GEO FOR BUSINESS

GLOBAL ENVIRONMENT OUTLOOK

UN environment programme

50 1972-2022

Future-proofing Infrastructure to address the climate, biodiversity and pollution crises

ISBN No: 978-92-807-3899-5

Job No: DEW/2397/NA

Cover design: Joseph Shmidt-Klingenberg and Sebastian Obermeyer

Graphic Design: Joseph Shmidt-Klingenberg and Sebastian Obermeyer

Layout: Jinita Dodhia/ UNON, Publishing Services Section/Nairobi

Disclaimers

Suggested citation: United Nations Environment Programme (2021). Future proofing infrastructure to address the climate, biodiversity and pollution crises. UNEP, Nairobi.

Future-proofing Infrastructure to Address the Climate, Biodiversity and Pollution Crises

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About GEO for Business

The United Nations Environment Programme [UNEP] and its global partners are proud to offer this series of stimulating briefs about the environmental challenges and business opportunities that demand transformational change at a global scale. These business briefs are meant to communicate the science of the environment to a broad business audience and provide possible pathways and roadmaps that business can follow to address these environmental challenges. The audiences these briefs hope to reach include companies in the supply chains of major multinationals, multinationals themselves as well as small to medium-sized enterprises. The themes of the first 5 briefs include:

- how to transform in a time of uncertainty,
- how to transform business models towards a fully circular model,
- how to transform global food systems,
- how to build environmentally sustainable and resilient infrastructure,
- and the role finance needs to take in a transforming world.

Key Messages

Infrastructure is both impacted by and impacts the environment in various feedback loops.

Between 1998 and 2017, climate-related disasters accounted for 91 per cent of all recorded disasters, with floods being 43 per cent of these events, affecting 2 billion people, mostly in Asia and Africa. In the future, extreme events are expected to have more severe impacts on infrastructure, such as:

- sea level rise, caused by ocean warming and sea ice melt, which will damage protective walls, create more flooding and saltwater intrusions, and inundate low-lying coastal cities
- temperature increases on land, which will accelerate the ageing of infrastructure through heatwaves and changes in freeze-thaw patterns resulting in further infrastructure degradation
- wildfires, which will increase in frequency and intensity, damaging infrastructure in their wake, and
- hurricanes and cyclones, which will increase in frequency and intensity, damaging or destroying infrastructure with the financial cost borne by national economies and the insurance industry.

Building conventional "grey" infrastructure tends to "lock in" carbon, biodiversity loss and pollution impacts.

This happens through the building and use of fossil fuel-based assets (for example, coal-fired power plants and roadways), which lead to more greenhouse gas emissions, degrade local air quality and fragment habitats that are critical for the movement of biodiversity. The production of steel and cement, which are manufactured using significant amounts of coal and energy from fossil fuels, means that traditional infrastructure has embodied emissions that cannot be eliminated by efficiency measures alone.

The public and private sectors can work better together to transform the design, refurbishment and building of infrastructure by:

- bringing relevant private sector actors into public planning and policy design dialogues, which not only ensures adherence to public procurement rules but drives innovation
- coordinating in areas such as strategy setting, mapping stakeholders' interests and influence, data gathering, prioritizing and planning, policy and project development, pre-tender consultations, and permitting
- tendering in ways that help innovations penetrate markets faster
- developing performance-based legislation incentives that remunerate companies that are active agents of change
- removing investment barriers in ways that, for example, accredit or reimburse adaptation-ready infrastructure investments or adapt price control mechanisms to reflect longer asset lifespans, and
- recruiting in ways that provide full and productive employment and decent work for all, including women and young people.

Businesses, both public and private, can benefit from this transformation through reduced risks, fewer stranded assets and new market opportunities.

Both private companies that are contracted by government through procurement processes and those that build infrastructure for their own needs can reduce risks, lower costs, end up with fewer stranded assets and open new markets by designing and building climate-proof nature-positive infrastructure. The key steps needed to achieve this transformation are:

- Integrate planning and design so that infrastructure is viewed as a system of systems, considering interconnections across sectors, between governance levels, across space and time and across all phases of an infrastructure's life cycle.
- Consider the multiple co-benefits of incorporating nature-based solutions, including hybridized blue-green-grey infrastructure, to help regulate water flows, reduce the heat island effect, treat wastewater, reduce stormwater run-off and improve water supplies.
- Add new metrics to infrastructure design and monitoring, such as biodiversity net gain, where infrastructure development leaves biodiversity in a measurably better state than before.
- Decarbonize and detoxify energy systems by considering renewable energy in new or existing infrastructure designs.
- Upgrade and expand zero-emission vehicle infrastructure so that electrification or zero-emission fuels become the new standard.
- Prioritize smart mobility, transit-oriented bicycle and walking infrastructure in new or refurbished designs.
- Focus on resource-efficient, compact and mixed-use urbanization as well as net-zero carbon building designs.
- Integrate water resource use efficiency in the design of infrastructure as well as a circular economy for waste.

Finally, public and private sector actors should focus on socially inclusive, people-centred infrastructure design to avoid effects like green gentrification or displacement of people living in poverty or informal settlements. Meaningful participatory engagement with all stakeholders is essential at all stages of an asset's lifespan, but especially in the planning and design stages. Strategic foresight and scenario planning are useful for identifying, mitigating or avoiding potential risks and improving coordination. Business is a critical partner in designing and building environmentally sustainable, inclusive and just infrastructure to help transform our world, as called for in the 2030 Agenda and Sustainable Development Goals (SDGs).

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1. Why do we need to build climate-proof nature-positive infrastructure?

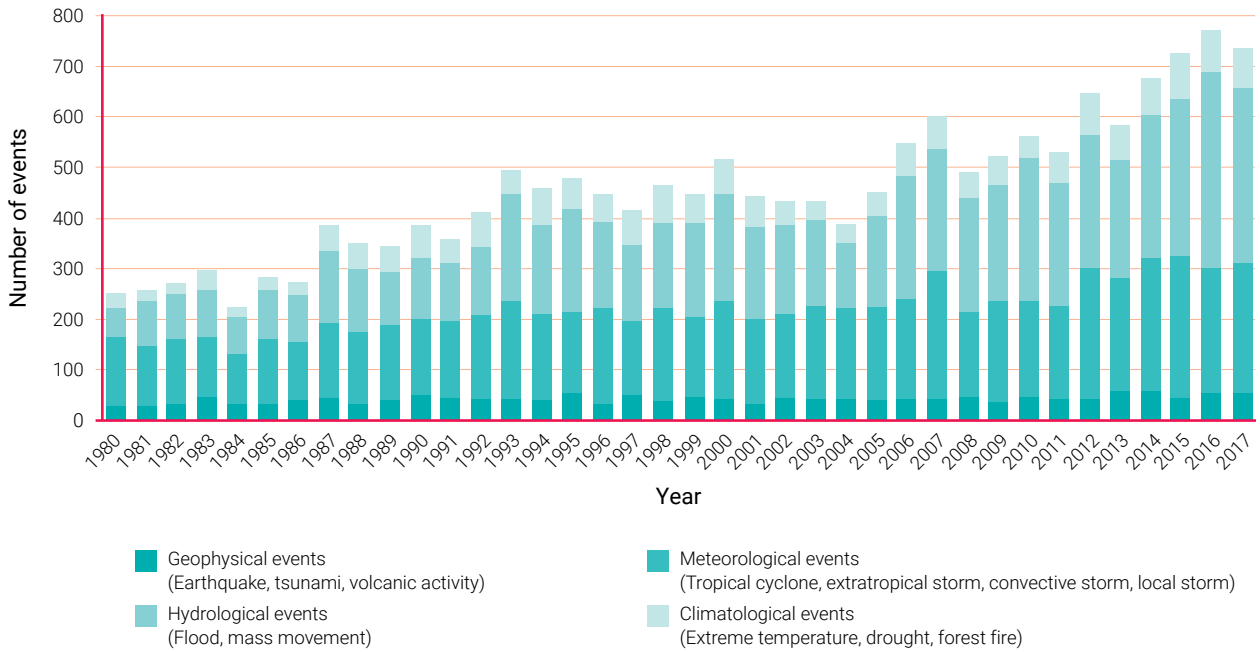
Businesses can benefit substantially from climate-proofing infrastructure through reduced risks, lower costs, fewer stranded assets and new market opportunities, such as enabling diverse local industries. Upscaling resilient, accessible, low carbon, and quality infrastructure is a prerequisite for achieving the 2030 Agenda for Sustainable Development and the Paris Agreement. Climate-proof nature-positive infrastructure further enhances environmental quality and systems' capacity to bounce back after shocks and helps achieve broader societal goals, such as social inclusion, health, knowledge-sharing and gender equality.

