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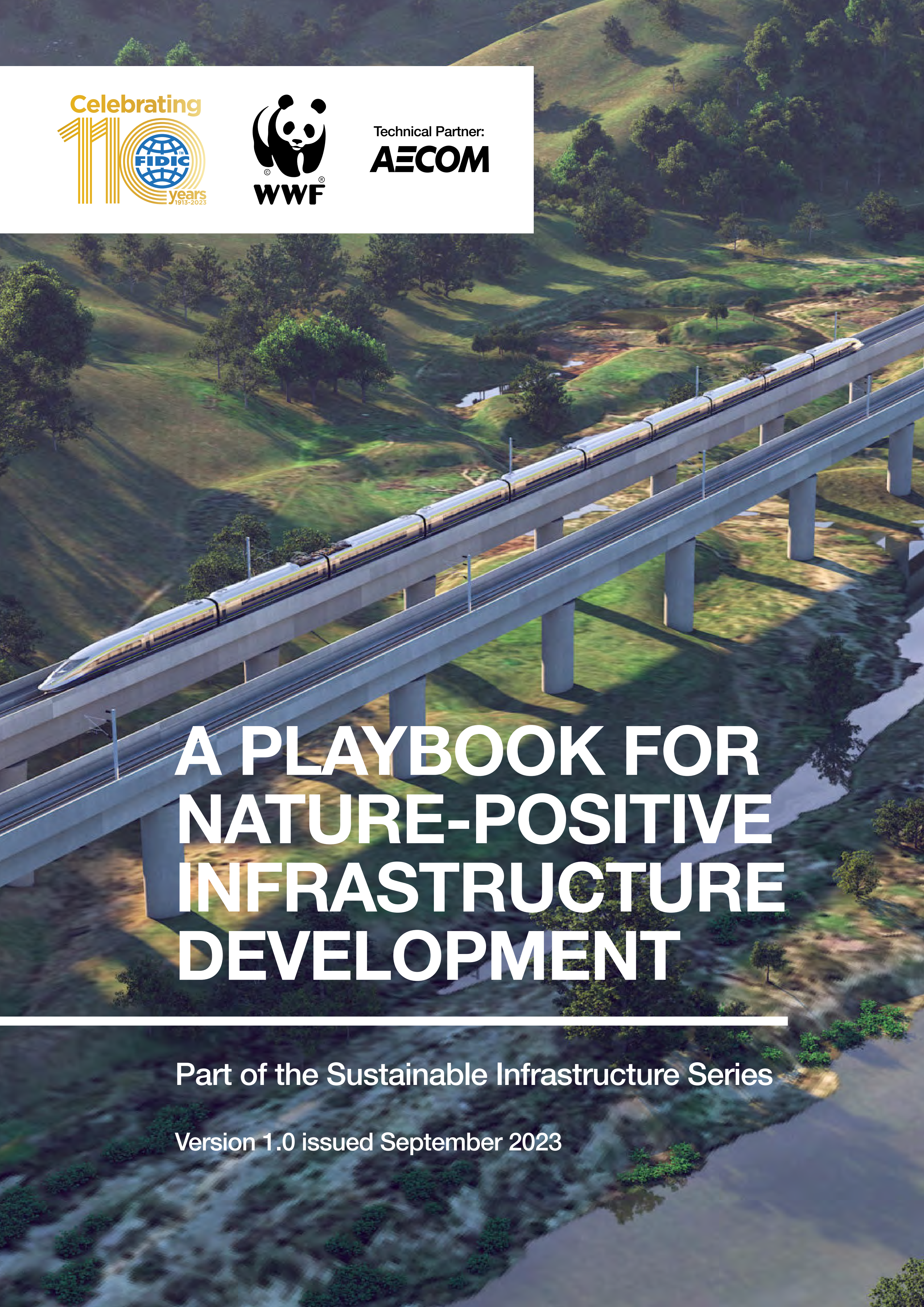

A PLAYBOOK FOR NATURE-POSITIVE INFRASTRUCTURE DEVELOPMENT

Part of the Sustainable Infrastructure Series

Version 1.0 issued September 2023

PARTNERSHIP

Technical Partner: AECOM

FIDIC AND WWF PARTNERSHIP

FIDIC, the International Federation of Consulting Engineers, is the global representative body for national associations of consulting engineers and represents over one million engineering professionals and 40,000 firms in more than 100 countries worldwide. Founded in 1913, FIDIC is charged with promoting and implementing the consulting engineering industry's strategic goals on behalf of its member associations and to disseminate information and resources of interest to its members.

For more than 60 years, WWF has been protecting the future of nature. The world's leading conservation organisation, WWF works in 100 countries and is supported by more than 1.3 million members in the United States and close to five million globally. WWF's unique way of working combines global reach with a foundation in science, involves action at every level from local to global and ensures the delivery of innovative solutions that meet the needs of both people and nature.

WWF and FIDIC recognise that the engineering and conservation communities both play central roles in shaping the transition to nature positive infrastructure. From the earliest points of infrastructure design, these two communities can shape projects to best meet nature-positive and net-zero objectives. They are well-positioned to challenge old norms; to not only break down barriers but to visualise the possible.

ABOUT TECHNICAL PARTNERS

Technical Partner: AECOM

AECOM is the world's trusted infrastructure consulting firm, delivering professional services throughout the project lifecycle. On projects spanning transportation, buildings, water, new energy and the environment, our public-and private-sector clients trust us to solve their most complex challenges. Our teams are driven by a common purpose to deliver a better world through our unrivalled technical expertise and innovation, a culture of equity, diversity and inclusion and a commitment to environmental, social and governance priorities. AECOM is a Fortune 500 firm and its Professional Services business had a revenue of $13.1bn in fiscal year 2022. See how we are delivering sustainable legacies for generations to come at aecom.com and https://publications.aecom.com/sustainable-legacies/.

SPONSORSHIP

The publication was made possible by funding from the Gordon and Betty Moore Foundation. The Foundation was established to create positive outcomes for future generations. In pursuit of that vision, they foster path-breaking scientific discovery, environmental conservation, patient care improvements, whilst also focusing on the preservation of the special character of the San Francisco Bay Area.

FOREWORD

Infrastructure is one of the main drivers of biodiversity loss. For example, 95% of deforestation in the Brazilian Amazon is within 5 km of a road. Infrastructure also contributes approximately 79% of global greenhouse gas emissions, with most associated with energy, buildings and transport[1].

There is increasing recognition that the two greatest challenges of our time – climate change and biodiversity loss – cannot be meaningfully addressed without a fundamental shift in how we conceptualise, design and construct our infrastructure. This brings to the fore the question: can we develop our infrastructure in a way that supports and restores ecosystem health and biological diversity, helps our societies adapt to climate change and enables our journey to net zero?

FIDIC and WWF have joined forces to develop a first iteration of a playbook for 'nature-positive' infrastructure development to help drive change in this sector. Globally, there has been growing interest in the potential of nature-based solutions to complement, or in some cases, even replace traditional or 'grey' infrastructure. The playbook provides an insight into the global state of play and acts as a tool for supporting the implementation of nature-based solutions. It also represents the exciting starting point of a much more ambitious goal of creating a 'living playbook' that will continue to expand global recognition of nature-positive infrastructure approaches for years to come as we progress towards new solutions and construction techniques that are truly nature-positive.

One of the main findings from our research for the playbook is that, despite the substantial interest in nature-based solutions expressed by infrastructure practitioners over the past decade, the actual uptake of projects is not as high as one might think. Many infrastructure practitioners remain concerned primarily with reducing or mitigating environmental impact, rather than systematically integrating ecosystem restoration into their project design. To be truly nature-positive, infrastructure development must go beyond merely reducing or mitigating impact and toward integrating ecosystem viability, biodiversity and climate goals into their design; a mechanism to do this is to deploy natural assets and their inherent functions to achieve this. This shift will not be easy, or quick – as the hundreds of examples referenced in the playbook demonstrate – and it will require knowledge sharing, exchange of best practice and peer-to-peer learning, which are the chief objectives of this playbook.

For this reason, FIDIC and WWF commissioned the playbook to provide practical support to engineers and facilitate a shift in practitioner norms towards nature-positive infrastructure development. FIDIC as the global representative body for the consulting and engineering sector engaged with AECOM one of the largest infrastructure advisory firms in the world to deliver the technical content of the playbook.

We extend our thanks to the FIDIC Sustainability Development Committee under the leadership of Tracey Ryan and Robert Spencer and to Evan Freund and Kate Newman of WWF for initiating the project and providing overall coordination to ensure the outcome is aligned with FIDIC and WWF strategic objectives. We also thank the Gordon and Betty Moore Foundation for their financial support of this initiative.

This project demonstrates how a wide variety of stakeholders can work together to promote and show the difference that engineers and the wider infrastructure workforce can truly make in ensuring that infrastructure becomes part of the solution to the global challenges of climate change and biodiversity loss. This is the first edition of the playbook produced as version one (V1.0). However, FIDIC and WWF would jointly use this report to engage its global members, consulting firms and wider stakeholders to aggregate additional case studies to be added to the report to generate the V2.0 of the playbook in the near future.

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GLOSSARY

TERM	MEANING IN THE PLAYBOOK
BIODIVERSITY	IPBES defines biodiversity as "*the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This includes variation in genetic, phenotypic, phylogenetic and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems*"[2].
BIODIVERSITY OFFSETTING	IUCN defines biodiversity offsets as "*measurable conservation outcomes designed to compensate for adverse and unavoidable impacts of projects, in addition to prevention and mitigation measures already implemented*"[3].
BIORETENTION	Bioretention refers to the process in which contaminants and sedimentation are removed from stormwater runoff.
CARBON OFFSETTING	The term carbon offsetting is typically used to describe activities that result in a reduction in GHG emissions, or an increase in carbon storage (e.g. through land restoration or tree planting), that are undertaken to compensate for emissions that occur elsewhere.
CARBON SEQUESTRATION	The term refers to the process of storing carbon in a carbon pool (e.g. biomass, soil, etc).
ECOLOGICAL RESTORATION AND ENHANCEMENT	In the context of this report, ecological restoration and enhancement refer to the processes of re-establishing ecological functionality and stability of ecosystems that have previously been degraded, damaged, or destroyed.
ECOSYSTEM SERVICES	The term refers to a variety of the benefits people derive from nature, including food, water, raw materials, but also regulating services associated with natural ecosystems, like prevention of soil erosion, water purification and pollination, as well as cultural services like recreation and a sense of place.
ENVIRONMENTAL IMPACTS	Environmental impacts refer to a wide range of impacts on the natural environment associated with infrastructure construction, expansion, operation and decommissioning, ranging from pollution of air, soil and water to carbon emissions.
GHG	According to the IPCC, greenhouse gasses (GHG) are the "*gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelength within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds, which causes the greenhouse effect*"[4].
GREEN INFRASTRUCTURE	There are several competing definitions of green infrastructure and this report assumes the commonly used definition developed by the European Commission: "*a strategically planned network of natural and semi-natural areas with other environmental features, designed and managed to deliver a wide range of ecosystem services, while also enhancing biodiversity*"[5].
GREEN-GREY / HYBRID INFRASTRUCTURE	The term is used to describe the type of infrastructure that combines 'green' elements (like forests, wetlands, mangroves) and human-built 'grey' infrastructure into a single system.
NATURE-BASED SOLUTIONS	There are several competing definitions of nature-based solutions and this report assumes a commonly used definition developed by the European Commission: "*solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions*"[6].
NATURE-POSITIVE INFRASTRUCTURE	There is currently no agreed or universally accepted definition of nature-positive infrastructure. For the purposes of this report, the term mirrors closely the definition developed by the UK Council for Sustainable Business (2022): "*a nature-positive approach puts nature and biodiversity gain at the heart of decision making and design. It goes beyond reducing and mitigating negative impacts on nature as it is a proactive and restorative approach focused on conservation, regeneration and growth*"[7]. As biodiversity crisis and climate change are related challenges, by extension, nature-positive infrastructure development would include considerations of climate as well.
NO NET LOSS / NET GAIN	The terms 'no net loss' or 'net gain' are used to describe projects or activities where the negative impacts on biodiversity or habitats are balanced or outweighed by measures taken to minimise the impacts, restore affected areas and finally offset residual impacts.
RESILIENCE	The concept of resilience in this report refers to infrastructure resilience, with the definition following that of the IPCC: "*the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions*"[8].
REWILDING	In the context of this report, rewilding refers to the practice of restoring an area back to its uncultivated state. It could either take an active form (e.g. through species reintroduction, or active landscape management to restore native biodiversity) or passive (e.g. through natural regeneration).
TRANSLOCATION	In ecology and conservation, translocation is defined as "*the wholesale removal of a functioning habitat from one area to another*"[9]. It is often used as a last resort option.

KEY MESSAGES

While nature-positive approaches for infrastructure development may be high on the agenda, to date, there have not been many examples of such projects implemented globally.

Faced with a dual threat of climate change and global biodiversity loss, infrastructure developers, designers and providers are under growing pressure to move from ‘no net loss’ to ‘nature-positive’ infrastructure development. In Europe and elsewhere, new policies and regulations that require disclosures on climate and biodiversity impacts are expected to drive a more robust approach to protecting natural ecosystems; these are in addition to global agreements and country-led commitments under the 2030 Agenda for Sustainable Development, United Nations Convention on Biological Diversity and UN Framework Convention on Climate Change, among others. Nevertheless, the progress to date remains limited and a strong evidence base of successful nature-positive infrastructure projects is currently lacking. The focus of many infrastructure projects remains on reducing the environmental impact of that infrastructure and making it more sustainable through integration of green elements (e.g. green roofs) rather than what has been defined as nature-positive infrastructure in this report.

In general, while there seems to be considerable interest in the potential of nature-based solutions to replace or complement certain functions of ‘traditional’ grey infrastructure, there is an implementation bias towards several well-established approaches (e.g. reforestation, restoration of wetlands, sustainable urban drainage systems, etc).

In line with the current shift of discourse towards ‘nature-positive’ infrastructure, there has been a growing interest in nature-based solutions by infrastructure practitioners. As a result, there have been numerous infrastructure projects that have integrated nature-based solutions, like reforestation, or wetland restoration to achieve certain climate or nature-related objectives. However, infrastructure developers’ interest in and uptake of, restoration of certain ecosystems and habitats (e.g. peatland) is limited, even when they could bring substantial benefits to the project in question. To move towards truly nature-positive infrastructure development, there is an urgent need to build stronger awareness of the potential of different nature-based solutions, even if they may not immediately come across as obvious solutions for the infrastructure practitioners.

There is a limited understanding of the full range of benefits of nature-based solutions; many of the (co-) benefits of these solutions are not well understood, measured or quantified, which is likely to be preventing their further uptake.

One of the principal advantages of nature-based solutions is that, if implemented properly, they bring a much wider range of benefits than traditional infrastructure alone and complement, strengthen, or in some cases even replace conventional infrastructure. Healthy ecosystems provide many services that can simultaneously enable more reliable infrastructure performance (e.g. forests upstream can have an impact on water quality and reduce sediment runoff, which could provide significant cost savings for water companies), help build resilience against climate and natural hazards, provide habitats for wildlife, but also a variety of wider societal benefits. While there has been some progress in trying to systematically understand or quantify some of those benefits, it would appear that some recent developments in that field (e.g. natural capital accounting) have not yet fully reached many infrastructure practitioners. As a result, there is a lack of thorough understanding of the full benefits that nature-based solutions and nature-positive infrastructure development, could bring.

There is a need to continue to build the evidence base for nature-positive infrastructure and share examples implemented worldwide.

There is an urgent need to move beyond nature-related commitments and advocacy and firmly place considerations of nature and climate at the forefront of the process of planning, implementing, maintaining and decommissioning infrastructure. Going beyond thinking about reducing or minimising impact to delivering nature-positive infrastructure projects will take time, resources and require coordinated action within the sector, but it is essential to meet key global commitments that relate to nature and climate. Infrastructure practitioners should be encouraged to exchange best practice, case studies, lessons learned from the implementation of their projects to build a strong knowledge base that could drive nature-positive infrastructure development.

01 INTRODUCTION

01 INTRODUCTION

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1.1 PURPOSE OF THIS PLAYBOOK

Faced with a dual threat of climate change and global biodiversity loss, infrastructure developers, designers and providers are under growing pressure to move from 'no net loss' to **'nature-positive' infrastructure development**. In Europe and elsewhere, new policies and regulations that require disclosures on climate and biodiversity impacts are expected to drive a more robust approach to protecting and enhancing natural ecosystems during infrastructure development, in addition to global agreements and country-led commitments under the 2030 Agenda for Sustainable Development, United Nations Convention on Biological Diversity and UN Framework Convention on Climate Change, among others.

Closely related to the concept of nature-positive infrastructure development is the concept of **'nature-based solutions'**, an umbrella term used to describe a variety of solutions that are inspired and supported by nature and which can simultaneously provide a wide range of environmental, climate, social and economic benefits. Central to the definition of nature-based solutions is the **overall net gain in biodiversity and ecosystem integrity, so the term is logically linked to the concept of 'nature-positive' infrastructure development.**

In recent years and partially in response to a growing discourse on nature-positive infrastructure, there has **been a substantial increase in the interest in nature-based solutions by infrastructure practitioners** looking to leverage the power of natural ecosystems to not only improve the environmental performance of their projects, but to also improve the overall performance and operational reliability of their infrastructure assets. As a result, a number of examples can be identified in the public domain that point towards successful application of nature-based solutions in the infrastructure sector, **that could be used as a starting point to further drive the progress on nature-positive infrastructure development.**

The purpose of this Playbook is to draw on a number of examples of projects that relied on nature-based solutions, as well as examples of projects that incorporated green and green-grey infrastructure solutions, to provide **a simple guide for infrastructure practitioners to identify and select potential solutions for their projects,** in order to drive the progress towards nature-positive infrastructure development. The idea is for the Playbook to be an evolving document that will be updated as the infrastructure sector moves towards being more nature-positive and information about more examples becomes widely available. The Playbook is structured **around the analysis of nearly 200 existing projects implemented around the world,** across different geographies and climatic conditions. It is therefore focused on identifying proven solutions that have already been tested and implemented, rather than listing theoretical approaches.

> It is important to note that this Playbook is not a **design guide** with detailed descriptions of every solution applied; rather, its objective is to provide general guidance for linking possible solutions on the basis of the infrastructure sector to which the project belongs to, challenges it aims to address and the benefits the project aspires to achieve. At the end of the report, references to some existing design guides and additional relevant literature are provided as a recommended reading.

1.2 TOWARDS NATURE-POSITIVE INFRASTRUCTURE DEVELOPMENT

There is currently **no agreed or universally accepted definition of nature-positive infrastructure.** As the term remains relatively novel, there are several competing definitions that seem to have several common features[10]. Firstly, there is an agreement that a nature-positive approach should **'put nature and biodiversity gain at the heart of decision-making and design'** and, secondly, that it needs to go **'beyond reducing and mitigating negative impacts on nature as it is a proactive and restorative approach focused on conservation, regeneration and growth'**. In effect, nature-positive infrastructure would **either** incorporate nature and biodiversity considerations as part of the project design or be accompanied with substantial ecological restoration and enhancement; but in any case, it would aspire to go beyond simply reducing or mitigating the environmental impact of an infrastructure project. As the biodiversity crisis and climate change are related challenges, by extension, nature-positive infrastructure development would **thoroughly consider climate change as well.**

In practical terms, this means that **nature-positive infrastructure is not limited to nature-based solutions.** Other types of infrastructure, including green infrastructure and a mix of green-grey infrastructure, could also be designed to be nature-positive and there are a variety of other solutions beyond those that were identified in this Playbook that could be explored to move the infrastructure sector towards being **truly nature-positive.**

There is need for caution with the use of the term nature-positive infrastructure. Initially, the Playbook was designed with the idea of capturing and identifying examples of nature-positive infrastructure projects implemented globally. However, during the process of selection of examples that would be included in the Playbook and the accompanying review of literature, it became clear that the infrastructure sector is still in the very early stages of integrating nature within design and decision-making process. The principal focus of many infrastructure projects **remains on reducing the environmental impact of that infrastructure and making it more sustainable through integration of green elements (e.g. green roofs)** rather than what has been defined as nature-positive infrastructure in this report.

Whilst there has been a recent attempt to scale up the use of nature-based solutions in the infrastructure sector, an in-depth review of publicly available sources and related project examples, carried out as part of this study suggests that the number of real projects (as opposed to numerous guidance documents, thought pieces, feasibility studies, etc.) **is not as extensive as one may think**[11]. Some encouraging progress has nevertheless been made, which will be evident in the following sections of this Playbook, that reference examples of projects that incorporated some of these solutions. However, it is important to note that at this stage it makes more sense to use examples referenced in the Playbook to **illustrate solutions** that could drive the sector towards being nature-positive, **rather than calling them nature-positive infrastructure projects per se.**

Finally and in line with these findings, there is an urgent need to move beyond commitments and advocacy of nature-positive infrastructure **towards building a strong evidence base of real projects that were delivered on the ground.** This will require assessing, quantifying and monitoring the impact these projects have had on nature and biodiversity and ensuring they are truly sustainable.

1.3 PLAYBOOK METHODOLOGY AND OUTLINE

The Playbook is based on **the analysis of around 200 relevant project examples implemented worldwide.** The analysis focused on identifying specific solutions that were used within a substantial number of projects that incorporated references to nature-based solutions, nature-positive infrastructure, green and green-grey infrastructure and other concepts commonly used in the infrastructure sector. Importantly, the common denominators were **'nature' and 'infrastructure'**, so examples of nature-based solutions that were deemed to be less relevant to infrastructure practitioners, were not necessarily included in the analysis.

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THERE WERE SEVERAL KEY CONSIDERATIONS THAT INFORMED THE SELECTION OF RELEVANT PROJECT EXAMPLES DURING THE ANALYSIS, INCLUDING:

Relevance of the project to infrastructure developers. This means that projects were screened for their suitability for infrastructure sectors like transport, energy, water and wastewater, buildings and public spaces and coastal protection. Other sectors (e.g. solid waste) were also screened for examples, but ultimately excluded from the Playbook as not enough relevant examples could be identified to justify their inclusion.

Location. The aim was to assemble examples of projects implemented around the world to maximise the Playbook's utility. While every effort was made to identify examples across a wide range of geographies, it has been observed that a significant number of the projects within certain sectors (e.g. within buildings and public spaces) have been disproportionately implemented in particular countries and regions, in response to local policy drivers and regulations (e.g. green roofs in the UK).

Variety and/or innovativeness. The objective was to cover a wide variety of solutions applied to each infrastructure sector. Attention was also given to the innovativeness of the solution and in some instances, experimental solutions were also included in the analysis, although priority was given to relatively well-established solutions.

Information available. Given the number of project examples initially reviewed (around 400) and that ended up being included in the analysis (around 200), the priority for inclusion has been given to those examples that included a significant level of detail, although exceptions were made where some of the solutions applied were interesting enough or considered replicable in other contexts

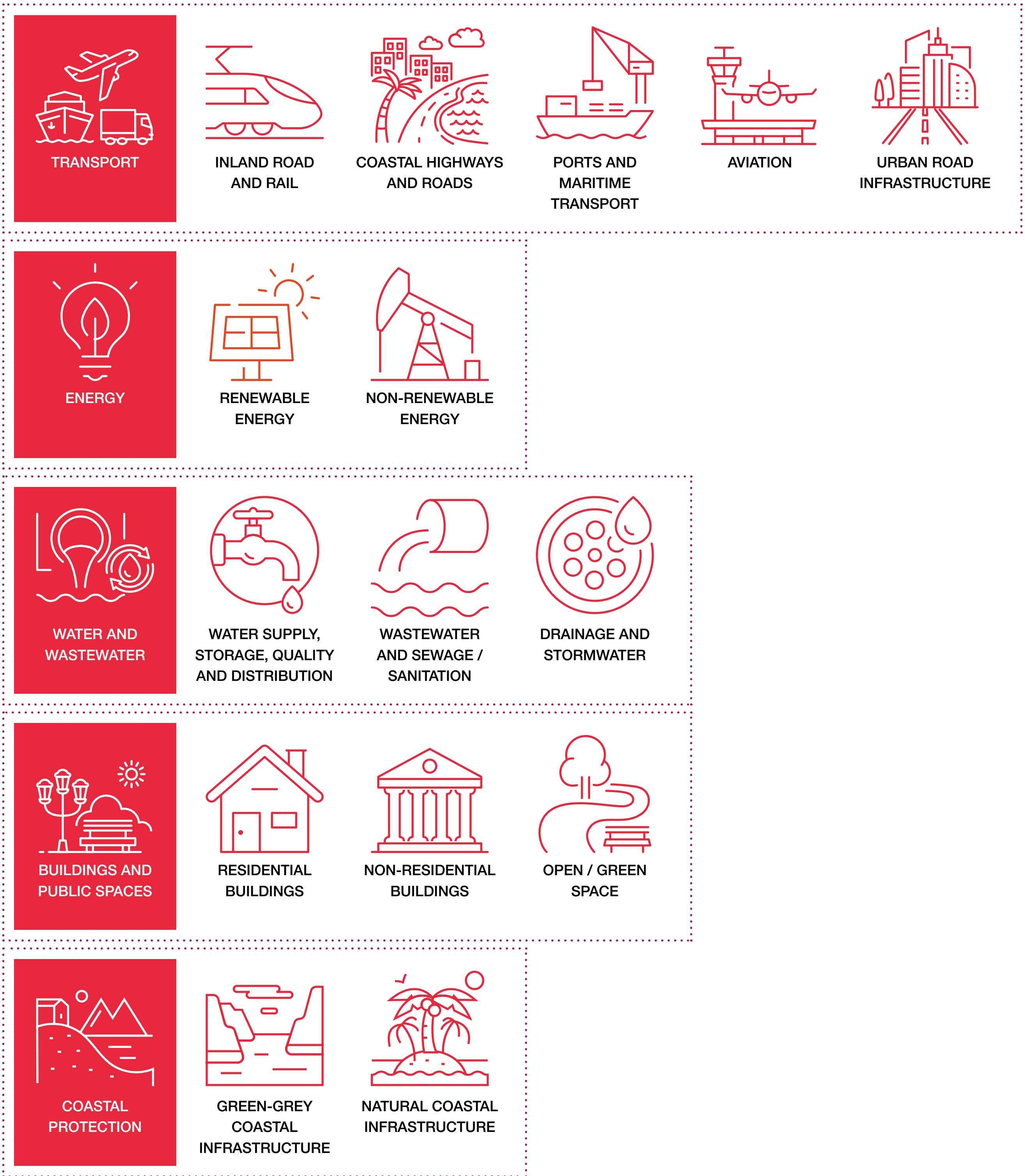
The project examples included in the analysis have been collected from a **wide variety of sources, including academic articles, reports, studies, media articles, websites, etc.** The examples were reviewed and selected for their relevance for the Playbook, however, due to the sheer amount of material reviewed and included, it was not possible to independently verify the claims about benefits achieved, details on the solutions implemented, etc. Some sources did not clearly state what are the benefits and what co-benefits, or even details about the project itself that would enable easier identification of the solution, so in some instances, this had to be inferred.

