Transforming the planet:
Our vision for the future of environmental science

Contents

Acknowledgements

Authors: Ethny Childs and Joseph Lewis

Design: Bea Gilbert and Lucy Rowland

Cover design: John Holcroft

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- Gary Kass, Visiting Professor at Centre for Environment and Sustainability, University of Surrey
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- Karen Devine, Director of Communities and Inclusion, British Ecological Society
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- Penelope Tollitt MRTPI CEnv
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- Sarah Horrocks BSc MSc MIAQM MIEnvSci CEnv CSci, Head of Air Quality & Emissions, Atkins
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About the Institution of Environmental Sciences (IES): The IES is a professional membership organisation unifying communities of scientists, policymakers, and academics to transform knowledge on environmental science and support the transition to a sustainable society.

Across the full range of environmental disciplines, the IES brings together and champions the voices of science, scientists, and the natural world. As a convening space for interdisciplinary expertise, the IES promotes transformational learning to support our members in their professions and as agents of change.

The IES offers a common home for all those involved in environmental work or action underpinned by science. We are devoted to championing the crucial role of environmental science in ensuring the well-being of humanity now and in the future.

Registered charity no. 277611

Contact: Institution of Environmental Sciences
6-8 Great Eastern Street
London
EC2A 3NT

T: +44 (0)20 3862 7484

E: info@the-ies.org

Executive Summary

Environmental scientists will play a key role in facilitating the transformation to a sustainable society. Adapting to changing social, economic and environmental contexts will be imperative, to ensure that the workforce is in the best position to provide leadership in developing multifunctional solutions to the interlinked environmental crises of climate change, biodiversity loss and pollution.

The Institution of Environmental Sciences' (IES) year-long Future of ES23 project brought the environmental science community together to outline a pathway for achieving a positive future for people and the planet. The work was informed by extensive engagement with environmental professionals on the key areas shaping the sector and this document outlines these findings.

The vision is a future where environmental scientists are knowledgeable, skilled, diverse, and trusted. Their role is to help people to solve environmental challenges and co-create a sustainable society where people and nature thrive.

Climate change, biodiversity loss and environmental pollution are already having myriad impacts on the natural environment, with consequences for the social and economic systems that rely on a healthy environment. The environmental scientists of the future must be able to work in partnership to address challenges holistically. Humanity has reason to be optimistic about the future, as long as it takes the actions necessary to achieve that future.

Transformative change, underpinned by systems thinking principles, is a key part of realising that change. Understanding the leverage points within social and natural systems will be essential to embedding an integrated approach and supporting a transition to a sustainable society. This society will need to be co-created with communities, with environmental scientists providing opportunities for knowledge exchange and outlining evidence-informed options to address challenges.

Sustainability is not possible without inter- and transdisciplinarity. To develop multifunctional solutions to social, economic and environmental challenges, environmental scientists need to work across specialisms and disciplines, reducing the likelihood of 'single factor solutions' with risks of unintended consequences. Tapping into expertise from the social sciences and engineering will be essential for this. Environmental scientists can lead by example in developing interdisciplinary teams, through utilising their existing expertise in working across specialisms to deliver research and applied science.

Effective inter- and transdisciplinary working depends on access to enabling skills, such as communication and strategic thinking. Teams with 'knowledge brokers' and 'boundary spanners' can support collaboration, allowing for genuine knowledge exchange. For environmental scientists to act as agents of change, many will also need technical skills, net zero skills, digital skills and knowledge of systems. To upskill the sector, learning providers and professional bodies need to update curricula and training, develop technical pathways, and expand lifelong learning opportunities.

With updated skills and knowledge, environmental scientists will ensure that technologies are used appropriately to support environmental understanding, analysis, modelling and prediction, limiting the risks which are inherent to technological change. Advancements such as real-time monitoring, remote sensing, Artificial Intelligence (AI) and machine learning, are already disrupting the sector, but have the potential to unlock approaches to environmental improvement.

Technological development is also revolutionising the amount, quality, connectivity, and granularity of environmental data. Increased availability of real-time data allows scientists to measure and predict environmental systems on large scales, but quality and interoperability can be variable. By increasing data sources through the roll out of standards and improved accessibility and transparency, environmental scientists can unlock a greater role of data in decision making. This will allow scientists to measure progress towards targets using integrated assessment approaches, which take account of a combination of data sources and better reflect the systemic nature of environmental issues.

Translating evidence to different audiences will continue to be crucial, so environmental science requires meaningful engagement with decision-makers and the public. The science-policy interface is likely to change significantly, including a greater role for public engagement and public empowerment.

Principles of environmental justice and Equity, Diversity and Inclusion (ED&I) must be embedded throughout environmental work. The complex, interconnected issues facing the environment require collaboration, coordination, and cooperation. Fundamental to tackling these issues and creating a truly sustainable future is the ability to deliver environmental work that transcends governments, cultures, and disciplines, delivering for both people and nature. Targeted interventions will be needed to increase the inclusivity of the sector so that those from diverse backgrounds are inspired and enabled to build careers in environmental science.

Achieving a just transition to a sustainable society requires that environmental work is underpinned by the concept of environmental improvement, as it is essential for securing the benefits of a healthy environment for future generations. Embedding principles of improvement will be a critical role of environmental scientists and this will depend on a profession that is equipped with the skills, knowledge and ways of working to support transformative change.

The profession must act to realise this vision now; due to path dependency, the decisions made now will have a large impact on the future. The IES is committed to a leadership role in shaping environmental science and working with our members and partners to achieve our vision: a future for environmental science that will enable current and future generations to benefit from all that a healthy environment offers and where both humanity and nature flourish.

Background

At the beginning of 2023, the IES launched a year-long horizon scanning and foresight project, Future of Environmental Science 2023. This project sought to bring together interdisciplinary perspectives on the future of environmental science, framed around five key themes:

1. Megatrends – examining megatrends like climate change, rapid urbanisation and technological development and their impact on the environment sector.
2. The science – exploring emerging science, research and development, and the relationship between science and society and their implications on the environmental sciences.
3. The regulatory landscape – analysing how regulation, policy, and funding for environmental research is changing, and interrogating the role of regulation in the future of environmental science.
4. The workforce – assessing how the environmental workforce is changing, and how it needs to change, in terms of demographics, skills needs and specialism spread.
5. The job – exploring how the day-to-day jobs of environmental scientists are changing and what they may look like in the future.

Each of these themes involved extensive member engagement, as well as engagement with external environmental experts, collaborations with other organisations, and desk-based research. The project consisted of more than 20 dedicated events, over a dozen articles and detailed reports and briefing papers on a few key topics. Throughout these activities, more than 30 stakeholder organisations were engaged in the work (from government departments and major environmental NGOs to academics and funding organisations), who either received updates or fed directly into the research, and the project had more than 80 contributors from across the environmental sciences, representing a range of interdisciplinary perspectives on what the future may look like. The events also attracted over 850 attendees across the year, underlining the rich engagement achieved with professionals in the sector.

These perspectives, along with complementary research and discussions, were mapped into high-level themes and the links between these themes were identified and recorded. Over the course of the year, the project explored a total of 661 themes, with more than 1,300 connections identified between them. This reflected the high level of complexity in the environment sector and underlines the importance of systems thinking to support the sector in adapting to a changing societal, economic and environmental context.

Findings from this project have culminated in the development of this vision statement, which seeks to provide an oversight of the key areas of discussion from across the year and underlines our recommendations for how the environmental sciences can support a future which works for people and nature.

Our goal for the project was to support our own organisational horizon scanning, but also to conduct the project in the public domain to support the environmental science sector in planning ahead and managing risk. The findings are therefore being released in this report open access to support the wider sector.

How will this feed into IES activities?

Every three years the IES undertakes a period of horizon scanning to inform the development of our new strategic goals. This is closely linked with our organisational Theory of Change; horizon scanning is a key activity within our pathway to impact to ensure that we as a professional body have a good understanding of contemporary environmental challenges, potential solutions to these, and the most effective levers and routes for systemic change.

Our Theory of Change outlines our organisational pathway to impact and reflects the dual nature of the work of the IES – the internal focus on supporting our members, and the external focus on supporting transformative change in the environment sector and society at large.

Our Theory of Change therefore focuses on two key impacts:

1. People have access to the relevant science to help solve environmental challenges
2. A knowledgeable, skilled, diverse and trusted environmental profession that is engaged in the transformation to a sustainable society

These two impacts are intrinsically linked, as the environmental profession plays a key role in helping different audiences have access to robust and relevant science. As such the latter of these impacts is nested within the former.

This Vision Statement directly feeds into the achievement of these impacts, by providing an overview of current challenges and opportunities in the sector and a framing to consider what the most effective levers for change will be to achieve the future we want. It also supports our Theory of Change in a broader sense, by identifying avenues in which the IES should be engaging with our key audiences, namely our members, policy makers, the public and education institutes.

Our Vision for the Future of Environmental Sciences

Humanity has everything it needs to create a better future for society and the environment, supported by environmental science and the change that scientists can create within our own community.

Moving away from the business-as-usual model of incremental, atomistic change, action which is faster, more ambitious, and more effective will achieve a much better response to environmental crises. Using transformative change and a strong understanding of systems to facilitate rapid triage of the worst consequences of environmental decline could pave the way to a future where natural systems are repaired, moving towards environmental improvement.

This is our vision for the future of environmental science. It is one where environmental scientists are knowledgeable, skilled, diverse, trusted, and engaged in the process of transformation. It is one where people have access to the relevant science to help them solve environmental challenges and co-create a sustainable society where people and nature thrive.

Achieving this vision paints a picture of a positive future for both the environment and wider society, in which people and nature mutually thrive.

Science transforming the planet: what can we hope for if we act now?

In our vision of the future, **environmental science** played a leading role in shaping society's understanding of environmental challenges. Humanity's success in addressing environmental challenges can be attributed to utilising **transformative change** by using the leverage points which were most likely to affect the overall system.

Through interdisciplinary collaboration with social scientists, engineers, and policy makers, environmental scientists were able to work with society to achieve the change needed and supported society in creating a shared vision for the future. At the centre of that shared vision were the principles of **interdisciplinarity, systems thinking, and sustainability**, which was facilitated by carbon and systems literacy across society.

To deliver a systems approach, science used the opportunity of **technological change** to shape the way that society makes decisions, managing the risks of new technology and novel chemicals while appropriately applying Artificial Intelligence, digital landscapes, and advances in monitoring and modelling to support society's approach to change.

Technology made transformative change possible by **consolidating data and evidence** on which interventions would be most likely to succeed and where unintended consequences may arise, informed by post-implementation reviews and real-time monitoring of the effects of policies. As a result, decision makers could take a reflective approach, adapting to failures more quickly than would otherwise have been possible, ensuring timely and effective action to address environmental challenges.

Environmental scientists used enabling **skills** to communicate evidence to the public and facilitate knowledge exchange, ensuring that society had a direct role in shaping the choices we made about what we wanted the future to look like. Through storytelling, strategic planning, and visualisation techniques, environmental scientists were well-placed to work with both policy makers and the public, bringing together research, policy, and professionals to translate complex decisions into actionable choices for the public.

Those skills were rolled out to the environmental workforce across many routes into the profession and through targeted professional development for those already working. By systematically approaching the ways that environmental scientists are educated, the sector was able to simultaneously increase the diversity of the profession by tackling the structural barriers to entering the workforce, bringing a wider range of perspectives into environmental science in the process.

This was a critical step to **rebuilding trust in science** and helping environmental scientists to bring different communities together to support change. People were empowered to make decisions about the future because science was relevant and accessible to them. At the same time, decision makers had the evidence they needed to act and made decisions which were truly informed by that evidence, using it to create the world that science and the public had co-created together.

As scientists worked to **support policy and the public** in making decisions, the growth in the environmental science sector allowed them to continue discovering new information about the natural world while also playing an increasing role in tackling challenges directly, identifying solutions and helping people to make decisions about which to use. At the same time, growing the sector allowed the inclusion of a more diverse workforce, ensuring that environmental science had the breadth of expertise and perspectives needed to tackle challenges.

By **embedding justice** and **environmental improvement** in all decisions, from the project level to high-level decisions about the future we want to see, we ensured that nature and the services it provides were plentiful and accessible to everyone. At the professional level, scientists promoted best practice that took every opportunity to seek environmental enhancement, rather than defaulting to protection or mitigation of harm. Using those case studies, these practices became widespread, ensuring improvement in more than just name.

At the societal level, scientists worked with people to shift their view away from the 'fortress model' that the natural world is separate from the human world. People began to see their role as part of a wider ecosystem, as well as how interconnected they are with nature. As a result, decision makers and communities pursued more holistic approaches to environmental challenges, which helped to secure multiple benefits throughout the transition.

In the end, humanity embraced a sustainable approach to living within planetary boundaries and transformed society into one that exists in partnership with the natural environment, providing a safe and just space for everyone.

Environmental scientists played a key role in achieving this change. The knowledge, skills, diversity, and reliability of the profession was a fundamental lever in ensuring that humanity had the evidence needed to craft the world they wanted to see.

This vision ends with a human society which is happier, optimistic for the future, and flourishing thanks to the benefits springing from an abundant natural world.

Recommendations: What key actions deliver a better future?

Many actions will be necessary to deliver the best possible future set out in this vision statement. These 10 recommendations represent the most pressing factors in determining whether that world will manifest. These recommendations are aimed at environmental scientists, the environment sector, governments, and all of society.

1. **Environmental scientists** work with social scientists to **build trust and co-create a future vision** for a sustainable society with communities, facilitating knowledge exchange and informing citizens of the evidence and how different approaches can be achieved.

2. **Environmental scientists** retain the objectivity of their science by drawing a line between science and activism, but are **ready to be 'informed agitators'** on behalf of science when needed.

3. **Environmental scientists** play a critical role in the transition to a sustainable society and the development of evidence-based solutions, enabled by technology. Scientific expertise **ensures that appropriate technologies are applied** to support understanding, data gathering, analysis, modelling and prediction.

4. **Environmental scientists** measure progress towards environmental targets **using 'integrated assessment approaches'** which utilise a combination of data sources and take account of the systemic nature of environmental issues. Findings from assessments are used to form evidence bases on the effectiveness of interventions.

5. **Environmental scientists** embed environmental justice across all projects to make them sustainable. The environment sector **employs a diverse field of environmental scientists** who champion environmental justice in their work and co-create solutions with communities.

6. **The environment sector** develops training to **support environmental scientists as agents of change**, providing enabling skills, technical skills, digital skills, and systems thinking skills. Competency frameworks are regularly reviewed and updated to reflect the skills mix needed in the sector.

7. **The environment sector** establishes **knowledge networks and communities of practice** to act as forums to support systems thinking and links between disciplines. They focus on providing case studies of practical applications of systems thinking and interdisciplinarity, as well as tools and frameworks to support those approaches.

8. **Governments and policy organisations** recognise the role of **evidence-informed policy design and delivery**, embracing the full range of scientific insights, whether or not they are politically convenient.

9. **Society's** approach to environmental crises is **integrated at every level**, from global governance to the ways environmental scientists work. Decision makers understand and respond to the climate crisis in the context of biodiversity loss, pollution, and the complex social and natural systems underpinning them.

10. **Society** meets the burden of **continuing environmental improvement** to prevent further environmental decline. No generation leaves the world in a worse state than they received it, recognising that a status quo of environmental decline means that 'do no harm' is an insufficient way of preventing damage.

Planet Earth and the future of the human habitat

How is the natural environment changing? How is it shaping the world people live in? What developments can be expected for the natural assets and services which are fundamental to human existence and wellbeing?

A cause for optimism in the face of environmental challenges emerges from the source of those challenges: humanity has the capacity to alter the natural systems around it in ways which would be unimaginable to those even a single generation in the past. Just like any animal, the places humans live are still habitats, even as urbanisation drives fundamental shifts in how they function. And just like with any animal, risks to the human habitat pose sombre threats to the survival of humanity.[1]

Yet if social and economic systems have created significant negative changes for the natural world, there should also be confidence that they can create significant positive changes. Looking ahead to the future of the environmental sciences, the ways that humanity interacts with its habitat will decide the outlook for the natural assets and services which are fundamental to human existence, and will impact other species sharing that habitat.

Environmental crises: interwoven challenges and unprecedented understanding

Before looking to the future, the present day sits in the shadow of multiple complex and interwoven environmental challenges. Climate change, biodiversity loss, and environmental pollution are the three primary harbingers of the degraded environment wrought by unsustainable systems of consumption and production which underlie global society and the economy.[2,3] Further manifestations emerge such as the degradation of soils, destructive resource intensity, and the socio-environmental challenges linked to urbanisation.[4,5]

Despite the challenges, the past of environmental science has armed the future with an excellent array of evidence to untangle the complexity of these challenges. Global efforts to address environmental degradation, led at their heart by UN science-policy panels like the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES), have provided all the information necessary to choose the future people want to see for the world within which they live.[6,7,8]

Humanity is not yet taking advantage of that overwhelming body of evidence to find a safe blueprint for its collective future. Without further action, the world is on a pathway towards a global average increase in temperatures of more than 2 degrees, driven by agricultural production linked to rising per capita consumption and unsustainable use of fertilisers and water; power systems bound up in harmful fossil fuels; and land use changes which sacrifice massive carbon sinks for short-term economic gains.[9,10]

Most troublingly, the current trajectory for the global climate is driven by a miasma of inaction, apathy, and greenwashing that disregards the need for action as a low-priority concern: as the house is burning down, there are still many who are more concerned with 're-painting the kitchen'.

The quantity of evidence on the subject makes the options incredibly clear. If humanity continues on its current path, or if it strays even further from developing sustainable models of production and consumption, it will face an increasing number of widespread impacts as irreversible tipping points are crossed for the climate and ecosystems.[11]

Without restating the work of science-policy panels, it is clear that the future of the natural environment will be inseparably tied to the extent of action to address climate change, biodiversity loss, and environmental pollution. In the absence of action, the work of environmental science will increasingly be bound up in the task of adapting human society to snowballing impacts, whereas a more concerted effort to address environmental crises in the short-term will create a future where environmental scientists are instead focused on safeguarding against future challenges and maximising the benefits of integration with the natural world.

Even in the present, the impacts of the triple crisis are widespread: heat records are routinely being broken as rising temperatures become a pressing threat to human health; water is becoming more scarce in the face of surface and groundwater droughts, and more fierce extreme weather events and flooding increase; food security is less certain as key agricultural producers face changing climatic conditions; and climate-led ecosystem changes drives desertification and new climate danger zones.[11]

"Nobody will be unaffected and even those who profit most from maintaining the polluting status quo will face significant costs and challenges."

Combined, these represent significant risks to human life, as well as the risk of lost income, infrastructure damage, and novel health concerns, such as the spread of zoonotic disease. The social and economic harms significantly outweigh any costs which could be accrued as the world transitions away from carbon-intensive economies.[12,13] As the impacts of the climate crisis are likely to compound exponentially unless carbon emissions are substantially mitigated, it will also be impossible to establish the stability and certainty in global market conditions needed to sustain long-term economic growth.[14]

The harms of climate change will also be distributed unfairly in any scenario, with island nations and subsistence farmers facing near-existential threats in the short and medium term.[15,16] Even then, the financial insecurities associated with climate change and biodiversity loss will be borne across all of society. Nobody will be unaffected and even those who profit most from maintaining the polluting status quo will face significant costs and challenges.

Getting past the era of environmental challenges: triage for the triple crisis

Looking to the future, humanity is faced with a range of options: pursue transformative change which brings the planet out of this crisis; triage the worst of the impacts while securing a sustainable transition; follow a 'business-as-usual' approach to eventually get through the climate crisis but not without sacrificing much in the process; or abandon hope and cascade into a world of collapsing natural systems.

The current trajectory is insufficient to address any of the three apex environmental crises. Presently, policy measures are setting the world on track for more than 2 degrees of global warming above pre-industrial levels. The main challenge is policy delivery: comprehensive and expedient delivery of all Nationally-Determined Contributions (NDCs), multilateral agreements, and climate targets could bring that number down to 1.7 degrees.[9,10,17]

To that end, the biggest difference between a world which achieves a transition to net zero with significant yet manageable climate-related impacts and a world where the impacts of climate change are serious and unmanageable is whether the secrets of effective implementation can be unlocked.