Despite increased recognition of the short- and long-term value generated by these transformations, significant movement away from fossil fuel-based and nature-negative infrastructure assets has yet to happen.[1] Meanwhile, many conventional infrastructure developments continue to cause irreparable environmental damage, economies face significant infrastructure gaps (about $15 trillion between 2016 and 2040),[2] and government policies do not sufficiently promote, and at times even hinder, innovation (see GEO for Cities Report).[3]

Infrastructure is both impacted by and impacts the environment in various feedback loops. Global average temperatures have risen more than 1°C since pre-industrial times with the building of fossil fuel-based infrastructure, resulting in more extreme weather events that then directly impact infrastructure. Between 1998 and 2017, climate-related disasters accounted for 91 per cent of all recorded disasters, with floods being 43 per cent of these events, affecting 2 billion people, mostly in Asia and Africa.[4] In the future, we can expect impacts such as:

- sea level rise, caused by ocean warming and sea ice melt, which will damage protective walls, create more flooding and saltwater intrusions, and inundate low-lying coastal cities
- temperature increases on land, which will accelerate the ageing of infrastructure through heatwaves and changes in freeze-thaw patterns
- wildfires, which will increase in frequency and

Figure 1: Analysis by Munich RE, a reinsurer, of the increase in the frequency of loss-relevant extreme weather events. Note: These events are already estimated to have resulted in the loss of 400,000 lives and have cost the global economy $1.2 trillion annually, wiping 1.6 per cent from global GDP.[7]



intensity, damaging infrastructure in their wake, and
- hurricanes and cyclones, which will increase in frequency and intensity, damaging or destroying infrastructure[5] – with the financial cost borne by national economies and the insurance industry **(Figure 1)**.[6]

Climate change is now its own driver of environmental change, as recognized for the first time in the United Nations Environment Programme's (UNEP) sixth Global Environment Outlook (GEO).[7]

Building traditional infrastructure also contributes to lock-in effects in which the use of fossil fuel-based assets (for example, coal-fired power plants) encourages activities that produce greenhouse gas emissions, degrade local air quality and cause habitat fragmentation.[8] The production of steel and cement, which are manufactured using a significant amount of coal, means traditional infrastructure's embodied emissions cannot be eliminated by efficiency measures alone.[9] Resource extraction and processing, which has more than tripled since 1970, contributes half of global greenhouse gas emissions and over 90 per cent of biodiversity loss and water stress.[10] Unless significant measures are taken to build circularity and environmental sustainability into infrastructure value chains,[11, 12] global material use could double to 190 billion tonnes by 2060, increasing greenhouse gas emissions by 43 per cent.[10]

1.1. Surviving or thriving as a business in an uncertain future

The COVID-19 pandemic has highlighted many vulnerabilities, including the way infrastructure investments are prioritized, leaving almost no corner of the planet untouched. Many businesses have suffered. Economic and social inequalities are widening, with risks and benefits not shared equitably across infrastructure owners, users, investors, ratepayers and communities living with basic infrastructure deficits.[3] Meanwhile, many firms suffer economic losses when stranded infrastructure assets are written down, devalued or converted to liabilities. Over the course of nine months in 2019 and 2020, the top oil and gas companies wrote down $87 billion worth of assets, directly affecting the value of their supporting infrastructure.[13] In the face of such long-term, systemic and existential changes, business cannot afford to continue along the same trajectory.

However, COVID-19 has also allowed us to take stock of the current situation and decide to build forward better. As countries emerge from the pandemic more fiscally constrained, many governments will reprioritize infrastructure spending within economic stimulus measures (such as the $1 trillion infrastructure bill being debated by the United States government).[14] This financial capital must be allocated to investments that achieve multiple policy objectives and, while addressing immediate needs, also cater for the future. These forward-looking investments can help avoid more costly retrofits further down the line. They can include low-carbon and renewable energy infrastructure, building retrofits, disaster response and early warnings, resilient healthcare systems, integrated waste management systems, digital connectivity, and hybridized green-grey-blue infrastructure. Businesses must manage their investment portfolios and partner with cities in new ways to reduce risk exposure, build resilience and optimize cross-sectoral benefits.

At the same time, other governments may cut committed infrastructure spending to save money. In an overtaxed, uncertain and overborrowed world where affordability is key, business investment in infrastructure must drive environmentally sustainable growth. In the past, infrastructure innovations have emerged from crises. For example, Cape Town recovered from a 2019 water crisis by diversifying to desalinized and groundwater sources and human-centred Water Sensitive Urban Design.[15] Lima managed drought by reactivating and upscaling nature-based water harvesting using pre-Incan technologies.

Thus, the aim of this brief is to offer practical recommendations for businesses, both public and private, on how to future-proof infrastructure against the effects of climate change and other risks and ensure that infrastructure investments contribute to sustainable development objectives over the medium (2030) to long term (2050). It also addresses actions that diverse actors in government can take to help engage the business community in developing environmentally sustainable infrastructure and create the enabling conditions for these contributions. The primary audience of this brief is businesses that have a role in planning, financing, designing, constructing, operating, maintaining and decommissioning infrastructure systems in both rural and urban contexts. This includes private investors, material manufacturers, construction companies, architecture and engineering firms, contractors, banks

and real estate brokers. They vary in size and scale of operation, from self-employed entrepreneurs to multinational corporations. Actors' interests, roles, responsibilities and influence often differ, but there may be some overlap. Recognizing the central role of the public sector in providing infrastructure, our secondary audience is government entities and other actors working with the private sector (for example, local city officials, planners, officers negotiating loans, environmental authorities issuing licenses).

This brief covers built, or "grey", infrastructure, natural, or "blue-green", infrastructure and hybrid infrastructure, which combines elements of grey and blue-green infrastructure. These types of infrastructure systems can be deployed in different sectors. This report focuses on energy (generation, transmission, distribution); transportation (anything that conveys materials, including public, cargo, freight and passenger transport and roads, bridges, ports, waterways and maritime routes, pipelines, railways and airports); water (treatment, distribution, storage, recovery); buildings and housing (human settlements) and waste management. It also considers cross-cutting themes: communication networks, behavioural change and lifestyle choices. This brief focuses on these systems because they are among the most critical in driving future change, represent a large proportion of post-COVID-19 recovery investments, impact businesses of all sizes and are themes not discussed in other GEO for Business briefs. Infrastructure can also be perceived as a service, where it delivers nature-based solutions, circularity and digital innovations that lead to deeper transformations.

Environmentally sustainable infrastructure design forms the foundation of more prosperous communities, increasing aggregate economic output and productivity,[17] delivering essential services, creating employment in low-income or informal sectors and achieving desired developmental, financial and institutional outcomes.[18] These benefits are essential for business to succeed over the entire infrastructure life cycle. For example, to prevent flooding of ports and roads, businesses can install green roofs and water piping to accommodate inlets of potable water and outlets of greywater and rehabilitate interconnected green spaces – all of which improves wellbeing, business efficiency, competitiveness and resilience and avoids the high costs of managing waste streams.

Box 1: Defining infrastructure

Infrastructure systems are understood here to include physical assets (also referred to as "hard" infrastructure) plus the knowledge, institutions and policy frameworks ("soft" infrastructure) in which they exist and that enable them to function.

Future-proofing refers to improving existing infrastructure and investing in new infrastructure that is flexible and resilient to potential risks to service delivery, such as those from climate change and other environmental crises (for example, raising roads above the predicted increase in flood levels).

Blue or green infrastructure (or ecological or natural infrastructure) is strategically planned and managed networks of natural and semi-natural lands, such as forests and wetlands, working landscapes, and other open spaces that are designed and managed to deliver a wide range of ecosystem services and functions and provide associated benefits to human populations and biodiversity in both rural and urban settings. Blue-green infrastructure can function on its own or be incorporated within the design of grey (or built) infrastructure, resulting in hybrid infrastructure (for example, sea walls combined with oyster reefs to protect against erosion and flooding). [16]

1.2. In which direction are investments really going and where should they be going?

The Organisation for Economic Cooperation and Development (OECD) has estimated that an annual average of $6.9 trillion in climate-compatible infrastructure investment is needed over the next decade to meet global development needs.[19, 20] There is still a significant gap between these investment needs and current trends, particularly in low- and middle-income countries.[21]

There is a disconnect between the current reality and what is necessary to radically decarbonize, detoxify and dematerialize our infrastructure for generations to come. For example, as of September 2020, G20 countries had committed $212 billion (52 per cent) to fossil fuel-based infrastructure, compared with $196 billion (48 per cent) to clean energy-based infrastructure, in their stimulus and recovery spending

for the energy sector.[22] About $90 trillion is likely to be invested in infrastructure by 2030.[23] With about 70 per cent of global greenhouse gas emissions coming from infrastructure, clearly, a significant shift in investment must be made towards low-carbon infrastructure to meet intended national targets of reducing emissions by 45 per cent by 2030 and ultimately achieving net-zero emissions by 2050.[24] Globally, the construction sector uses about 65 per cent of non-metallic minerals (sand, gravel), 15 per cent of ferrous metals and 3 per cent of non-ferrous metals.[25]

However, there are pathways with the potential to begin closing the gap between where infrastructure should be and where it currently is. For example, the International Energy Agency's Sustainable Recovery Plan estimates that $1 trillion invested annually between 2020–2023 could "spur economic growth, create millions of jobs and put emissions into structural decline".[26] In the longer term, significant action is required to reduce the carbon lock-in effects of new infrastructure developments.

The environmental sustainability of infrastructure can be gauged by the extent to which it contributes to one or more SDGs without undermining others. Ninety-two per cent of the 169 SDG targets are linked to investment in current and future infrastructure assets. For example, a hospital that contributes to achieving SDG3 on health and well-being relies on access to water and sanitation, while quality education and productivity rely on access to energy. However, if such a hospital is in the middle of a critical ecosystem and runs on electricity generated from fossil fuels, it can undermine other SDGs. Given that the manner in which the SDGs interact with each other is context-specific, interdependencies need to be factored into infrastructure design and planning.[24]

If business-as-usual planning and infrastructure development continues, the planet will not be able to sustain the resource requirements and the associated environmental impacts. Therefore, businesses have to consider the environmental consequences of both their and their clientele's activities, whether community-wide or household, now and invest in new and existing cities that are far more environmentally sustainable and inclusive. Critically, the infrastructure built now will define the future of the planet.

