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SPECIAL ISSUE ARTICLE

Climate action for health: Inter-regional engagement to share knowledge to guide mitigation and adaptation actions

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Abstract

Climate change, attributable to human activity, is increasingly contributing to a global health crisis. The scale, nature and timing of adverse effects on physical and mental health, via direct and indirect pathways, vary within and between regions but there are common challenges that can be tackled by better integrated mitigation and adaptation actions. The actions described in this paper would have benefits for health if appropriately implemented, both by reducing the health risks of climate change and from the ancillary (co-)benefits of mitigation such as from reduced air pollution as a result of phasing out fossil fuels. There are unprecedented health threats from climate change but also unprecedented opportunities to use scientific knowledge to inform policy and practice. Much can be done now to use the evidence already available to effect rapid and decisive action as well as generating new evidence to support effective policy development and implementation. This paper draws on an inter-regional, inclusive, project by the InterAcademy Partnership, the global network of more than 140 academies of science, engineering and medicine, to summarise evidence available worldwide in order to help inform options for policy making. A particular focus is on clarifying climate change mitigation and adaptation solutions and their implementation for the benefit of the most vulnerable groups. The present authors actively participated in managing this project which encouraged academies to capture diverse impacts and policy options by evaluating and synthesising evidence from their own countries to inform policy for collective and customised action at national, regional and global levels. Using a systems-based approach, recommendations from the project in this publication are transdisciplinary and multisectoral. Despite the accumulating evidence, protecting and improving human health have not yet become major focal points in global climate change policy discussions. Drawing on the IAP project outputs, we strongly recommend that health and health equity must now come to the foreground, accompanied by much greater allocation of climate finance to health-related programmes.

1 | SUSTAINABLE DEVELOPMENT, CLIMATE CHANGE AND HEALTH

The pace and extent of recent environmental changes pose serious challenges to global health gains made over recent decades. Many natural systems are being degraded at unprecedented rates (Whitmee et al., 2015) and there is considerable concern that the health of future as well as current generations is being put at risk to realise economic and development gains in the present. Moreover, as to be discussed subsequently in this paper and in the other contributors to the Global Policy special collection on "Challenges to a Sustainable Recovery", gains, for example in health and economic status, in high income countries have been made at the expense of the rest of the world, including through inequities in climate change impacts on health. Climate change is a global health crisis as well as an environmental and financial crisis (Willetts et al., 2022). Among the environmental challenges, climate change is arguably the greatest health threat (see WHO, 2021a and https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health) that defines the Anthropocene Epoch and it is already markedly affecting human health and health systems (Haines & Ebi, 2019; Vicedo-Cabrera et al., 2021). Tackling this threat and promoting health, health equity and sustainability demands fundamentally different modes of thought, institutions, technologies, policies, values and governance systems to those that are currently dominant (discussed in detail by Haines & Frumkin, 2021).

The scale, nature and timescale of the problems associated with the effects of climate change on health differ between countries and within their populations, influenced by geography and socio-economic status and often rooted in social inequities, exclusion and colonialism. However, there are commonalities, as will be described in this paper, which draws on recent work by the InterAcademy Partnership (IAP), the global network of more than 140 academies of science, engineering and medicine. This paper's authors actively participated in the regional and global assessments including development of recommendations. The inclusive purpose of the IAP project was to bring together the diverse evidence already available on the adverse effects of climate change on human health and the potential for science-based mitigation and adaptation solutions, and to clarify knowledge gaps that can be filled by new research, in order to inform development of public policy at national, regional and global levels. The following sections which include some key references (a much larger literature base is discussed in the project reports) discuss principles underlying the goal of this novel IAP project which is to add value to what has already been done by other international scientific groups (Section 2); describe the project design in detail

Policy recommendations

Our policy recommendations are selected from the IAP project reports to focus on themes of policy relevance covered in the present paper:

- Integration of health priorities is highly relevant for climate policy formulation and implementation in many sectors, such as agriculture/food/land use, energy, transport and urban planning, housing and for governance across local, national, regional and global levels.
- A focus on health helps strategic coordination between Nationally Determined Contributions under the Paris Agreement, National Adaptation Plans, air quality legislation, Sustainable Development Goals and other initiatives, such as for the circular economy and bioeconomy.
- As part of addressing the global climate finance gap, greater ambition in redirecting subsidies and other financial support away from fossil fuels and other polluting activities, to actions that aim to accelerate progress towards net zero GHG emissions, such as those for sustainable cities and food systems, can help to deliver health and equity objectives.
- The COVID-19 pandemic provides important policy lessons for responding to global challenges through cooperation and mobilisation of resources at scale, for recognising the core role of health-in-all-policies, and the need for scientific underpinning of decision-making.
- Post-pandemic fiscal stimulus plans and climate funds provide the opportunity, as yet mainly unrealised, to build in objectives for health, equity and environmental sustainability alongside economic recovery.
- Addressing climate change, together with biodiversity loss and food and nutrition insecurity requires better use of shared evidence between IPCC and IPBES for policy action, and the development of equivalent international scientific advisory capacity for sustainable food systems.
- Health professionals can help to influence climate change policy discussions across all sectors: their credibility is enhanced if the health sector itself acts ambitiously to reduce its own greenhouse gas emissions.

Academies, with their strong convening powers, have a continuing role in evaluation and delivery of evidence at science-policy interfaces, to advocate for the increasing health focus, to support greater national and regional ambitions to tackle climate change, and to amplify the voices of the vulnerable, who have been too often marginalised in policy debates.

together with its outputs (Section 3), summarising findings on pathways of health risks and the headline messages to policy makers; emphasising the importance of better planning and integration of science-based adaptation and mitigation solutions (Section 4); and the quantification and implementation of specific actions in different contexts (Section 5). In later sections we also address challenges arising from the intersection of concomitant health crises (in particular the COVID-19 pandemic, Section 6), the multiple related issues for sustainability and SDGs (Section 7); and for the horizontal connectivity of health actions across sectors (Section 8) and vertical policy connectivity between different levels of governance (Section 9); concluding with discussion of some of the priorities for new research and for the continuing roles of academies (Section 10). In the broader context of these later sections, climate change health issues are highly relevant to other priorities explored in the Global Policy special collection and we discuss the relevance to pandemic responses, a green recovery from COVID-19, other dimensions of "green deals" and the value of ecosystem services.

The considerable climate challenges to health necessitate that actions taken to identify and quantify solutions focus on the most vulnerable groups, capitalise on the health and other (co-)benefits of climate action, help to ensure development of resilient and equitable health systems, as well as address current fragmentation and imbalances in research systems and knowledge use. Substantial worsening of health and equity can be expected if no additional actions are taken (Haines & Ebi, 2019; IPCC, 2022; Romanello et al., 2021).

Despite the accumulating evidence, protecting human health has not yet become a major focal point in global policy discussions about climate change, although there is more attention now in consequence of the activities of IPCC and the Lancet Countdown on Health and Climate Change (see Section 2) and of the other comprehensive accounts cited (such as Haines & Frumkin, 2021). For example, although the Glasgow Climate Pact following COP26 in 2021 "recognizes the impacts of rising temperatures and extreme weather as social, economic and environmental threats, the lack of mention of the catastrophic effects on human health and wellbeing is a glaring omission" (Anon, 2022a). While the COP27 agreement on "loss and damage" has important health connotations, it is still essential to do more to raise the visibility of health issues in the global policy fora. In this context, it is noteworthy that the reporting of extreme weather events often focuses on costs of damages, mortality and displacement rather than the full picture of health impacts. Yet recent analysis of extreme weather events (Sheehan, 2022) reveals a very large likely burden of morbidity and points to the need for reporting routinely to include affected population estimates and the evolving science for public health framing to support urgency of action.

Furthermore, global drivers of environmental change elicit health effects that, for effective policy implementation, have to be considered together with the direct and indirect effects of climate change itself. In particular, air pollutants that are co-emitted with greenhouse gases (GHGs) from fossil fuel combustion, a principal driver of climate change, have major negative effects on human health, in particular on cardiovascular and respiratory diseases.

