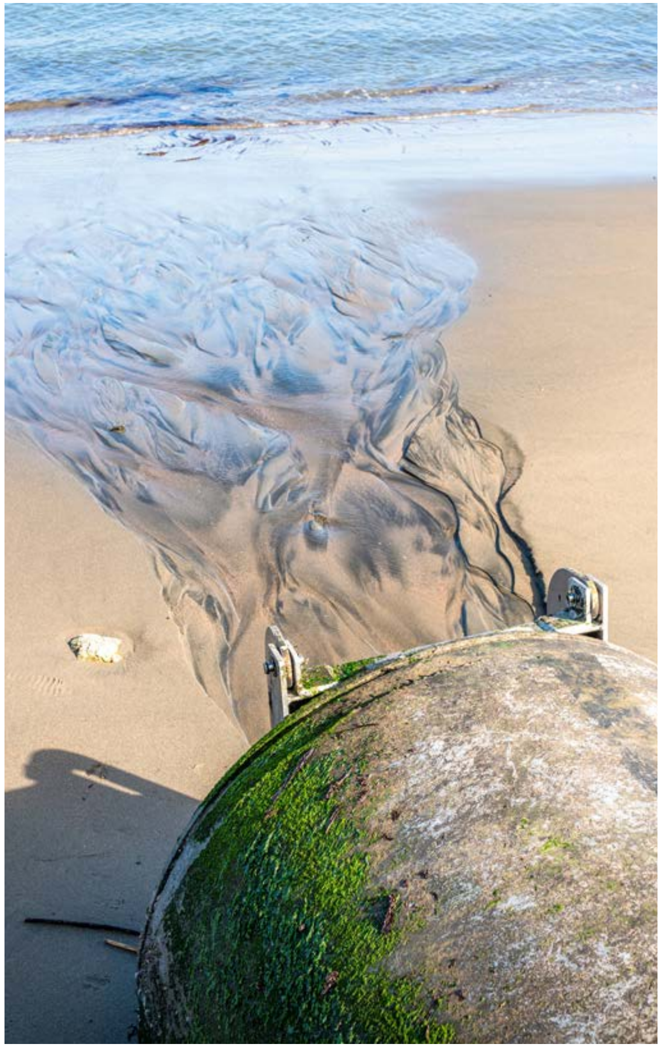
- **Geographic scope of influence:** for the factory to be built in the first place, land must be converted, which may have resulted in the removal of habitats, damaging biodiversity directly on and surrounding the factory's site. Pollution from the factory could be carried through the air and contribute to acid rain and acidification of river habitats, damaging biodiversity far from the factory's site.

- **Time of influence**: air pollution from the factory could have an impact on biodiversity within weeks of being released. Groundwater pollution could contaminate the soil over years of the factory's operation, polluting water sources decades into the future.

- **Extended consequences:** the loss of habitat from building the factory could cause a decline in a particular species of animal. This animal exists in a complex system, and its decline could result in the growth in number of the animal which was its prey.

The variety and difference in scales of impact, and the complexity of impacts, mean it is not always easy to tie impacts to a specific process, particularly where industrial activity takes place in clusters. The next page illustrates examples of these complex impacts and how they vary in scale and nature.

Understanding and articulating the complexity and severity of impacts across each of these lenses would not be a useful exercise for a practitioner, who will be making material decisions against many factors, including cost, function and carbon. Instead, a simplified approach was needed to articulate these impacts.



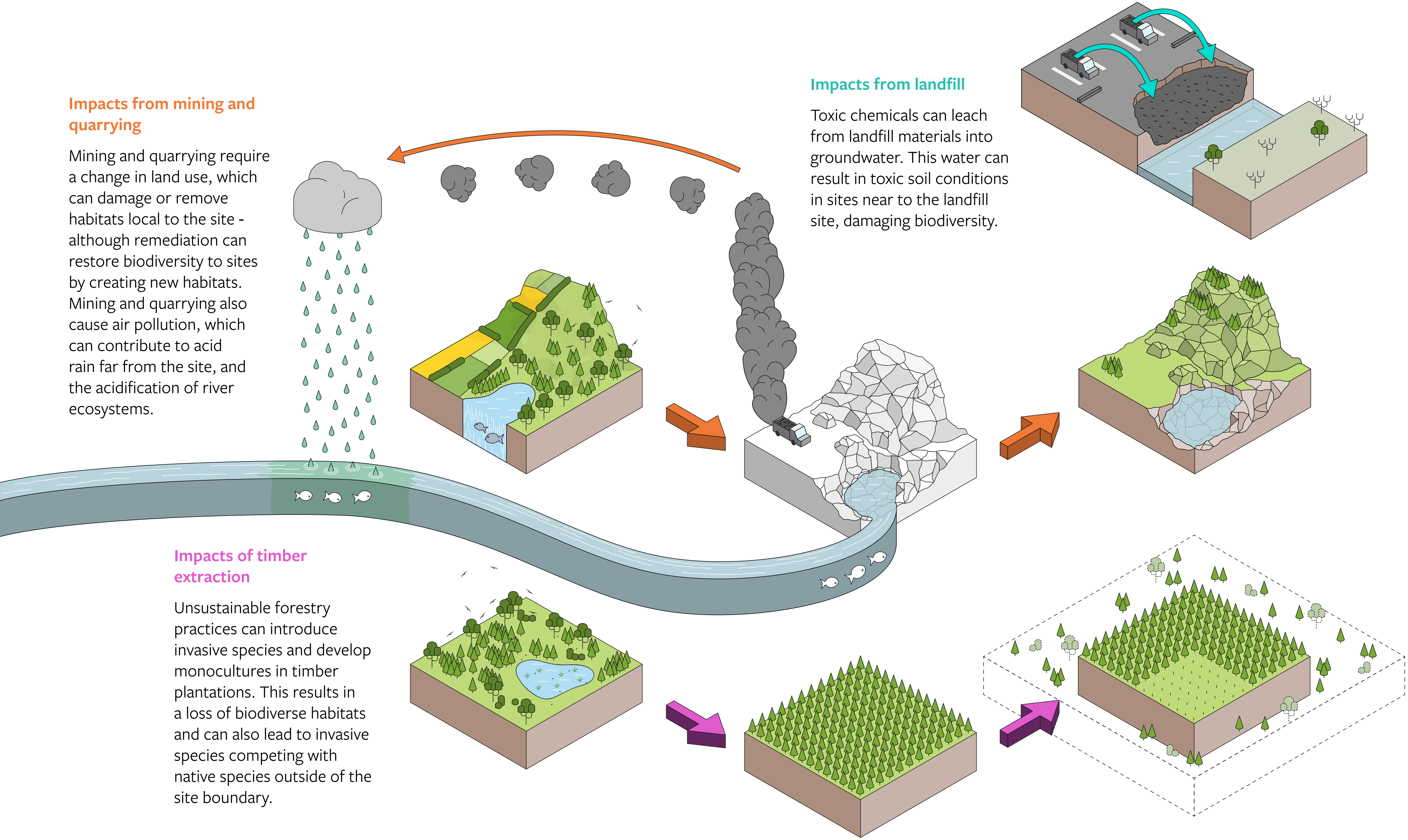
2.4 The complexity of biodiversity impacts

Impacts from mining and quarrying

Mining and quarrying require a change in land use, which can damage or remove habitats local to the site - although remediation can restore biodiversity to sites by creating new habitats. Mining and quarrying also cause air pollution, which can contribute to acid rain far from the site, and the acidification of river ecosystems.

Impacts from landfill

Toxic chemicals can leach from landfill materials into groundwater. This water can result in toxic soil conditions in sites near to the landfill site, damaging biodiversity.



Impacts of timber extraction

Unsustainable forestry practices can introduce invasive species and develop monocultures in timber plantations. This results in a loss of biodiverse habitats and can also lead to invasive species competing with native species outside of the site boundary.

2.5 A framework for understanding embodied biodiversity impacts

To give practitioners a useful and digestible way to understand biodiversity impacts, a simplified approach has been developed for this research.

Although Defra has created biodiversity metrics for Net Gain assessments, these are principally concerned with habitats, there is little data for existing facilities, and these do not cover processes outside of the UK.

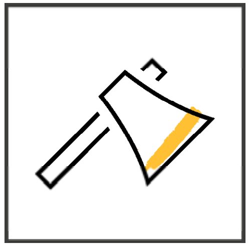
Instead, to align the research with existing language around biodiversity, the biodiversity impacts of materials are described using the **UN's five pressures on biodiversity.**

The UN environment programme defines five pressures driving global biodiversity loss: climate change, land-use change, pollution, the exploitation of species, and invasive species.

The climate change pressure is not addressed in this research: the contribution these materials make to climate change would be accounted for in embodied carbon considerations. Including the impacts of climate change on biodiversity in embodied biodiversity assessments would be 'double counting' these effects and, in this research, would have simply duplicated available information about carbon. This research did not, therefore, include climate change as a lens in the appraisal.

