The Academy of Medical Sciences

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Enabling greener biomedical research

FORUM workshop on Wednesday 15 March 2023

Jointly hosted by the Academy of Medical Sciences, the Medical Research Council (MRC), and the National Institute for Health and Care Research (NIHR)

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The Academy of Medical Sciences' FORUM provides an independent platform for senior leaders from across academia, industry, government, and the charity, healthcare and regulatory sectors to come together with patients and take forward national discussions on scientific opportunities, technology trends and associated strategic choices for healthcare and other life sciences sectors.

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Opinions expressed in this report do not necessarily represent the views of all participants at the event, the Academy of Medical Sciences, or its Fellows, the MRC or the NIHR.
All web references were accessed in May 2023.

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Executive summary

The UK Government has set a target of reaching net-zero greenhouse gas – or carbon - emissions by 2050.[1] This transformation will affect all sectors, organisations and individuals, and each has a contribution to make in achieving climate targets. This includes the biomedical research sector.

Both 'wet lab' and clinical research are making a sizeable contribution to the UK's carbon emissions. Laboratories are resource intensive, using significant amounts of water and an average of 5-10 times more energy per m^2 than standard office spaces.[2] A 2014 study estimated that laboratory-based, or 'wet-lab' bioscience research is responsible for almost 2% of global plastic waste.[3] The environmental impact of clinical research is also significant, with the approximately 350 000 clinical trials on ClinicalTrials.gov estimated to have a carbon footprint of 27.5 million tonnes.[4] Already, multiple individuals and organisations are pioneering and promoting greener approaches to research practice, delivering carbon savings (and in some cases cost savings as well). Based on evidence from this work, **there are practices that can be adopted immediately by individuals and organisations to make a difference.** However, there are significant obstacles to change, including uncertainty about which actions can truly make a difference, concerns about impacts on scientific quality and productivity, and not enough people with specialist expertise in sustainable research practices.

In March 2023, the Academy of Medical Sciences co-hosted a meeting with the Medical Research Council (MRC) and the National Institute of Health and Care Research (NIHR) to explore current initiatives to make biomedical research, including in 'wet lab' and clinical research, more environmentally sustainable – or greener – and potential next steps.[5] The meeting was part of the Academy's FORUM programme of events, bringing together representatives from the academic, industry and health service sectors along with patients, regulators and other relevant stakeholders.

Scene-setting talks focused on specific examples of green initiatives in laboratory science and clinical research in academic and industry settings, as well as a survey of researcher attitudes and the views of research support personnel, such as lab technicians and clinical trials unit staff. Meeting participants subsequently joined breakout groups to discuss key challenges and

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[1] UK Department for Business, Energy and Industrial Strategy (2019). *UK becomes first major economy to pass net zero emissions law*. https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law

[2] United States Environmental Protection Agency and U.S. Department of Energy (2008). *Laboratories for the 21st Century: An Introduction to Low-Energy Design.* https://www.nrel.gov/docs/fy08osti/29413.pdf

[3] Mauricio A *et al.* (2015). *Environment: Labs should cut plastic waste too*. Nature **528(7583),** 479.

[4] Adshead F, *et al.* (2021). *A strategy to reduce the carbon footprint of clinical trials.* Lancet **398(10297),** 281-282. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)01384-2/fulltext

[5] Due to time constraints, a variety of important issues were not directly considered as part of workshop discussions. These included 'dry lab' biomedical research, the sustainability impacts linked to translation of research findings, dissemination of research (including academic travel), laboratory buildings, or decision-making that balances the potential benefits of research and its environmental impact.

propose possible ways forward. These discussions highlighted several key themes falling within four general areas.

1. Prioritising environmental sustainability within the biomedical research ecosystem

'Bottom-up' activities need to be supported and complemented by a more strategic and better-resourced 'top-down' approach. Much activity to date has been driven by 'champions' with an individual commitment to sustainability. This bottom-up energy now needs to be matched by strategic commitments, investment and action by key senior stakeholders in organisational leadership roles.

There is a need to develop a workforce specialising in improving the environmentally sustainability of research practice. A reliance on 'champions' has generally depended on committed individuals taking on additional activities outside their core roles. Participants agreed research sustainability should be recognised as a specialist function in its own right and incorporated into job descriptions, with due attention given to issues such as capacity-building and career pathways. It would also benefit from the creation of dedicated posts within institutions.

Environmental sustainability needs to be seen as integral to good research practice. It was felt that environmental sustainability should be as integrated into research practice as, for example, health and safety. This would require an enabling policy framework, standards and guidance, and open-access tools and training to capacitate researchers and research support staff. Different training might be required to support individuals with different roles and functions in the research endeavour (e.g. technical staff, wet lab researchers, clinical researchers, staff supporting the delivery of clinical trials, etc).

Environmental sustainability standards are required to provide shared benchmarks and to promote accountability. As for health and safety, clearly defined standards (to be achieved by laboratories, clinical trial units, and other research facilities) would need to be developed to ensure consistent good practice.

Coordination, perhaps through a central entity, is required for environmental sustainability in biomedical research. Action is currently fragmented, with multiple individuals and bodies independently undertaking their own sustainability activities. Some efforts are being made to create consensus – for example, the UK Research and Innovation (UKRI) is developing a concordat on sustainability to help align activities of certain types of research organisations, such as funders and research institutions. Meeting participants felt that coordination and alignment of activities (perhaps through a central entity) would be beneficial to: promote networking and consortia development; provide an open access point to curated and, where relevant, assured information, tools and resources; facilitate the development of common metrics and standards; and establish a research agenda to build the evidence base supporting environmentally sustainable research practice. The scope and key functions of any new activity or entity would need to be carefully defined in relation to initiatives such as the UKRI concordat on sustainability.

2. Generating and disseminating evidence on environmentally sustainable research practices

Additional data would be useful on the environmental impact of research activities, equipment and consumables. Decision-making can be hampered by the fact that the carbon impact of many research activities cannot be accurately quantified. This makes it difficult for researchers, purchasers and funders to make comparisons, prioritise actions, or determine the impact of interventions. More evidence about the environmental impact of research would therefore be useful to close key knowledge gaps and support decision-making.

However, meeting participants commented that decisions can be made with a degree of uncertainty, and so incomplete data should not necessarily be seen as a reason for inertia.

Standardised and evidence-based metrics on sustainability are urgently required to guide decision-making, and facilitate comparisons between products and processes. If funders were to consider the environmental impact of research during the grant application process, a standardised tool to assess a project's environmental sustainability would be useful to allow comparability between applications.

Mechanisms are needed to ensure effective dissemination of information and sharing of experience. Evidence is beginning to emerge from studies of the environmental sustainability of research, and good practice is being developed. While the results of rigorous academic studies can be disseminated through the academic literature, it may not necessarily reach all those responsible for research sustainability, such as research support personnel in both wet lab and clinical research settings, through this route. Other types of output, such as case studies, could be produced, while communication channels such as social media, networks/communities of practice and peer learning could also support sharing of information.

A critical mass of experts is needed to study and develop environmentally sustainable research practices. Individuals with experience and expertise in research practice and sustainability are needed to generate the evidence to support decision-making and promote good practice, and to inform development of guidance. There is a need to consider how best to nurture and grow this group of suitably trained professionals. In particular, opportunities should be created for research support personnel and early career researchers.

3. Accelerating introduction of more environmentally sustainable practices in clinical research

A greater focus on green practice is required in clinical trials and other clinical research. Environmental sustainability has yet to be as prioritised in clinical research to the same degree as in laboratory research. This is in part due to specific challenges faced in the clinical research community, such as perceived regulatory barriers and lack of a central focal point or accreditation scheme (such as the Laboratory Efficiency Accreditation Frameworks (LEAF)) for clinical researchers wanting to look at environmental impact. The scope for greener clinical research should be more systematically assessed, drawing on the experience of groups in academia and industry that are promoting more environmentally sustainable practices.

Public and patient engagement should be built into a sustainability agenda for clinical research. It will be important to ensure any changes made to improve the environmental sustainability of a study are acceptable to participants in the research. Public and patient engagement and involvement could also enable and empower members of the public with an interest in sustainability to advocate for greener clinical research and to suggest practical changes that might underpin greener clinical studies.

4. Promoting and informing behaviour change

Coordinated and concerted efforts are needed to ensure that sustainability is embedded in the behaviour of individual researchers. As well as training and education, there is an opportunity to apply behavioural science frameworks to identify and implement interventions to influence the behaviour of researchers in wet lab and clinical research in different sectors. Efforts will be needed to ensure that key drivers of academic behaviour (e.g. securing grant funding, publishing papers) do not discourage green research practices and to communicate where key drivers of academic behaviour are aligned with environmentally sustainable research practice.

From the workshop discussions, it seemed clear that there was appetite within the UK biomedical research sector to adopt greener ways of working. Multiple stakeholders – individual researchers, technicians, the institutions they work for, funding agencies, pharmaceutical and biotech companies, regulatory authorities, clinical trials units, contract research organisations and publishers – can all take steps to reduce their own carbon footprints, and can incentivise changes in practice among those that they have influence over.

By acting together and drawing on the experience of integrating other essential activities, (such as public and patient involvement where much progress has been made in incorporating this into routine research practice), a green culture can be embedded in biomedical research, helping to achieve ambitious national climate targets – and creating a healthier world for all.

Introduction

Addressing the climate crisis is of increasing urgency. In its sixth assessment, the Intergovernmental Panel on Climate Change highlighted the perilous current global situation and stressed the need to take action now to avoid catastrophic consequences.[6]

Furthermore, as emphasised in a recent Academy of Medical Sciences' report and work of the Wellcome Trust on Climate Change and Health,[7,8] climate change is already having significant adverse impacts on human health – while, conversely, decarbonisation has the potential to deliver major health benefits.

The UK Government has set a target of reaching net zero greenhouse gas emissions by 2050.[9] To achieve this target, change will be required across multiple areas of life, including within biomedical research. Biomedical research activities make a significant contribution to the UK's carbon footprint, not least as a large consumer of single-use plastics.[10] With the UK Government also pledging to increase investment in research and development (R&D),[11] there is ever-greater onus on the biomedical research community to embrace a green agenda.