2 | IDENTIFYING A DISTINCTIVE APPROACH TO ASSESSING AND USING SCIENTIFIC EVIDENCE TO INFORM POLICY AND PRACTICE

Academies of science and medicine have a considerable history of interest in climate change and health topics. The present paper brings together regional assessments and global synthesis of climate change effects on health, with a focus on solutions for mitigation, adaptation and cooperation. The IAP work recognises that many of these issues are already being extensively evaluated by international bodies such as IPCC, WHO and the Lancet Countdown initiative. However, the, authors, concur with the expectation (Anon, 2022b) that "the research community's work stretches far beyond IPCC" for example in generating the science for attribution of impacts and for supporting, monitoring and evaluating policy to deliver solutions. One of the problems, hitherto, in generating and using scientific evidence has been the limited research conducted in, and by, low- and middle-income countries (LMICs; Berrang-Ford, Sietsma, et al., 2021) and in those regions experiencing disproportionate levels of warming (such as the Arctic and Mediterranean regions). There has been a lack of inclusivity both in designing contextually appropriate research and in using research outputs to inform policy and practice (for example, integrating new knowledge of environmental impacts of health care into clinical guidelines; Herrmann et al., 2022). The resultant problems for the users of evidence are compounded by a relative lack of data for assessing the costs and benefits of action, synergies and trade-offs. However, progress is being made in the science of attribution and, for example, more than one-third of warm season heat-related deaths (during the period 1991–2018) can now be attributed to anthropogenic climate change, with the effects observed on every continent although data from Africa and South Asia are scarce (Vicedo-Cabrera et al., 2021).

A core part of the IAP work has been the encouragement of science academies to summarise evidence of climate-health linkages for their own countries and regions to drive the focus on collective and customised solutions and to explore policy options. As the global network of academies, IAP harnesses the expertise

of leading scientists (more than 30,000 scientists, engineers and health professionals) with strategic objectives to advance sound policies, improve public health, promote excellence in science education, and support other Sustainable Development Goals, alongside helping to build capacity in advisory roles by less-experienced academies.

In taking an evidence-based perspective to tackle the priorities for health, health equity and climate justice, IAP seeks to identify where there is consensus but also underlines where evidence gaps need to be filled and where issues are still controversial. The legitimacy of IAP's work to add value to global deliberations depends on the scientific excellence of its academies and the transparency, objectivity and independence of its actions. This IAP work comes at a time when concern had been expressed that other bodies (such as IPCC, dependent on government approval processes; for example, De Pryck, 2021) have lacked sufficient legitimacy and have weakened their contribution by seeking to minimise controversy in their outputs. Notwithstanding such concerns, IPCC has contributed considerably to the understanding of climate change (for example, 2021, 2022) and, more generally, in providing research evidence that can be used in making decisions. Nonetheless, in responding to increasing challenges from climate change and other societal challenges there is need for a "renewed focus on the best evidence" (Global Commission on Evidence to Address Societal Challenges, 2022).

Academies are well-placed not only to use transdisciplinary scientific inputs for comprehensive assessment, but also then to contribute the evidence at science-policy interfaces to inform decision making. Effective responses to climate change require a systems-based approach (Pongsiri et al., 2017) to understand how human health outcomes emerge from complex interactions between natural and social systems. Translating this understanding into action depends on development of coherent and coordinated policy across all sectors (horizontal integration) and between local, national, regional and global levels of governance (vertical integration) to ensure "health-in-all-policies". The design of the IAP project provides a means to capture the diversity of evidence, attitudes and values: another challenge that may have limited the usefulness of earlier evaluations (Minx et al., 2017). While it can be challenging to capture the multiple diverse perspectives within and between countries, this becomes an important resource for identifying the common elements for developing robust solutions.

3 | FRAMING THE SCOPE AND CONDUCT OF THE IAP PROJECT TO IDENTIFY POLICY PRIORITIES

The project involved four regional academy network working groups, who have now all published regional reports: in Africa (NASAC, 2022), Asia (AASSA, 2021), the Americas (IANAS, 2022) and Europe (EASAC, 2019). Each regional working group comprised expertise primarily from health, biological, and social sciences and each had an ambitious mandate to analyse evidence on current circumstances and future prospects, clarify uncertainties and identify knowledge gaps, relating to effects of climate change on health and to the development of solutions and the procedures for their implementation. The "inter-regional" project design was first developed by IAP in a study on food and nutrition security and agriculture, and the value of using such an approach to advise on policy options has been discussed in detail elsewhere (Fears et al., 2020). One advantage of the project design resides in its heterogeneity, utilising diverse experiences, expertises and expectations across the regions while, at the same time, conforming to shared academy standards of clear linkage to robust evidence from multiple disciplines. The project strengths of co-design and consistency in quality assurance procedures coupled with the convening power of academies to facilitate transboundary discussion, provides a significant input to effect early and sustained contact with policy makers and other stakeholders.

Each regional report proffered advice on policy options for protecting and promoting human health in responding to and preparing for climate change, customised according to local contexts and strategic needs. The four regional reports are now being used as a resource for engaging in sustained follow up with policy makers and other stakeholders at national and regional levels. In addition, the reports have been used as part of the inputs to prepare a global synthesis report which examines inter-regional matters, local–global connectivities, and advises on those issues at the science–policy interfaces that should be considered by inter-governmental bodies and other institutions with roles and responsibilities worldwide. A global perspective is important to tackle the provision of global public goods, that is those that must be provided on a scale beyond the capacities of individual countries or regions. These include the reduction of GHGs; development of critical mass in science and technology; and governance of trade and other issues affecting the relationships between countries and regions. Furthermore, the global perspective on governance is warranted because national competition drives the externalisation of costs of climate change on human health and the environment. In addition, it is needed to correct regional imbalances and climate injustice, whereby countries with low greenhouse gas emissions may be affected most severely by the negative health consequences of climate change.

The global report has now been published (IAP, 2022) and an initial description of the project design and the early outputs was made (Fears, Abdullah, et al., 2021) to elicit feedback from the wider scientific community.

The analysis of climate change exposure pathways and the effects, direct and indirect, on health as discussed in the four regional reports and the global report are summarised in Figure 1, adapted from the global report (IAP, 2022).

The global report (IAP, 2022) also describes how these pathways and impacts can be set into the broader context of planetary health, and the DPSEEA (Driving forces-Pressures-States-Exposures-Effects-Actions) framework provides a useful approach to analysing the effects of global environmental change (Frumkin & Haines, 2019). Taking the example of air pollution: the driving force is primarily the demand for energy from fossil fuels and food from currently unsustainable food systems; the pressure is the emission of GHGs and other short-lived climate pollutants; the state is climate change; the exposure includes air pollution as well as changes in temperature, rainfall, extreme events, dietary shifts and other impacts; the health effects will be multiple, physical and mental; and desired

Pathways of risk

Direct	Indirect (ecosystems)	Indirect (societal)
Increasing temperature and frequency of heatwaves Increasing drought Increasing riverine flooding Sea level rise Increasing frequency of intense wildfires Other extreme weather events	Air pollution Allergens Water availability and quality Food and nutrition security Infectious disease threats (host, vector, pathogen)	Migration Damage to infrastructure and health services Economic effects of declining labour productivity and crop yields Conflict