2. The role of business in infrastructure systems

2.1 Key businesses operating in infrastructure systems and their role

Businesses involved in planning, developing and operating infrastructure can be broadly divided into two groups. The first group includes private companies that are contracted by government through procurement processes to work on public infrastructure projects. This group constitutes a significant proportion of infrastructure businesses in developing countries. For instance, in 2017, 55% of private investments in infrastructure was financed by non-private sources such as public banks, bilaterals and multilaterals.[27] Procurement processes are designed to deliver high-quality infrastructure quickly, offering the widest benefits at the lowest cost. While the infrastructure innovations discussed later in this brief have the potential to lead to large transformations, businesses are often limited in terms of the flexibility they have to propose new, more environmentally sustainable solutions.

The second group includes businesses that build infrastructure for the needs of business, such as oil and gas companies. Such businesses have more control over the design and construction of their infrastructure, being able to expedite some processes, and have a responsibility in terms of what solutions they come up with. They may have a narrower focus and shorter financial planning cycles, deliver fewer services and respond to a smaller, more homogenous set of stakeholder interests compared to the former group. However, they are also driven by market demand and still often need to obtain environmental impact assessment licenses depending on the national context.[28] In both cases, public and private actors do not operate in a vacuum, and all businesses depend on government policy.[29]

2.2 How can the public sector better collaborate with the private sector?

Before a clear roadmap can be developed for transforming infrastructure, we need to explore how the public and private sectors can work better together.

Co-creation. This involves bringing relevant private sector actors into public planning and policy design dialogues, which not only ensures adherence to public procurement rules but drives innovation. There are many benefits associated with co-creation. Take decarbonizing the transport sector through automobile electrification by way of example. Companies from three previously independent industries have different expertise that they can bring to the table. Oil and gas companies are used to long-term investments, while utility companies operate extremely complex transmission and distribution networks. Partnering with the automobile industry can rapidly accelerate the build-out of electric vehicle charging infrastructure and other supporting technologies. Urban electrification is a similar story. A study by the University of California, Berkeley showed how, with partnerships and legislative reform, the USA could enable companies to adopt a 90 per cent renewable energy grid by 2035, compared with only a 55 per cent deployment without new policies.[30] Regular consultation can also unlock higher levels of ambition, innovative business models, more integrated spatial planning and institutions, and better tendering processes.

Coordination. Successful multi-level, multi-stakeholder and cross-sectoral coordination models can take many forms and can be led by public utilities, city departments, separate legal entities, agencies or more informal structures.[31] Partnerships may cover a wide variety of infrastructure and technologies or have a specific focus (for example, district heating systems). It is crucial that the structure has a mandate and resources to bring stakeholders together. These structures' activities can include strategy setting, mapping stakeholders' interests and influence, data gathering, prioritizing and planning how to engage stakeholders, policy development, project development, pre-tender consultations, and permitting.[32] Such structures can help to scale up zoning and redirect developments away from risk areas while prioritizing strategic density, connectivity, public spaces, urban design, placemaking and rural-urban interdependencies. [33, 34] Coordination platforms can also allow co-investment platforms to pool public and private financial capital. Care must be taken because some local to national governments

do this well, while others do not, opening possibilities for collusion or corruption. Capacity needs to be built to enable coordination at multiple levels, build institutional memory and transfer knowledge internationally.

Tendering. This is an opportunity for the public sector to tap into the innovative power of the private sector and help innovations penetrate markets more quickly. Public authorities can revise narrower procurement criteria for additional services or for multiple options that may not be the cheapest initially but bring in more environmental sustainability, service quality, inclusiveness and integration considerations. For example, performance-based specifications can incentivize and catalyse innovation by specifying expected social and environmental sustainability targets for infrastructure development without being prescriptive about the means for achieving them. Reforming tendering processes has been shown in some cases to be more effective than traditional technology-push measures. It is important to have wide-ranging feasibility analyses and consultations. This requires tendering capacity to be built within cities, providing access to neutral expert advice while not overcomplicating the tendering process.[35]

Performance-based legislation. Such incentives remunerate companies that are active agents of change, enhance the quality of legislation and respond to rapidly developing technology. Here, governments define the regulations and functional standards intended to control aspects of infrastructure design, construction, materials, use and maintenance. For instance, in lending, the public sector can screen for exposure to risks of climate change[36] or debt subordination. Building codes can increase the lifespan of infrastructure, protect asset returns and improve the reliability of service provision[37]. Vehicle and fuel economy standards can stimulate manufacturers to improve fuel efficiency.

Investment barriers and price control mechanisms. Governments can help to remove investment barriers (for example, high investment costs, exclusionary effects). For instance, governments can revise regulations that accredit or reimburse adaptation-ready infrastructure investments or adapt price control mechanisms to reflect longer asset lifespans. Meanwhile, the private sector can lower discount rates to increase the value of future benefit impacts relative to near-term impacts. Natural capital accounting can help bring out nature-based solutions' multiple benefits when calculating the return on investment.

2.3 Increasing business resilience to environmental risks

In a world where pandemics and climate change are the "new normal" and resource scarcity a latent stressor, key emerging resilience risks will set new priorities for business leaders. Risks may include:

Disruption of value chains. COVID-19 highlighted the fragility of global value chains and associated infrastructure. For example, in 2020, oil suppliers in the USA were unable to ramp down production fast enough to meet the abrupt decline in demand. Oil prices went negative for the first time in history.[38] Likewise, in the future, extreme events could lead to interruptions in energy supply, resulting in skyrocketing prices for businesses whose profits are heavily dependent on energy prices (for example, commercial transportation, agriculture, industrial manufacturers) or that have a global supply chain (for example, the construction industry: building products and workforce). To counter this, businesses will need to make provision for disruptions (for example, building more flexibility into contracts, stress-testing infrastructure to withstand shocks).

Stranded assets. As extreme weather events grow in frequency and intensity, so could the risks of interruptions in centralized power grids and Information and Communication Technology (ICT) manufacturing operations **(Figure 2, Table 1)**. This could lead to higher costs and lower profitability. For instance, in 2019, some of California's deadliest wildfires were caused by neglected power lines in drought-prone, isolated areas relying on antiquated centralized electricity systems. More than 2.7 million people, as well as hospitals, schools, homes, gas stations, grocery stores and other businesses, experienced a public safety shutoff of the power grid, and had to use diesel and gasoline generators where possible.[39] Changes to rainfall patterns due to climate and land-use change could also lead to stranded assets, with widespread macroeconomic ramifications. Beyond climate change, growing disparities in access to ICT infrastructure worldwide, which is amplified by differences in wealth and education, also pose a risk to business. An estimated 51 per cent of the global population is still not connected to the internet, even though most of these people live within areas with 2G or 3G access.[40]

To manage stranded assets in the energy sector, for example, business must drive the penetration

of decentralized renewable energy, provide storage options to counter intermittency, retrofit buildings to reduce energy consumption and introduce apps that can monitor and change energy consumption. Moreover, ICT companies will have to reduce their carbon, energy and water intensity and toxic material usage – for example, data centres account for about 1 per cent of the world's total energy consumption.[41] ICT companies often rely on non-renewable minerals from mined metals that contribute to more water-related pollution,[42] while data centres can require high volumes of water to cool semiconductors.

Figure 2 provides an overview of the other disruptions that businesses may face because of these environmental challenges.

Changing workforce. Companies that invest in sustainable infrastructure will be increasingly attractive to a workforce that has an environmental ethic. These employees will be more attracted to businesses that invest in training and upskilling, thereby improving manager-employee relationships. More staff will want to be treated fairly, get recognition, operate with flexibility, receive challenging opportunities, work remotely and be paid fairly and competitively, and have gender parity and diversity in the workplace.

Informality. By 2050, 2-3 billion people, or 35-50 per cent of the urban population, are expected to live in informal settlements (low-quality houses or shacks built outside formal regulations, often in areas more exposed to natural disasters). Much of the workforce for the informal economy comes from these areas, and informality contributes one to two-thirds of global GDP, especially in low- and middle-income economies.[44, 45] Addressing the rise in informality is critical for business to survive because inequality fuels disputes over resources,

Figure 2: Examples of how climate change will likely impact infrastructure (adapted from [43])

= High confidence

= Medium confidence

= Low confidence

1. Disruption of public water supply due to lower summer rainfall
2. Increased wind damage to above ground infrastructure
3. Increased frequency of river and surface water flooding
4. Increased delays and safety risks due to rail track during heatwaves
5. Increased ICT faults due to lightning strikes
6. Changes in yield from renewable energy sources (onshore and offshore)
7. Disruption to offshore operations including energy extraction/ generation
8. Increased subsidence disrupting subterranean infrastructure
9. Reduced efficiency of waste treatment processes
10. Reduced power line capacity
11. Changes to vegetation and to performance of natural or 'green infrastructure'
12. Increased frequency of coastal flooding due to rising sea level
13. Loss of beaches that provide natural protection to low-lying coastal areas

Table 1: Key links between climate impacts and infrastructure sectors (adapted from [43])

	Climate Impact																			
	Sea level rise				Rainfall						Temperature						Other			
Infrastructure Sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Rail Transport	X				X	X	X	X		X	X	X	X	X		X	X	X			X
Road transport	X				X	X		X		X	X	X	X	X		X		X	X	X	X
Inland waterway transport	X	X		X		X					X	X	X						X		X
Ports and marine transport	X		X	X	X	X	X	X		X	X	X	X	X	X	X					X
Potable water	X																				
Waste water sanitation	X	X	X		X	X	X		X		X	X	X	X	X						
Flood and coastal erosion management	X	X		X	X	X				X	X			X	X						X
Information and communication technology	X			X	X	X	X				X	X	X				X				X
Solid waste	X			X	X	X	X		X	X	X		X		X						X
Nuclear, coal, oil and gas energy	X			X	X	X	X			X	X	X	X								X
Renewable energy generation	X				X	X	X	X					X							X	X
Power systems, transmission and distribution	X				X	X					X		X				X				X
Energy demand	X				X	X	X				X	X				X				X	