To provide additional insight and support the analysis, parallel research was undertaken to compile case studies that were initially identified from a long list of projects that were submitted by various stakeholders included in the development of this Playbook, including those from WWF's networks and FIDIC's networks and its Sustainable Development Committee (SDC) members. Details on each of these case studies can be found in Appendix A and Appendix B. The case studies included in this Playbook were selected to represent a range of sectors, geographies and solutions to address project challenges as well as on the basis of there being a sufficient level of detail available on the project itself.

Finally, **the analysis of project examples and compilation of case studies were accompanied by a desk-based literature review,** that sought to identify some of the key emerging issues in this field and provide additional sources of information that could accompany the elaboration of solutions. Based on the key findings of the analysis of examples and the literature review, the Playbook is structured around Sectors-Benefits-Solutions framework.

The 'Sectors' chapter provides an overview of key infrastructure sectors in which these solutions have been applied and provides a commentary around their implementation. For convenience, a typology has been developed specifically for this Playbook to allow easier association of solutions with each type of infrastructure in which they have been implemented, as summarised in Figure 1-1.

FIGURE 1-1. SUMMARY OF SECTORS IDENTIFIED IN THE ANALYSIS



Source: AECOM. 2023

The 'Benefits' chapter provides an overview of different benefits that have been delivered by particular solutions implemented, which have been organised around 'key' benefits (biodiversity, carbon and resilience) and 'additional' benefits (environmental, economic and social), as highlighted in Figure 1-2. These have been summarised to match how they are commonly described in the project examples and case studies. While this is by no means a definitive categorisation (as some projects may have been implemented primarily with various environmental, or economic objectives in mind) this distinction has been made to highlight the currently comparatively higher degree of attention given to biodiversity, carbon and resilience compared to other types of benefits. Likewise, the selection of benefits presented here is based on the most commonly identified benefits from the project examples covered in the analysis – it is not meant to be exhaustive or prescriptive in any manner. Additionally, while some of the solutions identified undoubtedly have many benefits, to avoid insufficiently defined 'long list' of benefits, the summary tables only list 2-3 key benefits for each solution identified[12].

FIGURE 1-2. SUMMARY OF BENEFITS IDENTIFIED IN THE ANALYSIS

KEY BENEFITS

BIODIVERSITY

- Habitat creation
- Habitat restoration
- Habitat connectivity

CARBON

- Embodied carbon / Operational carbon
- Carbon sequestration and storage / Carbon offsetting

RESILIENCE

- Coastal resilience
- Flood risk reduction
- Geotechnical
- Temperature regulation
- Water security / Drought risk reduction

ADDITIONAL BENEFITS

ENVIRONMENTAL

- Air quality
- Soil quality
- Water quality

ECONOMIC

- Jobs, livelihoods and food
- Cost savings
- Direct ROI
- Land value uplift
- Other (e.g. tourism)

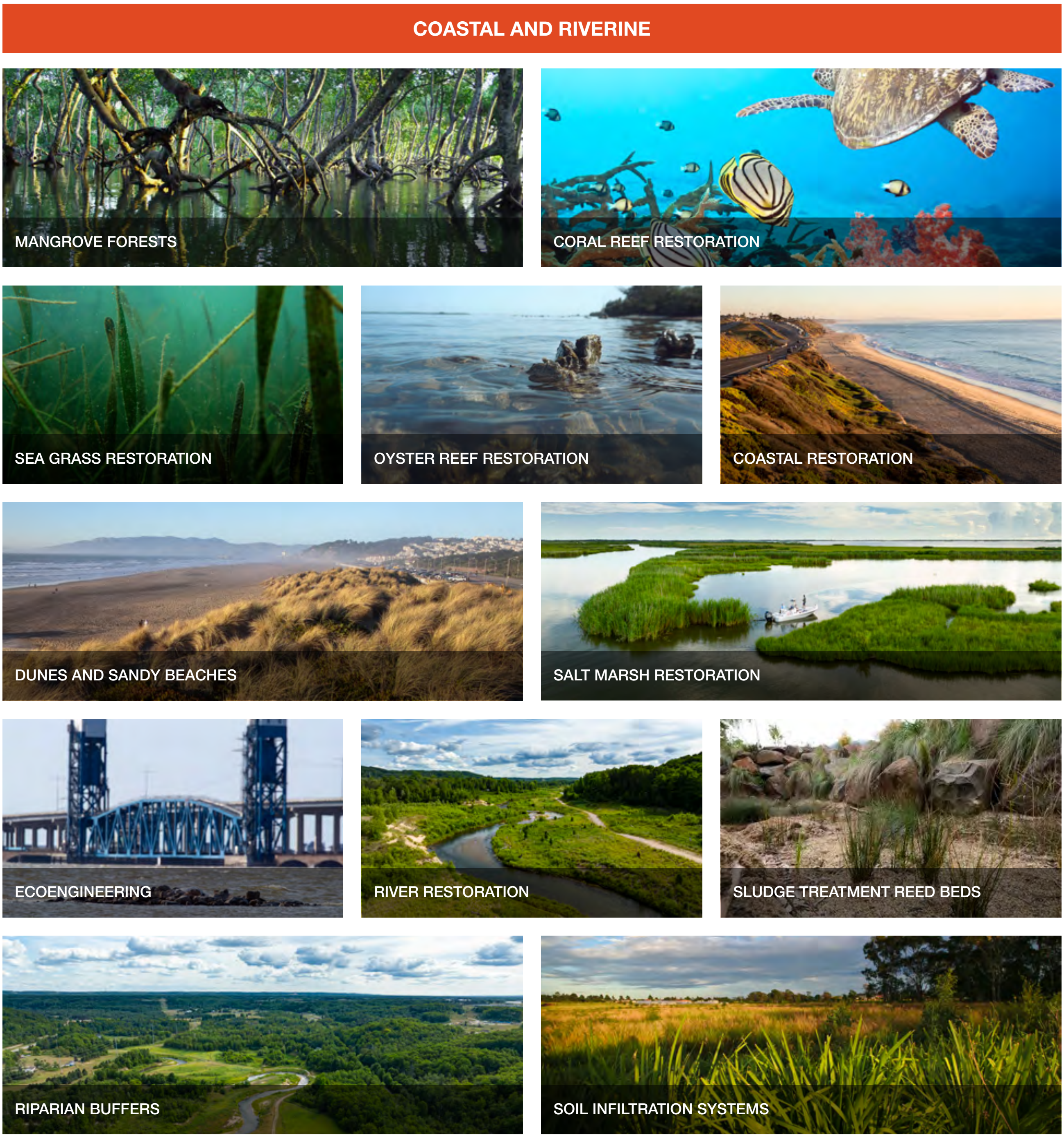
SOCIAL

- Cultural services
- Health and well-being
- Recreation / Amenity

Source: AECOM. 2023

Finally, the 'Solutions' chapter provides a **high-level summary of the most common solutions** identified in the analysis of examples, some typical success factors for their implementation and the conditions in which they were typically applied, summarised in Figure 1-3.

FIGURE 1-3. SUMMARY OF SOLUTIONS IDENTIFIED IN THE ANALYSIS



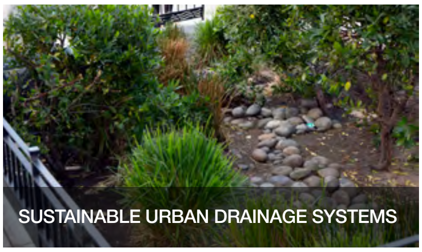
Source: AECOM. 2023

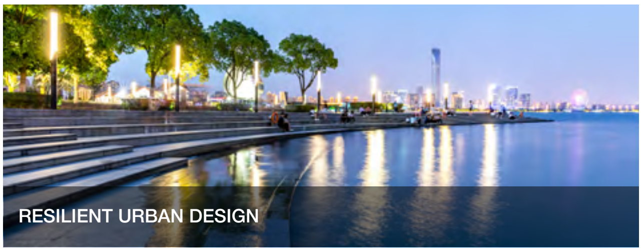
The current list is based on the examples found in the analysis, but is expected to grow and evolve further in the upcoming reiterations of the Playbook. It is worth noting that this list is not exhaustive, as the Playbook prioritised identifying well-established solutions which were covered in multiple project examples.

INLAND AND URBAN

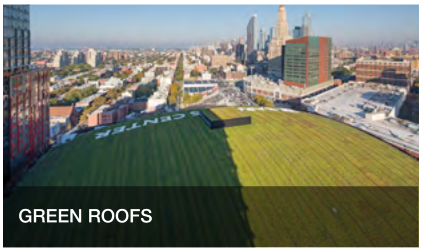

PEATLAND RESTORATION


WETLANDS (NATURAL AND CONSTRUCTED)


SUSTAINABLE URBAN DRAINAGE SYSTEMS


RESILIENT URBAN DESIGN


GREEN AND ‘LIVING’ WALLS


GREEN ROOFS


SOLAR GARDENS


AFFORESTATION AND REFORESTATION


BIOENGINEERING FOR LANDSLIDE AND EROSION PROTECTION


GREEN BRIDGES, WILDLIFE BRIDGES, ECOLOGICAL CORRIDORS


REWILDING, GRASSLANDS, MEADOWS


URBAN AND PERI-URBAN AGRICULTURE


BIO-BUILDING MATERIALS

02

SECTORS

02 SECTORS

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This chapter presents the summary of key findings from the literature review and analysis of project examples identified in each sector (i.e. **transport, energy, water and wastewater, buildings and public spaces and coastal protection**). As some of the solutions may only be applicable to a particular sub-sector of infrastructure (e.g. in the case of transport, some approaches may apply to coastal highways but not inland roads), a sector typology has been developed, which is summarised at the start of each sub-chapter in the section below[13]. For consistency, the subsequent discussion and key findings of the analysis are structured around this typology.

2.1 TRANSPORT

Transport infrastructure is key to economic development, enabling the movement of people, goods and services within and between countries, **but its construction, operation and maintenance puts a significant pressure on nature and natural resources**. Road and rail projects can have a significant effect on local hydrology, which can accelerate flooding and increase the risk of erosion. Further, nearly all large-scale transport infrastructure projects result in the disruption of wildlife habitats, creating barriers to species movement and increasing species mortality through habitat destruction and animal-vehicle collision. This is a major challenge and now more than ever, as fragmented habitats tend to be more vulnerable to the effects of climate change and other stressors. Transport infrastructure can also disrupt the provision of ecosystem services – including water and food provision – **an impact that is often overlooked and insufficiently understood**[14].

Despite the increasing number of regulations that require **assessing and mitigating environmental (air, water, soil quality) and ecological impacts of transport infrastructure**, it has been noted that the transport sector still lags behind in terms of strategic integration of nature and natural processes into the planning and implementation of projects[15]. It is more common to encounter approaches that focus on **reducing or mitigating the environmental and ecological impacts of transport infrastructure** than to find examples of projects that **strategically incorporate natural elements to simultaneously deliver multiple benefits.**

One of the potential barriers to the greater uptake of solutions that could facilitate the shift towards nature-positive infrastructure is **the lack of a thorough understanding of their benefits (quantitative and qualitative).** To an extent, this has to do with a limited number of existing studies that examine **the long-term benefits of different solutions for road infrastructure specifically** (including nature-based solutions, green and green-grey infrastructure), as opposed to **generic guides that exist for infrastructure more generally.** During the review of different project examples, it emerged that where various nature-positive approaches have been used, significant benefits have been accrued in terms of **increased resilience** (especially to hydrometeorological and geotechnical hazards), **reduced carbon footprint of the project** (e.g. through carbon offsetting) and **biodiversity** (through creation of new habitats and restoration of displaced habitats). The following sections present an overview of some solutions identified from the analysis of project examples organised by relevant type of transport infrastructure (Figure 2-1).

FIGURE 2-1. TRANSPORT INFRASTRUCTURE – TYPOLOGY

Source: AECOM. 2023

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2.1.1 INLAND ROAD AND RAIL INFRASTRUCTURE

The construction of road and rail infrastructure[16] is a significant driver of deforestation – both directly (through clearance within the right of way) and induced (through new secondary roads, agriculture and settlements), particularly in tropical regions[17]. This results in a high rate of carbon emissions and decreases the long-term capacity of local ecosystems for carbon sequestration through forest clearance and fragmentation. In many instances, **the links between forests and particular ecosystem services** are not fully considered before a transport project is approved and implemented, which can affect the performance and cost of the infrastructure itself **(e.g. forest clearing can increase the risk of erosion resulting in increased associated maintenance costs over the long term)** but can also **adversely affect local communities** (e.g. local livelihoods that depend on timber, fish, rubber, or other products may be affected by forest clearance)[18].

An increasing number of large-scale road and rail infrastructure projects aim at minimising net forest loss, or achieving net gain, at the end of the project by planting **a forest that was removed by the project on another site, translocating part of the ecosystem, or undertaking restoration of remaining woodland**[19]. Table 2-1 summarises some of commonly used solutions identified in the project examples. It is worth noting that the offsetting approach (i.e. planting trees) comes with its own set of particular challenges, including that new sapling may take many years to mature to start capturing significant amounts of carbon and bring some of the benefits associated with lost woodland. Further, translocation might be difficult or impossible to undertake successfully and the loss of certain ecosystems of high ecological value (e.g. ancient woodland) may not be possible to compensate meaningfully.

The expansion of road and rail infrastructure has a **considerable adverse impact on biodiversity through fragmentation of habitats** (with consequences for the genetic pool and ecological resilience) or their destruction (with consequences for the survival of species). This is particularly a pertinent issue for road projects in mountainous regions, or where slopes are particularly steep; as challenging terrains usually require more land clearance for the road to be created. Some of the commonly used solutions identified in the analysis include wildlife crossings, green bridges (though there is relatively little consistency in how they are defined in the literature)[20] and wildlife corridors, all of which have shown to be highly effective in enabling species movement[21]. These have also shown to be effective in **reducing animal-vehicle collisions** (especially when accompanied with roadside signs and warning systems) and to provide a range of co-benefits, including provision of spaces for recreation, as well as, depending on the material used, **climate resilience benefits** (i.e. flood risk reduction). Another common approach that has been identified in project examples involves **compensatory mechanisms** (e.g. creation of new protected areas, conservation 'corridors' around areas that were cleared, etc.) to compensate for biodiversity loss associated with large-scale road and rail projects.

In some instances, road infrastructure (i.e. replacement of vegetation with paved surfaces) can exacerbate the risk of flooding; some projects identified in the analysis sought to address this through **woodland creation (or linear tree planting)** that intercepts the flow of water and encourages infiltration and storage within the soil. Woodland creation and reforestation can also be used to reduce **heat stress associated with the use of materials like asphalt and concrete.** Furthermore, different types of **sustainable urban drainage systems (SuDS) and bioretention areas** are also being increasingly integrated as part of transport infrastructure to reduce flooding risk and improve water quality through filtration.

Various **bioengineering techniques (e.g. revegetation of slopes)** to protect soil surfaces against erosion and for soil stabilisation are commonly used and have wide applicability across different geographies and climates. While they are predominantly used to help build resilience to geotechnical hazards in the examples reviewed, it has been noted that they also have the potential to **reduce flood risk**.

TABLE 2-1. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO INLAND ROAD AND RAIL INFRASTRUCTURE PROJECTS

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Reducing forest loss, addressing disruption of ecosystem services and reducing carbon emissions	Afforestation, reforestation	Carbon sequestration and storage	Environmental (soil quality, air quality) Biodiversity (habitat restoration)	• Guizhou Zhengxi Expressway Project, China
Connecting fragmented habitats and addressing biodiversity loss	Afforestation, reforestation	Biodiversity (habitat connectivity and/or creation)	Carbon sequestration and storage	• Honduras Road Development Project • Colombia Mocoa–- San Francisco Road
	Green bridges, wildlife bridges, ecological corridors, culverts	Biodiversity (habitat connectivity and/or creation)	Resilience (flood risk reduction) Social (recreation / amenity)	• Dedin Green Bridge, Croatia • Mile End Green Bridge, UK • Groene Woud, Netherlands
	Rewilding, grasslands, meadows	Biodiversity (habitat creation)	Carbon sequestration and storage Resilience (flood risk reduction)	• Keyn Glas, UK
Reducing the risk of flooding and heat stress	Afforestation, reforestation	Resilience (flood risk reduction)	Carbon sequestration and storage Environmental (water quality, air quality)	• Strengthening Coastal Resilience in Benin

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OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
	Sustainable urban drainage systems (SuDS) and bioretention areas	Resilience (flood risk reduction)	Environmental (water quality)	• J4M8 Distribution Park, West Lothian, UK • Roadside Trees Drink Stormwater In Innovative Solution for Urban Climate Adaptation, Denmark
Stabilisation of soil	Bioengineering for landslide and erosion protection	Resilience (geotechnical)	Resilience (flood risk reduction)	• Meghalaya Integrated Transport Project, India • Himachal Pradesh State Roads Transformation Project, India • Geotextile Bridge Abutments in Veracruz, Mexico

Source: AECOM. 2023

2.1.2 COASTAL HIGHWAYS AND ROADS

While some nature-based solutions and green-grey infrastructure have been used extensively in an array of coastal settings (see section 2.5), their application is not always discussed directly in the context of protection of coastal highways and roads[22]. As a result, **the review of project examples did not identify an extensive number of projects** that incorporated some of these solutions **specifically for coastal highways,** but this may just be a matter of terminology.

Coastal highways and roads are particularly exposed to **climate-related hazards** and some of the solutions discussed below have the potential to either complement or significantly strengthen the ‘conventional’ coastal highway protection infrastructure (such as **seawalls**) against storm surges, erosion, shoreline retreat and sea level rise associated with climate change. Section 2.5 covers coastal protection and Table 2-2 overleaf provides a summary of several of those approaches particularly helpful for protecting road infrastructure.

The review of literature and some existing projects suggests that **mangrove forests** are among the most commonly used solutions to help build resilience against storm surges and sea level rise. Common co-benefits listed are environmental (especially improved water quality), economic (the impact on local livelihoods and job creation is most commonly referenced) and biodiversity (typically habitat restoration). **Coastal wetlands,** as well as **dunes and sandy shores,** are also deployed to increase resilience to coastal flooding, with some of the case studies listing similar co-benefits as for mangrove forests.

Various techniques for **coastal restoration,** as well as **salt marsh restoration,** are featured in several projects aimed at reducing coastal erosion, with biodiversity (habitat creation) typically singled as the most important co-benefit. Connecting fragmented habitats and reversing biodiversity loss also tends to be one of the objectives identified in the analysis and some of the solutions already mentioned **(e.g. restoration of mangrove forests, salt marsh, coral reefs and wetlands)** may also represent a way to restore habitats.

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TABLE 2-2. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO COASTAL HIGHWAYS AND ROAD PROJECTS

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Reducing forest loss, addressing disruption of ecosystem services and reducing carbon emissions	Mangrove forests	Resilience (flood risk reduction)	Environmental (water quality) Economic (jobs, livelihoods and well-being) Biodiversity (habitat restoration)	• Kiribati Adaptation Phase III • Mangroves for Coastal Resilience, Bulacan and Central Luzon, Philippines • Coastal Embankment Improvement Project – Phase I, Bangladesh
	Wetlands (natural and constructed)	Resilience (flood risk reduction)	Biodiversity (habitat restoration) Environmental (water quality)	• Resilient California State Route 37, USA
	Dunes and sandy beaches	Resilience (flood risk reduction)	Resilience (geotechnical)	• Long Beach Island Coastal Storm Damage Reduction, USA
Reducing coastal erosion	Coastal restoration, realignment and living shorelines	Resilience (geotechnical)	Biodiversity (habitat restoration)	• Marsh Restoration and Replenishment, Little Egg Harbor, New Jersey
	Salt marsh restoration	Resilience (geotechnical)	Biodiversity (habitat restoration)	• Salt Marsh Restoration, Florida, USA

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Connecting fragmented habitats and addressing biodiversity loss	Salt marsh and coral reef restoration	Biodiversity (habitat creation)	Resilience (flood risk reduction) Economic (jobs, livelihoods and well-being)	• Project GreenShores, Florida, USA • Salt Marsh Restoration, Florida, USA • Reef Restoration in Grenada
	Wetlands (natural and constructed)	Biodiversity (habitat creation)	Resilience (geotechnical)	• Hamilton Wetlands Restoration Project, USA • Wallasea Island Wild Coast Project, UK • Wetlands Restoration for Ecosystem and Community Resilience in He'eia, O'ahu, Hawaii

Source: AECOM. 2023

2.1.3 PORTS AND MARITIME TRANSPORT

In addition to some of the solutions for coastal protection covered in the section above, a **range of 'hybrid' approaches** (i.e. involving some combination of traditional 'grey' infrastructure and green infrastructure) have been successfully applied to ports and maritime transport projects.

Eco-engineering is one such solution and involves the use of alternative materials, or design with materials that are less carbon intensive and create habitats for marine life. Examples of projects using eco-engineering include those that replaced concrete with low-carbon alternatives, added **habitat tiles and vertipooles** on surface structures, or constructed **ecological seawalls**[23]. An interesting example has been found for ports located in Arctic areas[24], which are often prone to land destabilisation due to the thawing of the coastal permafrost. The solution here was to control local thermal conditions (**through radiation shields**) to reduce the loss of permafrost and stabilise the soils.

TABLE 2-3. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO PORTS AND MARITIME TRANSPORT PROJECTS

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Reducing coastal flooding and erosion, reducing embodied carbon	Ecoengineering, vertipooles, habitat tiles	Resilience (flood risk reduction)	Embodied carbon Biodiversity (habitat creation)	• Port of San Diego Coastal Protection, USA
	Bioengineering for landslide and erosion protection (permafrost control)	Resilience (geotechnical)		• Nature-based Approaches for Stabilizing Arctic Ports, USA

Source: AECOM. 2023

2.1.4 AVIATION

There has been a growing interest in tackling two of the most significant challenges associated with the construction and expansion of airports – embodied and operational carbon – as well as biodiversity loss from converted areas used for construction/expansion. Aside from the common approaches that are more focused on reducing or mitigating environmental impact through off-site **afforestation, reforestation, as well as biodiversity offsetting**[25], creation of **onsite (or underground) wetlands** to improve water quality and, through improved water quality, restore habitats, seem to be the gaining most traction.

TABLE 2-4. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO AIR TRANSPORT INFRASTRUCTURE

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Reducing or offsetting carbon emissions	Afforestation, reforestation	Carbon sequestration and storage	Biodiversity (habitat creation or restoration)	• Deer Grove Forest Preserve Habitat Restoration, USA
Addressing destruction of habitats and biodiversity loss	Biodiversity offsetting	Biodiversity (habitat creation)	Carbon sequestration and storage	• Biodiversity Offsetting for Sunshine Coast Airport, Australia • Biodiversity Offsetting for Heathrow Airport, UK • Biodiversity Offsetting for Juneau International Airport, Alaska, USA
Improving water quality and biodiversity value on site	Wetlands (natural or constructed)	Environmental (water quality)	Biodiversity (habitat creation or restoration)	• Helsinki Airport Wetland, Finland • Heathrow Constructed Wetland Project, UK • Salt Lake City International Airport Wetland, USA

Source: AECOM. 2023

2.1.5 URBAN ROAD INFRASTRUCTURE

In recent years, there has been a growing interest in nature-based solutions and green infrastructure in urban environments, including to address some challenges related to the expansion or construction of new road infrastructure. Common solutions include **sustainable urban drainage systems (SuDS) and bioretention areas** to reduce the risk of flooding and improve water quality; as well as the **planting of urban and peri urban trees and forests** to reduce the urban heat island effect.

Expansion of urban roads can have a **significant impact on local habitats and can lead to biodiversity loss.** In some of the examples identified, **green corridors, open green spaces, as well as the restoration of rivers and other waterbodies** have been commonly used to create habitats and restore biodiversity in urban areas. **Urban trees and forests** (in the form of protecting, restoring or replanting) are often deployed to reduce air pollution associated with both construction and operation of urban road infrastructure (vehicle exhaust).

