Nature Positive Handbook

Buildings and Infrastructure: Design

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Jacobs also contributed information to the Nature Positive Handbook - Buildings & Infrastructure Design chapter available here.

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1. Nature and design

1.1 How can the design of buildings and infrastructure take a proactive and regenerative approach to nature and biodiversity?

The U.K. Government is committed to delivering high quality infrastructure to boost growth across the country. The Total Value of Planned public sector investment in economic and social infrastructure is estimated to be over £600 billion, over the next five years [source].

This investment has the potential to put a great strain on nature through the consumption of raw materials and the associated emission of greenhouse gases (GHGs). Further, the delivery of buildings and infrastructure developments can have both direct and indirect negative impacts on biodiversity through land use change and the associated loss or degradation of habitats. Designers of buildings and infrastructure are in a unique position to turn these challenges into opportunities to support both economic and the environmental regeneration required to address climate and biodiversity crises.

1.2 What's being done?

The legislative and policy landscape is changing to better support the natural environment. The U.K. Environment Act 2021 now sets out statutory targets for nature recovery in the core areas of air quality, biodiversity, water and waste, and includes a new target to reverse a decline in species abundance by 2030. Nationally Significant Infrastructure Projects and Town and Country Planning Act developments will be required to deliver demonstrable gains in biodiversity and maintain them for a minimum of 30 years. Buildings and infrastructure will need to be designed to maximize their benefit for biodiversity [source], integrating with the wider landscape, with a renewed focus on nature recovery, supported by Local Nature Recovery Strategies as part of wider Environmental Land Management Schemes.

Already, work is underway to combine aims for economic growth with green priorities. Green public transport, cycling and walking have been highlighted as key areas requiring thoughtful design to encourage movement away from private vehicles, reducing GHGs and improving our air quality. Additionally, greener buildings are another focal point where design will be critical to the delivery of future-proofed properties with low carbon heating and high energy efficiency. The U.K. government will publish an updated National Infrastructure and Construction Pipeline later in 2023, reflecting this commitment.

1.3 The path forward

The buildings and infrastructure sector has a key role to play in ensuring that the economic recovery and future economic developments are environmentally and socially conscientious. This means not just mitigating or preventing environmental damage but enabling a restorative approach and actively seeking to enhance nature and biodiversity.

It is important to ensure that future building and infrastructure projects do not cause further degradation of the environment. Both globally and in the U.K., damage to the environment is occurring at an unprecedented rate and scale. Rapid economic growth and human development has driven the environmental crisis. Consequently, a wide range of environmental problems have emerged including climate change, ocean acidification, deforestation, ozone depletion, pollution, eutrophication, the spread of invasive species, soil erosion and degradation, habitat loss and declining biodiversity.

These changes have become so extensive that the fundamental physical, chemical and biological systems of the planet have been altered [source].

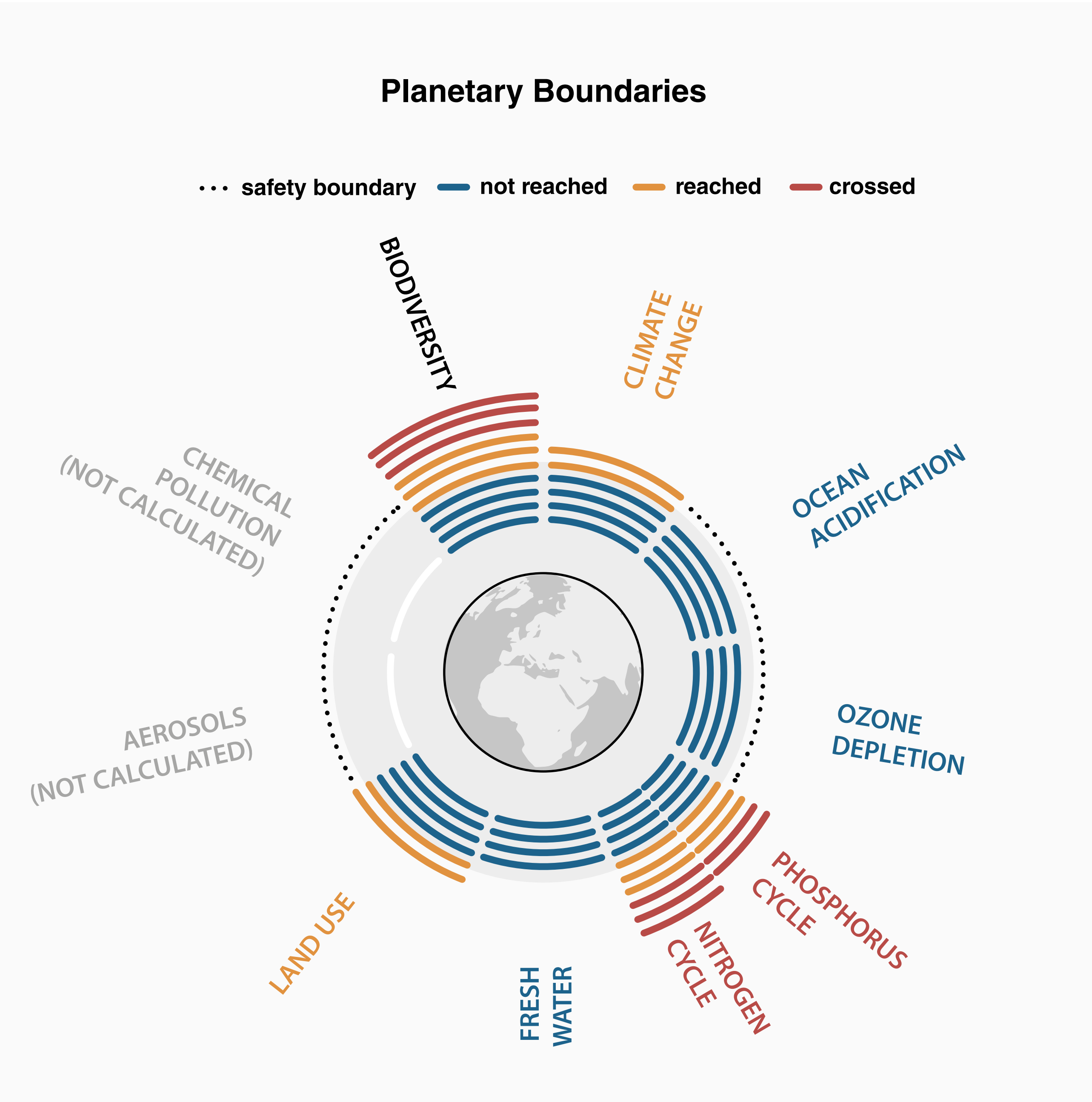


Figure 1: Planetary Boundaries

The planet is a series of interacting systems and sub-systems including the atmosphere, hydrosphere, geosphere and biosphere. Conditions favorable for life and human development are maintained through the ways in which these systems interact – called earth system processes. The extensive environmental damage is beginning to undermine these processes. Continued pressure on the planet from human activities risks triggering sudden, destabilizing and irreversible changes to earth system processes that will create an environment more hostile and less habitable to life and human society [source].

Planetary boundaries (See Figure 1), was devised to define limits to which human activities can disrupt the Earth's systems. Each boundary represents a threshold or tipping point that, if exceeded, significantly increases the risk of destabilizing the Earth's environment. Nine planetary boundaries have been defined which include climate change, biodiversity loss, biogeochemical cycles, ocean acidification, land use change, freshwater consumption, ozone depletion, atmospheric aerosols and chemical pollution [source].

Humanity is already existing outside the safe operating space for at least four of the nine boundaries: climate change, biodiversity, land use change, and biogeochemical flows. To bring human civilization back into safe operating limits, we need a fundamental re-think of the economy and our relationship with the environment. The Dasgupta review examined the economics of biodiversity and concluded that it is time to recognize that our economies are embedded within nature and not outside of it [source]. Under the current economic system, continual linear growth is required, demanding that ever more resources are extracted to produce goods later discarded as waste. This unsustainable model is now reaching its limits. This is because a system of continuous growth is diametrically opposed to the fact that the Earth is of a finite size and thus only has a limited number of resources available [source].

The construction industry and the built environment consumes approximately half of all of the world's resources making it one of the least sustainable industries in the world and a major contributor to environmental degradation [source]. However, this also means that the sector can play a leading role in the transition to a sustainable future. The U.K. Government's Construction Sector Deal, encompassing over half a trillion pounds worth of investment, stresses the importance of the industry enabling clean growth [source]. Even small changes in such a vast industry can lead to significantly better outcomes for the environment. Transitioning the built environment towards a circular economic model is emerging as one of the most important initiatives. The 2020 Circular Economy Package (CEP) sets out the U.K.'s commitment to moving towards a more circular economy [source] where resources can be continually reused so that waste is minimized and there is little need for the extraction of new resources. Applying this principle to the construction industry offers extraordinary potential to drastically reduce the sectors impact on the environment and climate change. The World Economic Forum estimates that a sustainable transformation of the building sector alone can reduce global GHG emissions by more than 30% [source].

The key to this transformation lies in design. In order for buildings and infrastructure to be produced sustainably, designers have to plan for this from the inception of a project considering the use of sustainable, recyclable, and non-toxic materials, how materials can be reused and put back into the economy, and how components can be designed to be easy to repair and maintain as well as easy to take apart. This can even extend down to the smallest of details such as designing components to use screws rather than chemical adhesive to enable easier deconstruction.

Similarly, designers should avoid using composite materials that cannot be recycled or reused. Design is key to shifting the sector from having a negative relationship with nature to getting nature positive [source].

As well as leading to significant economic changes, the pandemic has illustrated the value of nature for society in terms of mental health and wellbeing. However, these benefits are not always shared fairly across society, with clear inequalities in opportunities for engaging with nature [source]. Improving access to nature through infrastructure solutions and design can address this balance and generate social value.

Examples of different types of action are showcased here, not as a comprehensive checklist, but as inspiration for further positive action. Effective action begins with an understanding of the challenges facing nature.

1.4 Jacobs Executive Chair statement

Securing long-term equitable prosperity and societal wellbeing relies on the understanding and mitigation of negative impacts to our planet and the rebalancing of demands for nature's resources. From purifying our water, to pollinating our crops, to removing carbon from the atmosphere, our natural systems are critical. I believe we are seeing a renewed focus on society's relationship with our natural world and how we can address climate challenges and reduce biodiversity loss across our global ecosystems.

As critical infrastructure solution providers, we are in a unique position to help tackle the threats posed to nature from global warming, harmful pollution, over-exploitation of resources, land-use change and invasive species – and support a flourishing long-term future for humanity, living in harmony with the natural environment.

Nature provides us with an abundant source of inspiration and novel ways that can help us think differently and reimagine these solutions. By harnessing nature positive design and better integrating nature-based solutions into infrastructure development, we can shape outcomes that protect, sustainably manage and restore the vast array of ecosystem benefits that humanity depends upon.

Nature-based solutions are increasingly being woven into built environment design disciplines, while "by nature" inspired design, such as biomimicry, provides a unique platform for the development of sustainable and regenerative infrastructure that also supports greater equity among our communities.

In our quest to protect and restore the natural world, we must significantly amplify the role of natural capital throughout design and optioneering to realize the "true value' of infrastructure and achieve better outcomes for society and our planet. It is also important that we don't limit design and associated environment enhancement opportunities solely by what can be measured today. If we delay striving for environmental net gain because of a lack of defined guidance, we may miss out on opportunities to deliver nature positive solutions in the near-term.

In cities and communities around the world, green spaces and nature have become increasingly invaluable to residents. We need to design smarter to meet societal needs and ensure environmental gains are permanent, enabled by effective management and monitoring. With nature at the forefront of design, we can plan and develop climate-smart, nature-positive building and infrastructure solutions which enhance quality of life and enable humanity to adapt and thrive for generations to come.

Steve Demetriou,
Jacobs Executive Chair

2. Key challenges

2.1 Pollution

Pollution from and within the built environment is a threat to biodiversity and human wellbeing.

2.1.1 What's going on?

The buildings and infrastructure sector is a substantial contributor to various forms of pollution including water, air, noise and light pollution. Pollutants can be emitted throughout the lifecycle of a built asset or project – from construction, materials transportation, use of heavy vehicles and site works, through to its use and then final demolition. Engine powered tools and diesel generators release GHGs, nitrogen oxides (NOx), ozone, fine particulate matter and dust. In the U.K., construction activities are thought to be the primary sources of dust particles including PM 10 and PM 2.5 [source]. During use of an asset, traffic to or from it releases further pollutants. The heating and cooling of buildings can create air pollution. For example, gas-fired boilers, Combined Heat and Power (CHP) plants or air conditioning units can release Volatile Organic Compounds (VOCs), benzene and Hydrofluorocarbons (HFCs), all of which are toxic to human health and the environment.

An estimated 28,000 and 36,000 deaths a year can be attributed to long-term exposure to air pollution in the U.K., which disproportionally affects deprived urban areas [source]. The U.K.'s Environment Act 2021 looks closely at particulate matter as there is no safe threshold limit of exposure, and its build up on surfaces can affect local amenities, as well as impact the natural environment and biodiversity [source]. Polluted outdoor air can enter a building through openings such as doors, windows and mechanical ventilation systems, and infiltrate through, potentially impacting the health and wellbeing of occupants. Improperly designed buildings can also affect indoor air quality. For example, chemicals can shear off materials over time and pollute the indoor environment, potentially creating health problems.