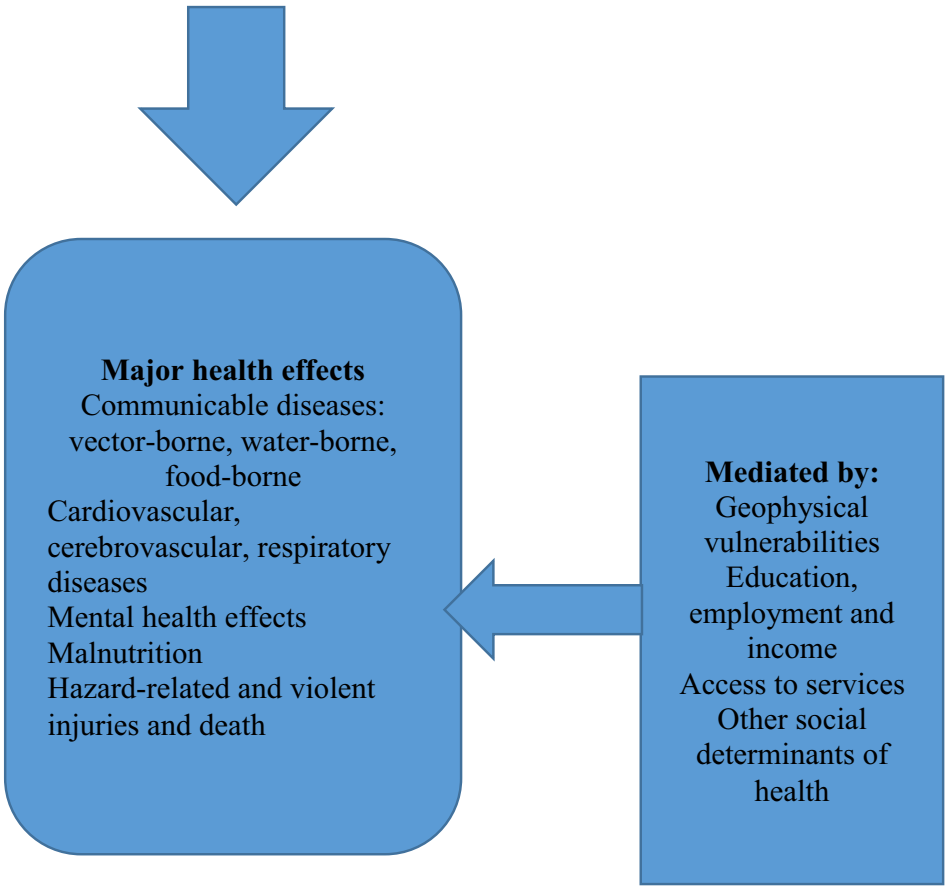

FIGURE 1 Direct and indirect pathways of exposure to climate change and their health consequences. The figure is not intended to be comprehensive but rather to emphasise some key exposures, mediators and effects.

actions include decarbonising the economy, providing clean energy and promoting effective adaptation. The DPSEEA relationships are two-way such that action can in turn reduce the driving forces. Therefore, to be comprehensive, the consideration of climate change health impacts needs to be augmented by accounting for the concomitant health effects of drivers of climate change such as fossil fuel combustion.

The individual reports describe in further detail the challenges for understanding interactions between the multiple pathways of risk (Figure 1), quantifying the compound effects of different hazards and exposures and incorporating the life course perspective for the cumulative risk of climate change on health. The reports agree on the requirement to focus research and action on vulnerable groups at highest risk from climate change, including the elderly, children, women, those with pre-existing medical conditions, outdoor workers, Indigenous Peoples, migrants and other marginalised populations, especially in LMICs. The IAP project literature analysis can be seen as complementary to the Lancet Countdown report (Romanello et al., 2021) which documents through annual assessments, alarming trends in many indicators, including heatwave exposure, reduction in work capacity, increasing exposure to intense wildfires, increased transmission of vector-borne diseases, sea level rise, declining crop yield and quality, and expansion of areas affected by drought. However, there are major geographical and topic gaps in the coverage of data on health impacts and the effects of climate actions on health.

In aggregate, key messages from the IAP project are listed in Box 1. The remainder of this paper discusses some of the policy implications of acting on these messages, citing examples of key systematic reviews and other principal references from primary sources. These and other literature are discussed in detail in the IAP project reports. That is, exemplifying how policy should be informed, integrated and interrogated to find and implement solutions to the societal challenges of climate change effects on health.

4 | NEED FOR BETTER INTEGRATION OF CLIMATE CHANGE MITIGATION AND ADAPTATION POLICIES TO DELIVER HEALTH BENEFITS

The IAP project concluded that both mitigation and adaptation approaches are essential as solutions but observed that they had often been applied in a fragmented way and require to be better integrated to achieve resilient, net zero emission societies. Adaptation becomes more feasible when there is decisive mitigation to reduce the risk of exposure to climate change. There will be limits to adaptation beyond which adverse health effects cannot be prevented, such as when extreme heat exposure exceeds physiological capacity to maintain core body temperature within safe limits. Policy proposals to mitigate climate change provide global health benefits through reduced impacts and can also lead to local improvement in the health of those populations undertaking the mitigation, for example in terms of improved air quality, active transport, and dietary modifications (Milner et al., 2023). Therefore, we emphasise it is vital for decision-makers to consider the potential multiple benefits for health and other outcomes when designing and implementing mitigation actions. Despite this prospective value and even though health co-benefits are now often explicitly considered when developing climate change mitigation policies, for example in the EU, it appears that their influence on final mitigation and adaptation policy outcomes has been limited (at least until relatively recently, Workman et al., 2019). Nonetheless, in the EU region increasing policy interest can be discerned. In the EU's previous Climate Adaptation Strategy (adopted in 2013 and discussed by EASAC, 2019) there was only one mention of health (and that was in the context of future intentions) whereas the most recent (2021) iteration of the Climate Adaptation Strategy mentions human health nearly 20 times.

Parties to the Paris Agreement are required to include a reference to mitigation and adaptation in their Nationally Determined Contributions (NDCs) and an increasing number are incorporating health issues into their NDCs. It has been found that poorer and climate-vulnerable countries, that contribute least to climate change, are more likely to engage with health in their NDCs (Dasandi et al., 2021). However, as discussed in the IAP project reports for countries irrespective of their income status, in many cases, the level of the NDCs' detail on health is rather superficial and not necessarily aligned with achieving emissions reduction commitments, or it may represent inadequate climate ambition (IAP, 2022). Modelling indicates that policies can be more ambitiously designed to capitalise fully on the potential to improve health in the near term and to reduce GHGs across a range of regional and economic contexts (Hamilton et al., 2021).

The adoption of the 2030 Agenda for Sustainable Development (and introduction of Sustainable Development Goals, SDGs) and the Paris Agreement have been followed by many countries developing a National Adaptation Plan (NAP). There are significant opportunities to create linkages between NAPs and NDCs, which can help to support integration of mitigation and adaptation actions, build political accountability and avoid duplication in governance structures. The WHO (2019) report on tracking global progress on health and climate change found that many countries, reporting a national health and climate change strategy, now identify health risks and have begun to implement early warning systems and health sector

BOX 1 IAP messages to policy makers

- Climate change is happening and is attributable to human activity. Climate change poses urgent challenges to development plans, growth and equity, and with risks to the integrity of societies well as to health and the environment.
- Climate change brings serious threats to human physical and mental health and health equity that are already apparent. Climate change is now impacting populations in diverse locations, but certain groups are increasingly vulnerable and experience a disproportionate burden of health effects. Equity is at the core of an effective response; solutions and their costs must be distributed fairly, and barriers to participation by those most affected must be dismantled.
- There is a need for better monitoring and surveillance of potential health impacts due to climate change across all countries, including assessment of the effects of other environmental changes (such as deforestation, pollution, freshwater depletion) that may interact with climate change to influence health.
- Rapid and decisive climate action could greatly reduce the long-term risks to health from climate change and bring near-term benefits for health, including through reduced air pollution. Every increment of heat matters: health risks are substantially lower at 1.5° than 2°C.
- Actions to tackle climate change and health impacts are urgent. In addition to the health, equity and environmental gains, 'net zero-carbon' development options can offer new economic opportunities subject to capacities and governance.
- Many solutions are within reach using present knowledge; mitigation and adaptation experience is growing, but action requires political will and sustained investment.
- The scientific community has important roles in generating new knowledge on effects of climate change on health and on appropriate climate mitigation and adaptation action, in countering misinformation and addressing equity in climate health responses. This requires international partnership and reform of the current geographical and other biases in designing, conducting and reporting research studies.
- While modelling studies can provide useful insights into the magnitude of benefits from adaptation and mitigation actions there is a pressing need for better evaluation of implemented actions to quantify benefits, trade-offs and costs and to document facilitators and barriers to change.
- Climate change intersects with and exacerbates the impacts of other global challenges including COVID-19. The COVID-19 pandemic provides important lessons about responding to global challenges through cooperation and mobilisation of resources at large scale, for example, international collaboration on research to develop and evaluate solutions.