TABLE 2-5. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO URBAN ROAD INFRASTRUCTURE

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Reducing the risk of flooding and heat stress	Sustainable urban drainage systems (SuDS) and bioretention areas	Resilience (flood risk reduction)	Environmental (water quality)	• J4M8 Distribution Park, West Lothian, UK • Sustainable Urban Drainage Systems in Diepsloot, Johannesburg, South Africa
	Afforestation, reforestation	Resilience (temperature regulation)	Biodiversity (habitat creation) Environmental (air quality) Carbon sequestration and storage	• Rainforest Recovery in Urban Areas, Salvador, Brazil • Resilient Urban Sierra Leone Project, Sierra Leone
Addressing habitat destruction and biodiversity loss and addressing air pollution	Afforestation, reforestation, open green spaces	Biodiversity (habitat connectivity and/or creation)	Resilience (temperature regulation) Social (health and well-being)	• Green Corridors Project, Tree Pits and Raingardens in Medellin, Colombia • Beijing Plain Area Afforestation Programme (BPAP), China
	River restoration and catchment management	Biodiversity (habitat creation)	Environmental (water quality) Social (health and well-being)	• Restoration of the River Ljubljanica, Slovenia • Daylighting River: Revitalising the Cheonggyecheon Stream, South Korea

Source: AECOM. 2023

2.2 ENERGY

The global energy transition is key to reducing GHG emissions and slowing down climate change and investment in energy transition technologies reached $1.3 trillion in 2022 – a record high[26]. Much of the investment targeting expansion of renewable energy infrastructure, in particular **wind, solar, hydro and geothermal**, has resulted in there being increased scrutiny over the impact of this infrastructure on **land, natural resources and biodiversity**. At the same time, partly in response to strong pressure from governments and civil society, large energy companies that rely primarily on fossil fuels have been increasingly turning to **carbon offsetting** through purchase of carbon credits from different sources **and changing their business models to include renewable energy sources**[27]. Despite these trends, the analysis did not identify a substantial number of actual projects in the energy sector that incorporate significant natural elements (beyond those that aim to reduce environmental impacts), so more work is needed to identify some possible solutions for this sector and support relevant actors to implement them.

Of the examples identified and reviewed in the energy sector, different solutions have been used to:

- **Improve energy efficiency and management of natural resources** (e.g. optimising the performance of solar panels through improved landscape management); and
- **Reduce the environmental and biodiversity impact of renewable energy infrastructure** (e.g. integrating pollinator-friendly plants to increase species richness near solar panels).

Some solutions covered in other sections could also be relevant (e.g. those referenced in the water and transport sub-chapters), but this section focuses specifically on solutions applied to renewable and non-renewable energy infrastructure – summarised below.

FIGURE 2-2. ENERGY INFRASTRUCTURE – TYPOLOGY

RENEWABLE ENERGY INFRASTRUCTURE

NON-RENEWABLE ENERGY INFRASTRUCTURE

Source: AECOM. 2023

2.2.1 RENEWABLE ENERGY INFRASTRUCTURE

Globally, the demand for construction and installation of energy infrastructure that runs on renewable sources is growing, often coupled with attempts to increase efficiency and performance of this infrastructure by relying on natural processes. One trend identified across numerous examples includes **the simultaneous integration of green roofs and solar panels ('bio-solar roofs')** that is said to result in higher energy savings and bring biodiversity benefits.

Spatial and technical constraints, including limited land available for installation of solar panels and / or inadequate structural stability of roofs that would enable the construction of rooftop solar, have in some instances been addressed through **community solar gardens**. These provide a way to maximise the use of space for renewable energy development and bring important social benefits, as well as, where possible, improved biodiversity through habitat creation.

Although in general, the impact of large-scale renewable energy projects on biodiversity is less well understood than that of non-renewable projects[28], their expansion has led to an increased awareness of a range of negative impacts, including habitat loss through clearance or displacement, species mortality through electrocution, collision with turbine blades, solar panels or transmission lines; and due to effects of dust, light, noise, vibration, etc)[29] Dams are also known to have an impact on fragmentation of species population, affecting habitat availability through changes to the natural flow regime and stream temperatures, etc.[30]

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In response, there has been an uptake in solutions to ensure renewable energy expansion is compatible with nature-positive objectives. The creation of **pollinator-friendly meadows under and around solar panels** is one example, which has been shown to have a positive impact on plant biodiversity as well as supporting carbon sequestration. **Habitat creation and biodiversity offsetting** are commonly used (in line with the ecological mitigation hierarchy) with some successful (but also some less successful) examples found worldwide, as well as experimental approaches to **nurturing reefs** on **offshore wind turbines to enhance marine ecosystems, or the restoration of peatland** as part of some projects.

Several projects have been identified that list **different solutions designed to make dams less disruptive to aquatic life** that claim to have significant biodiversity benefits. However, in light of considerable overall negative impact of these projects, as well as some ongoing efforts to promote dam removals and a shift away from large-scale hydropower, these examples were ultimately excluded from the analysis.

TABLE 2-6. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO RENEWABLE ENERGY INFRASTRUCTURE

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Reducing carbon emissions and operational carbon	Green roofs (bio-solar roofs)	Embodied carbon / operational carbon	Resilience (temperature regulation) Biodiversity (habitat creation)	• Clapham Park Total Green Roof System, UK • Munich Technology Center, Germany • Chartered Bank HQ, UK
Expanding access to solar energy infrastructure	Solar gardens	Economic (cost-savings)	Biodiversity (habitat creation) Social (health and well-being)	• City of Edina Community Solar Garden, USA • Jack's Solar Garden, USA
Addressing habitat destruction and biodiversity loss	Rewilding, grassland, meadows (pollinator-friendly)	Biodiversity (habitat creation)	Carbon sequestration and storage	• SA Water Native Bushes and Grasses Replantation, Southern Australia • The Windflower Solar Project, USA
	Biodiversity offsetting	Biodiversity (habitat creation)	Economic (jobs and livelihoods)	• Longfield Solar Farm, UK • Agaripe III Wind Complex, Brazil
	Coral and oyster reef restoration	Biodiversity (habitat restoration)	Resilience (coastal)	• ReCoral, Taiwan • Renewable Power Providing Habitats for Oysters, Netherlands
	Peatland restoration	Biodiversity (habitat restoration)	Carbon offsetting	• Peatland Restoration at Wind Site Farm, UK

Source: AECOM. 2023

2.2.2 NON-RENEWABLE ENERGY INFRASTRUCTURE

The impact of energy systems that run on fossil fuels on the environment and biodiversity is well known and in most countries, the construction and operation of this infrastructure is under intense scrutiny due to its recognised climate impact. Many of the publicly available project examples that were reviewed for this Playbook focused on the contents of environmental impact assessment and carbon and biodiversity offsetting, rather than innovative solutions.

Comparatively few case studies were identified that involved significant natural elements[31] and brought clear benefits, aside from the use of **bioengineering techniques to control erosion for onshore pipelines** and **biodiversity offsetting**, which are all summarised below.

TABLE 2-7. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO NON-RENEWABLE ENERGY INFRASTRUCTURE

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Reducing or offsetting carbon emissions	Mangrove forests	Carbon offsetting	Resilience (flood risk reduction)	• Sine-Saloum Mangroves, Senegal
Stabilisation of soil and reducing erosion	Bioengineering for landslide and erosion protection	Resilience (geotechnical)	Economic (cost savings)	• Natural Reclamation and Erosion Control for Onshore Pipelines, Canada
Addressing habitat destruction and biodiversity loss	Biodiversity offsetting	Biodiversity (habitat creation)		• Large Scale Site Development Restores Biodiversity, Canada • Wetland Creation and Citizen Science at Cherry Point, USA • Restoring Coral Reef in Mexico • No Net Loss in Biodiversity at Tangguh, Indonesia

Source: AECOM. 2023

2.3 WATER AND WASTEWATER

The need to meet the global demand for clean water and wastewater services **places a substantial pressure on the natural resources and biodiversity**, with water extraction, treatment and removal contributing **to the pollution of watercourses, overextraction and desertification**. The construction of dams, as the best-known example, can permanently alter river flows and adversely affect aquatic life. The impact of altering natural ecosystems, coupled with the added pressure on existing resources associated with climate change, is generating unprecedented pressure on terrestrial and aquatic biodiversity[32].

Of all sectors reviewed as part of the analysis, the water sector **provides the most significant number of projects that incorporated solutions that could be defined as nature-positive**. If designed and implemented well, some of the solutions identified in the literature offer the possibility of simultaneously tackling some of the main challenges associated with the water and wastewater sector while delivering multiple benefits, by relying on ecological processes that can improve the supply, availability, quality and treatment of water.

In addition to delivering these benefits, solutions identified in this section of the Playbook can **reduce the pressure on existing grey infrastructure**, effectively expanding its lifespan, increasing functionality and improving performance. For the purpose of this report, water and wastewater infrastructure can be broadly summarised into three types, as shown in Figure 2-3.

FIGURE 2-3. WATER AND WASTEWATER INFRASTRUCTURE – TYPOLOGY

WATER SUPPLY, STORAGE, QUALITY AND DISTRIBUTION | WASTEWATER AND SEWAGE / SANITATION | DRAINAGE AND STORMWATER

Source: AECOM. 2023

2.3.1 WATER SUPPLY, STORAGE, QUALITY AND DISTRIBUTION

Water insecurity and unreliable supply are some of the most common challenges water sector practitioners have sought to address by relying on natural ecosystems and ecological processes, including through improved land management (e.g. replanting and restoring forest ecosystems) around natural water reserves or infrastructure assets. This is particularly the case in tropical regions where forest ecosystems play an important role in **regulating atmospheric moisture and rainfall patterns**.

The exact impact of forest ecosystems on water resources varies greatly from place to place and is affected by multiple factors including (but not limited to) forest type, species, soil type and slope. It is worth noting that among some of the project examples reviewed, there was not always conclusive evidence of a clear causal link between **forest restoration and water supply** – unlike for water quality, which has been easier to assess and demonstrate[33].

Payments for Ecosystem Services (PES) schemes are one common mechanism used to promote sustainable management of land and forests for more reliable provision of ecosystem services, like water supply[34]. PES schemes have been gaining significant traction over the past few decades among water utilities and infrastructure developers that rely on local resources for supply. In general, the examples that focused on afforestation and reforestation (as part of a PES scheme or otherwise) note substantial benefits in terms of **water quality, increased water security and cost savings from potential disruption of services**.

An integrated approach to catchment management, which can include **different techniques for watershed management, stream and river restoration and planting riparian buffers**, is also used to improve long-term water availability and quality. Water scarcity and concerns about future water availability have led to an increased focus on water storage mechanisms, which is reflected in a number of projects that aim to expand and create **additional mechanisms for water storage**[35].

While river restoration is often undertaken to reduce the risk of flooding, it has also shown to be an important approach to addressing biodiversity and habitat loss, with an impact on both species' richness and abundance. The **reintroduction of species (e.g. beavers)** has also been cited in some examples as a viable approach to enhance hydrological processes and improve biodiversity on site[36].

TABLE 2-8. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO WATER SUPPLY, STORAGE, QUALITY AND DISTRIBUTION

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Improving water security and supply / water quality	Afforestation, reforestation	Environmental (water quality)	Resilience (water security / drought risk reduction) Economic (cost savings)	• Adaptation of Nicaragua's Water Supplies to Climate Change, Nicaragua • Sustainable Watershed Management in Glacial Mountain Ecosystems, Peru • Protection of the Chon-Aksuu Watershed, Kyrgyzstan • Coca-Cola USFS - NFF Partnership, USA

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
	Catchment management and riparian buffers	Resilience (water security / drought risk reduction)	Environmental (water quality) Economic (jobs, livelihoods and food)	• Sustainable Watershed Management in Glacial Mountain Ecosystems, Peru • Riparian Forest Restoration and Bank Protection, Evrotas Greece • Community-Based Land and Water Management, Sudan • Riparian Buffers - Queensland Urban Utilities, Australia • Maynilad Water Services and Manila Water, Philippines • Improving Degraded Riverine Areas in Rohingya Camps of Ukhiya, Cox's Bazar, Bangladesh • Upstream Thinking: A Private-Public Community Multiple Benefits Partnership, UK • Watershed Protection - Companhia de Saneamento Basico De Estado de Sao Paulo, Brazil • Bowmont Catchment Initiative, UK
	Sustainable urban drainage systems (SuDS) and bioretention areas (water storage)	Resilience (water security / drought risk reduction)	Environmental (water quality) Economic (jobs, livelihoods and food)	• Tank Cascades in the Dry Zone and the Rehabilitation of Small-Scale Water Storage, Sri Lanka
Addressing biodiversity and habitat loss	River restoration and catchment management	Biodiversity (habitat restoration)	Environmental (water quality)	• River Restoration – Glaven, UK • Weir Removal Project in West Cumbria, UK • River Keekle Restoration Project, UK • Restoration of the River Ljubljanica (Ljubljanica Connects) • Dun Creek Confluence Habitat Restoration, USA • Lower Boulder Creek Ecosystem Restoration Project, USA • Wallacut River Marsh Reconnection, USA • The Rottal Burn, UK • River Tolka, Ireland
	Rewilding, grasslands, meadows	Biodiversity (habitat restoration)	Environmental (water quality)	• Coca-Cola USFS - NFF Partnership, USA

Source: AECOM. 2023

2.3.2 WASTEWATER AND SEWAGE / SANITATION

As the body of evidence on the effectiveness of relying on natural processes to purify and control wastewater runoff grows, so too is the interest in understanding the conditions under which these processes could be incorporated in, or used as a replacement for, traditional wastewater infrastructure (such as sludge and wastewater treatment plants, etc).

In many places and particularly in developing countries, **combined sewers**[37] pose a serious environmental and health hazard during strong storms and rainfall events. A review of project examples found that a combination of **urban green space with wetlands** has been used to slow water runoff and reduce the risk of combined sewer overflow, which has also had the added benefit of having a tangible effect on micro-climate and aiding in temperature regulation. There are also examples of **expanding peri-urban areas for agro-forestry and agriculture** to allow increased water storage and filtration and thus reduce the risk of flooding and cross-contamination, with cited co-benefits of improving local jobs, food and livelihoods.

Some of the solutions cited below have wide applicability for wastewater treatment and can be used to treat most types of wastewater, including municipal, agricultural, industrial and stormwater, using **plants, bacteria, soil and other natural processes. Constructed wetlands** are among the most commonly used approaches, often using a mix of open water ponds and vegetation marshes to encourage development of bacteria and plants that can filter and treat wastewater before it is returned to rivers or the sea, with recorded benefits for both water quality and biodiversity.

Encouraging the development of aquatic plants, grass and microorganisms through the creation of **floating wetlands**, has also been used to reduce the pollution of waterbodies. The construction of **reed beds for sludge treatment** has also been identified in several project examples (treated sludge has afterwards been used in agriculture or construction and lower the costs of fertilisers or construction materials), in addition to different types of **soil infiltration systems** for domestic and industrial wastewater treatment (slow and rapid).

There have also been several attempts at using **living walls and green roofs** for treating domestic wastewater, in addition to increasing the biodiversity value of sites and regulating micro-climate.

TABLE 2-9. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO WASTEWATER AND SEWAGE / SANITATION

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Improving flood control and reducing runoff	Wetlands (natural and constructed) in combination with landscape restoration, parks and forests	Resilience (flood risk reduction)	Resilience (temperature regulation)	• Building Bangkok's Climate Resilience Through Nature-Based Solutions, Thailand
	Urban and peri-urban agriculture, urban gardening	Resilience (flood risk reduction)	Economic (jobs, livelihoods and food)	• Gorakhpur, India: A City Trying to Keep Its Head Above Water, India
	Resilient urban design and restoration of waterbodies	Resilience (flood risk reduction)	Social (recreation / amenity)	• Flood Bypasses, Green Infrastructure for Flow Regulation - Skanderborg Forsyning, Denmark

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Effluent treatment and improving water quality	Constructed wetlands and other waterbodies for filtration (e.g. ponds – surface, anaerobic)	Environmental (water quality)	Biodiversity (habitat creation) Economic (cost savings)	• Using Nature-Based solutions for Wastewater Treatment and Reducing Coastal Water Contamination, Pakistan • Integrated Constructed Wetlands for the Clifton Wastewater Treatment Works, UK • Enhancing Groundwater Supplies and Water Quality By Using Soils for Tertiary Treatment of Wastewater, Israel • Constructed Wetland in Litani River, Lebanon • Constructed Wetland - Anglia Water, UK • Integrated Wetland Management System: The Case of Neknampur Lake, India • Using Daphnia and Algae to Monitoring Water Toxicity and Early Detection of Pollution Surges - Rhine Water Quality Station, Germany
	Sludge treatment reed beds	Environmental (water quality)	Economic (other -supporting tourism development)	• Sludge Treatment Reed Beds in Mojkovac, Montenegro
	Soil infiltration system (slow and rapid)	Environmental (water quality)	Economic (cost savings)	• Advanced Wastewater Treatment Through Slow Rate Soil Infiltration System in Lubbock, USA
	Green roofs	Environmental (water quality)	Biodiversity (habitat creation) Resilience (flood risk reduction)	• Green Roof and Treatment Wetland in Tilburg, Netherlands
	Green and ‘living’ walls	Environmental (water quality)	Biodiversity (habitat creation) Resilience (flood risk reduction)	• Living Walls at Marina Di Ragusa, Italy

Source: AECOM. 2023

Technical Partner: AECOM

2.3.3 DRAINAGE AND STORMWATER

The reliance on natural processes to reduce the volume and flow rate of stormwater and the pressure on drainage systems is commonly used worldwide. Solutions that rely on natural processes for stormwater management are particularly used in urban areas, where urbanisation and related land use change drive up the increase in impermeable surfaces, which increase the risk of flooding.

Often, a combination of several interlinked solutions is deployed, typically as a combination of **trenches, ponds and wetlands** (permeable pavement / bricks are also used). Other common solutions also include **green spaces, parks and trees**, where the water is absorbed and retained at the source (like in the case of the 'sponge city' approach in China). **Wetlands (constructed or restored)** are sometimes used on their own to reduce the risk of flooding, with positive recorded impact on biodiversity through habitat creation or restoration.

In many cases, approaches to reduce the risk of flooding are combined with efforts to maximise the use of space for different social purposes (recreation, amenity, tourism, or even agriculture) and feature some form of watershed management and restoration of local waterbodies (like ponds and lakes).

TABLE 2-10. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO DRAINAGE AND STORMWATER

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Improving flood control and reducing runoff	Wetlands (natural and constructed)	Resilience (flood risk reduction)	Biodiversity (habitat creation)	• Building Bangkok's Climate Resilience Through Nature-Based Solutions, Thailand • Development of a Blue-Green City, Australia • Water Management and Flood Prevention – LafargeHolcim, France
	Catchment management	Resilience (flood risk reduction)	Environmental (water quality)	• Sun Valley Watershed Multi-Benefit Project, USA • Adaptation of Nicaragua's Water Supplies to Climate Change, Nicaragua
	Sustainable urban drainage systems (SuDS) and bioretention areas	Resilience (flood risk reduction)	Resilience (temperature regulation Biodiversity (habitat creation)	• Sussex Flow Initiative, UK • Sponge Cities, China • Urban stormwater management in Augustenborg, Malmo, Sweden • Piloting Natural Flood Management Designs at Marlfield Farm, UK

Source: AECOM. 2023

Technical Partner: AECOM

2.4 BUILDINGS AND PUBLIC SPACES

Buildings are a significant driver of **habitat loss, fragmentation and decline in animal populations**; they also tend to have a high carbon footprint (as a result of the embodied carbon in construction materials and carbon intensive construction processes). In an urban context, population growth and demand for housing and services can come at the expense of green areas that provide **significant social, economic and environmental benefits**. Some of these benefits are better understood than others: while the importance of urban natural ecosystems for air quality, temperature regulation, land value uplift, spaces for recreation and community are well known, others – such as the importance of biodiversity for maintaining some of these ecosystem services – are less well understood. In some instances, this can result in designing solutions that have more of an aesthetic than environmental function and cause damage to the native ecosystems (such as the introduction of exotic and invasive plant species, monoculture plantations, etc).

Through the literature review and analysis of existing projects, a significant number of projects were identified that have clear biodiversity objectives, or aim to increase resilience to different hazards, reduce environmental and carbon footprint, as well as deliver a return on investment across all scales (from individual buildings to landscape level). Since most examples fall into a category of residential, non-residential or broader spatial interventions, this typology is summarised in Figure 2-4.

FIGURE 2-4. BUILDINGS AND PUBLIC SPACES – TYPOLOGY

RESIDENTIAL BUILDINGS | NON-RESIDENTIAL BUILDINGS | OPEN / GREEN SPACE

Source: AECOM. 2023

2.4.1 RESIDENTIAL BUILDINGS

Driven by both regulatory (e.g. biodiversity net gain in the UK) and market demands (e.g. buildings with green and blue elements tend to have a higher market value), there has been a significant uptake in the integration of green elements (such as **green walls and roofs, living walls, tree facades**) at the building scale, often combined with the expansion of **open green spaces and tree planting** to increase biodiversity value of sites and restore or recreate some of the lost habitats. In addition to increasing biodiversity, some common co-benefits listed include temperature regulation and additional spaces for amenity and recreation.

A particularly interesting and notable development on housing estates includes **rewilding** (in this context, undertaking restoration activities to restore ecosystem functioning which, once restored, is left to its own devices), replacing highly manicured, water and energy intensive lawns and common areas. This has been said to bring multiple social and economic benefits, including cost savings.

A combination of various 'blue' and 'green' solutions (in an urban context sometimes referred to as **resilient urban design**, where building roofs and pavements are constructed to retain stormwater through thick soil pots, permeable bricks and trees) have been applied to multiple places. These have also been found to help regulate temperature, improve air quality and increase biodiversity on site.

Another commonly found example is a reliance on **urban trees and forests** close to residential buildings to reduce stormwater runoff and regulate micro-climate. Furthermore, **low-impact materials (recycled steel, bamboo and timber)** are gaining traction worldwide, often in combination to drive down the carbon footprint of buildings.

TABLE 2-11. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO RESIDENTIAL BUILDINGS

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Addressing habitat destruction and biodiversity loss	Green roofs	Biodiversity (habitat creation)	Resilience (temperature regulation) Social (recreation / amenity)	• Green Roofs in Basel, Switzerland • eThekwini Municipality Green Roof Pilot Project, South Africa • Forest House, Thailand • House for Trees, Vietnam
	Green and 'living' walls	Biodiversity (habitat creation)	Resilience (temperature regulation) Social (recreation / amenity)	• Bosco Verticale, Italy
	Afforestation, reforestation	Biodiversity (habitat restoration)	Social (recreation / amenity) Economic (cost savings)	• Pocket Parks: The Greening of Degraded Public Spaces, Nepal • Green Lungs of the City - Forest and Wetlands Park, Yiwu, China • Green Park Biodiversity, UK
Increasing resilience to impact of flooding / urban heat	Sustainable urban drainage systems (SuDS) and bioretention areas	Resilience (temperature regulation)	Environmental (air quality) Biodiversity (habitat creation)	• Green Buildings in Ho Chi Minh City, Vietnam
	Resilient urban design and restoration of waterbodies (lakes, ponds)	Resilience (flood risk reduction)	Social (health and well-being)	• Nanjing Eco-Island Yangtze River Waterfront, China

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
	Afforestation, reforestation	Resilience (temperature regulation)	Carbon sequestration and storage Biodiversity (habitat creation)	• Prestwich High Street, Bury and Howard Street, Salford, UK • Bolivia Urban Resilience
Reducing embodied and operational carbon	Bio-building materials and 'soft' measures	Embodied and operational carbon	Social (health and well-being)	• Designing and Engineering the Netherlands' Tallest Timber-Hybrid Residential Buildings, Netherlands

Source: AECOM. 2023

2.4.2 NON-RESIDENTIAL BUILDINGS

Similar solutions have been applied across non-residential buildings and sites; some of the project examples identified in the analysis include **restoration or construction of ponds, lakes and swales** to not only boost biodiversity, but also increase land value and reduce the risk of flooding at asset level. **Ecological enhancement and forest landscape restoration** (as well as combination of different green elements) in several cases have been undertaken to increase land value. Multiple examples cited the increased uptake of **green walls and roofs** across all types of non-residential buildings (e.g. government offices, schools and kindergartens, train stations, commercial buildings) to reduce the risk of flooding and heat stress.

TABLE 2-12. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO NON-RESIDENTIAL BUILDINGS

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Addressing habitat destruction and biodiversity loss	Sustainable urban drainage systems (SuDS) and bioretention areas	Biodiversity (habitat restoration)	Economic (land value uplift) Resilience (flood risk reduction)	• Green Park Biodiversity, Reading, UK
	Afforestation and reforestation	Biodiversity (habitat restoration)	Carbon sequestration and storage	• Wild West End, UK

Technical Partner: AECOM

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Reducing the risk of flooding and heat stress	Green roofs	Resilience (flood risk reduction)	Resilience (temperature regulation); Biodiversity (habitat creation)	• Green Roof and Water Management in Philippines Government Office Building, Philippines
	Green and 'living' walls	Resilience (flood risk reduction)	Resilience (temperature regulation); Biodiversity (habitat creation)	• Marks & Spencer Newcastle, UK
Reducing embodied and operational carbon	Green roofs	Embodied and operational carbon	Biodiversity (habitat creation)	• Birmingham New Street Station, UK
	Green and 'living' walls	Embodied and operational carbon	Environmental (air quality)	• A Green Wall for Kindergarten, Armenia • Villa M, France
	Bio-building materials	Embodied and operational carbon	Social (cultural services)	• Sara Kulturhus Centre, Sweden • The Anandaloy building, Bangladesh • Cambridge Central Mosque, UK
Generating return on investment	Urban and peri-urban agriculture, urban gardens	Economic (return on investment)	Social (recreation / amenity)	• Little Duxmore Farm, UK • Fifth Façade Project Jardin Das Oliveira, Portugal • Urban Farming (Modeltuin Genk Noord), Belgium • Changmai Urban Farm, Thailand

Source: AECOM. 2023

Technical Partner: AECOM

2.4.3 OPEN / GREEN SPACE

There are a number of interesting and innovative approaches to increase the proportion of green / open spaces in urban areas and simultaneously address some of the key issues associated with urban expansion. **Restoring wetlands and creating green corridors** are amongst the most commonly used solutions to restore or introduce terrestrial and aquatic biodiversity in urban areas, which also brings important co-benefits in terms of increased carbon sequestration and temperature regulation.