Laboratories are resource-intensive, using vast amounts of water and an average of 5–10 times more energy per square metre than standard office spaces.[12] Globally, the 350 000 clinical trials on ClinicalTrials.gov are estimated to have a combined carbon footprint of 27.5 million tonnes.[13] The global pharmaceutical and healthcare industries are also major emitters. In 2015, the global pharmaceutical industry's carbon emission intensity was 55% higher than, for instance, the automotive industry.[14] Globally, it has been estimated that the emissions of clinical research could be 100 million tonnes CO_2 equivalent per year,[15] making emissions from this research on par with countries the size of Bangladesh or Venezuela.[16]

Significant steps are already being taken to enhance environmental sustainability within the UK biomedical research sector (Annex 1). **Accreditation schemes** have been set up to promote sustainable laboratory management and research practice, including the Laboratory

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[6] Intergovernmental Panel on Climate Change (IPCC) (2023). *Synthesis Report of the IPCC Sixth Assessment Report (AR6).* https://www.ipcc.ch/assessment-report/ar6/
[7] Academy of Medical Sciences and the Royal Society (2021). *A Healthy Future: Tackling climate change mitigation and human health together.* https://acmedsci.ac.uk/file-download/94272758
[8] https://wellcome.org/what-we-do/climate-and-health
[9] UK Department for Business, Energy and Industrial Strategy (2019). *UK becomes first major economy to pass net zero emissions law*. https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law
[10] Mauricio A, *et al.* (2015). *Environment: Labs should cut plastic waste too.* Nature **528(7583),** 479.
[11] UK Department for Business, Energy and Industrial Strategy and UK Space Agency (2022). *Government announces plans for largest ever R&D budget.* https://www.gov.uk/government/news/government-announces-plans-for-largest-ever-rd-budget
[12] US Environmental Protection Agency and U.S. Department of Energy (2008). Laboratories for the 21st Century: An introduction to low-energy design. Available at: https://www.nrel.gov/docs/fy08osti/29413.pdf
[13] Adshead F, et al. (2021). *A strategy to reduce the carbon footprint of clinical trials.* Lancet **398(10297)**, 281-282.
[14] Belkhir L & Elmeligi A (2019). *Carbon footprint of the global pharmaceutical Industry and relative impact of its major players.* Journal of Cleaner Production **214,** 185-194. https://doi.org/10.1016/j.jclepro.2018.11.204
[15] https://shcoalition.org/low_carbon_clinical_trials/. This sentence was corrected in August 2023 as the Sustainable Healthcare Coalition figure of 100 million tonnes CO_2 equivalent per year is an estimate of the emissions of *clinical research*, rather than those of the science sector as a whole.
[16] Comparison with figures from: Crippa M, *et al.* (2022). *CO2 emissions of all world countries - JRC/IEA/PBL 2022 Report.* Publications Office of the European Union. https://edgar.jrc.ec.europa.eu/report_2022

Efficiency Assessment Framework (LEAF) and My Green Lab. Various **carbon accounting tools** have been developed, as have equipment sharing or recycling initiatives. Initial steps are also being taken on an organisational level. For example, **funding agencies** are already moving to align their strategic goals with environmental sustainability, publishing position statements on the topic, and trialling pilot projects that involve assessing the environmental impacts of research.[17] They have also begun to encourage greater attention to environmental sustainability, with UKRI leading on the development of a **sustainability concordat** that will provide a common agenda for funders, research institutions and other signatory organisations. Within industry, many pharmaceutical companies have developed **sustainability agendas**. At the individual level, there are many small steps that researchers and other laboratory staff can take to reduce the environmental impact of their work.[18]

While much focus is on **carbon emissions**, environmental sustainability encompasses many aspects, including the impact of waste materials and reagents on the environment. Efforts to reduce the carbon footprint of biomedical research should not unintentionally damage the environment in other ways. In addition, one recognised way to reduce carbon emissions is to **improve efficiency**. However, it is important to guard against the **rebound effect** – improving efficiency often does not reduce consumption, but rather increases the capacity for consumption.

Although many of the challenges are complex and there is a high degree of uncertainty about the degree of carbon impacts, the urgency of the issues means that responses are needed immediately. While systemic or structural changes may take time to enact, and further studies will be required to close gaps in knowledge, **even with the knowledge currently available actions can be taken now by individuals and organisations and make a difference**.

Many issues are relevant to all areas of science, but biomedical research has specific features that warrant particular focus, including patient participation, the preservation, handling, and disposal of biological samples and pharmaceutical products, and the intensity of resource use, including single-use plastics. Given the growing interest in the environmental sustainability of biomedical research, in March 2023 the Academy of Medical Sciences organised a FORUM meeting, co-hosted with the MRC and the NIHR, to explore the current state of play and potential next steps for achieving greener biomedical research. The one-day meeting focused on the practice of research, including laboratory science ('wet-lab') and clinical trials, in academic, industry and healthcare settings.

As touched on in workshop discussions, the environmental impact of 'dry lab' (i.e. computational) biomedical research and data storage is significant, not always recognised by researchers, and an important consideration given the greater focus on open science and increased sharing of big datasets. However, in order to enable meaningful discussion of wet lab and clinical research in the limited time available, 'dry lab' (e.g. computational) biomedical research was not explicitly covered by this workshop. Other important issues not fully explored during the workshop for a similar reason included the sustainability impacts linked to translation of research findings, dissemination of research (including academic travel), research buildings, or approaches to decision-making that balances the potential benefits of

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[17] MacFarlane M & Samuel G (2022). *Addressing the Environmental Impact of (Digital) Health Research Conversations with UK funders Summary Report.* https://kclpure.kcl.ac.uk/portal/files/179062600/Summary_Report_of_funding_body_sustainability_workshop_July_2022.pdf

[18] Proteintech. *13 tips how to be more eco-friendly in the lab.* https://www.ptglab.com/news/blog/13-tips-how-to-be-more-eco-friendly-in-the-lab/

research and its environmental impact.

This report summarises the four scene-setting presentations and the following breakout group discussions that considered the major challenges and potential responses to improving the environmental sustainability of biomedical research. The workshop agenda, attendee list and a glossary can be found in Annex 2, Annex 3, and Annex 4, respectively.

The current state of play of sustainable biomedical research in the UK

A series of four talks highlighted the current landscape of sustainable biomedical research practice at the FORUM workshop, including examples of initiatives related to laboratory science, clinical research, and research in industry, as well as insights into scientists' current attitudes and practices.

What would net zero (medical) science look like?

Laboratory research makes a major contribution to the carbon footprint of UK science. A range of initiatives are aiming to promote more environmentally sustainable practice.

Martin Farley, Sustainable Research Manager at UCL and Director of Green Lab Associates, noted that the UK Government and multiple public bodies, professional societies and universities have all been making commitments to transition to net zero, while individuals also have a role to play in reducing personal carbon footprints. For those involved in laboratory science, the high resource demands of equipment, for example, offer substantial scope for reductions.

Green laboratory science needs to consider laboratory buildings (not discussed in detail at this workshop), equipment and consumables, and laboratory operations. There is scope to reduce emissions in all these areas. Sometimes, simple actions can make an easily definable difference, such as switching off lights or equipment not in use. Often, however, the greenest course of action is not so obvious to the end-user, especially when it comes to purchasing sustainably. In particular, it is important to take a **whole life-cycle approach** that considers the carbon footprint of manufacturing, distribution, and disposal, as well as operational use.

In addition, carbon emissions associated with some activities, such as data storage, are 'invisible' and frequently not considered. Scope to cut emissions also varies significantly between different types of laboratory – for example, equipment such as scanners cannot be safely turned off when not in use.

Greener choices when **purchasing** consumables and equipment provides an opportunity to reduce scope 3 emissions (see Box 1). For example, in 2019–2020, 83% of University College London's carbon emissions came from the products it bought.[19] However, there are no standardised approaches for assessing the environmental impact and sustainability of products, making comparisons difficult. Some suppliers may see sustainability as an unwanted complication, although others (such as Midas Pattern Co. Ltd)[20] have achieved net-zero status.

Mr Farley suggested that **centralisation of facilities** can deliver efficiencies and allow the

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[19] University College London (UCL) (2020). Sustainable UCL Annual Report 2019–20. https://www.ucl.ac.uk/sustainable/sites/sustainable/files/sustainable_ucl_annual_report_2019-20.pdf
[20] https://www.midaspattern.co.uk

development of specialist expertise in sustainability. However, even individual labs can make a difference, for example by reusing labware.[21] If reuse is not possible, green options include 'biobased' tubes – polypropylene-based labware made from cooking oil as raw material.[22]

Recycling offers further opportunities to enhance sustainability, although 'reduce' and 'reuse' are generally greener approaches. 'Take-back' schemes, where materials such as containers are returned to suppliers for reuse, are still comparatively rare, leading to avoidable waste.

Mr Farley suggested that **sustainability standards** will be required to ensure the consistent adoption of more environmentally sustainable practices, similar to the case for health and safety, with clearly defined requirements for different types of laboratories. Although not a formal regulatory system, the **LEAF (Laboratory Efficiency Assessment Framework)** initiative is enabling laboratories to benchmark their sustainability status.[23] Nearly 100 institutions from 15 countries, covering 2000 laboratories, have signed up to LEAF. LEAF pilot studies identified significant carbon and cost savings (2.9 tonnes of CO_2 equivalent per lab per year and an average of £3700 per lab per year, respectively).[24]

Across ten categories (waste, people, purchasing, equipment, IT, sample and chemical management, research quality, teaching, ventilation, and water), laboratories can receive bronze, silver or gold levels of LEAF certification. Over time, as environmentally sustainable research practice becomes more embedded, the criteria to achieve gold-level accreditation are likely to become more demanding.

LEAF is currently adapting its assessment tools so that it can certify specialist spaces, such as commercial laboratories, clinical/diagnostic laboratories, and "dry labs" (which only contain computational equipment). The LEAF process is designed to be facilitative, with guidance and feedback provided, and aims to strike a balance between promoting positive change and generating an excessive administrative burden.

Funders are showing increasing interest in supporting green initiatives. Notably, however, it is often **research technicians** who are best placed to promote green approaches to laboratory operations and procurement. For chemistry labs, a growing number of resources are now available to facilitate quantification of the environmental impacts of different chemical processes, supporting greener practice. Globally, multiple large institutions have established green lab initiatives and several national networks have been created. In 2022, the **Sustainable European Laboratories (SELs) initiative** was launched as an umbrella network to connect and assist national-level organisations and to provide a collective voice for bodies promoting greener research.[25]

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[21] Farley M & Nicolet BP (2023). *Re-use of labware reduces CO2 equivalent footprint and running costs in laboratories.* PLOS ONE. https://doi.org/10.1371/journal.pone.0283697
[22] Moretti C, Junginger M & Shen L (2020). *Environmental life cycle assessment of polypropylene made from used cooking oil.* Resources, Conservation and Recycling **157(104750)**.
[23] University College London (UCL). LEAF: Laboratory Efficiency Assessment Framework. https://www.ucl.ac.uk/sustainable/leaf-laboratory-efficiency-assessment-framework
[24] Marshall-Cook J & Farley M. LEAF: Laboratory Efficiency Assessment Framework. Unpublished.
[25] https://sels-network.org

Box 1: Scope 1, 2, 3 carbon emissions

A system has been developed to categorise different kinds of carbon emissions created by an organisation's activities. Most organisations that quantify their emissions rely on the categories of scope 1 and 2. Workshop participants highlighted that more work needed to be done on understanding the impact of scope 3, and that organisations could be encouraged to influence their suppliers to reduce their footprint.