The first step will be to correctly align financial streams, which requires a robust and consistent global taxonomy so that the money raised for sustainable transition, mitigation and adaption goes to the right projects. About 90 per cent of the upfront investment needed for the transition is expected to have a low or neutral cost when compared to inaction, so delayed or greenwashed investments will mean significant losses for investors.[14,18,19,20]

While novel technologies may be able to accelerate or cheapen the transition, they cannot be a priority for investment while more pressing aspects of the transition remain unaddressed. Climate mitigation is achievable with the technology currently available, so investments in new technology which take money away from the transition should be avoided.[9] Put simply: zero sum investments are ultimately zero benefit.

Action which mitigates carbon emissions while also addressing biodiversity loss and environmental pollution should focus on systems approaches to the biggest drivers of those crises: infrastructure and land use, energy and power, transport, and consumption.[9] Transformative change of those systems will secure significant co-benefits for air quality, soil health, water quality, resilience, and socio-economic benefits, while also minimising the necessary costs of infrastructure adaptation.[5]

Addressing these four complex drivers would be a significant first step towards delivering on global climate and biodiversity commitments. Taking those steps will not create a future where all environmental challenges have been resolved but would help to triage the most significant threats to humanity's future so that the long-term task of creating sustainable communities and regenerating nature can continue.

Net zero carbon is only the first step in that journey, and the world is highly likely to reach net zero at some point in its future.[14] The question will be how much is sacrificed along the way, so the responsible course of action will be to adopt proactive pathways which minimise the costs of transitioning and maximise the potential for social, economic, and environmental benefits.

The role of land and place: agriculture, planning, and transport

A more sustainable approach to land use starts with agriculture and the planning system. Widespread adoption of regenerative agriculture and sustainable land management, driven by 'public money for public goods' approaches to farming will provide the supply-side changes necessary to support behavioural and dietary change by consumers.[21] In a world where consumption decreases alongside more sustainable practices, food security will be achievable while drastically reducing pollution to watercourses and land.[22,23]

Mainstreaming of sustainable design throughout the whole planning system, driven by environmental scientists working at the heart of decision making, will be crucial to decarbonising infrastructure and ensuring sustainable development which meets the planning system's linked social and environmental objectives.[24]

Sustainability considerations cannot end with carbon: nature, air and noise quality, and health must also be part of the design process, with sufficient environmental and ecological expertise available to local authorities to make informed decisions. In many instances, it will be necessary to protect spaces for nature, which requires framework-level planning to coordinate land use for multiple functions.[1]

Decision making will need to ensure that grid connectivity, the use of heat networks, building standards and energy efficiency improvements, and whole lifecycle environmental assessments are integrated into developments from the outset of projects at the design stage. This will only be possible in the context of short and long term strategies to address the environmental impacts of concrete, which accounts for nearly 8 per cent of anthropogenic greenhouse gas emissions.[25]

Sustainable approaches to planning will also support the decarbonisation of transport systems. The latter will require a transformative approach to how humans travel, aimed at reducing the need for medium-length and longer journeys by putting sufficient infrastructure close to where people live, such as through the development of '15 minute towns' and similar approaches.[5,26]

Local plans should make active travel a realistic and presumed option, but sustainable public transport and affordable electric vehicles will also be necessary for wider accessibility. Both of the latter require infrastructure development and sufficient consumer incentives for a viable transition, as well as transition plans for deployment and long-term resilience, avoiding any risk of 'lock-in' to the risk of single-points-of-failure, such as overdependence on electrification.[27]

In the circumstances where air travel and shipping are necessary, such as for freight and long-distance international travel, significant steps should be taken towards producing sustainable fuels, energy-dense batteries, sectoral decarbonisation roadmaps, and carbon offsetting plans.[28,29] Transforming the transport system will require significant reductions in the most-polluting forms of travel, so reasonable alternatives need to be made possible through rail and tram networks, as well as utilisation of digital technology to remove the need for travel.[5]

Decoupling and diversification: recharging our power systems

Power systems will require significant transformation and public understanding of the need for action on energy is already strong, which has driven declining costs for renewable energy production. Renewable sources are expected to be the largest global source of energy production by the end of the decade.[30] The cost of energy production from solar photovoltaics dropped 90 per cent between 2010 and 2019, with wind energy production also dropping 40 per cent.[10,14] As the insecurity and cost of fossil fuels drive up prices and uncertainty, feedback loops will continue to drive renewables into the wider energy mix, regardless of which pathways the world follows.

The challenges for the energy transition will be to situate those renewables in the overall energy mix of different countries, addressing the dual challenges of grid connectivity for deployment and integrated energy storage to address intermittence. Once scaled up, deployed, and decentralised, those renewable-heavy energy networks will be the backbone of a just energy transition which provides communities with sustainable and secure power sources.[31]

To achieve sustainable energy systems, we must diversify our energy sources away from fossil fuels, totally decoupling them from our economy and power generation. That will require communities to make decisions about their overall energy mix, so during the short and medium term, transitional energy sources may be necessary as we scale up the scope of renewable sources, including imperfect solutions such as blue hydrogen or nuclear energy.[5]

Where adopted, those technologies will need to be carefully managed to prevent negative social or environmental outcomes.[32,33]

In most realistic pathways, a diverse array of energy sources will be a necessary element of the transition away from fossil fuels, so the role of environmental scientists will be critical to ensuring the appropriate use and management of a diverse range of energy technologies.[34]

Many of the best solutions will be tailored to their local context, so at the national and international level, many energy solutions will need to be available, allowing scientists to inform communities about their options. Knowledge transfer will be a vital component of ensuring the just dissemination of information about energy choices. Implementing those decisions about energy may then require the use of novel policy approaches where appropriate, including community-owned energy and decentralised power grids.[5,31]

Moving from GDP to sustainable development and circular economies

Climate change, biodiversity loss, and pollution are, at their core, driven by the historic consumption of the environment through our economic systems and technological developments.[35] Transformative change will require humanity to address that consumption by moving towards a more sustainable economy.

The world's current approach exists under a paradigm of demand management, where Gross Domestic Product (GDP) growth remains the primary focus of economic systems. Such an approach cannot be achieved in perpetuity and will ultimately not be sustainable.[36,37] The inevitable truth is that the planet cannot simultaneously sustain limitless growth in capital, growth in population, and growth in resources.[38]

Historically, the global economy has depleted resources in favour of growing capital and expanding populations, but as the finite limits of resources are reached, perpetual capital growth will no longer be possible. Human society should make the shift away from growth-driven economics an active choice, rather than an inevitable policy failure which leads to destructive recessions, and which embeds financial insecurity and economic injustice.[14]

If we deliver on existing commitments, society could instead adopt a wellbeing or sustainable development approach, driving economic change which captures multiple social, economic, and environmental benefits in line with the Sustainable Development Goals.[36]

Working with the grain of existing economic models, this approach would shift the growth of the economy towards green jobs which provide net contributions to the environment, driven by skills development and consumer demand for sustainable businesses. Market mechanisms would utilise regulation to promote sustainability while also improving competition through 'level playing fields'.

Taking a transformative approach to resolving global consumption would require us to significantly alter economic systems to create a more circular economy.[5,39] Totally decoupling the global economy from systems of growth is unlikely to be realistic, but the system could be altered to significantly reduce the extent to which that growth relies on resource use and waste.[40]

That kind of change will rely on embedding lifecycle and whole value chain considerations across business models, while promoting behavioural change to encourage the application of the waste hierarchy: reduced consumption, reuse of products, and recycling of non-reusable materials. It would also involve novel approaches to how people live and work, such as community ownership of assets, tools, and services.

Even without reforming economic models towards circularity, greater reporting of corporate environmental impacts will be important to inform consumer choices and maximise the potential to minimise resource use. To avoid greenwashing, it may be necessary to employ novel approaches such as robust certification of companies and their environmental commitments.

Adaptation and resilience: how can we live with the choices we make?

Even in climate conversations, adaptation has been a significantly undervalued aspect of society's wider approach. In the wider context of the triple crisis, adaptation is even less embedded in solutions.[27] The hard-learnt truth from the climate crisis is that adaptation and resilience cannot be considered to be separate from the decisions made about mitigating or preventing an environmental crisis .

This is because resilience is bound up within the choices made about how environmental challenges are addressed. More incremental or atomistic approaches will increase the need for adaptation, either because vulnerability to hazards increases or because the hazards themselves increase in scope and scale.[11]

Particular caution should be taken in the face of tipping points in complex systems, as many are likely to be irreversible or may otherwise cause unintuitive and rapidly intensifying impacts on people and nature. For example, changes to both climate conditions and ecosystems can distort the way that pollutants in the natural environment behave, creating novel terminal products or causing contaminants to produce unexpected harms.[41]

Likewise, the cumulative impact of pressures on multiple systems must be accounted for, to ensure that humanity's capacity to adapt is sufficient to create resilience to all the consequences of its decisions and not just the most intuitive changes.

In the face of these challenges, society's approach to adaptation must be developed with reference to interlinked social and natural systems. Adaptation efforts have historically focused on the climate crisis, and within that context have disproportionately centred on flood defence.[27] A more holistic approach to adaptation will be necessary, regardless of which pathways are taken, integrating energy security, food security, water security, and ecosystem resilience into approaches to the climate crisis.[42]

Across adaptive efforts, governments should also account for the risks and challenges associated with biodiversity loss, pollution, and other environmental issues such as soil degradation.[65] Soil is essential to a substantial proportion of the global food supply – as much as 95 per cent in countries like the UK – so threats to soil are likewise threats to global food security, the supply of human labour which needs to be fed, and the complex value chains linked to global trade.[22,43]

Structural changes in ecosystems, including fragmentation, species distribution, and disruption of habitats, can all lead to the loss of functionality and the disruption of the ecosystem services which are vital to both humanity and the wider natural world.[1,7] These changes can exacerbate the ecological emergency, but can also have immediate effects on the way people live their lives, requiring adaptation to retain access to food, natural resources, and key regulating functions of the environment such as carbon cycling and storage. Most critically, the potential loss of some ecosystems, such as alpine systems or coral reefs, could have devastating cascading effects on the global environment.[9]

Urban environments will have a significant impact over the shape of the future. As economic growth drives land use change, there has been a substantial conversion of the human habitat from diverse ecosystems into urban or agricultural land, with the same systems driving unsustainable consequences for the natural world.[4]

This process of urbanisation has led to many socio-natural challenges, including for transport, air quality, and housing, but has also given rise to opportunities for shared access to goods and services. In the modern world, the challenges of urbanisation are often seen most dramatically in the global south, where populations are increasingly concentrated in urban centres.[9]

The challenge for the future will be to ensure that society maximises the opportunities of urban environments while adapting to the associated risks, making use of 'place-making' approaches such as '15 minute towns', as well as broader integration of sustainability principles in local plans and frameworks.[17,24] There are inherent justice questions at the heart of how cities and towns are designed, which are only likely to increase as demographic change drives competition for economic migrants and social change polarises attitudes to the jobs and services which urban centres can provide.[9]

Whether those opportunities are maximised will determine if urbanisation continues to drive environmental degradation without increasing opportunities, or if the process of altering the urban environment can become a positive influence on the urban landscape. That requires an approach to planning and design which embeds resilience, co-benefits, and environmental improvement at every stage.[76]

Many instruments already exist to support the proliferation of adaptive measures to address these challenges, though the majority are not yet scaled to meet those challenges, tuned towards adaptation as their objective, or operating with reference to the complex systems and interconnected crises which they must be able to address.[34]

Regulatory measures such as European Habitats Regulations, Biodiversity Net Gain approaches, or Nutrient Neutrality requirements have the capacity to embed adaptation throughout the processes most likely to interact with ecosystems.[1,42,45] Heuristics like the mitigation hierarchy demonstrate the potential to embed approaches, particularly if they are utilised at the design stage, while metrics and case studies can improve consistency of delivery across projects or scales. Key challenges can also be addressed more directly, such as setting priority habitats and aligning them with framework-level governance such as land use frameworks or national biodiversity commitments.[46]

Ultimately, individual measures will only be as effective at embedding ecosystem resilience into decision making as the principles, values, and understandings which underpin them. Before any of these approaches can succeed, society must value the inherent benefits of the natural world, not just as an economic asset but for the wider values and sources of wellbeing that it can address.[47,48]

This re-imagining of how we conceive value will be critical in making the difference between a society which respects nature and secures maximal benefits from it, and a society which takes moderate mitigatory and adaptive measures but does not fully

reckon with the vast potential opportunity or risks associated with the natural world.

The more that people imagine themselves to be separate from the natural world, the harder it will be to embed resilience to environmental crises, and the less likely society is to secure the full range of benefits on offer.

Pollution, chemicals, and systems approaches to cross-contamination

Recent years have seen a significant increase in the recognition of the climate crisis and ecological emergency in policy, media, and across society. Despite this, the extent of environmental pollution remains largely unacknowledged. Efforts to construct a UN-led science-policy panel on chemicals and pollution will likely make a substantial contribution to improving that situation, much akin to equivalent panels on climate change and biodiversity (the IPCC and IPBES, respectively).[49,50]

In many instances, efforts to address climate change and biodiversity loss will also address pollution, due to the interlinking nature of the crises and the ways that they are driven by the same social and economic systems.[6] This means that the majority of action on the triple crisis poses the potential opportunity for co-benefits.[3]

Contaminants, chemicals, and other pollutants have the potential to affect almost any natural system, all the way from core natural systems such as air, water, and land down to biological systems like the human body.[41] Within that context, specific challenges such as soil degradation and noise pollution have been under-addressed.[42] Action to address environmental pollution therefore interacts directly with society's ability to secure a vast array of ecosystem services, as well as basic human needs like health and wellbeing.

Likewise, many sources of pollution can affect multiple natural systems, often moving through one into another and polluting each along the way. For example, ammonia can be a serious challenge for both air and water quality, and one of its most significant sources in agricultural fertiliser can also lead to the degradation of soil organic matter.[42] Standard approaches such as the Source-Pathway-Receptor model are useful for managing the different consequences of a particular pollutant, as well as the ways that interim pollutants can be transformed as they travel through the environment.[51]

Even while these approaches can support robust risk assessment and direct interventions, the state of pollution requires framework-level approaches to ensure the overall strategic management of the crisis. This is especially important in the context of environmental pollution, where there is a simultaneous need for regulatory generality and regulatory specificity, which only framework-level governance will be well-placed to address.[52]

The need for a general approach to chemicals arises from the uncertainty surrounding emerging contaminants and novel chemicals, which are being generated and proliferated into the environment at an unprecedented rate. Chemical products for cleaning and personal care, agricultural chemicals such as fertilisers and pesticides, and deliberately biologically-active medical products are all contributors to an increasing presence of chemicals in the environment.[41]

Even if the social and economic drivers of chemical use are addressed, the precautionary principle demands that regulation retains the scope to consider dangerous pollutants outside of those specific chemicals for which there exists a deep and robust evidence base.

The regulation of Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) has demonstrated the incredible complexity of novel families of chemicals, including related chemicals like Perfluorooctane sulfonate (PFOS) and Perfluorooctanoic acid (PFOA). The vast and differentiated nature of these chemicals, their sources, their contextual safe limits, and their specific dose relationships demands a regulatory approach which has the flexibility to catch chemicals as soon as they emerge on the horizon. Broad legislation which allows chemicals to be regulated in general terms will be a necessary first line of defence against emerging contaminants and novel consequences of pollution.[41,53]

Simultaneously, specific regulations needed to deal with the different effects of pollutants on the environment. Tailored approaches and specific limit levels allow for more bespoke control over a wider array of pollutants. In addition, fine particulates, including PM2.5, can have no safe levels for human health, requiring a specific regulatory approach which goes beyond limit levels.[54,55,56]

To that end, framework-level governance will be essential to address pollution. As for most environmental challenges, it will be needed to unite different scales of action, different systems and pollutants which have linked sources and interwoven impacts, and different stakeholders involved in the governance landscape. It also has a fundamental role in creating coherency between regulatory floors which provide a general basis for addressing contaminants and targeted measures which address specific pollutants or contexts. Such frameworks offer a crucial basis for cross-stakeholder communication and public understanding, both of which will be necessary to address the drivers of chemical pollution.[57,58]

Much with the climate crisis and biodiversity loss, a core element of addressing environmental pollution will necessitate going beyond mitigation towards identifying opportunities for regeneration and remediation, embedding improvement at every scale.[44] While pollution is less scalar in nature than addressing a single negative output, such as carbon emissions, the development of approaches such as Air Quality Positive developments offers some insight into how more transformative approaches to pollution can take place.[59]

The best future the world can hope for would systematically reshape the economic and social drivers causing pollution, but a future which significantly addresses the context of environmental pollution can still be achieved with integrated frameworks for governing chemicals, using both general and targeted measures.

Environmental consciousness: how will humans shape the habitat we live in?

Fortunately, there has been a positive shift in public consciousness over recent decades. Younger generations place greater value on nature and the services it provides, driving a shift in willingness to act for the good of the planet.[60,61] This trend is only likely to increase, so there should be a considerable degree of optimism about the chance to overcome environmental challenges, as long as that consciousness transforms into action.[62]

The concept of conditional optimism can guide our thinking: humanity has reason to be optimistic about the future, as long as it takes the actions necessary to achieve that future.[63,64]

The psychology of environmental crises is inherently tied to the collective willingness to take actions, often without the immediate sense of the tangible benefits people gain from environmentally sustainable behaviours. By now, people are all too familiar with the 'free rider problem' and the 'tragedy of the commons', but frameworks have begun to emerge which are fundamental to reimagining the human conception of value.[36]

Ecosystem services, planetary boundaries, and 'doughnut economics' all challenge the ways that we think about what we want, but ultimately the decisions people make will be guided by personal values, not universal ones, which will in turn determine the shape of the future.[7,65] The role of environmental science in protecting the future of the human habitat is, first-and-foremost, about providing the evidence and understandings needed to help people understand what is at stake and what it would mean to them if it was lost.

The best world on offer is one where humanity becomes a species of ethical designers, pulling on the strings of sustainable social and natural systems which serve a range of interests and values. The worst world is one where humanity loses influence over the environment, which shifts on the whims of social structures under the yo-yoing tides of degraded habitats and generationally shifting values.

Between those two extremes, there is still a choice amongst the more likely scenarios. 'Business as usual' will bring about the unstemmed degradation of natural systems, caused by the step-by-step collapse of the 'body' of the human habitat.

As each of its organs fails, it may be possible to find artificial transplants which never function quite as well as the originals, and some parts of the body may survive the decline, but not without losing functionality and value for future generations. The body would hobble on, but not without loss.

A better future is achievable with action, as long as humanity meets the conditions of its conditional optimism. The most positive realistic future which can be achieved begins with the triage of environmental decline as environmental science brings humanity through the era of chaos marked by environmental crises into a settled peace where it adopts a more autious approach to remediating and repairing natural systems over time, allowing it to recapture crucial values which might otherwise be lost.

The key to that future is immediate action, informed by systems thinking and enacted with a transformative approach to change. Humanity has every reason to know that these crucial systems can change, and that such change can be beneficial for everyone. The next step is to embrace a more positive relationship with planet Earth and the human habitat.

How can we achieve the best possible future?

As the IES worked to produce this vision, we engaged with environmental scientists working across disciplines. The future they wanted to see for the environment is one where:

- Society's approach to environmental crises is integrated at every level, from global governance to the ways environmental scientists work. Decision makers understand and respond to the climate crisis in the context of biodiversity loss, pollution, and the complex social and natural systems underpinning them.
- Society transitions to a more circular and regenerative economy, enabled by the evidence of environmental scientists, novel approaches such as community ownership of assets, and regulatory requirements for greater corporate reporting of environmental impacts, encouraging businesses to embed climate, biodiversity, and the environment as whole value chain considerations.
- Governments underpin environmental ambitions with flexible and context-appropriate delivery plans, using transformative, rather than incremental, approaches to change. Environmental scientists support delivery by providing insights on implementation in practice.
- Governments cooperate globally on environmental pollution, mirroring the processes for climate and biodiversity, empowering the forthcoming global science panel to play an active role, supported by national policy which is sufficiently general to cover novel and emerging pollutants and sufficiently specific to address the effects of individual contaminants.
- Governments embed adaptation in decisions about mitigating or preventing environmental challenges, with the goal of creating sustainable social and natural systems where opportunities are maximised, risks are managed, and the balance between them is fairly-shared.

Emergence of the dragonfly: Crafting a new world through transformative change

How can a new vision for a transformed society be co-created? How can environmental meaningfully transform complex social, economic, and natural systems which inhere against change?