The expansion of **green spaces** often targets flood risk reduction and/or temperature regulation through a combination of several solutions **(rain gardens, bioswales, stormwater ponds, different types of vegetation), restoration of urban rivers and streams, green roofs and planting of urban trees and forests. Urban agriculture, gardens and pocket parks** are increasingly prevalent where spatial constraints make it difficult to ensure adequate proportion of space for recreation and community engagement, often with some distinct features that benefit local biodiversity.

TABLE 2-13. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO OPEN / GREEN SPACE

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Addressing habitat destruction and biodiversity loss	Wetlands (natural and constructed)	Biodiversity (habitat restoration)	Carbon sequestration and storage	• Deer Grove Forest Preserve Habitat Restoration, USA • Saramacca Canal System Rehabilitation Project, Suriname
	Afforestation, reforestation	Biodiversity (habitat connectivity)	Carbon sequestration and storage Resilience (temperature regulation)	• Green Corridors Project, Tree Pits and Raingardens, Colombia
Reducing the risk of flooding and urban heat island effect	Sustainable urban drainage systems (SuDS), bioretention areas	Resilience (flood risk reduction)	Resilience (geotechnical) Social (cultural services)	• Nanjing Eco-Island Yangtze River Waterfront, China • Stormwater Green Infrastructure in the Mid-Atlantic, USA • NbS for Building a Waterproof City, Netherlands • Grey to Green, UK
	River restoration, catchment management, riparian buffers	Resilience (flood risk reduction)	Biodiversity (habitat creation) Economic (land value uplift)	• Daylighting River: Revitalising the Cheonggyecheon Stream, South Korea • Dasha Ecological Corridor, China

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
	Green roofs	Resilience (flood risk reduction)	Resilience (temperature regulation) Biodiversity (habitat creation)	• eThekwini Municipality Green Roof Pilot Project, South Africa
	Afforestation, reforestation	Resilience (flood risk reduction)	Resilience (temperature regulation) Carbon sequestration	• Bolivia Urban Resilience, Bolivia • Resilient Urban Sierra Leone Project, Sierra Leone • Stormwater Management in Norway's Abandoned Airport, Norway
	Bio-based materials and 'soft' measures	Resilience (flood risk reduction)		• Climate Tile, Denmark
Increasing the amount of space for community purposes (e.g. farming)	Urban and peri-urban agriculture, urban gardens	Economic (jobs and livelihoods)	Social (health and well-being)	• Urban Farming (Modeltuin Genk Noord), Belgium • Rainforest Recovery in Urban Areas, Brazil • Changmai Urban Farm, Thailand
	Open green spaces (pocket parks)	Social (health and well-being)	Biodiversity (habitat creation)	• Pocket Parks: The Greening of Degraded Public Spaces, Nepal
Reducing carbon emissions	Afforestation, reforestation	Carbon sequestration	Biodiversity (habitat creation)	• Rainforest Recovery in Urban Areas, Brazil • Beijing Plain Area Afforestation Programme (BPAP), China • Green Lungs of the City – Forest and Wetlands Park, Yiwu, China

Source: AECOM. 2023

2.5 COASTAL PROTECTION

The analysis of project examples suggests there are a significant number of projects integrating different **nature-based solutions for coastal resilience**, reflecting a growing body of evidence of their effectiveness and positive cost-benefit ratio compared to conventional coastal infrastructure alone (like **seawalls, breakwaters, levees, dikes,** etc). This is especially the case when considering the latter's lack of adaptability to changing conditions like sea level rise and its impact on nearby habitats[38]. Another consideration is relatively low maintenance cost: once established, **coastal ecosystems can self-regulate and provide numerous ecosystem services**, including habitat creation, sediment stabilisation, biodiversity enhancement and carbon sequestration.

Among the examples identified during the analysis, most of them either include some type of **hybrid approach** (summarised as 'green-grey coastal infrastructure' in this section) that enhance biophysical conditions through a mix of green and grey elements, or a combination of usually two or three **natural coastal ecosystem restoration techniques** (summarised here as 'natural coastal infrastructure'). It is important to note some of the examples reviewed do not always contain enough information to make a clear distinction between the two types (so some project referenced listed should be considered as illustrative examples) and that many approaches to coastal resilience tend to include a **combination of different solutions** (e.g. simultaneous restoration of salt marsh and dunes).

FIGURE 2-5. COASTAL PROTECTION INFRASTRUCTURE – TYPOLOGY

GREEN-GREY COASTAL INFRASTRUCTURE

NATURAL COASTAL INFRASTRUCTURE

Source: AECOM. 2023

2.5.1 GREEN-GREY COASTAL INFRASTRUCTURE

There is a growing concern about the potential ineffectiveness of conventional grey coastal infrastructure against strong coastal storms and coastal flooding associated with sea level rise, coupled with their relatively high construction and maintenance costs. Accordingly, **reducing the pressure on existing coastal infrastructure, expanding its longevity and bringing biodiversity benefits** is driving a significant uptake in different techniques for **coastal restoration and alignment** (from **realignment of existing defence lines, beach nourishment, to restoring sand dunes and salt marshes**). While primarily implemented to reduce the risk of flooding, notable co-benefits include habitat creation and the creation of additional spaces for amenity and recreation.

Another commonly used solution involves **(re)planting mangroves and undertaking coastal afforestation** to provide an additional layer of protection near the seashore. Most examples relying on mangroves and coastal afforestation stress the importance of community involvement in the restoration process (possibly more so than for other approaches to coastal resilience) as a success factor, in light of numerous failed attempts at their restoration[39].

Eco-engineering approaches, including engineered reefs, are sometimes used on their own, or in combination with restoration of dunes to create 'living shorelines', to reduce the risk of flooding as well as generate more biodiverse habitats.

Finally, **different mechanisms for coastal restoration** are increasingly used jointly with grey coastal infrastructure to stabilise soils and reduce the risk of erosion, as well as to restore habitats lost during the construction of that infrastructure or strong weather events. In particular, some of the identified approaches include restoring **salt marshes via dredged sediment, beach nourishment and restoration,** as well as the use of **eco-blocks** that enable the growth of seaweed and support aquatic biodiversity.

TABLE 2-14. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO GREEN-GREY COASTAL INFRASTRUCTURE

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Reducing the risk of coastal flooding	Coastal restoration, realignment and living shorelines	Resilience (flood risk reduction)	Biodiversity (habitat creation) Social (recreation / amenity)	• Medmerry Managed Coastal Realignment, UK • Marsh Restoration and Replenishment, Little Egg Harbor, New Jersey, USA
	Mangrove forests (supplementing the grey infrastructure)	Resilience (flood risk reduction)	Economic (jobs and livelihoods)	• Kiribati Adaptation Phase III, Kiribati • Coastal Embankment Improvement Project - Phase I (CEIP-I), Bangladesh
	Ecoengineering, vertipooles, habitat tiles	Resilience (flood risk reduction)	Resilience (geotechnical) Biodiversity (habitat creation)	• Port of San Diego Coastal Protection, USA
	Sand dunes and shores (supplementing the grey infrastructure)	Resilience (flood risk reduction)	Biodiversity (habitat restoration) Resilience (geotechnical)	• Blankenberge - Depaving and Duning, Belgium • Surfer's Point Managed Shoreline Retreat Project, USA • Prins Hendrik Sand Dike, Netherlands
	Oyster reef restoration (engineered)	Resilience (flood risk reduction)	Resilience (geotechnical)	• Oyster Reef Building and Restoration for Coastal Protection, USA • Souris Beach Shoreline Erosion and Highway Protection, Prince Edward Island - a Hybrid Solution, Canada • Protecting Wetlands With a 'Living Shoreline', USA

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Reducing coastal erosion	Salt marsh restoration	Resilience (geotechnical)	Biodiversity (habitat restoration)	• Seal Beach National Wildlife Refuge Thin-Layer Salt Marsh Sediment Augmentation Pilot Project, USA • Chocolate Bayou Channel, USA • Virginia Point Living Shoreline • Deer Island Aquatic Ecosystem Restoration
Enhancing biodiversity, addressing habitat loss and reducing carbon emissions	Salt marsh restoration	Biodiversity (habitat restoration)	Carbon sequestration and storage	• Prime Hook National Wildlife Refuge Marsh Restoration Resilience Project, USA
	Ecoengineering, vertipooles, habitat tiles	Biodiversity (habitat creation)	Embodied and operational carbon	• Newlyn - Eco-engineering: Greening of Hard Infrastructure, UK • Rich Revetments: Enhancing Hard Substrates for Ecology, Netherlands • Houtril Dike Pilot Project, Netherlands

Source: AECOM. 2023

2.5.2 NATURAL COASTAL INFRASTRUCTURE

In addition to green-grey approaches, there has been a noticeable increase in the uptake of natural coastal infrastructure, following the proliferation of studies and cost-benefit analyses that can more precisely capture some of the co-benefits in a quantitative manner[40]. The review of literature and analysis of project examples suggests that natural coastal protection infrastructure shows **solid performance against less intense weather events, has a capacity to self-repair in their aftermath and can adjust to changing climate conditions,** including sea level rise.

Mangrove forests and reefs are among the most commonly used natural approaches to reducing the risk of coastal flooding, although their restoration success rate seems to vary dramatically between projects. Some of the commonly cited co-benefits include erosion control and economic benefits associated with fisheries and eco-tourism, although again, this varies between projects and is closely linked to the extent that community involvement was a feature of the restoration project.

Restoration of dunes, beach nourishment and salt marsh restoration are also among some of the most common solutions, followed by **restoration of coastal wetlands.** In addition to their role in reducing the risk of flooding, these solutions have also been described as bringing significant biodiversity benefits through habitat restoration and social benefits in terms of amenity and recreation. Other examples show that efforts to mitigate coastal erosion often involve different forms of **coastal restoration, including beach nourishment, but also coral reefs, mangroves** and other type of vegetation strategically planted to stabilise the soil.

Biodiversity benefits seem to be significant for projects featuring a combination of several solutions, including **restoration of salt marsh, seagrass, oyster reef and mangrove forests.**

In light of growing interest in **blue carbon**, several projects targeting carbon offsetting through restoration and protection of these ecosystems have been identified, however, they have not been included in the analysis as they are still at the early stages and insufficient information was available at the time of writing.

TABLE 2-15. SUMMARY TABLE – NATURE-POSITIVE APPROACHES TO NATURAL COASTAL INFRASTRUCTURE

OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Reducing the risk of coastal flooding	Mangrove forests	Resilience (flood risk reduction)	Resilience (geotechnical) Economic (jobs and livelihoods)	• Climate Resilient Participatory Afforestation and Reforestation Project, Bangladesh • Mangroves for Coastal Resilience, Philippines • From Mangrove to Mountain: Building Coastal Resilience in Timor-Leste • Building with Nature in Indonesia: Restoring an Eroding Coastline and Inspiring Action at Scale, Indonesia
	Dunes and sandy shores	Resilience (flood risk reduction)	Social (recreation / amenity)	• Urban Hybrid Dunes, Spain • Cardiff Beach Coastal Resiliency – A Living Shoreline, USA • Ostend - And the Nature Takes Care of the Rest, Belgium
	Wetlands (natural and constructed)	Resilience (flood risk reduction)	Biodiversity (habitat restoration) Environmental (water quality)	• Wetlands Restoration for Ecosystem and Community Resilience in He'eia, O'ahu, Hawaii
Reducing coastal erosion	Coral reef restoration	Resilience (geotechnical)	Biodiversity (habitat creation)	• Defending the Reef in Grenada, Grenada
	Coastal restoration, alignment and living shorelines	Resilience (geotechnical)	Biodiversity (habitat creation) Social (recreation / amenity)	• The Sand Motor, Netherlands - Mega Nourishment as a Coastal NbS, Netherlands • Creating a Living Shoreline in Louisiana, USA

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OBJECTIVE	SOLUTIONS	KEY-BENEFIT	COMMON CO-BENEFITS	REFERENCE PROJECTS
Enhancing biodiversity and addressing habitat loss	Combination of different approaches, including mangrove forests and coral reefs, sea grass and oyster reefs	Biodiversity (habitat restoration)	Resilience (flood risk reduction) Economic (jobs and livelihoods)	• Project GreenShores, USA • San Francisco Bay Living Shorelines Nearshore Linkages Project, USA • Restoring Degraded Urban Dunes - Eastern Coromandel, New Zealand • Salt Marsh Restoration, Florida, USA • Mangrove Restoration in Costa Rica • Kotok Field Lab on Beach Conservation and Coral Reef Restoration, Indonesia
	Wetlands (natural and constructed)	Biodiversity (habitat creation)	Resilience (geotechnical)	• Hamilton Wetlands Restoration Project, USA
Reducing carbon emissions / carbon offsetting	Sea grass restoration	Carbon sequestration and storage	Biodiversity (habitat restoration)	• Seagrass Restoration in the UK

Source: AECOM. 2023

03

BENEFITS

03 BENEFITS

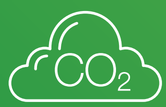
Three principal benefits have been identified as key factors driving increased uptake of nature-based solutions in the infrastructure sector:

PRINCIPAL BENEFITS

BIODIVERSITY

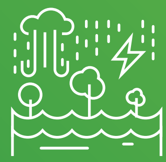
Through habitat creation, restoration, or enhanced connectivity.

CARBON[41]



Through reducing embodied and operational carbon, increased carbon sequestration and carbon offsetting

RESILIENCE



Through reducing flood risk, geotechnical, coastal, temperature regulation and drought risk reduction

While there has been substantial progress in measuring and quantifying these benefits[42], the review of the literature and project examples suggests that there is no consistency in the quantification and measurement approaches across different settings and contexts and that this remains an evolving field.

3.1 BIODIVERSITY

While the impacts of some types of infrastructure on biodiversity are better known than others (for instance, the impact of road and rail infrastructure expansion on species and habitat loss is in principle better understood and quantified than, for instance, the impact of wind farms),[43] **some estimates suggest that globally, expansion of infrastructure and the built environment affects about 29% - almost a third - of species on IUCN's list of threatened and near threatened species**[44]. Mammals and birds tend to be strongly affected[45], with recorded avoidance or reduced population density around newly constructed infrastructure within several hundred metres or even kilometres[46]. Any infrastructure that changes or diverts significant natural flows of water can also have large-scale impacts, potentially destroying wetlands, drying river basins and leaving communities vulnerable to flooding or drought. Add the effects of climate change such as shifting precipitation patterns and increasing the intensity and frequency of extremes like droughts and floods and these impacts are even more damaging.

A particularly concerning trend that emerged during the literature review relates to the seeming inadequacy of safeguarding policies in many places and limited observance of the established principles of the mitigation hierarchy, evidenced in recent expansion of energy, transport and other infrastructure in areas of high ecological value, from the Caucasus to Latin America[47].

There are several key incentives for infrastructure practitioners and developers to prioritise biodiversity in the planning, design and construction process – summarised in Figure 3-1.

FIGURE 3-1. INCENTIVES FOR INTEGRATING BIODIVERSITY CONSIDERATIONS IN INFRASTRUCTURE DEVELOPMENT

REGULATORY
An increasing number of countries are mainstreaming biodiversity net gain or no net loss into their plans, laws and regulations and TNFD and SBTN are expected to further drive investments in nature-positive infrastructure

MARKET-BASED
As scrutiny over environmental impact of infrastructure development sharpens, so, too is the business case for infrastructure projects with positive impact on biodiversity strengthening

INFRASTRUCTURE REILIENCE
Genetic diversity has a direct impact on provision of ecosystem services and their regulatory function, which can boost resilience

CARBON FOOTPRINT
Long term carbon sequestration and storage are directly linked to ecosystem health, of which biodiversity is a key component

Source: AECOM. 2023

While the substantial number of project examples with clear biodiversity objectives identified worldwide implies that a shift in thinking is occurring, the pace remains inadequate in the context of population growth, anticipated infrastructure need and the ongoing biodiversity crisis. Table 3-1 summarises the most commonly used approaches to infrastructure development where biodiversity – either in terms of habitat creation, restoration, connectivity, or offsetting[48] - was a key targeted benefit / objective. The list is not exhaustive and will continue to be updated in the future versions of the Playbook.

TABLE 3-1. APPROACHES TO NATURE-POSITIVE INFRASTRUCTURE WITH BIODIVERSITY AS KEY CONSIDERATION

SECTOR	COMMON APPROACHES IN THE ANALYSIS	REFERENCE PROJECTS
TRANSPORT	• Green bridges, wildlife bridges, ecological corridors, culverts • Afforestation, reforestation • Biodiversity and habitat offsetting	• Dedin Green Bridge, Croatia • Highway 17 Wildlife and Regional Trail Crossings and Trail Connections and Mitigation Credit Agreement, USA • Colombia Mocoa - San Francisco Road, Colombia
ENERGY	• Rewilding, grasslands, meadows	• SA Water Native Bushes and Grasses Replantation, Southern Australia • Agaripe III Wind Complex, Brazil
WATER / WASTEWATER	• River restoration and catchment management • Wetlands (natural and constructed)	• Weir Removal Project in West Cumbria, UK • Building Bangkok's Climate Resilience Through Nature-Based Solutions, Thailand
BUILDINGS AND ` PUBLIC SPACES	• Resilient urban design and restoration of waterbodies (lakes, ponds) • Afforestation, reforestation, open green spaces • Rewilding, grasslands, meadows	• Kingsbrook, UK • Green Park Biodiversity, UK • Deer Grove Forest Preserve Habitat Restoration, USA
COASTAL	• Mangrove forests • Dunes and sandy beaches • Salt marsh restoration • Eco-engineering, vertipooles, habitat tiles	• Mangrove Restoration in Costa Rica • Seal Beach National Wildlife Refuge Thin-Layer Salt Marsh Sediment Augmentation Pilot Project, USA • Newlyn - Eco-engineering: Greening of Hard Infrastructure, UK

Source: AECOM. 2023

As not all of these solutions necessarily bring substantial biodiversity benefits - for instance, multiple sources point out that linear tree infrastructure and some types of green walls and roofs may have limited biodiversity value and others may even represent a trade-off (e.g. monoculture plantations that store a significant amount of carbon in the short run but are detrimental to biodiversity), it is important to carefully consider potential trade-offs. This does not imply de facto incompatibility, but that caution is required with some approaches that are also expected to have significant carbon sequestration benefits[49].

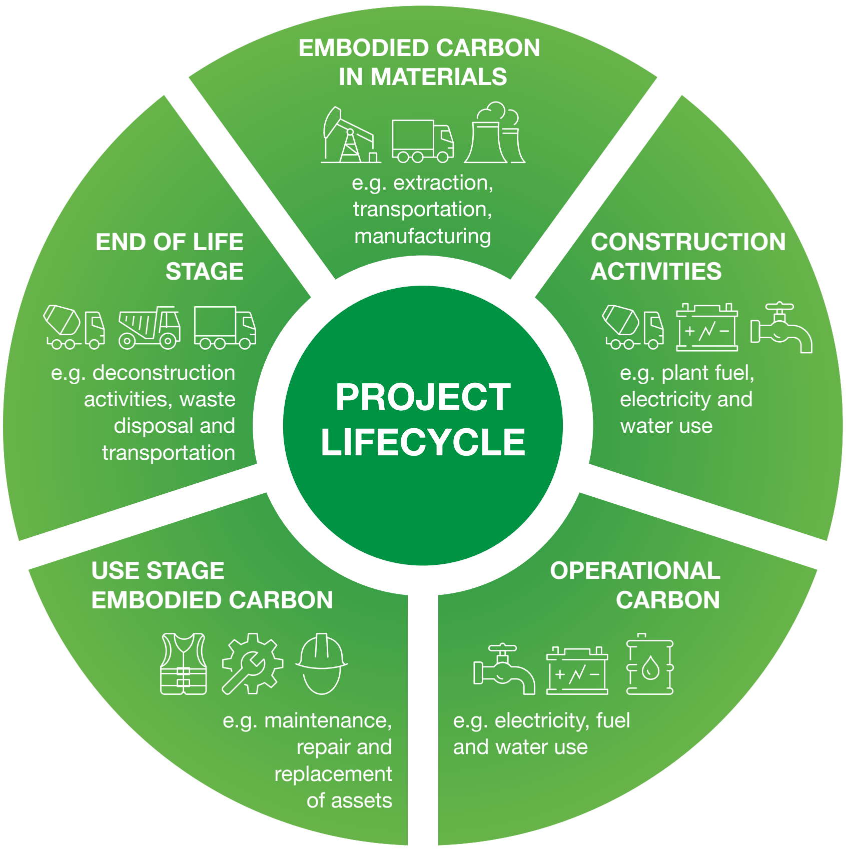
3.2 CARBON

Across all sectors, **infrastructure accounts for over 75% of all emissions globally**[50]. There is a strong drive from both the regulatory and market side to identify ways to reduce carbon emissions across the entire infrastructure project lifecycle, from **the design phase, through construction, operation, maintenance to decommissioning** – as illustrated in Figure 3-3. This includes reducing the carbon embodied in the infrastructure assets themselves (i.e. resulting from carbon emissions of the materials used and construction activities themselves), as well as the operational/use stage carbon emissions (i.e. emitted during operation of an infrastructure asset and the maintenance or repair). **Carbon offsetting** for emissions that cannot be designed out or reasonably avoided is seen as the last resort and **natural or engineered carbon sinks** can be used for those emissions that may be difficult to avoid.

Across virtually all sectors, there has been significant progress on low-carbon design and construction (including the use of less carbon-intensive materials) and the popularity of certain hybrid approaches (e.g. **green roofs and living walls**) has increased dramatically over the past decade. This not only reflects the increased awareness that nature-based solutions, green and green-grey infrastructure can improve a project's environmental impact through carbon sequestration, but also reduce embodied and operational carbon.

While approaches and the actual carbon benefits vary greatly across project types, infrastructure type and the precise circumstances in which different solutions are applied, it is worth noting that **the uptake of purely natural approaches (as opposed to hybrid) in some carbon-intensive sectors (like transport)** has been more limited.

FIGURE 3-2. CARBON THROUGHOUT THE PROJECT LIFECYCLE



Source: AECOM. 2023

Technical Partner:

Table 3-2 summarises some of the most common approaches to reducing embodied, operational / use stage carbon, as well as using carbon offsetting, identified in the analysis.

TABLE 3-2. APPROACHES TO NATURE-POSITIVE INFRASTRUCTURE WITH CARBON AS KEY CONSIDERATION

SECTOR	COMMON APPROACHES IN THE ANALYSIS	REFERENCE PROJECTS
TRANSPORT	• Afforestation, reforestation	• Birmingham New Street Station, UK • Guizhou Zhengxi Expressway Project, China • Deer Grove Forest Preserve Habitat Restoration, USA
ENERGY	• Afforestation, reforestation	• SA Water Native Bushes and Grasses Replantation, Australia
WATER / WASTEWATER	• Wetlands (natural and constructed)	• Integrated Constructed Wetlands for the Clifton Wastewater Treatment Works, UK
BUILDINGS AND ` PUBLIC SPACES	• Afforestation, reforestation • Green roofs • Green and 'living' walls • Bio-building materials and 'soft' measures	• Resilient Urban Sierra Leone Project • Rainforest Recovery in Urban Areas, Brazil • Clapham Park Total Green Roof System, UK • Chartered Bank HQ, UK • Designing and Engineering the Netherlands' Tallest Timber-Hybrid Residential Buildings
COASTAL	• Dunes and sandy shores • Ecoengineering, vertipooles, habitat tiles	• Houtril Dike Pilot Project, Netherlands • Newlyn - Eco-engineering: Greening of Hard Infrastructure, UK

Source: AECOM. 2023

3.3 RESILIENCE

While infrastructure is made to operate over many decades, its design is often seen to assume a future climate that is not significantly different to that of today. With a changing climate – and more extreme weather events – the infrastructure assets designed for current climate may in the future be operating outside of their tolerance levels, with possible consequences for both those assets and the entire systems they support[51].

There are two important drivers that explain the significant uptake of (and availability of financing for) nature-positive approaches for infrastructure resilience that have been identified in the analysis. These are, firstly, the **natural adaptability of some nature-based solutions to changing conditions**. In contrast to grey infrastructure, which does not adapt to changing conditions and climate, natural ecosystems can adapt to and, in some cases, thrive in, changing conditions. They can also recover from shocks and stresses (depending on their extent and nature) on their own, **reducing the costs and effort associated with their maintenance.**

The second and related driver is the increase in approaches attempting to **quantify the resilience benefits of natural ecosystems** – and the typically good cost-benefit ratio these cases present[52]. While there are more uncertainties related to the performance of natural ecosystems compared to conventional 'grey' infrastructure, the growing evidence base does seem to have played an important role in increasing their uptake, as numerous cases identified in the analysis seem to suggest.