Nitrogen pollution in the form of nitrogen oxides can also be very harmful to the environment. Nitrogen availability limits the primary productivity of many ecosystems and therefore impacts trophic dynamics and species distributions. Nitrogen pollution alters the availability of nitrogen which can disrupt food-web structures, enable invasive or non-native species and harm primary producers as excessive levels of nitrogen damage the cellular machinery required for photosynthesis. All of these impacts result in a loss of biodiversity and more specialized species. Nitrogen pollution also contributes to acidification and eutrophication of sensitive habitats and can reduce terrestrial carbon storage [source]. Easily transported by wind, air pollution also impacts natural areas far removed from the original source of emissions. Impacts can be so severe that in parts of the U.K., such as the Solent, property development cannot take place unless it demonstrates 'nutrient neutrality' [source]. The nitrogen cycle is a key earth system process and current levels of nitrogen pollution are far in excess of what can be considered safe limits. Building and infrastructure designers can help to limit nitrogen pollution by designing built assets that limit the need for the combustion of fossil fuels – installing renewable energy technologies (i.e., solar panels or micro-wind turbines) or facilitating sustainable transport.

The construction and use of buildings can also result in a wide range of water pollution effects. During construction, chemical contaminants (i.e. glues, paints, concrete wash or varnishes), heavy metals and hydrocarbons from fuel can mix or become dissolved in water. These pollutants can easily be transported off-site and enter nearby watercourses, ponds, lakes and groundwater or seep into soils. Groundworks and the use of heavy machinery can cause large amounts of soil erosion which can create silt laden waters – increasing the turbidity of water, which can have devastating effects on aquatic life.

During the operational lifetime of a building, poorly planned or maintained drainage infrastructure can cause further water pollution issues. For example, dissolved cleaning products or medicines can leak out of drainage systems into natural waterbodies. Effluent discharge is another issue that is becoming increasing problematic in the U.K., with 400,000 incidents occurring in 2020 alone [source]. Under current legislation, developers have the right to connect new property developments to sewers, even if it would overload the sewerage system. This can put significant strain on existing infrastructure and lead to serious water pollution issues.

Water pollution can be a significant risk to public health and cause environmental problems that can be difficult to rectify such as eutrophication and algal blooms. High-level efforts are underway to better understand the extent of impacts and to develop recommendations to Parliament and regulators, culminating in the release of the Environmental Audit Committee report and ongoing regulatory engagement with water companies [source]. For example, the Environment Act 2021 will lead to a new duty on water companies in England to progressively reduce environmental and public health harm from storm overflows. This included provisions to greatly expand opportunities for nature-based solutions to deliver combined water quality and wider benefits.

Construction also creates noise pollution within the urban environment with road traffic being the primary cause. And, while artificial lighting in the built environment is often unavoidable, poorly designed lighting can be problematic. Light pollution can disturb people, causing distraction while driving or impairing sleep, and excessive light can also undermine the enjoyment of the natural environment or the night sky.

Urban noise and light pollution can negatively affect wildlife including both plants and animals. Noise and light pollution impacts on wildlife are wide ranging and can cascade through an ecosystem in complex ways [source].

For example, by disturbing the way animals and plants perceive daytime, natural behaviors and biochemical cycles are upended. This effects circadian rhythms and biological activities, stunts growth, alters predator-prey dynamics, disrupts mating rituals as well as stymies navigation and migration [source]. Animals which are most active at night tend to be the most affected, such as owls, moths and bats. Light pollution can prevent bats emerging from roosts, reducing their foraging time to hunt and feed, and effectively impacting their growth rates and infant survival. However, by conscientiously designing buildings and planning construction activities, these impacts can be greatly reduced [source].

Plastic pollution and in particular microplastics are also a major concern. Because plastic does not naturally degrade and can persist for thousands of years, microplastics (defined as fragments of plastic less than 5mm in length) can very easily accumulate within the environment. And, microplastics are thought to now be present in every part of the environment, and have been found on mountain tops, rivers, lakes and across the marine environment, including at the bottom of the Mariana Trench [source].

At a broad scale, microplastics can disrupt biogeochemical cycles and reduce the ability of ecosystems to provide ecosystem services. However, the most concerning aspect of microplastic pollution is they are easily ingested. Once ingested, microplastics are incorporated into and accumulate within bodies and tissue. The construction industry significantly contributes to plastic pollution and is the second largest consumer of plastic in the U.K. after the packaging industry. Designers can help reduce the need for plastic and use natural materials or emerging alternative materials, such as biodegradable foam chips [source].

2.1.2 Getting Nature Positive

The built environment can cause significant pollution issues, with negative consequences for public health and biodiversity. However, conscientious project planning, building and infrastructure design can help markedly ameliorate the impacts of pollution. This includes using sustainable drainage systems (SuDS) to limit water pollution (3.1.1), appropriately designing lighting (3.1.2), using natural waste and storm water treatment (3.1.3), and designing out air pollution (3.1.4).

2.2 Over-exploitation

Exploitation of natural resources for the built environment is a threat to nature and biodiversity.

2.2.1 What's going on?

The U.K.'s construction industry is one of the largest consumers of materials, using approximately

380m tonnes

of resources each year, and also produces large amounts of waste. In 2018, construction, demolition, excavation and refurbishment activities produced around

180m tonnes

of waste, representing

62%

of all waste produced in the U.K. [source]. The principal materials used by the construction industry are stone, primary aggregates and metals (particularly steel and aluminum) – both directly and indirectly impacting the environment.

The current unsustainable extraction of raw materials is one of the main activities that is pushing planetary boundaries into unsafe territories, contributing to air pollution, climate change and driving the loss of habitats and biodiversity, as well as landscape degradation. Indirect impacts also arise from the pollution and GHGs linked to transportation, production and later disposal and waste management of materials.

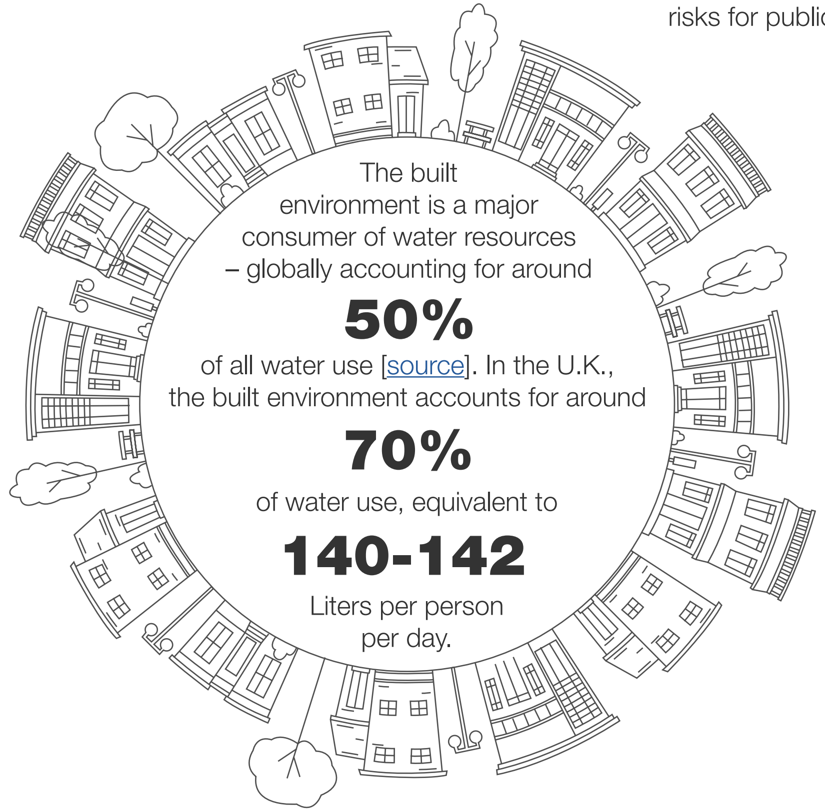
The construction industry is the world's largest consumer of steel and concrete (accounting for 50% of all steel use alone), and their production can be especially environmentally damaging. Iron ore, required to manufacture steel, is principally sourced from open-pit mines with heavy machinery, drilling and explosives used to extract ore. These practices scour natural landscapes, resulting in the loss of entire ecosystems from forests, mires, grasslands as well as lakes and rivers. Natural areas are replaced with heavily polluted, artificial and barren landscapes [source]. Concrete production creates numerous environmental problems. However, from a natural resources perspective the main issues are the use of water and the consumption of aggregates, especially sand. Rapidly growing demand for concrete is creating record demand for sand, with 50 billion tonnes being extracted each year, which is far above sustainable levels. To meet the intense demand, lake beds, riverbed, beaches and entire landscapes are being stripped bare. Entire small islands have been lost to sand mining. The extraction methods used cause major environmental disruption, destroying habitats, breeding grounds and increasing erosion rates in riverine environments [source]. Concrete production is also highly energy intensive and responsible for 7-8% of all global GHG emissions. Designers can help to reduce the impacts of natural resource extraction by opting to use recycled materials or those which can easily be replenished. For example, structural timber (also known as mass timber) could be used in place of concrete and steel [source].

Photo by Shane McLendon on Unsplash

Photo by Crawford Jolly on Unsplash

The construction industry can significantly reduce pressures on natural resources and the environment by consuming fewer materials, by applying more efficient designs and construction practices, producing less waste as well as using more recycled materials. In the U.K., the construction industry has made large improvements when it comes to recycling rates. In 2018, the recovery rate of non-hazardous waste was 92% [source].

However, significant improvements to the efficient use of resources are still needed. Designers should look to enhance material efficiency, making the most economical use of resources over the entire lifecycle of a building or infrastructure development, including its components. This could include a range of design initiatives based on the waste hierarchy and circular economy principles such as preventing over-ordering, opting to use suppliers that limit packaging, and designing buildings so they can be used as a source of components and materials at the end of their lifecycle, rather than ending up as demolition waste [source].



Historically, water availability in the U.K. has never been an issue. This is changing - with parts of the country now experiencing water scarcity, which climate change [source] has intensified. The U.K. Government 2020 policy paper 'Meeting our future water needs: a national framework for water resources' sets out the significant infrastructure solutions required to address future water scarcity risks for public supply [source].

Environmentally, water over-exploitation has several impacts. At a local level, the depletion of resources through over-extraction can damage ecosystems. At a broader scale, water pumping and treatment is energy intensive, which releases GHGs. The U.K.'s water industry is responsible for approximately 6% of total GHG emissions, with it being estimated that 0.79g of CO_2 are released per liter of water use.

Most built environment water use occurs during the in-use phase of buildings, i.e. the water used in homes, offices, schools and hospitals etc. And approximately 30% of residential and commercial water consumption is used for gardening and landscaping. To design more water efficient buildings, designers should aim to reduce daily water consumption from 140 liters per day to 125-80 liters per day by integrating water-saving technologies (i.e. low flow plumbing fixtures), rainwater harvesting systems, as well as grey water recycling, into building design. To help lower the amounts of water used during construction, designers and planners can employ water management strategies such as using recycled water in concrete production or using data loggers and water audits to monitor the use of water on construction sites [source].

2.2.2 Getting Nature Positive

The U.K. construction industry can significantly improve material efficiency though planning and design by considering the waste hierarchy, the application of circular economy principles (3.2.1) and using water efficient landscaping (3.2.2).

2.3 Land use change

Development has direct and indirect consequences for biodiversity and society.

2.3.1 What's going on?

The development of buildings and infrastructure often leads to a loss of semi-natural habitat and this impact extends into the wider landscape where increasingly scarce biodiversity havens have become fragmented and isolated, leading to a loss of connectivity for wildlife. Increased human pressures such as disturbance, trampling and introduction of invasive species can also degrade habitats.

Urban areas and brownfield sites have become important havens for wildlife, often providing alternative habitats for many species that have declined due to the loss of their native countryside habitats. Because brownfield land offers unique conditions relatively free of human disturbances, it can support an extremely diverse group of plants and animals [source]. For example, Canvey Wick in Essex (a former dumping ground) now supports nearly 2,000 invertebrate species, many of which are declining in the broader area. Unfortunately, 50% of wildlife-rich brownfield sites have been lost or are under threat because development of brownfield sites has been prioritized under the National Policy and Planning Framework, further contributing to biodiversity loss [source]. The loss of habitats and the biodiversity they support has wide-ranging effects on us as individuals and wider society. For example, the increase in impermeable surfaces lowers the capacity of the environment to cope with flooding. The loss of certain habitats, such as peatlands, woodlands and saltmarshes, can have serious consequences on nature's ability to lock up and store carbon. Similarly, a less well-connected landscape can impact the ability of pollinators to pollinate our crops that we rely on, and the wildflowers we enjoy.

With recent regulatory developments such as the Environment Act and the focus on achieving net zero carbon, steps are being taken to help address these impacts. For example, Town and Country Planning Act developments and Nationally Significant Infrastructure Projects will soon be mandated to achieve a 10% Biodiversity Net Gain secured for a minimum of 30 years in accordance with the Environmental Act. However, these advancements present new challenges, with demand for land having to be balanced between potential competing needs of nature recovery, agriculture and development. Typically, environmental enhancements are considered late in the design process, which can lead to project delays and the need for costly mitigation and compensation. Embedding nature early in design reduces impacts and creates opportunities for environmental enhancement. For instance, road building and road improvement schemes often lead to habitat loss and fragmentation; but considered route placement and integrated design features, such as green bridges, can benefit habitat connectivity.

Under the mitigation hierarchy – a design framework used to support environmental assessments and opportunities for environmental enhancements – impacts should first be avoided, then minimized and, only as a last resort, compensation should be provided, either on or off site in the location of maximum benefit. The earlier this is considered, the easier and more effective it is to implement.

It's also important to identify opportunities for wider benefits early in the design process. Engaging stakeholders from project inception can inform design choices, optimize outcomes for both biodiversity and people, and ease the consenting process.

2.3.2 Getting Nature Positive

Biodiversity impacts can be minimized and avoided by considering how a construction or infrastructure project can alter land use early in the design process. Yet the industry should seek to go further than this, and aim for projects to deliver biodiversity net gain. Actions include maximizing biodiversity net gain (3.3.1), designing for environmental net gain (3.3.2), enhancing habitat connectivity (3.3.3), and using green infrastructure (3.3.4).