Source: IAP (2022).

responsiveness to a range of risks, including heatwaves, flooding and poor air quality. However, there is considerable concern about the level of political commitment as well as the human and financial resources available for making these responses. There is also comparatively little multi-sectoral collaboration and the evidence base for supporting effective strategies to protect public health is frequently weak, particularly in LMICs (Scheelbeek et al., 2021). Individual country experience (including the requirement to minimise the risks of maladaptation, Eriksen et al., 2021) is discussed further in the IAP regional reports, and the synthesis report (IAP, 2022) brings together assessments in the context of achieving "triple win" objectives for health, equity and environmental sustainability.

One of the challenges for the better integration of mitigation and adaptation interventions is the lack of agreed metrics for measuring impact. Unlike mitigation, where the effectiveness of policy action might be measured in terms of GHG emissions reduced, no such consensus exists for the assessment of adaptation effectiveness; there are differing views on what adaptation success entails, its timescale, and who should define it (Dilling et al., 2019; Whitmee et al., 2021). At minimum, it is important for a commitment to some measurement and quantification to be made at the onset of an intervention and for desired adaptation endpoints to be evidence-based, but this is often not the case (Berrang-Ford, Siders, et al., 2021; Scheelbeek et al., 2021).

5 | ACTING ON THE EVIDENCE

5.1 | Mitigation

In the past, mitigation solutions focused on GHG reduction potentials, not usually taking into account direct effects on human health and well-being. But recent

systematic assessment shows that demand-side solutions (including those arising from individual choice and from community-level plans) to climate change mitigation are consistent with high levels of well-being (discussed in detail by Creutzig et al., 2022). All of the IAP project reports emphasise the importance of taking account of the health implications of policy in other sectors. In high- and middle-income countries, fossil fuel combustion in the energy, transport and manufacturing industry sectors is responsible for both a large proportion of GHGs and pollutants such as particulates that damage health. Domestic burning of solid fuels (mainly biomass) accounts for about 20% of the total excess mortality burden from ambient fine particulate ($PM_{2.5}$) air pollution worldwide. The contribution is higher in low-income countries than in high- and middle-income countries (Chowdhury et al., 2022). There is an additional burden of about 2.3 m annual household air pollution deaths from burning solid fuels and kerosene indoors (Fuller et al., 2022), There is evidence that some constituents of $PM_{2.5}$ such as black carbon may be more toxic than other constituents. Under the assumption of higher toxicity, domestic sources become a larger contributor to mortality.

While there is uncertainty about estimated magnitudes according to the assumptions made and differing methods of calculation, and it is noteworthy that recent evidence suggests harm at even lower concentrations of particulates than previously documented (McDuffie et al., 2021; Vohra et al., 2021), all researchers agree that it is a major health burden. One estimate from modelling (Lelieveld et al., 2019, discussed in EASAC, 2019) indicates that a phase out of fossil fuels could avoid an excess global mortality of about 3.6 million deaths/year at 2015 population levels from ambient air pollution. The global annual benefit could be up to 5.6 million fewer premature deaths from ambient air pollution if, additionally, emissions from non-fossil fuel anthropogenic sources, particularly from agriculture and household sources of ambient air pollution were controlled. In countries such as India, replacement of solid fuels with LPG reduced pressures on forests and achieved modest climate benefits in addition to reduced household air pollution, even though LPG is a fossil fuel (Singh et al., 2017). Additional benefits would accrue by making affordable electricity from renewable sources widely available for domestic use.

The recent, more ambitious Air Quality Guidelines published by WHO (2021b) provide an impetus for policy makers worldwide to revise their air quality legislation to drive air pollution levels downwards. Even at low pollution levels, below the current European and North American standards, air pollution is associated with increased mortality (Strak et al., 2021). For example, a "quasi-experimental" study design using census data in Canada to evaluate changes in exposure to ambient $PM_{2.5}$ after relocation and the consequences for long-term survival (Chen et al., 2021), demonstrated that moving from high to low $PM_{2.5}$ areas was associated with a total mortality reduction of about 13%. Increases in mortality of similar magnitude were observed for the cohort that move from low to high areas. Although assessment of potential confounding influences may require further consideration, this study adds to the overwhelming evidence for $PM_{2.5}$ mortality even in countries such as Canada where levels are considered low by global standards.

If they are to be fully effective policies aimed at replacing fossil fuels with renewable energy sources or sequestering CO_2 need to take account of health impacts because there may be inadvertent adverse consequences (Wang et al., 2020), for example, when domestic wood burning has been encouraged. Life cycle assessment can be used to understand and prevent possible adverse impacts and avoid "lock-in" consequences when investing in large-scale energy infrastructure (IAP, 2022). While the cost of renewable energy has fallen rapidly, in many countries retention of direct fossil fuel subsidies results in unfair competition with renewable energy sources (Guerriero et al., 2020), compounded by the implicit subsidies arising because of the failure to account for externalities in the pricing of fuel (Parry et al., 2021). The project global report (IAP, 2022) highlights the important policy objective to eliminate these direct and indirect subsidies and use the savings to finance health care and other social priorities (Gupta et al., 2015) particularly in those countries where there is no universal health coverage scheme (Cuevas & Haines, 2016). Modelling of policy options (Buchs et al., 2021) underlines the importance of taking environmental and energy poverty impacts of compensations for unfair distributional impact of climate policies into account at the design stage. Such compensation measures can achieve emission reductions and decrease energy poverty if they involve an expansion of the provision of green goods and services and equitable access to these goods and services (Buchs et al., 2021). Issues for social justice and reform of financial instruments are discussed further in Section 9.3.

All of the IAP regional reports provide examples of science-based strategies for sustainable cities. However, mapping of research on urban case studies reveals that cities with highest mitigation relevance to achieve GHG reductions and health benefits are systematically underrepresented (Lamb et al., 2019) as are low-income and ethnic minority communities who may have highest urban exposure to heat and other hazards. Increasing the pace and scale of urban transformation requires evidence-based changes in political, social and economic systems (Crane et al., 2021), particularly as historical housing policies may be directly responsible for disproportionate exposure to heat events and other hazards as seen in "redlined"

neighbourhoods in US cities, (Hoffman et al., 2020; Witze, 2021). Mitigation choices for sustainable cities would have multiple physical and mental health benefits, if appropriately implemented. For example, through the introduction of active transport options (studies in Latin America, de Sá et al., 2017 and in New Zealand, Mizdrak et al., 2019), or remodelling and expansion of green spaces (in Spain, Mueller et al., 2020), where the cooling of the urban environment can modestly reduce energy requirements.

Recent modelling (Reis et al., 2022), to internalise global health-economic impacts of air pollution into climate policy, emphasises the importance of implementing both climate change and air pollution policies together. Accounting for air pollution impacts reduces climate mitigation costs and inequality and increases global and regional welfare benefits (with China benefiting most from avoided mortality and Eastern Europe, including Russia, gaining greatest welfare benefit).

5.2 | Adaptation

Evidence is reviewed in the IAP regional and global reports to show that adaptation encompasses technological, behavioural, institutional, economic and societal approaches. Again, there is sufficient evidence indicating the need to act now (see Table 1 and comprehensive discussion of case studies in WHO, 2021a, 2021b), although evidence gaps, particularly in the effectiveness of implementation strategies, remain to be filled by new research (Whitmee et al., 2021). The current evidence base for prospectively designed quantification of interventions, that is the planned measurement of impacts as an endpoint in the research, in LMICs is particularly limited (Scheelbeek et al., 2021), as is the understanding of the limits to adaptation (Ebi et al., 2021). Analogous to mitigation action, it is also important to consider intersectoral issues in climate change adaptation (Buse et al., 2022), and to use integrated modelling tools in support of planning and action across sectors (such as for the food-energy-water nexus, Miralles-Wilhelm, 2016).

Issues for sustainable food systems will be discussed in more detail in Section 7.2 due to their prominent role in recent global policy development (such as the UN Food Systems Summit) and because they exemplify the prerequisite for a supportive regulatory framework that allows scientific advances to be translated into innovation.