Scope 1: Direct emissions, or emissions from sources that the organisation owns or controls directly (for example, emissions produced by company vehicles).

Scope 2: Indirect emissions, or emissions an organisation causes indirectly when the energy or heat it uses is produced. These emissions are produced by the energy providers, not the organisation itself. However, the organisation can still have an impact on these emissions, for example by choosing a supplier that uses renewable sources of energy.

Scope 3: Value chain emissions, or emissions that are not produced by the company itself, but that the organisation is indirectly responsible for. These come from different places depending on the type of organisation, but may include emissions created by the organisation's suppliers during production, packaging or transport of supplies. This category includes any emissions that do not fall within scope 1 or 2.

Making science greener: researcher perspectives and solutions

Changing the practice of research will depend on changing the behaviour of many thousands of individual researchers. It is therefore important to understand current attitudes in the research community including their perspectives on barriers to and opportunities for change. **Dr Deidre Black**, Head of Research and Innovation at the Royal Society of Chemistry (RSC), described some of the findings of a recent survey and workshops exploring the perspectives of researchers in chemistry and the disciplines with which it interfaces.[26] The survey received 700 replies, from individuals working at different levels across a variety of biomedical and non-biomedical research settings internationally, including from academia and industry.

The responses highlighted a high degree of awareness of sustainability impacts and a desire to take action – 79% were aware that their work activities had sustainability impacts, 84% wanted to act, and 63% had already taken action. However, a common response was that the issue was complex and multidimensional, and inter-related issues required difficult trade-offs to be made. Some respondents felt overwhelmed and uncertain about impacts and the most effective actions to take. It was also recognised that other important drivers or incentives, such as cost or time constraints, often discouraged green behaviours, suggesting that sustainability is yet to be fully prioritised by the sector.

Barriers and challenges were grouped into five areas: awareness and mindset; time and money; wasted experiments; data, knowledge and expertise; and safety, regulation, cost and quality.

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[26] Royal Society of Chemistry (2022). Sustainable Laboratories: A community-wide movement toward sustainable laboratory practices. https://www.rsc.org/new-perspectives/sustainability/sustainable-laboratories/

For example, there can be tensions between environmental sustainability and **health and safety –** plastic bins containing medical sharps containers, for example, are often incinerated for health and safety reasons, rather than being reused or recycled.

The survey also identified considerable variation in views and experiences, suggesting that challenges are often highly **dependent on context**, such as geographical location or work setting, and the type of research being carried out. Small companies, which may be struggling to stay afloat, will generally have less scope than large companies to dedicate time and resources to environmental sustainability issues, for example.

Many respondents indicated that they are already taking simple actions to reduce energy use and wastage, with younger staff often particularly committed to green action. Larger-scale solutions can include green buildings, such as the GlaxoSmithKline carbon-neutral laboratory for sustainable chemistry at the University of Nottingham.[27] Digitisation can promote resource efficiency, while centralised facilities can reduce waste by optimising processes and resource use. One example is the Cloud Lab run by Carnegie Mellon University in the US,[28] which runs experiments remotely 24 hours a day, 7 days a week, 365 days a year. By providing greater accessibility to researchers and automatically recording and uploading data on experiments, such laboratories could potentially minimise the need to build additional infrastructure, improve research reproducibility, and reduce duplication.

Improving the sustainability of medical research in the pharmaceutical industry

R&D and manufacturing within the pharmaceutical sector are major contributors to global greenhouse gas emissions, and the industry as a whole has recognised the part it needs to play in promoting more sustainable practice. **Penny James**, Chief Operating Officer R&D Biopharmaceuticals at AstraZeneca (AZ), described the approaches being taken by AZ.

AZ has consolidated its commitment to sustainability through a company-wide sustainability strategy, which recognises the linkage between sustainability and health. It also acknowledges that sustainability can deliver productivity gains, providing a further drive to adopt green practices.

The company has set concrete targets, for example to reduce scope 1 and 2 emissions (Box 1) by 98% by 2026, through actions such as the transition to electric vehicles, switching to renewable energy sources, and prioritising energy productivity. However, scope 3 emissions account for 96% of total AZ emissions. The company is actively engaging with suppliers to promote change along the entire supply chain.

AZ has adopted an end-to-end perspective on R&D, considering the whole product value chain. As well as suppliers, it is examining the greenhouse gas emissions of clinical trials, its product pipeline, and everyday operations and business travel. For product development, a focus on 'process mass intensity' (PMI) – how much product is generated for a set amount of input materials – provides a useful metric for gauging how efficiently raw materials are being converted into drug product. A variety of approaches can be taken to optimise PMI during different stages of product development, reducing the environmental impact of product manufacturing.

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[27] University of Nottingham. The carbon neutral laboratory. https://www.nottingham.ac.uk/chemistry/research/centre-for-sustainable-chemistry/the-carbon-neutral-laboratory.aspx

[28] https://cloudlab.cmu.edu

AZ has signed up to the **My Green Lab** initiative as a way of demonstrating progress. Based in the US and operating globally, My Green Lab runs a five-level certification scheme across 14 areas of laboratory practice.[29] My Green Lab has been selected by the UN Race to Zero campaign as a key indicator of progress for the pharmaceutical sector.

For clinical trials, the company is introducing changes such as virtual meetings to replace travel associated with trial management, optimising the trafficking and analysis of samples, and designing studies so it can reduce waste in data collection. It has developed a tool for internal use that provides triallists with guidance on how to reduce the environmental impact of clinical trials during the study design phase.

The AZ example illustrates a wider point about combining top-down and bottom-up approaches. It has adopted environmental sustainability as a strategic objective, with a goal to be science-based net zero by 2045, and recognises that environmental concerns must be integrated across all aspects of its work and the entire product development life-cycle. However, delivering on these high-level objectives will require changing of practice at all levels of the company.

Making clinical trials more environmentally sustainable

Clinical trials of new medical interventions involve several staff, many consumables, and can require extensive travel. This makes clinical trials an important and potentially impactful area for enabling environmentally sustainable practice. Despite this, progress to promote greener clinical trials has been scarce compared with pre-clinical research. In his talk, **Professor Rustam Al-Shahi Salman**, Professor of Neurology at the University of Edinburgh and Clinical Director of the UKCRC Network of Registered Clinical Trials Units, discussed evidence about the carbon footprint of clinical trials, interventions to reduce it, and outlined current initiatives to promote environmentally sustainable clinical trials.

Professor Al-Shahi Salman began his talk by highlighting that the most impactful way to reduce emissions is to **reduce redundancy in research** – i.e. the amount of research that is carried out that has no impact, for example because it lacked methodological rigour or unnecessarily duplicated a prior study.[30] Many organisations in the UK and globally have signed up to the *Lancet* REWARD (REduce research Waste And Reward Diligence) campaign, to implement best practice to reduce waste in research.[31]

Beyond commitments to reduce waste in research, other relevant initiatives are driving the UK clinical research environment towards more environmentally sustainable clinical trials. For example, within healthcare, the fact that the **NHS** was the first national health system to commit to net zero has provided impetus to decarbonise clinical research. The **Sustainable Healthcare Coalition** has been set up to connect those with an interest in sustainable healthcare practice, including clinical research.[32]

Assuming a study is well-designed and has the potential to close a gap in knowledge, there is scope to minimise its environmental footprint, with **the ultimate goal for all clinical trials being net-zero as standard**. Limited evidence is currently available on measuring and reducing the carbon footprint of trials, a notable exception being an analysis of the scope 1 and 2 emissions of the CRASH (Corticosteroid Randomisation after Significant Head Injury)

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[29] https://www.mygreenlab.org
[30] Chalmers I & Glasziou P (2009). *Avoidable waste in the production and reporting of research evidence.* Lancet **374**, 86-89.
[31] https://www.thelancet.com/campaigns/efficiency
[32] https://shcoalition.org

trial, a large international study[33]. However, the CRASH study has been cited only nine times, suggesting that sustainability is yet to gain recognition from the clinical trials community.

A later study by the NIHR Evaluation, Trials and Studies Coordinating Centre calculated and categorised emissions for 12 trials,[34] while the design of the CRASH-2 study showed that it was possible to reduce environmental impacts through clinical trial design.[35] In 2019, the NIHR released carbon reduction guidelines, which included 19 recommendations for reducing the carbon footprint of clinical research.[36]

In 2021, the *Lancet* published a commentary that highlighted the need for, among other things, a tool to measure the carbon footprint of trials and incentives to promote greener trial practice.[37] With funding from the NIHR and under the umbrella of the Sustainable Healthcare Coalition, the **Low Carbon Clinical Trial Consortium** is developing a tool for quantifying the carbon footprints of clinical trials.[38] The first step has been to produce a process map identifying all key sources of emissions and a calculator to estimate the carbon footprint of a clinical trial.

More research should be carried out to generate evidence on the greenest ways to carry out trials. In addition, Professor Al-Shahi Salman proposed that sustainability needs to be considered within trial design, which may require trade-offs to be made between what is scientifically most desirable and what is optimal from an environmental perspective. He suggested that there were opportunities to use both incentives and enforcement, and to highlight potential cost savings, in order to normalise greener practice within clinical research. Finally, he noted that voices of patients, carers and the public could also play a transformational role in advocating for and shaping greener clinical research practices.

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[33] Sustainable Trials Study Group (2007). *Towards sustainable clinical trials.* BMJ **334(7595)**, 671–673.
[34] Lyle K, et al. (2009). *Carbon cost of pragmatic randomised controlled trials: retrospective analysis of sample of trials.* BMJ **339,** b4187.
[35] Subaiya S, Hogg E & Roberts I (2011). *Reducing the environmental impact of trials: a comparison of the carbon footprint of the CRASH-1 and CRASH-2 clinical trials.* Trials **12(31)**.
[36] National Institute for Health and Care Research (NIHR) (2019). NIHR Carbon Reduction Guidelines. https://www.nihr.ac.uk/documents/the-nihr-carbon-reduction-guidelines/21685
[37] Adshead F, et al. (2021). *A strategy to reduce the carbon footprint of clinical trials.* Lancet **398(10297)**, 281-282.
[38] https://shcoalition.org/clinical-trials/

Moving the field forward

Existing initiatives are making progress in developing and promoting greener biomedical research practice. However, systemic challenges and evidence gaps prevent the adoption and scale-up of these initiatives and the development of novel solutions. To realise the benefits of greener biomedical research practice (to the environment, to health and other co-benefits),[39,40] it will be important to overcome these challenges. Following the introductory presentations, meeting participants discussed the challenges and proposed next steps for wet-lab research, clinical research and biomedical research more generally in breakout groups. The following themes emerged from these discussions.