2.4 Climate change

The construction, operation and maintenance of the built environment has been estimated to contribute to between 38-50% of all global GHG emissions [source]. The U.K. Green Building Council estimates that the built environment contributes to about 40% of Britain's total territorial carbon footprint [source], making the construction industry one of the major contributors to climate change. By reducing its carbon footprint, the industry can potentially limit the extent of future climate changes, and play a leading role in transitioning both the global and U.K. economy to a lower-carbon future.

2.4.1 What's going on?

The U.K. construction industry has made numerous advancements in lowering carbon emissions from the built environment – cutting carbon emissions by 30% during the past two decades. Recognizing the built sector is still a major emitter of GHGs [source], the U.K. Government has set a series of ambitious targets to decarbonize the sector by 2050. This will require the construction industry to reduce carbon emission by 68% by 2030 and by 78% by 2035 relative to 1990 levels. These targets are interim objectives on the path towards net zero carbon emissions by 2050 [source], and progress is being tracked by setting legally binding carbon budgets every five years [source].

Realizing these challenging carbon reduction targets requires a comprehensive transformation of the sector. The sector needs to consider how GHG emissions can be reduced at each stage in the lifecycle of a building or infrastructure asset, from material extraction through to construction, operation and demolition. To achieve net zero, design innovations are needed at each stage of a project's life cycle and

across both value and supply chains. Several industry bodies have already set out plans for reducing carbon emissions from the built environment, including the U.K. Green Building Council and the Institution of Civil Engineers. Following and implementing current industry best practices for carbon management such as PAS 2080:2023 is also recommended [source]. Design initiatives aimed at reducing the carbon footprint of the industry include whole-life carbon assessment, designing all new buildings with low carbon heating and cooling solutions, designing out waste, as well as end-of-life stage consideration for all major projects [source].

Ensuring that emissions from new builds are minimized is only part of the solution. The U.K. has the oldest building stock in Europe with a very low turnover rate of buildings. Consequently, 80% of the homes that will exist in 2050 have already been built and, due to the age of existing buildings, many have poor energy performances. So, retrofitting existing buildings to be more energy efficient is going to be as, if not more important, [source], and those involved in design and planning can help by developing pragmatic and affordable approaches that meet or exceed best practice.

By reducing the carbon footprint of new and existing buildings, the construction industry can help mitigate the severity and impacts of climate change. However, with the continuing use of fossil fuels and the GHGs already in the atmosphere, the U.K. is expected to see temperatures rise by an additional 0.6°C by 2050 over the 0.8°C of warming that has already occurred; expected to result in more frequent and more extreme weather events including flooding, heatwaves, storms, and storm surges [source]. Adapting to climate change – taking actions that reduce negative impacts and limit vulnerability – will be increasingly important. The construction industry can play a key role here too by designing resilient buildings and infrastructure that account for changing climates with more extreme weather events. The Climate Change Committee's latest assessment of climate change adaptation in the U.K. reports minimal progress across most sectors. The construction and property industries have no standardized climate change adaptation plan [source], yet the built environment is likely to be significantly impacted by climate change. New project managers and designers will need to plan for climate impacts and environmental conditions throughout the lifetime of a built asset, that are outside of what it was originally designed to withstand.

2.4.2 Getting Nature Positive

The construction sector is a hugely important part of the U.K. economy and society, so those involved in the design process are uniquely positioned to help with both climate change adaptation and mitigation efforts. Design changes can markedly help to adapt buildings to climate change and in doing so create better spaces in which to live and to work, while safeguarding peoples' health and productivity. This includes designing energy positive buildings (3.4.1), innovative approaches to low carbon heating and cooling (3.4.2), mitigating the heat island effect (3.4.3), embedding nature-based solutions (3.4.4), accounting for embodied carbon (3.4.5), and direct adaptation designs (3.4.6).

2.5 Invasive species

All parties involved in buildings and infrastructure design have a responsibility to help manage the spread and proliferation of invasive species as they can be harmful to the environment.

2.5.1 What's going on?

Invasive non-native species (INNS) are one of the most significant drivers of global biodiversity loss, contributing to 40% of animal extinctions in the past 400 years. The impacts are greatest within island ecologies, and the U.K. has among the highest presence of invasive species globally, and this appears to be increasing [source]. There are 3248 established non-native species in Great Britain, and as of 2021, 194 were classified as exerting negative impacts on biodiversity. This is an increase from 179 in 2014 and 49 in 2012.

Non-native species can threaten native biodiversity though the spread of disease, competition for resources, modifying ecosystems, direct consumption, parasitism and hybridization [source]. For example, in 1970, the signal crayfish was introduced from the USA to be farmed commercially but was released into the wild, leading to economic and environmental impact. Quick breeders and prolific consumers, they eat fish, frogs, invertebrates and plants - altering aquatic ecosystem dynamics and relationships. They also carry a disease known as crayfish plague, which is lethal to the native, white-clawed crayfish. They burrow networks of tunnels that can extend two meters into banks, causing erosion and collapse that lead to increased flood risk and silt loads [source].

The impacts of INNS can be far reaching, potentially affecting the ability of the environment to provide vital services such as regulating water quality. Invasive species can put additional pressure on native species already struggling under climate change and habitat loss, both of which can make conditions more favorable for invasives and exacerbate the problem.

INNS can have serious economic impacts too, costing the U.K. economy an average £1.8 billion per year, with construction and infrastructure one of the primary sectors impacted [source]. Invasive species such as Japanese knotweed and zebra mussels can cause significant damage to structural assets. If INNS are found onsite during construction, there is often a legal requirement necessitating their complete and potentially costly removal. It is far better to prevent INNS in the first place than it is to treat them once they have become established [source]. Steps within design and the early stages of the project lifecycle can mitigate these risks.

For example, considering invasive species and biosecurity within procurement decisions or assessing the risk of introduction, and considering mitigation early within the planning stage. Designers should consider future risks and the likelihood of new species being introduced, then take steps to block the pathways for their introduction.

3. Actions for nature

There are many positive actions that buildings and infrastructure companies can take to promote nature and biodiversity. The following inspiration ranges in complexity and scale – from actions to keep pace with competitors, actions to get ahead of the curve with innovation, and actions to change the system for the better.

3.1 Actions for pollution

3.1.1 Integrating Sustainable Drainage Systems (SuDS) into design

Action level: Keeping pace

Sustainable Drainage Systems (SuDS) are drainage solutions that seek to manage run-off at the source using techniques which mimic natural processes by encouraging infiltration and attenuation. Used as an alternative to, or in conjunction with traditional drainage systems, SuDS can provide multiple benefits, including passive water treatment, sediment management and improved local biodiversity.

The U.K.'s need for SuDS has arisen as human development, such as agricultural intensification, land drainage, urbanization and industrial expansion, modified flood risk [source]. Industrialization and urbanization created more impervious surfaces and a greater reliance on piped drainage. Concurrently, high intensity agricultural practices compacted and degraded soils which reduced infiltration rates and lowered the water-storing capacity of rural land. The net effect of these changes has been increasing run-off rates, subsequently increasing flood risk. Higher run-off rates can overwhelm drainage infrastructure during storm events, leading to surface water flooding. Rapid run-off also delivers more water into rivers during heavy rainfall events and earlier in the hydrograph. This creates higher peak flows, increasing the likelihood and duration of out-of-bank flows [source].

There is a growing impetus to manage stormwater more sustainably as problems with run-off, created by human activities, are exacerbated by climate change. One solution is to use SuDS for providing drainage which, by mimicking natural processes, aims to maintain the pre-development performance of a site's hydrological cycle. Typical SuDS techniques include filter strips and drains, swales, permeable surfaces, basins, ponds, soil storage, wetlands, green roofs and rainwater harvesting. These measures are used to manage rainwater at its source by slowing and storing run-off, increasing infiltration, and promoting evapotranspiration. Rather than relying on a single intervention type, multiple SuDS techniques are advised for a given project. The most effective SuDS projects use different measures to complement each other in what is referred to as a 'management train'.

SuDS techniques can provide a range of additional benefits over more traditional drainage methods. Depending on the techniques used, SuDS can recycle rainwater (reducing demand on mains supplies), create green spaces that improve biodiversity, as well as promote health and wellbeing, and treat water by removing contaminants and filtering sediment. For example, a retention pond for attenuating stormwater can filter out pollutants and have banks designed to support semi-aquatic vegetation and flowing plants. Appropriate planting will attract wildlife, including pollinators, amphibians and birds. Constructing walkaways for access around the pond creates amenity value for the local community, promoting health and wellbeing. To aid design and development, freely available tools such as B£ST (the Benefits of SuDS Tool) can be used to help evaluate scheme benefits and overall performance [source].

The four pillars of SuDS design are key to the implementation of effective SuDS projects (outlined in CIRIA's SuDS Manual [source]). Designers can use these pillars as overarching principles to help guide the development process.

- **Water Quantity** – the quantity of run-off should be controlled to manage flood risk and support natural processes.
- **Water Quality** – the quality of surface run-off should be managed to reduce water pollution.
- **Amenity** – SuDS should provide visual amenity and contribute towards a sense of place.
- **Biodiversity** – SuDS should also support nature.

Designers should also look to future proof SuDS designs. This may include accounting for climate-related risks by considering greater rainfall intensities and higher ambient temperatures as a warmer climate may affect the success of certain types of plants. Further urbanization should be considered where additional post-construction features are built such as conservatories or second driveways that increase impermeable surfaces.

Further SuDS implementation guidance includes national level planning policies, such as the National Planning Policy Framework (NPPF) [source] and the Sustainable Drainage Systems Non-Statutory Technical Standards [source]. These set out several key provisions regarding the design, maintenance and operation of SuDS for residential, non-residential and mixed-use developments. At a regional and local level, planning authorities have their own provisions for SuDS schemes, often detailed as part of Local Plans and Strategic Flood Risk Assessments (SFRAs). Local authorities can also formalize their SuDS policies though supplementary planning documents (SPDs), making these SuDS specifications legally enforceable. Several councils have produced more detailed SuDS planning documents called design codes [source]. Councils may reject development applications that do not adhere to their local SuDS provisions.

3.1.2 Reducing light pollution through design

Action level: Keeping pace

Light pollution is defined as unwanted excessive or obtrusive light emanating from a property, in particular from a building's exterior lighting system. This unwanted light can cause numerous problems for both people and wildlife [source].

More specifically the problems with light pollution can be categorized as:

- **Glare** – excessive brightness that causes visual discomfort
- **Skyglow** – illuminates the night sky above the occupied area
- **Light pollution** – light illuminates unintended or unnecessary places
- **Clutter** – grouping of too bright, confusing, and excessive light sources

Light pollution can have significant environmental impacts, especially on wildlife. Light trespass upsets natural behaviors including disrupting sleep/wake cycles, misbalancing prey predator dynamics, driving species away from usable habitats, disrupting migration (especially in birds) and altering the biochemistry of both animals and plants which can affect growth and development. Light pollution is considered to be a significant problem in the U.K. [source].

Light pollution is normally a sign of inefficient lighting that is costly and wasteful, generating unnecessary carbon emissions. The primary problems with nighttime lighting are its directionality, intensity and colour. Light pollution is best dealt with at the design and planning stage, with measures to limit its effects:

- Design positioning so that light beams are directed downwards.
- Take advantage of lighting controls such as timers and motion detectors, so lights are only used when they are needed.
- Control the amount of light emitted by shielding, placing and eliminating light above the 90° plane.
- Shield lights from normal viewing angles to prevent glare.
- Use lighting rated 3000 kelvin or less for a warmer reddish light.
- Do not use more than 250 watts High Intensity Discharge (HID) bulbs for commercial lighting.
- Make use of landscaping that can hide or scatter light.

Several useful guides can assist with designing efficient lighting, including the UNEP Guidelines for Consideration of Bats in Lighting Projects [source], CIBSE's Code for Lighting [source] and CIBSE's The Exterior Environment [source]. Sustainable building schemes such as Building Research Establishment Environmental Assessment Method (BREEAM) also provide both guidance and scheme credits for light pollution reduction.

3.1.3 Nature-based solutions for water

Action level: Keeping pace

Wetlands can capitalize on their naturally occurring physical, ecological and biochemical processes to provide a number of benefits, from purifying water to managing flood risk or creating local environmental and amenity value. Wetlands are distinct ecosystems with a natural filtration and water retention ability.

There are several different constructed wetland (CW) designs which provide engineered treatment solutions for storm waters or sewage flows. Consider which design best suits the particular area, what the main purpose of the wetland is and what type of pollutants and removal can be expected:

- **Media-based wetlands** – Allows process water to flow through the media with plants growing on it. Their typical area of application is in tertiary treatment for solids and biochemical oxygen demand reduction. Aerating these wetlands will also increase treatment capacity and increase oxidation and nitrification rates. However, these wetlands are highly vulnerable to clogging and cannot be upscaled due to short-circuiting problems.
- **Treatment marsh type wetlands** - These free water surface wetlands contain no media and typically require a large area. They allow process water to flow through the thatch of emergent plant and long sediments from which the plants grow. The treatment of water occurs mainly through settling and biogeochemical interactions between water and both mineral and organic surfaces in the marshes. There is very limited short circuiting and no clogging in treatment marshes. They can also be scaled up more readily than media-based wetlands due to no media requirement. Treatment marshes are typically used for tertiary or stormwater treatment.

Media-based wetlands are often used to treat small-scale domestic sewage as part of the secondary and tertiary treatment stages. Treatment marshes may be used to treat sewage, agricultural and urban stormwater runoff. It's also possible to combine solutions and create hybrid systems.

In the U.K., the vast majority of CWs are media-based systems. The European treatment wetland market is mature with many installations of proven treatment performance [source]. Recently, the U.K. market has started adopting and building treatment marshes, as intensification of these wetlands have allowed for smaller surface area to achieve target water quality. For example, a linear Free Water Surface (FWS) CW was retrofitted into a widened stream channel in Dagenham, East London, to treat surface runoff from a 440ha residential and commercial area. The CWs removed approximately 50% of the suspended solids and heavy metals. Anglian Water, in collaboration with Norfolk Rivers Trust, has also built a treatment marsh at the end of one of its water recycling centers at Ingoldisthorpe to act as a polishing step before discharging into the River Ingol. However, in the U.K., cold temperatures can reduce CW efficiency by slowing down the rate of biochemical reactions.