Many current adaptation actions require scaling up and this has implications for the provision of public subsidies and building standards, such as for new building construction and renovation. It is critically important to be aware of the negative consequences of widely used approaches, such as air conditioning (Lundgren-Kownacki et al., 2018) that increase demands for energy and can increase inequities. There are other trade-offs to be considered, for example increasing biodiversity in sustainable cities might increase risk of exposure to disease vectors and pathogens (Lohmus & Balbus, 2015) and allergens (EASAC, 2019). Analogous to the objectives for mitigation, adaptation priorities can usefully focus on the "triple win", attaining health, equity and environmental sustainability (Bell et al., 2019; Guerriero et al., 2020). To be successful, the various

TABLE 1 Health adaptation solutions worldwide.

Hazard	Approaches to health adaptation
Heat	Heat-health early warning systems and targeting vulnerable groups (such as elderly); innovation for building design, insulation and more sustainable cooling; green space and infrastructure; addressing occupational health issues (such as advice on outdoor working)
Wildfires	Advice to identify, manage and treat health impacts, including targeting information to vulnerable groups (and their involvement in finding and implementing solutions) and recognising cross-border pollution threats; reducing demand for commodities whose production drives wildfire-induced land clearance
Flooding	Mapping areas at risk; improved urban planning and other land use, coastal defences; nature-based solutions (such as wetland and mangrove restoration); behavioural adaptation; linkage with responses within Disaster Risk Reduction Framework
Infectious diseases	Increased surveillance and early warning systems for vector-borne disease; reducing environmental exposure to vectors and pathogens, including modifying human behaviours; improving water, sanitation and food systems; innovation and increased access to diagnostics, therapeutics and vaccines
Food and nutrition insecurity	Promoting healthy, sustainable diets and ensuring that they are available and accessible to vulnerable groups; linking climate services and agricultural production with focus on climate-resilient nutritious crops; conservation of genetic resources, and breeding for improved resistance to environmental stresses and diseases
Forced migration	Better linkage between policies for migration and health, including strengthening host country health systems to be climate-resilient and migrant-inclusive

Note: Specific examples are provided in the four regional and global InterAcademy Partnership reports.

actions listed in Table 1 need to be accompanied by climate-health education, including for health professionals: AASSA (2021) and Bogatov et al. (2021) discuss the particular example of education in environmental medicine in the Russian Federation Far East.

6 | ADDRESSING THE CONCURRENT HEALTH CRISES OF CLIMATE CHANGE AND COVID-19

The IAP global and regional reports describe how climate change and COVID-19 are converging crises: both have major public health and economic consequences exerting disproportionate effects on vulnerable groups (Wyns & van Daalen, 2021), and interact in various ways. In some LMICs, for example in Africa (NASAC, 2022), the costs of climate change and the pandemic together are producing unaffordable consequences for their societies, particularly the most vulnerable groups, and will undermine sustainable development programmes and multiple SDGs. Flooding and heatwaves have impaired the public health response to COVID-19 (for example in India, Golechha & Panigrahy, 2020) and other climate change impacts, such as on forced migration, compound the global risks of COVID-19 (Phillips et al., 2020). The impact of COVID-19 on food systems has worsened nutritional vulnerabilities in low-income groups (in Africa, Ali et al., 2020) and climate change exacerbates other underlying factors associated with structural inequities and COVID-19 (for example among Indigenous Peoples in the Peruvian Amazon, IANAS, 2022).

Furthermore, as the risk of death due to COVID-19 is increased by pre-existing cardiovascular and pulmonary disease it may be higher following exposure to air pollution (Bourdrel et al., 2021; Pozzer et al., 2020). While this relationship may be difficult to quantify because of confounding factors and short time-series research studies, a recent cohort study (Kogevinas et al., 2021) confirmed an association between air pollution, COVID-19 disease and the magnitude of the antibody response among seropositive participants. The impact of air pollution on COVID-19 can also be expected to incur additional social costs, estimated in one study in the Netherlands to be up to 1.5% of GDP (Juijn et al., 2022).

Can lessons learnt from the response to COVID-19 be applied to tackling climate change by updating NDCs and NAPs, and in regional, inter-regional and global initiatives? We now highlight several recent issues. In informing and improving the health response to both pandemics and climate change there is need for better coordination and monitoring worldwide linking health and environmental monitoring and these improvements could be driven by initiatives such as the Planetary Health Watch (Belesova, Haines, et al., 2020). Among lessons that can be transposed from COVID-19 responses to acting on climate change (see detailed discussion in Chan, Gobat, et al., 2021; Marmot et al., 2021; Wyns & van Daalen, 2021 and the synthesis in IAP, 2022) are: adhering to the best available science; reinforcing global solidarity and building collective resilience; integrating action for health in multi-sectoral development policies; contributing long-term support for health systems in LMICs; international crisis coordination as part of providing and protecting public goods; tackling disinformation; building back fairer systems to achieve health equity; and promoting citizen engagement as part of the objective to create and use evidence-based systems that are inclusive.

One policy priority, also addressed elsewhere by contributors to the Global Policy special collection, is to progress coordinated action for sustainable recovery after the pandemic (Belesova, Heymann, & Haines, 2020). That is, systems-based recovery policies must embed the objective to reduce anthropogenic climate change-induced health problems alongside the objectives for ecosystem restoration, equity and inter-generational justice as part of economic rescue and stimulus packages (Fears, Gillett, et al., 2021). AASSA (2021) discussed some of the barriers facing national attempts at sustainable post-pandemic recovery exemplified by India's investment in technology and self-sufficiency (alongside reduction in government bureaucracy, Singh, 2022), and China, which faced a difficult choice in deciding whether to maintain its pandemic-induced reduction in fossil fuel consumption. Many countries have indicated their desire to steer at least some of their post-pandemic stimulus spending to green ends but so far (UNEP, 2021) the post COVID-19 opportunity for a low-carbon transformation has been mostly missed, because economic stimulus package actions are reneging on emissions pledges (Nahm et al., 2022).

7 | CLIMATE CHANGE, BIODIVERSITY, SUSTAINABLE FOOD SYSTEMS AND SDGS

7.1 | Biodiversity intersections

The climate change crisis is also a biodiversity crisis: both are caused predominantly by human activities with consequences for human health as well as ecosystem functions. The climate change and biodiversity crises also influence each other. Rising temperatures, changing precipitation and extreme weather events affect biodiversity in terrestrial, freshwater and marine environments, whereas biodiversity secures climate-regulating functions, and ecosystems are major reservoirs of carbon. Promoting biodiversity and the ecosystem functions associated with it can support

climate action in various ways, particularly through well-designed nature-based and community-based solutions. These often encompass both mitigation and adaptation actions with potential, not yet always quantified, benefits for human health (Griscom et al., 2017). The regional IAP reports discuss specific examples, such as for flood protection and forest conservation (community forests in Nepal may aid both mitigation and adaptation, Pandey et al., 2016). Our emphasis is on "well-designed" solutions. Otherwise, climate mitigation expectations might unhelpfully encourage land use with low biodiversity value, such as afforestation with non-native monoculture or widespread planting of unsuitable bioenergy crops (with potential negative consequences for food and nutrition security). Particular concerns have been raised about plans for afforestation of traditional grasslands and savannas in Africa (Bond et al., 2019), because these biomes already conserve substantial carbon, absorb less solar radiation than forests, and represent major areas of biodiversity. Therefore, externally funded initiatives to replace traditional African and other landscapes with plantations need careful consideration which heeds local voices in mitigation and adaptation decisions. Moreover, Indigenous Peoples are often the guardians of the most biodiverse areas (see IANAS, 2022 for the Americas and Fa et al., 2020 for analysis worldwide) and may have concerns about the imposition of nature-based solutions that undermine their customary rights (Reyes-García et al., 2022).

Valuing the natural world and protecting ecosystems are part of the themes covered in detail by other contributors to the special collection of Global Policy. Specific initiatives continue to be proposed but there is also merit in effecting better coordination of existing policy instruments. The parallel UN developments on biodiversity (Convention on Biological Diversity) and climate change (Framework Convention on Climate Change) provides an opportunity to explore interconnectedness and interdependence of the shared evidence base (Pörtner et al., 2021). A case can be made for closer coordination between IPCC and IPBES in using shared evidence to inform policy (IAP, 2022). It may also be desirable to proceed further and promote convergence between policy action for climate change and biodiversity with action for sustainable food systems.