1. Prioritising environmental sustainability within the biomedical research ecosystem

'Bottom-up' activities need to be supported and complemented by a more strategic and better-resourced 'top-down' approach.

Participants noted that much progress has been made through the commitment of 'champions' – individuals who have driven forward sustainability within their own institutions or specialist fields. Networks and consortia have also been created to link people with common interests across different locations. Several organisations, including UK funding agencies, have been 'early adopters', recognising the need for a more sustainable approach to biomedical research.

While much has been achieved through this 'bottom-up' approach, participants suggested that it has led to fragmentation and a proliferation of small-scale initiatives that can be difficult to sustain. Participants also noted that many changes are not possible or appropriate for individuals to make; for example, turning off or changing settings on communal equipment to reduce energy usage. Where sufficient evidence exists (see below), participants suggested that institutions should take a lead on mandating practices to reduce environmental impact. Individual efforts require high-level support from management and leadership to ensure that targets are enforced, resources are allocated, and relevant skills are developed.

Over the longer-term, participants felt that bottom-up activities need to be complemented by a more strategic sector-wide approach that recognises the need for investment in people and coordination.

Proposed next steps from the workshop:

1.1 As an urgent priority, there should be increased commitment from institutional and organisational leaders to improve the environmental sustainability of biomedical research, including supporting bottom-up

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[39] Academy of Medical Sciences and the Royal Society (2021). A Healthy Future: Tackling climate change mitigation and human health together. https://acmedsci.ac.uk/file-download/94272758

[40] Farley M & Nicolet BP (2023). Re-use of labware reduces CO2 equivalent footprint and running costs in laboratories. PLOS ONE. https://doi.org/10.1371/journal.pone.0283697.

approaches.

1.2 Evidence-based actions that can be taken to reduce environmental impact should be identified by and implemented across organisations.

There is a need to develop a workforce specialising in improving the environmentally sustainability of research practice.

A reliance on 'champions' has generally depended on committed individuals taking on additional activities outside their core roles. Participants felt that the environmental sustainability of research should now be recognised as a specialist function in its own right and embedded within specific roles.

Research support personnel, such as technical staff and procurement managers, have a critical role to play in the management of laboratory facilities and procurement of equipment and consumables, so will be central to the evolution of greener laboratory practice. Some participants reflected that the importance of the work done by research support personnel often goes unrecognised and they may feel disempowered, or even penalised, for attempting to improve the environmental sustainability of research practice.

As knowledge continues to grow in this area, the need for specialist expertise will become ever greater. Participants suggested that responsibilities for the environmentally sustainability of research practice could be written into existing job descriptions. Specific **capacity-building** initiatives might be required to build the skills base in greener research practice, especially in clinical research where initiatives have not progressed as much as those in laboratory research. In addition, it was suggested that there may be a need to create **dedicated new posts**. This could provide an opportunity to review and revise **career pathways** for technical staff, which could include specialisms related to the environmental sustainability of research.

A further open question is the relationship between research sustainability and wider institutional sustainability staff, such as those responsible for estates management or teaching. Technical staff with responsibility for sustainability often have 'a foot in both camps', requiring a detailed knowledge of laboratory practices and equipment but also benefiting from links to other staff responsible for sustainability across institutions. Such links should be nurtured and technical staff included in discussions about organisation-wide sustainability. One advantage of linking technical staff to an institution's sustainability office is the potential to pass on technical knowledge relating to research processes to other sustainability staff, as part of reciprocal exchange of information and experience. This is particularly important because, as Mr Farley highlighted in his talk, scientific activities and facilities account for a large proportion of the environmental impact of many universities.

Proposed next steps from the workshop:

1.3 Staffing plans, including plans for the training of current staff and researchers, should be developed by organisations to underpin a long-term shift to green research practice.

1.4 Teams responsible for organisation-wide sustainability should include technical staff with expertise in environmentally sustainable research practice, especially universities and other organisations that are particularly research-active.

Environmental sustainability needs to be seen as integral to good research practice.

A common theme at the workshop was that sustainability needs to become part of the **culture of good research practice**, with **health and safety** highlighted as an approach to be mirrored. Everyone working in a research setting is now conscious of the need to protect the health and wellbeing of researchers, other laboratory staff and research participants. Legislation and formal guidance clearly sets out what is required and what processes should be followed.

Other frequently cited analogies at the workshop included **public and patient involvement (PPI)** and **equity, diversity and inclusion (EDI)**. The activities of funders and regulators have helped to mainstream PPI within UK medical research, while schemes such as Athena Swan accreditation have encouraged greater focus on EDI. These areas may hold lessons for similar mainstreaming of a green agenda within biomedical science (or research more generally).

Some meeting participants noted that in some cases it may be necessary to assess acceptable 'trade-offs' between the environmental sustainability of research practice and research methodologies during the design stage. This is so that any potential negative environmental impact of chosen methodology does not undermine the overarching goal of biomedical research to benefit health and humankind. This value proposition was compared to the necessary trade-offs that are considered when assessing the financial costs of research studies and clinical trials, or the number of animals used in research studies. However, meeting participants emphasised that research quality must be sufficient to achieve reliable and meaningful results, otherwise the research effort would be wasted and thereby adversely impact the environment. In addition, it was pointed out that many research practices that are more environmentally sustainable have the added benefit of improving research quality. It will be important to communicate the benefits to research quality of such environmentally sustainable practices to help mitigate any concerns of researchers. The conversation about trade-offs in biomedical research to reduce environmental impact should continue in a collaborative, transparent, and evidence-based manner, supported by the development and standardisation of tools to measure the environmental impact of different research practices, as discussed below.

It was also suggested that sustainability should be built into induction processes, promoted through education and training from the earliest stages of research careers, and form part of staff appraisal procedures. Some UK institutions are starting to build this in. However, progress varies between institutions and there is room for improvement, as indicated by the student-driven Planetary Health Report Card initiative (which scores medical schools).[41]

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[41] https://phreportcard.org/

Proposed next steps from the workshop:

1.5 Strategies should be developed at an organisational level to promote and sustain a green research culture, for example through induction processes, training and staff appraisal procedures, learning from how this has been achieved for health and safety, PPI and EDI.

1.6 Acceptable ways to improve the environmental sustainability of research practice while maintaining sufficient research quality should be explored in an evidence-based manner and in collaboration with funders, researchers, technical staff, trial participants (in the case of clinical research), and other key stakeholders.

Environmental sustainability standards are required to provide shared benchmarks and to promote accountability.

It was suggested that, as for health and safety, clearly defined **standards** to be achieved by laboratories and other facilities, and to govern the procurement of equipment and consumables, should be developed to ensure consistent sustainable practice.

Participants suggested that a central body will need to be identified (or created) with the authority to develop standards and guidance, and to provide an oversight function. As mentioned above, additional **tools and training** will also be needed to build the capacity of researchers, laboratory technicians and other research specialist staff to meet these standards. It was noted that training and support may need to be tailored to role and area of operations. However, the need to avoid an excessive administrative load was also recognised.

Some institutions have developed **sustainable procurement frameworks**, which set out guidelines for interacting with suppliers and the environmental standards they are expected to meet. The **NHS** has also made firm commitments to sustainability and has introduced explicit sustainability criteria into its procurement processes.[42] Lessons could be learned from such organisations pioneering greener procurement.

Proposed next steps from the workshop:

1.7 Green research standards should be developed and monitored to enable more environmentally sustainable research practice. A suitable organisation to do this will need to be identified.

1.8 There is a need for organisations to implement sustainable procurement frameworks.

1.9 Lessons learned from NHS sustainable procurement practices should be identified and shared.

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[42] https://www.england.nhs.uk/greenernhs/get-involved/suppliers/

Coordination, perhaps through a central entity, is required for environmental sustainability in biomedical research.

Participants reflected that while much progress has been made through the pioneering activities of individuals and organisations, this has created a fragmented landscape with multiple accreditation systems, a wide range of guidance, and an array of networks and consortia.

Participants suggested creating a focal point or entity to serve a coordinating function, including:

- Providing a single **entry point** to relevant information, publications and tools.
- Acting as a **forum** for promoting greater coordination and alignment of activities.
- Promoting **networking** and consortia development.
- Facilitating the development of common metrics, open-access tools and standards.
- Helping to identify **gaps in knowledge** that could be addressed through research and collaboration.

Pulling together all relevant resources and sources of information was seen as a particularly valuable function.

Conceivably this focal point could be a new entity, an existing body, or a network of organisations. Its scope would need to be defined, but participants suggested that ideally it would cover research taking place in academic, healthcare and industry settings (as industry activity in this area can be considered pre-competitive and contributing to the public good). A further consideration would be whether this focal point was specific to biomedical science or the full spectrum of UK research.

It was suggested that lessons could be learned from the part that the National Centre for Replacement, Refinement and Reduction of Animals in Research (NC3Rs) has played in promoting good practice in animal use in research.

Proposed next steps from the workshop:

1.10 The remit and purpose of a central coordinating entity for green research should be mapped out (in relation to pre-existing initiatives) and taken forward in collaboration with research organisations across the biomedical sector, including wet lab and clinical research, and with stakeholders across academia, healthcare and industry.

2. Generating and disseminating evidence on environmentally sustainable research practices

Additional data would be useful on the environmental impact of research activities, equipment and consumables.

One of the major challenges highlighted by many meeting participants is the **lack of data on carbon impacts**. Some decisions, such as whether to switch off a light, do not require extensive evidence, but some choices rely on a more in-depth understanding of carbon impacts. For purchasing decisions, this might include conducting **whole-life-cycle carbon assessments** – an assessment of the carbon impact on the environment of an object or building, from the materials and fabrication, throughout its use, and including its disposal.

Similar exercises will be useful to help choice between different research methodologies – for example, considering the environmental impact of remote monitoring compared to monitoring of trial participants on site for a clinical trial. A lack of information about and understanding of whole-life-cycle carbon assessments and similar assessments can make decisions harder, making it difficult to prioritise actions, make comparisons, or determine the impact of interventions in the short as well as long term. It will be important to identify areas with a high degree of uncertainty that would significantly benefit from whole-life-cycle carbon assessments. However, participants emphasised that this should not slow down progress in other areas, where sufficient, if not complete, evidence exists to take action.

Many companies are developing more efficient or environmentally sustainable equipment, with the help of various accreditation schemes such as the LEAF and My Green Lab's ACT label.[43,44] However, replacement of functional equipment with more efficient models may not necessarily be the greenest action, given the **'embodied carbon'** in the existing product. Decisions frequently need to consider such trade-offs, which can be challenging to assess, particularly when impacts might cross different domains of sustainability (e.g. carbon production versus rare metal extraction). A **range of tools** have been developed to support decision-making relating to sustainability, ranging from those that assess environmental impact only to those that suggest solutions (some of these are listed in Annex 1). Participants suggested that further evaluation and dissemination of the most useful tools would be beneficial, alongside the development of new tools to meet priority community needs.