Table 3-3 summarises some of the most commonly identified nature-based approaches that list resilience as a key objective.

TABLE 3-3. APPROACHES TO NATURE-POSITIVE INFRASTRUCTURE WITH RESILIENCE AS KEY CONSIDERATION

SECTOR	COMMON APPROACHES IN THE ANALYSIS	REFERENCE PROJECTS
TRANSPORT	• Bioengineering for landslide and erosion protection • Green bridges, wildlife bridges, ecological corridors and culverts • Wetlands (natural and constructed)	• Meghalaya Integrated Transport Project, India • Ecoduct Wambach, Netherlands • Resilient California State Route 37, USA • Water Management and Flood Prevention – LafargeHolcim, France
ENERGY AND WASTE	• Bioengineering for landslide and erosion protection	• Natural Reclamation and Erosion Control for Onshore Pipelines, Canada
WATER / WASTEWATER	• SuDS and bioretention areas • Mangrove forests • Afforestation, reforestation • Wetlands (natural and constructed) • Catchment management and riparian buffers	• Sun Valley Watershed Multi-Benefit Project, USA • Adaptation of Nicaragua's Water Supplies to Climate Change • Riparian Forest Restoration and River Bank Protection, Greece • Watershed Protection - Companhia de Saneamento Basico De Estado de Sao Paulo, Brazil • Sustainable Watershed Management in Glacial Mountain Ecosystems, Peru
BUILDINGS AND ` PUBLIC SPACES	• Resilient urban design and restoration of waterbodies (lakes, ponds) • Wetlands (natural and constructed) • Green roofs • Afforestation, reforestation, open green space • SuDS	• Nanjing Eco-Island Yangtze River Waterfront, China • eThekwini Municipality Green Roof Pilot Project, South Africa • Bolivia Urban Resilience, Bolivia • Saramacca Canal System Rehabilitation Project, Suriname • Stormwater Green Infrastructure in the Mid-Atlantic, USA
COASTAL	• Coastal restoration, alignment and living shorelines • Dunes and sandy shores • Mangrove forests • Afforestation, reforestation • Wetlands (natural and constructed) • Ecoengineering, vertipooles, habitat tiles • Sea grass restoration • Oyster reef restoration	• Medmerry Managed Coastal Realignment, UK • Marsh Restoration and Replenishment, Little Egg Harbor, New Jersey, USA • Urban Hybrid Dunes, Spain • Mangroves for Coastal Resilience, Philippines • Coastal Embankment Improvement Project - Phase I (CEIP-I), Bangladesh • Wetlands Restoration for Ecosystem and Community Resilience in He'eia, O'ahu, Hawaii • Port of San Diego Coastal Protection, USA • Oyster Reef Building and Restoration for Coastal Protection, USA

Source: AECOM. 2023

3.4 ENVIRONMENTAL, SOCIAL AND ECONOMIC BENEFITS

Other benefits of some of the solutions listed in the Playbook, mainly environmental (in terms of air, soil and water quality) and **socio-economic** (ranging from cultural services, recreation and amenity, to health and well-being, jobs, livelihoods and food, direct return on investment / cost savings) are commonly listed as co-benefits in the examples of projects identified in the analysis, although in some instances some of these can also be principal benefits (most commonly, water quality).

In terms of **environmental benefits**, approaches identified in the analysis describe the application of different solutions for removing pollutants from the air either during or after the project has been completed (interestingly, very few solutions identified have specifically been implemented with the purpose of addressing air pollution) – these rely mainly on trees, scrubs and other type of vegetation (like green roofs and walls). A significant number of examples from the analysis list water quality as a key benefit associated with restoration or construction of wetlands, mangrove planting, sustainable urban drainage systems, afforestation and reforestation, creation or restoration of different waterbodies (lakes, ponds), river restoration, riparian buffers, soil infiltration systems and reed beds, as well as peatland restoration.

When it comes to **social benefits**, virtually all approaches identified in the analysis have social benefits, but in some cases, these are not always explicitly stated (possibly because they are often more difficult to quantify than environmental benefits). There have been examples of projects where a particular solution is implemented primarily with social benefits in mind (especially in urban areas, where creation of new green areas, pocket parks and waterbodies have been driven primarily by concerns for enhancing the quality of life, creating spaces for recreation and amenity, etc) but it is not always clear from some of the projects analysed to what extent specific considerations around gender and social inclusion have driven the selection of a particular solution. Similar issues have been identified in the literature review. For example, a recent report by the World Bank assessed how many of the projects focused on nature-based solutions associated with its lending operations across all regions integrate substantial considerations of gender and social inclusion and found this figure to be only around 65%[53].

A substantial number of examples list important **economic benefits**, ranging from direct impact on local jobs, food provision and livelihoods (especially where an extensive area of forests and mangroves is restored), land value uplift and some form of direct return on investment (ROI) or cost savings. These are all summarised in the Table 3-4 overleaf.

TABLE 3-4. APPROACHES TO NATURE-POSITIVE INFRASTRUCTURE WITH ENVIRONMENTAL, SOCIAL OR ECONOMIC CO-BENEFITS

BENEFIT		COMMON APPROACHES IN THE ANALYSIS	REFERENCE PROJECTS
ENVIRONMENTAL	AIR QUALITY	• Green and 'living' walls • Resilient urban design and restoration of waterbodies (lakes, ponds) • Afforestation, reforestation	• A Green Wall for Kindergarten, Armenia • Green Buildings in Ho Chi Minh City, Vietnam • Prestwich High Street, Bury and Howard Street, Salford, UK
	SOIL QUALITY	• Afforestation, reforestation	• Guizhou Zhengxi Expressway Project, China
	WATER QUALITY	• Wetlands (natural and constructed) • Mangrove forests • Sustainable urban drainage systems (SuDS) and bioretention areas • Afforestation, reforestation • Waterbodies (lakes, ponds) • River restoration and catchment management • Riparian buffers • Soil infiltration system • Sludge treatment reed beds • Peatland restoration	• Development of a Blue-Green City, Australia • Integrated Constructed Wetlands for the Clifton Wastewater Treatment Works, UK • J4M8 Distribution Park, West Lothian, UK • Enhancing Groundwater Supplies and Water Quality By Using Soils for Tertiary Treatment of Wastewater, Israel • Using Daphnia and Algae to Monitoring Water Toxicity and Early Detection of Pollution Surges - Rhine Water Quality Station, Germany • River Restoration – Glaven, UK • Riparian Buffers - Queensland Urban Utilities, Australia • Advanced Wastewater Treatment Through Slow Rate Soil Infiltration System in Lubbock, USA • Sludge Treatment Reed Beds in Mojkovac, Montenegro • Upstream Thinking: A Private-Public Community Multiple Benefits Partnership, UK
SOCIAL	CULTURAL SERVICES	• Bioengineering for landslide and erosion protection • Bio-building materials and 'soft' measures	• Geotextile Bridge Abutments in Veracruz, Mexico • Cambridge Central Mosque, UK
	HEALTH AND WELL-BEING	• Urban and peri-urban agriculture / gardening • Afforestation, reforestation • Open green space • Bio-building materials and 'soft' measures	• Urban Farming (Modeltuin Genk Noord), Belgium • Diama Dam and Addressing Schistosomiasis, Senegal • Beijing Plain Area Afforestation Programme (BPAP), China • The Anandaloy Building, Bangladesh
	RECREATION / AMENITY	• Afforestation, reforestation • Open green space • Resilient urban design and restoration of waterbodies (lakes, ponds) • Sand dunes and shores • Green bridges, wildlife bridges, ecological corridors and culverts • Green roofs • Coastal restoration, realignment, living shorelines	• Pocket Parks: The Greening of Degraded Public Spaces, Nepal • Nanjing Eco-Island Yangtze River Waterfront, China • Urban Hybrid Dunes, Spain • Mile End Green Bridge, UK • Fifth Façade Project Jardin Das Oliveiras, Portugal • Kingsbrook, UK • Medmerry Managed Coastal Realignment, UK
ECONOMIC	JOBS, LIVELIHOODS AND FOOD	• Urban and peri-urban agriculture / gardening • Mangrove forests • Afforestation, reforestation • Catchment management • Oyster reef restoration	• Changmai Urban Farm, Thailand • From Mangrove to Mountain: Building Coastal Resilience in Timor-Leste • Coastal Embankment Improvement Project - Phase I (CEIP-I) • Community-Based Land and Water Management, Sudan • Oyster Reef Building and Restoration for Coastal Protection, USA
	LAND VALUE UPLIFT / DIRECT ROI / COST SAVINGS	• Solar gardens • Afforestation, reforestation • Open green space • Wetlands (natural and constructed) • Riparian buffers • Soil infiltration system • Bioengineering for landslide and erosion protection	• City of Edina Community Solar Garden, USA • Nature-Based Solutions to Reduce Sediment Loads Affecting Hydropower Plant Operation, Indonesia • Constructed Wetland - Anglia Water • Riparian Buffers - Queensland Urban Utilities, Australia • Advanced Wastewater Treatment Through Slow Rate Soil Infiltration System in Lubbock, USA • Natural Reclamation and Erosion Control for Onshore Pipelines, Canada
	TOURISM / OTHER	• Coastal restoration, realignment, living shorelines	• Prins Hendrik Sand Dike, Netherlands

Source: AECOM. 2023

04

SOLUTIONS

As described in the introduction, the aim of this Playbook is to support design and engineering practitioners across the world identify alternative or complementary solutions to traditional "grey" infrastructure during design, construction and operational phases. This section summarises main solutions that were identified in the analysis of project examples, with a reference to some key success factors for their implementation, to help guide practitioners. The solutions are summarised as 'coastal and riverine' and 'inland and urban' for the purpose of this Playbook (although it should be noted that there is an overlap between these). It is also worth noting that this is not an exhaustive list; it mere summarises the solutions where information on the projects has been made publicly available. The intention is for this list is to continue to grow in future iterations of this Playbook, to incorporate new solutions and learning from projects implemented in the interim.

4.1 COASTAL AND RIVERINE SOLUTIONS

4.1.1 MANGROVE FORESTS

SECTOR:
Coastal Protection

KEY BENEFIT:
Resilience

COMMON CO-BENEFITS:
Economic and Biodiversity

Mangrove forest located in the Mida Creek – Malindi. ©Timothy K on Unsplash.

Mangroves, a salt-tolerant type of trees and shrubs found in tropical and subtropical coastal areas, can be used to provide a protective buffer against erosion and coastal storms. While mangroves are commonly used to build coastal resilience, the evidence base collected from the literature and project examples shows that they also have a high carbon sequestration potential, help improve water quality, provide habitats for fish and birds and have an important role to play in providing livelihoods to fishing communities.

Key considerations: while there is a high uptake of approaches focused on mangroves conservation or restoration, multiple project examples reviewed underline the importance of community engagement and buy-in as a key success factor for their effective restoration and conservation.

4.1.2 CORAL REEF RESTORATION

Coral reef habitats. ©AECOM.

SECTOR: Coastal Protection

KEY BENEFIT: Resilience

COMMON CO-BENEFITS: Economic and Biodiversity

Coral reefs, a highly diverse underwater ecosystems that can be natural or engineered, provide wave attenuation benefits comparable to certain types of grey infrastructure (like breakwaters). They provide a critical barrier to waves and storms and provide habitats to an estimated quarter of all marine species (most notably, fish) as well as jobs, food and livelihoods for coastal communities. Restoration of coral reef, which can include a wide range of actions, from growing and planting nursery-grown corals onto reefs, to ensuring marine habitats are suitable for coral growth, can bring substantial biodiversity and income generation as co-benefits.

Key considerations: multiple project examples, as well as literature review, indicate that the integration of reef restoration with restoration of other marine habitats (such as mangroves and seagrass) is critical to maximise positive outcomes.

4.1.3 DUNES AND SANDY BEACHES

Sand dunes in California. © David Lloyd, AECOM.

SECTOR: Coastal Protection

KEY BENEFIT: Resilience

COMMON CO-BENEFITS: Social and Biodiversity

Dunes and sandy beaches, form a critical passage of sediment between ocean and land and represent the first line of coastal defence against flooding and coastal erosion. A number of projects identified in the analysis focus on replenishing beaches to artificially widen them (using sand from some outside source) and restoring dunes (including the vegetation that provides greater stability and allows them to expand), often in combination to help build additional resilience.

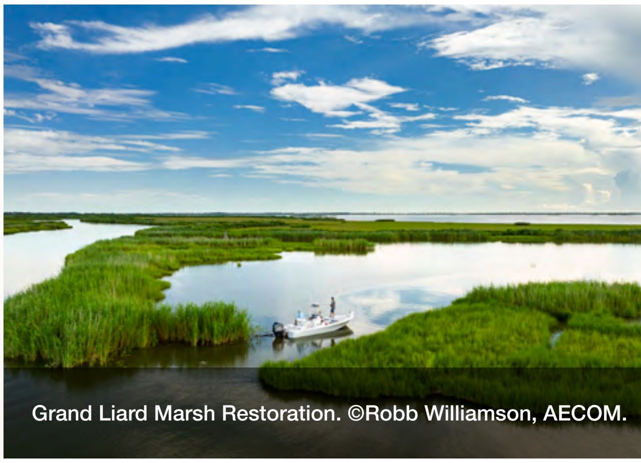
Key considerations: examples identified in the analysis and the literature review stress the importance of proper planning and modelling as crucial components of success, to reduce the need for additional rounds of (costly) replenishment of sand that may be required in the future. Restoring or expanding dunes and sand beaches, in addition to their resilience benefits, has also been implemented to restore critical habitats and provide additional areas for recreation and tourism.

4.1.4 SALT MARSH RESTORATION

SECTOR:
Coastal Protection

KEY BENEFIT:
Resilience

COMMON CO-BENEFITS:
Biodiversity



Grand Liard Marsh Restoration. ©Robb Williamson, AECOM.

Salt Marsh, highly biodiverse, salt-tolerant coastal ecosystems, are typically found in estuaries all over the world. By capturing and storing sediment, they grow and expand over time, but have been threatened by poor coastal management practices. Like other coastal ecosystems, salt marshes provide critical protection against coastal hazards, but also represent a significant carbon sink and provide a breeding ground and refuge to marine species. They are vital habitats for breeding and feeding of many migratory birds, as well as for fish and aquatic invertebrate species. A substantial number of project examples have been identified in the analysis that suggest significant benefits of salt marsh restoration for coastal resilience and local habitats.

Key considerations: as with other examples, an integrated approach to salt marsh restoration by combining it with restoration of other coastal habitats (e.g. oyster reef or seagrass which could act as breakwater) could maximise the benefits of intervention.

4.1.5 SEAGRASS RESTORATION

SECTOR:
Coastal Protection

KEY BENEFIT:
Carbon

COMMON CO-BENEFITS:
Biodiversity

Seagrass habitat. ©Joe Whalen, Unsplash.

Seagrass meadows, coastal ecosystems that absorb nutrients from water through their root system, are biodiversity hotspots for marine species and a huge pool of blue carbon. Some of the project examples identified in the analysis focus either on their restoration and expansion to increase carbon sequestration (and / or offset carbon emitted elsewhere) or to preserve or restore vital habitats they provide for marine species.

Key considerations: seagrass restoration approaches should aim to maximise genetic diversity in new populations to increase the survival rates and adaptive response to climate change.

4.1.6 SOIL INFILTRATION SYSTEMS

Rouse hill landscape restoration.
©Michael Clarkson, AECOM.

SECTOR:
Water / Wastewater

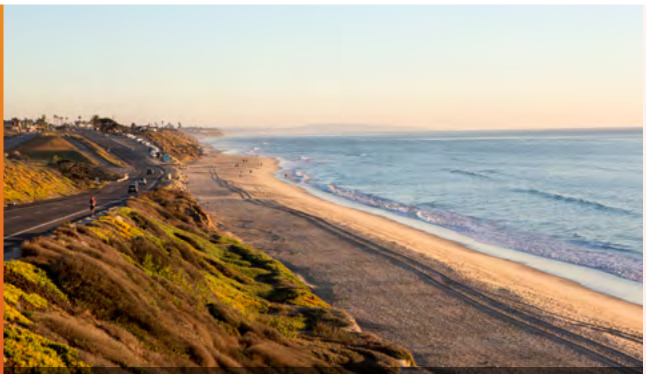
KEY BENEFIT:
Environmental

COMMON CO-BENEFITS:
Economic

Slow or rapid infiltration is one of several simple, low-cost techniques for wastewater treatment that relies on soil ecosystems. In the project examples identified during the analysis, it has been used for treating both municipal and industrial wastewater. The advantage of this method is that it is applicable in a variety of climates and site locations. The main benefit is improved water quality at a comparatively lower cost.

Key considerations: this approach typically requires a long-term commitment of land (sometimes significant).

4.1.7 COASTAL RESTORATION AND ALIGNMENT, LIVING SHORELINES



Regional beach sand replenishment project.
©David Lloyd, AECOM.

SECTOR:
Coastal Protection

KEY BENEFIT:
Resilience

COMMON CO-BENEFITS:
Economic and Biodiversity

Coastal restoration is an umbrella term that refers to a variety of larger-scale techniques for restoring the protective functions of coastal ecosystems, which could include, for example, a simultaneous restoration of salt marsh, mudflat, grassland and other habitats, beach nourishment and coastal realignment to reduce the risk of coastal flooding and erosion. Examples identified in the analysis largely focus on coastal protection (including of water, wastewater and transport infrastructure) and habitat creation, with social and economic co-benefits including jobs, livelihoods, food and additional spaces for amenity and recreation.

Living shorelines, a broad term used to describe various techniques for stabilisation of the coastal edge via the use of natural native materials (sand, rock, oysters plants etc.), are often used as an alternative to, or addition to, engineered coastal infrastructure that causes erosion (like seawalls) to buffer shores against storms and simultaneously provide habitats for wildlife. Often used in combination with the restoration of other coastal ecosystems (reefs, salt marshes, etc), living shorelines can be effective in reducing erosion, contributing to local biodiversity and strengthening coastal resilience.

Key considerations: as many of the examples indicate, no shoreline stabilisation technique (neither 'hard' nor living shoreline) can be guaranteed to prevent the loss of infrastructure during extreme weather events, but the suitability of each technique will greatly depend on local conditions.

4.1.8 ECO-ENGINEERING, VERTIPOOLES, HABITAT TILES

SECTOR:
Coastal Protection

KEY BENEFIT:
Biodiversity

COMMON CO-BENEFITS:
Carbon, Resilience


Virginia Point Breakwater. ©Robb Williamson, AECOM.

Eco-engineering, in the context of this report, is used to describe either a hybrid infrastructure solution that combines traditional engineering techniques with some natural element, or an engineered solution with a largely environmental objective. Commonly applied in coastal settings, eco-engineering approaches are typically concerned with improving coastal resilience with a substantially lower carbon footprint and with lessened pressure on local habitats – examples could range from eco-concrete, ecological seawalls, vertipooles and habitat tiles and some experimental approaches.

Habitat tiles and vertipooles[54] have been used to address a critical weakness of grey coastal infrastructure – its lack of suitability as a passage for marine species (including oysters that improve water quality) which in turn weakens the coastal ecosystem. Habitat tiles and vertipooles address this issue, allowing colonisation by different organisms and supporting food networks. In another example, oyster nursery chambers were introduced on wind turbines to create new habitats and attract other species.

Key considerations: is it worth noting that quite a few project examples identified to date are experimental and that there is a need for the evidence base to grow furhter to be able to better assess the impact of eco-engineering approaches on habitats and biodiversity.

4.1.9 RIVER RESTORATION AND CATCHMENT MANAGEMENT

SECTOR:
Water / Wastewater

KEY BENEFIT:
Environmental

COMMON CO-BENEFITS:
Resilience, Biodiversity

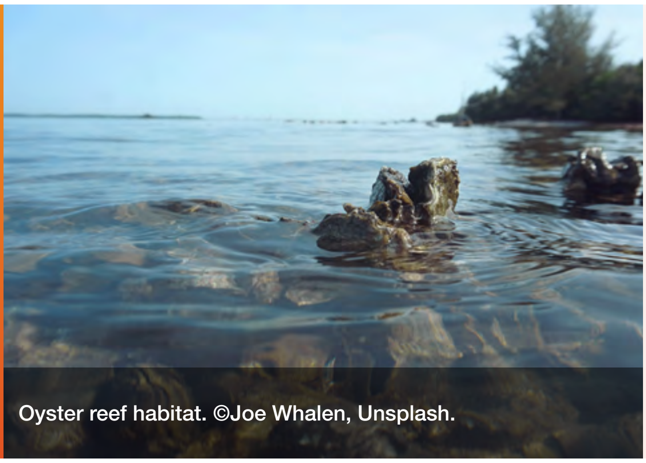

River restoration scheme. ©Robb Williamson, AECOM.

River restoration encompasses several strategies and techniques to restore the natural functions of rivers, including restoring natural river flow, in-stream enhancement, dam removals, etc. In many of the examples identified in the analysis, river restoration has primarily been undertaken to restore native habitats and reverse biodiversity loss, or improve water quality, however, multiple social benefits have also been identified, including the creation of additional spaces for amenity, recreation, etc.

Key considerations: many examples note that river restoration projects require particularly close monitoring in the first few years.

Technical Partner: AECOM

4.1.10 OYSTER REEF RESTORATION



Oyster reef habitat. ©Joe Whalen, Unsplash.

SECTOR:
Coastal Protection

KEY BENEFIT:
Resilience

COMMON CO-BENEFITS:
Economic and Biodiversity

Oyster reefs, a colony of (living and dead) oysters formed on estuaries, play an important role in coastal resilience by reducing energy and height of waves. Their three-dimensional structure also provides high-quality habitats for many organisms as they support complex food networks. While coastal resilience has been identified as the primary objective of approaches that rely on oyster reef restoration, their restoration also brings important co-benefits in terms of provision of habitats and enhanced production of fish and invertebrates, as well as removal of excess nutrients from coastal ecosystems.

Key considerations: as with other nature-based approaches, yielding long-term benefits of oyster reef restoration can take time (in some cases, decades).

4.1.11 RIPARIAN BUFFERS

Boardman river ecosystem restoration.
©Rob Williamson, AECOM.

SECTOR:
Water / Wastewater

KEY BENEFIT:
Environmental

COMMON CO-BENEFITS:
Resilience, Biodiversity

Riparian buffers refer to a strip of vegetation (mainly composed of forests and shrubs) adjacent to a waterbody (river, stream, lake, wetland) that is planted to intercept pollutants and improve water quality and stabilise stream banks. Riparian buffers are usually planted with native species across several zones to increase their effectiveness and they require very little maintenance to perform their function. In addition to their resilience and water quality benefits, riparian buffers provide important habitats to both aquatic and terrestrial species.

Key considerations: a review of the examples suggests that key design decisions related to this solution will have to be determined depending desired widlife, water and stabilisation benefits.

4.1.12 SLUDGE TREATMENT REED BEDS

SECTOR:
Water / Wastewater

KEY BENEFIT:
Environmental

COMMON CO-BENEFITS:
Economic


Melbourne wetlands. ©AECOM.

Sludge treatment reed beds, are a type of constructed wetland that can be used for effective treatment, storage and disposal of sludge. They are a low-energy, low-cost way of processing sludge, developed from the planting of reeds into a pre-existing sludge drying beds. Their principal benefits are environmental and economic, as their construction requires only a fraction of the cost associated with conventional sludge treatment methods.

Key considerations: as only a few case studies using this solution that have a considerable level of detail have been identified, there is a need to build stronger evidence base with more projects.

4.2 INLAND AND URBAN SOLUTIONS

4.2.1 PEATLAND RESTORATION

SECTOR:
Water / Wastewater

KEY BENEFIT:
Environmental

COMMON CO-BENEFITS:
Carbon, Biodiversity


Peatland at a windfarm. ©Rob Williamson, AECOM.

Peatlands are terrestrial wetland ecosystems in which moisture prevents plants from decomposing entirely. As a result, organic material accumulated exceeds that which is decomposed, resulting in the overall accumulation of peat. Found on every continent and across all climatic zones, peatlands are incredibly rich in carbon and sequester more carbon than any other terrestrial ecosystem. However, this carbon is released when peatland is drained or degraded (mainly by agriculture, burning, mining for fuel and commercial tree planting). The restoration process tends to focus on raising the water table, blocking drains and repairing the vegetation layer.

Key considerations: the project examples from the analysis suggest that peatland restoration may be of particular interest to water companies as it affects water quality and infrastructure developers looking to offset carbon and restore habitats.

Technical Partner: AECOM

4.2.2 WETLANDS (NATURAL AND CONSTRUCTED)

Grand Cui Wetlands. © AECOM.

SECTOR:
Water / Wastewater

KEY BENEFIT:
Environmental

COMMON CO-BENEFITS:
Resilience, Biodiversity

Natural wetlands, or sites where water covers the soil or is present near the surface of the soil all year round, vary widely in type, but can generally be classified as coastal (tidal) and inland wetlands. Irrespective of their type, wetlands provide important habitats for plants, mammals and invertebrates, sequester carbon and can reduce the risk of flooding and improve water quality. Depending on where they are located, wetlands also bring important social benefits, including providing spaces for recreation, amenity and can drive up tourism. The analysis identified an extensive number of case studies focused on restoration or rehabilitation (repairing some functions) of wetlands worldwide, mainly for biodiversity, carbon or water quality purposes.