In the research, the impacts on biodiversity throughout each material's lifecycle are discussed through these four lenses.

Land-use change
Conversion of land covers such as forests, wetlands and other natural habitats for other uses: agriculture, development, etc.

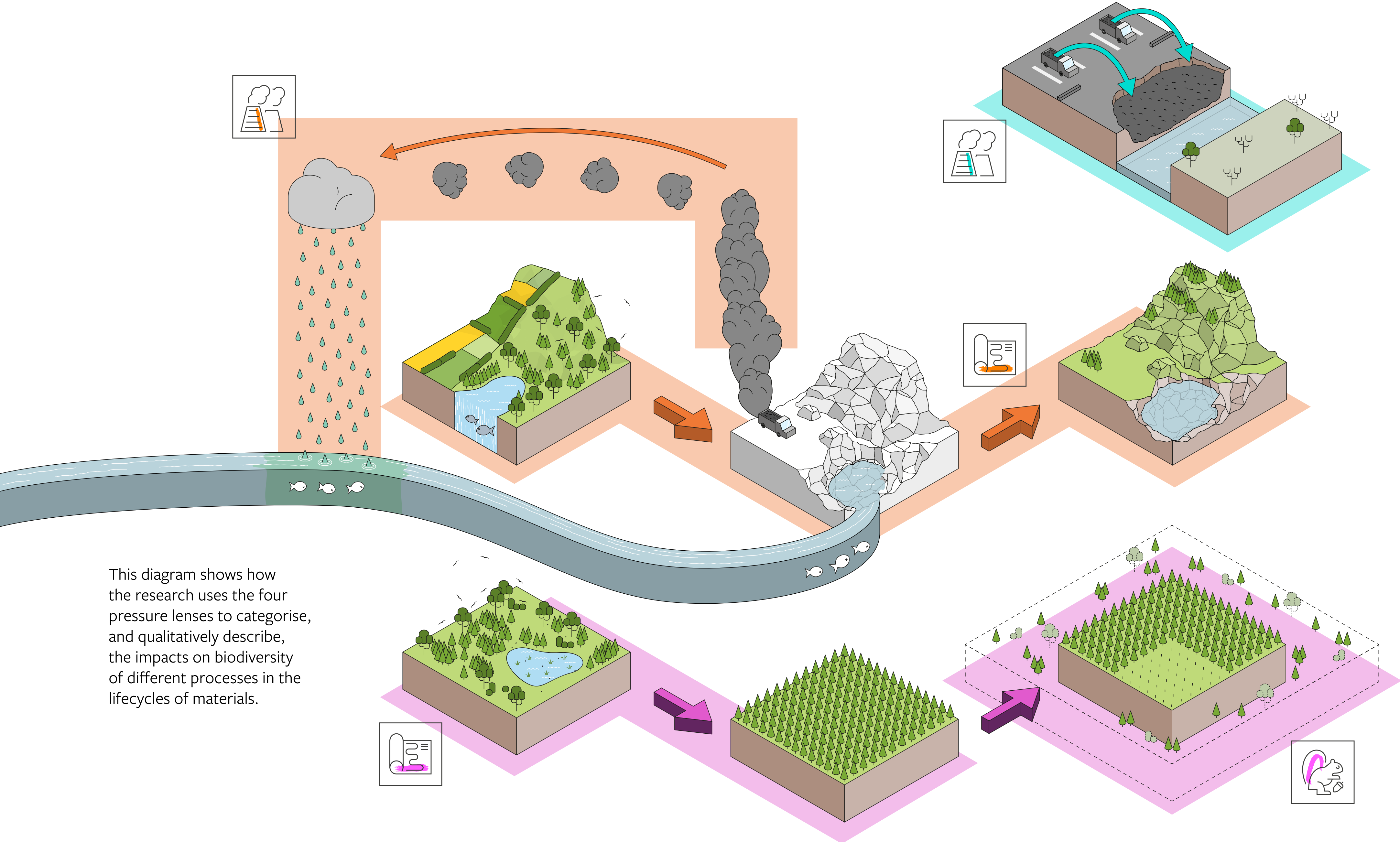


Species exploitation
Human exploitation of animals, plants and other living things for food and materials.

Pollution
Pollution, including from chemicals and waste, damaging biodiversity. This includes air, water, noise, and soil pollution.

Invasive species
Introduction of invasive, non-native species which out-compete local biodiversity for resources.

2.5 A framework for understanding embodied biodiversity impacts

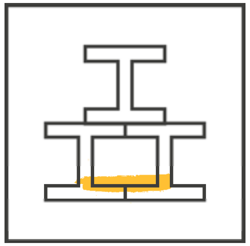


This diagram shows how the research uses the four pressure lenses to categorise, and qualitatively describe, the impacts on biodiversity of different processes in the lifecycles of materials.

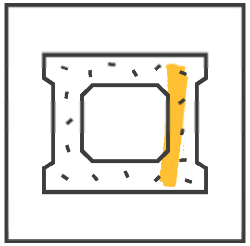
2.6 Selected materials

This research presents a qualitative appraisal of the embodied biodiversity impacts of five construction materials: steel, concrete, timber, asphalt and earth.

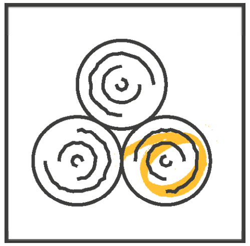
These five materials are a focused starting point, as they are frequently specified by civil and structural engineers on projects. These may not be the materials with the greatest impacts on biodiversity, but they are relevant for practitioners and provide a starting point for a wider analysis of all materials. Further research is recommended into other materials with potentially significant biodiversity impacts, such as rare earth metals.



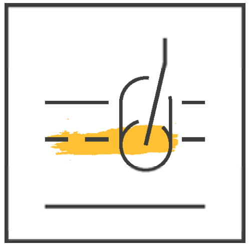
Steel
Steel is commonly used as a structural material in buildings and bridges, both as steel sections and as the reinforcement used in concrete. It is also used on railways, in transmission towers, and in cladding of buildings.



Concrete
Concrete is the most widely used construction material in the UK (and worldwide). A mix of cement, aggregate and water, concrete is used in structural elements, foundations, retaining walls, and transportation infrastructure.



Timber
Timber is used as a structural material, at a large scale in residential construction and, increasingly, on various other sector projects. Timber is also used for finishes and decorative elements, as well as for door and window fittings.



Asphalt
Asphalt is a mixture of bitumen and aggregates, and is widely used for paving and road infrastructure, airport runways and residential roofing.

Earth
Earth is used in many forms in the industry: sand, rock and gravel are used as aggregates, earth is moved to shape the topography for cuttings and embankments, and topsoil is used for landscaping.

2.7 Methodology

For each of the five key construction materials, the following approach was taken to develop an understanding of the embodied lifecycle impacts.

1 Defining material assumptions

A set of initial assumptions was made to define typical characteristics for each of the five key materials, to set the scope for the lifecycle mapping. For manufactured materials, it was assumed that standard, current-day practices are used: for example, the research did not assume the use of sustainable cement alternatives. The purpose of this was to include lifecycle processes where information on impacts was most likely to be available, and to make the research as relevant as possible to the majority of that material.

2 Mapping the high-level lifecycle processes

The high-level lifecycle of materials was mapped, the lifecycle processes were defined and the locations where those processes take place for materials supplied to the UK, were identified This was achieved through a review of lifecycle analysis studies, trade information and other academic and grey literature, in addition to engagement with UK supply chain bodies. The processes were grouped according to where they took place: for example, instead of detailing the multiple processes taking place in a cement factory, these were included only as 'cement factory operations'.

3 Identifying evidence of impacts on biodiversity

The potential impacts of those processes on biodiversity were identified and articulated through the four 'key pressure' lenses.
The impacts were not quantified; instead, the research provides a qualitative overview of what the impacts might be, and what would influence the severity of those impacts. The research aimed to find evidence of recorded biodiversity impacts where possible, but often only found evidence of a potential impact. These impacts were identified through a review of academic and commercial research, and other grey literature.

4 Rating the likely severity of impact

Based on an understanding of the UK supply chain, the factors influencing the severity of impact, and consultation with a biodiversity expert, a qualitative judgment was made of the likely severity of impact on biodiversity for each process. The severity was categorised as high, medium or low severity of negative impact, or positive impact. For some processes, multiple possible severities were identified, due to variety in the UK supply chain or uncertainty in enforcement of controls.

2.8 Boundaries

The following boundaries were set to define the scope of the research.

1 Defining material assumptions

Only materials used commonly in the UK were assessed.

The specific boundaries set for each material, in terms of which variation(s) of that material were assessed, can be found in the results section.