7.2 | Food systems

Food systems are very sensitive to the effects of climate change and IAP project reports emphasise that the global burden of non-communicable diseases is projected to worsen in consequence. The most recent modelling data (Jägermeyr et al., 2021) forecast earlier impacts of climate change on crop yield than had been assumed hitherto. At the same time, food systems contribute substantially to GHG emissions, the pollution and degradation of natural resources and the loss of biodiversity (Fanzo et al., 2018; Rockström et al., 2020; Whitmee et al., 2015). Agriculture and associated land conversion accounts for approximately 30% of GHG emissions worldwide (Crippa et al., 2021). IAP work highlights that the policy objective is to reduce malnutrition in all its forms while reducing the contribution that food systems make to climate change (Aleksandrowicz et al., 2016). There is potential for improving agronomic practices, and one example described by AASSA (see AASSA, 2021 for detail) is avoiding burning of crop stubble in India, which will lead to improvements in soil health alongside reductions in GHGs and air pollution (Abdurrahman et al., 2020). There are also opportunities to decouple increases in livestock and crop production from GHG emissions by breeding improved strains of animals and plants and other agronomic innovation (Mottet et al., 2017; Tongwane & Moeletsi, 2018). However, improved agronomic practices alone will not suffice; concomitant actions to reduce waste, and increase consumption of sustainable diets (Willett et al., 2019) will have benefits for health, if appropriately implemented. There should be a particular focus on policies – where culturally appropriate, relevant and sustainable – to increase the consumption of vegetables, legumes, fruit, nuts and seeds, including by improving affordability. This will require considerable policy support because climate change will impact the yields of these food groups (Alae-Carew et al., 2020; Scheelbeek et al., 2018).

However, we also emphasise that it is imperative to avoid climate change policy interventions that risk increasing food and nutrition insecurity in vulnerable populations (Canales Holzeis et al., 2019). Unfortunately, in proposing recommendations for policy solutions, issues for the accessibility and affordability of the proposed healthy and sustainable diets are often overlooked (Hirvonen et al., 2020). Actions to transform food systems under climate change have multiple sectoral implications, policy objectives and interlinkages (Table 1 and Canales & Fears, 2021). Government policies can promote the rebalancing of consumption by introducing various measures, including dietary guidelines, food labelling (for environmental sustainability as well as nutritional content, Brown et al., 2020), and incentives/disincentives (pricing and taxation) to promote consumption of healthy, sustainable dietary choices, while protecting vulnerable groups. Changing consumer behaviour requires changes to infrastructure and pricing systems that currently encourage unhealthy, unsustainable eating habits (Marteau et al., 2021).

Several of the IAP regional reports noted that the opportunity to help adapt agriculture to the adverse consequences of climate change requires not only excellent science but also a flexible and proportionate

regulatory system that encourages innovation for climate resilience. The advent of genome editing techniques facilitates the improved breeding of crops with traits for resistance to biotic and abiotic stress, improved nutrient composition and improved use of soil nutrients (Canales & Fears, 2021). However, current regulation of genome editing is still fragmented and inconsistent worldwide and the resultant incoherence deters innovation and competitiveness, creates non-tariff barriers to trade and undermines collective action to deliver sustainable food and nutrition systems. International regulatory institutions have largely failed to adapt to fundamental advances in biotechnology regulation (Rabitz, 2019) and, in the interests of global governance, it is crucial to understand the conditions under which these international institutions do, or do not, adapt. This understanding may also need to be accompanied by scaling-up and rationalisation of scientific assessment processes, for example at the regional level, to facilitate adoption of innovation and avoid regulatory overreach while reconciling the principle of fair and equitable benefit sharing (Rabitz, 2019). The announcement of a change on UK policy for plant genome editing (DEFRA 20 January 2022) may, in due course, furnish a case study on institutional change (and on the relationship between national and regional policy formulation). It is noteworthy that DEFRA cited the potential value of edited climate-resilient wheat (variation of ZIP4 gene which maintains fertility in different temperatures) as one reason for the policy reform.

The particular case of genome editing discussed in the IAP project reports exemplifies one potential value among others, that may be derived from implementing a global, science-based intergovernmental advisory panel for food systems (von Braun et al., 2021, discussing outputs from the UN Food Systems Summit), equivalent to those for biodiversity (IPBES) and climate change (IPCC). In turn, this additional advisory function would help to drive the necessary convergence between policy initiatives for sustainable food systems, biodiversity and climate change. In past decades, there has been a surge of international agendas to address global challenges and a focus on human health helps to catalyse the strengthening and linkage of these agendas (Bowen et al., 2021).

7.3 | SDGs

Climate change threatens progress on all SDGs (Fuso Nerini et al., 2019) and will have even greater impact on the achievement of sustainable development in the decades beyond 2030 (EASAC, 2019). Well-designed mitigation and adaptation strategies can support progress towards multiple SDGs whereas poorly designed interventions may have adverse effects (Honegger et al., 2021). A comparative study of the SDGs and NDCs (Cohen et al., 2021) underscores the relevance of employing the mitigation co-benefits principle in assessing SDG benefits and trade-offs. For example, strategies to mitigate emissions of short-lived climate pollutants including by the promotion of healthier and low GHG diets can advance multiple SDGs (Haines et al., 2017). At the same time, in addressing SDGs, there is an opportunity for others in civil society (public and private sectors) to fill the ambition gap on climate action left by insufficient state commitment in formulating and implementing NDCs and NAPs (Chan, Boran, et al., 2021).

8 | ROLE OF HEALTH SECTOR IN LEADING CLIMATE CHANGE POLICY DEVELOPMENT

Drawing on the conclusions from the IAP project, we suggest that health professionals have an obligation to engage actively in tackling climate change, for three main reasons:

- Framing climate change as a health crisis is a valuable means to attract public interest and motivate change (Bothner et al., 2019). A recent European Citizens' Panel initiative (https://ec.europa.eu/commission/presscorner/detail/en/IP_22_285) highlighted climate change and health, with public interest expressed on issues for food systems, active transport, greener cities, improving education, redirecting agricultural subsidies, nature-based solutions, and the circular economy.
- Health professionals are trusted when they sound the alarm and, in their community-based commitments, they can be champions of action by advising on risks, how to support sustainable, healthy lifestyles and how to elicit transformation in other sectors (Luong et al., 2021; Xie et al., 2018).
- With its objective to do no harm, the health sector must hold itself accountable for its carbon footprint. Until recently, this has rarely been included in public policy mitigation discussions yet the sector's current carbon footprint is about 5% of national net emissions (EASAC and FEAM, 2021; Lenzen et al., 2020; Romanello et al., 2021; Salas et al., 2020).

Mitigating the sector's GHG emissions requires interventions both to the health care system and to the factors driving demand for health care, that is adopting strategies to reduce the incidence and severity of disease, thereby decreasing the amount and intensity of care required (MacNeill et al., 2021). There is increasing momentum within the health care and social care sectors for hospitals and other infrastructure to measure their carbon footprint and implement

plans for reducing it to net zero as soon as possible (EASAC and FEAM, 2021; Romanello et al., 2021); NHS England has helped to pioneer these ambitions (Tennison et al., 2021). Other country initiatives, including Argentina, Indonesia, Romania and USA, are discussed by IAP (2022) and, following COP26, an increasing number of countries ($n = 62$ currently) are supporting an alliance coordinated by WHO on climate resilient net zero health systems (Alliance for Transformative Action on Climate and Health, https://www.who.int/initiatives/alliance-for-transformative-action-on-climate-and-health). However, the meaning of "resilient" in this context requires further clarification and a smaller number of countries has agreed to a deadline by which to achieve decarbonisation. Prioritising mitigation within the health sector will also bring local and near-term benefits to health, for example through greener hospitals (Corvalan et al., 2020), improved diets (Guillaumie et al., 2020) and in new models of care (Ebi et al., 2018). Evaluation of the carbon footprint of primary care practices demonstrates considerable variation in CO_2 eq emissions (life-cycle analysis in Switzerland, Nicolet et al., 2022) and it was concluded that optimising structural and organisational aspects of practice work could have major impact on the carbon footprint.

