Longlist of knowledge gaps in Planetary health

Contents

Introduction

This longlist of knowledge gaps in Planetary health is part of the advisory report of the Royal Netherlands Academy of Arts and Sciences *Planetary health. A new field to be developed*, 2023.

The longlist of knowledge gaps is based on existing research agendas published in 2015 or later and expert input from reviewers of the first draft of the longlist. It only includes knowledge gaps focussing on a better understanding of the relationship between global environmental change and human health, and finding an answer to the question of how best to protect human health against these new threats. The 'upstream drivers' of global environmental change, such as the economic, demographic, social or cultural factors behind climate change or biodiversity loss, were considered to be out of scope. The same applies to the technical methods necessary for mitigation and adaptation strategies, e.g., for cutting greenhouse gas emissions or preventing floods. Such drivers or techniques were only included if there are knowledge gaps related to their impacts on human health.

Knowledge gaps are structured into four areas, 15 subareas, and 40 broader 'research themes'. Each knowledge gap is illustrated by one or two literal quotes from source documents or expert comments. Subarea D2 includes some general recommendations on research practices and the training of scientists which are not strictly speaking knowledge gaps.

AREA A: UNDERSTANDING HUMAN HEALTH IMPACTS OF GLOBAL ENVIRONMENTAL CHANGE

A1. SUBAREA: ASSESSING THE IMPACT OF GLOBAL ENVIRONMENTAL CHANGES ON HUMAN HEALTH

A11. RESEARCH THEME: CLIMATE CHANGE AND HEALTH

KNOWLEDGE GAP A111.

Impacts of climate change on health through extreme weather events

- Integrated research on the effects of extreme weather conditions on health and well-being (HERA)
- Research is needed to further knowledge of extreme weather and climate events on health, including injuries and illnesses, infectious disease emergence and spread, food security, and mental health, and on healthcare institutions, including the costs of impacts (Ebi)

KNOWLEDGE GAP A112.

Impacts of climate change on health through sea-level rise and river flooding

- There are a limited number of precise, quantitative studies of projected impacts of sea level rise at 1.5°C and 2°C, which particularly influence the human health, agriculture and water resources of small island nations (IPCC 1.5)
- Health impacts of flooding, not only coastal related to sea level rise but also inland from rivers and extreme precipitation events (expert input)

KNOWLEDGE GAP A113.

Impacts of climate change on health through working conditions and earning power

- The relative absence of evidence on the effects of [climate change on health through] agricultural shifts and livelihood instability...are also a concern (Berrang-Ford)
- [H]ealth effects of climate change through loss of earning power and workers' health deterioration (expert input)

KNOWLEDGE GAP A114.

Impacts of extreme climate change scenarios on health

- The health effects of climate change tipping points (e.g. sudden collapse of glaciers in Antarctica, slowing or cessation of the warm Gulf Stream in the Atlantic Ocean) (expert input)
- Research and modelling to understand the implications of 'high-end' climate change scenarios and nonlinearities (dangerous and irreversible tipping points), what might be the warning signals and time frames, and the various limits to adaptation (EASAC)

KNOWLEDGE GAP A115.

Impacts of climate change on under-researched health outcomes

- We found major gaps in evidence on climate health research for mental health, undernutrition, and maternal and child health (Berrang-Ford)
- Knowledge gaps on the health and well-being risks in the context of socio-economic and climate change at 1.5°C, especially in key areas such as occupational health (IPCC 1.5)

A12. RESEARCH THEME: BIODIVERSITY LOSS AND HEALTH

KNOWLEDGE GAP A121.

Impacts of biodiversity loss on health (general, explore mechanisms)

- To characterise the causal mechanisms by which (interactions of changes in) natural systems affect health (Lancet)

- Investigate how biodiversity supports the safeguarding of human health directly (through e.g. microbiome and related immunological benefits) and indirectly (through ecosystem services and related safety and security) in various contexts (HERA)

KNOWLEDGE GAP A122.