3.1.4 Designing out air pollution

Action level: Keeping pace

Thoughtful design can reduce air pollution at source and mitigate the impacts of residual emissions.

The University of Birmingham's Urban Design for Air Quality outlines three broad strategies for lessening air pollution impacts [source]. These should be considered as early as possible within the design process before deciding the location of buildings and infrastructure.

- **Reduce** – design should aim to reduce emissions associated with road transport, one of the most significant sources of air pollution in urban areas. Including vehicle charging facilities can expedite the transition to electric vehicles and prevent emissions, alongside the promotion of active travel through the provision of high-quality walking and cycling routes and connection with existing active travel routes.
- **Extend** – maximizing the distance between the pollution source and people promotes the dispersal of air pollution before it becomes problematic. Opening up a development through design allows a greater mixing of air through wind flow. Segregated active travel routes can distance users from air pollution sources. Setting infrastructure like bus stops and buildings back from the road can reduce exposure, especially where vehicles are usually idle. Where this is not possible for buildings, sensitive rooms where people typically spend most of their time should be located away from the roadside.
- **Protect** – special consideration must be given to those most vulnerable to air pollution, such as children, older adults and people with certain health conditions – design should look to distance air pollution sources from areas, like schools and hospitals, where they may congregate.

Green infrastructure should be integrated within designs to cut across each of these strategies. By making active travel routes more attractive, greenery can help encourage people to walk or cycle rather than take the car, reducing emissions. Similarly, mixed planting and grass verges between roads and active travel routes can encourage the dispersal of air pollutants. Dense green barriers can also protect those most vulnerable to air pollution. Green infrastructure aids biodiversity through improving habitat connectivity, as well as a host of wider benefits such as supporting a sense of place.

3.2 Actions for over-exploitation

3.2.1 Designing buildings for circularity

Action level: Ahead of the curve

Applying circular economy thinking to buildings and infrastructure design can significantly reduce resource use, waste and associated environmental impacts. The circular economy approach is a different way of thinking about resource consumption and economic development. The traditional economic linear approach is to extract, use and then dispose of resources. However, under a circular economy, everything is designed and engineered to be continually reused and recycled, eliminating waste and allowing nature to regenerate [source].

Circular construction applies the circular economy approach to the built environment, closing building material loops by reusing, sharing, leasing, repairing, refurbishing, upcycling or recycling, which in turn can minimize the environmental footprint. Realizing the potential of the circular economy requires a systems approach to all aspects of the value chain. This is very much a design-driven process, and those involved need to consider different business models for circular construction projects, material choices, the way designs will interact with people and systems throughout the buildings lifecycle, how different materials are combined and how easily they can be reused, repaired, refurbished or disassembled [source].

The key to applying circular economy principles to buildings and infrastructure is to design in layers to optimize sustainable design choices over the entire asset's lifecycle. A built asset can be viewed as a system of interacting layers, with different building components grouped together based on purpose and rate of change. One layer is comprised of core structural components, such as the foundations and superstructure, and will be designed for maximum durability. A second layer might be drainage or the heating ventilation and cooling systems (HVAC). Rather than solely designing these components to maximize longevity, it is more efficient for them to be designed to enable ease of repair, retrofit and substitution. This allows a building's use or discrete components to be adapted more easily relative to climate change [source].

Further design guidance can be found in The European Commission's Circular Economy Principles for Building Design, which discusses core principles of designing for circularity, focusing on improving building durability and adaptability, as well as reducing waste and promoting high-quality waste management [source]. Ideas to consider include:

- Design to reduce the total amount of materials used over the project's lifetime, including favoring non-virgin and renewable materials over primary and non-renewable resources.
- Design for disassembly and value conservation – using materials, components and fittings that can be easily dismounted, dismantled, recovered and reused once their initial use is over. Avoid the use of materials, adhesives or sealants that may contain hazardous chemicals as this prevents components from being used in the future, creating avoidable waste and a loss of value.
- Design buildings that can be more easily adapted to suit different or future needs. This allows for greater flexibility in building use during its lifetime. Being able to repurpose buildings easily reduces the cost and resources necessary to do so, as well as reducing the need to construct new buildings.
- During the coming decades, buildings will need to be adapted to different climate conditions and more extreme weather events. More adaptable buildings designed to make maintenance easier will enable components and systems to be replaced, upgraded or swapped with more suitable alternatives.

Sustainable Timber

The construction industry is estimated to use approximately 5 million cubic meters of timber each year and demand is expected to grow. Increasing the use of wood in construction is being promoted as a pathway towards greater sustainability and circularity. At first this may seem paradoxical as the production of timber necessitates tree felling. However, if done sustainably, there are a number of environmental benefits: timber is regenerative and the growing of trees absorbs carbon dioxide from the atmosphere, and wood can easily be reused and recycled, meaning no waste is created [source]. Architects and designers should consider using greater quantities of wood and take advantage of its adaptability and range of design possibilities. Any timber that is used must be sustainably procured, which means checking it is sustainably certified though a recognized scheme and considering land stewardship and social aspects such as labor conditions and workers' rights [source].

Timber also offers a wide variety of properties that result in higher quality, aesthetically pleasing builds, providing pleasant acoustics and sound insulation, suitable indoor air humidity and, in terms of pine, antibacterial properties. Correctly built solid timber buildings are airtight, yet hygroscopically breathable, and even out the variations in indoor air humidity. Since wood is a natural, non-toxic material, it creates a healthier indoor environment, as synthetic materials can release microscopic toxic fumes long after construction [source].

- Provide training to upskill workers to improve construction techniques so buildings are more durable, adaptable and easily deconstructed in a safe manner [source].
- Take a joined-up, systems approach that consults actors from across the value chain. The earlier in the design process end-users, technicians, suppliers and communities are involved and their needs considered, the better. Co-ordinating such a project can be challenging. However, establishing best practices for business collaboration can help, such as those set out in ISO 44001 [source] ISO 20887 [source] and ISO 15686-1 [source].

For each project, consider these aspects as part of a cost-benefit analysis so that circular economy principles can be applied in a proportionate way, with benefits outweighing costs. The BS8001 standard is recommended for further guidance and best practices for the application of circular economy principles [source].

3.2.2 Designing landscapes for water efficiency

Action level: Ahead of the curve

With climate change increasing the frequency of droughts, water conservation through landscaping will become increasingly important.

Landscaping water efficiency or xeriscaping uses plants that thrive in the local climate, perform well in the existing soil, and require a small amount of supplemental water, while promoting biodiversity. Xeriscaping is becoming increasingly popular for its environmental and financial benefits, saving money on water costs and requiring far less maintenance than traditional landscaping. It can also assist with stormwater management [source]. Another form of sustainable land use is native landscaping, which focuses on using the gardens and green spaces of private and commercial buildings to create and/ or rejuvenate native habitats. By making use of

indigenous plants, trees, shrubs, groundcover and grasses – plants already adapted to the local climate and environment – the need for fertilizer, synthetic pesticides and watering can be reduced to a minimum, if not entirely eliminated [source].

Approximately 30% of water use in residential areas, 22% in office buildings, and 28% in schools is used for maintaining landscaping. A significant amount of water used in gardening is also wasted because of overwatering.

However, xeriscaping can reduce outdoor water use by between 50 to 75%. The following design, principles can be applied to effectively design a water efficient landscape [source]:

- **Planning** – start by identifying shady and sunny areas, sloped and flat areas, and how air moves on site. Plants that have a similar need for water, sun and maintenance should be grouped together to increase irrigation efficiency and reduce maintenance time.
- **Low-water using plants** – choose plants with low water requirements and strategically position trees to provide shade in summer months and allow the winter sun in.
- **Limit grass areas** – turfgrass consumes large amounts of water and has high maintenance requirements. As such, it should only be used in areas that receive a lot of footfall. Alternatives should be considered for areas with lower footfall, such as seeded wildflowers, native grasses, or other drought tolerant ground covers.
- **Water harvesting techniques** – this involves using measures such as channeling runoff from rain to planted areas, or to a container for later use. It can also include sloping pavements and terraces to direct runoff to where it's needed, collecting rainwater, or constructing earth mounds or berms at the edge of the building to hold water on site. Locate plants where they can take advantage of this extra water.
- **Efficient irrigation** – make use of efficient irrigation methods and systems. This includes drips and soaker hoses that direct water straight to the base of the plant and prevent the water evaporation and wasted run-off that sprinklers allow. Use a timer or controller to schedule irrigation and change schedules often to match the weather.
- **Use mulches** – apply mulches at the base of plants to retain moisture, keep weeds down, and control erosion. Mulches can also reduce soil compaction and salt build-up. Typical mulches include compost, bark chips, and inert materials, such as decomposed granite and river run rock.
- **Use of indigenous plants** – matching plants to climate will not only help to nearly eliminate the need for watering and greatly reduce maintenance requirements but encourage biodiversity development by providing food and habitat for local wildlife.

3.3 Actions for change in land use

3.3.1 Maximizing biodiversity net gain

Action level: Keeping pace

Considered design can lead to the best possible outcomes for biodiversity and the benefits it provides.

Under the U.K. Environment Act, developments under the Town and Country Planning Act and Nationally Significant Infrastructure Projects will need to provide a minimum of 10% biodiversity net gain. CIEEM's Biodiversity Net Gain Principles and Guidance [source] and BSI's Process for Designing and Implementing Biodiversity Net Gain [source] set out in detail how best to approach development with respect to biodiversity.

Biodiversity Net Gain refers to development that leaves biodiversity in a measurably better state than it was in before the development. It's vital to ensure that human activity becomes not only sustainable but works to undo past harms to landscapes and habitats.

Achieving Biodiversity Net Gain is now a legal requirement in the U.K. Environment Act. In addition to meeting regulatory requirements, incorporating and focusing on Biodiversity Net Gain can allow projects to have positive local impacts, benefiting local authorities, wildlife groups, landowners and other stakeholders, and aligning with local priorities for nature conservation.

The Mitigation Hierarchy provides an important framework for managing risks and possible impacts of land use change on biodiversity and should be implemented from the earliest stages of design:

- Avoid impacts in the first place through careful design, avoiding high value sites and habitats for biodiversity. This is easiest to implement early in the project life-cycle.

- Minimize impacts where avoiding adverse effects is not possible.
- Compensate for losses in biodiversity elsewhere only when it's not possible to avoid or minimize your impacts.

Be ambitious and bold with the design, using a multidisciplinary team including ecology and landscape representatives to deliver a holistic approach. Different designs can be evaluated using biodiversity auditing and accounting tools. For example, Biodiversity Metric 4.0 is a calculation tool developed by the U.K. Government for quantifying nature losses and gains resulting from land management development or changes [source]. However, such tools should be used with caution and designs should deliver the best possible habitat within the local context, not just those which score the highest within the Metric.

Design choices should be informed by Local Nature Recovery Strategies and/or other available local biodiversity strategies to integrate with the wider landscape and support habitat connectivity.

Restoration or enhancement of existing habitats is simpler, less risky and more cost effective, so work with what is already present to make the most of onsite opportunities.

Consider the project legacy regarding current and future conditions, such as soil conditions and habitat management, so that habitats are resilient and likely to succeed. This may include working in collaboration with landowners and/or conservation charities to ensure effective management in the long run (30 years as a minimum).

Stakeholder engagement and sustainability considerations should be embedded at all project stages – including design – so that co-benefits can be identified, and biodiversity gains can provide wider value.

3.3.2 Designing for environmental net gain

Action level: Ahead of the curve

Building and infrastructure development offers an opportunity to deliver wider environmental benefits through taking a natural capital approach and designing for environmental net gain.

By considering potential impacts on natural assets, developers can make the most of opportunities to provide environmental enhancements. Targeting environmental net gain through design can leave the environment in a demonstrably better state.

The National Infrastructure Commission sees environmental net gain as building on biodiversity net gain, defining it as 'an approach to development that leaves both biodiversity and the environment in a measurably better state than prior to development'. As such, environmental net gain is measured using biodiversity metrics, alongside a broader range of metrics that assess ecosystem services. For example, this might include recreation, flood protection and air quality [source].

Development is often thought of as having a negative impact on the natural environment but the close relationship that infrastructure shares with natural capital can be leveraged to deliver wider benefits. Integrating nature-based solutions into scheme design can mitigate the impacts of development while delivering co-benefits. For example, designing sustainable urban drainage systems can provide biodiversity and amenity benefits, while also managing risks by improving resilience in the face of climate change-related flooding. Critical to this is the application of the mitigation hierarchy throughout the design process:

- Firstly, impacts should be avoided as much as possible.
- Unavoidable impacts should be minimized.
- Only as a last resort should unavoidable losses be compensated for. Compensation should initially be explored within the development footprint, but ultimately informed by where it will have the greatest benefit.

The National Infrastructure Commission's Design Principles for National Infrastructure recommends pursuing opportunities to benefit the natural environment throughout the project lifecycle. Engaging with local people and organizations will ensure the design complements the surrounding area and meets demand for wider benefits [source].

Natural capital assessments can be important in quantifying and demonstrating environmental net gain.

3.3.3 Enhance habitat connectivity through design

Action level: Keeping pace

Considering habitat connectivity in design can address historic fragmentation and support biodiversity.

When designing buildings and infrastructure, habitat connectivity needs to be a design consideration to reduce and prevent habitat fragmentation. Habitat loss and fragmentation can reduce species' population size and create increasingly isolated populations, threatening the long-term viability of species.

The Lawton Review

The Lawton Review can be used as a guide for improving habitat connectivity thereby reducing fragmentation. It offers five approaches to improve the resilience and coherence of ecological networks, summarized by the 'bigger, better, more joined up' concept [source]:

- Improve habitat quality through better management.
- Increase the site size.
- Enhance connections between sites through corridors or 'stepping-stones'.
- Create new sites.
- Boost the wider environment, including buffering wildlife sites, to reduce pressure on wildlife.