2 Mapping the high-level lifecycle processes

This research looked only at the UK materials supply chain (even where this included processes taking place outside of the UK)

The research did not include the construction, use and deconstruction stages (A5–C1) as the processes included in these, and any impacts thereof, will be covered in either Biodiversity Net Gain (for new construction) or Environmental Impact Assessments (for deconstruction of an existing asset).

3 Identifying evidence of impacts on biodiversity

The research only included the impacts resulting from land-use change at the extraction stage, as this was seen to be the most significant cause of habitat destruction, and the only stage at which the type of land being used was tied to the process. For example, it was impossible to know the quality and type of habitats on the site of a previous cement factory and, therefore, the impact due to land-use change.

4 Rating the likely severity of impact

The research did not make a qualitative comparison between the magnitude of each process taking place. For example, for asphalt, the assessment did not quantify, or qualitatively assess, how much bitumen as opposed to aggregate is needed for a unit quantity.

3 | Findings

3.1 How to read these results

The following pages detail the results of the analysis for each of the five materials.

Each sub-section presents the defined material assumptions, key findings from the analysis, and a diagram showing the severity of biodiversity impacts throughout each material's lifecycle. The full detail of the research supporting these severity ratings can be found in the Evidence Base Appendix to this document.

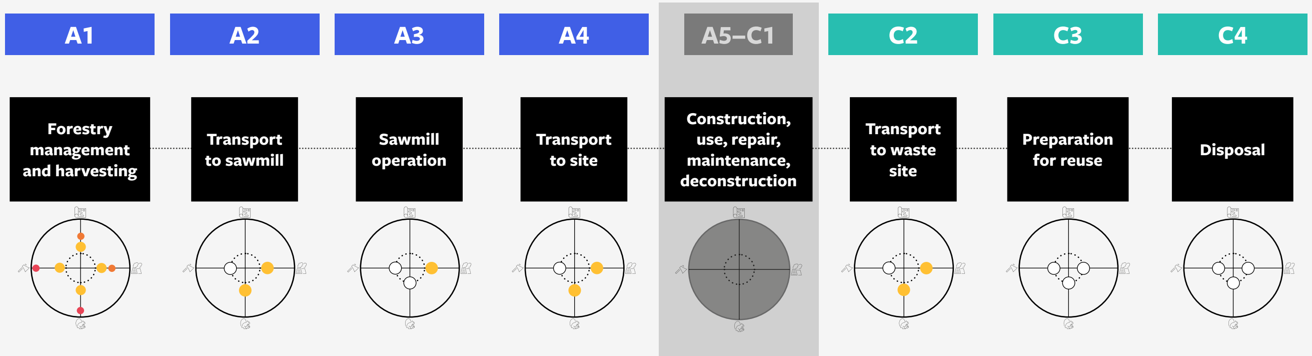
Starting assumptions

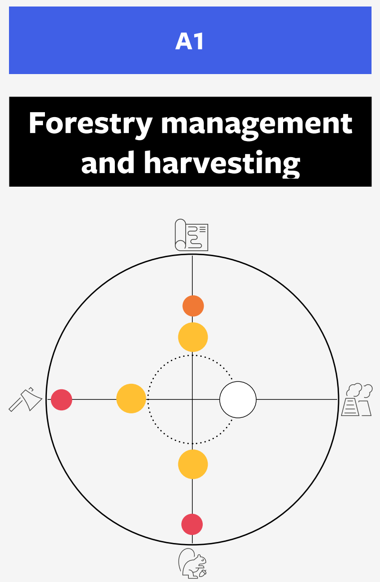
The assumptions made for each material's lifecycle are defined. Detailed assumptions about specific processes included in the lifecycle are contained in the Evidence Base Appendix.

Key findings

The key findings that emerged from the mapping of the material are outlined.

Lifecycle impacts map: key





This is the lifecycle stage this process aligns to.

This is the title of the lifecycle process.

- Low severity impact
- Medium severity impact
- High severity impact

The size of the dot shows the likelihood of that level of severity. For example, this shows that the majority of timber is expected to have a low severity impact on land use, and a minority of timber to have a medium severity impact.

An empty dot shows that no **evidence** of possible or recorded biodiversity impact for that process was found.

No dot shows that that pressure was not included in the scope for that process; the reason given is described in the appendix.

3.2 Concrete

3.2.1 Material summary

Starting assumptions

Concrete is composed of cement and aggregates, and is usually reinforced with steel bars (rebar). Cement, traditionally composed of limestone, is increasingly being replaced with lower-carbon alternatives, including by-products from blast furnace operations.

This research focused on portland cement, the most commonly used cement, and aggregate. The mix of aggregates can vary; sand, gravel and rock aggregates were included in this research.

Rebar was not included in the assessment of concrete; the assessment of steel covers hot rolled steel sections.

Key findings

- The majority (more than 70 per cent) of cement used in the UK is sourced from the UK. Similarly, the majority of aggregate is sourced in the UK.

- Concrete requires quarrying and dredging of raw materials for cement and aggregate (including limestone, clay and rock), which can damage or remove habitats.

- UK cement producers must abide by Net Gain requirements and there is strong commitment to quarry rehabilitation, with guidance and case studies published in association with the RSPB and Natural England.

- The impact of aggregate extraction depends on the method: the majority of UK aggregate is land-won, which is less likely to have a negative impact compared with marine-dredged sand and gravel, which can have significant detrimental effects on marine habitats.

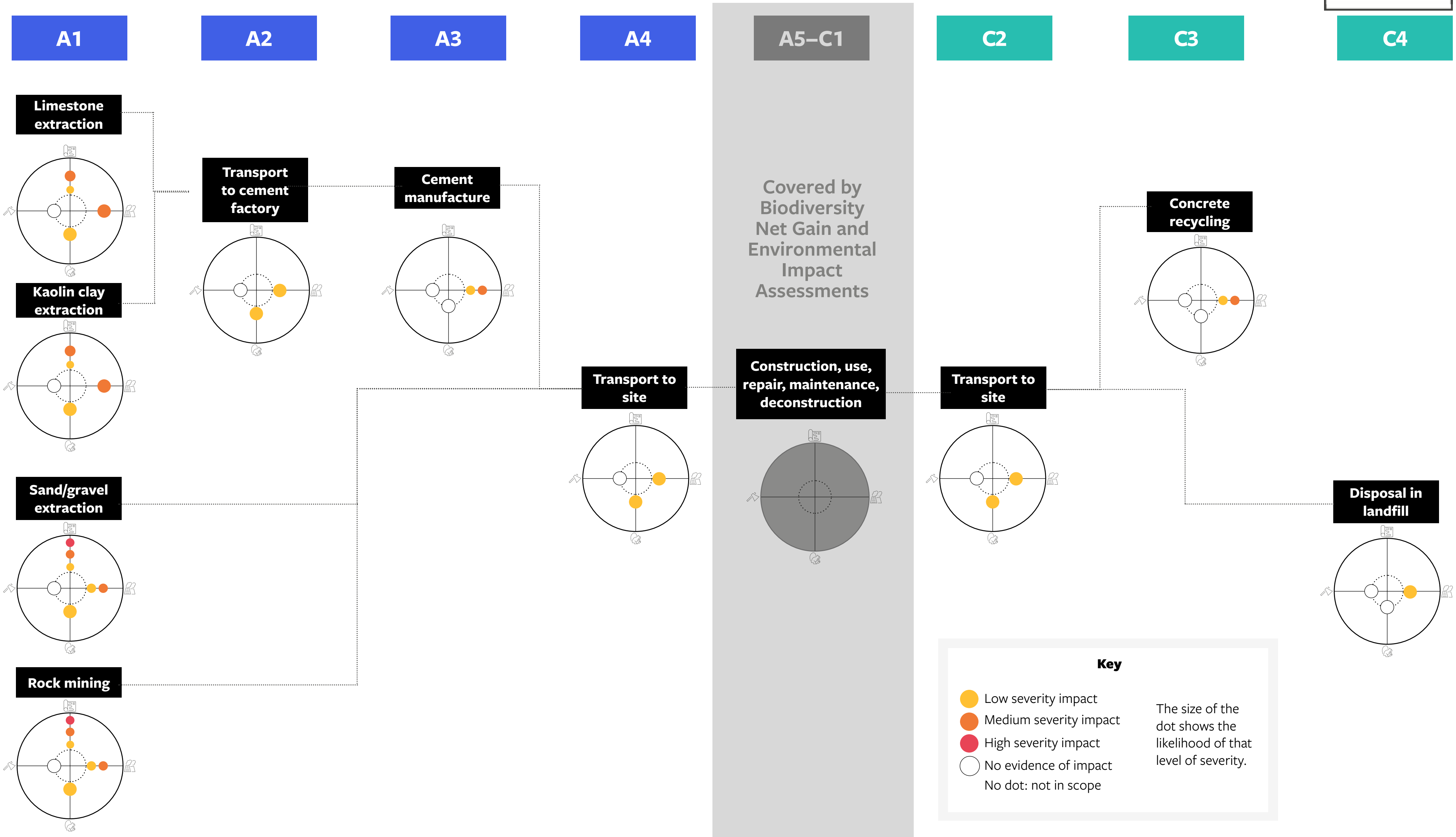
- Cement production can cause air and water pollution. Globally cement production is a significant cause of air pollution but in the UK, emissions are regulated by the EA and continuously monitored. However, publicly available records of monitored levels were not easily found.