When talking about the future, metaphors come all too easily. The butterfly is a popular one: the transformation from one thing into another captures all the possibility associated with a world remade in a more beautiful image.

However, an understanding of complex systems reveals that such a simple approach to transformation is inaccurate. Social, economic, and environmental systems are entangled in feedback loops, subtle drivers, and holistic pressures over time, making them resilient to some changes and wildly susceptible to others.[1] The result is that changes often lead to policy failures or unintended consequences. To address the complexity of systems, transformative change approaches are needed, utilising key leverage points to manipulate whole systems.[2,3]

In that context, it is not the metamorphosis of the butterfly humanity should be seeking, but the emergence of the dragonfly. When a nymph transforms into a dragonfly, many subtle pressures come together to create a new creature beneath the surface of the nymph's skin. Once that unseen change has begun, the nymph moults, shedding away its past appearance as it adopts a new form. Often, more than a single moult is needed as the creature grows into what it needs to become. Nonetheless, at the end of the journey, the world bears witness to a full transformation: the emergence of the dragonfly.

Through that lens, much can be learnt about the requirements of transformative change. 'Transition' is not as simple as putting society's hopes into a cocoon and expecting them to emerge flawlessly on the other side. Systems inhere against change, so it is necessary to work with their key drivers, making those subtle transformations beneath the surface until the whole system emerges transformed. Just as the emergence of the dragonfly is only possible under the right circumstances, enabling conditions must be met to facilitate transformative change. And much as the nymph must moult many times, so too does transformative change require iteration and reflection in order to be fully realised.[4]

Systems literacy will be a crucial element to engaging the public in meaningful choices about the future, but systems understanding is a more urgent prerequisite for policy design.[5] Transformative change is a necessary element of meeting society's hopes to transition away from the unsustainable pressures which drive environmental challenges. For that change to be achievable, the most potent leverage points at the heart of social and natural systems will need to be used to create a better future.

Why do we need transformative change?

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) defined transformative change in its

Global Assessment as "*a fundamental, system-wide reorganisation across technological, economic and social factors, including paradigms, goals and values.*"[6] That definition aligns with the understanding that environmental challenges have been caused by many complex, reinforcing pressures arising from social, economic, and natural systems.

To address those challenges, their causes need to be addressed, requiring holistic interventions which work across the complex systems they operate within. Incremental or atomistic approaches may still lead to a world where those challenges are addressed, but they will do so at considerable cost: unambitious approaches will mean sacrificing natural systems or services which provide immense benefit to people and the planet.[7]

Less ambitious approaches often fall down when the complex and deeply embedded drivers in social and natural systems inhere against change or produce unexpected consequences. As a result, changes may not be meaningful or lasting, and they may come with negative costs, side effects, or the need for further changes at a later date.[8,9]

Focusing on key levers like education, skills, economic systems, and governance will be critical to creating a vision of the future that works for everyone.[10,11] Environmental scientists are well-placed to do so: understanding natural systems can expose where those levers will be most impactful, and the capacity for interdisciplinary working across specialisms allows scientists to understand the unexpected consequences that interventions may cause. In a future where environmental science takes advantage of learning from across environmental challenges, building links with social science and engineering in the process, transformative change can be achieved.[5]

Regardless of which pathways society adopts, widespread changes are inevitable. Technological developments will mean massive changes for society and the economy, providing opportunities to improve the sustainability of systems of consumption and production as a significant co-benefit.[12]

Likewise, the climate crisis will cause substantial changes for the world, whether or not society seeks to address it.[13] Choosing to pursue transformative change puts humanity in control of what those changes look like, providing the chance to secure multiple benefits and mitigate potential risks. Transformative approaches can address the mutual causes of climate change, biodiversity loss, and environmental pollution, avoiding the need for multiple costly transitions and increasing the likelihood that the root causes of the crises are addressed.[14]

The benefits of such an approach are manifold: costs will be significantly lower because an integrated approach is more efficient, it will be easier to secure a 'just transition' because social and economic structures causing injustice can be tackled at the same time that their effects on natural systems are addressed, and adaptation can be integrated more easily because society has greater control over what the world looks like after the transition.[15,16] Altogether, transformative approaches minimise risk and maximise opportunities.

If the only certainty in the world is that change is inevitable, pursuing transformative change is an easy way to make that change a force for good in the world.

People and perspectives: Who will drive transformative change?

Achieving transformative change will not be easy; it requires novel thinking and a strong understanding of the systems people work and live within. Fundamentally, the core questions will be: who will drive transformative change, what systems and frameworks will underpin it, and how can that transformative change be delivered?

In that context, the 'who' factor is especially critical: people are at the heart of transformative change, not only because they are key operating agents whose actions embed feedback loops and routines into systems, but because transformative change exists for human benefit. The principle at the heart of transformation is the creation of a particular vision of the world, where society embraces rather than consumes the environment, using transformative change to reach that goal. Without a vision, transformation is a meaningless endeavour, so the wants and needs of human society are fundamental to determining that destination.

Values and world views are two of the most fundamental drivers of social systems. If the natural world is viewed as an economic resource or a wilderness to be tamed, society is unlikely to align its ambitions with environmental conservation and improvement, so many seemingly independent pressures will continue to arise.[17]

Conversely, if people recognise nature's fundamental role in underpinning the ecosystem services society relies on, it is more likely that those considerations will be recognised as decisions are made, mitigating the impact of many small decisions which add up to an unsustainable society.[18] For example, the choices people make every day as consumers reflect a wide range of considerations which arise from their finances, their personal preferences, and their values. The things people buy shape the global economy, which shapes how people interact with the world.[19] Changing social values may seem abstract, but they can fundamentally reshape humanity's relationship with nature.[20]

For individual actions to help guide transformative change, everyone must be working towards the same vision of the future. To maximise the potential leverage of collective action on social and economic systems, efforts must be taken to reach a consensus about the future people want to achieve. Co-creation approaches, carbon literacy, and community collaboration tools like citizen assemblies are critical ways to unite society, but they need to be scaled up to make the most of their potential.[7]

"Environmental science must avoid falling into the trap of dictating one approach to policy at the expense of the public being able to make its own decisions."

The need for greater unity is particularly stark in the context of increasingly polarised societies where scientific evidence has become politicised in public opinion. Environmental science must avoid falling into the trap of dictating one approach to policy at the expense of the public being able to make its own decisions.[21] Instead, science should provide evidence on the implications of choices and the ramifications of taking particular pathways, including the costs and co-benefits associated with decisions.[22]

When society has collaboratively created a vision of the future, science and policy will be empowered to design the mechanisms which will bring about that future, aided by robust monitoring and effective policy delivery.

The role of effective science communication in supporting collaborative decisions about the future will be paramount, and science must play a role in providing the scientific literacies, like carbon literacy, which will be necessary to empower community decision making.[25] To that end, the relationship between science, the public, and policy will be vital in supporting transformative change, even beyond the extent to which it informs public consent for decision making.

Within policy processes, the perspective of participants plays a crucial part in determining how they interact with those systems, so having 'process literacy' as a means of engaging with processes and the roles people play within them is a prerequisite to the proper functioning of those systems.[23] Key stakeholders will need to understand their role in a manner which allows for the potential to secure multiple benefits for society, the economy, and the environment.

For example, where planning and development processes are seen to be adversarial between developers, local authorities, and environmental experts, those parties engage in an adversarial manner. There is less propensity for data sharing, less willingness to collaborate on design early in the process, and less capacity for mutually beneficial outcomes. When policy systems operate in such a way, drivers in those systems stress against the overall potential to secure multiple benefits.[27]

Building stronger relationships between science, the public, and policy can maximise the potential for cohesive systems which are open to the possibility of transformative change. An early step in the transformation must be to ensure adequate satisfaction and familiarity with the processes involved in the transformation itself, as well as those in a post-transition society.

Systems and frameworks: What will drive transformative change?

Going beyond the role of participants in social and policy systems, those systems themselves will be critical to driving any kind of transition away from a world of environmental crises, making use of the key leverage points necessary to achieve transformative change.

Given the prolific role played by the global economy in shaping policy decisions and the actions of individuals, economic leverage points have a special power in driving or subverting environmental degradation.[15] Embedding circular economy principles and sustainability throughout corporate value chains will be crucial to addressing the unsustainable pressures linked to global economic growth, because those principles provide the means to increase the efficiency of resource use without losing value or compromising on the quality of the environment.[25]

In a future where businesses increasingly factor sustainability into corporate strategies through ESG principles and corporate carbon initiatives, the potential to achieve the decoupling of economic systems from unsustainable activity will depend on accountability and transparency, as policy frameworks will be an important part of holding businesses to account, so that consumers can make informed decisions about how to spend money in line with their values.[26]

Both in economics and in the broader environmental space, effective policy depends on the ability to unite different spatial scales and carry decisions through to delivery. Where different environmental strategies, regulations, and policies operate at specific scales or contexts, frameworks must bring them together to ensure coherence and to prevent issues falling into gaps between policies.[23]

Uniting policies through framework-level governance allows for targeted policies which address the key leverage points necessary to transform systems, while also respecting the interactions between those drivers and ensuring a systems approach to solutions. Even if policy tools are independently geared towards environmental outcomes, their effectiveness at securing those outcomes depends on the coherence between them, the scope of targets across the system, and the ability of the overall framework to ensure that every aspect is contributing towards the same outcomes.[22]

For example, land use frameworks have the potential to align planning policy, nature recovery strategies, agriculture, and other uses of land.[27] Even if each individual policy regime has environmental objectives, there is no guarantee that they will collectively meet national and international objectives for nature unless they are contextualised in a bigger picture. Nature does not recognise boundaries drawn on maps or departmental jurisdictions, so policy frameworks must be able to work beyond those limits as well.

Not only can framework-level governance prevent gaps in policy, it can support the effective delivery of policy. Embedding post-implementation reviews and iterative monitoring of implementation allows these tools to be tested and fine-tuned until the governance system as a whole has been transformed.[4]

Leveraging policy and practice: How will we drive transformative change?

To achieve transformative change in practice, it won't be enough for people to want change and to recognise the systems which can make it a possibility. Key leverage points must be actively targeted with effective interventions, linking the policy scale with robust monitoring and implementation, driven by the relationships between scientific evidence, policy makers, industry, research institutes, and the public.[22]

In doing so, the social and economic instincts which drive individual and collective action will be vitally important, so the insights of social sciences like behavioural economics and sociology are fundamental.[28] At the same time, environmental science can support the appropriate application of technological advances to facilitate change.[29] Only by drawing together these technological, economic, and social factors with knowledge and evidence from environmental science can meaningful transformative change be achieved, manipulating the drivers in complex systems, rather than succumbing to them.[6]

For example, a city seeking to reduce unhealthy levels of air pollution might seek to impose clean air restrictions linked to transport, such as low emission zones for private vehicles. While many people support these policies, they may also feel disempowered by the uniform application of fines throughout the zone or by how those fines are deployed, restricting choices about how they travel. The result is that these policies are difficult to implement and may face resistance from communities, so may be hard to maintain with the degree of agility necessary to respond to changing pressures on the environment.

A transformative approach to implementing these policies could make use of technological developments while also integrating modern social approaches to address the challenges for implementation.

Empowering people from the start, citizens would be supported in shaping regulation. Based on the model of citizen assemblies, the local community would be brought into meetings where they would be given direct access to scientific evidence on the effects of air pollution from transport, then supported in developing different options for limit levels and fines, all informed by the expertise of air quality professionals and post-implementation monitoring of the effectiveness of existing low emission zones.

Once members of the community had decided upfront what levels of air pollution they were collectively comfortable with, regulation would be put in place to apply fines to vehicle emissions when those limits were breached. Real-time monitoring stations at key locations within the low emission zone could collect robust data about pollutant levels with hyperlocal specificity, supported by reliable validated artificial intelligence to cover for any gaps in data.

Based on the data, the autonomous system could automatically update enforcement action in line with the earlier decisions of the community. Fines, exceptions, and bans could all be deployed as desired. If pollution was particularly rife, harsher penalties could be automatically enforced. If the circumstances were less severe, the system could automatically become more lenient.

Taking this kind of autonomous regulatory change approach could have a number of benefits: society would be immediately empowered with evidence and the power to make its own decisions. Once it has, the decision does not need to be re-litigated every time regulatory action takes place, because society has already made its choice. In the process, regulation would have been depoliticised while also increasing citizen empowerment.

For this kind of approach to be successful, it would be vital to ensure that any citizen input is legitimate and represents the views of the community, so social and economic transformation would be necessary.[22] Real-time monitoring and Artificial Intelligence would need assured reliability and consistent delivery, so technological transformation would be necessary.[30] Finally, policy processes and regulation would need to be able to keep pace with real-time changes in the environment, so regulatory transformation would be necessary.

This hypothetical case study is only one example of the ways that transforming all these systems together could achieve novel approaches to tackling environmental challenges. It would not be suitable for all issues or all places, but demonstrates that transformative change has the capacity to bring systems together in ways that empower communities, embed scientific evidence, and provide real solutions to seemingly insurmountable challenges.

What the future holds: is transformative change still achievable?

In the face of dynamic social, economic, and natural systems which push back against attempts to change them, it can feel that uncertainty is overwhelming and that there is not much agency to shape the future. However, much like the dragonfly, many small, coordinated and well-managed changes beneath the surface can come together to transform the world.

Through a focus on transformative change, it becomes possible to see the conditions that will allow people to feel 'conditional optimism'.[31,32,33] There is every reason to be optimistic about the ability to create lasting beneficial change, as long as the conditions of making that change a reality are met. Those conditions are the subtle changes at key leverage points, which give rise to the power of transformative change.

The world is not yet aligned with transformative approaches to environmental crises, but such approaches are still achievable. The critical factors which will determine which future humanity faces will be how well people work collaboratively to build a shared social vision of the future and how quickly they embrace the path to that future through transformative change.

Once humanity knows what it wants to achieve and makes the necessary preparations, society will be ready to take flight through transformative change, carried on the wings of the dragonfly.

How can we achieve the best possible future?

As the IES worked to produce this vision, we engaged with environmental scientists working across disciplines. The future they wanted to see is one where:

- Environmental scientists work with social scientists to build trust and co-create a future vision for a sustainable society with communities, facilitating knowledge exchange and informing citizens of the evidence and how different approaches can be achieved.
- Governments adopt framework-level governance to coordinate processes, and learning providers disseminate process literacy to help society guide those processes towards transformative change.
- The environment sector spreads scientific literacy (including on carbon, oceans, and systems) throughout society through education pathways, lifelong learning, and public engagement by scientists.
- Governments replace unsustainable economic drivers, like fossil fuel subsidies or economic barriers to sustainable consumer choices. Society reimagines what is seen as valuable, embracing transparency, accountability, and sustainability.

The rise of sustainability, interdisciplinarity and solutions-driven science

What do we need to deliver a sustainable future? What is the role of environmental scientists in realising this future? How can we develop multifunctional solutions to the crises we face?

Transitioning to a sustainable society is essential for securing a positive future. Sustainability at its core is predicated on the need for interdisciplinarity and systems thinking. It depends on the interaction between social, economic and environmental systems and ensuring they are in balance to safeguard the longevity and wellbeing of humanity.[1] These systems cannot be looked at in isolation, and neither our social or economic systems can achieve their optimal function without a healthy environment.[2]

One of the key drivers that has led to the multiple environmental and social crises facing our society is the disconnect between how we manage these systems and a lack of consideration of the interconnectedness between them. Infinite economic growth driven by extractivist industries is not possible in a world of finite resources and delicate ecosystems — the environmental cost of our economic systems is a woefully under-considered negative externality that cannot continue. Only through true interdisciplinary working can solutions be developed that holistically address the interlinked environmental and social crises facing humanity and take into consideration the social, economic and environmental dimensions of the world.

Environmental scientists can lead by example in this area. At its core, environmental science requires understanding of systems and there are already numerous examples of projects where environmental science expertise has supported the development of systems-led design and solutions.[3,4,5,6] Capitalising on, and disseminating learnings from, these types of projects will be a key role of environmental scientists of the future.

Embedding interdisciplinarity

The importance of interdisciplinarity for the future of environmental science cannot be overstated. Environmental science is fundamentally an interdisciplinary field, bringing together knowledge from geography, geology, biology, physics and chemistry to understand the world around us. However, specialisation within the sector can lead to the development of siloed approaches to environmental challenges and the implementation of single-factor solutions aimed at dealing with specific environmental concerns, rather than taking into account the wider systems within which they sit.

As understanding of the interconnected nature of environmental and social crises grows more evident, the need for multifaceted perspectives and integrated approaches becomes more accepted. Frameworks such as the UN Sustainable Development Goals[7] and Kate Raworth 's Doughnut Economics[8] recognise this importance. They place environmental considerations as a key determining factor in reaching a sustainable future or "safe and just space", which not only meets the social and economic needs of humanity but also allows for a society that operates within planetary boundaries.

The question now is how to take these frameworks, along with other relevant frameworks, and use them in tangible, evidence-based ways to facilitate interdisciplinarity and the development of multifunctional solutions.

Currently, practice is not reflecting ambition in many cases, with interdisciplinary and systems thinking based projects still in the minority. Environmental scientists are often leading in this space among scientific disciplines, but further work needs to be done to embed interdisciplinary practice across the environmental sciences, and STEM as a whole. Environmental projects which utilise this type of thinking such as integrated catchment management[9] and natural capital approaches[10] should be analysed to determine what works — and what does not — and to apply this to future interdisciplinary work.

Science for solutions

The rhetoric surrounding the need for interdisciplinarity reflects the shift in the scientific community away from traditional 'discovery science' focused on purely understanding the environment, to a more challenge-led and solutions-driven approach, much more focused on the application of science and integrated approaches to environmental challenges. Discovery science will always be an essential element of the work of the scientists, but this must go together with solutions-led science to drive change. Implementing solutions to the complex, interconnected issues facing our environment is dependent on breaking down siloes between environmental disciplines and convening scientists to develop holistic solutions and avoid unintended consequences.

Moving away from single-factor solutions will depend upon deep knowledge of the environment and our place within it, as well as behavioural change and a philosophical shift in the way we structure work and our education systems.

Discipline-led science can stymie this type of thinking as it can restrict what is deemed relevant to a particular specialism. This in turn can smother innovation and creativity, particularly in the 'publish or perish' culture prevalent in science and research. High-impact journals are often discipline-focused, with interdisciplinary research often published in lower status journals. This leads to the further fragmentation of knowledge into disciplinary siloes.[1]

Reframing how we think about research and research funding is therefore a key part of the puzzle in realising interdisciplinary science.

There is now also a greater understanding that interdisciplinarity needs to go beyond collaboration between environmental disciplines (although this is naturally essential) but also covers the importance of collaborating with other disciplines in the social sciences and engineering, as well as transdisciplinary science which involves collaboration with non-academic stakeholders. An example of where this is needed is related to the built environment. There is a strong interaction between the natural and built environment, through behaviour, planning and decision-making, and environmental scientists will need to work with the engineering community to create mutually beneficial solutions that enable development and contribute to environmental improvement.

There is a need for greater porosity between the social sciences and environmental sciences to support the behaviour shifts needed to drive transformative change, particularly with regards to delivering a just transition and improving Equity, Diversity & Inclusion within the profession. Tapping into the social sciences can help the environmental profession understand the barriers to multicultural participation in science and can help develop initiatives to effectively engage with those from diverse backgrounds.

Uniting research, professional practice, policy and the public will allow for the development of solutions that can be interfunctional across these different areas and take account of the full suite of skills and knowledge available in society. It will also allow different stakeholders to feel a sense of ownership and empowerment over the transition to a sustainable society, maximising its likelihood of success.

Embracing environmental systems

Placing the environment at the heart of our decision making will be a fundamental part of supporting solutions-led science. We need to realign our society to one that fits within the environment as a functional element, as opposed to consuming it for short-term gains.

Through embracing and enhancing the environment the ecosystem services it provides which are essential to human health, wealth and wellbeing can be protected and supported. This will rest upon a realignment of how society views its place within the environment as well as the value prescribed to different elements of it. This needs to go beyond nature-based solutions aimed at dealing with single issues, to consider how we can curate complex systems can be curated with symbiotic gains for both humanity and the wider environment. This will require both development of deep systems-based knowledge of the environment and a paradigm shift of how society considers itself within the larger ecosystem of planet Earth.