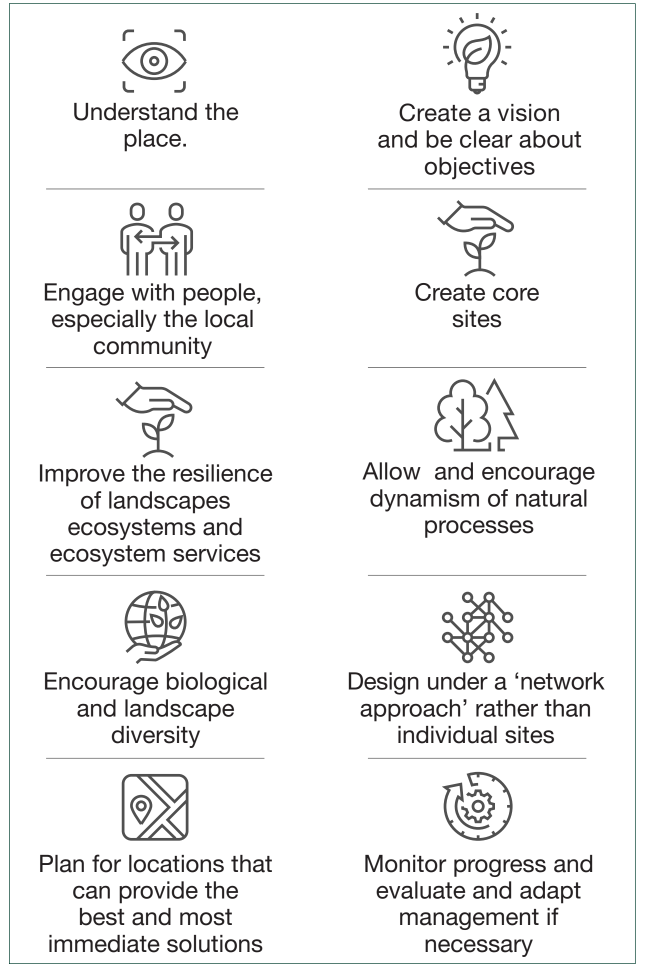
Ecological networks are made up of a number of components: core areas, corridors and 'stepping stones', restoration areas, buffer zones, and sustainable use areas. Local planning authorities (among other stakeholders) need to be consulted ahead of design and implementation to ensure the baseline ecological network components are well understood and that this information is used to inform the design. Where possible, ecological restoration zones should be established which enhance existing wildlife sites, improve connectivity, and restore ecological processes.

When designing in urban areas, ecological networks should also be used to reconnect people with nature and to support urban biodiversity. This can be achieved through the creation of linear features in the landscape, which should be practically designed for activities like cycling and walking but also as wildlife corridors (acknowledging potential conflicts). Throughout the design phase, attention should be paid to how ecological processes can be supported and helped in the face of environmental change.

More recent initiatives, which have evolved out of the approaches offered by the Lawton Review, should be consulted during design. Once established, the Nature Recovery Network, part of the 25-Year Environmental Plan, aims to form a national network of biodiverse places and:

- Offer spaces for nature conservation through wildlife-rich habitats, corridors and 'stepping stones'.
- Support climate change mitigation and adaptation through carbon capture and flood management, while protecting our historic natural environment.
- Benefit our health and wellbeing by connecting us to nature in our daily lives.

To support the development of the Nature Recovery Network and its ambitious goals, as part of the design process, local mapping should be used to identify existing ecological network components to best inform where actions for nature recovery can be most effectively taken, and what decisions should be taken for habitat recovery (as part of Local Nature Recovery Strategies). Natural England offers 10 principles for designing nature networks [source]:



Natural England: [Source]

Natural England offers rules of thumb which build on the Lawton Review principles and should be considered whenever designing infrastructure and buildings that have the potential to incorporate ecological network components [source].

3.3.4 Use the natural environment to support biodiversity and people.

Action Level: Ahead of the curve

Green infrastructure approaches include diverse strategies to incorporate nature within urban settings. Such strategies include green spaces, parks and gardens, living roofs, city farms, green corridors, and bird and bat boxes. Green infrastructure can support biodiversity and wildlife, enhance climate change resilience, and create social and economic benefits including active travel and attracting businesses to the area. A biophilic approach should be considered within green infrastructure design, supporting our natural drive to be in contact with nature and the natural world [source]. Positive benefits from increased connection with nature include improved productivity, better physical and mental wellbeing, lower levels of stress and better recuperation after stress. Biophilic design creates a built environment which supports this innate human attraction; green infrastructure can be implemented in design in a way which supports human wants and needs while balancing and improving the natural environment.

Green infrastructure should enhance the character of an area in line with its surrounding habitats and landscapes and be implemented at all spatial scales to be accessible and inclusive. Guidance for green infrastructure is readily available. The Town and Country Planning Association in partnership with the Wildlife Trusts provide an extensive list of options to consider within design and implementation, including:

- Multi-function habitats on buildings e.g. roofs, facades.
- Bat and bird boxes on all houses.
- Trees or hedges along streets and roads.
- Plants, hedgerows, log piles and other shelters to attract insects and provide wildlife refuges.
- Avoiding impermeable surfaces.
- Harvesting rainwater.
- Ensuring space is available for renewable energy sources.
- Creating accessible urban parks, natural green spaces, sports facilities and pitches, and play areas which offer habitats for biodiversity and recreation for all age groups.
- Creating a network of green and blue corridors for people and wildlife around existing assets. This includes a network of safe routes linking homes, schools, streets, open spaces and parks for people to move around safely, as well as the creation of active travel routes.
- Ensuring private garden space is provided where possible, including at least one side of the garden as a hedgerow habitat, and any broader connectivity opportunities such as creating gaps in fences between gardens.

The U.K. Green Building Council (GBC) also issued guidance on how to implement green infrastructure strategies [source]:

- Identify stakeholders and collaborative groups.
- Engage experts.
- Discern policy context and form connections to planning frameworks.
- Evaluate existing features and characteristics of the project site.
- Establish a green infrastructure plan.
- Consider local context and opportunities in line with the surroundings.
- Identify clear targets and a baseline for monitoring.
- Create an action plan and assess different design options for best value.
- Ensure the plan meets stakeholders needs and expectations.

Implement, monitor and manage the green infrastructure plan:

- **Implement** – establish who will be responsible for the implementation; it may be helpful to leverage the expertise of key stakeholder groups such as conservation charities.
- **Monitor** – monitor and report on targets to stakeholders.
- **Manage** – agree who is responsible for the legacy and maintenance of a project.
- Consider a green infrastructure strategy at an organizational level

Building with Nature released a Standards Framework (BwN 2.0) that adds to the guidance for green infrastructure and how it should be designed and implemented [source]. BwN 2.0 offers core, wellbeing, water and wildlife standards:

Core standards	
01 Multifunctional and connective	02 Effective in response to the climate emergency
03 Optimizes environmental net gains	04 Focused on the local context
05 Forms distinct sense of place	06 Ensures effective place-keeping

Wellbeing standards	
07 Brings people closer to nature, ensuring accessibility for everyone	08 Design for inclusivity

Water standards	
09 Climate resilient water management	10 Brings water closer to people

Wildlife standards
11 Provides wildlife enhancement

Finally, the Green Infrastructure Framework (as facilitated by Natural England) is a commitment in the U.K. Government's 25-Year Environment Plan. The Green Infrastructure Framework launched in January 2023 and comprises:

- **Green Infrastructure Principles:** the why, what and how of good green infrastructure.
- **Green Infrastructure Standards:** guidance on national standards for green infrastructure quantity and quality.
- **Green Infrastructure Maps:** mapped environmental, socio-economic datasets to support the standards.
- **Green Infrastructure Planning and Design Guide:** practical, evidence-based advice on how to design good quality green infrastructure.
- **Green Infrastructure Process Journeys:** guides on how to apply all the products in the Green Infrastructure Framework across England.

3.4 Actions for climate change

3.4.1 Designing energy positive buildings

Action level: Changing the game

Energy positive buildings (EPB) also known as energy-plus buildings, go a step beyond net zero as they are designed to, on average, produce more energy than they import from external sources.

There are several drivers for developing net-positive buildings, such as meeting the U.K.'s net zero carbon emissions target, potential economic returns for building owners, and enhanced market value. EPB are realized by combining energy-efficient construction technologies to reduce the energy demand of operational processes as far as possible and then using renewable energy to cover the residual energy demand. The energy surplus is supplied by electricity-generating renewables such as photovoltaic systems or wind turbines. Excess energy can either be stored or fed back to the energy provider [source]. EPB design can go beyond looking at individual properties and seek to create systems of connected EPB that contribute to the energy support of other buildings.

This can form Positive Energy Districts (PED) where excess resources are shared at a neighborhood or district level through smart grids [source].

EPB and PEDs require a comprehensive, systematic and integrated design approach to the three net-positive buildings principles:

- **Maximize energy efficiency** – the first step is to minimize the building's energy requirements, using established methods and technologies such as passive design, thermal insulation, low carbon heating systems, energy recovery, low energy lights and applications and ensuring energy-conscious user behavior (visualizing consumption, smart metering).
- **Passive renewable energy** - used to cover the residual energy demand. Windows, walls and floors are made to collect, store, reflect and distribute solar energy, in the form of heat in the winter and reject solar heat in the summer.
- **Active renewable energy** – made possible through the integration of thermal solar collectors, biogenic fuels, geothermal energy and electricity-generating systems such as photovoltaic panels or wind turbines.
- **System-based planning** – planning for what will be done with the excess energy generation. This could include storing the energy using batteries and/or feeding it to a small grid, with the potential to generate revenue for the owner or occupant.

EPB and PED designs apply to new buildings, and existing buildings can be retrofitted with the necessary technology.

Retrofitting existing buildings to be EPB and PED could become important in the U.K., with building turnover being relatively slow. For example, only 1-2% of total building stock each year is classified as new builds [source]. It's estimated that 80% of the U.K.'s housing stock that will exist in 2050 has already been built. The U.K. has the oldest housing stock in Europe with a median building age between 64 and 57 years old [source]. Older buildings tend to have lower energy efficiencies and many existing buildings were found to have energy efficiencies below Energy Performance Certificate (EPC) band C.

3.4.2 Innovative approaches to low carbon heating and cooling

Action level: Ahead of the curve

Energy consumed by buildings accounts for 23% of the U.K.'s total GHG emissions. This primarily results from electricity consumption and the use of natural gas for heating and hot water [source].
The U.K. Government has identified decarbonizing the heating and cooling of buildings as central to the Clean Growth Strategy [source], achieving the U.K.'s Net Zero carbon emissions targets and its obligations under the Paris agreement and Climate Change Act 2008 [source].

A range of innovative design solutions are available to reduce a building's carbon footprint, including:

- **Passive design strategies** – maximizing the amount of heating, cooling, lighting and ventilation provided by sunlight, wind, vegetation and other naturally occurring resources. Passive design usually considers the building's location site and design focusing on its orientation, aspect ratio, massing, windows, ventilation paths and usage.

- **Radiant cooling** – radiant cooling systems use cool water rather than air as the medium for delivering cooling through tubes in the ceiling, wall, floor or panels.
- **Direct ground coupling for fresh air and chilled water** – galvanized steel tubes, known as earth-to-air heat exchangers, are used to heat and cool fresh air being introduced into a building by bringing it in from underground. Additionally, groundwater can sometimes be used as the source of chilled water, reducing or eliminating the need for mechanical chilled-water systems.
- **Ground coupling** – the thermal characteristics of the earth and groundwater in the building vicinity are used for cooling and heating purposes, achieved through:
  - **The direct approach** – groundwater is used in radiant cooling systems and air is cooled through direct ground contact.
  - **The indirect approach – heat pumps are used in conjunction with** the ground or groundwater to move heating and cooling energy between the building and the earth. Ground source heat pump systems use the ground as both a heat source and heat sink, via two main methods:
  - **Horizontal ground** – coupling systems use plastic piping placed in horizontal trenches to exchange heat with the ground.
  - **In vertical systems** – U-tube plastic piping is placed in boreholes and manifolded in shallow trenches at the surface.

Energy Positive Building Case studies

A range of EPB and PED projects are underway and now being viewed as an important planning tool for meeting energy and emission reduction targets. This includes:

- Sustainable Urban Development program as part of the Strategic Energy Technology (SET) Plan Action – this aims to support the planning deployment and replication of 100 PEDs across Europe by 2025.
- Making City 2018 – development of new long-term strategies to transform the urban energy system towards PED.
- CityxChange – development and distribution of positive energy blocks and districts across Europe by 2050.

In the U.K., the SOLCER (Smart Operation for a Low Carbon Energy Region) project constructed new EPBs and retrofitted five existing buildings [source]. For the new build, the house was constructed to the PassiveHaus standard using passive building design and a structural insulated panel system. This was combined with Mechanical Ventilation and Heat Recovery systems (MVHR), a Transpired Solar Collector (TSC), an air source heat pump and an integrated thermal water store. The internal electrical appliance loads were reduced using LED lighting and energy efficient appliances. Electricity was generated using an integrated solar PV roof linked to a lithium battery store. Monitoring of the building's energy performance found the house had an energy import to export ratio of 1.55, indicating an energy positive performance was achieved. For the retrofits, market available technologies were employed including external wall and loft insulation, low-E double glazing, LED lighting, lithium storage batteries, PV roof panels and MVHR. The cost per house was in the range of £23,000 to £30,000 [source].

Low carbon heating and cooling systems can greatly reduce operational costs, heating cost, ventilation and air conditioning equipment, and downsize the footprint of mechanical apparatus, while increasing usable flood space. Low carbon heating and cooling are also important criteria for BREEAM and BREEAM Infrastructure assessments making up to 20% of the available credits [source].