Key:

1. Damage or disruption from Coastal flooding
2. Tidelocking
3. Saline intrusion
4. Coastal erosion
5. Damage or disruption from River flooding
6. Damage or disruption from Pluvial flooding
7. Droughts and low precipitation
8. Altered capability or efficiency
9. Biological processes and/or disease
10. Stability of earthworks
11. Severe heat
12. Severe cold, snow and ice
13. Altered capacity or efficiency
14. Subsidence and/or desiccation
15. Biological processes and/or disease
16. Demand for service
17. Lighting strikes
18. Humidity
19. Solar radiation
20. Fog
21. Storminess and wind damage

which in turn manifests in crime, conflict, corruption, policy uncertainty and a vicious cycle of discouraging investor confidence, among other things.[46] There are significant opportunities for business to build infrastructure in informal settlements. For instance, landlords often build infrastructure like pit latrines and charge for it, yet currently, these enterprises are not formally recognized. Business can invest in self-built, in-situ upgrading in informal settlements, ensuring that safety regulations for construction are adhered to while working with communities and government to service those with the lowest incomes and those without tenure.

Investment ratings. Between 1990 and 2015, urban areas expanded by a ratio of 5:1 in relation to urban population growth.[47] Businesses will have to respond to changing consumer demand to build infrastructure that is designed to ensure densification rather than sprawl and avoid cutting into prime agricultural areas.[48] If not, companies' financial ratings could be threatened due to food security and economic development trade-offs.[8]

Transportation infrastructure development, particularly in developing countries, can lead to greater access to natural resources, increasing the economic viability of extractive logging [49-51], non-timber products, and hunting activities[52]. This can threaten the reputation of companies if the infrastructure they are building leads to indirect impacts on deforestation and fragmentation. This has been shown, for example, in the Brazilian Amazonia, where 94.9 per cent of all deforestation occurs within 5.5 metres of paved or unpaved roads or within 1 kilometre of a navigable river. [53] By 2030, in Africa, transportation corridors could fragment over 400 existing protected areas and degrade a further 1,800 or so protected areas.[54]

Global estimates show that about 25 million kilometres of new transportation infrastructure are expected to be built by 2050. [55] Companies' investment ratings could be at risk, especially those whose valuations are driven by brand and reputation and require a social licence to operate and access to raw materials. This increase in transportation infrastructure may also pose new risks, such as cultural dissolution, poaching, land-use conflicts and widening inequalities. Businesses will need to apply the "mitigation hierarchy", a set of guidelines that strives to minimize environmental and wildlife impact and achieve net-zero biodiversity loss.[56]

The construction of new infrastructure has been shown to lead to greater human-wildlife conflict or contact,[57] potentially increasing the likelihood of transfer of pathogens.[58] Agropastoral communities could have their livelihoods impacted and potentially blame investors and contractors. The amount of material that infrastructure consumes also puts remote areas under a lot of pressure, mainly through mining activities. Conversely, businesses can help prevent security threats while securing livelihoods and engaging communities.[18] For instance, in the Masungi Georeserve in the Philippines, businesses worked with government to invest in community water provision and protect the tourism industry.[59]

Resource constraints. As entirely new industries are formed to decarbonize the economy, infrastructure businesses must be aware of both the short- and long-term product risks associated with new and expanding resource constraints.[60] For example, lithium-ion battery demand to support photovoltaics is expected to grow by 280 per cent from 2016 through 2030,[61, 62] resulting in a significant increase in demand for cobalt of between 235 and 430 kiloton by 2030.[63] Such a dramatic increase could disrupt commodity prices and global supply, affecting all businesses that produce battery products.

3. How can business drive environmental sustainability in infrastructure systems?

Considering the world's infrastructure will more than double in the next 20 years, a very narrow window of opportunity is presently available to make this infrastructure more environmentally sustainable.[64, 65] It makes sense for businesses to invest in the following design innovations which will be required to contribute to this transformation.

3.1 Integrate approaches through systems thinking

Critically, integrated planning and design views infrastructure as a system of systems, considering interconnections across sectors, between governance levels, across space and time and across all phases of an infrastructure's life cycle. For example, as the planet warms, the urban heat island effect intensifies,[66] and demand for air conditioning grows. District heating and cooling is a major business opportunity and helps to ensure healthy living conditions.[67] In dense urban areas, district heating radically increases thermal efficiencies and decreases heat loss through heat recycling, combined heat and power systems, and economies of scale.[68]

Box 2 presents ten principles that can be used to support integrated, systems-level approaches to sustainable infrastructure that can increase governments and other stakeholders' abilities to meet a given level of service needs with less infrastructure that is more resource-efficient, resilient and cost effective, less polluting and has fewer risks than business-as-usual approaches.

3.1.1 Hybrid green, blue and grey infrastructure

Because of their multiple co-benefits, nature-based solutions are now being strongly advocated worldwide to help deliver a range of services, including regulating water flows, reducing the heat island effect, treating

Box 2: Ten guiding principles for sustainable infrastructure[69]

1. **Strategic planning** to ensure the alignment of infrastructure policies and decisions with global sustainable development agendas and to strengthen the enabling environment.
2. **Responsive, resilient and flexible service provision** to meet actual infrastructure needs, allow for changes and uncertainties over time, and promote synergies between infrastructure projects and systems.
3. **Comprehensive life cycle assessment of sustainability,** including the cumulative impacts of multiple infrastructure systems on ecosystems and communities over their entire lifespans, to avoid "locking in" infrastructure projects and systems with various adverse effects.
4. **Avoiding environmental impacts** of infrastructure systems and investing in natural infrastructure to make use of nature's ability to provide essential, cost-effective infrastructure services and provide multiple co-benefits for people and the planet.
5. **Resource efficiency and circularity** to minimize infrastructure's natural resource footprint, reduce emissions, waste, and other pollutants, and increase the efficiency and affordability of services.
6. **Equity, inclusiveness, and empowerment** through a balance between social and economic infrastructure investment to protect human rights and promote well-being, particularly of more vulnerable or marginalized groups.
7. **Enhancing economic benefits** through employment generation and support for the local economy.
8. **Fiscal sustainability and innovative financing** to close the infrastructure investment gap within the context of increasingly constrained public budgets.
9. **Transparent, inclusive and participatory decision-making** that includes stakeholder analysis, ongoing public participation and grievance mechanisms for all stakeholders.
10. **Evidence-based decision-making** that includes regular monitoring of infrastructure performance and impacts based on key performance indicators and the promotion of data sharing with all stakeholders.

wastewater, reducing stormwater run-off and improving water supplies. These applications have many benefits for businesses, as these solutions are often more cost-effective to build and maintain than conventional infrastructure and are well suited to the use of local resources and labour, which helps with the sustainability and reliability of supply chains **(Table 2)**.[70] They can also create numerous co-benefits that are especially relevant in the context of COVID-19, including employment creation and green jobs and improved living conditions in low-income settlements **(Figure 3)**.[71] **Table 2 and Annex 1** illustrate practical measures for businesses to adopt blue-green infrastructure for the built environment.

Table 2: Examples of existing business initiatives building resilience and multiple co-benefits through blue-green infrastructure

Location	Intervention	Business cost savings and social and environmental co-benefits	Source
Besos River, Spain	Restored constructed wetlands and riparian systems to polish treated wastewater from large conventional treatment plants.	Flood control, habitat restoration, preservation of 200 bird species, water reuse and improved soil quality. Leisure opportunities. Revenue from more than 1 million visitors per year.	[72]
Somalia	Emergency drought response and recovery project. Sand or subsurface dams in ephemeral riverbeds increased access to underutilized water supplies for domestic and livestock use.	Capture, direct, and store water in soil, aquifers, or reservoirs, combined with traditional grey infrastructure to enhance water harvesting, increase soil moisture, replenish the water table, avoid water losses from evaporation and run-off, poverty alleviation.	[73, 74]
Yatenga Province, Burkina Faso	Agroforestry, planting pits, stone bunds, technical measures to control surface water run-off and enhance water infiltration.	Improved groundwater recharge levels, ensured wells hold water throughout the dry season, restored degraded landscapes, farmer livelihoods benefits.	[75]
Pennsylvania, USA	Installed blue-green infrastructure with a sewer system to improve wastewater treatment and reduce stormwater run-off.	$120 million in avoided grey infrastructure financial capital costs, nearly $ 4.8 million in annual benefits beginning after 25 years (for example, reduced wastewater treatment and pumping costs ($661,000), energy ($2,368,000), air quality ($1,023,000), climate change benefits ($786,000)).	[73, 76]
Richmond Water Enhancement Experimental Wetland, California, USA	Companies have decommissioned industrial sites and planted wetland vegetation on 90 acres of former effluent treatment ponds.	Biodiversity resilience, pollinator habitat, habitat enhancement for bats and migratory waterfowls, nonpoint source pollution control (for example, nutrients, pesticides, sediments, suspended solids).	[77]

Figure 3: Features of sustainable infrastructure that create multiple benefits (adapted from OECD, UNEP and the World Bank Financing Climate Futures: Rethinking Infrastructure report [19]).