Impacts of biodiversity loss on ecosystem services essential for human health

- [T]he science linking biodiversity to ecosystem functioning and services must be extended to explore trade-offs between services at multiple temporal and spatial scales so that information can be incorporated into models of optimal land use (Cardinale)

- To assess threshold values for crucial ecosystem services, such as availability and access to food and water (Lancet)

A13. RESEARCH THEME: GLOBAL POLLUTION AND HEALTH

KNOWLEDGE GAP A131.

Impacts of specific aspects of outdoor air pollution on health

- [S]tudies of fine particulate matter in relation to respiratory and cardiovascular disease morbidity and mortality in adults. Recent years have documented in addition health impacts on reproductive health, neurological and psychiatric disease, and systemic impacts affecting children's and adults' health (HERA)

- European data on health effects and impacts of emerging or unregulated air pollutants, including ultrafine particles, air toxins, infectious and non-infectious micro-organisms, biological molecules (endotoxins, mycotoxins, and allergens), are largely missing (HERA)

KNOWLEDGE GAP A132.

Impacts of specific aspects of water pollution on health

- Assess health impact of plastic and specific contaminants in the marine environment and terrestrial water systems entering the food chain and their impact on human health (HERA)

- Assessment of human exposure to chemicals in drinking water, including frequently occurring pollutants and mixtures, also at low concentrations needs to be addressed to better evaluate health risks particularly in the long-term (HERA)

KNOWLEDGE GAP A133.

Impacts of toxic chemicals in globally distributed products, materials, and goods on health

- Assessment of the health impact of specific global pollutants, for example metals, persistent organic pollutants (POPs) and pesticides (HERA)

- [E]valuation of human health effects in large families of understudied chemicals (e.g. antimicrobial agents, flame retardants, food additives, pesticides, pharmaceuticals, plasticisers, surfactants, and other substitutes for additives to materials and goods) and health effects of endocrine disruption (HERA)

KNOWLEDGE GAP A134.

Impacts of microplastics and other small particles on health

- Little is known with respect to the human health risks of nano- and micro-plastics, and what is known is surrounded by considerable uncertainty (SAPEA)

- The impact of plastic micro-fibers and micro-beads (released through clothes laundering and the rinsing off of cosmetics and tyres) on human health (expert input)

KNOWLEDGE GAP A135.

Impacts of contaminated sites on health

- [C]ontaminated sites are well identified hot spots that remain a source of exposure to legacy compounds for decades and there is a need to identify ... their impacts on human health (HERA)

- Environmental monitoring of contaminated sites and human biomonitoring/health survey of the population living in proximity to contaminated sites (HERA)

A14. RESEARCH THEME: OTHER GLOBAL ENVIRONMENTAL CHANGES AND HEALTH

KNOWLEDGE GAP A141.

Impacts of specific aspects of urbanisation on health

- Assess the complexity and relationships between current urban transport and residential energy practices, exposures (air pollution, noise, heat island, excessive light and often lack of greenspace), and health effects and impacts (HERA)

- Very little research has been devoted to the subject of slum health... [Slums] remain invisible in many data systems...the evidence base in slum health is underdeveloped (Lilford)

KNOWLEDGE GAP A142.

Impacts of land degradation on health

- National monitoring efforts that directly collect subnational and perhaps household-level data are essential to our understanding of the impacts of desertification on human wellbeing (MEA)

- Understanding the impacts of desertification on human wellbeing requires that we improve our knowledge of the interactions between socioeconomic factors and ecosystem conditions (MEA)

KNOWLEDGE GAP A143.