Constructed wetlands (see also sludge treatment reed beds) are designed to rely on vegetation and soil microbiology to treat wastewater and stormwater runoff. They may have limited applicability to highly polluted waters with a significant presence of highly toxic substances.

The analysis identified an extensive number of projects that deployed constructed wetlands as an alternative to otherwise costly water treatment processes, with documented benefits also including new habitat creation, flood risk reduction and other benefits.

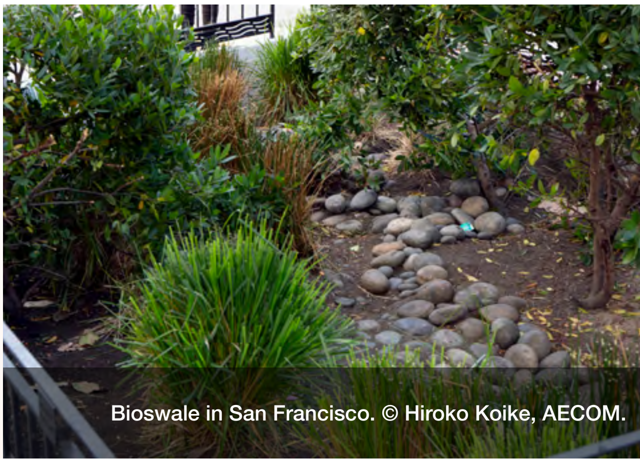
Key considerations: As there are many degradation factors and stressors on natural and constructed wetlands, ranging from encroachment, contamination and invasive species, regular monitoring and maintenance will be a particularly important factor in ensuring the success of the implementation.

4.2.3 SUSTAINABLE URBAN DRAINAGE SYSTEMS (SUDS), BIORETENTION AREAS

SECTOR:
Buidlings and Public Spaces

KEY BENEFIT:
Resilience

COMMON CO-BENEFITS:
Biodiversity, Environmental



Bioswale in San Francisco. © Hiroko Koike, AECOM.

Sustainable urban drainage systems (SuDS) provide an alternative to the direct channelling of surface water through a networked system of pipes and sewers. Based on their design and objective, SuDS can convey surface water, slow down and store runoff, or allow water to soak into the ground, etc. SuDS can range in size considerably depending on the area they are meant to cover and are often used as an umbrella term for everything from retention ponds, green roofs, swales, to permeable pavement. The analysis identified a substantial number of examples worldwide that use some form of SuDS (even when it is not necessarily referred to as such) to improve water quality, reduce the risk of flooding in urban areas and deliver biodiversity benefits.

Bioretention areas, used to describe shallow landscaped depressions that are used to manage and treat runoff, are widely used for water treatment and to improve aesthetic value of sites. The analysis identified a number of examples applied all over the world, across multiple scales (from the building-level to neighbourhoods to large urban scales).

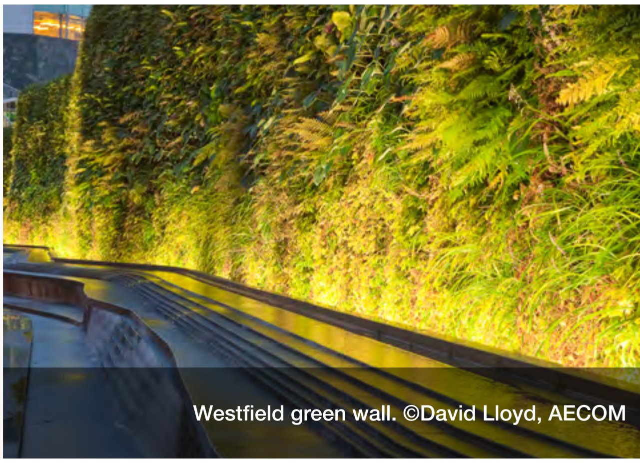
Key considerations: While the number of examples suggest their relatively high level of effectiveness, this subset of solutions requires intensive and regular maintenance.

4.2.4 GREEN AND 'LIVING' WALLS

SECTOR:
Buidlings and Public Spaces

KEY BENEFIT:
Resilience

COMMON CO-BENEFITS:
Biodiversity



Westfield green wall. ©David Lloyd, AECOM

Green walls (also known as living walls) incorporate plants that are inserted into a growing medium and then placed on building walls. While many of the examples identified in the analysis seem to suggest that aesthetic reasons are commonly behind the decision to integrate green walls into building design, temperature regulation and biodiversity are also important drivers, as well as air quality regulation.

Key considerations: as with the other types of biophilic design, the selection of species and maintenance requirements will be some of the key considerations for successful implementation.

4.2.5 RESILIENT URBAN DESIGN AND RESTORATION OF WATERBODIES (LAKES, PONDS)

Suzhou jinji lake. ©Xuetao Znang, AECOM.

SECTOR:
Buidlings and Public Spaces

KEY BENEFIT:
Resilience

COMMON CO-BENEFITS:
Biodiversity, Environmental

Resilient urban design, in the context of this report, refers to the approaches identified in the analysis which combine multiple SuDS over a large area, or combine SuDS likes swales with different restoration approaches (e.g. afforestation, green spaces, wetland restoration, etc).

Lakes and ponds provide vital ecosystem services including fresh water, habitat for fish, help regulate microclimate, purify water and provide recreational and cultural opportunities. The examples that have been identified in the project analysis focus on the restoration and rehabilitation of waterbodies for the purpose of reducing urban temperatures, restoring or creating habitats and sequestering carbon.

Key considerations: as with many other solutions identified, the aspect of community involvement has been a recurring theme in identified case studies.

4.2.6 SOLAR GARDENS

Solar panels. ©Robb Williamson, AECOM.

SECTOR:
Energy

KEY BENEFIT:
Social

COMMON CO-BENEFITS:
Biodiversity

Solar gardens are gaining traction in areas with land constraints for the expansion of renewable energy infrastructure and are the energy equivalent of urban gardens where food is grown on shared plots of land. Solar panels, connected directly to the electricity distribution grid and then distributed to homes and businesses in the community, can also be designed to include a range of habitats to deliver biodiversity or other co-benefits.

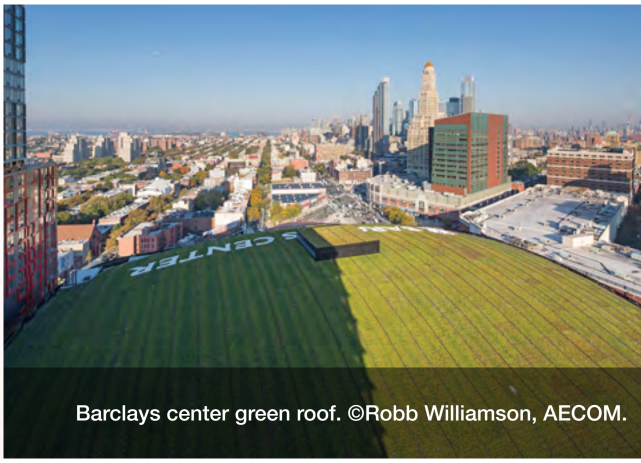
Key considerations: While not all solar gardens necessarily integrate habitat restoration, several examples identified in the analysis highlight the significant contribution that well-designed and managed solar gardens that enable wildflowers and pollinators to thrive can have on local biodiversity, so it is essential to continue learning from best practices in this space.

4.2.7 GREEN ROOFS

SECTOR:
Buidlings and Public Spaces

KEY BENEFIT:
Resilience

COMMON CO-BENEFITS:
Biodiversity, Economic



Barclays center green roof. ©Robb Williamson, AECOM.

Green roofs, a type of vegetated roof system, can be extensive, semi-intensive and intensive and have been increasingly used in urban areas to reduce the risk of flooding, regulate micro-climate and create habitats. Commonly referred to as the key element of biophilic design, green roofs are among the most popular type of hybrid infrastructure and examples identified in the analysis suggests that they are used widely across all building types (residential, commercial, public, etc). More recently, a combination of rooftop solar with green elements (also known as 'bio-solar roof') has become increasingly common as research suggests that green elements can increase the energy output and efficiency of solar panels.

Key considerations: While the structural requirements are among the most important aspects to consider, the level of maintenance required will depend on the type of green roof and location so this should also be taken into account as an early consideration.

4.2.8 AFFORESTATION, REFORESTATION AND OPEN GREEN SPACE

SECTOR:
Buidlings and Public Spaces

KEY BENEFIT:
Carbon

COMMON CO-BENEFITS:
Biodiversity, Resilience

Reforestation. © AECOM.

Afforestation, reforestation and all types of forest restoration and management are the most common type of nature-positive approaches identified in the project examples. Ranging from planting urban trees and forests to regulate micro-climate in cities, restoration of forested watersheds in tropical areas to increase the availability and supply of water, to forest compensation schemes, there is an increased emphasis on afforestation and reforestation to deliver a wide range of benefits, from carbon sequestration, flood risk reduction, temperature regulation, improved water and air quality, creation of spaces for recreation and amenities and others.

Key considerations: while not of all the approaches tried out are necessarily successful (usual reasons for failure include planting invasive species, poor planning and inappropriate location), if designed and implemented correctly, their benefits can be substantial.

4.2.9 REWILDING, GRASSLANDS AND MEADOWS

Rewilding centre. © Chris Coupland, AECOM.

SECTOR:
Buidlings and Public Spaces

KEY BENEFIT:
Carbon

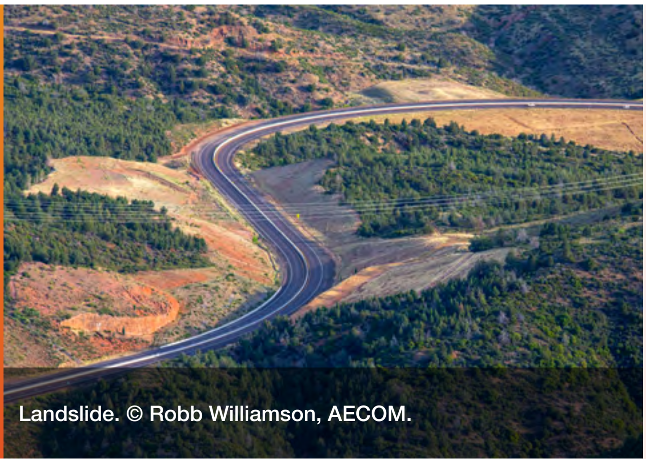
COMMON CO-BENEFITS:
Biodiversity, Economic

Rewilding is another concept and practice that has been gaining traction recently and in the way it has been used in examples identified in the analysis, it refers to the practice of restoring an area back to its 'original' state. It could either take an 'active' form (e.g. reintroducting lost species) or 'passive' (e.g. natural regeneration). It has been increasingly popular across the UK, on private estates, public spaces, around solar and wind farms, but there are also large-scale dedicated initiatives that aim to rewild large areas of land where ecosystems have been modified to such an extent that most of the native biodiversity is gone.

Grasslands and meadows are often targeted for restoration (or rewilding) in several project examples identified, with benefits including increased carbon sequestration and biodiversity.

Key considerations: the notion of 'rewilding' can cause some confusion and is open to misinterpretation, so there is a need for greater clarity on different techniques that are increasingly being used.

4.2.10 BIOENGINEERING FOR LANDSLIDE AND EROSION PROTECTION



Landslide. © Robb Williamson, AECOM.

SECTOR:
Transport

KEY BENEFIT:
Resilience

COMMON CO-BENEFITS:
Economic

Bioengineering refers to the use of vegetation (both live and dead plants) to stabilise the soil and prevent erosion and landslides. Plants that are used will depend on the slope, but will typically have strong fibrous roots and will often be small enough to be planted in closely packed lines. The analysis identified a substantial number of project examples (especially in the transport sector) that rely on bioengineering.

Key considerations: it should be noted that this solution may not be applicable in areas where the depth of slope failure is too high, as poor predictability of growth means its strength cannot be guaranteed in the same way. It usually is substantially less costly than alternative engineering approaches and can bring additional benefits (e.g. habitat creation).

4.2.11 GREEN BRIDGES, WILDLIFE BRIDGES, ECOLOGICAL CORRIDORS AND CULVERTS

SECTOR:
Transport

KEY BENEFIT:
Biodiversity

COMMON CO-BENEFITS:
Resilience


Route 138 wildlife crossing. © Robb Williamson, AECOM.

Green bridges, wildlife bridges and ecological corridors in the context of this report refer to all types of roads, bridges and passages in general whose design and function have been particularly made with biodiversity and climate in mind. The analysis identified a significant number of project examples across the world where biodiversity and climate change considerations clearly shaped the design and ultimate construction of a bridge, road, or other piece of infrastructure.

Culverts would also fall under this category of solutions. All of these types of wildlife crossings and ecological corridors have shown to have significant benefits for habitat connectivity and, depending on the design, flood risk reduction.

Key considerations: several examples note the importance of biodiversity monitoring (e.g. via camera traps) for monitoring the effectiveness of these structures.

4.2.12 URBAN AND PERI-URBAN AGRICULTURE, URBAN GARDENS

SECTOR:
Buidlings and Public Spaces

KEY BENEFIT:
Economic

COMMON CO-BENEFITS:
Social, Resilience


Urban farm in Cape Town. © Anaya Katlego, AECOM.

Urban and peri-urban agriculture include any practices (ranging from aquaculture, livestock, plants to gardening) that yield food through agricultural processes taking place on urban land, often as part of the strategy for building the resilience of the food supply, but also to promote social cohesion, or in some cases even being used as open areas that can serve as flood buffers. The most common type identified in the analysis are community gardens, or conversion of abandoned land for peri-urban agriculture. The principal benefits are economic – jobs, livelihoods and well-being, but can also include biodiversity and flood risk reduction.

Key considerations: some of the key factors affecting the uptake of this solution include access and affordability of urban spaces, as welll as the availability of (trained) labour.

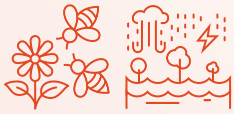
Technical Partner: AECOM

4.2.13 BIO-BUILDING MATERIALS AND 'SOFT' MEASURES

Timber frame building. ©AECOM.

SECTOR:
Buidlings and Public Spaces

KEY BENEFIT:
Carbon



COMMON CO-BENEFITS:
Biodiversity, Resilience

Bio-building materials, ranging from timber, clay, earth, hemp, rock and bamboo, are increasingly used in the construction of all types of buildings. The most common examples identified in the analysis of existing projects include bamboo and timber-based residential and non-residential buildings, where the main benefit includes reduction of embodied carbon.

Across other sectors, construction of breakwaters and other coastal structures using local materials like rock and stones have been identified as low-carbon options that also have significant biodiversity benefits.

'Soft' measures, in the context of this report, have been included to showcase examples of projects that have done extensive preparatory work, studies, reports and assessment of biodiversity value on site and have shaped the design to ensure positive impact on biodiversity would occur during the works (see also Appendix B). As the focus of this report is almost entirely on actual physical measures, only a small number of projects incorporating 'soft' measures have been included in the analysis.

Key considerations: while bio-based building materials are becoming increasingly common in the industry, there are nevertheless important sustainability considerations when it comes to sourcing some of these materials.

4.3 ADDITIONAL RESOURCES

The table below lists some of the existing design guides and additional resources that may be a useful next step for readers and infrastructure practitioners. The list is not particularly comprehensive and there are many other sources out there, but it is likely to be a useful starting point for practitioners interested in this topic.

TABLE 4-1. ADDITIONAL REFERENCES

SECTOR	DOCUMENT
TRANSPORT	• Landscape Institute. 2015. Technical Guidance Note on Green Bridges. London. Available at: https://landscapewpstorage01.blob.core.windows.net/www-landscapeinstitute-org/2018/01/tgn-09-2015-green-bridges.pdf • Inter-American Development Bank. 2016. Natural Capital and Roads – Managing Dependencies and Impacts on Ecosystem Services for Sustainable Road Investments. Washington. Available at: https://publications.iadb.org/publications/english/viewer/Natural-Capital-and-Roads-Managing-Dependencies-and-Impacts-on-Ecosystem-Services-for-Sustainable-Road-Investments.pdf • ADB. 2019. Green Infrastructure Design for Transport Projects: A Roadmap to Protecting Asia's Wildlife Biodiversity. Manilla. Available at: https://www.adb.org/publications/green-transport-projects-asia-wildlife • ADB. 2020. Bioengineering for Green Infrastructure. Manilla. Available at: https://www.adb.org/publications/bioengineering-green-infrastructure
ENERGY	• IUCN. 2021. Mitigating Biodiversity Impact Associated with Solar and Wind Energy Development. Gland. Available at: https://portals.iucn.org/library/sites/library/files/documents/2021-004-En.pdf • WWF and Biodiversity Consultancy. 2023. Nature-Safe Energy: Linking Energy and Nature to Tackle the Climate and Biodiversity Crises. Gland. Available at: https://wwfint.awsassets.panda.org/downloads/cleanaction_nature_safe_energy_report.pdf
WATER AND WASTEWATER	• World Bank. 2021. A Catalogue of Nature-Based Solutions for Urban Resilience. Washington. Available at: https://documents1.worldbank.org/curated/en/502101636360985715/pdf/A-Catalogue-of-Nature-based-Solutions-for-Urban-Resilience.pdf • World Bank. 2023. Assessing the Benefits and Costs of Nature-Based Solutions for Climate Resilience: A Guideline for Project Developers. Washington. Available at: https://openknowledge.worldbank.org/entities/publication/9ed5cb4b-78dc-42a4-b914-23d71cef24a2 • Institute Catala de Recerca de l'Aigua (ICRA). 2021. NbS List. Available at: https://snapp.icra.cat/nbslist
BUILDINGS AND ` PUBLIC SPACES	• Green-Grey Community of Practice. 2020. Practical Guide to Implementing Green-Grey Infrastructure. Gland. Available at: https://www.conservation.org/docs/default-source/publication-pdfs/ci-green-gray-practical-guide-v08.pdf • Nature-Based Solutions Initiative Case Studies. Available at: https://casestudies.naturebasedsolutionsinitiative.org/ • World Bank. 2023. Integrating Gender and Social Inclusion in Nature-Based Solutions: Guidance Note. Washington. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099060123165042304/p1765160ae46bb0aa0aefa0235601f9d0c6
COASTAL INFRASTRUCTURE	• US Department of Transportation – Federal Highway Administration. 2018. White Paper: Nature-Based Solutions for Coastal Highway Resilience. Washington. Available at: https://media.coastalresilience.org/SC/FHA_Coastal_Highway_Resilience.pdf • Environment Agency. 2021. Saltmarsh Restoration Handbook. Bristol. Available at: https://catchmentbasedapproach.org/wp-content/uploads/2021/10/Saltmarsh_Restoration_Handbook_FINAL_20210311.pdf • Environment Agency. 2021. Seagrass Restoration Handbook. Bristol. Available at: https://catchmentbasedapproach.org/wp-content/uploads/2021/10/ZSL00168-Seagrass-Restoration-Handbook_20211108.pdf • Environment Agency. 2021. European Native Oyster Habitat Restoration Monitoring Handbook. Bristol. Available at: https://nativeoysternetwork.org/wp-content/uploads/sites/27/2021/11/European%20Native%20Oyster%20Habitat%20Monitoring%20Handbook_WEB_Final.pdf • McKinsey. 2022. Blue Carbon: The Potential of Coastal and Oceanic Climate Action. New York. Available at: https://www.mckinsey.com/capabilities/sustainability/our-insights/blue-carbon-the-potential-of-coastal-and-oceanic-climate-action • US Army Corps. 2021. Engineering with Nature Atlas. Available at: https://ewn.erdc.dren.mil/atlas-series/volume/engineering-with-nature-an-atlas-volume-2/

Source: AECOM. 2023

APPENDIX A CASE STUDIES:

PROJECTS

As noted in the introduction, case studies were identified to highlight some of the examples of the solutions covered in the Playbook, to show how some of these have been implemented in practice. This appendix explores eight projects implemented within sectors of transport, energy, waste and wastewater, buildings and public spaces and coastal protection. This is not an exhaustive list of the work that has been undertaken internationally and simply aims to highlight some solutions and projects that have been carried out to support their replication or enhancement in other settings. Additional examples will be included in this section in future iterations of this Playbook.

A.1 TRANSPORT

I) ACTIONS TO PRESERVE WILDLIFE, FOREST AND COMMUNITIES ALONGSIDE NEW EAST COAST RAIL LINK IN MALAYSIA

SECTOR	TYPOLOGY
TRANSPORT	INLAND ROAD AND RAIL INFRASTRUCTURE

PROJECT	DELIVERY ENTITY	CLIENT	LOCATION
Environmental and Social Safeguards for the East Coast Rail Link (ECRL)	Aurecon and ERE Consulting Group (acquired by Aurecon)	Malaysia Rail Link	Malaysia

SHORT DESCRIPTION

East Coast Rail Link is a 640km railway connecting different parts of the east coast region with the west coast region in Malaysia. It includes 20 stations, including 14 passenger stations, five combined passenger and freight stations and one freight station. The project balanced environmental considerations, economic costs, social impact and engineering constraints and integrated 20 wildlife crossings to strengthen habitat connectivity between different areas where new rail infrastructure was constructed.

PROJECT BENEFITS

KEY BENEFIT(S) OF THE PROJECT

BIODIVERSITY	The project aims to conserve biodiversity and ensure habitat connectivity by creating 20 wildlife crossings. The project design was optimised over a period of three years with inputs from the public and non-governmental organisations and this led to 90% less forest loss compared with the original design, saving almost 2,000 hectares of forest. A wildlife management plan has been put in place to safeguard wildlife during construction.
RESILIENCE	The design of the railway tracks considered climate change and flood avoidance as a major component of the project. The team designed the track based on a one-in-a-hundred-year flood possibility and factored in appropriate solutions.

CO-BENEFIT(S) OF THE PROJECT

CARBON	N/A[55]
ENVIRONMENTAL	The project followed Aurecon's 'Avoid, Tunnel, Mitigate' design philosophy. This means that as much as possible, the project avoided having the railway track cut through sensitive or large portions of forest by realigning the track design. If that was not feasible, the team proposed tunnels to bypass the area subject to local terrain. The last resort has been to mitigate impact by using wildlife crossings to facilitate wildlife movement. The project is also protecting, restoring and promoting sustainable use of forests and water systems.
SOCIAL	This project reduces inequality by bridging the economic gap between the west and east coast of the Malaysian peninsula and by building sustainable communities.
ECONOMIC	The rail link will reduce travel time along the east coast of the Malaysian peninsula from an eight to 10-hour journey by road, to four hours by rail, thereby spurring economic development with improved connectivity.

SOLUTIONS

As the scale of the ECRL project generated significant public attention, it was important to address legitimate concerns about its impact on Malaysia's forest ecosystems and rich wildlife. Aurecon and ERE Consulting Group were appointed to undertake the environmental and social impact assessment to optimise railway alignment to conserve important habitats and minimise disruption to local communities. The many engagements with non-governmental organisations led to significant changes in the project alignment and design. The alignment was adjusted many times and the multiple design changes were made to facilitate wildlife crossings as well as to protect key forest habitats. The alignment of the railway was ultimate optimised to achieve 90 percent less forest loss (compared to the original design of the railway) and the consultant team worked to construct multiple tunnels and wildlife crossings as part of the project.

FINANCIAL SOURCE	SCALE	ECOSYSTEM SERVICES ASSESSMENT	CLIMATE CHANGE RISK ASSESSMENT
Combination of funds from the Malaysian government and China EXIM Bank	Development / Project	No	No

SOURCES OF ADDITIONAL INFORMATION

- https://www.aurecongroup.com/projects/government/east-coast-rail-link-malaysia

II) CATCHMENT-SCALE GREEN AND BLUE INFRASTRUCTURE TO CONNECT HABITATS SURROUNDING A MAJOR ROAD IN CORNWALL, UK

SECTOR	TYPOLOGY
TRANSPORT	INLAND ROAD AND RAIL INFRASTRUCTURE

PROJECT	DELIVERY ENTITY	CLIENT	LOCATION
A30 Keyn Glas, Green Ribs	Arup	National Highways[56]	UK

SHORT DESCRIPTION

Keyn Glas is a landscape scheme of fifteen integrated environmental enhancement projects on farmland either side of the A30 road in Cornwall, UK. It is funded by the UK's National Highways' Environmental Designated Fund. Green Ribs constitutes six of the fifteen Key Glas projects, delivering green and blue infrastructure across a large area of farmland extending up to 3km either side of the A30 road. The first tranche (Phase 1) of the work was completed in March 2020. It resulted in planting of 13,000 trees in the creation and restoration of large areas of woodland and five traditional orchards, the creation of wetlands and four new pond habitats, as well as the restoration of 2km of traditional Cornish hedgerows and several ha of species rich grasslands. The project is a great example of how upgrading of inland road infrastructure can be used as a catalyst to deliver wider environmental benefits by transforming the surrounding landscape. Delivery of Phase 2 of Green Ribs started in winter 2022 and is underway at the time of writing.

PROJECT BENEFITS

KEY BENEFIT(S) OF THE PROJECT

BIODIVERSITY	Phase 1 comprising three of the six Green Ribs projects has successfully connected 32 habitat areas across 9 farms and helped across habitat severance from the A30 road. Using DEFRA's Biodiversity Calculator[57], it was calculated the delivered works will result in a net gain of biodiversity of 97% for habitat units and 242% for hedgerow units. The impact of these gains will be long-term as plants and animals grow and populate across the landscape.