1. Cisterns provide storage for captured water and pressure for non-potable uses.
2. Permeable pavement along the service drive intercepts runoffs and pollutants from parcels and the road surface.
3. Shade canopies create a 'cooling corridor' over sidewalks to enable mobility during extreme heat and collect rainwater that can be used for below-ground irrigation.
4. Back-in street parking can be a safer alternative to improve lines on sight while maximizing on-street parking for residents and patrons.
5. Charging and information totem provides USB charging while waiting for public transit, displays announcements and shades the bus stop.
6. Suspended Pavement Systems provide large volumes of uncompacted soil below grade for rapid and healthy growth of street trees.
7. Subsurface Storage and Conveyance provide a regional water capture and distribution within the transportation corridor.
8. Curbless planted medians enable wheelchair accessibility from on-street parking and allow sheet-flow off-street run-off over permeable pavement. Street trees planted at intervals in tree wells provide relief from heat.
9. Protected bike lanes improve cyclist safety and provide alternative transportation.

3.1.2 Biodiversity net gain

Biodiversity net gain is where infrastructure development leaves biodiversity in a measurably better state than before. Companies can set a goal for a site or project at the corporate level or even through the supply chain. The fundamental process involves a sequence of four key actions: avoid, minimize, restore and finally offset any remaining negative impacts to achieve a net gain of biodiversity. Where natural features are irreplaceable and cannot be restored or offset once affected by development, it is critical to identify and then avoid impacts. While a proxy of "biodiversity" is measured and defined differently across countries and sectors, robust metrics are used to measure losses and gains so that gains outweigh losses. The earlier in a project life cycle this process starts, the better.[78]

Commercial advantages include:

- Smarter, more effective approaches to achieve compliance: Many governments and financial institutions already mandate biodiversity net gain as calls for COVID-19 "green recoveries" dominate plans.
- Demonstrated leadership: Committing to biodiversity net gain sends a strong message that the company is moving towards working for the overall good of biodiversity.
- Measurable outcomes: While other sustainability targets are measurable (for example, net-zero carbon, such as the Science-Based Targets Initiative, and waste), traditional measurements from development are often qualitative and confusing for people without specialist knowledge. Measurable outcomes provide clarity in communication at all levels of a company, from construction teams to senior executives.[78]

Practical avoidance and mitigation measures include:

- Work with government to better align roads and rail connections through development corridors with cross-border connections. This reduces costs, particularly in landlocked countries where transport costs account for 20–60 per cent of delivered food prices.[79]
- Secure wildlife permeability across seasons for roads, railways and pipelines, using culverts, monitoring animal crossing points and underpasses, controlling traffic speeds, and minimizing fencing.[80]
- Avoid the spread of non-native species by applying national guidelines.[81]
- Work with local structures, including local and indigenous peoples, already protecting biodiversity.[82]
- Design engineering solutions to avoid impacts on biodiversity by applying International Finance Corporation standards,[83] green investment guidelines[84] or other international benchmarks.

Practical net gain measures include:

- Create more high-quality habitats.
- Develop long-term habitat management and monitoring plans for climate resilience.
- Boost the resources available for native species to thrive.
- Expand protected areas, especially where protected areas are accessible via roads or navigable rivers. Protected areas have four times less deforestation than unprotected areas, even when highly accessible. Companies could be in a better position to acquire access to land if best practices are adopted.[53]

3.2 Decarbonize and detoxify energy systems

3.2.1 Renewable energy and storage assets at the company level

During the 2020 COVID-19 lockdown, the global installed capacity of renewables grew by 10.3 per cent[85] while global energy demand dropped by 5 per cent,[86] the sharpest decline since World War II. Of the assets already built, coal-fired power plants were the first to go offline. Demand slumped due to their significantly higher marginal operating costs. It is now cheaper to replace 80 per cent of coal-fired power plants in the USA with renewables.[87] Energy storage paired with renewable generation can help reduce power interruptions as well as stabilize the voltage and frequency of the power supply.[88] In addition, deploying renewable energy and storage infrastructure generates green jobs[89] and has health benefits **(Table 3)**. Smart meters and variable storage can also help reduce consumption and create grid efficiencies with load shifting – this alone could save $270 billion globally in new power generation infrastructure that would otherwise have been needed.[90]

3.2.2 Renewable energy systems connected through microgrids

Businesses working in developing countries have an opportunity to partner with governments to leapfrog and skip expensive centralized power generation models (large-scale assets with high voltage distribution lines) and build out community microgrids instead. Here, individual buildings not only use energy but generate and provide reliable power to the community, thereby strengthening grid resilience.

3.2.3 Zero-emission transportation and smart mobility

Upgrade and expand zero-emission vehicle infrastructure

The widespread adoption of zero-emission vehicles (ZEVs) is essential for mitigating climate change and transforming away from internal combustion engine vehicles and their global warming contributions. Adopting ZEVs could increase business supply chain resilience, eliminate dependence on fuel delivery and reduce adverse local health effects from air pollution.

Table 3: Cases of building resilience through decarbonized energy systems

Location	Intervention	Commercial and environmental benefits	Source
Sweden	Centralized district heating systems and switched from fossil fuels to biomass and waste-based energy generation.	Drastic carbon footprint reduction (about 85g to 10g CO2/MJ between 1980 and 2015).	[68]
Netherlands	Port Authority captured residual heat and transferred this to the city.	Energy and cost savings, depending on facilities' distance from central areas and energy demand outside of industrial areas.	[91]
Southeast Asia	CleanGrid Partners announced a $100 million microgrid portfolio.	Adaptation to typhoons while providing an uninterrupted electricity supply.	[92]
Philippines	Hybrid project with a 1.4 MW solar photovoltaic system – with 2.4 MW battery storage unit, 1.2 MW of backup power and 14 km of transmission lines.	Serving 700 customers, cost savings with an expected payback of 8-9 years.	[93]
India	Clean Technology Fund and the Asian Development Bank, through a public-private partnership, constructed a solar park.	Early investment reduces project risks and creates employment.	[94]
Burkina Faso	Synergie Solaire centralizes companies' funds and skills to support NGOs financially and technically provide energy access.	Solar electrification of schools, health centres and water purification facilities. Collection and recycling of solar systems.	[95]
Republic of Gambia	United Nations Industrial Development Organization developed a training centre for young women to design, install and maintain stand-alone power systems.	City market, street lighting and other businesses are switching to 100 per cent solar.	[96]

In 2014 alone, roughly 16,000 premature deaths in the USA were caused by internal combustion engine fuel. Although an approximate 50 per cent ZEV mandate would add 10 million jobs globally,[97] businesses face significant challenges in achieving this goal. For example, while the cost of lithium-ion batteries has declined drastically over the last decade, charging stations are few and far between in many countries. While the USA has an ambitious plan to build 500,000 roadway charging stations,[98] business has yet to profit from such investments.[99]

Furthermore, significant research and development are still needed to bring to market at scale zero-emission aviation, shipping, trucking, and rail vehicles that are cost-competitive with their internal combustion energy counterparts **(Figure 4)**. The transition to ZEVs requires not only technological and economic innovations, but also customer acceptance. Further research is needed so the industry can reuse or remanufacture batteries or safely dispose of them when they are no longer viable for transport uses. They could possibly have a second life storing wind or solar energy, or their rare earth elements could be recycled while mitigating the local environmental impacts of production.[100]

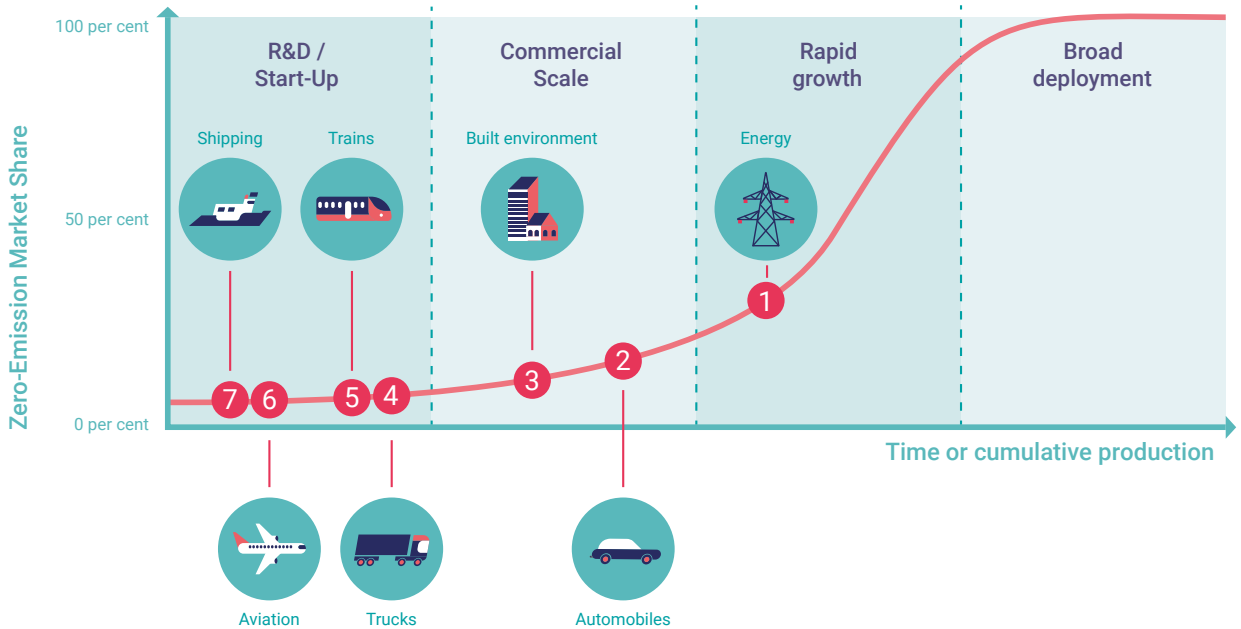
3.2.4 Smart mobility, transit-oriented bicycle and walking infrastructure

Mobility in the transportation sector is undergoing an evolution in many parts of the world, with much innovation coming from the private sector and outstripping public investments. Through public-private partnerships, companies are redesigning local transportation infrastructure layouts and shifting travel from personal vehicles to buses, trains, bicycles and walking. To keep up the pace, transit agencies are bringing on more companies to help with various interventions due to their efficiency and customer service.