- The majority of concrete in the UK is crushed and recycled to be used as aggregate or fill; significant evidence of the biodiversity impacts of this process was not found.

- As the majority of both cement and aggregate is produced in the UK and the raw materials extracted locally, the impacts from transportation are comparatively low compared with other materials with longer supply chains.

3.2 Concrete

3.2.2 Lifecycle impacts map



3.3 Steel

3.3.1 Material summary

Starting assumptions

Hot rolled steel is the form of steel most commonly used for primary structural applications. There are various additives that can be added to alter the properties of steel as a material, for purposes such as weathering or strengthening.

Hot rolled steel sections are manufactured in two ways in the UK, using the blast oxygen furnace (BOF) and the electric arc furnace (EAF). The majority of steel used in the UK construction industry is manufactured using the BOF.

This research has focused on hot rolled steel sections manufactured in a blast oxygen furnace. It is worth noting that the extraction stage is not present in the EAF process, as it uses recycled steel only.

Key findings

- Steel requires the raw extraction of coking coal, limestone and iron ore through mining and quarrying, which can damage or remove habitats, cause groundwater contamination and make sites more prone to invasive plant species.

- The UK imports coking coal and iron ore from a variety of locations, including Canada, Sweden, Brazil, South Africa, the USA and Australia. This complexity and variety in the supply chains meant it was difficult to provide a universal picture of the biodiversity impacts of extraction.

- There is evidence of the mining of iron ore and coking coal having significant impacts on biodiversity in locations from which the UK imports (including Sweden and Canada).

- The majority of steel used in the UK is manufactured in the UK – these processes can cause pollution resulting from the disposal of slag, but these are regulated by the Environment Agency in the UK.

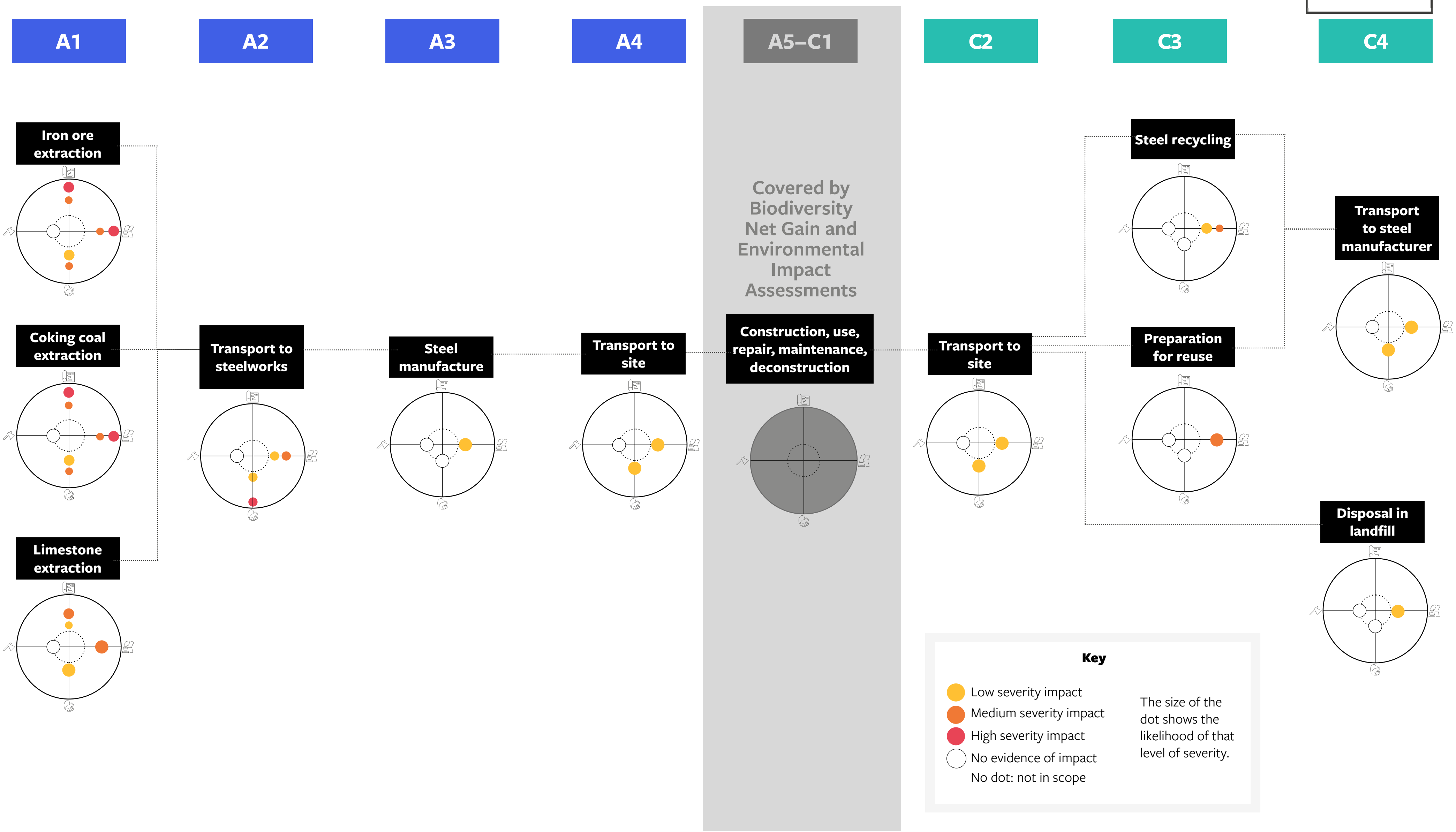
- The majority of steel is recycled or reused, which can require cleaning and other preparation. The processes of recycling steel and cleaning steel for reuse can cause water pollution, but they are also covered by Water Discharge regulations.

- Clear evidence of where these processes take place was not found, so it is assumed that these impacts are controlled by UK pollution regulations.

- Although very little UK steel ends up in landfill, where it does occur this can cause groundwater contamination through leachate.

3.3 Steel

3.3.2 Lifecycle impacts map



3.4 Timber

3.4.1 Material summary

Starting assumptions

Timber products in the UK include softwood timber, hardwood timber, and manufactured timber products such as glulam, plywood and MDF.