3.4.3 Mitigating the 'heat island' effect through urban cooling

Action level: Ahead of the curve

The urban heat island effect is an issue not often considered in site and landscape design. This can be a major issue, especially for building design in urban areas where temperatures can be substantially higher than those in surrounding rural areas, usually by 1 to 6°C [source].

The urban heat island effect is caused by the removal of vegetation and its replacement with asphalt, concrete roads, buildings and other structures. This is because man-made structures and surfaces tend to absorb a greater proportion of the incoming solar radiation, which is then re-radiated as heat. Buildings in urban areas typically absorb around 90% of total incident solar radiation. Also, when vegetation is removed from an area, natural cooling effects, such as shading and evapotranspiration, are lost [source].

Heat islands are problematic because:

- They adversely affect human health, especially in children and older people, as increasing temperatures expose the populace to a greater risk of heat-related illnesses and mortality.

- They create additional cooling requirements for buildings, which necessitate more energy use to support the higher cooling loads, resulting in more air pollution, more GHGs, greater resource extraction impacts and higher operational costs.
- Typically, electricity use in cities increases 2-4% for every temperature increase of one degree Celsius. During warm periods when more energy is used to power air conditioning, more heat passes from buildings into the urban environment, further raising temperatures and creating a vicious negative reinforcing feedback loop.

Elements that can be integrated into design to provide urban cooling include:

- **Cool roofs** – roofs that stay cool in the sun by minimizing solar absorption and maximizing thermal emittance. There are multiple types of cool roofs to suit various building designs and structural components, with different techniques available for low-sloped and steep-sloped roofs. Measures can include white roof coatings, roofing membranes, foam roofing and aluminum roof coatings.
- **Choosing high emissivity materials** – The Solar Reflectance Index (SRI) is a measure of the solar reflectance and emissivity of materials that can be used as an indicator of how hot they are likely to become when solar radiation is on their surface. The lower the SRI, the hotter a material is likely to become in the sunshine.
- **Green roofs** – roofs that are purposely fitted or cultivated with vegetation. The vegetated surfaces disrupt radiative heat transfer through the roof and to the surrounding environment. This acts to reduce indoor air temperatures and to lower the heat island effect by changing the reflectivity of urban surfaces as well as providing evapotranspiration cooling.
- **Solar shading** – solar shading can be used to optimize the amount of solar heat gain and visible light that's admitted into a building. This can have a significant impact on the energy use of a building as well as on the thermal and visual comfort of occupants. Solar shading can be incorporated into a building's design by considering canopies, overhanging eaves or balconies, trees and other vegetation, external louvres or brise soleil, light shelves, awnings and solar control glazing.
- **SuDS** – features with permanent water and vegetation can be incorporated into a building's design or added as retrofits. This may include greening a building's envelope using measures such as green walls or making use of porous paving systems.

The Construction Industry Research and Information Association (CIRIA)'s SuDS Manual SuDS Manual provides design guidance on some of these design elements [source].

3.4.4 Integrating nature-based solutions for climate change into design

Action level: Ahead of the curve

A hierarchy approach to managing nature for climate benefits should be adopted in design. Key habitats such as woodland, peatland and saltmarshes represent nature-based solutions that should increasingly be used and managed in the U.K. for carbon sequestration and reduction. These natural climate solutions (NCS) combine the needs of climate change interventions, biodiversity conservation and human wellbeing enhancements through an ecosystem approach. When integrating nature-based solutions in design, hierarchies can be used to identify what the best strategy is.

A recent paper published in Nature magazine outlines four criteria for an NCS hierarchy [source]:

- The extent of mitigation potential.
- Cost effectiveness.
- Time horizon and permanence.
- Co-benefits.

According to the NCS hierarchy, 'protection NCS' should be implemented first to reduce emissions through preventing the loss (e.g. through conversion of forests, wetlands, etc.) or degradation of ecosystems. Protection NCS are prioritized as they offer a high volume of mitigation which can be quickly achieved at a lower cost per tCO2e. Protection NCS typically provide a wealth of co-benefits and align with global commitments to protect forests and support biodiversity.

Second in the hierarchy, 'improved management NCS' should be used to reduce and limit emissions in agriculture and forestry areas. Improved management NCS provide mitigation alongside commodity production and can remove carbon from the atmosphere.

'Restoration NCS' focused on high carbon habitats is last in the hierarchy, as failure to originally protect these lands can release large amounts of carbon, which will not be sequestered through habitat restoration in a long time. Additionally, restoration NCS can have high costs and feasibility constraints.

In areas with existing woodland or the potential for future trees to be planted, improved woodland management must be considered when designing mitigation. This ensures the most appropriate trees are planted and maintained for greatest carbon benefits, and for the positive co-benefits, such as biodiversity. Protection of native woodland, particularly ancient woodland, is key. Primarily, native woodland should be incorporated into design due to its significant ecological and social benefits, as well as its effective long-term carbon storage.

Areas of degraded peatland must be restored as when degraded it can emit large amounts of CO_2. With only minimal restoration in the U.K., peatland will release 1,674 MT CO2e by the end of the century [source]. With widespread peatland restoration, the release of 663 MT CO2e could be avoided nationally [source]. In Scotland, the loss of all carbon stored in peat soils would be the equivalent of more than 120 times Scotland's annual GHG emissions [source]. Peatland can sequester more carbon than all other vegetation types in the world combined and is the largest natural terrestrial carbon store [source]. Additionally, peatland provides essential ecosystem services such as minimizing flood risk and supporting drinking water catchments. Existing peatland must be protected, sustainably managed and restored to prevent further release of GHGs.

Saltmarshes, while limited in their ability to reach the U.K.'s net zero target alone, due to their relatively small total area, still provide significant sequestration capabilities. The U.K.'s saltmarshes have been lost due to land claims and may face further losses from sea level rise and coastal defenses. Globally, saltmarshes store more than 50% of coastal blue carbon [source]. Importantly, coastal wetland habitats may capture and store carbon at a higher rate per area than woodland or peatland [source]. When designing in coastal areas, care must first be given to protect and expertly manage existing saltmarsh and to emphasize their critical importance in sequestering carbon. If possible, restoration should be undertaken, given additional environmental benefits provided by saltmarsh such as natural flood defenses and nursery grounds for fish.

Restored, successfully managed and protected woodland, peatland and coastal saltmarsh are NCS which provide carbon benefits alongside supporting biodiversity and bettering the environment for human enjoyment. When designing mitigation in and around these environments or potential environments, guidance such as the Woodland Carbon Code [source], the Peatland Code [source] and the currently in development, Saltmarsh Carbon Code [source] should be used.

3.4.5 Embodied Carbon Footprinting

Action level: Ahead of the curve

Designers can measure the embodied carbon footprint of their buildings to account for climate change impacts more transparently.
Embodied carbon is the total GHGs emitted in the acquisition and processing of raw materials, including manufacturing, transportation and final installation of building components. The definition can also be extended to include the maintenance, replacement, deconstruction, disposal and end-of-life aspects of the materials and systems that make up the asset [source].

Products requiring a greater amount of energy to produce and transport usually have a higher environmental impact. However, this must be balanced against the durability of the materials because although more durable products may have a higher upfront energy cost, they'll have a lower embodied energy per time in use. This also extends to recycled components, as certain recycled materials have a much lower embodied carbon footprint – for example recycling steel uses approximately 80% less energy than manufacturing new steel [source].

To date, regulations such as the U.K. Building Standards have tended to focus on the reduction of operational GHG emissions (i.e., heating, lighting, cooling and ventilation). But the embodied carbon associated with construction is increasingly gaining attention for two reasons. Firstly, embodied carbon has been found to be more significant than previously thought. Recent figures show embodied emissions can account for between 20-50% of the total carbon emitted for a given building project. The second is that reducing embodied carbon is thought to be critical for meeting 2030 and 2050 emissions reduction targets and delivering net zero buildings [source].

While embodied carbon reduction targets are not yet mandatory, they'll likely be included in future legislation. At present both the EU and the U.K. are considering proposals for legal limits on embodied carbon. However, building sustainability schemes including BREEAM, BREEAM Infrastructure, LEED and Green Star all recognize embodied carbon measurement and mitigation [source]. Embodied carbon reduction is best tackled as early as possible during design so that reduction opportunities can be highlighted and acted upon. Assessing embodied carbon can be complex, so it's recommended that embodied carbon assessment tools and best practice guidance are used. This includes the U.K.GBC's embodied carbon tool [source] and The Institution of Structural Engineers' 'A brief guide to calculating embodied carbon' [source].

PAS 2080 – Carbon Management in Infrastructure, a global standard for managing infrastructure carbon, looks at the whole value chain through intelligent design, construction and use. PAS 2080:2023 is recommended for infrastructure delivery, and PAS 2080 guidance has been developed by the Construction Leadership Council and The Green Construction Board, with support from wider organizations [source].

As a starting point, commonly used methods for reducing embodied carbon include:

- **Low-carbon concrete mixes** – typically concrete is the biggest source of embodied carbon for any given construction project. This can be redressed by using lower carbon concrete mixes made from fly ash, slag, calcined clays, or even lower-strength concrete where feasible.
- **Transportation emissions** – use materials and construction products made from locally available raw materials. Prioritize the use of suppliers that are close to the construction site.

- **Reuse materials** – where possible, salvage materials such as brick, metals, concrete (including broken concrete) or wood. Recovered materials have a much lower embodied carbon footprint than newly manufactured materials.
- **Carbon sequestering materials** – use products that sequester carbon such as wood and straw.
- **Maximize design and structural efficiency** – optimizing a building's design results in less material being needed for construction. The less material required, the fewer resources need to be extracted, manufactured, consumed and disposed of.
- **Choose materials with lower embodied carbon** – during the design phase, choose to construct the building with materials that have lower embodied carbon.
- **Adaptability** – design the building so it can change its use over time to minimize future refurbishments.

Minimizing embodied carbon can lead to more efficient building designs, requiring fewer resources and lowering capital expenditure. The use of more durable materials will also reduce maintenance, repair and replacement costs. Lowering embodied carbon can also assist with achieving credits in some building assessment sustainability rating schemes [source].

3.4.6 Design for Climate Change Adaptation Pathways

Action level: Ahead of the curve

Even with immediate, sustained and rapid reductions in GHG emissions, the climate will continue to warm. This is because of emissions that will be released in the interim to achieving net zero and the thermal inertia of the climate system [source]. This means a level of climate change will be unavoidable. While it is difficult to precisely anticipate the amount by which the climate will change, there will certainly be more (and more intense) rainfall, flooding, droughts, heatwaves, storms, storm surges and rises in sea levels over the coming decades [source].

Buildings and infrastructure can be vulnerable to climate-related risks, because architects, engineers and designers will tailor structures to operate within the parameters of the local climate. Typically, this may account for a given range of temperatures, groundwater levels, geology, storm return periods derived from historical weather records and sea levels. However, climate change is going to increasingly alter weather patterns, exposing built assets to conditions they were not designed for. This is likely to result in greater and more frequent damages, which may impact structural features [source]. For example, one concern is that warmer and wetter conditions will cause the steel inside reinforced concrete, to rust. As the steel rusts, it expands inside the concrete creating cracks that weaken the structure and can compromise structural integrity [source].

Buildings and infrastructure assets poorly adapted to climate change pose both a public health and economic risk. Economically, assets that are exposed to climate change risk significant devaluations, as they will become much less desirable as places to live or work. More extreme weather exposure will cause greater and more frequent damages creating increased maintenance to offset damages. Expensive retrofits may even be required. Mounting repair and maintenance costs alongside devaluations could even lead to assets becoming stranded [source]. From a public health perspective, indoor conditions may become increasingly intolerable. For example, more intense and more frequent heatwaves can overheat buildings [source]. Potential climate change impacts that designers may want to consider include:

- Greater ranges of temperatures will increase thermal stress from materials expanding and contracting. Metals and concrete are particularly vulnerable to this effect as metals can buckle once their designed tolerance is exceeded, and concrete can crack.
- Subsidence issues are expected to become more problematic. This is because in warmer and wetter climates, soils are going to experience greater levels of swelling as more water is absorbed during wet periods. However, soils are also going to shrink more when dried out during longer periods of warm dry weather. Buildings with foundations in clay soils are particularly vulnerable to this.
- Higher temperatures will expand the regions where certain insects can live. Living spaces must be designed or redesigned to protect against timber-eating termites that cause major structural damage and disease-carrying insects.
- Warmer, wetter and more storm-prone climates will cause external cladding to deteriorate more rapidly and leak more often, increasing the chance of damp and encouraging the spread of rot and mold.
- In coastal areas, rising sea levels will raise the water table, increasing salinity. The higher levels of chloride will accelerate rusting and the corrosion of building and infrastructure foundations.

Designers and engineers can use several adaptations to offset or prevent climate change impacts on the built environment. For example, foundations can be designed to be larger and sturdier than required to anticipate greater levels of subsidence. Overheating can be reduced through thermal shading, increasing ventilation and using lightly colored materials or paints [source]. Green infrastructure to manage urban heating can provide benefits for biodiversity and communities' health and wellbeing. Thinking adaptively broadens the design context, leading to collaborative working opportunities across sectors. A more comprehensive approach may be necessary, particularly for new construction projects, integrating adaptation as early as possible during the planning and design stages to be more cost-beneficial [source].

Designers can use adaptation pathways, a planning approach used to address climate change impacts while accounting for uncertainties of the climate's future state. Considering multiple possible future scenarios based on climate sensitivities and vulnerability assessments, designers can follow these key steps in developing climate change adaptation pathways [source].

Impact Assessment

Determine what climate-related risks are expected to occur based on regionally and locally focused climate predictions. Then identify how these climate risks could affect the proposed building or infrastructure project. It is also recommended to examine non-climatically-driven future risks as well.

↓

Vulnerability and Risk Assessment

To start the assessment, collect information on the climatic drivers identified in step one as well as data for socio-economic urban and technical context. Then define the challenges, levels of risk, key problems and vulnerabilities. Define tipping or turning points when alternative management strategies are needed.