More data are required to quantify carbon impacts, to inform the development of **guidance** that could be used by a range of stakeholders, including researchers and technical staff, others with responsibility for procurement, and funders, to facilitate **assessments of sustainability in grant application processes**.

Within research centres, **institutional databases** or other information repositories could be established to support individual decision-making and procurement.

Proposed next steps from the workshop:

2.1 Additional data on carbon footprints and other sustainability-related impacts of research processes and equipment should be generated to inform decision-making, prioritising areas with most uncertainty and most impact.

2.2 Tools to enable practical use of this new evidence in decision-making by researchers and research support personnel should be developed, such as institutional databases to support procurement decisions.

Standardised and evidence-based metrics on sustainability are urgently required to guide decision-making.

Many methods are currently used to calculate and communicate carbon footprints or other aspects of sustainability. It was argued that standardised methods and metrics should be

[43] University College London (UCL). LEAF: Laboratory Efficiency Assessment Framework. https://www.ucl.ac.uk/sustainable/leaf-laboratory-efficiency-assessment-framework

[44] https://act.mygreenlab.org/

agreed and used to assess and report on sustainability. This will facilitate data syntheses, and enable comparisons between products and processes to be made more easily.

If funders were to consider the environmental impact of research during the grant application process, meeting participants noted that it would be essential to agree on what to measure and how to measure it. Some meeting participants pointed out that the diversity of applications would mean that applicants would need to conduct the assessment of their project's environmental sustainability, but that it would be useful if applicants used an assessment tool provided by the funder, to allow comparability between applications. Such a tool would ideally be applicable across research fields.

Proposed next steps from the workshop:

2.3 A common set of metrics for determining carbon footprints and other sustainability-related impacts should be agreed.

2.4 A tool that can be utilised by funders and researchers during grant applications should be developed.

Mechanisms are needed to ensure effective dissemination of information and sharing of experience.

Participants reflected that relatively little information has been generated to date on environmentally sustainable research practices, but the volume of research is beginning to increase and closing evidence gaps was seen as a key priority.

Studies are being published in the **academic literature,** which may only reach a subsection of professionals who could benefit from them. There are a range of other communication channels that could be used to share information and good practice. These could include short **case studies** or 'technical tips', shared through peer learning mechanisms and/or social media.

Networks may also be an effective mechanism for sharing good practice, as illustrated by a network for technicians in the East Midlands, led from the University of Nottingham that was highlighted at the meeting. A central entity to coordinate green research practice in the UK (see above) could also help to disseminate information and guidance.

Proposed next steps from the workshop:

2.5 Greater sharing of sustainability analyses, through the academic literature and other routes should be encouraged. Research journals and funders would be well placed to do this.

2.6 A repository or platform for the sharing of information should be established.

A critical mass of experts is needed to study and develop environmentally sustainable research practices.

Participants noted that only a small number of researchers are currently carrying out research to close evidence gaps into and support decision-making for improving the environmental sustainability of research practice. Given the relative paucity of evidence, it was felt that more studies will be needed, which will require the development of a larger **research community** with the requisite skills. Such researchers will also have a key advisory role and be central to the development of guidance.

Funders and institutions will need to consider what forms of support and academic infrastructure are required to build this critical mass of research expertise, and to sustain it over time. For example, opportunities to engage and support early career researchers and research support personnel in the study and development of environmentally sustainable research practice should be explored. These would provide professional development opportunities and help to build environmental sustainability into the research culture of the future generation of researchers. However, participants noted that it will be important that they are given the necessary support and recognition from more senior staff to do this work and implement any findings.

Proposed next steps from the workshop:

2.7 Programmes of support required to establish and sustain a critical mass of researchers investigating green research practice should be developed, including opportunities for early career researchers and research support personnel. Funders and research institutions would be well placed to take this forward.

3. Accelerating introduction of more environmentally sustainable practices in clinical research

A greater focus on green practice is required in clinical trials and other clinical research.

It was noted at the meeting that the development and promotion of environmentally sustainable research practice is not as advanced for clinical research as it is for laboratory science. In part, this may reflect the higher degree of **regulation of clinical research**, which mandates specific practices and is perceived by some to limit scope for green innovation. Meeting participants suggested that regulators such as the Health Research Authority (HRA) and the Medicines and Healthcare products Regulatory Agency (MHRA) could positively influence the environmental sustainability of clinical trials, particularly given the increased emphasis on the proportionate, risk-based approach to regulation in the UK.[45] Dialogue with regulators could help to identify ways to promote changes that are more environmentally sustainable while still being acceptable from a regulatory perspective – for example, related to **remote monitoring**. Clear communication of changes in practice or regulatory guidance

[45] https://www.gov.uk/government/consultations/consultation-on-proposals-for-legislative-changes-for-clinical-trials/outcome/government-response-to-consultation-on-legislative-proposals-for-clinical-trials. Note that this consultation outcome was not explicitly discussed by meeting participants, being published after the workshop. However, the proportionate, risk-based approach of the MHRA to regulation highlighted therein was discussed.

could encourage more risk-averse clinical researchers to embrace greener practices. However, it will be important to avoid over-regulation to avoid making the UK a less attractive place to conduct clinical research.

In addition, it was suggested that in clinical research there is no immediately obvious equivalent of the technical staff who often take a lead role in greening of laboratory practice. How and where to build capacity to promote greener clinical research is therefore an open question, though **clinical trials units** might be one possible option; clinical trials unit staff often have delegated responsibility for site management and monitoring so can help to influence.

Many clinical trials involve laboratory analyses, so their environmental impact will be reduced by progress in the greening of laboratory practice. However, there are multiple specific aspects of clinical study design that could be assessed to identify the potential for efficiencies or more sustainable practices to be introduced, including platform trials, and trial participant and investigator travel. For example, the adoption of electronic consent procedures could help reduce trial participant and investigator travel and associated carbon emissions.

The **pharmaceutical industry** has begun to identify potential ways to make trials more sustainable. Workshop participants urged them to share their analyses and recommendations, considered to be in the pre-competitive space, with the wider clinical trials community.

This area of work could also build on the initial steps being taken by the **Low Carbon Clinical Trials Consortium** to develop a tool for quantifying the carbon footprints of clinical trials (see above).

Proposed next steps from the workshop:

3.1 Regulators (e.g. the HRA and MHRA) should work with key stakeholders to determine how they can positively influence the environmental sustainability of clinical trials.

3.2 The individuals or groups who could have responsibilities for promoting green practice in clinical studies need to be identified.

3.3 Pharmaceutical companies along with other organisations should share their tools and approaches to the greening of clinical trials.

3.4 Case studies to illustrate green innovations in clinical trial research practice should be developed and shared.

Public and patient engagement and involvement should be built into a sustainability agenda for clinical research.

Meaningful PPI and engagement will be essential as a source of practical perspectives on how a trial can be organised and run in order to reduce its carbon footprint in a manner that is **acceptable to trial participants** and avoids unintended consequences. Participants felt that PPI and engagement could also provide an opportunity for **motivated public and patient representatives to advocate for a greener approach** in clinical studies and biomedical research more generally.

Recent years have seen a growing emphasis on PPI in clinical research (also reflected by the presence of public and patient representatives in this workshop). As mentioned above, there are lessons to be learned from the mechanisms used to encourage PPI that could be applied to the promotion of environmentally sustainable biomedical research practice.

Proposed next steps from the workshop:

3.5 Approaches to reduce the environmental impact of clinical trials should be acceptable to trial participants and PPI and engagement will be an important mechanism to achieve this. This is a particularly relevant consideration for the NIHR and the HRA.

3.6 The lessons that PPI mainstreaming could have for embedding of sustainability in research practice and culture should be explored, including learning from the ways policies and standards were introduced to improve PPI in research. This is a particularly relevant consideration for funders and regulators.

4. Promoting and informing behaviour change

Coordinated and concerted efforts are needed to ensure that environmental sustainability is embedded in the behaviour of individual researchers.

Although there is evidence that many individual researchers are strongly disposed to green research,[46] mainstreaming of green science will require behaviour change from each and every researcher, including those who are not passionate about the topic.

A variety of mechanisms were suggested to shape individual behaviour. These included **education, training**, and **incentives, rewards, and recognition**. In addition, **regulatory frameworks** can provide formal guidelines on required behaviours.

Nevertheless, it was recognised that some deeply embedded aspects of science could potentially discourage green practice. Most scientists keenly feel the pressure to secure grants and to publish papers. If pursuing a green agenda was felt to be an obstacle to the publication of papers, this could generate resistance to change.

Suggested responses included **developing and disseminating the evidence** to demonstrate that greener practices can be compatible with rigorous science (such as running ultra-low-temperature freezers at slightly higher temperatures). **Funding agencies** can send an important signal about how much they value environmental sustainability, by being willing to fund more expensive but greener options. Clear and effective **messaging** about the benefits of green research practice could also help to promote positive behaviour change. For example, meeting participants commented that the added bureaucracy of additional questions about environmental impact (e.g. for funding and regulatory and ethics approvals) could dishearten applicants. They suggested that the additional questions could be accompanied by estimations of the human and economic benefits of reducing environmental impact (e.g. in terms of reduced mortality and/or cost), as encouragement for applicants to buy-in to more

[46] Royal Society of Chemistry (2022). Sustainable laboratories: A community-wide movement toward sustainable laboratory practices. https://www.rsc.org/globalassets/22-new-perspectives/sustainability/sustainable-labs/sustainable-laboratories-report.pdf

sustainable research practice. They commented that this approach could be an especially effective encouragement to medical science professionals who may be particularly driven by an ambition to improve health outcomes.

Participants also highlighted the potential to take a **behavioural science lens** and to develop a behaviour change framework to apply in this area. This could draw upon existing models such as the capability, opportunity and motivation for behaviour change (COM-B) framework. The COM-B framework provides a systematic approach that could help to identify and overcome potential obstacles and support the design of effective incentives and behaviour change programmes.[47]

Over the longer term, it was felt that embedding sustainability in **research culture** in an evidence-based manner could lead to strong **peer pressure** to avoid environmentally harmful practices.

Proposed next steps from the workshop:

4.1 Factors likely to discourage adoption of green research practice should be identified and addressed. Some of these factors are associated with the drive to publish, and research journals are well placed to help address them. Incentives for best practice should also be developed and promoted.

4.2 Funders should consider how best to embed evaluation of the sustainability of research practices into grant applications and funding committees, using clear effective messaging that encourages buy-in of researchers whilst being conscious of the administrative burden on researchers.