Fundamental to this will be reimagining land use and how society manages habitats and their associated ecosystem services. Developing a common framework for assessing value to different stakeholders and deciding the role of environmental professionals in acting as stewards for these environments will be an important success factor.

For example, where private land is used for a specific purpose that provides services for the wider population, professionals will be needed who understand these services, how they are valued and how to manage and optimise them for the public good. This is already being done in some aspects of environmental work, such as flood management, but this needs to be scaled up to support more complex implementations across the environmental science profession. Digital knowledge systems will be an important part of understanding, managing and modelling our environment and supporting the application of systems thinking and interdisciplinarity.

From specialisms to systems - Challenging disciplinary norms

Environmental science, by its nature, is based upon an understanding and management of systems. It is no surprise, therefore, that fundamental to discussions on the future of environmental science is the need for embedding systems thinking principles. Although interdisciplinarity and systems thinking are currently 'in vogue' in scientific and political rhetoric, in practice there seems to still be a level of confusion and reticence about how it can be applied.

To build a positive future of environmental science it is crucial that tools are developed to embed systems thinking and build bridges for truly interdisciplinary practice. Frameworks will be needed to support interdisciplinary working as well as novel approaches to knowledge sharing like best practice communities and knowledge networks, case studies of successful projects using interdisciplinarity, upskilling in science communication and systems literacy, and forums to connect disciplines. Professionals also need to be open to new approaches and ways of working, whilst maintaining the high standards and robust scientific methods that are currently used. This aligns with that broader need for shared understandings which unite the public, policy makers and integrate multicultural perspectives and scientific literacy.

There will always be a need for subject specialists within the environmental sciences, but environmental scientists who act as knowledge brokers and boundary spanners are also needed. These scientists will play an important role in facilitating the sharing of environmental science knowledge between specialists and supporting the creation and management of interdisciplinary teams. Defining what constitutes a 'green job' will also be part of this and will shape the sector to come, as it is likely this definition will broaden as sustainability becomes embedded across industries and sectors. There should be a strong focus on skills in interdisciplinary working, including enabling skills such as communication, collaboration and influencing.

Systems literacy will be needed, not just among the scientific community, but more broadly among policy makers and the public. There is a role for environmental science and scientists in supporting raising the public's consciousness and understanding in this area and supporting evidence-led behaviour change and solutions. This will go beyond just needing specific tools or techniques for systems approaches, but also a deep understanding of the natural and social systems themselves.

"To be successful, environmental scientists will need a good understanding of the political and social landscape they are operating in…"

It is also important to note the blurred lines between science and activism in the environmental sector and how this may impact the interface between the public, science and policy makers and thus the role of environmental scientists as change agents.[11] To be successful, environmental scientists will need a good understanding of the political and social landscape they are operating in, and tools to navigate it effectively.

Key to this will be considering how they can translate scientific evidence into useful formats for different stakeholders. Developing a common language and values framework are an important aspect of supporting interdisciplinary teams and bridging understanding across specialisms. Practicing systems thinking through a practical, rather than a purely theoretical, framing can also be effective at supporting shared understanding and considering how systems thinking can be used in the day-to-day work of different stakeholders. Dedicated communities of practice and knowledge networks can facilitate collaboration and knowledge-sharing between disciplines and provide a useful forum for sharing case study examples of what works (and importantly what doesn't) in different contexts.

Evolving education systems

The increased understanding of interdisciplinarity and systems thinking has important implications for education in environmental science and how environmental scientists of the future can best be supported. Embedding sustainability across the curriculum and bridging gaps between disciplines will be an important part of equipping the next generation of environmental scientists with the necessary skills in systems thinking and interdisciplinary working.

Education is responsible for shaping how students see the world around them. Currently, in the UK students are taught through the lens of different subjects and that means as they specialise they all develop differing perspectives on the world and their place within it. This can be valuable in certain contexts, but it does limit understanding of the systems they work within. Through evolving education systems to support systems thinking and interdisciplinarity, ways of working that naturally support the development of holistic and multifunctional solutions can be developed.

A major factor for the lack of interdisciplinarity is that education systems and research institutions are still heavily discipline-based, with a focus on developing technical expertise in a specialism rather than a broader understanding of the systems that underpin environment and society. Moreover, this is often reflected at the decision-making level, with government departments often siloed around topics and specialisms leading to a lack of connectivity and porosity between departments. This inevitably leads to decisions being made for single reasons, without a thorough understanding of potential implications of actions in other areas of the system and without realising the potential for multiple benefits.

There are already examples of good practice in supporting interdisciplinarity in education, such as Education for Sustainable Development (ESD)[12] and the Planetary Health Education Framework,[13] as well as the requirement for all QAA subject benchmark statements to make reference to the QAA/Advance Higher Education Guidance on ESD.[14] Dedicated institutions, such as the London Interdisciplinary School, are also providing examples of education to support interdisciplinarity, but these are few and far between and traditional discipline-led education is still the norm.

Frameworks and case studies to facilitate systems thinking in academia will be important to support a roll-out of best practice approaches to supporting interdisciplinarity. The Planetary Health Education Framework,[13] which uses a transdisciplinary lens to support action-oriented science, is focused on fusing theories, methodologies and expertise across disciplinary boundaries. The aim is to provide a basis for academics to work across disciplines, and with other civic and non-academic partners, to tackle real-world challenges and support simultaneous improvements in human and environmental wellbeing. The ESD CoDesignS Framework is another example of supporting interdisciplinarity and sustainability, providing support for all disciplines to embed ESD in curriculum design.[15] Learnings from approaches like this can support specialist scientists to collaborate across disciplines and apply their specialist knowledge to key challenges.

Evolving education systems is also necessary to equip future professionals with the skills and knowledge needed to succeed in careers and drive change in professional practice. In the environment sector, many employers are facing skills and resource challenges and if education is not adapted to the needs of society, this skills and resource gap is only likely to widen. There is evidence that graduates are also driven to pursue careers that make a different to people's lives and want to work with organisations with good sustainability principles. Providing students with skills in interdisciplinarity and systems thinking will help them understand their role within society and how they can contribute their expertise to a more sustainable future throughout different career paths.

If a piecemeal approach to embedding sustainability and interdisciplinarity in education continues, through trying to shoehorn sustainability modules into a discipline-focused curriculum, change will not be achieved in the appropriate timeframes. A concerted effort across education, research and the professions is needed to embed interdisciplinarity, prepare future environmental scientists and upskill the current workforce to deliver solutions that work for people and planet.

Changes to education also need to happen at all levels, from primary through to higher education.[16] The most effective forms of educational change will be for those who experience it from the beginning of their education journey, at primary levels. This will be a slow process so must be done concurrently with other forms of supporting interdisciplinarity. This could include the roll out of alternative forms of learning, such as the International Baccalaureate, which support a more holistic educational approach. Technical education can also play an important role in supporting interdisciplinarity, by focusing on provision of skills at the applied level and helping those on technical education pathways to develop an understanding of how their theoretical knowledge applies to day-to-day work.

It is also important to consider how education systems and research ecosystem can support greater diversity in the sector. Breaking out of traditional moulds of education may help facilitate increased diversity. When adapting education systems, it is important that the sector moves forwards with humility, accepting that western norms of education do not have all the answers, and that community and indigenous knowledge is also a key source of information for supporting change in our education.

The role of the professions in delivering a sustainable future

There is currently no profession that fully embraces sustainability due to its boundary-spanning nature. In order to support transformative change to a sustainable society, embedding sustainability, and by extension interdisciplinarity, throughout the professions will be key.

Professional and licensing bodies need to embrace sustainability and consider how they can embed sustainability into their CPD, competencies and best practice. This can be difficult; professional bodies are often constrained by their objects and discipline of focus. Collaboration and partnership across professional bodies will therefore be key for this to tap into the relevant expertise and to ensure systemic, rather than siloed change. These partnerships must be built on an ethos of mutual benefit and transparency and provide space for collaborative development of materials to support their respective members and the development of professional practice for sustainable development.

Professional bodies must also utilise their unique position in society to convene key stakeholders and drive change in

professional standards and competencies, with the aim to support their members not just as professionals, but as change agents in society. Vehicles for collaboration between professional bodies should be championed, such as Licensing Bodies and specific forums like the Professional Bodies Climate Action Charter which can assist in the development of collaborative approaches and resources.

Professional bodies should also utilise their links with education institutions to drive change in best practice regarding sustainability upskilling within education settings and providing opportunities for developing skills in interdisciplinary working and systems thinking. There are various ways this could be achieved, including considering updating accreditation criteria and creating teaching resources.

A focus on lifelong learning is also a fundamental part of ensuring that the environmental workforce is upskilled in the skills needed for interdisciplinary working and sustainability. Professional bodies, along with the wider education and training sector, will need to play a key role in this through the provision of regular CPD opportunities aligned with current best practice.

How do we achieve a sustainable future?

Interdisciplinarity is a theme that has woven through almost all the discussions in the Future of ES23 project. Ambition and rhetoric around supporting interdisciplinarity is where we want it to be, but this ambition must now be met with changes in practice that embed principles of interdisciplinarity, systems thinking and sustainability throughout environmental science and beyond. If we continue on the current path, we will not move fast enough to embed these skills and as such will continue to develop single-factor solutions to increasingly complex environmental and social problems.

It is important to note that embedding interdisciplinarity and systems thinking is not mutually exclusive with supporting discipline specialists – without disciplines interdisciplinarity would not exist. However, forging links across disciplines and allowing for knowledge exchange remains central to delivering a better future for our society, economy and environment.

We already have much of the knowledge and technical capability that we need to develop a sustainable future. Now, it is just about piecing together that expertise to build the future we want.

As the IES worked to produce this vision, we engaged with environmental scientists working across disciplines. The future they wanted to see in terms of interdisciplinarity is one where:

- The environment sector establishes knowledge networks and communities of practice to act as forums to support systems thinking and links between disciplines. They focus on providing case studies of practical applications of systems thinking and interdisciplinarity, as well as tools and frameworks to support those approaches.
- Research institutions and funding organisations support research which utilises interdisciplinary teams and focuses on solutions-led science, creating new funding streams, supporting the development of interdisciplinary research departments, and removing structural barriers to collaboration.
- Learning providers embed sustainability, interdisciplinarity and systems thinking principles at all stages of education, focusing on understanding social, economic, and environmental systems and supporting skills in science communication, collaboration and stakeholder engagement.
- The environment sector supports professionals as agents of change by developing standards and lifelong learning resources on sustainability, systems thinking and interdisciplinary skills. Environmental scientists forge stronger links with social sciences and engineering to avoid siloed approaches.

Specialisms and systems: Skills to secure a sustainable future

What skills are needed to deliver the transition to a sustainable society? What are the skills needs in the environment sector? How can we ensure that environmental scientists are equipped with the skills and knowledge to practice solutions-led science?

In a changing world, the skills in the workforce need to adapt rapidly to the needs of society and the demands from employers. In response to increased legislation around environmental improvement, net zero and sustainability requirements, the demand for environmental expertise is significantly growing and leading to expanded career pathways and employment opportunities. This is producing novel skills needs in the sector and reframing what it means to be an environmental scientist. The prominence of environmental science expertise is only set to increase as we ramp up action to deliver a sustainable future.

Increased acknowledgement of the need for an integrated approach to environmental, social and economic issues is also causing an expansion in what is considered part of the environmental sector and creating a more broadly defined "green skills" need. It should be noted that when discussing skills, this encompasses a broad spectrum of the skills, knowledge and competencies needed at all levels in the sector.

Effective implementation of solutions-led science will hinge upon an environmental science workforce equipped with the necessary technical, systems thinking and enabling skills, such as communication and strategic thinking.

Enabling skills

The role of environmental scientists in society is increasing in prominence, driven by increased public interest in environmental challenges, regulatory requirements around organisational sustainability, and greater understanding of the need for integrated solutions to environmental and social issues. This is leading to enabling skills in the environmental workforce becoming increasingly vital.

Enabling skills support the effective translation of environmental science into action, paving the way for environmental scientists to act as agents of change. Enabling skills are varied, and environmental scientists need a variety of them in their toolkit to tackle complex issues and engage with key stakeholders effectively. Not all environmental scientists will need all of these skills, but having access to these skills within project teams will be important to support more effective outcomes.

These skills include:

- **Science communication**: verbal and written communication skills are essential to drive change. Environmental scientists need to be able to distil complex concepts to a variety of stakeholders to support effective knowledge transfer and inform action. This needs to be done in a way that presents key findings whilst avoiding oversimplification. This will be especially important when communicating complexity, informed by systems thinking. Communication skills will need to be adapted for different audiences and will range from public engagement, to influencing policy makers, to engaging with industry and commercial organisations and, importantly, those in other disciplines. Each of these engagement types will require different communication skills and environmental scientists will need to be adept at identifying how best to communicate based on their stakeholders' existing knowledge base and interests, as well as the goal of the interaction. Informing and driving behavioural change will be a key aspect of science communication work, and environmental scientists should seek to learn from, and collaborate with, social scientists to upskill in this area. Media training will also be important to develop skills in this area tailored to leveraging media resources for change.

- **Problem-solving and critical thinking**: these skills are aligned with the need for solutions-led science. Environmental scientists will need to be skilled in applying theoretical knowledge, case study insights and previous experience to novel situations. Applying scientific reasoning to real-world concerns should be a key target for environmental education to support a focus on solutions and to foster skills in problem-solving. Critical thinking complements problem-solving skills, allowing scientists to approach problems using a logical and systematic approach. Critical thinking will also be essential to supporting the development of new ideas and questioning the status quo.

- **Innovation**: given the scale of the change needed to transition to a sustainable society, skills in innovation should be cultivated in the sector to support complex problem-solving and adapting to new ways of living. Undoubtedly, unforeseen issues will also materialise on the journey to a sustainable society and novel problems will require novel solutions. Innovation will need to be a fundamental part of environmental scientists' toolkit to support change, adapt to change, and leverage change to support environmental improvement.

- **Leadership and collaboration skills**: these skills are essential components for supporting interdisciplinary science and the integration of knowledge across disciplines. Those within interdisciplinary teams will need to build strong relationships with other members and have a good understanding of

where they can best add value. To facilitate the reframing of society that embraces nature, environmental scientists will also need to show strong leadership skills to champion environmental science and effect change. Foundational to this will be the development of skills in formulating and enacting strategic plans.

- **Community engagement skills**: co-creation of solutions with communities will be needed to support a just transition and create community buy-in, and this will hinge on the effectiveness of community engagement skills. Environmental scientists will need to be equipped with appropriate and effective collaboration and communication skills to support this.

- **Process literacy**: to enact change, environmental scientists need robust knowledge of policy and organisational governance. Policy knowledge should go beyond understanding regulation and reporting requirements, to cover how the policy process works and how it can be influenced. Understanding the interface between policy, the public, and science will also be crucial to develop levers for change. Knowledge of organisational governance and how it can be influenced will also be key. Creating senior leadership buy-in is a key success factor for embedding sustainability and limiting greenwash.

Technical skills

Between 2022-2023, job postings requiring green skills rose by 22.4%, with the share of talent in the workforce increasing by almost half as much (12.3%).[1] The growth in the number of environmental science related roles indicates the increasing demand for technical skills associated with the environmental sciences and the need for growth in the next generation of environmental scientists.

"Technical expertise will be crucial to our transition to a sustainable society, but how this technical expertise is framed is changing."

Technical skills, those that cover specialised environmental knowledge and expertise, will always be essential to addressing environmental crises and will be at the core of realising a future where society is aligned with the environment. Technical expertise will be crucial to our transition to a sustainable society, but how this technical expertise is framed is changing. A focus on sustainability and solutions-led science is leading to a demand in skills driven by challenge areas, for example water management, regenerative agriculture, Biodiversity Net Gain, natural capital, nature-based solutions and the circular economy. Emerging areas of science, like dealing with novel contaminants, will also likely lead to an increased focus on skills in environmental chemistry and land and water remediation.

This demonstrates the need for specialists in environmental science such as freshwater science, ecology, land condition and climatology to focus on how their technical expertise can be applied to real-world challenges to support policy delivery. This is shifting the focus from more theoretical principles to application. This follows a natural progression for environmental scientists; by its nature environmental science is more heavily focused on application than the other scientific disciplines. This puts environmental scientists in a leading position to drive forward solutions-led science and take a leadership role in interdisciplinary teams.

Field and lab expertise will continue to be important skills areas for environmental scientists, but the skills mix needed in these environments will adapt in response to changing technologies and information. Proficiency in sample collection and analysis will remain fundamental but the methods for these are likely to change significantly. For example, innovations in field and lab instruments and the rise in automated or remote technologies will impact the activities of environmental scientists in these areas. Environmental scientists will need to show flexibility and adaptability to manage these changes, learn how to use specialist technology, and use their expertise to determine the best tools and techniques available to them.

As we strive for environmental improvement, environmental impact assessment and related technical disciplines will also remain pivotal in order to support a planning system which delivers sustainable housing and infrastructure for society, with built-in environmental improvement. Environmental-led design will be a key success factor for this and will likely be another area of skills growth needed.

In an increasingly complex legislative environment, skills and knowledge of regulation and reporting requirements will be vital, particularly in periods of legislative flux. The emergence of net zero and related policy illustrates how legislative change can drive skills needs.

Technical routes into the sector will be key for filling these skills needs and strides are already being made in this area. There is a need to increase the number of technicians with level 4-5 education in the workforce, as there is evidence that a lack of these qualifications in the workforce may be contributing to the 'productivity gap' in the UK workforce.[2] Historically, environmental science has typically been a graduate-level occupation, but as the workforce expands, differentiation of roles and new routes into the sector will be needed. Technical education will be key to fulfil this need and further technical routes into the sector should be developed, including apprenticeship schemes.

A focus on skills for the climate transition

A suite of carbon reporting legislation has come into practice mandating eligible companies to disclose their annual greenhouse gas emissions to support the delivery of net zero ambitions.[3] This requirement is leading to growing demand for skills related to carbon accounting and reporting, supporting organisations in understanding how to measure greenhouse gas emissions and set targets for reducing emissions aligned with a net zero future.[4]

Measuring and reporting on carbon is only one dimension of an organisation's net zero journey. Detailed carbon management plans must be developed and delivered to support achievement of carbon reduction targets. Carbon management plans require a set of skills in addition to carbon accounting and measuring baseline emissions as they require a process of setting targets and devising a strategy to deliver this target through evidence-based action. Organisations will need to utilise a plethora of different expertise, covering areas like energy, waste management and transport.

Given the context-specific nature of developing these types of plans, those developing carbon management plans need to show initiative in applying different types of carbon reduction measures in different contexts, and exhibit skills in considering environmental concerns holistically to develop solutions with co-benefits and reduce the likelihood of disbenefits. Moreover, actions need to show a solid understanding of an organisation and its related supply chains, to ensure that measures are feasible and achievable. Finally, delivery of carbon management plans requires strong collaboration skills across organisational departments and buy-in from senior leadership. This highlights the importance of enabling skills in addition to technical skills in this field.

Key skills that therefore need to increase in the sector to support the delivery of net zero include technical expertise in carbon accounting, renewable energy, low-carbon infrastructure and whole life carbon management, circular economy, and utilities and waste management. Enabling skills in communication, implementing policy, supporting behavioural change, strategic thinking and innovation will also be fundamental to supporting effective carbon reduction.

Beyond carbon reduction measures, reporting requirements under the Task force on Climate-related Financial Disclosures (TCFD) also stipulate the need for climate risk reporting. Global temperatures have increased 1.1°C above pre-industrial levels[5] and climate projections show that even if all current Nationally Determined Contributions (NDCs) are met, the globe is on track for a further 1.3°C degrees of warming.[6] Increased global temperatures are already leading to increased occurrence of extreme weather events and climate hazards and these are predicted to further increase in frequency and severity as temperatures rise.[7]

Moreover, a move to renewable energy systems based on electrification can lead to increased system vulnerabilities through overreliance on specific infrastructure, in this case national grids. We must ensure that our systems are resilient to climate change and its associated impacts. Skills related to climate adaptation, resilience and risk management should therefore be prioritised for skills development, and resilience should be a key component of organisational strategy. Carbon management plans should thus be developed in tandem with climate adaptation plans to manage risk.

Putting together climate adaptation plans will require dedicated skills and knowledge regarding climate resilience and climate risk. This includes the ability to assess current and future risk and use this information to prioritise adaptation measures that are likely to have the biggest impact on resilience. This in turn requires a sound knowledge of different adaptation measures and their applicability, as well as an understanding of governance frameworks to support the delivery of adaptation plans.