↓

Identify Potential Adaption Options

Use existing examples, case studies and a literature review to decide adaptation options. Evaluate each option based on agreed criteria, such as effectiveness, cost-efficiency, axillary benefits, potential barriers or implementation time.

↓

Formalise Adaptation Options

Group identified adaptation options into possible adaptation packages or design pathways, and quantitatively or semi-quantitatively assess the cumulative effects of each adaptation.

↓

Plan Measures

Create the implementation plans for each design pathway.

↓

Monitor and Evaluate

Implement a Monitoring, Evaluation, Reporting, Improvement and Learning (MERIL) system to track key indicators of systems change (e.g. tipping points). This will underpin any adjustments to strategies, operational plans and implementation practices.

Climate change adaptation is not without its risks, and adaptive planning can be difficult to implement, but buildings and infrastructure need to be future-proofed. The European Commission recently published technical guidance on climate-proofing infrastructure. The U.K. Town and Country Planning Association's climate change adaptation guide outlines how adaptation can be implemented in the planning, design and development of new and existing communities in the U.K. It offers a range of strategies to manage high temperatures, flood risk, water resources and quality, and ground conditions, across the conurbation/catchment, neighborhood and building scales. Several standards, such as BS 8631:2021 and ISO 14090:2019 provide guidance to frame the design process so it includes an adaptation pathway approach.

3.5 Actions for all challenges

3.5.1 Sustainable building certification schemes

Action level: Keeping pace

Sustainable building certification schemes are a set of rating systems and tools used to assess a building or a construction project's sustainability and environmental performance. In the U.K., the most well-known and recognized schemes include BREEAM, BREEAM Infrastructure and Passivhaus.

BREEAM

BREEAM Building Research Establishment Environmental Assessment Method, launched in the U.K. in 1990, sets best practice standards for the environmental performance of buildings through design, specification, construction and operation [source].

With separate BREEAM assessments for different types of buildings, each assessment is based on a scoring system that evaluates how sustainability has been incorporated into energy and water use, health and wellbeing, pollution, transport, materials, waste, ecology and management processes. Buildings are rated and certified on a scale of 'Pass', 'Good', 'Very Good', 'Excellent' and 'Outstanding' [source]. While a voluntary scheme, some organizations and local planning authorities require BREEAM certification (or equivalent), either as part of a local plan, or as a planning condition imposed on developments [source].

BREEAM Infrastructure

BREEAM Infrastructure assesses sustainability performance for civil engineering and public projects. Developed by the Institution of Civil Engineers and now run by the BRE group, BREEAM Infrastructure operates alongside BREEAM, using evidence-based assessment criteria and external verification to provide a result that can be made public and used for promotion. BREEAM Infrastructure integration in the development of projects and contracts can positively influence design and construction management and often leads to significantly better outcomes, such as more sustainable projects in civil engineering, performance improvements, better value and cost reductions, and enhanced team collaboration [source

Passivhaus

Passivhaus is a German-developed energy performance standard primarily for new dwellings, commercial, industrial and public buildings. Several approved U.K. organizations offer certification. The scheme is primarily intended for new buildings, but it can be used for refurbishment projects, but this can be more expensive [source]. Based on passive design principles with the goal of reducing heating demand to a very low level, Passivhaus requirements are rigorous, far exceeding those of the current U.K. Building Regulations.

It's estimated that upfront costs can be up to 8-10% more on U.K. projects, however the scheme is popular among architects and designers, with many different options and pathways available to meet the certification criteria:

- Space heating demand should be less than 15kWh/m²/yr, with 90% less energy needed for heat than an average home, and 75% less than the average new build.
- Exterior walls must achieve a U-value (sum of thermal resistance) of less than 0.15.
- Windows must have U-values less than 0.8.
- Less than 0.6 in air changes/hour at 50Pa (Pascal), which is 20 times more airtight than a standard build.
- Over 80% heat recovery from ventilation exhaust air. Mechanical Ventilation with Heat Recovery (MVHR) provides constant fresh air and keeps heat inside the house.
- Optimized solar gain – the house retains heat from the sun and occupants' activities.

As of November 2020, 1,300+ dwellings across the U.K. had achieved Passivhaus accreditation.

Other certification schemes

Other commonly employed building and construction certification schemes include:

Leadership in Energy and Environmental Design

Leadership in Energy and Environmental Design (LEED) is a voluntary environmental certification system developed by the U.S. Green Building Council in 2000 [source], covering design, construction, operation and maintenance. Projects are assessed against categories including water efficiency, energy usage, emissions material and resource use, indoor environmental quality and design innovation. These categories are given weighted credits to produce an overall score and rating of either platinum, gold, silver or certified [source].

3.5.2 Stipulating nature positive considerations within procurement contracts

Action level: Ahead of the curve

Take nature into account when purchasing goods and services.

Procurement contracts play a key role in infrastructure and building design, including nature positive considerations which allow them to be a vehicle of positive environmental change, as well as benefiting society and the local economy more broadly. By expanding procurement processes and rules to ensure infrastructure design incorporates nature positive ideology, this supports biodiversity and carbon priorities, and spreads a strong nature positive message for change to the wider market.

The European Commission's Nature-Based Economy Working Group of Task Force III produced a draft White Paper on how to address procurement challenges for nature-based solutions [source]:

- **Address knowledge gaps** – build the capacity to take advantage of potential opportunities from nature-based solutions, e.g. developing awareness of nature-based solutions, their benefits and value.
- **Better valuation of non-monetary benefits** – procurement processes need to better align with the non-monetary values of nature-based solutions, including the incorporation of natural capital assessments.
- **Support suppliers** – procurement can be altered by providing financial and technical support to enable the development of new types of suppliers, e.g. land managers whose natural assets provide benefits, such as flood risk management and better water quality.
- **Strengthen regulatory support for nature-based solutions** – local codes and requirements for nature-based solutions can be integrated into the procurement processes. Implement standards for nature-based solutions or other quality assurances as reference criteria.

3.5.3 Taking a natural capital approach

Action level: Ahead of the curve

Accounting for nature can empower designers to manage risks and maximize opportunities.

Taking a natural capital approach is about thinking of nature as an asset that provides benefits to society and using this to inform decision making. Understanding the value of nature helps better manage it to meet society's needs. Taking a natural capital approach to buildings and infrastructure highlights high-value natural assets to be retained and protected within designs, where conventional environmental assessments may miss value of high economic or social importance.

Similarly, a natural capital approach can identify investment priorities or opportunities for environmental improvements to help a project deliver multiple benefits. Visualizing beneficial and adverse natural capital impacts can support collaborative working between disciplines in the design process and demonstrate and communicate project benefits to stakeholders.

Though not always necessary, placing a monetary value on a project's effect on the natural environment can make these impacts more transparent and enable more holistic cost-benefit analysis to support business case development. DEFRA's Enabling a Natural Capital Approach helps decision makers account for the value of the environment. Considering natural capital early in the project lifecycle helps minimize risks and optimize opportunities [source].

4. Case studies

4.1 Scottish and Southern Electricity Networks Transmission

The loss of habitats and wildlife has become a major issue in the U.K. The decline of Britain's natural environment is occurring at an alarming rate and resulted in nearly half of Britain's biodiversity being lost since the industrial revolution [source]. Scottish & Southern Electricity Networks Transmission (SSEN Transmission) has voluntarily committed to delivering biodiversity net gains for its current and future projects and operations. Working towards this goal has led SSEN Transmission to develop a bespoke biodiversity metric, allowing the organization to transparently assess their impacts on nature. Using its new methodology, SSEN Transmission has achieved up to 34% net gains in biodiversity.

4.1.1 What we know

The biodiversity and climate crises are intrinsically linked, so organizations need to urgently account for both in design and planning. Enhancing biodiversity can support improved provision of ecosystem services, creating multiple benefits across a range of factors.

SSEN Transmission is supporting the decarbonization of the energy sector by connecting renewables to Great Britain's electricity network. Recognizing the importance of biodiversity in its recent projects and operations, SSEN Transmission has driven change by voluntarily developing and adopting a bespoke biodiversity metric. This was adapted for the Scottish context to transparently assess their impacts on nature.

4.1.2 What we're doing

SSEN Transmission has committed to no net loss of biodiversity for all projects gaining consent from April 2020, and net gain on all projects gaining consent from 2025. Biodiversity-positive thinking is being embedded at all stages of project life cycles, through assessment, monitoring and the inclusion of biodiversity net gain targets as planning objectives [source].

New approaches and tools are being used to measure and quantify biodiversity to act in accordance with regulatory requirements, as well as develop understanding of impacts that developments and landscape changes have on biodiversity. Interventions to avoid biodiversity losses include a variety of strategies such as replanting previously felled habitats with mixed woodland, replacing habitats lost due to works with higher value habitats, removal of invasive non-native species, improving the condition of marshy grasslands, and restructuring existing woodlands to enhance biodiversity.

SSEN Transmission is not just focused on achieving the maximum biodiversity value according to its metric, it's making wider species considerations too. For example, special osprey nesting platforms have been integrated into scheme designs. Similarly, vegetation mixes are chosen to maximize benefits for locally occurring species, and species protection plans have been implemented for a wide range of species, including beavers.

4.1.3 What it's worth

At the Caithness Moray HVDC Project, the construction of new substations was accompanied by the creation of diverse habitats to support local Biodiversity Action Plan species. The project resulted in a 34% gain in biodiversity units, while also identifying improvement opportunities in future projects, such as incorporating biodiversity net gain assessments earlier in the planning process.

Another substation construction project in Thurso created pollinator habitat to support the Great Yellow Bumblebee and other key pollinators, through the planting of native low-maintenance plant species. Planning was completed in collaboration with local stakeholders, such as the Bumble Bee Conservation Trust, and large environmental gains were seen for a relatively low cost. The ongoing adaptive management and monitoring has ensured long-term benefits [source].

"By embedding biodiversity into the design of new projects, SSEN Transmission helps support both UN as well as Scottish Government biodiversity strategies, and is able to demonstrate to external stakeholders sustainable enhancements from development projects. It has also created opportunities to work with local environmental organizations and communities to support biodiversity initiatives in the wider landscape, leaving a positive long-lasting legacy. The approach to biodiversity helps support SSEN Transmission's wider sustainability ambitions of promoting the natural environment, supporting local communities and tackling climate change."

Francis Williams - Environmental Net Gain Manager, Scottish & Southern Electricity Networks

Image: Jacobs/LDA

4.2 HS2 Colne Valley Landscape & Habitat Creation

High Speed 2 (HS2) is a planned high-speed railway line in the U.K. to connect London with the West Midlands. It's the largest infrastructure project in Europe and will be integral to transforming the U.K. to a low carbon economy. The project is composed of multiple construction sites involving the building of bridges, tunnels, tracks and train stations, presenting opportunities to simultaneously improve the local environment and communities.

One of the largest individual HS2 construction projects is the Colne Valley, where the HS2 rail line will cross the Colne Valley Regional Park, a 4300-hectare (ha) area of countryside comprised of a mosaic of parks, green spaces, reservoirs and the River Colne. A viaduct is being constructed which will carry the railway over the Colne Valley Regional Park. Project planning and execution employed a wide range of innovative techniques and engineering best practices. Using Jacobs' technical expertise, environmental disturbances were minimized, negative impacts have been offset, and the natural landscape was improved with the creation of restored calcareous grassland, woodlands, wetlands and recreational routes.

4.2.1 What we know

In addition to increasing capacity on the U.K.'s busy railways, HS2's primary aim is to modernize and connect major destinations across England by forming a new national backbone of state-of-the-art high-speed rail [source]. As well as offering a fast, low-carbon option for long-distance travel, the numerous infrastructure projects that make up the wider scheme offer a multitude of opportunities to use innovation and sustainable design to ensure positive local outcomes for both people and nature.

One such project is set in the Colne Valley, where the new high-speed rail line traverses the western slopes of the valley between crossing the River Colne on the 3.2km viaduct and the bored tunnel under the Chilterns escarpment. Prior to HS2's construction, the area consisted of arable farmland; however, the landscape was once home to calcareous grasslands, a chalk-based habitat that is valuable but rapidly declining across the U.K. [source]. This collaborative project plans to create one of the largest extents of chalk grassland in the area.

4.2.2 What we're doing

The Colne Valley project represents a synthesis of innovative landscape and ecological design alongside engineering best practice. More than the infrastructure needed to construct a railway viaduct, the result will include a varied landscape of tree-lined ridges, wood pasture, wetland, restored calcareous grassland, and recreational routes.

Chalk arisings from the boring of the Chiltern tunnel will be placed in layers and capped with local soils to create calcareous grasslands in the area. This presents a dual benefit of eliminating the need to remove these arisings to off-site and the associated carbon emissions in doing so, while creating a valuable habitat.

Noise levels from the operating railway, a sensitive issue on any transportation project, were carefully considered and control measures developed through collaborative working among the design team. With consideration to the ecological and landscape requirements, the earthworks design was refined to provide a high level of acoustic screening, eliminating the need for unsightly acoustic barriers. While these are unavoidable on the viaduct, the barriers have been carefully integrated into the design and provide the best possible acoustic performance while meeting the architectural and other design aspirations in this sensitive area.

4.2.3 What it's worth

The 140-ha site within the wider Colne Valley will be landscaped using 2.6 million cubic meters of chalk arisings from the 16-km long Chiltern tunnel. The diverse landscape mosaic will support biodiversity through habitat creation and connectivity, climate change mitigation through the creation of habitats with higher carbon sequestration than the baseline, and social amenities and well-being will be supported by over 4 km of recreational routes. A long-term rewilding approach will allow habitats to function naturally and require minimal management intervention.

Calcareous grassland is one of the richest habitats found in Western Europe, containing over 40 plant species per square meter. It is a unique habitat, with 50% of the world's occurrence being found in the U.K., but with significant declines since World War II. The landscaped improvements to the Colne Valley site will create approximately 88 ha of new calcareous grassland and 26 ha of woodland.