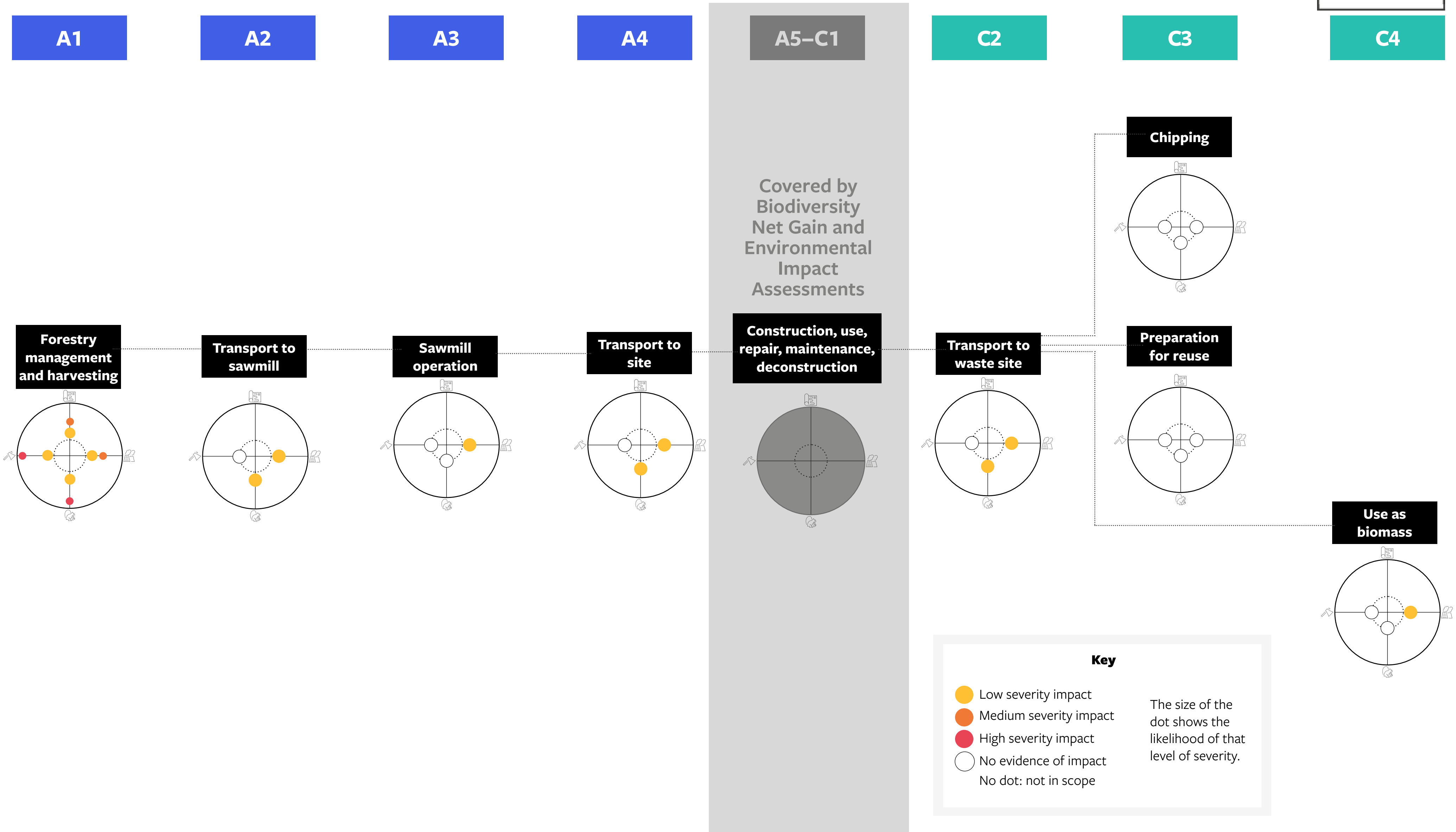
This research focused on sawn softwood timber, which is harvested from timber plantations and processed into a sawn section for use as a structural element.

Key findings

- The majority of sawn softwood timber used in the UK is from the UK and the EU.
- Historically, timber planting in the UK in the 1980s and 1990s introduced monoculture forests, which had detrimental impacts on biodiversity, but these practices are no longer in use.
- Almost all UK timber is now sourced from FSC- and PEFC-certified sources, which require forests to be effectively managed, with diversity of species and mixed habitats, and to manage impacts from tree felling, soil disturbance, coppicing, etc. These standards also prevent the use of many pesticides.
- The most important biodiversity impacts of the use of timber are at the extraction stage in the management of forestry.
- The main impact of sawmills on biodiversity is likely to be via long-term climate change due to energy use. Sawmills in the UK and the EU have made carbon commitments and many are transitioning to low-carbon fuels.
- As the majority of sawn softwood timber is produced in the UK and the EU, the impacts from transportation are relatively low compared with other materials with longer supply chains.
- Limited evidence was found of biodiversity impacts at the end-of-life stages, particularly in preparation for reuse and for woodchipping.
- Other types of timber product (such as plywood) may be likely to present a higher risk of being from less traceable or effectively managed sources, particularly hardwoods which are more difficult to certify.

3.4 Timber

3.4.2 Lifecycle impacts map



3.5 Asphalt

3.5.1 Material summary

Starting assumptions

Asphalt is composed of bitumen and aggregate. Various additives can be added to the mix to change its material properties.

This research has focused on bitumen and aggregate only. The mix of aggregates can vary; sand, gravel and rock aggregates were included in the assessment. Recycled aggregates are also frequently used, but the biodiversity impacts of these were not included in this assessment.

Key findings

- Bitumen is sourced both domestically and from abroad. A comprehensive understanding of the upstream supply chain was not possible for this assessment due to a lack of clear available information.

- Bitumen is produced as a by-product of the crude oil refinement process. For crude oil extraction, only offshore drilling was considered as this is the method predominantly used in the UK.

- Crude oil extraction can have severe impacts on biodiversity, in terms of damaging marine habitats and pollution due to leaks and spills. Despite regulations controlling leaks, there is evidence these still take place.

- Crude oil (and bitumen) are likely to be transported by tanker, which can also have negative impacts on marine habitats due to noise and chemical pollution.

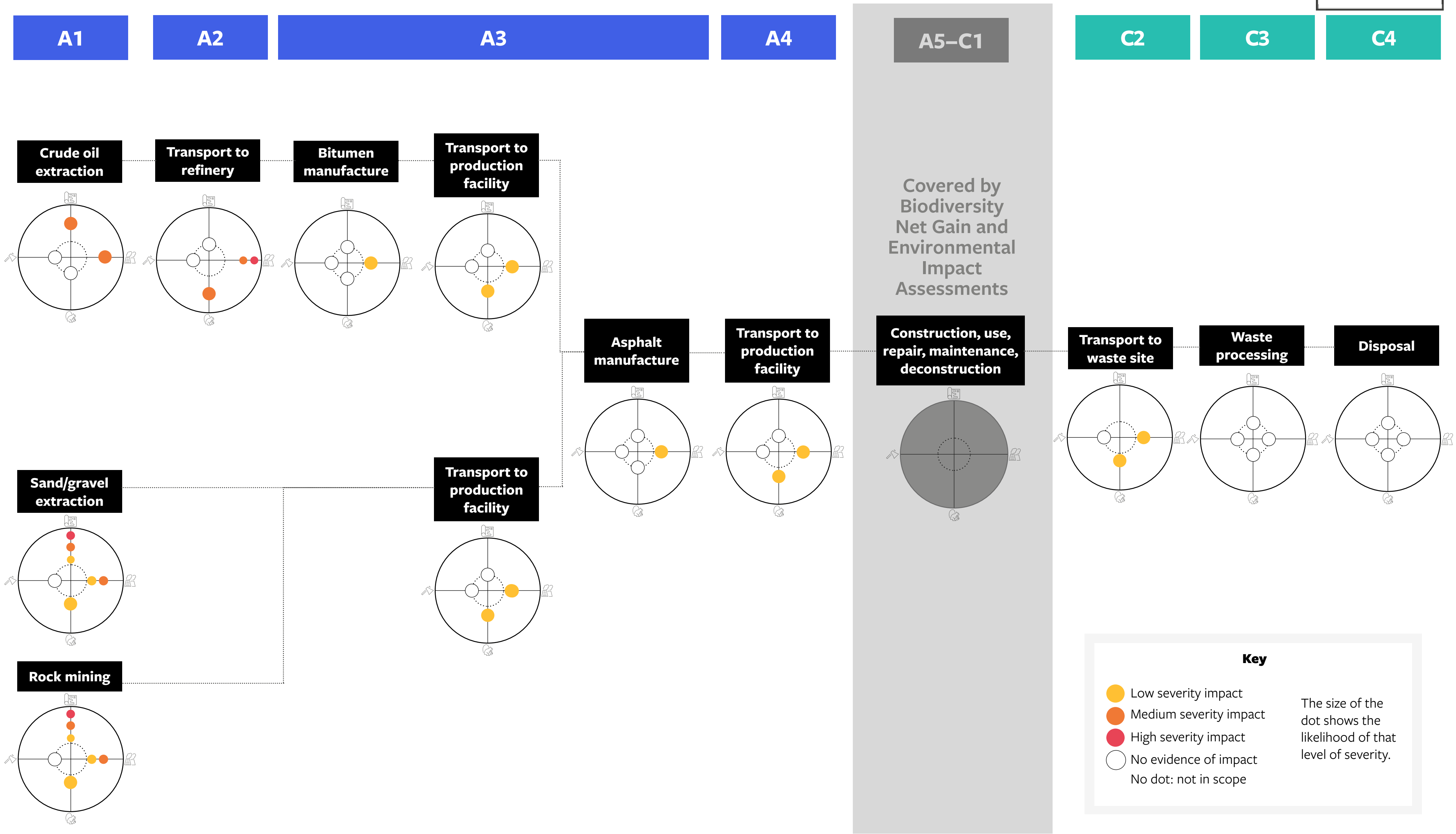
- Similarly to concrete, the impacts from the extraction and transportation of aggregates depends on the method used to extract them, with dredged sand and gravel likely to have the most severe impact on biodiversity.

- The manfuacture of asphalt itself in the hot mixing process will be regulated in the UK, and no direct evidence of potential or occurring biodiversity impacts was found. The specific regulations relevant to this process in countries from which the UK imports were not reviewed in detail.

- Very little data was found on the end-of-life impacts of asphalt: a minority is reclaimed for use as aggregate, but how the remainder of it is disposed of is unclear.

3.5 Asphalt

3.5.2 Lifecycle impacts map



3.6 Earth

3.6.1 Material summary

Starting assumptions

Earth is used in many forms in the built environment, both as topsoil (which can be the most biodiversity-rich layer) and as fill for forming topographies. Fill is often composed of aggregates.