To support these skills there needs to be a concerted and complementary approach across education institutes, employers, and professional bodies to support the upskilling of the current environmental workforce and skills development for the environmental scientists of the future.

Currently, there are no comprehensive, industry standard carbon management training courses to support skills development in this area. Moreover, although there are a number of climate-related degree courses, these often do not include sufficient practical experience in implementing carbon management plans on the ground. Degree courses should ensure that they offer opportunities to develop skills in practical decarbonisation solutions that can support the delivery of net zero targets. Alternative routes into the profession should also be utilised to support skills growth in this area; technical pathways like apprenticeships offer brilliant potential to provide a vehicle for fostering practical net zero skills. Action plans for net zero skills should be delivered, backed by significant investment, to meet the skills needs in these areas.

As emissions reduction measures move towards tackling scope three emissions, carbon literacy training will also continue to increase in importance as a significant proportion of emissions in this scope will relate to behavioural change. Current climate literacy training should also be updated to reflect the increased focus on adaptation and resilience and to support understanding and buy-in for adaptation plans. Climate literacy needs to be rolled out across all disciplines to enable interdisciplinary collaboration in research and development — a key determinant of achieving climate-related targets and managing risk effectively.

Digital skills

Technological innovation has led to the digitisation of a significant proportion of working practices. In the future, this is likely to continue with digital literacy and associated skills becoming increasingly important in all sectors of society. Managing digital workspaces, using new technologies and handling data will all be important aspects of the future environmental profession.

Technological innovation has revolutionised the way environmental scientists collect, curate, analyse and visualise data on the environment. This has led to a step-change in the quantity and granularity of the data we collect. Increasingly sophisticated methods for analysing data are helping us to understand our environment and model and predict future environmental systems. Handling big data sets and integrating data sets are already recognised skills needs in the sector, and this will only increase further in the future.

This has major implications for the skills needs in the sector. Although not all environmental scientists will need to be experts in data science, there will be a level of proficiency in digital skills required across the sector. Environmental scientists will need skills in using new technologies and expertise on which technologies are best suited for particular purposes. Skills across the spectrum of data collection, quality assurance and cleaning, analysis, visualization, and modelling will be needed.

Advancements in machine learning, AI and remote sensors will increasingly lead to the automation of the more routine components of data collection, cleaning and analysis. This may shift the focus of the skills needs in environmental scientists towards the more complex area of data interpretation. For example, the rising focus on managing environmental risk and assessing progress towards environmental targets will likely result in a greater need for skills related to environmental modelling and prediction, especially around topics like climate change, pollution dispersion and ecosystem dynamics. This will shift the focus for environmental scientists to integrating data insights with real-world assessment to feed into decision making. This will hinge upon the ability to integrate data sets to provide insights at the systems level.

Systems literacy

Environmental scientists are being increasingly consulted to develop integrated solutions to environmental challenges. To effectively fulfil this need, they need to be upskilled in systems thinking principles to support the development of multifunctional solutions aligned with a sustainable future.

This requires specialist knowledge of environmental systems and how they interact, as well as a broad understanding of the social and economic systems in which they operate. Managing this complexity will be a key requisite of future environmental scientists. Moreover, in the face of multiple environmental crises, supporting adaptive capacity in society will be vital. This requires environmental scientists to develop skills in solutions optioneering to support evidence-based decision making, with insights on how the different solutions impact and interact within systems.

Systems thinking is inextricably tied to interdisciplinarity, which in turn is a key enabler to supporting sustainability science.[8] As sustainability moves up the agenda, skills in both interdisciplinarity and systems thinking will be crucial to effectively address the interlinked crises of climate change, biodiversity loss, and environmental pollution in a just way. To achieve this, systems literacy skills will not only be needed among environmental scientists, but across all disciplines, decision makers and the public. Due to environmental scientists' existing expertise in spanning the boundaries between disciplines, they will need to support the dissemination of interdisciplinary and systems thinking skills by acting as agents of change in society. This will require strong enabling skills alongside existing technical skills.

The importance of competency

Given the complex skills mix needed in the environmental workforce to support solutions-led science founded on principles of sustainability, competency frameworks, such as the UNESCO Competency Framework[9] and Chartered Environmentalist,[10] are needed to support targeted professional development. Competency frameworks and associated registrations, as well as underpinning ethical frameworks, provide quality assurance of those leading environmental work and feeding into key decisions. This is imperative to support the development of an environmental workforce with the right skills and attributes to drive change, as competencies go beyond assessing knowledge, to ensure that professionals have the necessary skills, experiences,

abilities and behaviours to use their knowledge effectively in the real-world. To counter the risk of skills 'tick-boxing', principles of continuous learning should be embedded throughout professional practice, aligned with competencies.

Competency frameworks should be reviewed and updated periodically to make sure they reflect the skills needed in a changing world and do not remain static or outdated. Competency frameworks across disciplines should embed sustainability and interdisciplinary principles; this should not be siloed in environmental work alone.

In a world where engagement across the policy, public and scientific worlds are needed more than ever, professional registrations can be an effective tool to build trust and counter bad practices. This cannot be one-sided, however; competencies and skills within stakeholders will also need to be developed to realise change. Skills audits should be conducted across disciplines and stakeholders to identify gaps in skills and knowledge, target provision and inform sectoral transition roadmaps.

Environmental scientists of the future

The environmental workforce is well-equipped to support the transition to a sustainable society given its focus on real-world problems and interdisciplinary science. However, to fully realise the role of environmental scientists as agents of change, education and upskilling must complement strong environmental knowledge and technical skills with a suite of digital, systems thinking and enabling skills. These skills should be underpinned by structures to support targeted professional development and recognition to support environmental scientists in reaching their full potential as architects of the future.

As the IES worked to produce this vision, we engaged with environmental scientists working across disciplines. The future they wanted to see for skills is one where:

- The environment sector develops training to support environmental scientists as agents of change, providing enabling skills, technical skills, digital skills, and systems thinking. Competency frameworks are reviewed and updated to reflect the skills mix needed in the sector.
- The environment sector develops new technical pathways to fulfil skills needs, such as apprenticeship schemes focused on carbon management and climate adaptation. Learning providers complement the development of technical knowledge with more opportunities to apply knowledge to real-world problems, supporting a shift in focus to solutions-led science.
- Professional bodies and learning providers develop comprehensive, industry-recognised training and guidance on carbon management, accounting, and reporting to support upskilling and the emergence of best practice. This training includes opportunities to develop skills and knowledge on practical measures to reduce emissions, as well as how to measure risk and build resilience through adaptation.
- Governments support skills audits of the professions and wider stakeholders to inform the development of skills strategies which support sectoral transition pathways aligned with a sustainable future.

Enabler or inhibitor? Technological development and the environmental sciences

How can technology support environmental scientists? What are the impacts of technological development on working practices? What are the opportunities and risks of technological development?

Technological development and increased digitisation are key megatrends affecting all areas of society and science.[1] The accelerating speed of technological development, particularly in the areas of machine learning, Artificial Intelligence (AI) and remote sensing is having profound implications on the ways of working of environmental scientists and the ability to monitor, analyse and model environmental systems. Advancements in these areas are proving disruptive to the environmental sector and wider society, changing the ways environmental scientists and society at large understand, manage, and interact with our environment.[2]

Technology and the environment have a complicated past. They are often considered as the antithesis of each other, with technological development being driven by humanity's need and desire to control or supersede aspects of the environment.[2] Technological development was at the heart of the Industrial Revolution, with climate change driven by anthropogenic activity a direct result of our technological innovation during this time.[3] Moreover, technological development has resulted in the production of a multitude of novel chemical and biological products which have resulted in adverse environmental impacts.[4]

Despite technology's chequered impact on the environment, it will play a fundamental role in supporting our transition to a sustainable society and will continue to be a shaping force in the future of environmental work.

Understanding our environment

Environmental scientists are now able to monitor, record, analyse and model our environment at an unprecedented level. Technological innovation has led to the development of several technologies that support these functions, including earth observation techniques such as Geographic Information Systems (GIS), remote sensors, analytics platforms, and cloud technologies, which can record and analyse environmental data in real-time at increasing granularity and hyperlocality when used in combination with advancements in data science.[5] This in turn supports environmental scientists in making predictions about aspects of the environment and informs time-critical decision making related to environmental conditions.[6]

Rapidly detecting changes in our environment is a useful tool for managing environmental risks and developing early warning systems, pinpointing issues in environmental systems, tracing sources of pollution and predicting changes to the environment based on different factors. It is also an important tool for accountability in the environmental space, allowing us to record adherence to government policies and legislation, and provide opportunities for more fully understanding our impacts on the environment.[7]

The emergence of digital twin technology provides environmental scientists with an opportunity to model and simulate environments under different conditions, supporting systems-led approaches and reducing the risk of novel interventions due to the ability to test them first for likely effects.[8]

Being able to observe and understand more of our world, along with the technological capability to bring numerous observations together to inform decision-making, will continue to play a significant role in the future work of environmental scientists. How we ensure that this technology is used to inform solutions-led science will heavily depend on environmental scientists applying these findings, translating them to decision-makers and using them to change course when needed.

The rise of green technology

Technology is often lauded as our salvation from environmental crises, particularly climate change, with our faith in technological solutions perhaps leading to a level of apathy in our action towards a net zero future. It is widely acknowledged that we have much of the technological capability to meet net zero, but that the changes needed at a societal and economic level are inhibiting progress. Understanding what technology is needed, and how this should be applied, will be an increasingly important role for the environmental professionals of the future.

'Green technology' refers to technology that is designed to mitigate and/or reverse the effects of human activity on the environment . This encompasses a wide range of different technology types, ranging from renewable energy technology to electric vehicles to carbon capture, utilisation and storage to name just a few.

There has been a large increase in the number of technologies described as 'green', but the environmental credentials of these and their potential application to support solutions-based science is not always clear or correct. Understanding the resource implications of rolling out new technologies, their embodied carbon and their ability to fit within a circular economy are all important aspects of considering how — and if — different technologies should be used.

Technology alone is not a panacea for environmental crises, but instead should be used as a tool to support our transition to a sustainable society which embraces the environment. Technologies that enhance the environment should be prioritised, with a focus on technologies to support green infrastructure and nature-based solutions where possible. Technologies that treat the symptom instead of preventing the disease should be used as a last resort, prioritising technology that treats issues at their root and can lead to multiple long-term benefits.

This highlights the need for targeted investment focused on environment-enhancing technologies and the optimisation of existing technologies and supportive infrastructure, such as grid connectivity and storage systems, as opposed to sinking investments into novel technologies that will take too long to pay environmental dividends or which are highly resource-intensive and incompatible with a circular economy.

Working in the field (or in the cloud)

Technological development has had profound impacts on the working practices in the sector, some of which were accelerated by the Covid-19 pandemic. Day-to-day jobs of environmental scientists vary greatly across specialisms, but hybrid and remote working are newer aspects that are shifting the working landscape further.

Fieldwork will always be a key factor of environmental work, but there are also increased uses of remote survey techniques, such as using GIS and Unmanned Ariel Vehicles (UAVs), to carry out tasks that previously had to be done onsite. This means that many environmental professionals now must manage a trichotomy of working practices — online, onsite and office — as well as the interface between these working environments.

Each way of working requires different skills and knowledge and the ability to switch between them as needed. Managing outputs from hybrid approaches is also changing the way work is done; technological advancements lead to the ability to access data sets from a number of different sources and at higher volumes than ever before. This can shift the focus of working practices away from data collection and towards data analysis, with associated implications for working practices and the skills needed.

These changes to working practices may lead to a disconnect between the perception of an environmental science career and what the day-to-day job looks like. Some may enter the sector hoping for a hands-on working environment out in the field, but this is likely to be only part of the work of future environmental scientists. Managing and collaborating via digital workspaces will also be a key constituent of environmental work and the expectations and skills around this will need to be fostered accordingly.

For graduates and new entrants into the sector, hybrid working can present a number of challenges. A less consistent approach to onsite and office working can change the process of professional development – learning through osmosis from colleagues in the office environment has previously played a key role in supporting the development of enabling skills, such as communication, management and leadership. Hybrid working is leading to more people turning to online training and 1:1 meetings for professional development opportunities. Though this is likely to work for some, it might be more challenging for others. Organisations will need to manage these challenges through varied and flexible approaches to ensure that their skills needs are met and to retain employees. One crucial consideration is that increased remote working availability can lead to a more inclusive working environment – which is important given the diversity issues currently faced by the sector.[9]

The rise in remote and hybrid working is also leading organisations to consider further how they can instil a sense of organisational culture and socialisation between team members. This can be challenging, but perhaps presents an opportunity to learn from young people in the sector, many of whom would have grown up being part of online communities. It can also support organisational alignment with the ethics and values of young professionals, by providing opportunities for greater flexibility and work-life balance, both shown to be increasingly important for entrants to the workforce.[10]

The rise of digital workspaces such as digital Environmental Impact Assessment (EIA)[11] could facilitate greater collaboration across disciplines and organisations. Digital EIA workspaces allow specialists from across the EIA process to work collaboratively and remotely in real-time, facilitating engagement with key stakeholders through digital environmental statements. Augmented reality can also be used in the planning and development space to connect with key stakeholders in project development.

Robotic and autonomous systems have the potential to support environmental science through their ability to replace human activity which is high risk or repetitive, support research and innovation, and improve accessibility to hard-to-reach areas for surveying.[12] Biotechnologies, novel materials and 3D printing will provide opportunities for new applications to support the restoration of ecosystems[13] and production methods that support circular economy ambitions.[14]

Artificial Intelligence (AI) is high in the public zeitgeist, with open access applications leading to questions about how it will influence society and the world of work. Although AI applications are increasing in the environment sector,[15] many of these are still in their infancy and it remains unclear how AI may affect working practices in the future. Trends in current AI technology development indicate that it could play a key role in future environmental data analysis and modelling. For environmental scientists this would mean that less time would be spent performing these functions themselves, with a focus instead on identifying the best use of AI technologies, writing appropriate command code and interpreting AI outputs. Moreover, as AI technologies develop and their use expands, environmental scientists will need to play a role in demystifying the use of AI and offering assurances on the validity of AI analysis through complementary real-world monitoring. It's important to recognise that AI will be unable to take the role of environmental scientists in demystifying complex concepts, interpreting the values of nature, and translating evidence into forms which support evidence-based interventions and decision making. AI will likely play a role in making some of the mundane aspects of environmental work more procedural, leaving more time for environmental scientists to face the bigger question of how we use science and evidence to transition to a world which fully embraces and enhances the environment

Engaging with the environment

Given the scale of societal change needed to realign our relationship with the environment, providing opportunities for stakeholders — such as decision-makers and the public — to connect and engage with the environment is of paramount importance. Behavioural change and increased consciousness of our environment can be facilitated through technology by communicating information in new ways and providing opportunities for active engagement. Technology can also improve the accessibility of stakeholder engagement options by providing the option to engage with environmental science from home.

"...technological development is redefining and expanding the way that citizen scientists can feed into scientific research..."

Technologies are facilitating stakeholder engagement on multiple levels, such as through digital workspaces, augmented reality, and novel data visualisations with adjustable parameters.[16] This can support interdisciplinary working by providing digital spaces for collaboration and developing novel ways of communicating science and evidence dependent on audience needs and interests. Visualisation can be an effective tool for bridging gaps between disciplines and translating complex scientific evidence into more digestible formats. It is important that this is done in a way that does not lead to the oversimplification of complex environmental information.

The availability of low-cost technologies, such as low-cost sensors, are facilitating citizen scientists to engage further with our environment and contribute data at local levels, which feed into nation-wide and, in some cases, international projects.[17] Citizen scientists are at the interface of science and the public, and technological development is redefining and expanding the way that citizen scientists can feed into scientific research and engage with scientists and each other. Digital platforms allow remote training for citizen scientists and the ability to submit data in real time, as well as the ability to connect with other citizen scientists and build online communities.

Technology and digital spaces can therefore provide rich opportunities for building connections with the natural world for those from all backgrounds, paving the way for collaboration and knowledge sharing in innovative and creative ways.

System error – technological risk

Technological development does not come without risk, and as the use of technology in all sectors continues to grow it is important to ensure that there is a careful consideration of risks and that these are mitigated effectively to ensure resilience in our systems.

Technological systems are vulnerable to human risk, in the form of both human error and malicious intent, such as through hacking and novel and dangerous deployments. Moreover, single points of failure and cascading risks are inherent to overreliance on technological systems. In cases where system failure occurs due to single points of failure, it can be unclear how to deal with the issue, especially as technological set-ups get increasingly complex and sophisticated. Overreliance on technological systems also has implications for public infrastructure, such as energy grids, and must be used in a way that does not overburden existing and new infrastructure, particularly in the move to a renewable energy system based on electrification.[18] Building resilient systems should therefore be a priority from the outset to protect against risks and ensure that technology remains an enabler, rather than a barrier, to professional scientific endeavour.

One key example is the rapid emergence and reliance on new remote sensing technologies. Complex real-time monitoring systems can be vulnerable to single points of failures which can have cascading impacts throughout the system, reducing the resilience of systems and thus their reliability. This is particularly pertinent when linked to early warning systems related to extreme weather events and observation networks which depend on consistent data gathering.[19]

The growth in technology related to the environment, such as low-cost air quality sensors, also raises issues related to whether they are scientifically robust and are deployed correctly, especially in the case of non-specialists. This results in limitations to the data collected by them and causes quality control issues – all of which must be accounted for when using the data for decision-making and evidence-based interventions. Environmental scientists need to rapidly respond to advancements in technologies and ensure they are upskilled in deploying appropriate technologies, understanding their outputs and their limitations, and practicing reactive agility to manage risks and maximise benefits of technological use. Supporting scientific literacy across other non-specialist stakeholders, such as citizen scientists, will also be important given this issue to ensure understanding of the correct use, and limitations, of certain technologies and resultant datasets.

The environmental impacts of new technology can also not be ignored, both in terms of resource consumption, embodied carbon and associated pollution. Many green technologies rely on transition-critical minerals which can be resource-intensive to produce and rely on extractivist methods that can be deeply

damaging to ecosystems.[20] For example, increased demand for heavy metals needed for technology like electric vehicles can result in harmful deep-sea mining practices. This not only damages ecosystems, leading to degraded habitats and biodiversity loss, but can lead to contamination issues over larger areas.[21] Technologies which depend on rare materials and finite resources must be made in a way that is compatible with realising the circular economy, to ensure that new resource extraction is limited, along with the associated damage to the environment.

Technological development has also led to the emergence of novel contaminants, such as PFAS and nanomaterials, which are spreading rapidly throughout the globe in our land, water and air. Some of the impacts of these are still uncertain, but evidence is emerging which indicates associated risks to ecosystem and human health.[22] Environmental scientists of the future are likely to play an increasing role in understanding how these contaminants are impacting our world and managing and remediating novel contaminants, as well as championing the precautionary principle in their use to help mitigate environmental and health risks. Dealing with emerging contaminants is likely to have implications for how we manage waste and deal with contamination in our land and freshwater systems.

In some cases, technology and digital systems will require high initial investment and maintenance costs which has implications for the accessibility of technologies, especially in lower income countries. The accessibility of technological solutions should therefore be a consideration to ensure the benefits are wrought by society as a whole, as opposed to limited benefit to specific commercial enterprises. Where technological solutions are adopted to address climate change and its impacts, it will be especially important to ensure that these are shared globally, to fully safeguard against the loss and damage associated with past technological developments.

Harnessing the power of technology

Technology will be a fundamental part of future working practices for environmental scientists and of supporting our transition to a sustainable society. However, we must not become complacent and think that technological innovation holds the key to dealing with all of our environmental crises.

Technology can be a tool to support action but must be pursued in tandem with transformative change at economic and social levels. The expertise of environmental scientists should remain central to our transition to a sustainable a society, with technology acting as an enabler rather than a 'silver bullet' solution. Cutting-edge technologies, such as AI and machine learning, should be used to support environmental scientists in the development of more effective solutions to complex environmental challenges, providing insights into the uncertainty, intricate interactions among multiple variables, and highly nonlinear processes that exist in the environment.

The risks and uncertainties surrounding technology should be acknowledged and managed to ensure resilience of our systems and the decreased likelihood of unintended consequences. How technology is leveraged in the environment sector should be subject to careful consideration, with a thought for how technology is regulated and quality assured to ensure its validity for supporting evidence-based decision making or its application to environmental issues.