4.3 Behavioural science studies should be conducted to understand and identify interventions that encourage researcher behaviour to adopt more environmentally sustainable behaviours in their work.

[47] Michie S, van Stralen MM, West R (2011). *The behaviour change wheel: a new method for characterising and designing behaviour change interventions.* Implementation Science **6(42)**.

Conclusion

The workshop illustrated the great enthusiasm within the biomedical research community to drive forward change and embrace greener research practice. Meeting participants noted that there is now a major opportunity to harness this energy to continue to make progress and ensure that the UK actively pursues efforts to address the sustainability of biomedical research.

It was clear from the meeting that **multiple stakeholder groups** need to play their part in reducing carbon emissions. **Individual laboratory researchers** need to consider the sustainability implications of their daily practices and what changes they can make. **Research support personnel** (including technicians, clinical trials staff, lab managers, and procurement officers) are in a potentially pivotal position to influence laboratory practices and purchasing decisions.

However, individuals need to be able to act in a system that is supportive of their efforts. It was felt that **institutions** need to show leadership and commit to greener research, alongside their commitment in other areas, such as estates management; this will mean considering issues such as the need for staff with appropriate expertise, capacity-building and new career pathways for experts who study how to improve the environmental sustainability of research practice. **Funders** are in a potentially powerful position, and could strengthen their assessment criteria of sustainability within grant applications; this would be aided by use of common metrics across institutions, while the draft sustainability concordat being developed by the UKRI will support consistency in practice across funders and institutions that are signatories.

It was suggested that the **clinical research sector** may not be so advanced in its consideration of environmental sustainability, possibly because regulations are perceived to limit the potential for introduction of sustainability innovations, and because there is no clear equivalent to technical staff, who are playing a key role in wet-lab sustainability. Nevertheless, there is scope to build on existing networks focusing on sustainability and to consider the role that clinical research networks and clinical trials units can play in driving forward a greener clinical research agenda.

Regulatory authorities are also in a position to promote this agenda. In consultation with the wider sector, organisations such as the MHRA and the Health and Safety Executive should examine how they might enable and encourage more sustainable practice, without compromising their commitments to safety and to flexible, proportionate regulation. Likewise, bodies such as the HRA could explore whether they could incentivise a transition to sustainable practice in a similar way to their encouragement of PPI in trials.

Publishers have played an important role in promoting good research practice, including transparency in clinical trial reporting. Participants suggested that they could similarly exert influence by requiring reporting on sustainability-related analyses associated with studies (e.g. calculation of carbon emissions).

Industry, particularly the pharmaceutical industry, has already begun to prioritise environmental sustainability, with a strong awareness of the reputational risk associated with environmentally damaging practices. Many companies have clearly defined strategies that incorporate promotion of environmentally sustainable research practice and publicly report on progress (e.g. in Environmental, Social, and Governance (ESG) reports). Industry can also deliver community benefits by sharing its experience, tools and analysis for others to learn from. It was noted that smaller biotech companies, and the medical devices sector, dominated by relatively small companies, may find transitioning to greener practice more challenging.

Finally, it was suggested that there was much to learn from the experience of others. The **NHS**, for example, has adopted ambitious carbon reduction goals and has experience of shifting towards more sustainable purchasing. In terms of the culture shift required within research, the embedding of **PPI and EDI** were highlighted as areas where change has been achieved in a relatively short period of time. Although the journey is not yet complete, progress with PPI and EDI may offer lessons on how green practice can become the norm in biomedical research.

Participants also recognised that some changes discussed during the workshop would take time to implement, but there are already well-evidenced actions that people and organisations can take now to have a positive impact. It is likely that all researchers, research support personnel, management, and leadership could already find ways to cut energy or resource use in their day-to-day roles. Joining a lab accreditation scheme was widely seen as a mechanism to help focus minds and provide new ideas for enhancing sustainability.

As was stressed at the workshop, due to the escalating nature of the climate crisis, urgent action is needed. A challenge was laid down for everyone, at the workshop and beyond, to identify two changes they could make to ensure their working practices, and those in their realm of influence, continue to become ever greener. However, concerted, coordinated effort across the sector is urgently needed to agree on priorities, timelines, and immediate actions to create a system that ensures greener research practices are adopted.

Annex 1: Case studies, networks, and other initiatives from the workshop

The table below includes examples of initiatives and case studies in the area of environmentally sustainable biomedical research, gathered in the run up to and discussions during the workshop. The list is not curated and is provided for information only; it is not intended to be exhaustive and the Academy, the MRC and the NIHR take no responsibility for the content of third-party websites or the activities of third-party organisations.

Name	Description	Link
Accreditation schemes		
Laboratory Efficiency Assessment Framework (LEAF)	This framework provides actions that lab users can take to save plastics, water, energy and other resources. By taking part in the programme, laboratories will reduce their carbon emissions and create an environment that supports research quality.	https://www.universitiesuk.ac.uk/latest/insights-and-analysis/leaf-new-standard-sustainable-science
My Green Lab	This non-profit organisation aims to make research more environmentally sustainable. Their programs include the 'My Green Lab Certification' for laboratory sustainability best practises and the 'ACT Environmental Impact Factor Label' for the rating of the environmental impact of laboratory products.	https://www.mygreenlab.org/
Initiatives and case studies led by academia		
Green Labs initiative (University of Bristol)	This initiative aims to minimise the environmental impact of lab research across the University of Bristol.	https://www.bristol.ac.uk/sustainability/doing/labs/
Plastics Network (University of Birmingham)	This network is an interdisciplinary team of 40+ academics working together to shape the fate and sustainable future of plastics. The network works across all campuses of the university, including medical research, chemistry and engineering, environmental research, social sciences, and policy.	https://www.birmingham.ac.uk/research/spotlights/plastics-network.aspx
Laboratory plastic recycling initiative (KCL)	An initiative that has seen the basic and clinical neuroscience laboratories at KCL change the way their waste is disposed of, to ensure more plastic waste can be recycled.	https://www.kcl.ac.uk/aboutkings/strategy/sustainability/get-involved/staff/sustainability-champions/lab-champions/case-studies/case-studies
Sustainable Trials Study Group (LSHTM)	This group was convened by the London School of Hygiene & Tropical Medicine to find ways of reducing greenhouse gas emissions from clinical trials.	https://www.bmj.com/content/334/7595/671
Tackling environmental sustainability in healthcare (University of Plymouth)	Education at undergraduate, master's and doctoral level embeds the topic of sustainability in various courses and projects.	https://www.plymouth.ac.uk/school-of-nursing-and-midwifery/sustainability

Research into strategies to reduce the carbon footprint of clinical trials (multiple organisations)	This NIHR funded project looked at opportunities for reducing the carbon footprint of clinical trials. The project was a collaboration between contributors from the following organisations: Sustainable Healthcare Coalition, Environmental Resources Management, University of Edinburgh, Cardiff Centre for Trials Research, Institute of Cancer Research, UK Health Alliance on Climate Change, University College London, and University of Liverpool.	https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)01384-2/fulltext Ongoing project: https://fundingawards.nihr.ac.uk/award/NIHR135419
Technical Sustainability Working Group (University of Nottingham)	A group of technicians working to embed sustainability within the laboratories of the university. The group has implemented a number of practical solutions to improve sustainability and reduce the carbon footprint of the university. For example, they have removed water condensers from chemistry labs and replaced them with air condensers, saving over 3 million litres of water.	https://www.nottingham.ac.uk/sustainability/sustainable-labs/tswg.aspx
Open-source tool to assess the carbon footprint of research (Cornell University)	A tool developed by an interdisciplinary team of scientists that can estimate the carbon footprint of research activities.	https://arxiv.org/abs/2101.10124
Making biobanks more sustainable (King's College London)	A project titled 'Environmental Impact Assessment of Biobanking Strategies: Creating a Sustainable Biobanking Roadmap for sample storage'.	https://kclpure.kcl.ac.uk/portal/en/projects/environmental-impact-assessment-of-biobanking-strategies-creating-a-sustainable-biobanking-roadmap-for-sample-storage(8e44cfcf-b266-45f2-af46-3249bf858b25).html
Initiatives and case studies led by industry		
Plant on a Truck initiative (Janssen)	This initiative from the pharmaceutical company Janssen uses a mobile purification plant to treat water and recycle waste chemicals.	https://www.janssen.com/belgium/plant-truck-circular-economy-0
Cyclic planning (Lundbeck)	At its pharmaceutical production in Denmark, Lundbeck introduced 'cyclic planning', which is a planning setup that ensures a more stable and predictable execution of production. This reduces the use of materials and the amount of waste generated in production.	https://efpia.eu/media/554663/circular-economy.pdf
Green Chemistry initiative (Pfizer)	The pharmaceutical company, Pfizer, is integrating green chemistry in their research and development to reduce waste and environmental impact and increase the safety of processes and products.	https://www.pfizer.com/about/responsibility/green-journey/greener-processes
Green Chemistry initiative (Takeda)	The pharmaceutical company, Takeda, uses green chemistry to reduce the environmental impact of their manufacturing process.	https://www.takeda.com/corporate-responsibility/reporting-on-sustainability/planet/protecting-our-planet-stories/protecting-our-planet-sustainable-products

Ambition Zero Carbon (AstraZeneca)	AstraZeneca are committing to have zero carbon emissions from operations across the world by 2025, and to make their entire value chain carbon negative by 2030.	https://www.astrazeneca.com/media-centre/articles/2020/ambition-zero-carbon-22012020.html#
Initiatives and case studies led by funding bodies		
NIHR Carbon Reduction Guidelines	The NIHR has developed recommendations for researchers on topics including the selection of research questions, making full use of existing evidence, efficient study design and conduct, avoiding unnecessary data collection, sensible clinical trial monitoring practices, good practice in reporting research, and reducing the environmental impact of the NHS through research.	https://www.nihr.ac.uk/documents/the-nihr-carbon-reduction-guidelines/21685
MRC funding for projects on environmental sustainability in life science and medical practise	This funding opportunity from MRC from 2022 provided funding for research into making life science and medical practise more environmentally sustainable.	https://www.ukri.org/opportunity/environmental-sustainability-in-life-sciences-and-medical-practice/
UKRI sustainability concordat for the research sector	This concordat for increasing the environmental sustainability of research and innovation across the country is currently being drafted by UKRI.	https://researchprofessionalnews.com/rr-news-uk-research-councils-2022-12-ukri-developing-sustainability-concordat-for-research-sector/
Collaborations		
Sustainability Exchange Initiative	This initiative is a collaboration between leading organisations from the further and higher education sectors. It combines resources and experience from top sustainable development and education bodies.	https://www.sustainabilityexchange.ac.uk/home
Sustainable Markets Initiative (SMI) Health Systems Taskforce	This taskforce brings together global health leaders from industry, the WHO, UNICEF and academia, and aims to accelerate the delivery of net-zero health systems. Part of their work has focused on how emissions in clinical trials can be reduced through digitalisation.	General: https://www.sustainable-markets.org/taskforces/health-systems-taskforce/ White paper 'The Digital Solution for Sustainability in Clinical Research': https://a.storyblok.com/f/109506/x/42119be232/smi-hstf-digital-health-whitepaper.pdf
Sustainable Healthcare Coalition	This healthcare sector-led group aims to identify opportunities to inspire sustainable practices in healthcare through the collaboration of its members. One of their projects, led by the Low Carbon Clinical Trials Consortium, focuses on making clinical trials more environmentally friendly. The Low Carbon Clinical Trials Consortium is currently developing a tool to quantify the carbon footprints of clinical trials.	General: https://shcoalition.org/ Low Carbon Clinical Trials: https://shcoalition.org/clinical-trials/
Green Neuroscience Working Group (British Neuroscience Association)	This working group aims to minimise the negative environmental impact of undertaking research, teaching and practice within the neuroscience sector.	https://www.bna.org.uk/about/policy/green-neuroscience/