CO-BENEFIT(S) OF THE PROJECT

CARBON	The soft landscape interventions were designed to be inherently low carbon. Over time as they establish the works will become carbon positive. The estimated carbon benefits from tree planting delivered in Phase 1 alone, will amount to ~10 tCO_2 sequestered per annum in perpetuity.
ENVIRONMENTAL	This scheme features natural flood management plan, which aims to attenuate and slow down stormwater runoff. The measures will capture and reduce runoff of agricultural silts and will prevent pollutants from entering watercourses. Trees planted close to the A30 as part of the project are also purported to tackle air pollution by intercepting airborne vehicle pollutants.
RESILIENCE	Natural flood management measures will help to reduce the risk of flooding. By roughening the texture of the land, making it 'spongier' and the vegetation will hold water in the landscape. Additionally, native species of flora, that are more resilient to extreme weather conditions, were selected to ensure long-term sustainability of the scheme.
SOCIAL	The scheme was designed in a way to complement existing agricultural practices and enhance farm assets for local landowners and communities. In exchange for hosting the interventions on their land, farmers and landowners signed 10-year management, committing them to look allowing National Highways access for monitoring and maintenance. More broadly, the scheme will result in creation of richer, more diverse and resilient ecosystems, that are expected to bring significant amenity benefits to local communities and visitors to central Cornwall.
ECONOMIC	The cost/benefit ratio of these projects was measured at several gateways during the design and construction stages. The tools used were National Highways' own Environmental Appraisal Tools[58], designed to appraise linear transport infrastructure projects. To meaningfully measure the benefits of these varied environmental projects, the tools had to be adapted and used in an innovative way. This approach was based on clear assumptions agreed in detail with the National Highways Environmental Team and Designated Funds Team. All the Keyn Glas projects offered good value for money with positive cost/benefit scores.

SOLUTIONS

The Green Ribs extend up to 3km out from the A30 - going beyond standard highway mitigation, which is normally confined to the highways soft estate. The interventions in each Green Rib connect core habitat areas and create landscape corridors through planting of woodland and orchards, creation of grassland and meadows, restoring ponds and wet habitats and hedgerows. These projects will leave a legacy of a more beautiful, biodiverse, productive and resilient landscape for the long-term benefit of local people and nature.

FINANCIAL SOURCE	SCALE	ECOSYSTEM SERVICES ASSESSMENT	CLIMATE CHANGE RISK ASSESSMENT
National Highways' Environmental Designated Funds	Landscape	No	No

SOURCES OF ADDITIONAL INFORMATION

- https://www.arup.com/projects/keyn-glas-a30-environmental-designated-funds
- https://nationalhighways.co.uk/our-roads/a30-designated-funds/

III) FOREST AND WETLAND HABITAT RESTORATION THROUGH OFFSETTING FROM TRANSPORTATION IN THE UNITED STATES OF AMERICA

SECTOR		TYPOLOGY	
TRANSPORT		AIR TRANSPORT	
PROJECT	**DELIVERY ENTITY**	**CLIENT**	**LOCATION**
Deer Grove Forest Preserve Habitat Restoration	Stantec	Openlands	USA (IL)

SHORT DESCRIPTION

The site's 1,800-acre forest reserve included oak ecosystems were degraded over many decades by invasive and weedy shrubs and trees, shading the ground and reducing oak reproduction. Working in collaboration with the landowner, the project focused on ecosystem restoration and developed enhancement, management and monitoring plans to revitalise the area's oak ecosystems and associated streams, wetlands and prairies. Wetlands which were previously impaired by drainage ditches and tiles were restored. The funding for this project came from the city of Chicago to offset the wetland impacts from the expansion of the Chicago O'Hare International Airport.

PROJECT BENEFITS

KEY BENEFIT(S) OF THE PROJECT

BIODIVERSITY	Presently, the project supports more than 400 native plants and 25 of conservation priority bird species. The project has resulted in the restoration of 247 acres of woodland, 95 acres of wetland and 75 acres of prairie. Monitoring results have documented extensive expansion of wetland habitats and a notable increase in flora diversity throughout the project area.

CO-BENEFIT(S) OF THE PROJECT

CARBON	The estimates of the site's carbon capture potential is calculated to be 1,497 metric tonnes of carbon dioxide equivalents per year.
SOCIAL	The project provides over 10 miles of trails for recreation activities such as walking. Volunteering activities are often organised on site, which provides additional opportunity for social engagement and educational activities.

SOLUTIONS

Extensive field data collection and site assessment was used to assist the project team in developing restoration monitoring and management plans which preserved existing natural resources and worked to restore ecological function, reduce the pressure from invasive species and other disturbance vectors.

At Deer Grove, design solutions sought to recreate historic vegetation and hydrology patterns while maintaining a highly adaptive management approach capable of changing to meet dynamic ecological responses and changing climate conditions. Built design elements, including streambank stabilisation practices, stormwater conveyance and public access features utilized natural-channel design principles and on-site materials. Where practical, existing stormwater infrastructure was replaced with natural materials and hydraulic patterns.

FINANCIAL SOURCE	SCALE	ECOSYSTEM SERVICES ASSESSMENT	CLIMATE CHANGE RISK ASSESSMENT
Government	Project	Yes	No

SOURCES OF ADDITIONAL INFORMATION

- https://www.stantec.com/en/projects/united-states-projects/d/deer-grove-forest-preserve-wetland-restoration
- https://www.ser-rrc.org/project/deer-grove-forest-preserve-mitigation-planning-and-implementation/
- https://openlands.org/projects/deer-grove/

A.2 ENERGY

I) UTILISING RESTORATION HYDRO TURBINES ON THE LUBI RIVER IN THE DEMOCRATIC REPUBLIC OF CONGO TO PROTECT FISH POPULATIONS

SECTOR	TYPOLOGY
ENERGY	RENEWABLE ENERGY INFRASTRUCTURE

PROJECT	DELIVERY ENTITY	CLIENT	LOCATION
Lubi River Project	Natel Energy	MyHydro	Lubi River, Kasai Province, Democratic Republic of Congo

SHORT DESCRIPTION

The Lubi River project is the first of 33 potential sites in the Democratic Republic of Congo that will use Natel's Restoration Hydro Turbine (RHT) design as a part of a partnership with international project developer, MyHydro. RHT designs feature uniquely thick, forward-slanted blades, which enable safe through-turbine passage of fish while maintaining high efficiency (90-93%). Safe fish passage eliminates the need for fine fish exclusion screens, reducing O&M and CAPEX costs and increasing plant efficiency. Four 1.9 meter (6 foot) diameter RHTs will be installed on the Lubi River near Mbuji-Mayi in the Kasai Province, where grid electricity is not available and the population exceeds more than 4 million people. According to the World Bank, less than 10% of Kasai Province residents have access to electricity. The project, scheduled to begin production in 2024, will generate approximately 4.5 MW of clean, reliable electricity.

PROJECT BENEFITS

KEY BENEFIT(S) OF THE PROJECT

BIODIVERSITY	Validated in several peer-reviewed journal articles, Natel's RHT designs present an approach to generating reliable baseload energy from hydropower while preserving the livelihood of fish species. Natel defines a "fish-safe" hydropower turbine as one that causes negligible injury or mortality to all resident and migratory fish species at all life stages, as compared to natural hazards encountered during a fish's life cycle. Traditional hydropower-based infrastructure interferes with fish migration routes and often results in high mortality rates particularly when there are multiple dams along the same river system that species must pass in succession. Fish protection at hydropower plants has typically been to block turbines with fine screens and to route fish around the turbines through low-flow fishways. This approach can still delay fish migration and expose fish to predators and screens themselves sometimes harm fish who become trapped against them. Additionally, many fish still enter turbines where they are subject to traumatic injuries or death. This project's design offers a fish-safe option, whereby numerous species can pass multiple dams consecutively without the need for owners to pay for screens.
SOCIAL	Installation of the RHT will provide clean, grid-based electricity to the surrounding community, replacing fossil fuel use without impairing river ecology. Natel's fish-safe turbine designs will enable local recreation to continue in terms of fishing and other aquatic activities that may otherwise have been affected by installation of a traditional impoundment-based dam with traditional turbines.

CO-BENEFIT(S) OF THE PROJECT

CARBON	Assuming 90% overall plant availability and 50% CF, the site operator can generate roughly 21,000 MWhr, or roughly 14,900 metric tonnes of CO2 according to EPA's calculator[59].
ENVIRONMENTAL	Natel's RHTs have demonstrated fish safety across multiple species including salmonids, alosines and eels with study results published in peer-reviewed journals. Adding fish-safe RHTs to the Lubi River will continue to allow fish and sediment to travel with the bulk of a river's flow, maintaining river connectivity, while providing a clean power source that replaces fossil fuel consumption.
RESILIENCE	The Lubi Project is a Run-of-River (RoR) project, offering many of the same benefits that traditional hydropower projects offer (e.g. reliable baseload generation) though without the need for an impoundment structure. RoR facilities are quicker to install and result in fewer GHG emissions from reduced construction requirements. The Lubi Project enhances climate resilience by introducing turbines that preserve the ecological structure of the resident river system, while delivering reliable, renewable energy to an area without access to grid power.
SOCIAL	Installation of the RHT will provide clean, grid-based electricity to the surrounding community, replacing fossil fuel use without impairing river ecology. Natel's fish-safe turbine designs will enable local recreation to continue in terms of fishing and other aquatic activities that may otherwise have been affected by installation of a traditional impoundment-based dam with traditional turbines.
ECONOMIC	In addition to the aforementioned benefits of RoR style hydropower and utilizing a fish-safe turbine, the Lubi Project will supply uninterrupted power supply 24/7 to the local community at a minimum of half the cost of off-grid solar alternatives because it will not need to be supplemented overnight by other forms of generation or storage.

SOLUTIONS			
The nature-based solution utilised in the Lubi Project is Natel's fish-safe Restoration Hydro Turbine (RHT) which maintains river connectivity by enabling downstream passage of aquatic life and sediment. Natel's patented fish-safe design features distinctively thick, forward-swept blades that eliminate the need for fine fish screens and increase total plant efficiency while reducing both upfront CAPEX costs, as well as recurring operations and maintenance costs. Natel's RHT designs can be installed as part of new hydropower developments that maintain river connectivity for downstream migrating fish, or can be provided as runner-only or turbine-only in-place replacements. Natel can apply fish-safe RHT designs to hydropower applications of any configuration up to 40 meters of hydraulic head.			
FINANCIAL SOURCE	**SCALE**	**ECOSYSTEM SERVICES ASSESSMENT**	**CLIMATE CHANGE RISK ASSESSMENT**
MyHydro	Project	No	No

SOURCES OF ADDITIONAL INFORMATION

- https://www.natelenergy.com/projects/lubi-river-drc
- https://apnews.com/article/africa-business-a71eb253600bc009931e2e935a436653
- https://my-hydro.com/

A.3 WASTE AND WASTEWATER

I) USING CONSTRUCTED WETLAND FOR EFFECTIVE WASTEWATER TREATMENT IN THE UNITED KINGDOM

SECTOR	TYPOLOGY
WATER / WASTEWATER	WASTEWATER AND SEWAGE / SANITATION

PROJECT	DELIVERY ENTITY	CLIENT	LOCATION
Sanitary Integrated Constructed Wetland at Clifton Wastewater Treatment Works	Stantec	Yorkshire Water	UK

SHORT DESCRIPTION

An Integrated Constructed Wetland[60] (ICW) was designed and implemented for Clifton Wastewater Treatment Works (a Yorkshire Water[61] treatment site) delivering full water treatment flow. This was the first wastewater treatment works to have an ICW operating techniques agreement, a new form of permitting. Stantec worked in partnership with the Environment Agency to gain consensus on the format and content of the agreement.

The IWC was designed with a mixture of open water ponds and shallow vegetated marshes to provide a complex mixture of aerobic and anaerobic environments to sustain a diverse population of microbial activity and plant life. These biological processes are unique to wetland systems and provide the basis for a variety of control mechanisms to operate simultaneously along an extended treatment flow path. The result is that inorganic and organic constituents can be physically removed through filtration, biologically degraded to non-toxic forms, absorbed by wetland plants, adsorbed to both soil and plant surfaces, or chemically transformed and sequestered within the saturated wetland substrates.

The ICW has been designed to be a fully passive process with flows gravitating through the system with no automatic control elements; these natural falls also created aeration between each pond with rock lined cascades. The pond perimeters were stabilised using geojute blankets with native wildflowers and grasses to minimise erosion but also add biodiversity and aesthetics.

PROJECT BENEFITS

KEY BENEFIT(S) OF THE PROJECT

ENVIRONMENTAL	This project aimed to demonstrate long-term sanitary treatment performance of constructed wetlands with a specific focus on phosphorus retention.
BIODIVERSITY	In total 24,000 native plants were used in the ICW. The project delivers a Biodiversity Net Gain of 40% – one of the first Biodiversity Net Gain positive wastewater treatment works in the UK. Topsoil from the excavation of the ponds was reused for a pollinator nature reserve immediately adjacent to the project to enhance the biodiversity of the surrounding area.

CO-BENEFIT(S) OF THE PROJECT

CARBON	The design minimised the need for concrete (a high embodied carbon material), which in turn significantly reduced carbon emissions of the project. Additionally, no waste (i.e. from excavation etc) was removed from the site – it was all reused, further avoiding carbon emissions from transportation. The operational carbon saving is estimated to be 79% with embodied carbon saving of approximately 50%.
RESILIENCE	ICW slows the flow of water entering the River Don catchment, thereby helping to reduce flood risk and lessening the vulnerability of local communities to climate change.
SOCIAL	No excavation waste removed from site which protected the local community from disruption. The nature reserve adjacent to the site presented an opportunity to engage with local schools, provide educational visits and to study wildlife and plant bug houses.
ECONOMIC	The project was completed at 35% lower capital cost compared to a conventional solution, as well as an estimated 40% reduced operational costs.

SOLUTIONS
Shallow ponds were filled with a variety of plants to promote ecological conditions for nutrient uptake and promote a diverse habitat. • The first phase of the process utilises the existing primary settlement tanks for primary treatment. However, as the retention time within the tank was less than 24 hrs, additional retention was added with the creation of a small open water pond to reduce the solids and organics load into the subsequent wetland cells by between 15-20%. • The next four cells were designed as secondary and tertiary treatment for the removal of the Total Suspended Solids, Biochemical Oxygen Demand, ammonia and phosphorus. The plant species were limited in the first two cells to six robust species which tolerate the higher organic loads; and in the next cells a more diverse range of plants (greater than 20 species) to provide polishing treatment while also increasing biodiversity.

FINANCIAL SOURCE	SCALE	ECOSYSTEM SERVICES ASSESSMENT	CLIMATE CHANGE RISK ASSESSMENT
Private finance (client)	Site	No	No

SOURCES OF ADDITIONAL INFORMATION
• https://www.stantec.com/en/projects/united-kingdom-projects/c/clifton-integrated-constructed-wetland

II) RESTORING AND REHABILITATING WETLANDS TO SUPPORT WATER TREATMENT IN INDIA

SECTOR	TYPOLOGY
WATER / WASTEWATER	WASTEWATER AND SEWAGE / SANITATION

PROJECT	DELIVERY ENTITY	CLIENT	LOCATION
Citizen Revival of Hauz Khas Lake by Creating the Hauz Khas Urban Wetlands	EVOLVE Engineering	-	India

SHORT DESCRIPTION
The Citizen Revival of Hauz Khas Lake project involved a large lake clean-up in Delhi at Hauz Khas Lake. The lake measures 14.5 acres and is fed by a mix of partially treated and raw sewage as well as rainwater. The project involved the construction of 425 sqm. of wetlands capable of treating up to 2 million litres of water a day. The project has removed nearly all odour around the lake and floating scum, as well as the removal of all suspended and floating matter from the incoming water supply. This has contributed to a substantial improvement in the water quality. The project also included the installation of the first floating solar aerator and sub surface fine bubble aerator in Delhi, in a water body.es. The pond perimeters were stabilised using geojute blankets with native wildflowers and grasses to minimise erosion but also add biodiversity and aesthetics.

PROJECT BENEFITS	
KEY BENEFIT(S) OF THE PROJECT	
ENVIRONMENTAL	Water quality in the lake was significantly improved with water samples before and after the work was undertaken, showing a decrease in Biochemical Oxygen Demand (BOD) from 35-244 to 18 mg/l and a reduction in total phosphates from 4-8mg/l to <1 mg/l.
CO-BENEFIT(S) OF THE PROJECT	
CARBON	The wetlands themselves sequester carbon and the use of this solution as opposed to a conventional sewage treatment plant results in significant carbon savings.
BIODIVERSITY	The constructed wetlands inside the existing drains transformed the existing sewage filled channels into a wetland ecosystem with banks, channels, filter media and vegetation and provided habitats for birds and insects. The floating wetlands bring green cover and provide nesting sites for birds and a habitat for fish.
RESILIENCE	The constructed wetlands reduce the risk of flooding, thereby brining considerable resilience benefits.
SOCIAL	The project demonstrates how previously ignored sewage filled open drains can be adapted to provide recreational areas, eliminating the odour and reducing the exposure of the public to hazardous materials. As a citizen-led project, the public were involved with the construction and even paid for and adopted floating islands, creating awareness of solutions as well as teaching citizens how they can build floating wetlands to clean up their local waterbodies.
ECONOMIC	The total cost of creating the wetlands was less than the authorities spend in one year treating the lakes with bacteria or chemicals.

SOLUTIONS			
The project adapted two existing drains and converted them to water purifying wetland ecosystems to treat the incoming, as well as the existing, water in the lake. The project provided four different solutions: • Converted inlet channel to constructed wetland to filter incoming water; • Converted stormwater drain to constructed wetland to treat lake water; • Installed floating wetlands through 'Adopt an Island' scheme; • Installed fine bubble sub-surface solar powered aerator.			
FINANCIAL SOURCE	**SCALE**	**ECOSYSTEM SERVICES ASSESSMENT**	**CLIMATE CHANGE RISK ASSESSMENT**
Public donations, a crowd funding campaign, funding from EVOLVE Engineering and CSR funding from Pernod Ricard India Foundation	Watershed	No	No

SOURCES OF ADDITIONAL INFORMATION

- https://www.thehindu.com/news/cities/Delhi/floating-islands-of-promise-in-hauz-khas-lake/article24548602.ece
- https://www.indiatoday.in/mail-today/story/how-hauz-khas-lake-got-a-new-lease-of-life-1546331-2019-06-11
- https://youtu.be/KXEelJ4OYso
- https://www.youtube.com/watch?v=YUihIOO-Ylo&ab_channel=HawaBadlo
- https://www.downtoearth.org.in/video/water/good-news-this-man-is-reviving-hauz-khas-lake-using-artificial-wetlands-60432

A.4 BUILDINGS AND PUBLIC SPACES

I) RESTORATION OF A BROWNFIELD SITE SUPPORTING ENHANCED BIODIVERSITY, SOCIAL VALUE AND WATER TREATMENT

SECTOR	TYPOLOGY
PUBLIC SPACE / BUILDINGS	OPEN / GREEN SPACE

PROJECT	DELIVERY ENTITY	CLIENT	LOCATION
Snow Creek Stream Environment Zone Restoration Project	CDM Smith Inc.	Placer County	USA (CA)

SHORT DESCRIPTION

The Snow Creek Stream Environment Zone is located in North Lake Tahoe, Placer County, CA. The project involved a restoration project of a brownfield site that had previously been used as a concrete plant since the 1950s. It restored sensitive environmental areas, provided storm water treatment and constructed a multi-use trail connecting two existing trails providing recreational benefits. The area was regraded and a new channel was constructed to restore the site's predevelopment hydrology and the habitat. The restored area was revegetated with native wetland and upland plant species, using existing plants from the undeveloped portion of the project area. Approximately 3.1 acres of riparian area were restored and about 0.25 acre of wetlands re-established to mitigate the disturbance caused by the concrete plant. A pre-treatment forebay, an infiltration basin and a new channel that is routed through constructed wetland areas prevent sediments from flowing to Snow Creek and eventually to Lake Tahoe.

PROJECT BENEFITS

KEY BENEFIT(S) OF THE PROJECT

SOCIAL	Additional outdoor recreational space was provided for local communities/visitors - walking trail improvements were undertaken, as well as educational and wayfinding signage was installed along a 1,800-foot route, including bridges over biodiversity sensitive areas.
BIODIVERSITY	The project protects wetlands and surface water, which buffers, enhances and restores wetlands and other water bodies. This included 3.1 acres of riparian area and 0.25 acre of wetlands re-established.

CO-BENEFIT(S) OF THE PROJECT

CARBON	The project contributed to reducing emissions converting the land from a brown field site to a green space (land use change). The vegetation planted sequesters carbon from the atmosphere.
ENVIRONMENTAL	Native plants have been selected at the site to mitigate the need of pesticide and fertiliser use – preventing surface and groundwater contamination.
RESILIENCE	The project increased resilience and long-term recovery prospects from natural and man-made short-term hazards, including wildfire, flooding, soil erosion and drought.

SOLUTIONS

The project supported new storm water treatment facilities and other water quality improvements, as well as efforts to increase biodiversity and native landscaping.

- Bridges were used as bicycle trails over sensitive areas.
- Willow trees were planted near the natural storm water channel will provide shade for water temperature for control.
- Storm water will be pre-treated in a concrete forebay with gabions prior to entering a restored drainage channel, stream environment zone and wetlands.
- Improved/ re-established wetlands will reduce sediments within storm water.

FINANCIAL SOURCE	SCALE	ECOSYSTEM SERVICES ASSESSMENT	CLIMATE CHANGE RISK ASSESSMENT
Public (grant – five sources)	Development / Project	No	No

SOURCES OF ADDITIONAL INFORMATION

- https://www.placer.ca.gov/1657/Snow-Creek-Stream-Environment-Zone-Resto
- https://sustainableinfrastructure.org/project-awards/snow-creek-stream-environment-zone-restoration-project-1/

A.5 COASTAL PROTECTION

I) BUILDING COASTAL RESILIENCE THROUGH LIVING SHORELINE IN THE UNITED STATES OF AMERICA

SECTOR	TYPOLOGY
COASTAL PROTECTION	GREEN-GREY COASTAL INFRASTRUCTURE

PROJECT	DELIVERY ENTITY	CLIENT	LOCATION
Virginia Point Living Shoreline	AECOM	Texas General Land Office and Scenic Galveston	USA (TX)

SHORT DESCRIPTION

The Virginia Point Wetland Protection Project used a living shoreline approach to stabilize the eroding shoreline[62]. The final design included over 6,000 linear feet of nearshore, segmented limestone breakwaters parallel to the Virginia Point shoreline. The placement and spacing of the breakwaters were designed to produce several large cells behind the breakwaters to allow for up to 35 acres of future marsh planting. The breakwater cells were designed to retain and accumulate sediment naturally to create a sediment bed for marsh planting and some of this acreage was planted when in the necessary elevation range. The breakwater crests provide nesting areas for birds, but also provide habitats to other terrestrial species.

PROJECT BENEFITS

KEY BENEFIT(S) OF THE PROJECT

BIODIVERSITY	Prior to the project, this area went from coastal prairie to unvegetated bay bottom and had lost transitional wetlands. After the project, wetland development, tidal pools and the stone structures themselves have re-established habitats for crab, shrimp, oyster, fish and birds, increasing the biodiversity value of the site considerably.
RESILIENCE	Prior to the project, the coastal shoreline was subject to extensive waves and erosion, as natural transition zones and wetlands had been lost due to infrastructure development and ship traffic. This project restored shoreline buffers that will naturally expand over time.

CO-BENEFIT(S) OF THE PROJECT

CARBON	The wetland vegetation replacing unvegetated bay bottom will improve carbon storage in the soils while the breakwaters will protect existing carbon-rich soils within the coastal prairie and prevent the release of sequestered carbon.
ENVIRONMENTAL	This project restored the natural system that allows for the bay, wetlands and prairie to work in a connected manner, allowing for buffer and migratory zones that will maintain the health of the system in the face of relative sea level rise and other coastal pressures.
ECONOMIC	Combination of vegetation and stone breakwaters, alongside natural oyster reef structures, minimised the amount of material required to protect the shoreline, thereby being a cost-effective solution.

SOLUTIONS

A combination of green-grey solutions (living shoreline, salt marsh restoration, breakwater) to reduce coastal erosion.

FINANCIAL SOURCE	SCALE	ECOSYSTEM SERVICES ASSESSMENT	CLIMATE CHANGE RISK ASSESSMENT
Federal and state funding	Development / Project	Yes	Yes

SOURCES OF ADDITIONAL INFORMATION

- https://www.nfwf.org/sites/default/files/2021-11/tx-virginia-point-14.pdf
- https://asbpa.org/2019/09/09/winners-of-inaugural-best-restored-shore-award-illustrate-innovation-in-successful-coastal-restoration/

APPENDIX B CASE STUDIES:

PRE-IMPLEMENTATION ASSESSMENTS AND FEASIBILITY STUDIES

During the case study collation processes, a number of pre-design/implementation studies and assessments were also identified. This chapter aims to highlight some of activities that have been undertaken, to support the rationale for incorporating nature positive and nature-based solutions into infrastructure design.

Please note, that this is not an exhaustive list of the work that has been undertaken internationally. It simply aims to highlight some activities that have been carried out. Additional examples will be included in this section in future iterations of this Playbook.