We must also continue to adapt to an increasingly digital workspace and embrace the opportunities that lie within for increasing diversity, accessibility and engagement in the environmental sciences.

As the IES worked to produce this vision, we engaged with environmental scientists working across disciplines. The future they wanted to see for technology is one where:

- Environmental scientists play a central role in the transition to a sustainable society and the development of evidence-based solutions, enabled by technology. Scientific expertise ensures that appropriate technologies are applied to support understanding, analysis, modelling and prediction.
- The environment sector uses technology to inform systems approaches to challenges, particularly by combining datasets and parameters, modelling environmental systems, and facilitating interdisciplinary collaboration.
- Governments and funding organisations focus investment on proven technologies which support the transition, rather than sinking investment in uncertain technologies or those that will take too long to develop to make contributions to addressing environmental challenges.
- Governments assess technology and digital systems for risk to support resilience and reduce the likelihood of 'single points of failure' or 'cascading risks'. Regulation focuses on reactive agility to maximise the benefits and reduce the risks of technological development.
- Environmental scientists use technology to facilitate increased engagement with decision makers and the public through innovative and creative approaches to evidence-informed decision making, behavioural change, and accessibility.
- The environment sector assures the quality of new environmental technologies to ensure the validity of data captured and the appropriateness of applying technology to environmental science.

Transforming the data landscape to transform the environment

How are novel developments in data shaping environmental science? What are the challenges associated with 'big data'? How can data shape our decisions as we work towards environmental improvement?

Data is the cornerstone of environmental science. It provides us with the ability to observe the world around us, measure trends, and understand our impacts. It is a fundamental part of solutions-led science, giving us the tools to quantify the impact of our activities and use this to inform future evidence-based action.

Over the last few decades, the data landscape has shifted significantly, with a substantial increase in our ability to collect and curate data. This has revolutionised the amount, quality, connectivity and granularity of the data we collect. Technological innovation has allowed us to collect data at the hyperlocal to global scales, leading to vast datasets collected through diverse means – from hand-sampling to remote sensing to global observation systems. In turn, new technologies and statistical software utilising machine learning Artificial Intelligence (AI) allow us to analyse data at a scale previously impossible.

Data is critical to securing funding for environmental work and advocating for environmental action. Robust data and evidence are needed for effective engagement with government and industry, whether on supporting the roll-out of environmental schemes or in proving efficacy in dealing with environmental issues. In areas where best practice is still emerging, such as for the application of certain nature-based solutions, the collection of data and evidence is particularly important. Without sufficient data and evidence, securing funding for new nature-based solutions can be very challenging, leading to stasis on the ground.

Data for decision making

Within the environmental and regulatory landscape there are a number of international and national targets and goals, including international frameworks like the Global Biodiversity Framework,[1] as well as national legislation and policy like the Environment Act[2] and Environmental Improvement Plan for England,[3] which includes legally binding domestic targets.

Increasing the evidence-base for environmental science is a fundamental requirement for quantifying and mitigating the impact of human activity and supporting national and local policy development. Real-time environmental data can provide evidence on the success of interventions at the hyperlocal, local and national levels.

Data and evidence also play an important role in accountability and ensuring that stakeholders are meeting their requirements, targets or pledges.[4] Increasingly sophisticated data collection can also pinpoint harmful practices and hold perpetrators accountable, helping to trace environmental incidents and sources of pollution.[5] This can play an important role in supporting the 'polluter pays' principle in environmental regulation.

Data can act as a conduit for information transfer, providing a common language for specialists and non-specialists. It is therefore essential that data continues to be a driving force in the development of environmental decision-making in the future and that we fully realise the potential of our growing data capabilities to support environmental improvement, rather than limiting environmental harm.

The role of data in monitoring environmental improvement

Current environmental goals and targets will never materialise into environmental improvement in the future, unless we can measure progress towards them and scale up or adapt approaches in response to findings. If we continue with 'business as usual' whereby we focus our data insights on informing target setting, rather than target delivery, we will not achieve the environmental improvement needed.

Monitoring methodologies and data collection must therefore be an integral part of environmental projects, to report and monitor progress towards environmental goals, review the effectiveness of policy interventions, and allow for continuous improvement.[6]

For longer term commitments, such as Biodiversity Net Gain (BNG) requirements, monitoring will be essential to determine if the BNG increase has been maintained over the required 30-year timeframe and will provide invaluable insights on the efficacy of different mitigation methods. This also has important implications for measuring compliance and dealing with enforcement of policies, as it raises the question of how to deal with projects which do not meet this legislation. This puts a spotlight on the skills needs in local authorities and other delivery organisations which will need the capability and capacity for interpreting datasets to ensure planning and related activities are aligned with policy requirements.

Assessing progress towards long-term environmental improvement will need to go beyond purely monitoring data. Integrated assessment approaches will be needed to address effectiveness of interventions on complex, systemic environmental issues. This will require a combination of different data and information sources including monitoring data, environmental accounts, practice-based knowledge, and stakeholder perspectives. This will also support a move towards more interdisciplinary science by combining insights across disciplines.

Analysis of retrospective data should be combined with modelling and predictive data capabilities to measure progress towards environmental goals and inform decision making to ensure a scientific approach based on the objective of continuous improvement.

The rise of infrastructure-level data

The rise of novel data sources has allowed for the development of complex, interlinked systems of data collection. These go beyond more traditional project-level data to infrastructure-level data, which combines outputs from a variety of sources to provide data at larger spatial and temporal scales. An example of this type of system is the Global Ocean Observing System (GOOS),[7] a permanent global system for observations, modelling, and analysis of marine and ocean data. The use of infrastructure-level data in environmental science will likely continue to increase significantly, with a key role of environmental scientists of the future being able to effectively utilise this data for a variety of projects.

The benefits of this type of data are that it provides a sustained source of information to not only help us better understand aspects of the environment, but also to build robust evidence for environmental trends, and, subsequently, allow us to better predict changes to our environment. This is an important part of ensuring we are on track to meet environmental ambitions or signal the need for a change in course.

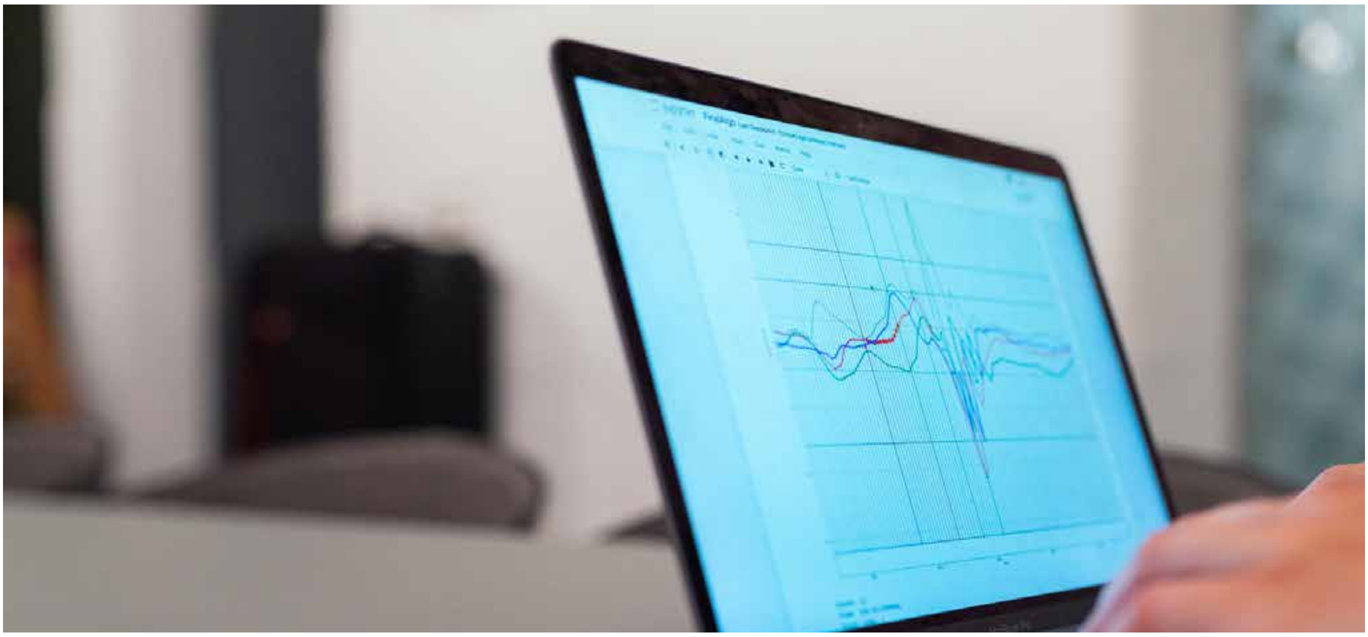
It will also be a key component of supporting systems-led approaches to science. Data at the infrastructure-level provides a much greater ability to understand the complex, interlinked systems that comprise our environment. Siloed, project-level data is much less equipped to support systems approaches as data collection is narrow in focus and often not able to provide the duration of data collection needed for understanding longer-term issues.

Infrastructure-level data does have some challenges for its implementation and use.[8] It often has high capital and maintenance costs and requires resources in capacity-building for those installing and using these data systems. Using existing infrastructure to feed into data systems is one way of decreasing the high initial costs of implementation and instead would just incur marginal costs of building capacity and capability to use in this way. Where infrastructure-level data systems traverse national borders, it will also require international treaties to support its expansion. This can be a major benefit of infrastructure-level data as it provides an opportunity for international collaboration and alignment with international environmental governance systems and targets. This is critical to addressing complex environmental crises.

Despite the rise in infrastructure-level data, funding systems are still heavily skewed towards project-level data, with funding often not available for longer-term, large-scale projects. Transforming our practice around data collection and adapting our funding models for science and research will be key to fully capturing the value that this type of data system can provide. This would also create a shift away from project-level proprietary data in the sector to open source, infrastructure-level data that can support increased capability across research communities. This infrastructure-level data should be developed following a public good model, which supports the rise of open-source data.

Improving the accessibility, interoperability and transparency of data

There is already a vast quantity of data available on the environment around us. However, a large amount of this is proprietary, locked behind paywalls, or hidden in different areas of the internet. To ensure that we are not just collecting data, but actually translating its findings into learning and action, an increase in the amount of open data will be essential for unlocking the value of large datasets. Open data is incredibly



important for supporting systemic change and allows for the same dataset to be put to myriad uses, providing a much more efficient and equitable system.

Data should be managed in a centralised database to maximise accessibility. To make the most of the data available, we also need to ensure that is interoperable so that it can be used across systems for a multitude of stakeholders and applications. Application Programme Interfaces (APIs) should also be developed to support data analysis and visualisation across the sector.

To support the establishment of centralised databases, it is vital that open data standards are developed. This will support stakeholders in collecting, publishing, accessing and sharing data that is of better quality and aligned with an agreed 'common language' for data. This is also a useful tool for sharing data across disciplines, where there may be different norms around dataset formats — essential for supporting interdisciplinary science. One of our immediate goals should be to move towards coherence and standardisation of environmental data to ensure validity and consistency of data, and to improve transparency.

Transforming data into actionable information requires powerful visualisation techniques which can highlight insights, such as trends, anomalies and statistically significant findings into easily digestible information for a variety of stakeholders. Decision makers need data to inform evidence-based policy, often in fields in which they are not specialists. This means that data needs to be presented in a robust but understandable format. Data can also be a powerful tool for engaging with the public, helping to cut through scientific jargon to deliver targeted messages that can support awareness-raising and behavioural change. Data visualisations should be used to their full potential in these areas, whilst ensuring that insights are not oversimplified or misinterpreted.

The power of the public – citizen scientists

Technological innovation has also enabled extensive growth in the number of citizen scientists mobilising to collect environmental data, from measuring soil health[9] to water quality[10] to wildlife sightings.[11]

Declining government investment in environmental protection is leading to a lack of evidence around aspects of the environment.[12] There is a need to supplement sparse datasets with new information to support targeted action and measure effectiveness of policies and interventions. Citizen science data can be combined with other data sources, such as remote sensor data and infrastructure-level data, to support powerful insights in environmental science.

This can be a useful tool for filling data gaps in national datasets, as well as empowering and building environmental citizenship among members of the public through 'hands-on' experience of environmental work. Increasing public connection with the environment supports other important pathways to improving the impact of environmental work, supporting behavioural change and community-led action. Citizen science can democratise the process of evidence gathering and gather new insights into different individual and cultural approaches to evidence gathering and analysis.

The rise of citizen science data does not come without challenges. There are many schemes nationwide , with great diversity in how they are implemented and managed, and varying levels of quality assurance protocols. Although citizen science data can lead to locally rich pictures of environmental status, the data landscape as a whole is fragmented due to the range in quality of citizen science projects and the resulting data.

This has a number of important implications for environmental scientists. Working with citizen scientists requires several important skills especially soft skills related to science communication and public engagement. This highlights the importance of having environmental scientists with inter and trans disciplinary working skills who can span boundaries and act as knowledge brokers. For those using citizen science datasets there are also questions around ensuring the quality and validity of data, requiring a good understanding of the uncertainties and limitations of datasets, as well as how they can be quality assured and cleaned so that they are robust enough for use in scientific study.

In order to maximise the vast potential benefits of the work of citizen scientists in the future, it is important to put in place a national standardised framework for citizen science projects which can support the development of schemes that meet the scientific rigour needed to support evidence-based change.[13] Key success factors for establishing a more robust network of citizen science projects will be the development of data platforms, data integration tools, and training packages, as well as rolling them out in a cost-effective manner to those coordinating projects.

Unlocking the value of data through skills, communication, and quality assurance

The rise in data collection is helping us to fill data gaps and can support us in assessing the effectiveness of policy decisions and mitigations, providing early warnings of change and removing the subjectivity surrounding enforcement decisions. Data developments have had profound implications on the work of environmental scientists. Skills in handling and analysing big datasets, managing diverse datasets, modelling, and data collection techniques are important to effectively leverage the opportunities that data brings.

These skills will be important tools in the arsenal of environmental scientists of the future. Although not all will need to be experts in conducting data analysis, there will be an overarching need for environmental scientists to understand how data can be used for insights, the best data analytics tools to use, and, importantly, to understand the outputs from data analytics software to inform action. Translating data analysis to different audiences and combining findings from multiple datasets will also be key skill requirements for many environmental scientists. This includes understanding the uncertainties and limitations inherent in datasets and being able to communicate them effectively. These types of skills should be fostered through higher education and technical pathways into the environmental sciences, as well as dedicated CPD programmes.

“Unlocking the value of data will be an important part of the mission of future environmental scientists.”

As the number of different ways of collecting data increases, issues arise for assessing the quality of data. The accuracy and precision of sensors and monitoring equipment can be variable and should be considered as an uncertainty and a limitation to the datasets collected through these types of instruments. Ensuring data is cleaned and checked for accuracy is an area where machine learning and AI are likely to provide support by identifying potentially erroneous data points and flagging these to the user.

Unlocking the value of data will be an important part of the mission of future environmental scientists. These insights will be vital to enabling evidence-informed decision making, designing interventions to support the restoration and conservation of our ecosystems, and supporting our transition to a society in harmony with our environment.

As the IES worked to produce this vision, we engaged with environmental scientists working across disciplines. The future they wanted to see for data is one where:

- Environmental scientists measure progress towards environmental targets using ‘integrated assessment approaches’ which utilise a combination of data sources and take account of the systemic nature of environmental issues. Findings from assessments are used to form evidence bases on the effectiveness of interventions.
- Governments establish centralised environmental datasets, rolling out standards to support interoperability and quality assurance, supporting evidence-informed decisions and policy delivery.
- Governments develop ‘infrastructure-level’ data systems under a public goods model, facilitated through international agreements and frameworks where needed. Research funders support these systems by adapting funding models and project timelines.
- The environment sector develops a national standardised framework for citizen science projects to support standards for how projects are delivered and managed, providing quality assurance for data collection.
- The environment sector prioritises digital skills development in data analysis, visualisation, interpretation, and communication, supporting data as a tool for evidence-informed decision making.

Delivering a just transition: The importance of equity, diversity and inclusion in the environmental sciences

Global challenges require global solutions. The complex, interconnected issues of biodiversity loss, pollution and climate change will continue to be the key focus of future environmental work and will require unprecedented collaboration, coordination and cooperation. Fundamental to tackling these issues and creating a truly sustainable future aligned with the Sustainable Development Goals (SDGs) is the ability to deliver environmental work that transcends governments, cultures and disciplines and delivers for both people and nature.

The concept of environmental justice is integral to this. Environmental justice is often defined as *the fair treatment and meaningful engagement of all people regardless of race, colour, national origin, or income, with respect to the development, implementation and enforcement of environmental laws, regulations, and policies.*[1] However, environmental justice should go beyond environmental policy, to also recognise the disproportionate impact of environmental crises on marginalised communities and should therefore also cover equitable exposure to environmental good and harm.[2] Examples of environmental justice issues are wide ranging, from low-income communities facing poor air quality in the UK[3] to the impacts of climate change disproportionately affecting marginalised communities in the global south.[4]

Developing a future for the environmental sciences that is built on principles of environmental justice will require targeted intervention to increase the inclusivity of the sector to enable and inspire people from diverse backgrounds to pursue and maintain a career in environmental science. The sector will also need to ensure that it is porous to new ideas and ways of working from other disciplines; the social sciences will be a key ally in transitioning to an environmental workforce that is representative of the society that it serves.

Justice at the core

There is no such thing as a purely environmental initiative. This means that environmental justice principles need to be embedded throughout the environmental sciences, with multicultural participation in environmental policy and practice playing a key role. Environmental justice started as a social movement in the mid-20th Century and is therefore rooted in social activism.[5] To ensure that the environmental science of the future is underpinned by justice, interdisciplinary working and links with the social sciences will be key success factors. Systems thinking approaches must take account of social context, and environmental scientists must be equipped with the skills needed to understand these social systems.

Managing the relationship between science and activism will continue to be an important dimension of the environment sector. Effectively navigating the interface between science, policy and the public will be an important part of this to ensure that environmental activism and environmental science can be complementary approaches to ensuring better environmental decision-making. Science can empower society to engage with contentious issues and can be a tool for driving change. To capitalise on the synergies of science and activism, it is essential that scientists continue to work with robust evidence, but that we embrace openness, transparency, and collaboration to support change. This in turn will be a vital part of creating broad and diverse connections and improving inclusivity in environmental science.

The good news is that we are not at 'square one'. There is widespread understanding of the need for improved Equity, Diversity and Inclusion (ED&I) in environmental science and the rhetoric for environmental justice and inclusivity is there. There are also numerous examples of organisations and policy looking to address barriers to inclusion.[6,7,8] However, it is essential that we move beyond rhetoric to develop systemic solutions that support tangible change in the sector through targeted initiatives and a better understanding of what works. Siloed, small-scale initiatives will not be effective in dismantling the structural barriers to improved inclusivity in the sector. Change is therefore needed at multiple levels concurrently. We must inspire people from diverse backgrounds to engage with environmental science, enable them to pursue careers in the sector and nurture those already in the sector to support them in reaching leadership positions.

We must also consider all dimensions of inclusivity, including protected characteristics such as ethnicity, gender, disability, neurodiversity, sexuality and socio-economic background, and the intersectionality of these. Through concerted and targeted action barriers can start to be dismantled and a stronger environmental profession can be built for the benefit of everyone.

Equity, Diversity and Inclusion – A non-negotiable

Foundational to achieving environmental justice is the inclusion of diverse voices and expertise in environmental science, the environmental professions and in environmental decision-making. ED&I initiatives are therefore at the heart of delivering a just transition.

Currently, the environment sector is one of the least ethnically diverse sectors in the UK.[9] Other aspects of diversity also face challenges, such as the inclusion of disabled people and those from low socioeconomic backgrounds. The only way to build a sector that delivers for people and nature is to build one which is diverse. Science alone cannot solve environmental challenges. The translation of science into practical applications and decision-making is what creates change. For transformative change, science must inform, and be done in tandem with behavioural and political change. Effective behavioural change will not be realised in a sector that is not inclusive or representative of society. It is therefore not only a moral and ethical imperative to support ED&I, but also a pragmatic one.