MRC and NIHR Trials Methodology Research Partnership – Greener Trials subgroup	The MRC-NIHR Trials Methodology Research Partnership brings together networks, institutions and partners working in trials and trials methodology research. The Partnership has added a new subgroup on Greener Trials.	https://www.methodologyhubs.mrc.ac.uk/about/tmrp/
Other initiatives and case studies		
International Institute for Sustainable Laboratories (I2SL)	The International Institute for Sustainable Laboratories (I2SL) is involved in sustainable laboratories and related high-technology facilities, from design to engineering to operation. Their mission is to engage all stakeholders in advancing the safety and sustainability of laboratories and other high-tech facilities globally.	https://www.i2sl.org/index.html
Greenhouse Gas Protocol	The GHG Protocol is an accounting tool for business and government that sets the standards for measuring and managing carbon emissions.	https://ghgprotocol.org/
Green Light Laboratories	Green Light Laboratories offer their customers the means to identify the most sustainable lab equipment for their needs and use their equipment in the most efficient, cost saving manner.	http://greenlightlabs.co.uk/ https://www.lab-innovations.com/guest/andy-evans-green-light-laboratories/
Green Lab Associates	Green Lab Associates guide and advise client laboratories to ensure these environments are as sustainable as possible, saving money, reducing pollution, and maximising research potential.	https://www.greenlabassociates.com/
NIUB-Nachhaltigkeitsberatung: Sustainability for life sciences	Individual consulting and research work for laboratories or life science companies to become more sustainable.	https://niub-nachhaltigkeitsberatung.de/en/
The Planetary Health Report Card Initiative	A student-driven, metric-based tool for evaluating and improving planetary health content in health professional schools.	https://phreportcard.org/
RecycleLab	RecycleLab offers services for plastic recycling waste management for the science and healthcare sector, including plastic waste collection, decontamination and recycling.	https://recycle-labs.com/
Warp It	Warp It provides a platform for sharing, giving away or loaning unwanted and unneeded items with other departments within the organisation or with other organisations (schools, not-for-profits, etc.), thereby helping to facilitate the (re-)use of items that would otherwise have been thrown away.	https://www.warp-it.co.uk/
The Freezer Challenge (My Green Lab and I2SL)	This international initiative led by My Green Lab and the International Institute for Sustainable Laboratories (I2SL) is aimed at making cold storage in laboratories more energy efficient.	https://www.freezerchallenge.org/the-challenge.html
LabCycle	LabCycle offers sorting, decontamination, and recycling for different disciplines and sectors to create the first high-grade recycled lab plastic supply chain.	https://labcycle.org/

HEaTED	Higher Education and Technician Educational Development	https://heated.org.uk/
The Caring Scientist: Mission Sustainable	This podcast by wet lab scientists Nikoline Borgermann and Adriana Wolf Perez aims to create awareness about the environmental impact of laboratory work and to provide hands-on tips on how to reduce it.	https://anchor.fm/caring-scientist
Networks		
Max Planck Sustainability Network	A grass-roots initiative in the Max Planck Society, Germany's non-university research organisation, to create a sustainable scientific environment by improving cooperation and administration and reducing resource intensity in both scientific and day to day practise.	https://www.nachhaltigkeitsnetzwerk.mpg.de/
Sustainable European Laboratories (SELs) Network	This network aims to lead scientific research towards sustainable practice – for example through collecting and integrating knowledge on sustainable laboratory practises or helping establish green lab initiatives within Europe.	https://sels-network.org/
Green labs Austria	Aims to connect Austrian with international labs that share the vision of sustainable research.	https://greenlabsaustria.at/
Greenlabs Portugal	A network of Portuguese grassroot "green teams" made up of scientists and other employees of research institutes that advocate for sustainable research practices to reduce the environmental impact of research in Portugal.	https://greenlabs.pt/
Irish Green Labs	Network of labs in Ireland to assist public sector labs to optimise their energy management systems, including targeted actions combatting any negative impact that laboratory activities could have on the environment. Irish Green Labs climate actions now fall under the four pillars of Energy, Plastic, Chemistry and Water.	https://irishgreenlabs.org/
Green Your Lab	Network of sustainable science and green lab enthusiasts.	https://greenyourlab.org/
Green Labs NL	A group of Dutch scientists with a passion for sustainability.	https://www.greenlabs-nl.eu/
Laboratory Efficiency Action Network	An organisation of individuals who all work in publicly funded institutions. They meet regularly and share best practice and resources through an online forum.	https://www.lean-science.org/

Annex 2: Agenda

Time (min)	Start
9.30 – 9.35	**Opening remarks from Co-chairs** **Professor Frank Kelly FMedSci,** Humphrey Battcock Chair in Community Health and Policy, Imperial College London **Professor Paula Williamson FMedSci**, Professor of Medical Statistics, University of Liverpool
	Session 1: Scene-setting talks
9.35 – 9.55	**What would net zero (medical) science look like?** **Martin Farley,** Director, GreenLab Associates; and Sustainable Research Adviser, University College London
9.55 – 10.10	**Making science greener: Researcher perspectives & solutions** **Dr Deirdre Black,** Head of Research and Innovation, Royal Society of Chemistry
10.10 – 10.25	**Improving the sustainability of medical research in the pharmaceutical industry** **Penny James,** Chief Operating Officer R&D BioPharmaceuticals, AstraZeneca
10.25 – 10.40	**Making clinical trials more environmentally sustainable** **Professor Rustam Al-Shahi Salman,** Professor of Clinical Neurology, University of Edinburgh; and Clinical Director, UKCRC network of registered Clinical Trials Units
10.40 – 11.00	Discussion and Q&A with speakers
11.00 – 11:20	Break
	Session 2: Breakout groups – split between wet lab and clinical research
11.20 – 11.55	**Breakout session: Aim 1** Groups will discuss the systemic and stage-specific challenges to enabling environmentally sustainable 'wet-lab' **or** clinical research **or** both, and the different stakeholder groups affected/involved. Participants may consider what knowledge gaps that exist, preventing a movement to more environmentally sustainable research practices.
11.55 – 12.00	Break
12.00 – 13.00	**Breakout session continued: Aims 2 & 3** Identify interventions/potential solutions to the challenges identified before the break, highlight the key stakeholders for implementing these, and consider their acceptability (e.g. to patients in the case of clinical research). Consider whether these interventions present opportunities (e.g. cost savings, commercial, research opportunities etc).
13.00 – 14.00	Lunch
	Plenary session
14.00 – 14.10	**Vote on next steps**
14.10 – 15.25	**A whole delegation discussion**, led by the Co-Chairs.
15.25 – 15.30	**Closing remarks by the Co-Chairs** **Professor Frank Kelly FMedSci,** Humphrey Battcock Chair in Community Health and Policy, Imperial College London **Professor Paula Williamson FMedSci**, Professor of Medical Statistics, University of Liverpool
15:30 – 16:30	Networking
16:30	Event close

Annex 3: Attendee list

Steering committee

- **Professor Frank Kelly FMedSci**, Humphrey Battcock Chair in Community Health and Policy, Imperial College London (*co-chair*)
- **Professor Paula Williamson FMedSci**, Professor of Medical Statistics, University of Liverpool (*co-chair*)
- **Dr Susan Simon**, Director (Capital and Estates) & Chief Environmental Sustainability Officer, Medical Research Council (MRC)
- **Elena Dimitrova**, Environmental Sustainability Officer, Medical Research Council (MRC)
- **Dr Sophia Lentzos**, Head of Sustainability, National Institute for Health Research (NIHR)
- **Dr Mehriban Akin**, Associate Director (Environment, Health and Safety), Merck Sharp & Dohme (MSD)

Speakers

- **Professor Rustam Al-Shahi Salman**, Professor of Clinical Neurology, University of Edinburgh; and Clinical Director, UKCRC network of registered Clinical Trials Units
- **Dr Deirdre Black**, Head of Research and Innovation, Royal Society of Chemistry
- **Martin Farley**, Director, Green Lab Associates; and Sustainable Research Adviser, University College London
- **Penny James**, Chief Operating Officer R&D BioPharmaceuticals, AstraZeneca

Attendees

- **Fiona Adshead**, Chair, Sustainable Healthcare Coalition
- **Dr Mehriban Akin**, Associate Director (Environment, Health and Safety), Merck Sharp & Dohme (MSD)
- **Jo Allatt**, Senior Environmental Sustainability Programme Manager, UK Research and Innovation (UKRI)
- **Dr Roland Brown**, Director (Analytical R&D), Pfizer Pharmaceuticals
- **Dr Fanny Burrows**, Net Zero Research & Innovation Technical Lead, NHS England
- **Dr Isabela Butnar**, Principal Research Fellow, University College London
- **Caroline Daw**, Account Manager (Pharma), Merck Life Science
- **Elena Dimitrova**, Environmental Sustainability Officer, Medical Research Council (MRC)
- **Dr Jo Durgan**, Research Scientist, Babraham Institute
- **Andy Evans**, Managing Director, Green Light Laboratories Ltd
- **Dr Lisa Fox**, Assistant Operations Director, Institute of Cancer Research
- **Dr Elisa Garcia-Wilson**, Sustainability Officer, University of Dundee
- **Dr Katie Gillies**, Director (Health Care Assessment Programme), University of Aberdeen
- **Jessica Griffiths**, Research Associate, Institute of Cancer Research
- **Sarah Grimshaw**, Research Regulation Specialist, Health Research Authority
- **Lee Hibbett**, Technical Manager, University of Nottingham
- **Professor Judy Hirst FRS FMedSci**, Professor of Biological Chemistry, University of Cambridge
- **Dr Anne Horan**, Senior Programme Manager (Science Divisions), Royal Society of Chemistry
- **Charlotte Houghton**, Sustainability Project Officer, University of Oxford