Commercial benefits include:

- Demonstrates leadership: As the transportation industry deploys new technologies and experiences, the attendant cultural change and public transit's centrality to vibrant economies will be magnified.[97]
- Adds economic value, increases social inclusion and provides efficiency gains: The greater mobility of goods and people adds to the activity of other sectors.[7, 102, 103]

Figure 4: An illustrative view of the progress of sectors along the zero-emission infrastructure S-curve and their subsequent market share. Most of the subcomponents of the transportation sector (shipping, aviation, trains and trucking) are still in the R&D/start-up phase, largely due to the lack of cost-competitive, sustainable options available. Automobiles are the exception, with commercial-scale production, near-cost-competitive models currently being produced. Estimates suggest that ZEVs will be cost-competitive with internal combustion engines by 2022, which will only further accelerate the investment in charging infrastructure worldwide.



- Creates employment: Land transport accounts for more than 60 million direct jobs worldwide, representing almost 2 per cent of global employment.
- Captures land value: Integrated planning increases property value and companies' visibility.[102]
- Supports a more productive, healthy workforce: Employees who cycle to work are healthier and more productive, which saves companies on insurance costs and helps to retain staff.[97]

Businesses can contribute to transit-oriented and "15-minute cities" by:

- designing transport corridors with mixed-used density and seamless multimodal access[104]
- investing in mass public transportation over private car infrastructure [105, 106]
- locating business' operational bases where employees can commute using transport systems other than private cars
- "avoiding", "shifting", "improving" transport to create shorter, less complex supply chains, and
- building bicycle parking and investing in other active modes of transport to increase city bikeability and walkability **(Table 4)**.

Table 4: Cases of commercial benefits from bicycle infrastructure

Location	Intervention	Commercial and environmental benefits	Source
USA	Installed bikeways	Reducing the distance to off-street bikeways by a quarter of a mile increased property values and raised median home values by $510 in 2006. Time and financial savings for clients due to less congestion.	[108]
Australia	Installed bike facilities	Increased companies' visibility and sales. Per square foot, bike parking produced almost three times the revenue for businesses as car parking per hour.	[107]
Denmark	Restricted vehicle traffic and built bicycle infrastructure	Drastically reduced air pollution levels and vehicle-related fatalities in cities and increased quality of life for all.	[109]
Bangladesh	Used bicycle and cycle rickshaws	Provides door-to-door services for roads that are too narrow for large modes of transport.	[110]
Sri Lanka	Included non-motorized vehicles for two-way lane traffic design	Increased adoption of non-motorized vehicles, including bicycles, at 1.5 per cent/ year.	[110]
Taiwan	Plan to construct 12,000 km of cycling path	Increased bike use for daily shopping, work, recreation and tourism sites.	[110]
Zambia, Zimbabwe	Programme with 50,000 bicycles	Student attendance increased for 500 schools in rural areas. Bicycles designed for tough roads and high loads.	[111]
India	Bicycle Bank Programme which purchased bicycles for women and girls	Reduced travel time and access to school resulted in the increase in the number of rural female students that passed 10th grade exams. Enabled them to pursue their career.	[112]

Businesses can play a role in deploying smart mobility by:

- installing ZEV charging points, low-energy street lighting, e-buses, vehicle routing, parking systems, and road pricing (for example, tolls and congestion charges)[107, 108]
- investing in ICT infrastructure in transport (for example, navigation, autonomous vehicles, online home working, storage logistics systems through intermodal shifts, smart motors with variable speeds), and
- integrating technologies that promote easy cross-modal fare payment, route optimization and itinerary planning using smartphone apps.

3.2.5 Compact built environment

Resource-efficient, compact and mixed-use urbanization

Urban sprawl needs to be contained and the urban fabric made more compact to counter the expected doubling of housing floor space by 2050 globally. The challenge of urbanization also requires basic services (for example, water, sewage) to be improved for the nearly 2-3 billion people living in informal settlements. [113] Decarbonizing the carbon content of buildings and structures requires rapid innovation to lower demand, increase the efficiency of buildings, lower the cement and steel content, recycle or reuse materials, and repurpose buildings and structures.[114]

Commercial benefits of compact urbanization and agglomeration economies include:

- saving 38–50 per cent on upfront costs for new construction of roads, sewers, water lines and other infrastructure[113]
- attracting employees that want to work in mixed-use and transit-oriented cities, improving their quality of life, work satisfaction and performance. People living close to public transport services have been shown to work more days annually than those without such access[7, 115]
- moving products, materials and by-products while accessing services easily around the city, and
- using land more efficiently.

Practical actions businesses can take include:

- promoting strategic intensification,[105] where businesses prioritize more intensive, connected use of land, not only densification while reducing the urban footprint on agricultural land [67] (see the GlobalABC Roadmap for Buildings and Construction)
- designing urban blocks with porosity for wind flows and vertical landscaping
- avoiding "one-size-fits-all" construction solutions, and instead prioritizing place-based vernacular construction practices that save money, make operations and maintenance easier, and use local materials and indigenous techniques[34]
- designing infrastructure that generates green jobs and absorbs the “youth bulge”
- reducing the overall pressure on resources through adaptive reuse strategies to encourage conservation and renovate old buildings for new uses, by providing economically viable alternatives to vacant or under-utilized structures or premature demolition[116, 117]
- designing infrastructure, especially buildings made of steel and cement, to reduce the average material intensity of construction, which is forecasted to require between 6–8 or 8–17 tonnes/capita/year by 2050[118]
- building infrastructure using climate forecasts and insuring assets against climate risks
- powering neighbourhoods with renewable sources and waste, and
- promoting multiple incentives including green finance in the real estate industry (for example, see the UNEP Greening the Building Supply Chain Action Framework[119]).

3.2.6 Net-zero carbon buildings

Infrastructure’s long lifespan makes it essential that the built environment is designed for circularity now. The key pillars of net-zero carbon buildings are energy efficiency, life cycle assessments, the use of low-carbon or carbon-neutral cement and steel, and the generation or procurement of renewable energy. Strategies showing significant potential to reduce emissions by 2050 in G7 countries include more intensive use of homes (about 70 per cent reduction), designing buildings that use less material (8–10 per cent), sustainably harvested timber (1–8 per cent), and improved recycling of construction material (14–18 per cent). Overall, using these strategies in the G7 could result in cumulative savings in greenhouse gas emission in the period 2016–2050 of 5–7 Gt CO_2e.[113]

Design housing for behaviour change and sustainable lifestyle choices

People are more inclined to employ sustainable lifestyle behaviours if infrastructure is comparably safe, of similar quality, healthy, dependable, convenient, accessible, attractive, and reasonably priced. The design and renovation standards of housing utility systems can influence resource consumption in homes (for example, water-efficient toilet tanks, smart grid control, building automation, motion detection switches) (see the UNEP Framework for Shaping Sustainable Lifestyles).[120]

3.2.7 Water efficiency and stewardship

Integrating water resource use efficiency in the design of infrastructure

All businesses use water in one way or another. Some, such as the bottled water industry, are wholly dependent on water, some require large amounts for extraction and processing, while others only need it to support daily water requirements. Yet, access to safe water systems is one of the most significant global risks.[121] Approximately 25 per cent of water and 12 per cent of potable water used globally is associated with building infrastructure, mainly for construction purposes and occupation. Businesses can achieve efficiency gains in water resource use through planning and design and real-time monitoring of the entire water use cycle, using computer software that models and allocates optimal amounts of water across industries. [105, 122]

Repairing or retrofitting ageing infrastructure

Businesses can reduce costs from water leaks due to ageing infrastructure by repairing existing infrastructure, increasing storage and lowering contamination. For example, Malta loses approximately 30 per cent of its water through leakage, spillage and evaporation because of poor infrastructure. Businesses could save costs of irrigation water through efficiency improvements. [123] When constructing infrastructure, water management schemes need to account for unpredictable precipitation and water cycles. Further, the application of traditional water conservation methods, such as anicuts, which provide benefits to agricultural communities, should also be explored, especially while constructing large infrastructure projects in rural areas. Upgrading and retrofitting infrastructure makes industries cleaner by reducing toxic building materials and greenhouse gases. As waste-neutral policy goals become more prevalent, companies that do not participate in the circular economy risk harming their brand. [11, 12]

Corporate water stewardship

It is in the corporate interest to care about the governance of large-scale water infrastructure because water is a shared resource (see the CEO Water Mandate and its Water Resilience Coalition). Some efforts towards corporate water stewardship programmes have been undertaken through the USAID Water and Development Alliance. [124] Other companies have used technology and incentives to drive the dramatic reduction of water consumption in consumers' homes, aiming to increase water use efficiency by 35 per cent while sourcing at least 5 billion litres of water from circular sources.[125]

Inequitable access to water can also cause reputational damage, delays and financial losses for businesses.[126] For example, hydropower investments tend to benefit urban areas to the detriment of rural populations who suffer environmental and social costs.[127] Meanwhile, the cost per capita of a water connection increases exponentially when comparing highly dense megacities to remote rural areas due to reduced population density. In most drylands, groundwater is an important resource, hence aquifers need to be mapped and characterized to optimize water extraction. Alongside communities and government, businesses must work towards adaptive water governance and co-management (for example, sector-specific Integrated Water Resources Management; a "one water" approach). This involves developing efficient, flexible water systems by holistically considering all components of the water cycle and water's interaction with other sectors, from the start of the watershed through to the various points of use.