B.1 TRANSPORT

I) INCORPORATING THE VALUE OF NATURAL CAPITAL INTO ROAD PLANNING PROCESSES IN PERU

SECTOR	TYPOLOGY
TRANSPORT	INLAND ROAD AND RAIL INFRASTRUCTURE

PROJECT	DELIVERY ENTITY	CLIENT	LOCATION
Pucallpa Road	Natural Capital Project, Stanford University and The Nature Conservancy	-	Peru

SHORT DESCRIPTION

The proposed Pucallpa-Cruzerio do Sul Road (hereafter "Pucallpa Road") that aims to connect Peru and Brazil represents an important opportunity to bring the value of natural capital into road planning processes. Where the Pucallpa Road would cut through the Peruvian Amazon, it would likely impact local ecosystem services for 250,000 people including more than 15,000 indigenous people. Provision of ecosystem services such as clean drinking water, climate regulation and food and medicine for Amazonian communities, would be at risk under the proposed development plan. The Natural Capital Project at Stanford University, in partnership with The Nature Conservancy, assessed the impact the completed road would have on ecosystem services and whether mitigation activities could equitably offset these impacts. Drinking water quality, in terms of sediments, nitrogen (N) and phosphorus (P) and carbon storage for climate regulation were the principal services investigated using the Natural Capital Project's free open-source InVEST software. The analysis found that the proposed Pucallpa Road would result in substantial losses of ecosystem services. Mitigation through restoration and avoided deforestation could offset some, but not all, ecosystem service losses. However, the Natural Capital Project's analysis showed that indigenous communities were likely to bear disproportionately high losses of ecosystem services and these losses could not be fully offset.

POTENTIAL BENEFITS IF THE RECOMMENDED SOLUTIONS ARE IMPLEMENTED

BIODIVERSITY	Restoration and avoided deforestation, of biodiversity habitat.
CARBON	Global climate regulation and carbon storage.
ENVIRONMENTAL	Sediment retention / erosion control, nutrient retention (N&P) and water quality improvements provided.
RESILIENCE	N/A
SOCIAL	Benefits provided to local communities, especially indigenous communities, in terms of drinking water and other forest-based ecosystem services.
ECONOMIC	N/A

SOLUTIONS

The report compares two approaches two mitigation: a practical approach that considers the most feasible locations for forest protection and restoration given current land tenure and a targeted approach that focuses on the most effective places on the landscape to achieve natural capital gains. The report evaluated the potential for no net loss for four ecosystem services: (1) drinking water quality regulation for the pollutants (2) nitrogen and (3) phosphorus; and (4) carbon sequestration. The report found that the impacts of road-associated deforestation are likely to be much greater than the impacts of the road alone, especially for erosion control and phosphorous regulation services. If social equity is considered, no net loss is possible with both the practical and targeted approaches only for carbon sequestration and for the road-only impacts of erosion control services. No net loss is not possible for nitrogen and phosphorous regulation services, nor for the impacts of the road plus associated deforestation on sediment retention / erosion control. Overall, the targeted approach comes closer to achieving no net loss than the practical approach. If social equity is ignored, no net loss of all four ecosystem services can be achieved using the targeted approach but not the practical approach. However, by ignoring social equity, this method creates ecosystem services winners and losers.

FINANCIAL SOURCE	SCALE	ECOSYSTEM SERVICES ASSESSMENT	CLIMATE CHANGE RISK ASSESSMENT
Grant funding (USAID)	Project	Yes	No

SOURCES OF ADDITIONAL INFORMATION

- https://naturalcapitalproject.stanford.edu/publications/can-pucallpa-cruzeira-do-sul-road-be-developed-no-net-loss-natural-capital-peru
- http://dx.doi.org/10.1890/140337
- https://naturalcapitalproject.stanford.edu/software/invest
- https://www.conservation-strategy.org/project/cost-benefit-analysis-proposed-pucallpa-cruzeiro-do-sul-road
- https://education.nationalgeographic.org/resource/amazonian-road-decision/

B.2 ENERGY

I) APPLICATION OF A NATURAL CAPITAL ASSESSMENT FRAMEWORK TO QUANTIFY THE BENEFITS OF A WASTE-TO-ENERGY PLANT IN CHINA

SECTOR	TYPOLOGY
ENERGY	NON-RENEWABLE ENERGY INFRASTRUCTURE

PROJECT	DELIVERY ENTITY	CLIENT	LOCATION
Sanya Waste-to-Energy Plant	AECOM	China Everbright Environment Group Limited	China

SHORT DESCRIPTION

Modern waste-to-energy[63] facilities offer an advanced engineering approach to eliminate marine plastics from source by thermal destruction and the benefit can be quantified by natural capital means on environmental, social and economic grounds. This study for the Sanya Waste-to-Energy Plant was accompanied by a natural capital-based sustainability assessment framework that includes:

- the quantification of the benefits caused by the avoidance of marine plastic pollution by waste-to-energy projects; and
- an inclusive sustainability evaluation framework that holistically assess the environmental, social and economic performance associated with marine plastic pollution.

To assess the impact of changes in natural capital, the ecosystem services are categorised based on their functions, namely the:

- provisioning (biomass, genetic material from all biota, water);
- regulation and maintenance (regulation of physical, chemical, biological conditions); and
- cultural (interactions with living systems that are dependent or independent on presence in the environmental setting), ending with 12 types of goods and benefits.

The Framework recommended the net benefit from conserving natural capital, mainly due to marine plastic reduction, evidencing the client's contribution to a cleaner and more sustainable marine environment.

POTENTIAL BENEFITS IF THE RECOMMENDED SOLUTIONS ARE IMPLEMENTED

BIODIVERSITY	The avoidance of marine plastic pollution could contribute to a healthier marine environment, which supports the biodiversity and natural populations of different aquatic species and helps fish farming. The valuated economic benefit in terms of fisheries production is in the range of CNY 0.2 – CNY 8.0 million per year.
CARBON	Residual emission of +265,376 tCO2e (equivalent to CNY -11.9 million in terms of carbon pricing) per year after discounting avoided methane emissions generated from the degradation of municipal solid waste and the production of green electricity that replaces the use of fossil fuel power from the grid.
ENVIRONMENTAL	Elimination of marine plastics would reduce the need for municipal hygiene services in marine debris clean-up, valuated at around CNY 29.1 – CNY 154.8 million per year.
RESILIENCE	Marine microplastics could affect the photosynthesis and growth of phytoplankton, hence marine plastics reduction could help maintain the carbon sequestration function of the marine environment as well as upkeeping a vibrant marine ecosystem in the local water including corals, marine turtles, marine mammals and fish. Yet, the effect is not quantified.
SOCIAL	The reduction of marine litter and a healthier marine environment would help improve the standing of Sanya as a well-known tourist spot. The expected total economic benefit from tourism is in the range of CNY 23.2 – CNY 310.0 million per year. Marine plastic reduction would also bring a smaller extent of avoidance in marine accidents which is valuated at around CNY 1.3 – CNY 3.6 million per year.
ECONOMIC	The combined net benefit of the listed benefits is in the range of CNY 41.9 million – CNY 464.5 million per year.

SOLUTIONS

The project suggests the benefits of the waste-to-energy plant and provides alternative means of qualifying the benefits derived from the project for the environment and nature.

FINANCIAL SOURCE	SCALE	ECOSYSTEM SERVICES ASSESSMENT	CLIMATE CHANGE RISK ASSESSMENT
Private funds (owner of Sanya Waste-to-Energy Plant, China Everbright Environment Group Ltd.)	Watershed	Yes	Yes

SOURCES OF ADDITIONAL INFORMATION

- https://www.power-technology.com/marketdata/power-plant-profile-hainan-sanya-waste-to-energy-project-china/
- https://www.adb.org/news/adb-china-everbright-environment-form-strategic-partnership-ocean-health-asia
- https://www.cebenvironment.com/en/csr/sustainability/sr2022.pdf

B.3 WASTE AND WASTEWATER

I) NATURAL WATERWAYS TO SUPPORT WATER RETENTION IN WATER SENSITIVE AREAS IN AUSTRALIA

SECTOR	TYPOLOGY
WATER / WASTEWATER	DRAINAGE AND STORMWATER

PROJECT	DELIVERY ENTITY	CLIENT	LOCATION
Western Parkland City, Sydney (Aerotropolis) Development of a Blue-Green City	Sydney Water Planning Partner – Sydney Water, Aurecon and Arup	NSW Department of Planning & Environment	Australia

SHORT DESCRIPTION

The project recognised the value of the natural waterways systems of the Western Parkland City in Sydney; this natural capital approach has been critical in developing a landscape-led design for master planning. The master planning and investment business cases incorporate water sensitivity, retention of water on country and developed design principals to endure for the lifecycle of the city development.

POTENTIAL BENEFITS IF THE RECOMMENDED SOLUTIONS ARE IMPLEMENTED

KEY BENEFIT(S) OF THE PROJECT

ENVIRONMENTAL	Integrated water cycle management and waterway health are fundamental to master planning the hot and dry Western Sydney suburbs. Stormwater harvesting, permeable land targets and passively watered street trees will retain water in the landscape, reduce urban heat and protect waterways. Excess stormwater will be discharged to mimic natural flow regimes to protect the water quality and flow regime of the local waterways.
RESILIENCE	Integration of the blue and green systems of the waterways, recycled water, drinking water and sewerage to efficiently support blue green industrial development and recreation open space. Thermal modelling has demonstrated that the combined benefit of the wetlands and irrigation has the potential to reduce the ambient site temperature by five degrees centigrade.
ECONOMIC	The Great Sydney Water Strategy reports that a more integrated approach to water cycle and land use planning could generate significant economic benefit (~$6.6 billion NPV by 2056) for the Western Parkland City. Economic value includes benefits arising from integrated water management, open-space, urban cooling and environment and heritage.

CO-BENEFIT(S) OF THE PROJECT

BIODIVERSITY	Integration of blue and green systems of the waterways, riparian areas, bushlands, parks and open spaces, tree canopy and private gardens will protect the hydrology of local waterways and regionally significant floodplain biodiversity. Conservation of native vegetation will also maintain biodiversity.
CARBON	Positive impacts on emissions reductions by reducing urban heat and associated energy costs. Urban cooling from water retained in the landscape, irrigation with recycled water and the enhanced tree canopy cover will create significant energy demand reduction at precinct level.
SOCIAL	Health benefits for the community by improved amenity and recreation related benefits arising from proximity to open space. The Aerotropolis will make a significant contribution to 200,000 new jobs for Western Sydney by establishing a new high-skill jobs hub across aerospace and defence, manufacturing, healthcare, freight and logistics, agribusiness, education and research industries.

SOLUTIONS

The assessment found that the best approach to protecting the water quality and ecology of the waterways is preventing significant hydrologic change by applying a stormwater retention approach with a focus on harvesting stormwater. This was focussed on reuse in the catchment and using the cities water demands to solve the issues caused by the new precincts.

Stormwater harvesting is proposed via a network of linked constructed wetland and water storages that will capture, clean and store stormwater that exceeds the natural hydrology of the waterways. The wetlands will mimic the existing catchment processes and proved controlled release of water to the waterways as well as proving an abundant supply of raw water for irrigation and non-potable water demands across the precinct/district.

FINANCIAL SOURCE	SCALE	ECOSYSTEM SERVICES ASSESSMENT	CLIMATE CHANGE RISK ASSESSMENT
Developer and customer charges	Development / Project	No	No

SOURCES OF ADDITIONAL INFORMATION

- https://www.sydneywatertalk.com.au/aerostormwater

B.4 COASTAL PROTECTION

I) ECOLOGICAL ENHANCEMENT FEATURES FOR COASTAL PROTECTION IN THE UNITED KINGDOM

SECTOR	TYPOLOGY
COASTAL PROTECTION	GREEN-GREY COASTAL INFRASTRUCTURE

PROJECT	DELIVERY ENTITY	CLIENT	LOCATION
Virginia Point Living Shoreline	AECOM	Texas General Land Office and Scenic Galveston	USA (TX)

SHORT DESCRIPTION

The Virginia Point Wetland Protection Project used a living shoreline approach to stabilize the eroding shoreline . The final design included over 6,000 linear feet of nearshore, segmented limestone breakwaters parallel to the Virginia Point shoreline. The placement and spacing of the breakwaters were designed to produce several large cells behind the breakwaters to allow for up to 35 acres of future marsh planting. The breakwater cells were designed to retain and accumulate sediment naturally to create a sediment bed for marsh planting and some of this acreage was planted when in the necessary elevation range. The breakwater crests provide nesting areas for birds, but also provide habitats to other terrestrial species.

POTENTIAL BENEFITS IF THE RECOMMENDED SOLUTIONS ARE IMPLEMENTED

KEY BENEFIT(S) OF THE PROJECT	
BIODIVERSITY	Prior to the project, this area went from coastal prairie to unvegetated bay bottom and had lost transitional wetlands. After the project, wetland development, tidal pools and the stone structures themselves have re-established habitats for crab, shrimp, oyster, fish and birds, increasing the biodiversity value of the site considerably.
RESILIENCE	Prior to the project, the coastal shoreline was subject to extensive waves and erosion, as natural transition zones and wetlands had been lost due to infrastructure development and ship traffic. This project restored shoreline buffers that will naturally expand over time.

CO-BENEFIT(S) OF THE PROJECT	
CARBON	The wetland vegetation replacing unvegetated bay bottom will improve carbon storage in the soils while the breakwaters will protect existing carbon-rich soils within the coastal prairie and prevent the release of sequestered carbon.
ENVIRONMENTAL	This project restored the natural system that allows for the bay, wetlands and prairie to work in a connected manner, allowing for buffer and migratory zones that will maintain the health of the system in the face of relative sea level rise and other coastal pressures.
ECONOMIC	Combination of vegetation and stone breakwaters, alongside natural oyster reef structures, minimised the amount of material required to protect the shoreline, thereby being a cost-effective solution.

SOLUTIONS

A combination of green-grey solutions (living shoreline, salt marsh restoration, breakwater) to reduce coastal erosion.

FINANCIAL SOURCE	SCALE	ECOSYSTEM SERVICES ASSESSMENT	CLIMATE CHANGE RISK ASSESSMENT
Federal and state funding	Development / Project	Yes	Yes

SOURCES OF ADDITIONAL INFORMATION

- https://www.nfwf.org/sites/default/files/2021-11/tx-virginia-point-14.pdf
- https://asbpa.org/2019/09/09/winners-of-inaugural-best-restored-shore-award-illustrate-innovation-in-successful-coastal-restoration/

II) SAFEGUARDING NATURAL CAPITAL TO ENHANCE COASTAL RESILIENCE IN COLOMBIA

SECTOR	TYPOLOGY
COASTAL PROTECTION	NATURAL COASTAL INFRASTRUCTURE

PROJECT	DELIVERY ENTITY	CLIENT	LOCATION
Gulf of Morrosquillo	Natural Capital Project, Stanford University	-	Colombia

SHORT DESCRIPTION

Using the Gulf of Morrosquillo as a pilot area, the Natural Capital Project undertook research in collaboration with Colombia's Department of National Planning to demonstrate where key ecosystems, such as mangroves and other forests, provide societal benefits. The analysis was completed with the Natural Capital Project's free, open-source software InVEST®. This assessment provides recommendations for where safeguarding natural capital could contribute most to securing nature's benefits into the future for the Gulf of Morrosquillo's citizens and visitors. There is significant opportunity for these results to be scaled and expanded across the country to help inform spatial and land-use planning in other regions.

POTENTIAL BENEFITS

BIODIVERSITY	Protection and creation of ecosystems for fauna.
CARBON	Coastal ecosystems support global climate regulation by storing carbon in the soils of coastal ecosystems, also known as blue carbon. Mangroves sequester carbon at a rate of two to four times greater than tropical forests.
RESILIENCE	Coastal ecosystems reduce vulnerability to costal change, such as erosion and flooding from storms.
SOCIAL	Provides drinking water security and protection of coastal infrastructure and people.

SOLUTIONS

Spatial development planning, protection of coastal ecosystems (mangroves and corals) and inland forests.

FINANCIAL SOURCE	SCALE	ECOSYSTEM SERVICES ASSESSMENT	CLIMATE CHANGE RISK ASSESSMENT
Moore Foundation	Watershed	Yes	No

SOURCES OF ADDITIONAL INFORMATION

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- https://registry.verra.org/app/projectDetail/VCS/2290
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10. For sources and different definitions of 'nature-positive' approaches, see: Sophus, O.S.E. zu Ermgassen, et al. 2022. Are Corporate Biodiversity Commitments Consistent With Delivering 'Nature-Positive' Outcomes? A Review of 'Nature-Positive' Definitions, Company Progress and Challenges. Journal of Cleaner Production 379. Available at: https://osf.io/preprints/socarxiv/rq6z2/
11. This conclusion does not necessarily apply to government-led or community-led nature-based solutions, etc which were not the principal focus of analysis.
12. It is worth noting that the link between solutions and benefits in each table under 'Sectors' chapter is indicative – naturally, whether certain benefits have been derived will depend on how the project is implemented, etc.
13. It should be noted that this typology has been developed specifically for this assignment and is not meant to imply this is how either sector is typically categorised.
14. In part, this has to do with transport infrastructure in emerging economies, which are often biodiversity hotspots.
15. See, for example, Blackwood, L. and Renaud, F.G (2022). Barriers and Tools for Implementing Nature-Based Solutions for Rail Climate Change Adaptation. Transport Research Part D. 113.
16. Although road and rail infrastructure are discussed together, it is worth pointing out that small-scale (especially rural) roads may only have marginal impacts on deforestation, unlike most rail projects. Some literature even suggests potentially positive outcomes – see, for example: www.greengrowthknowledge.org/sites/default/files/downloads/resource/Kaczan_Can%20roads%20contribute%20to%20forest%20transitions.pdf
17. See, for example, Botelho. J. et al. 2022. Mapping Roads in the Brazilian Amazon with Artificial Intelligence and Sentinel-2. Remote Sensing 14(15), 3625. Available at: https://www.mdpi.com/2072-4292/14/15/3625
18. For an interesting overview of the links between road infrastructure and ecosystem services, see IADB. 2016. Natural Capital and Roads: Managing Interdependencies and Impacts on Ecosystem Services for Sustainable Road Investments. Washington, Available at: https://publications.iadb.org/en/publication/17173/natural-capital-and-roads-managing-dependencies-and-impacts-ecosystem-services
19. Offsetting should only take place if it has previously been determined that the project has a strong justification, cannot be rerouted and there is no way of implementing it without deforestation, in line with ecological mitigation hierarchy – avoid damage, minimise it, restore locally and only then offset.
20. In the examples identified, the term 'green bridge' is used to describe either an in-situ bio-remediation system that uses fibrous materials with stones to reduce the risk of flooding, or connectivity bridge that links together natural areas that have been artificially divided by roads and railway lines, or a combined system that aims to achieve both. There is no consistency in the literature as to how the term is used.
21. See also: Natural England. 2015. Green Bridges: A Literature Review. London.
22. US Department of Transportation – Federal Highway Administration White Paper. 2018. Nature-Based Solutions for Coastal Highway Resilience. Washington.
23. According to some estimates, around two-thirds of coastal and marine structures are concrete based, with a significant impact on biodiversity (chemical mix discourages the growth of marine life) and water quality.
24. Areas with constant coastal permafrost.
25. There are many examples of offsetting – only a selection was included.
26. IRENA. 2023. Global Landscape of Renewable Energy Finance. Abu Dhabi. Available at: www.irena.org/Publications/2023/Feb/Global-landscape-of-renewable-energy-finance-2023
27. See, for example, Shell's page on nature-based solutions www.shell.com/energy-and-innovation/new-energies/nature-based-solutions.html as well as www.theguardian.com/environment/2023/jan/19/shell-to-spend-450m-on-carbon-offsetting-fears-grow-credits-worthless-aoe. Last accessed on 28/03/2023.
28. There is a gap in the literature when it comes to some of the impact of renewable energy infrastructure on biodiversity (with the possible exception of dams).
29. IUCN. 2021. Mitigating Biodiversity Impact Associated with Solar and Wind Energy Development. Gland. https://portals.iucn.org/library/sites/library/files/documents/2021-004-En.pdf
30. A summary of the dams' impact on biodiversity could be found here: Wu, H. et al. 2019. Effects of Dam Construction on Biodiversity: A Review. Journal of Cleaner Production, Vol. 221, pp. 480-489.
31. See the reference to carbon credits on the previous page.
32. IPBES. 2019. Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Bonn. Available at: www.ipbes.net/global-assessment
33. UNECE. 2018. Forests and Water. Geneva. Available at: https://unece.org/DAM/timber/publications/sp-44-forests-water-web.pdf
34. DEFRA. 2013. Payments for Ecosystem Services: A Best Practice Guide. London. Available at: https://www.cbd.int/financial/pes/unitedkingdom-bestpractice.pdf
35. See, for example, World Bank. 2023. What the Future Has in Store: A New Paradigm for Water Storage. Washington **or** WWF. 2022. Sustainable Groundwater Management for Agriculture. Washington.
36. See, for example Natural England. 2021. Advice and Recommendations for Beaver Reintroduction, Management and Licencing in England. London. Available at: https://publications.naturalengland.org.uk/publication/5010277084168192
37. In places with combined sewers (where sewage and stormwater runoff are transported together to a treatment plant or disposal site), storms or otherwise increased precipitation can lead to overflows and exceed the capacity of the treatment plant or storage site, which can lead to the contamination of other water bodies.
38. Grier et al. 2015. Future of Our Coasts: The Potential for Natural and Hybrid Infrastructure to Enhance the Resilience of Our Coastal Communities, Economies and Ecosystems. Environmental Science and Policy 51: 137-148.

39. Tonneijck, F., Van der Goot, F., Pearce, F. 2022. Building with Nature in Indonesia. Restoring an Eroding Coastline and Inspiring Action at Scale. Wetlands International and Ecoshape Foundation.
40. See, for example, McKinsey & Company. 2022. Blue Carbon: The Potential of Coastal and Oceanic Climate Action. Available at: https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/blue%20carbon%20the%20potential%20of%20coastal%20and%20oceanic%20climate%20action/blue-carbon-the-potential-of-coastal-and-oceanic-climate-action-vf.pdf
41. For the purpose of this report, carbon refers to carbon emissions alone, not carbon equivalent.
42. For example, for biodiversity this could be species richness post-intervention, for carbon there are standard accounting principles that can be used to measure overall reduction in emissions associated with infrastructure projects, for resilience usually there is a reliance on insurance models to calculate avoided damages from storms, etc.
43. See, for example, UNEP. 2022. Mapping Environmental Risks and Socio-Economic Benefits of Planned Transport Infrastructure: A Global Picture. Nairobi. This publication uses novel methods and metrics to estimate the impact of large-scale transport infrastructure that is under way or planned in 137 countries on wildlife, carbon storage and other issues.
44. World Economic Forum. 2020. The Future of Nature and Business. Geneva. Available at: https://www3.weforum.org/docs/WEF_The_Future_Of_Nature_And_Business_2020.pdf
45. This is according to research identified and reviewed for this report – it may well be that the impact on other taxa is not sufficiently well understood or explored at this stage.
46. Lopez et al. 2010. The Impacts of Roads and Other Infrastructure on Mammal and Bird Populations: A Meta-Analysis. Biological Conservation 143: 1307-1316.
47. See, for example, WWF. 2017. Infrastructure at Odds with Biodiversity? Gland. Available at https://www.cbd.int/financial/2017docs/wwf-infrastructuremain2017.pdf
48. In line with the mitigation hierarchy, offsetting should be the last resort – plenty of evidence suggests that offsetting results in net loss of biodiversity (at least temporarily).
49. See, for example, Key et al. 2021. Can Nature-Based Solutions Deliver a Win-Win for Biodiversity and Climate Change Adaptation? Unpublished manuscript, available at: https://www.preprints.org/manuscript/202110.0336/v1
50. Thacker S, Adshead D, Fantini C, Palmer R, Ghosal R, Adeoti T, Morgan G, Stratton-Short S. 2021. Infrastructure for Climate Action. UNOPS. Copenhagen.
51. See, for example. McKinsey. 2020. Will Infrastructure Bend or Break Under Current Climate Stress? Available at: https://www.mckinsey.com/capabilities/sustainability/our-insights/will-infrastructure-bend-or-break-under-climate-stress#/
52. https://www.naturebasedsolutionsinitiative.org/publications/cost-benefit-analysis-for-ecosystem-based-disaster-risk-reduction-interventions-a-review-of-best-practices-and-existing-studies/
53. World Bank. 2023. Integrating Gender and Social Inclusion in Nature-Based Solutions: Guidance Note. Washington.
54. Vertipooles and habitat tiles are vertical artificial rock pools that provide habitats to marine species.
55. Carbon reduction has been achieved through the construction of the railway itself, by shifting cargo movements from trucks to rail.
56. National Highways is a government-owned company charged with operating, maintaining and improving motorways and major roads in England. It also sets highways standards used by all four UK administrations, through the Design Manual for Roads and Bridges.
57. See: https://www.gov.uk/guidance/biodiversity-metric-calculate-the-biodiversity-net-gain-of-a-project-or-development
58. See: https://www.gov.uk/government/publications/mod-sustainability-and-environmental-appraisal-tool-handbook
59. United States Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator. Found here: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator
60. An ICW is a low energy, nature-based method of wastewater treatment.
61. Yorkshire Water is a water supply and treatment utility company in the UK.
62. Living shorelines use natural or recycled materials, along with the strategic placement of plants and/or other organic material, to reduce erosion, protect property, create habitats and enhance coastal resilience. Living shorelines work best in low energy environments, such as bays and estuaries or other areas protected from large waves.
63. Modern waste-to-energy facilities take non-hazardous waste – otherwise destined for landfills or dump sites – and combusts it, generating steam for green electricity. Slag is processed to recover metal for recycling while all gases are collected, filtered and cleaned to minimise environmental impacts. It particularly helps eliminate plastics which are non-biodegradable and could easily be carried to the marine environment from the landfill or dump site, causing irreversible ecological impact to marine organisms.

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