The high cost of transporting bulky materials on and off site means that the disposal or importing (to a site) of earth is disincentivised and avoided wherever possible. However, topsoil is often imported for landscaping purposes.

Topsoil can be extracted by being stripped from another site, which is often a consequence of development on greenfield sites. Topsoil is often mixed with sand to provide drainage or aesthetic qualities. This is known as 'manufactured' topsoil.

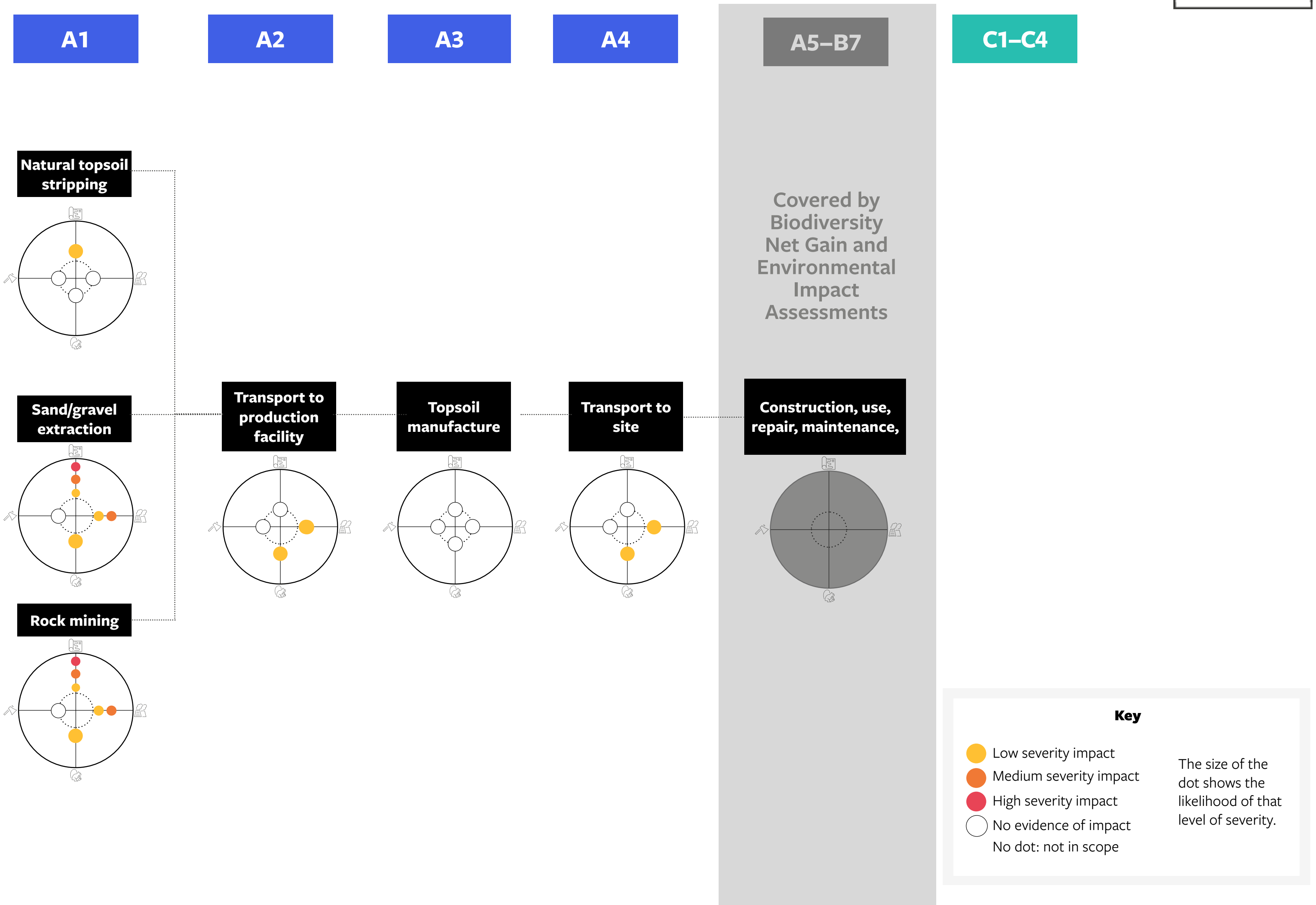
This research covers topsoil as a standalone material, and as manufactured topsoil including including sand and gravel.

Key findings

- It was not possible to conclude from existing information how much of the topsoil used in the UK is manufactured, as opposed to collected, in the UK, and how much is imported from outside the UK.
- This lack of information is important, as imported topsoil would be likely to present a significant risk in terms of invasive species. However, it was not possible to understand conclusively how much is imported or from where.
- As natural topsoil stripping is likely to take place as part of new developments on greenfield land, this may be covered entirely by Biodiversity Net Gain requirements.

3.6 Earth

3.6.2 Lifecycle impacts map



4 | Reflections on the findings

4.1 Actions for practitioners

The aim of this research was to enable practitioners to understand embodied biodiversity impacts and compare materials based on those impacts. Although quantifying the impacts and enabling a side-by-side comparison was not within the scope of this report, the research did identify four initial actions practitioners can take to reduce the impacts of the materials they specify.

These actions, shown on the right in order of priority, are based on the insights from the mapping, and the discussions from an industry roundtable held with infrastructure providers, engineers, consultants, and contractors working within the construction industry.

The first two recommendations align with the carbon reduction hierarchy, to reduce the amount of material usedin the first place and, where material is needed, to reuse existing materials where possible.

1 Minimise the amount of material needed

None of the materials or processes were assessed to have significant positive impacts on biodiversity. As these processes are not nature positive, the easiest way for a practitioner to reduce the impact on biodiversity is to use as little material as possible.

2 Prioritise reused materials

For most materials, the extraction stage results in the most significant biodiversity impacts. While this is in contrast to carbon (the impacts of which are often greatest at the processing stages), it means reusing existing materials could significantly reduce biodiversity impacts.

3 Utilise existing responsible sourcing and certification schemes

It was not in the scope of this research to explore these schemes in detail, but there are responsible sourcing schemes and certifications for some materials which address biodiversity impact. Practitioners can use these to ensure that a supplier has at least considered biodiversity.

4 Understand where materials have been sourced from

Materials with longer and more complex supply chains were harder to analyse in terms of biodiversity impact, as there is greater uncertainty. Where materials are not covered by certification, practitioners should specify and source materials with clear provenance.

4.2 Wider insights

The actions for practitioners are based on the initial qualitative appraisal of each material. However, there is more to be done on an industry scale to address these issues and to enable practitioners to change their behaviour.

The following pages discuss some of the reflections resulting from this research, which informed the recommendations made to industry. These wider insights are based on both the findings from the analysis, and the discussion at the industry roundtable event held to review those initial findings.

The three key themes of these insights are shown on the right.

Data limitations

The research found a lack of available, consistent and independent information about both the UK material supply chain, and the impacts on biodiversity throughout that chain. These data limitations included a lack of independently published information, inconsistency in language used to describe both processes and biodiversity impacts, and a lack of reporting against commitments made by the supply chain.

The need to consider systemic impacts

The scope of the analysis in the report was a qualitative assessment against the four 'key pressure' lenses. This limited the research to assessing only the immediate impacts of the processes in a material's lifecycle, as opposed to the (potentially very significant) systemic impacts on wider ecosystems. The research also did not consider the potential impacts as a result of changes in demand or supply, particularly where the impacts of some processes may become much more severe if they are carried out on a larger scale.

The difficulty of comparing or quantifying impacts

The research found a desire for a quantifying approach and a need for simplicity, to enable practitioners to compare materials easily. However, this presented a potentially significant challenge in balancing that need for simplicity with a need to avoid over-simplifying the complexity, variety and nuance of biodiversity impacts.

4.2 Wider insights

4.2.1 Data limitations

This research found a lack of available, consistent and reliable data about both the UK materials supply chain, and the impacts on biodiversity throughout that chain. The limitations present in this data have affected the accuracy and reliability of the results, and shaped the suggested next steps in the routemap (see Section 5) for further work.

The research focused principally on two sets of data (related to steps 2 and 3 in the methodology):

1 Where lifecycle processes took place (understanding the supply chain)

2 How those processes impact biodiversity. (understanding the impacts)

The research found a number of specific challenges when searching for this information.

Data limitations: lifecycle process data

Lag in timeliness of data

Information about material supply was often outdated or not consistently dated between sources, which made it difficult to build an accurate picture of the UK's material supply. This was particularly relevant where the UK imported from countries with volatile political situations.