The realisation of net zero targets is also dependent upon a growing environmental workforce and the widespread growth of green skills in the economy. To meet this demand, the sector needs to inspire more people from all segments of society to pursue environmental careers. Moreover, a number of environmental specialisms are struggling with resourcing and recruitment issues,[10] underlining the need to attract and retain a wider pool of talent.

A key starting point to improve ED&I in the sector is supporting multicultural participation in environmental science and demonstrating that the environment sector is relevant and welcoming to people from all backgrounds. This will require identifying and understanding barriers to ED&I in the sector, and cocreating solutions to support greater diversity.

Diverse routes support diverse voices

Perceptions and knowledge of the sector can be a barrier to diversity. Showcasing the breadth of careers in the sector, the relevance of these careers to people from diverse backgrounds and their lives, and highlighting role models to create a sense of belonging are all important aspects of ED&I initiatives. This must start from a young age, with people from all backgrounds having a good understanding of the environment, the ecosystem services that it provides, and the careers that exist to support it. It is therefore vital that different career pathways into the environment sector are promoted, such as technical pathways and apprenticeships, to showcase the breadth of career types within the sector and challenge perceptions of what makes an environmental scientist.

Making traditional routes, such as Higher and Further Education, in the sector more inclusive will not be enough to tackle the issue of diversity in the sector. These routes have a number of in-built structural barriers that inhibit diversity.[11] Therefore, it is important that as we work to break down these barriers, we also develop new routes into the sector. Technical pathways and apprenticeships will be a key component of this, as will paid internships, ringfenced opportunities for those from diverse backgrounds, sponsoring diverse talent, and creating networks to foster a sense of community.[5,12,13]

As working practices change in response to global megatrends, it is important that we keep ED&I at the forefront to ensure that changes to working practices do not pose a barrier to inclusion and that practices that support greater diversity, such as the emergence of flexible working, are supported. ED&I initiatives must also extend beyond recruitment into the sector and support working practices within roles. For example, a key challenge in the environment sector can be working practices on site. Organisations should ensure that processes and frameworks are in place to support inclusive working environments across the sector for those from diverse backgrounds. A number of initiatives of this type are already in place and the learnings from these should be disseminated to support change.[14]

Action is needed at multiple levels to support ED&I,[5] including:

- Inspiring younger generations through outreach and "inreach" through community champions[15]
- Ensuring working environments are inclusive to all
- Creating entry routes into the sector aligned with different educational backgrounds and increasing the visibility of employment opportunities

- Ensuring ED&I is embedded into recruitment practices at all levels and creating and investing in scholarships, bursaries and internship opportunities that are ringfenced for people from underrepresented backgrounds
- Retaining talent in environmental science research through ringfenced opportunities for people from underrepresented backgrounds
- Supporting those from underrepresented backgrounds in the sector into leadership positions
- Cocreating solutions and championing diverse voices when we communicate with decision makers
- Exploring the impact of intersectionality or people's experiences in the workplace through further research

Moving beyond ED&I

As we progress with ED&I in the environment sector and work to break down structural barriers, it is important to remember that achieving ED&I goals should be the minimum of what we achieve in this space.

In the multicultural world we live and work in, it is worth reminding ourselves that even ED&I has been developed in the context of historic and modern colonialism. Moving beyond ED&I, we should rethink inclusion so that it is instead based around cross-cultural integration, benefiting from the strengths and knowledge of all parties involved. This can bring up some difficult, philosophical differences, such as the alienation between science and spiritualism, but would allow for truly equitable relationships where power is shared, and solutions are co-created.

Environmental justice and future generations

Sustainability is defined by our actions not impacting the ability of future generations to meet their needs.[16] Environmental justice, therefore, should not only be framed as an issue affecting society currently, but it is also at the heart of sustainability science. If we continue with business as usual, we will impart innumerable environmental injustices on future generations.

"The actions we take today will directly impact our ability to deliver the just transition..."

The future of the environmental sciences therefore cannot be discussed without considering environmental justice. The actions we take today will directly impact our ability to deliver the just transition to a sustainable society and must be the foundation of delivering a vision for the future of environmental science.

As the IES worked to produce this vision, we engaged with environmental scientists working across disciplines. The future they wanted to see for environmental justice and ED&I is one where:

- Environmental scientists embed environmental justice across all projects to make them sustainable. The environment sector recruits a diverse field of environmental scientists who champion environmental justice in their work and co-create solutions with communities.
- The environment sector develops ED&I initiatives at multiple levels, breaking down structural barriers to inclusion, including through increased outreach, modernising recruitment processes, and adopting new working practices. Lessons learned from initiatives are shared widely to support systemic change.
- Environmental scientists use inter- and trans-disciplinary collaboration to drive just approaches to transformative change which champion the voices of underrepresented communities.
- The environment sector and learning providers promote greater diversity of career pathways to support underrepresented communities in pursuing and retaining careers in the environmental sciences.
- The environment sector champions multicultural participation in environmental science and cross-cultural integration and collaboration to support the co-creation of solutions to environmental challenges.

A broad church for a shared environment: Raising SPIRES to unite science, policy, and the public

How can science be made relevant to the public and useful to policy? What should the science-policy interface of the future look like? How can science bring together an increasingly polarised society?

The natural world has the potential to benefit all people and places, now and in the future. That mutually beneficial relationship is subject to how well different perspectives on the environment are reflected, and the extent of those benefits is subject to how well links are built which capitalise on different sources of knowledge.

In particular, the relationship between science, policy, and the public is crucial for ensuring effective regulation, evidence-led policy, and an empowered public. Despite the importance of this relationship, the interface between science, policy, and the public has 'hollowed out' over time, as interactions have become increasingly transactional, and trust has become strained and polarised.[1]

"...science must be available to the public to provide information, identify solutions, and demystify the complexities of natural systems..."

While these challenges persist, there is already significant progress being made in modern science communication to improve the relationship between science, policy, and the public. Those efforts will be fundamental to determining whether the future of environmental science is one where society is estranged from the knowledge and the means to deal with environmental challenges, or one where the public is empowered to pursue transformative change.

Science and society: empowering the public

Solutions to environmental challenges are irrelevant until they are legitimised by public opinion. There are inherent subjectivities in the way society responds to the crises facing humanity, so people must have a say in which pathways are pursued.[2] To that end, science must be available to the public to provide information, identify solutions, and demystify the complexities of natural systems so that the public is empowered to make meaningful choices.

Over time, the relationship between science and society has become fragmented and polarised. That estrangement has been caused, in part, by the way that science is portrayed in the media, as well as by the alienation of science from the public due to increasingly complex policy decisions.[3] In step with that polarisation, many benefits of public interaction with science are also being lost, including the ability to reach a consensus on the existence of problems and the solutions which are best placed to address them. Science-informed understandings of both will be necessary to secure effective change.[4,5]

Where once there was a strong social desire to understand the breadth of science, the complexity and expansiveness of scientific inquiry has made such a feat impossible. Instead, the public engages with science on a 'need-to-know' basis, leaving the more technical aspects to policy makers and relying on news and popular media to learn about environmental topics.[6]

With the onset of social media and the 'mediatisation' of news, the latter has weakened the public's interface with science.[7] As the consumption of media takes place in increasingly short bursts, there has been a growing demand for content which is concise, staunchly defending a non-nuanced argument, and simple enough to fit into a tweet or short video. Global politics and the rise of populism have demonstrated the effect of mediatisation on how leadership is viewed, but it also jars with the ways that science works, which is inherently complex.[8]

These trends have not universally lessened trust in science, despite the claims of some politicians that society has "had enough of experts".[9] Instead, public opinion is polarised, with many viewing scientists as some of the most trustworthy figures in society and others viewing science as completely removed from their interests.[10] While the majority of society still trusts science and cares about environmental issues, the ability to form a consensus across society relies on engaging everyone, including those who currently feel disenfranchised by evidence-led policy.[3]

Several solutions are already beginning to emerge, all of which will need to be employed to secure the best vision for the future. Popular science has demonstrated the strong desire of the public to be informed by science, and environmental programmes such as Blue Planet and Wild Isles have been successful in garnering public support for policy action.[11]

David Attenborough's filmography has historically focused on explanation rather than advocacy, but nonetheless drives society to action, suggesting that the lack of scientific information has effectively disempowered people from making choices that they would otherwise make.[12] Popular experts like Sir David are vital resources in building trust with the public in ways that work alongside the human desire to be entertained and the behavioural drivers that have caused challenging trends like mediatisation.[13,14]

While short-term economic value systems have dominated decision making over the last century, they can be co-opted through frameworks like ecosystem services which reiterate the economic importance of nature. [15] Reframing issues like air quality as health concerns rather than purely environmental ones has also been successful, raising the issue on public agendas and framing it as an area of science where expertise remains highly trusted.[16,17]

Participatory approaches like citizen science, forums of empowerment like climate assemblies, and broad networks that bring together other trusted groups can all support engagement.[18] In each of these instances, case study examples of best practice are already producing strong results.[1] To secure the best possible future for the environment, those solutions should be scaled up to bring in groups who are currently still estranged from science.

Science and policy: informing decision makers

Much like its relationship with society, science must have a good relationship with policy, governments, and decision makers to effect meaningful change in the world. As the legitimacy of modern environmental science comes from the extent to which it helps society overcome challenges, a priority for the future of environmental science will be to ensure that meaningful relationships are established with decision-makers.[19]

Historically, the relationship between science and policy has been two-way: policy sets strategic priorities for science, provides research funding, and employs or appoints experts within governments; meanwhile, science provides evidence for policy, shapes our knowledge of the world which influences priorities, and educates the public who direct policy makers. However, the relationship has become increasingly linear over time, as science is called upon by policy to answer specific requests for evidence but does not inform the general rationale behind decision making processes.[3]

As a result, modern environmental science often struggles to see the evidence it produces used by policy, especially when there is uncertainty around data, when evidence bases are vast or complex, or when evidence needs to be collated between governmental and non-governmental sources across multiple spatial or temporal scales.[20] At the same time, political megatrends, such as populism and the rising political prominence of authoritarian regimes spurred by an increasingly poly-nodal world, have made scientific evidence a lower priority for many decision makers.[21]

The COVID-19 pandemic caused a period of increased global reliance on scientific evidence, as well as unprecedented visibility of scientists to the public. This pushed back against some of the changes to the science-policy interface, normalising the prominence of science and its role in informing decision making, though the latter remains controversial, particularly given the heavily politicised role of science in the pandemic.[10]

Science and policy interact across multiple organisations and processes, often subconsciously or without deliberate design. These inherent and diffuse relationships will be most important to address as key leverage points with the capacity to transform policy processes and governance systems, while also giving regulation the scientific credibility needed to outlast political cycles and the certainty to create ‘level playing fields’ for businesses and consumers.[22]

In the face of prolonged uncertainty caused by apathetic and somewhat polarised public opinion on science, the need for a reimagined science-policy interface is urgent. Despite those uncertainties, significant opportunities are available to create a relationship between science, policy, and the public that brings all three together, empowering the public to engage in scientific ideas and policy decisions, ensuring effective decisions through evidence arising from well-targeted environmental science, and legitimising science and policy through public consent.

Science, research, and practice: coordinating the evidence landscape

Within the scientific community, there are many constituent elements which must be properly aligned to maximise the potential of science to aid policy and serve society. Insights from environmental professionals often do not make their way to researchers, and the findings of research rarely influence practice on the front lines. While best practice is driving links between research, industry, and practice, more can be done to make these approaches consistent and widespread.[23]

Testing research against the experiences of professionals working on the front lines and feeding research into guidance, are crucial for ensuring continuing development of best practice and confirming that theoretical understandings of the interactions between nature and society hold up in practice.[24] Likewise, if research is untargeted or not informed by practical insights, it may lead to less effective use of money, science capital, and time, all of which are limited in the context of pressing environmental challenges.

Industry also has a fundamental role to play in these relationships, particularly given the rising number of green jobs and the vast knowledge and expertise contained within the private sector. Capitalising on networks of professional practice will be vital to informing research and policy, as well as rolling out best practice, so the private sector needs a strong incentive to engage.[25]

Environmental expertise can be quality assured through professional registration, standards of competency like the UNESCO Competency Framework, and Continuing Professional Development (CPD).[26] This quality assurance is often directly influential for an organisation's financial 'bottom line' so can be a strong incentive to drive collaboration.

Environmental scientists, particularly young professionals, are also increasingly motivated by the potential for interdisciplinary collaborations and the sense that they are part of environmentally ethical communities.[27] If global economic conditions cause the labour market to continue growing tighter on average over the next half century, companies that allow their employees to collaborate and network will be more attractive to the best talent.[24,28] Novel technologies and increased flexible working are only likely to facilitate these interactions even further.

The final lever needed to bring together scientific communities of research and practice will be robust and comprehensive skills development, particularly for underutilised skills such as relationship building, storytelling, articulating complexity, understanding policy and economics, and media training. These will all also be fundamental to the capacity of environmental scientists to engage effectively with the public and policy.[29]

SPIRES: bringing everything and everyone together

The broadest churches have the tallest spires. As environmental science improves its relationships, it should bring more communities into contact with the broad church of interdisciplinary expertise that science can contain.

Managing those diffuse and complex interactions to ensure that the implications of science are useful and relevant to humanity could be facilitated through a "SPIRES" (Society, Policy, Industry, Research, the Environment, and Science) model:

- **Society** must be engaged to legitimise science. The relationship between science and society determines if evidence is meaningfully used and if science is fulfilling its duties to the public. For the relationship to succeed, more than just the most vocal or science-positive voices should be engaged, including those who have been historically excluded, such as indigenous communities.

- **Policy** must be engaged to implement science. The relationship between science and policy determines if society is empowered to make choices based on evidence. For the relationship to succeed, science should be part of the consideration of policy design and implementation.

- **Industry** must be engaged to leverage science. The relationship between science and industry determines whether the majority of environmental scientists are working towards the goals and interests of society. For the relationship to succeed, interdisciplinary and challenge-led science should be relevant to consumers and businesses, so that best practice is encouraged as widely as possible.

- **Research** must be engaged to drive science. The relationship between science and research determines if there is sufficient evidence to empower the public and inform policy. For the relationship to succeed, research should be guided to address pressing issues emerging from practice, as well as the needs of policymakers and the public.

- **The environment** must be engaged to ethicise science. The relationship between science and the environment determines how scientific evidence can provide benefits for society. For the relationship to succeed, the connection between society and nature should be reimagined, alongside how people value the natural world.

In practice, these relationships are inherent, subconscious, and decentralised, so the focus of environmental science should be on altering the interactions which already exist to improve relationships between parties.

Best practice is already emerging. Evidence and monitoring can be embedded into the feedback loop of policy implementation to make regulation more effective and inform the public's appreciation of what works.[20] Research-informed scientific literacies can be spread to increase public understanding of science and policy. Networks and knowledge communities can be developed which unite science, society, and policy to solve environmental challenges.[24]

The challenge for the future will be to make these practices more widespread, bringing together all applications of science at a single point that connects to society: the tip of the SPIRE. Evidence-informed monitoring without public support may be illegitimate. Scientific literacies which do not facilitate solutions may be disempowering. Knowledge networks without access to evidence may be ineffective.[3]

Only combining all three will be sufficient to empower communities to make decisions about the future and to give policy the data it needs to create change.

How can we achieve the best possible future?

As the IES worked to produce this vision, we engaged with environmental scientists working across disciplines. The future they wanted to see for the interface between science, policy, and the public is one where:

- Governments and policy organisations recognise the role of evidence-informed policy design and delivery, embracing the full range of scientific insights, whether or not they are politically convenient.
- Environmental scientists acknowledge the polarisation of public opinion and rebuild trust by increasing skills in public engagement to address 'mediatisation' and scientific literacy for the public.
- Businesses utilise the scientific expertise in their workforce, encouraging collaboration and professional registrations to assure high standards and make work environments more attractive.
- Environmental scientists build stronger links between research, policy, and practice, informing research priorities with professional insights and translating research findings into best practice for professionals.
- Environmental scientists embrace the dual mandate of informing the public to support decisions and create change, and securing a healthy environment which thrives and serves the interests and values of humanity.

Discovery or solutions: Redefining environmental science for the next generation

How is the definition of environmental science evolving? What is the changing role of environmental science? Are research institutions equipped to deal with emerging issues in environmental science?

Any future for the environment will be determined at its heart by environmental science and the scientists who will deliver that future, both through the evidence and understandings that help people to engage with the environment, as well as the insights that drive environmental solutions.

Science will need to be accessible to a wider section of society than ever before, drawing on a broad coalition of voices and networks to ensure it addresses the inherently subjective questions associated with the application of science, incorporating diverse voices and maximising the potential for interdisciplinary collaboration. This access must be transparent and accountable, ensuring that provisional and emerging evidence is well understood by all stakeholders.

Science is already changing, but the workforce will need to continue changing to bring together society, policy, and evidence to address the immense environmental challenges facing our planet.

What is modern environmental science?

Over the last year, the IES's Future of ES23 horizon scanning and foresight project has been seeking to scope and shape the future of the environmental sciences. As well as assessing what the future will look like, and how a more positive future can be created, the IES has also taken stock of developments for environmental science, seeking to modernise the way that the discipline is understood and defined, building on the IES definition established in 2017.[1]

Definitions are important. If environmental science is defined in too narrow terms, it may limit the scope for collaboration and interdisciplinary working. If environmental science is defined too broadly, it may open the door to greenwashing and other forms of misinformation that weaken public understanding and trust in science. A good definition is clear, accessible, and has strong boundaries that support targeted interventions and actions.[2]

In the first instance, common-language definitions of environmental science were considered alongside rich pictures and other visualisations. These inspired a working 'root definition' constructed in line with Soft Systems Methodology (SSM), which was used as a starting point for further discussions.[3] The IES reflected on this provisional definition with reference to Critical Systems Heuristics (CSH), with the primary goals of challenging the definition's boundaries, as well as the extent to which it reflected the reality of environmental science beyond the perceived reality of the IES's immediate stakeholders and network.[4] Finally, senior leaders in the environment sector were consulted for their perspective on the working definition.

The work culminated with a synthesis, intended to capture a single working definition that captured the accessibility of common-language approaches, the completeness of the root definition, and the critical reflectivity of the CSH approach through a systemic triangulation process. For the purposes of this vision statement, the IES's understanding of environmental science is:

> *Modern environmental science is an interdisciplinary challenge-led field studying, developing, and disseminating knowledge of natural processes and systems through scientific tools, methods, and understandings, including their application to social and economic systems, the creation and assessment of solutions to environmental challenges, and the two-way interactions between the human and natural worlds.*
>
> *Environmental scientists work across natural and social disciplines, incorporating academics, policy professionals, environmental engineers, and practitioners. They use scientific methods to inform environmental work, as well as insights from diverse sources of knowledge including professional practice, the interactions between science, policy, and society, and indigenous forms of knowledge.*

How has the role of environmental science changed?

The legitimacy of modern environmental science comes from the ability of evidence and insights to inform decisions and educate the public about the socio-natural world.[5] This relies on a bedrock of trust that those insights are objective and impartial, driven by a reproducible and reliable scientific approach. To maintain that trust, environmental science and the ways scientists use it must be defensible.[6]

Historically, science served society through discovery: the more people learned about the natural world, the more it informed the many ways that humanity interacted with it. Without science's role in society changing, the needs of society have adapted in the wake of pressing environmental crises. These crises now necessitate that environmental science concerns itself with solutions, and with communicating the insights that support those solutions to decision makers and a broad public audience.[7]

Building on recent theoretical developments, including Jesse Schrage et al.'s archetypes of sustainability scientists[8] and the Motivational Interviewing approach adapted by Robert Costanza

for the purpose of communicating the need for sustainable wellbeing,[9] it is possible to identify five persona roles which environmental scientists can adopt at different times to meet their obligations to humanity:

- **The Sceptical Arbiter**: environmental science challenges conventional thinking and contests hypotheses about how the world must and should work, allowing the public to reconsider social systems and interactions with the natural world.
- **The Expert Communicator**: environmental science demystifies evidence and understandings of natural systems and the consequences of our interactions with them, allowing the public to understand and engage with the environment, now and in the future.
- **The Neutral Convenor**: environmental science brings together scientific disciplines, policy, and society to acknowledge and address environmental challenges, allowing the public to share different perspectives and debate what matters.
- **The Open-minded Designer**: environmental science identifies solutions to environmental challenges, provides options for society, and explains the costs and trade-offs associated with different pathways, allowing the public to make choices about the future.
- **The Rational Translator**: environmental science operates at the interface between evidence, policy, and society, brokering knowledge and spanning the boundaries between different competencies, allowing the public to ensure that evidence informs the design and delivery of solutions.