However, although the health care sector can do much for itself in terms of transformational decarbonisation actions (within facilities and supply chains), even more could be done with a supportive public policy environment. For example, in the EU (EASAC and FEAM, 2021), health sector decarbonisation can be encouraged by greater regional ambition in health policy governance, by implementing criteria for sustainable public procurement (including pharmaceuticals and catering), by "Green Deal" support for sustainable construction and renovation in the health sector, and by introduction of new models of health care. Digital health may bring substantial opportunities for decarbonisation, including the expansion of telemedicine (AASSA, 2021; Holmner et al., 2014 describes the example of Indonesia), if supported by national and regional digital health strategies in the context of universal health coverage.

9 | PROMOTING INTERACTION BETWEEN LEVELS OF GOVERNANCE

Although there are evidence gaps to be filled through new research, this cannot be used as an excuse to delay acting on the best available evidence. But there are still many other barriers to implementing and integrating solutions for policy and practice (Table 2, and see Buse et al., 2022 for broad discussion of barriers and facilitators of intersectoral action).

9.1 | National

We highlight the importance of determining policy responsibilities for tackling climate change at different levels of governance, integrating between them and between different sectors.

Many policy solutions are advanced at a national level, including mitigation and adaptation in target sectors via NDCs and NAPs (Oktari et al., 2022; Somanathan et al., 2014). National strategies must also be well connected with more local policies (Chan, Boran, et al., 2021) for cities and local authorities and these interconnections could be facilitated by platforms to encourage cooperation with scientists in local decision making (IAP, 2022). Moreover, formalised city networks (such as C40) are transcending municipal collaborations towards more complex networked governance arrangement for deployment of low-carbon technologies and practices that may underpin "new forms of city shaping in an urban age era of rapidly unfolding endangerment" (Davidson et al., 2019). However, there is much more to be done in improving coordination of isolated bottom-up (local) and top-down (national) solutions. For example, in a sampling of towns in the Eastern region of the Czech Republic, few had formulated climate adaptation strategies and were, therefore, unprepared for future change (Kristofova et al., 2022). When towns had acted, there was little attention given to population health and they did not follow either national or European adaptation strategies.

In addition to national responsibilities, health policy objectives have regional connotations (Figure 2) and regional institutions can consolidate national inputs to UN reporting systems (Schoenefeld et al., 2019).

9.2 | Regional

Regional action is particularly important where there are cross-border health threats, for example arising from air pollution (in the Indian Subcontinent, David & Ravishankara, 2019), infectious diseases (such as malaria and dengue, Colón-González et al., 2021; Sinka et al., 2020) and climate change-forced displacement, (Milán-García et al., 2021), or where there are health challenges arising from use of shared resources such as water and electricity generation and food production (in the Indus Basin, Vinca et al., 2021). Moreover, there may be regional and global spill over effects if national policy action leads to adverse consequences elsewhere, inadvertently or not. For example, many nations are currently exporting their lack of environmental sustainability (with displacement of both environmental and social impacts) through international trade (Wiedmann & Lenzen, 2018), importing food or biomass generated unsustainably elsewhere. Competition between food,

TABLE 2 Tackling barriers to implementation of solutions.

Perceived obstacle	Examples (details are in the 4 regional reports)
Lack of resources and their appropriate prioritisation	Lack of financial investment in: infrastructure, resilient and affordable health systems, and implementation of science-based mechanisms for solutions. Less than 0.5% of multilateral climate finance is allocated to health projects (see further discussion in Watkiss & Ebi, 2022)
Insufficient focus on vulnerable groups and their participation in planning and policy implementation to effect change	Indigenous Peoples, elderly, children, women and those regions/occupations where there is increased exposure to climate hazards
Limited access to data	Particularly in LMICs for monitoring and surveillance and for evaluation of efficacy of solutions. Access to data is expensive for researchers outside of government and there may be only limited opportunities for collaboration to generate data
Lock-in to old technologies	In energy, construction, transportation and agriculture sectors. This is an opportunity whereby LMICs can apply innovative technologies to leapfrog previous generation practices that depended on fossil fuels or unsustainable patterns of production and consumption
Lack of public engagement and awareness of hazards	Especially regarding awareness of indirect pathways for health impact. An opportunity for health professionals to lead in advocating transformative change. Stimulating public interest also spurs political interest at national and local government levels
Opposition from vested interests and misinformation	Commercial and political interest groups often oppose rapid phase out of fossil fuels, withdrawal of subsidies and effective carbon pricing (Whitmee et al., 2021). Other obstacles may be imposed, for example in local planning policy

Note: Adapted from IAP (2022).

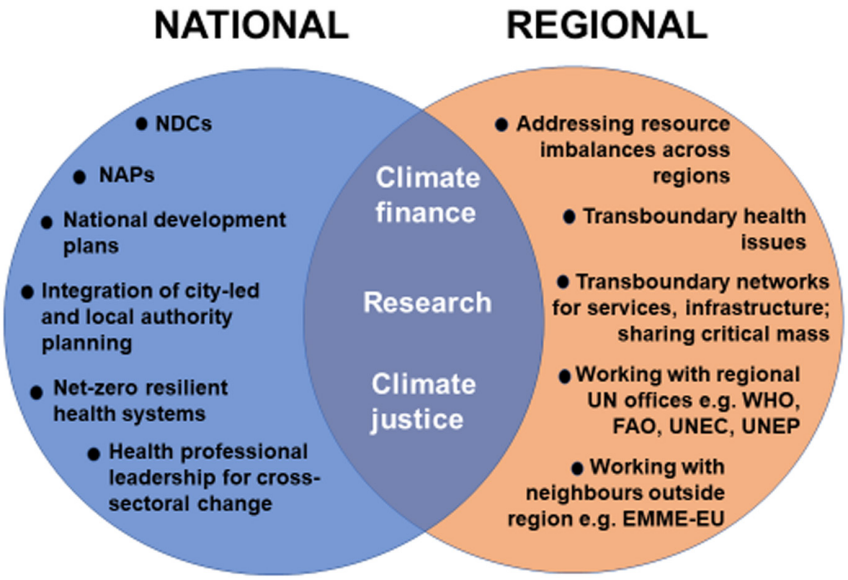

FIGURE 2 Navigating the policy matrix, see IAP (2022) for details. EMME is Eastern Mediterranean-Middle East region (see EASAC et al., 2021).

feed and fuel priorities (Muscat et al., 2020) and the effective use of natural resources demands consideration of multiple factors to understand trade-offs and set priorities (Haines, 2021). Regional collaboration is also important when action can be enhanced by the critical mass of resources afforded by multiple countries working together in a region, and where there are already established networks of trade and fiscal policies (although these may not necessarily compensate for climate change damage, for example to food security, Alvi et al., 2021). Augmented regional cooperation is also pertinent when focusing on climate-health issues within the broader strategic regional policies such as for "Green Deals" in Africa (NASAC, 2022) and Europe (Haines & Scheelbeek, 2020). Momentum at the regional level is particularly relevant for the African continent in view of the disproportionate impact of climate change and the recent emphasis in Africa on research capacity and innovative solutions, alongside other coordinated action on sustainable development, is important (UN Economic Commission for Africa, 2022).

9.3 | Global

There is considerable scope for integrating policy development for shared health goals in climate research, climate action and climate justice at the global level. In addition to UN responsibilities for climate change, biodiversity and sustainable food systems, there is also continuing opportunity for integration with policy options for disaster risk reduction (Sendai Framework, Oktari et al., 2022; Valente et al., 2022). In this case, the desire for coordinated action needs to acknowledge differences in timescale, between the immediate response that may be required in a disaster reduction strategy and longer-term action for resilience in climate-health pathways. Globally coordinated initiatives may also be possible as part of G7 and G20 initiatives and when linked to other strategic initiatives in pursuit of the circular economy (WHO Europe, 2018) and bioeconomy (Haines, 2021) objectives to integrate supply-side and demand-side considerations.