Variety in supply chain

For some materials such as asphalt, the variety in the supply chain (particularly of raw materials) presented a challenge to understanding the potential severity of impacts in great detail, as it required investigating supply chain regulation and interdependent impact categories. There was greater uncertainty for materials with more complex supply chains.

Inconsistent language

Often, the language used to describe materials, processes or elements of the supply chain was not consistent.
For example, domestic production of materials was often described in material quantity, whereas imports of materials were described by varying indicators of value.
This presented a challenge to producing an accurate picture of material supply flows and the likelihood of different impacts.

Material categories were also not always consistent: different taxonomies for waste products and imports were used, which made it difficult to isolate specific materials.
For example, crude oil imports were included in bulk 'oil and gas' imports.

4.2 Wider insights

4.2.1 Data limitations

Data limitations: biodiversity impact data

More information on pressures as opposed to impacts

There was generally more information published on pressures generated by processes, but a lack of information on exactly how those pressures had affected biodiversity or local ecosystems as a result. This sometimes reflected a greater focus on human health considerations.

For example, evidence of specific pollutants being released from manufacturing facilities was found, but the impact those pollutants actually had on biodiversity was not clear.

There is a risk that the assumptions of how those pollutants could affect biodiversity are inaccurate.

A lack of clear reporting against commitments

Often, commitments were made by material suppliers or manufacturers towards sustainable or nature-positive practices, but evidence of meeting these commitments was not always clear.

For newer commitments, this might reflect a lack of ‘lagging’ data demonstrating the impacts of modern processes: time is needed to understand the recorded impacts of more nature-positive approaches, and current data may only reflect past practice.

This was not universal; in some cases, there were available data and case studies demonstrating positive impacts on nature from supply chains.

A lack of independently published information

Information about the possible impacts on biodiversity, and how these are controlled, was often published by supply chain actors or material suppliers. There is a risk this information may be biased to represent these impacts in a positive light, particularly where monitoring and reporting of biodiversity impacts was not clear. There was also a related lack of information about how regulations, standards and best practices are enforced or monitored.

We were also limited by the published language of evidence, as we only reviewed literature published in English and available through common search approaches. This may have led to an unfairly more onerous appraisal of processes carried out overseas.

4.2 Wider insights

4.2.2 The need to consider systemic impacts

The need to consider systemic impacts

Limiting the analysis through the four 'key pressure' lenses was necessary to simplify the initial assessment. However, this also limited the research in terms of assessing the potential systemic impacts of material lifecycle processes in three ways and these limitations should be considered when setting boundaries for more detailed assessments.

Current focus on human health

In many cases, the research found that most of the available information was relevant only to specific parts of ecosystems: humans, protected species and vegetation. Often, controls on pollution (particularly air and noise pollution) were focused on human health, and it was not possible to assess to what extent they limit impacts on other elements of ecosystems.

Effects across ecosystems

As discussed in the introduction, biodiversity is a characteristic of a system, and impacts on one element of that system can have severe knock-on effects. For example, there is evidence that pollution caused by iron ore mining can impact river ecosystems. However, there is less evidence indicating the secondary impacts, such as which other ecosystems are connected or which species in those ecosystems might be susceptible to change.

These systemic effects are very complex, and it would not be in the remit of an engineer to try to understand or factor them into decision-making.

Potential effects across supply chains

This research did not consider the potential system-level impacts of supply chain changes. For example, there is evidence that that the sustainable forestry management practices used for the majority of sawn softwood timber may not be commercially feasible if applied at scale. In addition, the comparatively less severe impact on biodiversity from the timber supply chain in the UK may be reliant on current levels of demand not changing.

4.2.3 Difficulty of comparison and quantification

Difficulty of comparison and quantification

The initial approach taken in this research was based on helping engineers understand and compare the embodied biodiversity impacts of the materals they might use, to enable them to factor these impacts into their decision-making alongside cost, carbon and other factors. This research did not aim to quantify those impacts, but did identify some potential challenges to doing so in future.

Alternative approaches

Reflections from the research and the industry roundtable surmised that a 'single quantity' approach might not be the most useful way for engineers to reduce the impact the materials they specify have on biodiversity loss.

This reflection informed the routemap and recommended the next steps proposed in Section 5.

Difficulty of quantification

In the comparison with embodied carbon as a concept, it was recognised that the variety and complexity of embodied biodiversity impacts did not lend those impacts to being easily compared or represented as a single-unit quantity.

However, the industry roundtable indicated a desire for engineers to have a single-unit quantity with which to compare materials based on impact, in a similar way to cost or embodied carbon.

While some quantification approaches (such as the Defra Biodiversity Metric and some measures covered in LCA databases) have quantified these impacts, it was not possible to find an approach which summarises the impacts on biodiversity throughout a material value chain into a single metric.

Although there are quantitative metrics available, utilising multiple metrics would make a quick comparison (on a level with cost and carbon) between materials very difficult. For example, approaches to combining and levelling land-use change impacts with pollution impacts could be very difficult, particularly if systemic impacts need to be accounted for.

There is a challenge to balance the need for a simple, understandable way of understanding and accounting for biodiversity impacts, with the need not to oversimplify or lose the nuance and detail of those impacts.

4.3 Future approaches to quantification

This research did not aim to quantify but, rather, to provide an initial qualitative view of the embodied biodiversity impacts of five key construction materials, and to set the frame for further work.

However, there are some existing approaches to quantifying biodiversity impacts, which serve different purposes and could be used for future, more detailed analyses.

The Doughnut Economics Action Lab (DEAL) framework in particular has been developed to account for off-site biodiversity impacts in assessments of biodiversity for urban development. This approach to calculation could form the basis of future research into quantification of the impacts of construction materials.

Natural Capital accounting is an approach that includes nature in assessments of wealth. Traditional approaches such as GDP capture the economic output generated by producing cattle, but not the economic damage due to the deforestation needed to graze them.

The approach is similar to carbon pricing, in that it internalises the impact of damage to ecosystems based on the economic value those ecosystems provide. There are numerous approaches to Natural capital valuation, which include market, non-market and non-use values.

The approach has been critiqued for assuming that natural assets can be easily substituted: for example, removing a woodland can be offset by planting trees elsewhere. A 2020 European Commission report also suggested there is little evidence of these valuations impacting decision-making yet[21].

The Doughnut for Urban Development work by the **Doughnut Economics Action Lab** includes a tool with a calculation approach for the off-site, lifecycle biodiversity impacts of different elements of urban development, which can contribute to an overall biodiversity assessment. This tool is based on proprietary data from the EcoInvent database.

The **biodiversity metric** is an accounting tool developed by Defra for Biodiversity Net Gain calculations. It uses a habitat-based approach to assess an area's value to wildlife, by calculating 'biodiversity units' using the size, quality and location of habitats. The metric is used for Biodiversity Net Gain calculations and will be used on all new sites after November 2023, when the Biodiversity Net Gain legislation is introduced.

5 / *Routemap and recommendations*

5.1 A routemap for action

This research provides a springboard for the industry by providing practitioners in the built environment with a first view of how construction materials impact biodiversity throughout their lifecycles. However, there is more work to do to enable the industry to address the crisis.

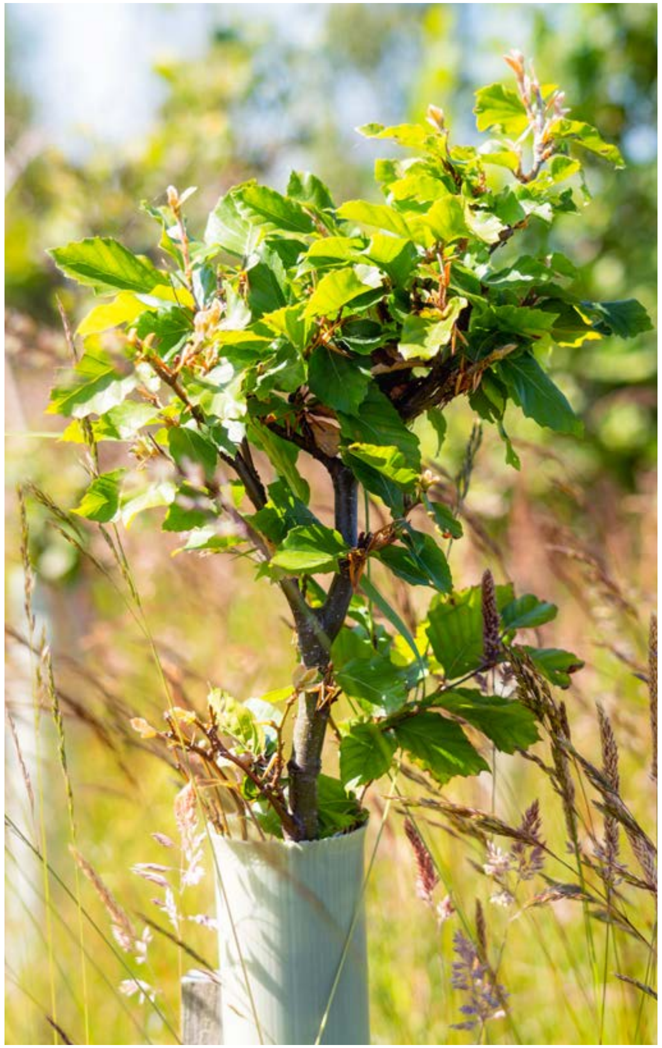
To progress this research and provide a strategic approach to next steps, this report proposes a framework for an **industry routemap** to reduce the embodied biodiversity impacts of construction materials, and for initial next steps to progress this research within that framework.