“...as environmental science engages increasingly in challenge-led endeavours, it should be unapologetic about its role in propelling forward solutions...”

While many scientists use these personas to be solutions scientists who support a transition in the face of interlinking crises, others still need to focus on discovery, further developing humanity’s collective knowledge of environmental systems through a precautionary lens, so that future generations have the evidence needed to address challenges which do not yet exist.[10]

To that end, environmental science should be broadly defined enough to serve society in many roles, and sufficiently detached from specific challenges that scientists can engage in precautionary inquiry. At the same time, as environmental science engages increasingly in challenge-led endeavours, it should be unapologetic about its role in propelling forward solutions for society.

Ethical challenges: where should lines of appropriateness be drawn?

The boundaries set by the ways environmental science is defined align with the ethical commitments of environmental scientists. Scientists often care about the same issues as activists, but they are not activists, at least not in their professional capacity.[5] The growing public consciousness of environmental issues brings with it challenging boundaries between the personal and professional lives of scientists, some of whom may be activists outside their work and who may feel that the science they engage in is just one aspect of an integrated ‘work-life mission’.[11]

Those challenges will be increasingly difficult to navigate as environmental challenges grow more present in public discourse, though the margin of appropriateness for scientists remains largely unchanged. Environmental science has often been bound up in deeply subjective questions about how people live their lives, from clearing smog to repairing the ozone layer.[2]

Regardless of how politically sensitive these issues are, environmental science remains appropriate as long as it serves the source of its legitimacy, which comes from the ways that it informs society’s responses to environmental challenges through scientific methods and insights.[12] Straying from objective evidence into subjective views would be inappropriate, but that doesn’t preclude environmental scientists from being ‘informed agitators’ who advocate for responses informed by the evidence and who speak truth to power on the challenges and trade-offs that will arise from society’s decisions about how it responds.[13,14]

If the legitimacy of environmental science comes from empowering the public to make informed decisions, then the mandate of scientists must be to offer and pursue real solutions to environmental challenges which can be implemented in practice and which avoid unintended consequences.[7]

Science may not always be seen as an ally to policy makers whose preferred solutions may not work in practice, or to activists whose communications may be diluted by the complexity of scientific knowledge, but for environmental science to meet its ethical obligations, it must not compromise on the truth of its insights and evidence.[5]

Validity, reliability, and reproducibility: Maintaining the tenets of environmental science

If the future of environmental science will be determined by its potential to secure society's trust and serve as a useful ally to policy and industry, it must be objective enough in its approach to be a reliable ally as well. Science has always sought to achieve that goal through the scientific method and the fundamental criteria that underpin good research: validity, reliability, and reproducibility.[15]

Maintaining those tenets will require adaptation in the face of a changing science landscape. As data collection becomes increasingly supplemented with artificial intelligence and machine learning techniques, it will be necessary to ensure the validity of data which arises from projections and expectations rather than 'in the field' data collection. As citizen science projects increasingly supplement data for resource-constrained organisations, it will be necessary to ensure the reliability of data that is collected under less rigorous scrutiny, which may otherwise lead to peaks and troughs in the consistency of collection periods.[16]

As environmental science increasingly enters the space of solutions-led science, reproducibility will also be a significant challenge to overcome, as many solutions will be novel in nature. Post-implementation reviews and robust monitoring, incorporating infrastructure-level data, will be vital to achieving that reproducibility.[17] To that end, the process of implementation depends on other core features of the classical scientific method, such as observation and experimentation.

A robust research and innovation landscape will be pivotal to maintaining these standards, which requires funding to be sufficient, accessible, flexible, and targeted. To ensure the appropriate social controls over the direction of that research, it should also be transparent and democratised in its allocation. Research needs to match the interdisciplinary and challenge-led nature of emerging environmental science, so funding applications should allow for holistic and thorough projects, which may require novel funding approaches and research practices.[18]

Crucially, there is a wide body of environmental research which is not fully utilised , so stronger links between research science and professional science could convey the findings of emerging research into practice and transfer discovery on the ground into new focus areas for research. For example, a large amount of climate research is not directly cited in policy documents or reflected in professional practice, instead filtering through the vast crucible of IPCC reports.[19] Practitioners on the ground are unlikely to have an awareness of the specifics of this research or its implications for their work.

The private sector has a role to play in this process, particularly on funding emerging areas of research and bringing financial and intellectual capital to drive investment in pressing challenges. The COVID-19 pandemic demonstrated the power of private sector science to identify and implement solutions when society's urgency is great enough, so decision makers should learn from the successes of that approach as they seek to address environmental challenges.

Who are the environmental scientists of the future?

Environmental science is an increasingly collective endeavour, thriving on interdisciplinarity, systems thinking, and collaboration. The success of environmental science in the future will depend considerably on the extent to which scientists can connect with one another to solve environmental challenges, utilising knowledge networks and communities. Even then, for any interdisciplinary activity to succeed, scientists will also need to be skilled as individuals.[7]

Recent years have seen an expansion in the working roles and sectors of environmental scientists. Beyond traditional fields such as research, policy, industry, and consultancy, there are many emerging science roles in entrepreneurship, social enterprise, environmental design, and corporate sustainability. Equally, many new routes into the profession have emerged, including through apprenticeships, technical education, and career changes facilitated by the rise of green jobs.[20]

This provides an opportunity to leverage scientific capital in sectors where it was not previously possible, as long as networks are utilised to build links between the profession, practice, and research. At the same time, greater equity, diversity, and inclusion across the workforce has the potential to increase the breadth of knowledge and expertise in environmental science.[21] In this context, education is a key leverage point, as are professional bodies who serve as custodians of competency and best practice.

Emerging disciplines, such as data science and behavioural science, are fundamentally important to measuring the success of environmental policies and shifting the patterns of individual action that drive unsustainable consumption and production. Similarly, many areas of social science have increasing importance for environmental science. All of these fields could help to maximise society's chance at a positive future, as long as collaboration is balanced with the ongoing need for robust physical and natural science.[2]

As these novel specialisms begin to rise, there has also been an increased recognition of the importance of many previously underappreciated fields, such as soil health and environmental resilience beyond the most pressing impacts of climate change.[10] Even within longstanding fields of environmental science, there is a significant amount of novel science in response to megatrends linked to environmental crises, technology, and social trends.[22]

For example, in groundwater science, environmental crises are driving groundwater droughts and diminishing buffering capacity, leading to increased study of the effects on watercourses and novel approaches to resilience. Technology has provided new tools for data collection and collation, and economic demand has driven a rise in financing for groundwater management.[2]

These trends will determine whether science can support society's environmental ambitions. If they are correctly nurtured and linked through interdisciplinarity, then they will reinforce the capacity of the scientific community to address environmental challenges.

Environmental science has seen a trajectory of growth over recent decades, so the key question for the future will be how those scientists and the science they produce interact with society, build strong credentials to engender widespread trust, and play the mutual and complementary roles of developing solutions and precautionary discovery.

How can we achieve the best possible future?

As the IES worked to produce this vision, we engaged with environmental scientists working across disciplines. The future they wanted to see for environmental science is one where:

- Environmental scientists retain the objectivity of their science by drawing a line between science and activism, but are ready to be informed agitators on behalf of science when needed.
- Environmental scientists embrace their dual role in creating solutions to environmental challenges and discovering evidence about the natural world to inform future generations.
- The environment sector facilitates collaboration across industry, research, policy, and practice, using competency standards, professional bodies, and routes into the profession to promote collaboration and knowledge sharing.
- The environment sector provides the skills needed for scientists to engage in multiple roles in society, including challenging conventional thinking, demystifying the environment, bringing groups together, and communicating visions for the future.
- Research funders modernise their approach, ensuring funding is sufficient, accessible, targeted, transparent, democratised, and interdisciplinary in design. Governments and businesses should deploy partnerships to drive private sector finance for science, particularly for priorities such as the implementation of environmental solutions.

The future of environmental ambitions: Mitigation hierarchies, protection pyramids, and the quest for improvement

How can ambitions increase beyond the bare minimum or a 'tick-box' approach to regulation? How can aspiration for environmental improvement be embedded in every interaction with the social and natural world?

Environmental science will help society to shape the future, but environmental scientists will also contribute to that vision directly, as their work sets the tone for what constitutes good practice and how a high-level vision translates into action in practice. It has taken a long time to make the case in favour of the mitigation hierarchy as a baseline approach.[1] Even now, the idea of minimising the environmental consequences of society's actions whenever possible remains politically controversial and efforts to engage the hierarchy beyond the mitigation stage are ad hoc or minimalist.[2,3]

All the preferable pathways for the future involve reimagining the value of nature, which necessitates a more universal application of the classic mitigation hierarchy and a more consistent approach to how society uses it. In professional practice, a presumption of mitigation must rapidly be replaced with a presumption of protection, which should eventually become a presumption of environmental improvement, taking every opportunity to maximise the multiple benefits that nature can provide as the default for environmental work.[4]

There are many complex drivers and competing interests which prevent environmental improvement becoming an embedded assumption, so science should work with society to shift perspectives and values in a way that brings society along on that journey. The promised potential of the mitigation hierarchy can still be fulfilled, seizing the opportunity to protect nature from harm and improving humanity's ability to receive all the benefits it promises for our society, economy, and environment.[5]

Overcoming greenwashing: the argument for ambitious environmental action

Before reimagining the standard approach to environmental action, society and politics first need to be convinced that environmental approaches should be considered at all. For many in society, the environment remains very estranged from their lives, so they may not be aware of the full range of ways that humans benefit from a healthy environment every day.[6]

As social values evolve, change has already begun and public consciousness of environmental issues is increasing, though there are still polarised perspectives on the extremes. While a vocal minority are not supportive, the overwhelming consensus is the desire for a healthy environment. That desire is not a selfish one: even without complete knowledge of nature's benefits, many people still care about the environment and want to see it thrive. If policy and evidence empower the quiet majority, the future will likely be shaped by environmental values that inevitably create a better world.[7]

Younger generations are becoming more environmentally conscientious, so by the time the global population peaks in around 2065, there is likely to be a strong mandate for environmental action, regardless of decisions about the environment in the near future.[8] Those short-term choices will determine whether that action is focused on maximising positive opportunities or mitigating and managing the risks created by past decisions.

Although many people value the environment, it can be difficult to encourage decision makers to prioritise nature due to a focus on short term economic gains that are more aligned with political timescales.[9] Science and economics have the potential to inform one another, working together to make the case that economic benefit and the value provided by a healthy environment are complementary, rather than contradictory.[10,11] Frameworks such as planetary boundaries and 'doughnut economics' are critical ways of harmonising the economic and natural worlds to create shared visions of the future.[12,13]

Even when businesses and communities accept these visions and set ambitious goals to create a more sustainable world, there is a significant gap between intentions and implementation.[14] Many approaches are 'greenwashed': environmental values are abandoned in practice, even while organisations continue to express their support for those values. Transparency and accountability can help to push past greenwashing, but unambitious or misleading environmental commitments will continue until strong environmental improvement principles are embedded into processes and targets.[15]

'Weak sustainability' approaches seek to substitute the value of the natural world with socially-constructed value, losing out on the full benefits of nature which could be secured by a 'strong sustainability' approach.[16] For the mitigation hierarchy, this often leads to approaches that emphasise mitigation at the expense of regeneration, or which replace natural capital in one place with 'technically-equivalent' but functionally inferior social capital in another.[17]

The truth is that these approaches to sustainability are not enough on their own to create a better world, so a 'business-as-usual' approach which adopts the mitigation hierarchy in name – but not in practice – will leave ecosystems significantly depleted and plagued by many mitigated but still persisting environmental challenges.[18]

For a better future, the mitigation hierarchy must be understood in the context of natural systems: small cumulative effects can come together to create immense consequences, so tolerating mitigated environmental harms cannot be society's default position.[5] The assumption must be that, whenever possible, environmental degradation does not happen in the first place, which requires the adoption of more robust expectations of environmental protection.

Safeguarding against crisis and the environmental protection pyramid

Through the lens of rising environmental crises, the ideal of environmental protection has become an increasingly mainstream position, though it still struggles to be prioritised in decision making, particularly in those linked to planning processes and the economy.

The folly of deprioritising environmental protection in favour of short-term economic gain has now been made apparent as environmental crises pose a serious threat to long-term economic stability and growth. In the future, it may still be possible to secure both economic and environmental benefits simultaneously, but environmental protection will have to play a fundamental role in ensuring the long-term viability of natural assets that are critical for future economic and social prosperity.[19]

Environmental protection should be the broad baseline which serves as the 'first line of defence' against degradation; it should be a standard assumption that society does not degrade the environment in most circumstances, avoiding harm whenever possible. In a future with effective environmental governance, that assumption would be paired with principles for decision makers and a broad regulatory regime that safeguards against potential negative outcomes for the environment in sufficiently general terms to prevent degradation.[6]

Upon that robust baseline, a more targeted and holistic use of the mitigation hierarchy as a whole could avoid projects or environmental interventions falling back towards the easiest approach. Instead, mitigation should be the peak of the pyramid – the narrow end case where no other protection measure can reach, with a sharp point which only touches the most extreme cases.[17]

Beyond the immediate future of environmental crises, environmental protection still has a crucial role to play in preventing and addressing new challenges. Even if humanity addresses climate change, biodiversity loss, and environmental pollution, global megatrends are already setting the scene for future crises. Everything environmental science has learned about past crises will be fundamental to understanding and addressing future ones.[20]

Rapidly accelerating technological development raises significant uncertainty and implications for the environment.[21] Likewise, novel chemicals emerging in agriculture, health, personal care, and cleaning all pose the threat of new pollution concerns, alongside the novel use of existing chemicals.[22] Social and political change may also lead to unexpected environmental effects, either through social change or the loss of key environmental protections.[23] In the absence of effective regulation, economics and corporate activity will always leave open the potential for environmental degradation where private decision makers are detached from the public beneficiaries of natural assets.

Society's choices about the transition will also drive new challenges for humanity and nature which require different approaches to environmental protection. Delaying the climate transition will have long-term consequences, disabling or diminishing natural services for the future and leaving environmental systems disconnected, so less ambitious action now will require broader protections in the future.[24] Similarly, using one solution to solve many different problems, such as an over-reliance on electrification, may increase the risk of 'single points of failure', requiring more focused protections to ensure long-term resilience.[25]

"...regeneration of the environment will be necessary to maximise the full benefits that society and nature are able to achieve."

Across all these pressures, the message is clear: environmental protection is an essential baseline to safeguard the multiple benefits of nature. Mitigation, offsetting, and risk minimisation are essential tools where harm is unavoidable, though they cannot become default approaches. Beyond these, society could benefit from going even further, not just protecting the environment against future harm, but embedding a positive desire to improve nature whenever humanity interacts with it.

Environmental improvement: seizing the reimagined value of nature

It may be too much to hope for a future where environmental challenges have been fully addressed, but even in a world beyond crises, environmental ambitions will remain relevant. In a post-crisis world, regeneration of the environment will be necessary to maximise the full benefits that society and nature are able to achieve. That process of renewal cannot and should not wait. Beginning the process of environmental improvement as soon as possible will create the healthiest environment for the benefit of future generations.[26]

Environmental improvement has already been embraced in principle throughout the environmental sciences, particularly in industry and consultancy where best practice is encouraging professionals to find ways to go beyond minimal approaches. Driven by regulatory approaches such as Biodiversity Net Gain, Nutrient Neutrality, or Air Quality Positive developments, the UK environmental profession is moving in the direction of improvement when it is possible to include it as a consideration in projects.[4] This has been especially critical for the private sector, where the 'level playing field' provided by regulation is a vital means of providing the certainty needed to change working practices.[27]

Several challenges remain. The first is to spread best practice to secure a future where regulation is informed by evidence and where environmental professionals can access information and guidance through peer-to-peer learning and knowledge communities.

The second challenge is to ensure that improvement takes place in practice and not just in name. Critical specialisms such as Impact Assessment have often struggled to overcome the perception that regulation is a 'box ticking' exercise. Moving those specialisms towards best practice will require everyone involved in developments to view their role in those processes in a new light.[28]

For example, if regulation for consenting processes is viewed as a barrier or part of an adversarial system, participants will push back against environmental protection. Conversely, if participants in a process view themselves as working towards the same goal of social, economic, and environmental outcomes from the outset of a project, they can support a move toward sustainable development. These processes shape many of our key interactions with the natural world, so they should be collaborative wherever possible, rather than competitive.[29]

Securing environmental improvement will depend on whether society can reimagine its understanding of value to be more inclusive of the many ways that nature benefits humanity. Moving away from outdated 'fortress models' of nature which see the environment as separate from people's lives will allow environmentally positive actions to be embedded in decisions, embracing humanity's place as part of the natural world.[17,30]

Environmental values have the potential to reach across different places and scales, taking account of diverse knowledge and viewpoints. When they do, those values can reach the decisions of businesses and policy makers, creating a more equitable system of value which maximises the potential for environmental justice and integrated social, economic, and environmental benefits.[31,32]

In that world, projects would be multi-functional, maximising opportunities, minimising risks, and achieving many different goals for people and nature at the same time. Interactions with nature would be mutually beneficial and sustainable over the long-term, as the natural world overflows with functionality and 'ecosystem services'.

Ultimately, fulfilling the promise of environmental improvement and a systems-informed mitigation hierarchy is as selfish as it is altruistic. Nature operates through reciprocity: it gives back what humanity puts into it. A gradually diminishing environment will give future generations less and less of what they need.

Environmental protection is a necessary minimum to maintain humanity's quality of life in the future, but embedding environmental improvement offers the promise of a future where the most bountiful gifts of the natural world still lie ahead.

How can we achieve the best possible future?

As the IES worked to produce this vision, we engaged with environmental scientists working across disciplines. The future they wanted to see for environmental improvement is one where:

- Society meets the burden of continuing environmental improvement to prevent further decay. No generation leaves the world in a worse state than they received it, recognising that a status quo of environmental decline means that 'do no harm' is an insufficient way of preventing damage.
- Environmental scientists embed the mitigation hierarchy across plans and projects, understanding it with reference to systems thinking and the potential for many small, mitigated harms to create much greater consequences for the social and natural world.
- Governments provide a broad regulatory baseline for environmental protection to safeguard against negative environmental outcomes, only breaking the presumption of protection in rare circumstances where harm is unavoidable and society has accepted that there are no suitable alternatives.
- The environment sector spreads best practice on environmental improvement through peer-to-peer learning, communities of knowledge, and professional bodies like the IES.

In conclusion: From our vision to yours

Our vision for the future of environmental science marks the end of one project, but it is also the beginning of the work to make that vision a reality.

Over the coming years, the Institution will continue working with members and partners to prepare the sector to achieve a better future. It will inform the Institution's next organisational strategy in 2024, as well as our approach to developing the skills and competencies of IES members through training, events, and knowledge communities.

Visions of the future are iterative by nature, subject to changing circumstances which revise the details but not the destination. Visions also iterate as they are exposed to more perspectives, which will be important as the IES engages a broad coalition of partners to achieve a better future for people and the planet. In the process of doing so, the IES will hope to realise this vision while helping society create its own.

Throughout the Future of ES23 project, the message has been clear. Humanity has the potential to address environmental challenges, with environmental science playing a fundamental role in shaping solutions and facilitating the transition to a sustainable society.

That future demands that environmental scientists are knowledgeable, skilled, diverse, and trusted, engaging them in the process of transformation towards a sustainable society. It demands that global governments take the situation seriously, embracing the role of evidence and accepting the full range of scientific insights, whether or not they are politically convenient. It demands that science is relevant and accessible to everyone, helping people use evidence to craft the world they want to see.

Humanity has a tremendous influence over the world around it, so people living now have a responsibility to safeguard and enhance the environment for the good of future generations. Only with the expertise of scientists can environmental improvement be consistently realised, so the mission of environmental science and the Institution must be to support people on the path to reimagining and transforming their relationship with the natural world.

Environmental science will be the foundation which sets the world on the journey towards that goal, as scientists and communities embark together on the collective endeavour of **transforming the planet**.

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Institution of Environmental Sciences
6-8 Great Eastern Street | London
EC2A 3NT
+44 (0)20 3862 7484

info@the-ies.org
www.the-ies.org

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