3.3 Foster the circular economy

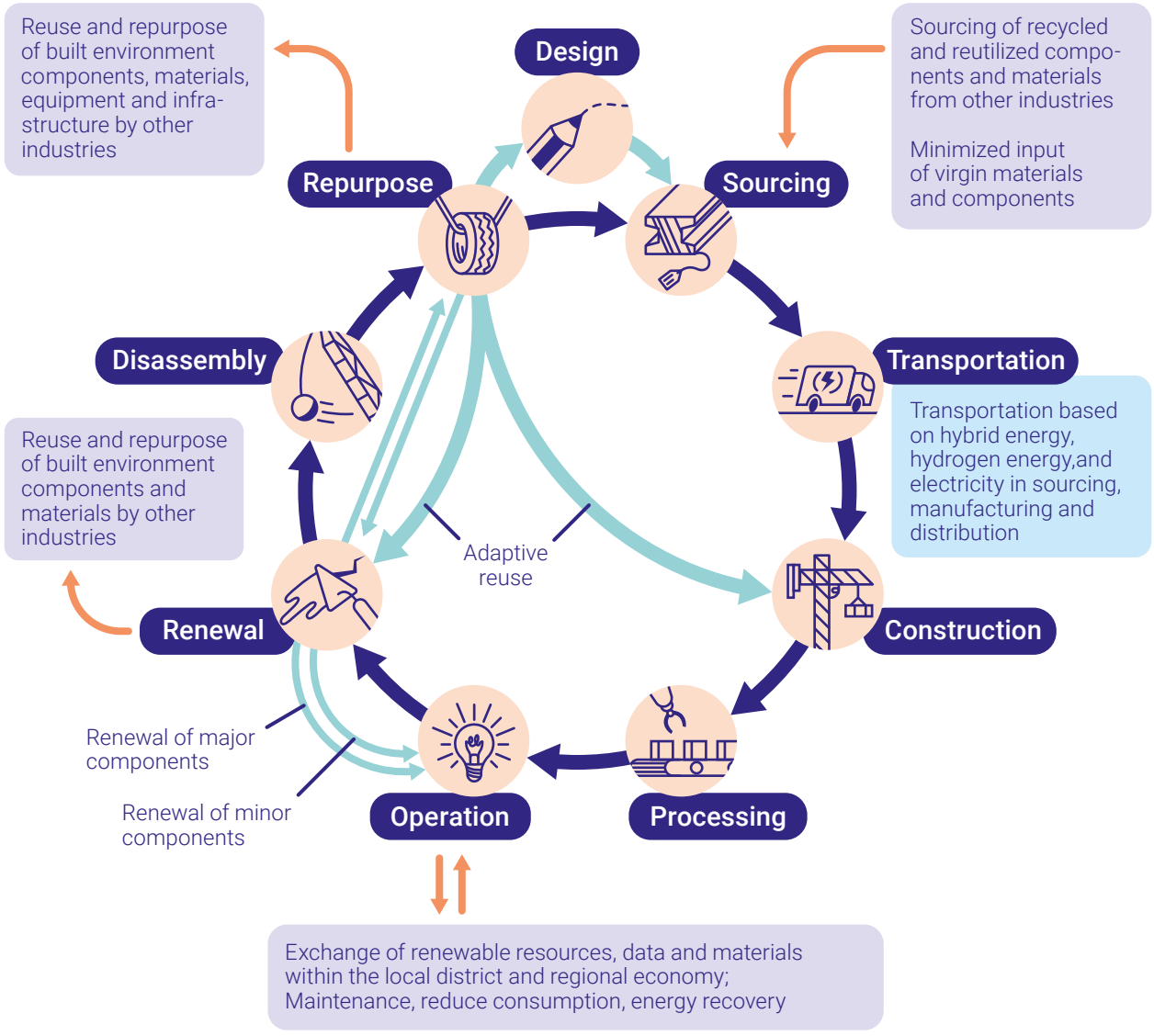
Infrastructure companies are particularly important in the design and optimization of the material conveyance systems that link cooperating firms. Circularity can be a profitable industrial activity, where separate firms and industries are networked to use resources (for example, **Figure 4**). Such activities

are part of the circular economy, which is "based on the principles of designing out waste and pollution, retaining the value of materials and products and keeping them in the economy, while also regenerating natural systems". Key elements of a circular economy that go beyond recycling include redesign, rethink, reduce, reuse, repair, refurbish, remanufacture and repurpose. [127-130]

Consumers can be engaged in end-of-life diversion programmes and educated on the importance of retaining value.[127] A report by Ellen MacArthur Foundation proposes in-depth pathways by which this can be achieved, with annual net material cost saving opportunities of $340-380 billion/year at the European Union level for a "transition scenario" and $520–630 billion/year, or a recurring 3–3.9 per cent of the European Union's 2010 GDP, for an "advanced scenario". [131, 132]

Industrial symbiosis, a subset of the circular economy, is a means of cooperatively approaching profitable and sustainable infrastructure-based activities.[128, 133] For instance, eco-industrial parks that include manufacturing and service businesses located together can mutually enhance environmental, economic and social performance.[134] Waste from one company can be inputs for another.[127] Services, utilities and by-product resources can be shared across industries to add value, reduce costs and improve the environment. [127] Such arrangements are increasingly incorporated into mega-infrastructure projects.[135]

Figure 5: Application of circular economy principles to commercial property in the built environment.[11]



Note: The entire life cycle and value chain of a product is considered when assessing circularity, as opposed to the linear process where waste generated is simply released into the environment at the end of the production process.[136, 137]

3.4 Focus on socially inclusive, people-centred infrastructure design

To be successful, infrastructure design and implementation must have a multi-stakeholder participatory consultative process. This helps identify priorities and bring investment decisions closer to the end user. If local stakeholders are not consulted, and there are negative environmental or social impacts, then protests and conflict can block operations. To retain the social licence to operate, businesses need to show real commitment through active, effective community engagement processes starting as early as possible. The importance of this cannot be overstated, as active, responsive engagement is surprisingly rare – yet it is typically at the heart of many infrastructure development challenges. Conflicts with stakeholders over infrastructure projects can have significant financial impacts on the businesses involved, both direct in terms of scheduling and budget and indirect in the form of reputational damage and the ability to win contracts.

Apply a needs-focused and community-based perspective to ensure infrastructure is aligned with sustainable development objectives and responsive to societal guidance. Businesses that apply community-based design go beyond simply providing a service or meeting a need by ensuring community participation in the implementation. This approach supports different social classes, poverty levels and forms of governance. Many indigenous communities have a long-established understanding of risk and have developed adaptive, flexible measures in response. Accounting for this knowledge is key to addressing the localized nature of risk and responding in a cost-effective way. [138, 139]

Align health outcomes with infrastructure delivery. The quality, versatility and active nature of the spaces where people live and work must evolve and thrive in a fast-changing reality. [140, 141] Yet planning and investment across health outcomes and infrastructure are rarely well-aligned.[142] Before designing infrastructure, business can conduct baseline studies to map community health assets and prioritize assets according to place-based needs (for example, family planning and nutrition).

Apply a gender-sensitive approach. Business needs to understand gendered roles in managing natural resources and using infrastructure services – and how infrastructure development can counter disparities (for example, improving the respiratory health of women who cook with fuelwood by switching to electrification). Project developers should ensure that infrastructure systems are designed to meet the different service needs of men and women, prevent adverse impacts on different genders resulting from project activities, provide equal opportunities and promote women's economic empowerment beyond temporary employment. Systematically including women's perspectives in decision-making requires institutional commitment, capacities to understand gender inclusion, mainstreamed gender responsiveness and access to information. [143]

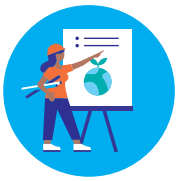
Hire locally. Recruiting staff who live nearby is sometimes a requirement for publicly funded infrastructure projects, but not necessarily for private-sector businesses. By creating local employment during construction and other phases, businesses can gain social support and ensure some profits are invested back into the community. [137] Businesses can also benefit from reduced labour disruptions and community support for the project. Employers should anticipate the impact on local communities of their choice of staff and mitigate trade-offs (for example, gentrification, driving up costs, competing skill sets).[144]

Adhere to cultural norms. It is critical that businesses understand cultural norms prior to designing infrastructure developments and amend their practices accordingly to avoid adverse ramifications (for example, cultural diffusion and violence associated with xenophobia). Community expectations of business's role can and often do differ substantially from assumptions. To better understand local assumptions of the role of business, infrastructure developers should meaningfully engage with indigenous, traditional or local authorities as early as possible. [145]

Remove language barriers that can lead to potential conflicts, affect safety during operations or reduce companies' competitiveness. Business can mitigate potential issues by offering language training, providing bilingual trainers (for example, for enrolment) and advisors (for example, for healthcare), using voice recognition translation tools, or requiring employees to obtain a level of language certification.[146]

4 Priority actions for sustainable and resilient infrastructure

This brief has reviewed the impacts of climate change on infrastructure and the impacts of infrastructure on society and the environment (in particular, biodiversity loss and pollution). It has also provided guidance on how businesses that build public or private infrastructure can increase their resilience and drive innovation in the future. Building on this brief's analysis, a roadmap of priority actions that businesses should follow – and the public policy measure that can enable and incentivize them – can be recommended. This will help to operationalize the broader sustainable infrastructure principles and go a long way to transforming our world, as called for in the 2030 Agenda and GEO-6.