This framework is aligned with the COM-B model, defining actions to help provide built-environment practitioners with the capability, opportunity and motivation to reduce the embodied biodiversity impacts of the materials they select for their designs, specify in their contracts and procure for the buildings and infrastructure they work on.

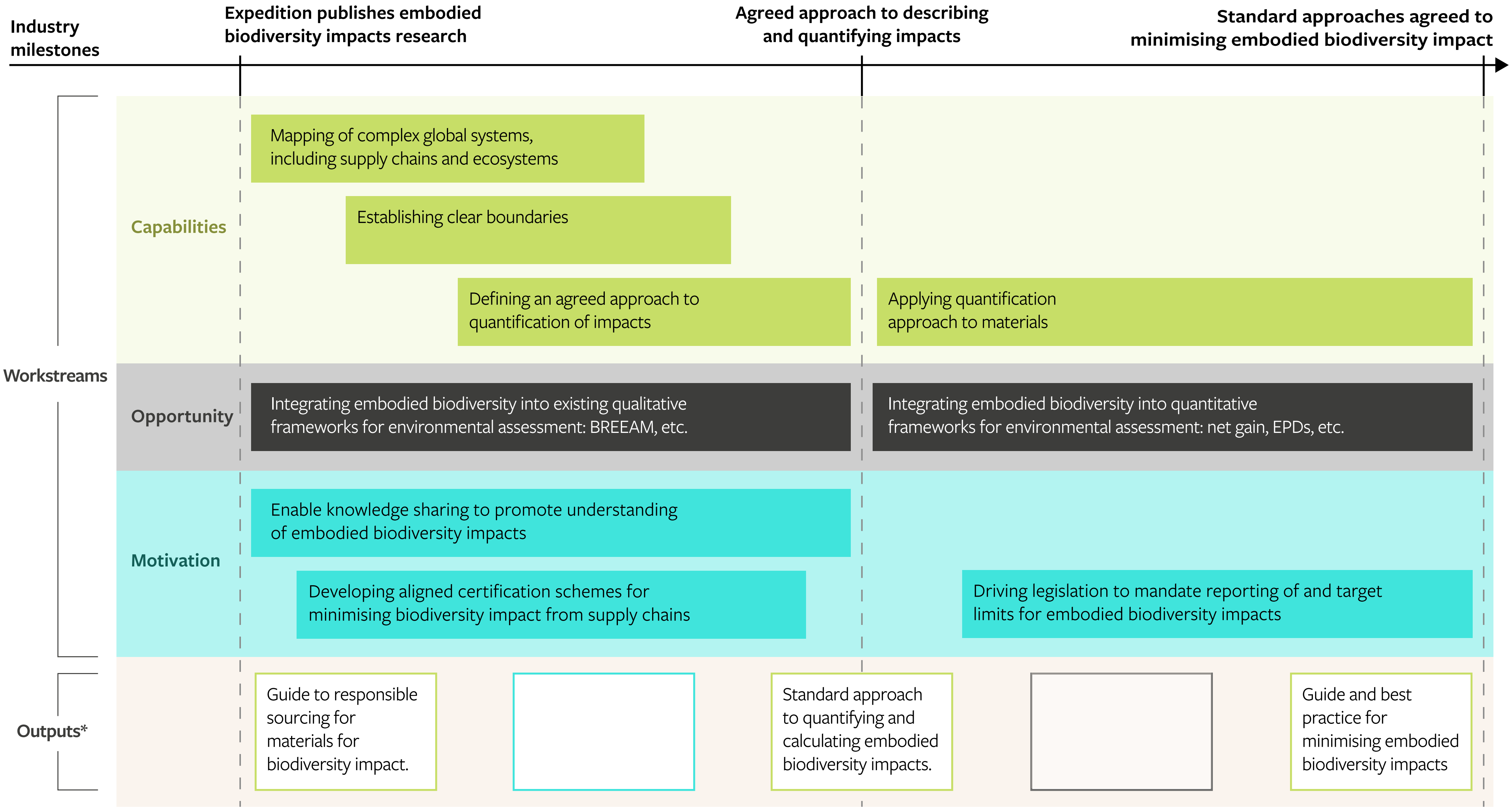
The framework is structured as three parallel **streams of work**, covering capability, opportunity and motivation, and two **milestones**, set as initial goals for the industry to reach. These streams and proposed milestones are a starting point for the industry to iterate and refine collaboratively, as the understanding of the topic develops.

The information and insights gathered in this research should form a starting point for the industry, to give practitioners the capability to understand, articulate, and compare the embodied biodiversity impacts of materials.

Three themes of work are proposed to **further develop the knowledge gathered in this report**, and to turn that knowledge into useful **outputs** and tools for practitioners to use, in order to understand, describe and compare embodied biodiversity impacts with a view to reducing them.



5.1 A routemap for action



**This report presents possible outputs from the capability workstream, as that was the focus of this research. Outputs from other workstreams will also be required.*

5.2 Routemap recommendations

5.2.1 Capability

This research provides a starting point to give practitioners the capability to understand and describe the embodied biodiversity impacts of key materials. There are three themes of work for further developing this capability:

Mapping complex global systems

Accounting for the often localised nature of biodiversity impacts will require a detailed understanding of the global supply chain for materials and of the ecosystems and habitats affected along that supply chain.

This research has presented a high-level view of the supply chains and typical effects on ecosystems. The next step is to map these systems in more detail and with more certainty, to give practitioners more confidence in the impacts, and identify focus areas for reducing biodiversity impacts throughout the supply chain.

This could involve developing material flows within supply chains, understanding regulation and commitments within the supply chain, and understanding the ecosystems and impacts on those systems in more detail and with more certainty.

Establishing clear boundaries

The complexities of impacts on biodiversity will require clear boundaries to be set and widely agreed on, so that understanding the impacts becomes manageable for practitioners working in the built environment.

This research set boundaries for the high-level analysis, both in terms of lifecycle stages and impacts. These could be used as a starting point for establishing agreed boundaries.

The inaccuracies introduced as a result of those boundaries should be carefully understood and articulated to ensure they do not misrepresent the types or extent of impact.

Defining an approach to quantification

An approach to quantifying biodiversity impacts will need to account for the multifaceted nature of the impacts and the level of certainty of impact, particularly where evidence of impact is limited. This research took a qualitative approach, but also identified possible quantification methods, based on existing approaches such as Net Gain and Natural Capital.

A collaborative approach, building on the system-mapping and established boundaries, should be taken to define an industry-standard approach to quantification.

This will give practitioners in the built environment the capability to compare impacts and allow the industry to identify areas for improvement within the supply chain.

5.2 Routemap recommendations

5.2.2 Opportunity and motivation

Practitioners will also need the opportunity and motivation to reduce the embodied biodiversity impacts of the materials they specify.

These were not the focus for this study, but the research has identified some initial high-level recommendations to develop each of these:

Opportunity

Practitioners will need opportunities to reduce embodied biodiversity impacts of the materials they specify. This includes influence in decision-making around material specification and sourcing, and opportunities to prioritise these impacts.

To some extent, many practitioners in the built environment already have a significant influence in decision-making around materials. However, some may not have the opportunity to raise embodied biodiversity impacts as a consideration in these decision-making processes.

These opportunities could be further developed by integrating embodied biodiversity impacts into existing frameworks for environmental assessment, such as BREEAM and GRESB. This would ensure that, in completing these standard assessments, practitioners have the opportunity to identify and minimise these impacts.

Motivation

Practitioners will need both intrinsic and extrinsic motivation to consider and prioritise embodied biodiversity impacts; particularly when there are conflicting priorities around cost and carbon.

Intrinsic motivation may come from practitioners understanding the severity of the biodiversity crisis and wanting to reduce these impacts, which may be enabled by knowledge-sharing activities. The UK Green Buildings Council is currently building an online knowledge repository around the very similar concept of Embodied Ecological Impacts, which could form a cross-industry knowledge platform.

Extrinsic motivation may come from clients requesting low embodied biodiversity impact materials. In the future, this could be driven by legislation or standards mandating the reporting of these impacts and, eventually, setting target levels of impact.

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Authors and acknowledgements

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