Solutions to tackle the effects of climate change on health can be cost-effective (IAP, 2022) but it is necessary to be much more ambitious globally. Other contributors to this Global Policy special collection and in a rapidly expanding literature, alongside increasing political interest (COP27) focus on some of the particular priorities for fiscal reform. For example, in line with the Paris Agreement rulebook on climate change, to allocate proceeds from the operation of carbon markets and other instruments to internalise external costs, to finance adaptation costs and support action on Loss & Damage (Thomas et al., 2020), as part of the broader efforts for delivering health and social justice (Markkanen & Anger-Kraavi, 2019). Economic reforms arouse opposition from vested interests (Table 2); and including the costs of climate change-related adverse effects on health will increase the social cost of carbon drastically (Bressler, 2021). A structured synthesis comparing policy instruments to advise practitioners on what to select (Penasco et al., 2021) can help to strengthen the bridge between science and policy. Moreover, global climate change litigation has growing momentum to compel governments and companies to pursue more ambitious GHG mitigation and adaptation goals. Research on source attribution – identifying the relative contributions that different economic sectors and activities make to climate change – is an increasingly important part of the scientific evidence in climate lawsuits (Schiermeier, 2021).

There is a considerable global climate finance gap. For example, it has been estimated (Achampong, 2021, drawing on Oil Change International and World Bank assessments), that 70 times more finance has gone to fossil fuels through G20 countries' international public finance institutions in a one-year period (average between 2015 and 2020) than to the UN FCCC Adaptation Fund in its entire 20-year history (up to 2021). Financial reform (Table 2, and see Watkiss & Ebi, 2022 for further discussion of new financial models and approaches) must include removal of subsidies and other public financial aid for fossil fuels and other polluting activities, and harmful agricultural subsidies on intensively produced commodities such as meat, palm oil and sugar, repurposing these latter to support production of fruit and vegetables (Springmann & Freund, 2022). Redirecting harmful subsidies to support universal health coverage, healthy food choices and other societal goals may be key to achieving public and political support (Buchs et al., 2021). Transformative change will require even more radical policy making, for example, by reviving interest in developing and implementing alternatives to GDP as a metric to monitor and support societal well-being (Stiglitz et al., 2009): a recent WHO Brief (WHO, 2022) re-emphasises the importance of revaluing health and well-being as the central measure of success in society and economy. Another transformative approach lies in adopting personal carbon allowances (Nerini et al., 2021) to deliver near-term health and health equity benefits (IAP, 2022) as well as intergenerational fairness.

10 | SCIENCE AS A PUBLIC GOOD TO INFORM POLICY AND PRACTICE

10.1 | What are the challenges for research?

There is sufficient evidence available to act now. But there are also priorities for filling evidence gaps through new research, for example, how to evaluate the health consequences of mitigation and adaptation action. The research enterprise worldwide is currently skewed and there is insufficient involvement of LMICs (Table 2). The IAP project reports describe multiple opportunities for strengthening R&D systems and for education and training worldwide. There are instances of good practice, even in regions beset by political differences. For example, the SESAME project for scientific cooperation in the Middle East, developed by UNESCO, supports research in areas relevant to action on climate change, and its success depends on the willingness by participant countries to exchange data and support shared scientific infrastructure (IAP, 2022).

Data integration is an essential part of evidence synthesis but the traditions for using evidence to inform policy have been different in the health and environmental change communities (as described by Minx et al., 2019). It is now important to bring together the best of both traditions to incorporate transdisciplinary approaches and systematic assessment of the evidence. Among other priorities for R&D systems, addressed in the IAP reports are the needs to:

- Involve stakeholders and rightsholders (including Indigenous Peoples and other vulnerable groups)

in the co-design of research. In addition to IAP project examples, co-design is exemplified in the work of USAID in Mozambique on the association between precipitation and diarrheal disease (Horn et al., 2018). Assessment of the literature on flooding research indicates the scale of the challenge for co-design: current studies are often skewed towards resilient places and people with much less coverage of LMICs, urban areas and mental health issues. This relative neglect should be addressed by researchers engaging with local communities (Hino & Nance, 2021).

- Support qualitative as well as quantitative studies, to understand the lived experience of climate change impacts on health and the context in which adaptation and mitigation efforts unfold.
- Use citizen science and social media in data collection, as long as they are based on rigorous scientific standards or draw on diverse ways of knowing (e.g. Indigenous knowledge systems).
- Link health, environmental and socio-economic data sets to improve monitoring and surveillance activities (Belesova, Haines, et al., 2020; Belesova, Heymann, & Haines, 2020); facilitate attribution of health effects to anthropogenic climate change; improve quantification of solutions (Rocklov et al., 2021); understand which responses are most cost-effective at improving human health and can be scaled up. The need to link population-based mental health outcomes databases to weather data is one high priority (Hwong et al., 2022).
- Employ machine learning techniques in climate change research and the use of research outputs to inform selection and implementation of solutions (Berrang-Ford, Sietsma, et al., 2021; Huntingford et al., 2019).
- Understand how much confidence to place in different types of research evidence when informing judgements on the policy options to address health and health system problems (Lewin et al., 2012).

10.2 | How can academies help in moving from ambition to action?

The strong convening powers of academies, together with their commitment to primary research and evidence synthesis, enable the gathering and analysis of data and information from across disciplines and other knowledge sources, sharing perspectives between sectors and countries and fostering cooperation in setting and monitoring research priorities. Furthermore, academies worldwide are developing considerable experience in bringing together the scientific community and public policy makers to inform knowledge-policy interfaces. And, given the findings that public support for a policy can be increased by communicating evidence for its effectiveness (Reynolds et al., 2020) and that many citizens regard academy outputs as a credible source of information (Hicks et al., 2022), academies and others in the scientific community can develop a useful public role to assess policy impact as well as drive policy formulation.

National policy makers are sometimes hesitant to act if evidence for climate effects on health is not available for their own territory (Chersich & Wright, 2019). Academies can help to assuage this reluctance by showing how the evidence from elsewhere may be relevant in multiple settings. At the national level, academies can also help to advocate for and support an increased focus on health in NDCs and NAPs, coupled with encouraging greater representation of science and health expertise in national negotiating teams.

Policy decisions depend on more than evidence and must also reflect, for example, societal attitudes towards risk and motivation to change (van Valkengoed & Steg, 2019). Because there is considerable variation in attitudes and values within regions, academies and their regional networks can be well placed to help policy makers understand diversity and the barriers and facilitators of change so that policy can be evidence-based and also economically and socially feasible. Moreover, centralised global health initiatives may become detached from the local realities in diverse settings. This problem may be compounded by fragmentation and disconnects between the national and global systems for use of evidence in policy development. Regional cooperation has the potential to act as a bridge and thereby spur necessary action to inform and design global initiatives customised to be relevant to local settings while, at the same time, enhancing regional scientific diplomacy.

The wide geographical coverage of IAP and its regional networks enables representation and amplification of the voices of those – from LMICs and vulnerable populations – who are not always heard during the processes whereby evidence informs international policy. In incorporating these voices, academies can play a critical role among other stakeholders in articulating the need for health equity and climate justice, in holding policy makers to account and raising ambitions: "ensuring diversity and inclusion in the scientific community could reduce the elite image of science and change power dynamics in knowledge-generating pathways" (Anon, 2022b).

We have drawn on the extensive work of the IAP project in concluding that, it is urgent to act on the evidence to promote and integrate adaptation and mitigation solutions to tackle the adverse effects on health, increasingly attributed to specific climate change impacts. And to bring these interventions to scale (Patz & Thomson, 2018). More emphasis is needed on implementation research to document effective scale up, assess trade-offs, barriers and enablers for action in different contexts. Complex system-based approaches

must be transdisciplinary and multi-sectoral and health must come to the foreground in climate change discussions (Buse et al., 2022). Work by academies can augment other international initiatives in articulating the value of action and raising the profile of health issues. Much can be done now: there are unprecedented threats but there are also unprecedented opportunities to use scientific advances to develop and evaluate solutions.

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DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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