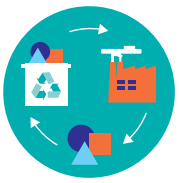


1. **Construct integrated infrastructure that optimizes systemic interdependencies and cross-sectoral partnerships.** Well-integrated infrastructure, with built-in redundancies and flexibility, can continue to operate when stressed. It has greater fiscal, institutional and technical capacity to respond and adjust to more sustainable future pathways. It allows for more spatial flexibility and optionality. Business leadership should be based on a systems-integration skill set. Sustained partnerships can help share skills between sectors, improve brand and reputation, and address interconnections, as shown in the case of the International Coalition for Sustainable Infrastructure.[147] Global Covenant of Mayors for Climate and Energy.[148] Alliance for a Climate Resilient Earth[149] and American Society of Civil Engineers' Future World Vision.[150]

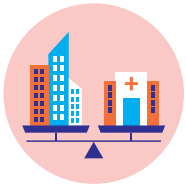
2. **Invest in resilience early to save costs.** Investing in environmental sustainability and resilience early in the asset development process is cheaper and easier and provides positive outcomes.[151] Public-private partnerships, innovative financing, different service delivery models and other financial mechanisms can accelerate the deployment of capital to future-proof essential infrastructure. In some cases, businesses can develop new revenue streams, such as selling energy and waste treatment as a service, to provide critical services without the need for governments to accrue additional debt.

3. **Deploy nature-based solutions and hybrid infrastructure in ways that benefit people and aim for biodiversity net gain.** Physical construction should not compromise ecosystems, erode human rights or destabilize politically fragile contexts.[137] Investing in blue-green and hybrid blue-green-grey infrastructure in ways founded on social equity helps reduce emissions, costs and maintenance requirements, deliver essential services, protect people and assets from hazards, and increase economic activity. The biodiversity net gain approach has widespread benefits for people, the economy and nature.

4. **Balance short-term economic considerations and timelines with investments bringing wider, long-term benefits.** In striving for a quick economic turnaround, companies often focus on short-term costs and benefits and create additional risks by bypassing consultation and transparency processes, forfeiting the social licence to operate and undermining environmental safeguards, among other things.[152] Instead, businesses should consider the entire life cycle costs and benefits and how incorporating social and environmental sustainability into infrastructure can ensure financial sustainability of assets, safeguard resilient service delivery, reduce maintenance and operation costs and the risk of stranded assets, and advance environmental and social objectives that have numerous co-benefits.[151] There are tools available for valuing the costs and benefits of infrastructure sustainability so that they can be factored into decision-making.



5. Support all levels of enterprise and green jobs with gender equity as a cross-cutting objective. To generate quality green jobs at all levels, business can train marginalized groups (including the low-income and informal sectors) to hone technical or entrepreneurial skills, strengthen micro-financing networks and cooperatives, and identify where market linkages can be created.[137] Local resource- and labour-based infrastructure development requires businesses to develop appropriate management procedures in line with the International Labour Organization's Decent Work Agenda. The private sector can support the public sector to expand infrastructure services for the urban poor, including affordable, good-quality housing.



6. Accelerate a just transition with socially inclusive infrastructure. The recent pandemic highlights the need for infrastructure to provide services to all sectors of society, particularly vulnerable or marginalized groups. Ongoing effective and inclusive engagement can not only boost morale and reputation, build trust and stimulate creative thinking,[153] it can also help avoid green gentrification and secure grievance mechanisms. Multi-stakeholder partnerships can help small- to medium-sized enterprises access adaptation resources from the private sector, enhance data access, build capacity and relationships, and support business incubation.[154] Tools such as participatory rural (and urban) appraisal can be useful for identifying and integrating different types of scientific and indigenous knowledge, involve all actors along value chains, and gauge contextual nuances, in the understanding that there is no single approach that is appropriate in every situation. No one must be left behind.

7. Apply adaptive governance and co-management based on the local context. When developing environmentally sustainable infrastructure, particularly in emerging economies, no business operates in a vacuum. The private sector must work with government to identify what works and what does not and the most efficient methods. Stakeholders such as institutional investors or banks must provide low-cost financing facilities or instruments, where the suggested public finance route is not possible at scale. Business has an important role to play in strengthening institutions for greater regional and international coordination. Business must work with local communities to co-manage infrastructure at all stages of assets' lifespans, but especially in the planning, design, and monitoring stages.

8. Facilitate new sustainable lifestyles and modes of mobility with digital technology and infrastructure. Businesses have a major opportunity to improve patterns of mobility and modes of operation across all sectors using ICT, from transport (for example, remote working) and the built environment (for example, smart cities) to energy (for example, district heating). The use of digital technology can both reduce the amount of physical infrastructure that needs to be built (for example, by enabling remote working) and improve the sustainability of infrastructure systems. Digital infrastructure can go a long way towards reducing carbon footprints, strengthening the circular economy and improving flexibility for resilience. Digital technology can also help to enable circularity and integration, which allow for greater fiscal, institutional and technical capacity to adjust to more environmentally sustainable future pathways. It allows for more spatial flexibility and optionality.

9. Utilize scenario planning and strategic planning to align infrastructure spending with the SDGs and the Paris Agreement. Beginning an infrastructure investment with scenario planning can help prepare for a range of potential futures, including the extent of exposure to key physical risks to infrastructure from direct (for example, property damage) or indirect losses (for example, forgone economic activity from disruption) or legal implications (for example, if climate risk disruption means companies cannot deliver against their contracts).[155] Strategic planning allows business to evaluate how reliant particular regions are on the most critical materials, equipment, products and suppliers, and helps them to plan, design, build and operate new assets that account for the climate changes that will occur over their lifetime.[137, 145] Scenarios can test corporate risk management and governance systems to ensure they are robust enough to provide early warnings of any potential cost, time or contractual issues.[151]

10. Implement robust contingency planning and monitoring. Quality environmental impact assessments following international standards constitute effective tools for assessing how likely it is that infrastructure developments will lead to unintended consequences and unexpected costs, especially when employed early on.[151, 156] Yet they are rarely effectively used. Environmental assessments support evidence-based decision making, corporate social responsibility and brand image. The combination of good environmental impact assessments together with industry standards (for example, the International Standards for Sustainable Infrastructure) can be significant enablers for business. Furthermore, digital tools can support contingency planning and monitoring of the environmental and social impact of infrastructure developments. However, policy reform is needed to speed up the process of obtaining consent for environmental impact assessments and bring down costs so businesses can fully benefit from these tools when designing and evidencing the business case for climate-proof nature-positive infrastructure.

References

A link to all of the references can be found here.

Glossary

A link to the glossary can be found here.

Annex 1: Examples of practical measures for businesses to adopt blue-green infrastructure for the built environment

Blue-green infrastructure uses	Solutions	Examples	Business effects	Source
Cooling and reducing the heat island effect and pollution	Planting stormwater, native and drought-tolerant trees, green roofs, and vegetation (for example, shrubs, grasses, groundcover)	Vegetation that reduces the urban heat island effect by shading buildings, deflecting radiation, and releasing moisture into the atmosphere, reducing paved surfaces in public spaces (e.g., in streets, pavements, vacant lots, squares, along roadsides), increasing infiltration and roadside cooling.	Reduces energy costs for air conditioning, provides access to tax credits for installing green roofs, reputational and aesthetic gains.	[77, 157, 158]
Wastewater treatment	Constructed wetlands	Wetlands that remove pollutants and excess nutrients before wastewater is discharged into the environment.	Improves the quality of water before it is discharged into the environment, while creating natural landscapes in urban areas, protecting infrastructure from floods, improving cost effectiveness, avoiding water contamination when the combined sewer overflow is higher than expected, useful in rural and older cities (where domestic and municipal wastewater, run-off and stormwater are collected in the same pipe network).	[159]
	Treatment channels	Channels are used to treat industrial water, by strategically placing rocks within naturally occurring streams, lining channels with limestone to naturally balance acidic waters without using chemicals.		[24, 33, 160]

Reduce stormwater run-off	Bioswales	Shallow ditches that protect nearby water bodies and capture stormwater run-off from impervious surfaces.	Mitigates localized flooding which reduces foot traffic, causes infrastructure damage, and increases water pollutants. Store stormwater in urban areas, which can be reused for the irrigation of green spaces.	[161]
	Bioretention ponds	Strategically placed bioretention ponds with soils and plants to remove water pollutants while storing stormwater until it infiltrates the ground or evapotranspires.		[162]
	Rain gardens	Depressed areas vegetated with grasses and other perennial plants that collect, slow, and filter rainwater.		[163]
Green buildings	Strategic planting and erosion control	Buffer strips of native vegetation around fields, xeriscaping (less irrigation).	Used to remediate sites, control nonpoint source pollution, increase drought resiliency, lower maintenance costs, generate revenue from produce, reduce pressure on competing land uses, reduce food miles travelled, recycle resources, regulate buildings' temperature, link consumers to production and design innovation, less pesticides and associated emissions, social facilities, and improve community food security to a limited degree depending on soil quality and local pollution.	[164]
	Bioengineering	Wetland vegetation, pollinator habitat, and habitat enhancement for bat and avian species.		[113]
	Local food production	Vertical farming, green rooftops, rooftop greenhouses, indoor farms, and community gardening.		[82, 165-167]