- **Allison Hunter**, Technical Operations Manager, Imperial College London
- **Philippa Johnstone**, Programme Manager, Royal Society
- **Ian Jones**, Owner, Jinja Publishing Ltd
- **Dr Sophia Lentzos**, Head of Sustainability, National Institute for Health Research (NIHR)
- **Anna Lewis**, Sustainable Science Manager, University of Bristol
- **Addie MacGregor**, Sustainability Executive, Association for British HealthTech Industries (ABHI)
- **Neil Mackillop**, Senior Director, AstraZeneca (Clinical Development)
- **Dr Poppy Marriott**, Deputy Lab Services Manager, Laboratory of Molecular Biology, MRC
- **Carolyn McNamara**, Senior Manager of Technology and Innovation, KCR
- **Dr Ainhoa Mielgo**, Associate Professor, University of Liverpool
- **Kirit Mistry**, Chair & Lead for Health Inequalities, South Asian Health Action
- **Nicola Perrin MBE**, Chief Executive Officer, Association of Medical Research Charities (AMRC)
- **Dr Guy Peryer**, Lecturer (Research Methodology), Applied Research Collaboration (ARC) East of England, NIHR
- **Isabella Ragazzi**, Research Associate, University College London
- **Dr Daniela Rodriguez Rincon**, Research Policy Manager, Association of the British Pharmaceutical Industry (ABPI)
- **Dr Gabrielle Samuel**, Research Fellow, King's College London
- **Dr Sheri Scott**, Senior Lecturer, Nottingham Trent University
- **Dr Susan Simon**, Director (Capital and Estates) & Chief Environmental Sustainability Officer, MRC
- **Dr Nick Souter**, Postdoctoral Researcher, University of Sussex
- **Danielle Stephens**, Lead Entrepreneur, RecycleLab
- **Professor Matt Sydes**, Professor of Clinical Trials and Methodology, MRC Clinical Trials Unit at UCL
- **Dr Mathew Tata**, Research Funding Policy and Governance Manager, CRUK
- **Dr Anne Taylor**, Head of Grant Operations & Associate Director of Funding Operations and Governance, Wellcome Trust
- **Dr Elia Tziambazis**, Managing Director, Boston Consulting Group (BCG)
- **Dr Nicola Wallis**, Senior Vice President (Biology), Astex Pharmaceuticals
- **Gayle Wilson**, Senior Life Sciences Technician, Keele University

Staff and Secretariat

- **Dr Anna Hands**, FORUM Policy Manager, the Academy of Medical Sciences
- **Kate Little**, FORUM Policy Officer, the Academy of Medical Sciences
- **Lydia Melville**, Communications Project Officer, the Academy of Medical Sciences
- **Hannah Webb**, Policy Intern, the Academy of Medical Sciences
- **Elisabeth Kamper**, Policy Intern, the Academy of Medical Sciences
- **Dr Claire Cope**, Head of Policy, the Academy of Medical Sciences
- **Dr Hannah Chance**, Policy Officer, the Academy of Medical Sciences
- **Victoria Stepanova**, Programme Officer, the Academy of Medical Sciences
- **Dr Melissa Bovis**, Public Engagement Manager, the Academy of Medical Sciences

Annex 4: Glossary

This section provides definitions for some terms related to environmental sustainability. For a more extensive glossary, please refer to one of the following sources:

- *https://www.appropedia.org/Glossary_of_sustainability_terms*
- *https://earthshiftglobal.com/sustainability-terms*

Alternative energy
Refers to one of two categories: replacements of existing petroleum liquids (for example biodiesel); or replacements for fossil fuels that can be used to generate and store electrical power (for example wind or solar energy).

Biodegradable
Capable of being decomposed through the action of organisms, especially bacteria.

Carbon Dioxide Equivalent (CO_2e)
A unit used to measure the impacts of releasing (or avoiding the release of) the different greenhouse gases (carbon dioxide, methane, ozone, nitrous oxide, chlorofluorocarbons, water vapor). It is obtained by multiplying the mass of the greenhouse gas by its global warming potential. One carbon dioxide equivalent is defined as the global warming potential of one ton of carbon dioxide (CO_2). So for example, one ton of ammonia (NH_3), a substance that contributes 23 times as much to global warming as one ton of carbon dioxide (CO_2), is equivalent to 23 CO_2e.

Carbon emissions
Carbon dioxide (CO_2) produced by human activity (for example the use of planes or cars, factories, burning of fossil fuels like coal, etc.). Carbon dioxide is a greenhouse gas, which accumulates in the Earth's atmosphere and trap heat.

Carbon footprint
The amount of carbon dioxide (CO_2) released into the atmosphere as a result of the activities of a particular individual, organization, or community. Usually measured in tonnes of carbon dioxide (CO_2).

Carbon neutral
Producing net-zero carbon dioxide emissions overall. Organisations achieve carbon neutrality by balancing out carbon emissions with projects that offset carbon emissions (for example, through technologies that remove carbon dioxide from the air, so called carbon capture technology; or through supporting projects that plant trees, which convert carbon dioxide into oxygen).

Carbon offset
A reduction or removal of carbon in the atmosphere in order to compensate for emissions produced somewhere else.

Circular planning (or cyclic planning)
Planning of processes and systems in which wastes, especially water and materials, are reused and recycled.

Circular economy
An economic system that aims to minimise production and disposal and maximise use of products or services (as opposed to traditional linear economy, which has a heavy focus on production and disposal of products or services). Circular economy aims to use products or services to their fullest and to repurpose any material once a product is disposed of (for example by using materials for the production of new products or services).

Clinical research
Medical research that involves interactions with patients or patient populations (including clinical trials) and is aimed at improving our understanding of human health and disease and improving or developing treatments.

Closed loop economy
The most sustainable form of production and consumption. Any materials disposed of at the end of the lifecycle of a product are reused to create other products (In other words, there is no material left over that is disposed of but not recycled/reused).

Ecological footprint (also Eco-footprint, footprint)
A measure of the area of biologically productive land and water needed to produce the resources and absorb the wastes of a population. This includes the total area of productive land or sea required to produce all the crops, meat, seafood, wood and fibre the population consumes, the area of land and sea needed to sustain its energy consumption, and the area of land and sea needed to give space for its infrastructure.

Energy footprint
The area required to provide or absorb the waste from coal, oil, gas, fuelwood, nuclear energy and hydropower: the Fossil Fuel Footprint is the area required to sequester the emitted CO_2 taking into account CO_2 absorption by the sea etc.

Footprint
In a very general environmental sense, a "footprint" is a measure of environmental impact. This is usually expressed as an area of productive land (the footprint) needed to counteract the impact.

Fossil fuels
Carbon containing material found in the Earth’s crust that formed from the remains of dead plants and animals. These include coal, oil and natural gas. Humans burn fossil fuels to generate energy. Most of the energy used by humans today is from fossil fuels.

Energy efficient
Using less energy to provide the same level of energy service. Energy efficiency is linked to the carbon footprint. A process that uses less energy also has a smaller carbon footprint. This is because much of our energy is made by burning fossil fuels such as coal or gas, which releases carbon into the atmosphere. There is also carbon embodied in the technologies we use to generate energy, even renewable energy.

Embodied carbon
The amount of carbon emitted during the construction of a building (including during the extraction of raw materials, the manufacturing and refinement of materials, transportation, building work itself, and disposal of old building materials).

Global warming
The observable rise in global temperatures due to the enhanced greenhouse effect caused by humans, which traps the Sun’s heat in the Earth’s atmosphere.

Greenhouse effect
The process in which certain components that accumulate in the Earth's atmosphere ('greenhouse gases') trap the heat created by sunlight and cause warming of the planet's surface.

Greenhouse gas
Components of the atmosphere that contribute to the greenhouse effect. These include the following gases: carbon dioxide, methane, ozone, nitrous oxide, chlorofluorocarbons, water vapor. All of these gases accumulate in the Earth's atmosphere and can trap the heat created by sunlight.

Net zero
Achieving a balance between the carbon emitted into the atmosphere and the carbon removed from it. Net zero is reached when the amount of carbon emitted is no more than the amount of carbon removed. This can be achieved through a combination of reducing emissions and increasing efforts to remove carbon from the atmosphere.

5 Rs of sustainability
A set of principles of sustainability including: Refuse, reduce, reuse/repurpose, rot, recycle. In detail, they refer to:

- Refusing to buy any non-recyclable products or products in unnecessarily wasteful packaging and look for reusable or returnable items instead.
- Reducing the use of non-recyclable products and products that are harmful or wasteful.
- Reusing/repurposing items you would typically throw away instead of buying new ones, and repurposing items that cannot be used again for their originally intended purpose by using them for something else (e.g. using an old mason jar for holding pens).
- Rotting (i.e. composting) waste from food such as fruit or vegetables.
- Recycling any items that cannot be reused but whose materials can be recycled (paper, cardboard, plastic, metal, glass).

Rebound effect
An effect where increases in efficiency lead to lower costs of product and services, which in turn leads to increased consumption. Increased consumption (partly) cancels out the energy and resource savings that were initially made by increasing efficiency.

Recycling
Collecting and reprocessing a material (for example from waste) to be used again.

Renewable energy
Energy from a source that is not depleted when used (e.g. wind, geothermal or solar power).

Scope 1/2/3 carbon emissions
A way of categorising different kinds of emissions created by an organisation's activities.

- Scope 1: Direct emissions, or emissions from sources that the organisation owns or controls directly. (For example emissions produced by company vehicles.)
- Scope 2: Indirect emissions, or emissions an organisation causes indirectly when the energy or heat it uses is produced. These emissions are produced by the energy providers, not the organisation itself. However, the organisation can still have an impact on these emissions, for example by choosing a supplier that uses renewable sources of energy.
- Scope 3: Value chain emissions, or emissions that are not produced by the company itself, but that the organisation is indirectly responsible for. (For example, emissions created by

the organisation's suppliers during production, packaging or transport of supplies.) This category includes any emissions that do not fall within scope 1 or 2.

Sustainability
The ability of a system to be maintained at a certain rate or level (e.g. avoiding the depletion of natural resources in order to maintain an ecological balance). Requires a structure where people, planet and profit coexist in harmony without compromising one or the other.

Supply chain
The entire process of producing and delivering a product or service. (for example from acquiring the needed materials, through to when the end user consumes the product, including all the steps that happen in between, such as transport, production, packaging etc.)

Wet lab research
A type of research that takes place predominantly in the laboratory with minimal, if any, contact with patients.

Whole-life-cycle assessment
A systematic analysis of the potential environmental impacts of products or services during their entire lifetime, including production, distribution, use and end-of-life phases, as well as the upstream (e.g., suppliers) and downstream (e.g., waste management) processes associated with each step.

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