This success story for biodiversity, along with acoustics and a multitude of other design elements will significantly contribute to HS2's legacy.

Image: Tideway

4.3 Thames Tideway Tunnel

The Thames Tideway Tunnel infrastructure project focuses on upgrading the section of London's sewer system that runs under the tidally influenced reaches of the River Thames and Inner London. The objective is to capture, store and convey almost all the raw sewage and rainwater that currently overflow into the estuary. To optimize outcomes, the scheme employed industry-leading and innovative approaches to project planning and management. The innovations and scheme improvements resulted in an estimated 236,800 tC02e saving.

4.3.1 What we know

London's sewer system is 150-years-old and originally built for a population less than half of its current size. Even being forward thinking at the time and planning for population growth, the system's capacity has exceeded to the point where even light rain risks untreated sewer overflows to the River Thames [source]. This has led to an average of 39 million tonnes of untreated sewage being discharged into the Thames each year [source].

The project aims to upgrade and modernize the system to meet both demand and future-proof the system for the next hundred years. This involves constructing a tunnel 25 km long and more than 65m deep, providing a 94% reduction in sewage pollution alongside other sewage network upgrades, once complete [source].

4.3.2 What we're doing

Tideway is embracing numerous approaches involving lean construction, collaborative planning and continuous improvement. Construction materials and excavated spoil are primarily being moved by barge, reducing road congestion and protecting vulnerable road users.

The project is also operating within the context of policy drivers. This includes London's target to reduce carbon emissions by 78% by 2035 [source], and goals within the construction and infrastructure sector, such as reaching net zero emissions for steel manufacture by 2035, for cement by 2040, and largely decarbonizing all construction material manufacture by 2040. By working to ambitious carbon budgets and using clear reporting parameters, the project is addressing the challenges of global climate change and demonstrating good practice in reducing the project carbon footprint.

4.3.3 What it's worth

Various initiatives within the planning and management of Tideway's construction are estimated to have generated considerable carbon reductions. Careful selection of an optimal, shortest possible route for the tunnel led to a 19% reduction in material use with an estimated saving of 199,000 tCO2e. The decision to transport materials primarily by river avoided an estimated 23+ million HGV kms to date, equivalent to a reduction of 14,500 tCO2e, as well as 240 tonnes of nitrogen oxides. Reducing the thickness of the secondary lining in the tunnel's central area alone resulted in 16,000 m3 less concrete being needed, saving 7,300 tCO2e by the end of March 2021.

Tideway is also supporting local communities through investment, job creation and new public spaces along the Thames. It was named Infrastructure Project of the Year at edie 2021 Sustainability Leaders Awards [source].

Image: Tideway

Image: Transpennine Route Upgrade, Network Rail

4.4 Transpennine Route Upgrade

The Transpennine Route Upgrade (TRU) is a large infrastructure project that aims to improve the railway line between York and Manchester, including Leeds and Huddersfield. This covers 76 miles of train lines that run through the Pennines, a rural area that's well known for its natural beauty and designated ecological areas. The environmental impacts of works were considered from the outset, and the project has sought to minimize negative impacts and generate net positive environmental outcomes, with a Biodiversity Net Gain target of 10%. To achieve this, the project has used scientific best practices, the implementation of organizational policies and principles, as well as stakeholder inclusion.

4.4.1 What we know

TRU aims to improve long-term connectivity across the North of the U.K. [source]. The program places a heavy focus on the environment, with a heightened focus on preserving and increasing biodiversity in works areas.

Achieving Biodiversity Net Gain is now a legal requirement in the U.K. Environment Act. Projects can ensure compliance with legal frameworks, while reaching a higher level of sustainability and environmental responsibility by incorporating concepts like Biodiversity Net Gain as key performance indicators. Further information on how infrastructure projects can maximize biodiversity net gain is available in section 3.3.1.

4.4.2 What we're doing

Biodiversity should be considered from the planning process in any project using the mitigation hierarchy explained in section 3.3.1. From its planning stages, TRU has considered the impacts of works on biodiversity, natural capital and ecosystem services. In line with Network Rail's Net Positive Principles, the project has sought to minimize negative environmental impacts and generate net positive impacts. The principles were incorporated into the early planning stages, along with identifying key stakeholders to work with.

An example from one development site involved natural vegetation regrowth after intervention to slightly below the pre-intervention baseline, according to DEFRA-developed biodiversity indicators. However, this was offset by work off-site to replace amenity grassland with a more natural wildflower meadow, resulting in a much greater gain. As measured, the sites taken together represented a Biodiversity Net Gain of 41%. Under the Environment Act, the minimum requirement for Biodiversity Net Gain is 10%.

4.4.3 What it's worth

TRU has a Biodiversity Net Gain target of 10%, which is recognized as 'leading practice' within its industry. Meeting this requires active management of biodiversity at both the program and delivery levels, and presents the opportunity to deliver significant and lasting biodiversity benefit. The project has made use of scientific best practices to exceed new targets for environmental gains laid out by the Environment Act.

Policies and principles followed by Network Rail ensure that opportunities for positive impacts are identified, pursued and monitored based on science and accepted best practice. Stakeholder inclusion at all stages of the project is of vital importance to ensure the program's biodiversity impacts are positive at a local level. Habitats and biodiversity are preserved and enhanced wherever possible, with offsetting as compensation for negative impacts only used when more favorable approaches are not possible.

Image: WWT

4.5 Steart Marshes Managed Realignment Scheme

The Steart Peninsula is an exposed section of coast in Somerset, south-west England, next to the Severn Estuary. The area is vulnerable to flooding from the mouth of River Parrett which flows into Bridgwater Bay where some of the strongest tidal forces in the world are generated. Maintaining the peninsula's existing flood defenses is prohibitively costly and unsustainable, with this being exacerbated by rising sea levels and increased frequency of severe storms.

There was a clear need for a new and sustainable approach to flood protection. Managed realignment was identified as being the best option. Jacobs used a combination of stakeholder and community engagement, hydrodynamic modeling and environmentally-friendly construction practices. The overall result was a reduced risk of flooding to the surrounding community and infrastructure. In addition, 183 hectares of saltmarsh, 40 hectares of intertidal mudflat, 79 hectares of coastal grazing marsh and 26 hectares of freshwater lagoon were created, significantly improving the coastal environment and biodiversity.

4.5.1 What we know

In the U.K., managed realignment is the most common method to restore coastal habitat. This allows the sea to return to areas that had previously been reclaimed by creating carefully planned breaches in coastal flood barriers. This can offer a sustainable, long-term management option that restores valuable habitats while reducing pressure on flood defenses [source]. In much of the northern hemisphere, saltmarshes and mudflats have historically been reclaimed from the sea to produce grazing or agricultural land. However, over the past 20 years recognition of the value of these areas has increased, due to their role as habitats for sensitive species, and for their provision of natural defense against coastal erosion and inland flooding. Restoration efforts have therefore become more common [source].

The Steart Coastal Management Project undertook a combined managed realignment, with regulated tidal exchange and freshwater restoration techniques used to create a range of sustainable coastal habitats, compensating for habitat losses elsewhere in the Estuary due to rising sea levels.

4.5.2 What we're doing

The project represented a particularly complex piece of work, with the planning stages requiring detailed hydrodynamic modeling, to ensure the scheme would create the maximum possible habitat while minimizing impacts on the surrounding estuary. Technical expertise from Jacobs in the design, permitting, construction and monitoring of Steart Marshes resulted in the successful creation of new valuable habitat.

Since being breached, the new exit channel from the marshes has been carefully monitored in cooperation with academic researchers to further understand the hydrodynamic processes at work and inform similar future projects [source].

4.5.3 What it's worth

The Steart Coastal Management Project is one of the U.K.'s largest coastal habitat creation schemes, restoring more than 400 ha of natural habitat, including large areas of saltmarsh and mudflat which are home to many sensitive species. Local villages and roads will benefit from improved flood protection [source], and the habitat creation supports both climate change mitigation (through carbon sequestration) and adaptation (through protection from coastal flooding).

Rigorous modeling enabled the scheme's planning and option selection to be well-informed about how different decisions would affect the flooding characteristics of the newly reclaimed habitat, and its influence on flood protection of nearby dry lands. Careful planning and collaboration ensured the scheme was cost-effective and received planning approval on its first submission.

A separate MSc research project demonstrated the considerable economic benefits from the range of ecosystem services provided by the coastal wetland habitats, valuing them between £500,000 and £900,000 annually in 2008 [source].

Image: WWT

Image: Arcadis

4.6 Otterpool Park Garden Town

Otterpool Park is a proposed garden town located in the Kent countryside, close to the seaside towns of Folkestone and Hythe. Otterpool Park is planned to provide up to 10,000 homes, 12 hectares of employment space, open green areas and community facilities. Kent County Council proposed this project as a sustainable solution for meeting house building targets, growing the local economy, and to maintain the economical delivery of local services. Arcadis led the planning and development of the project and innovatively integrated ecosystem services and natural capital assessment tools into the planning process, alongside stakeholder engagement and multidisciplinary collaboration.

4.6.1 What we know

The concept of a 'garden town' can be traced back over a century, and recognizes the shortcomings that many of our cities and common approaches to urban design have for both nature and society. By developing new communities in accordance with a plan that includes nature and natural spaces, public transport, and access to essential goods and services, these communities can be more sustainable and resilient places for both nature and people. Incorporating modern ecosystem services assessment tools in the planning process means the latest scientific understanding is used, ensuring developments create a net gain for biodiversity and other natural qualities.

Demand for housing in the U.K. is growing, with Folkestone & Hythe District Council committing to building 14,600 new homes between 2014 and 2037. Otterpool Park will meet some of this demand, supporting 8,500 homes initially, with potential to increase to 10,000. A master plan is being developed to include community facilities such as schools and health facilities, as well as a layout to encourage walkable access and public transport use [source].

4.6.2 What we're doing

Otterpool Park is being planned to incorporate nearly 50% of green space. This project is being led by Arcadis in collaboration with a diverse range of environmental experts to ensure the landscape is sustainable and supportive of wildlife as well as the health and wellbeing of residents. Quantifying positive and negative environmental impacts allowed targets for environmental net gain to be set and carried through the planning, design and the delivery process.

The site is mostly formed of arable farmland and improved grassland, which has limited biodiversity value, so the landscape-driven masterplan supports natural habitats and is anticipated to achieve a 20% Biodiversity Net Gain.

Graphics were used during the design process to support multidisciplinary collaboration and communication with stakeholders. This ensured the functionality and benefits of green infrastructure were not compromised throughout the design process.

4.6.3 What it's worth

The master plan for Otterpool Park has been used as a case study for how ecosystem services and natural capital assessment tools were trialled and effectively integrated into the planning process. Strategies such as Sustainable Drainage Systems (SuDS) were prioritized to support multiple benefits including carbon sequestration, passive cooling and visual amenity. The findings of the natural capital assessments were presented as part of the planning application.

The project demonstrates how natural capital and ecosystem service assessment tools can be incorporated into planning, how high biodiversity net gain targets can be achieved, and how a multidisciplinary approach to planning can be used without compromising core development goals. Deliberate efforts have been made to share findings with the ecology profession, as well as specialists on construction projects. This will enable future projects to benefit from the approach's advantages and lessons learned.

4.7 Burton Washlands Scheme

The Burton Washlands scheme set out to reimagine how the Washlands could be used more effectively, as existing design and management were producing sub-par outcomes, and failing to ameliorate the impacts of flood incidents. Areas designated as recreational spaces and amenity parklands were commonly under water. Binnies (part of RSK) led the identification, development and implementation of measures to improve the provision of ecosystem services though naturalistic approaches. The projected results included new and improved wetland habitats, improved access and stronger connections between the town and the Washlands, which was assisted by improved environmental interpretation and education facilities.

4.7.1 What we know

A natural capital approach is valuable for understanding and quantifying the benefits of nature-based solutions, such as creating and restoring habitats that in turn provide a multitude of ecosystem services. Natural capital assessments take stock of the existing environment, and how various habitats and other natural features contribute benefits and, where possible and appropriate, consider these benefits in terms of their economic value. This knowledge can then be used to guide project decisions, for example through cost/benefit analysis.

The Burton Washlands is a 630-ha floodplain in the heart of Burton upon Trent, containing both environmental challenges and opportunities. Binnies carried out this scheme, which focused on collaborative 'place-making' to strengthen connections between people, places, and nature, maximizing shared value. The aim was to balance regular, natural flooding of the area with the need for flood risk management, public access and recreation, while promoting nature conservation and an environmentally sustainable approach to green space management [source].

4.7.2 What we're doing

A landscape vision was developed by Binnies, which prioritized working collaboratively with key stakeholders, including the local community. Digital natural capital accounting approaches were used to inform decision making and support the case for funding. The vision has taken on a holistic approach seeking to maximize and combine goals concerning flood management, nature and conservation, access and recreation, local history and heritage.

The scheme represents a partnership between the East Staffordshire Borough Council and the Environment Agency, Staffordshire Wildlife Trust, the National Forest and Trent Rivers Trust. A key aim at all stages has been responding to feedback from residents and stakeholders.

4.7.3 What it's worth

The scheme is linked to the larger £20m Burton Flood Risk Management Scheme, adding numerous nature-based co-benefits to a project already delivering flood risk prevention. The Washlands scheme is transforming the area into a natural oasis, unlocking environmental, economic and social value, while addressing challenges of flood risk, health deprivation, water quality and climate change.

The natural capital assessment valued the scheme's nature restoration at £2.66m over a 40-year lifetime, which attracted an investment of £2.5m. This clearly communicated the benefits of the project, which led to consent being secured within three months of publication.

> *"The landscape vision for the Burton Washlands enabled the landscape to be looked at holistically, and will maximize the value of the Washlands for people and wildlife. It has created a process of dialogue and collaboration across disciplines and organizations, and now provides the platform to explore the best delivery opportunities available."*
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> **Tim Brooks MCIEEM**
> Environment Planning Specialist, Environment Agency

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