Impacts of freshwater scarcity on health

- Research priorities [including the measurement and projection of] water supply quantity and quality stressors. Quantity stressors included shortage, drought, and water loss. Quality stressors related to industrial, agricultural, and other pollutant sources that lead to groundwater contamination and fecal pollution in watersheds (Setty)

- Among direct health impacts of water scarcity, physical and mental health [need to be] considered ... water-borne diseases ... carcinogenic diseases ... skin diseases ... mental health impacts (Paudel)

A2. SUBAREA: ASSESSING IMPORTANT COMMON PATHWAYS BETWEEN GLOBAL ENVIRONMENTAL CHANGES AND HEALTH

A21. RESEARCH THEME: GLOBAL ENVIRONMENTAL CHANGE AND FOOD

KNOWLEDGE GAP A211.

Impacts of global environmental change on food insecurity

- Investigate the impacts of climate change and ecological change on resource security with emphasis on...effects on the food chain (HERA)
- Research is needed on the role of rising atmospheric concentrations of carbon dioxide, climate change, land-use change, and changing diets on the magnitude and pattern of food insecurity (Ebi)

KNOWLEDGE GAP A212.

Impacts of global environmental change on food quality and safety

- Research is needed on the linkages between biodiversity changes and...dietary diversity and health (HERA)
- Research also is needed on solutions to address reductions in food quality from higher carbon dioxide concentrations, and food safety from the increasingly industrialized production practices (Ebi)

A22. RESEARCH THEME: GLOBAL ENVIRONMENTAL CHANGE AND INFECTIOUS AGENTS

KNOWLEDGE GAP A221.

Impacts of global environmental change on exposure to infectious disease risks

- The ecology of biological agents, including the identification of pathogen reservoirs (e.g. animal species, soil, water, air compartments) and vectors both in rural and urban habitats, particularly where human populations and livestock live in close contact with wildlife and/or where human exposure and vulnerability is documented (HERA)
- Systemic research into the contribution of climate change to the emergence and spread of infectious diseases (HERA)

KNOWLEDGE GAP A222.

Impact of global environmental change on susceptibility to infectious disease risks

- Investigate how biodiversity supports the safeguarding of human health directly (through e.g. microbiome and related immunological benefits) (HERA)
- It is key to characterize the vulnerability of humans in terms of multiple exposure in rural, urban, occupational environments (HERA)

A23. RESEARCH THEME: OTHER COMMON PATHWAYS BETWEEN GLOBAL ENVIRONMENTAL CHANGE AND HEALTH

KNOWLEDGE GAP A231.
Impacts of global environmental change on drinking water

- Investigate the impacts of climate change and ecological change on resource security with emphasis on water stress (HERA)
- Research is needed to anticipate the likely impacts of warmer temperatures and changes in the hydrological cycle on drinking water quality and quantity (expert input)

KNOWLEDGE GAP A232.
Impacts of global environmental change on conflict and migration

- [E]nhance the understanding of the role of environmental change in complex emergencies such as forced migration, conflict, and civil unrest (Lancet)
- Investigate the impacts of climate change and ecological change on resource security with emphasis on...population displacement and migration, including related health impacts (HERA)

KNOWLEDGE GAP A233.
Impacts of global environmental change on mental well-being

- Mental health impacts from changing biophysical conditions are also a growing research frontier...Many interdisciplinary questions in this area remain to be explored (NSF)
- [F]urther clarity and theoretical development of the concept [of eco-anxiety] is required to advance conceptual understanding of eco-anxiety...Future research could explore a much broader construct of eco-emotions and climate change-related mental health impacts (Coffey)

A3. SUBAREA: ASSESSING HEALTH SYSTEMS' CONTRIBUTION TO GLOBAL ENVIRONMENTAL CHANGE

A31. RESEARCH THEME: HEALTH CARE'S CONTRIBUTION TO GLOBAL ENVIRONMENTAL CHANGE

KNOWLEDGE GAP A311.

Health care's contribution to greenhouse gas emissions

- Pathway analyses of climate emissions from health care (Ebi)
- Development of a common model for calculating the carbon footprint for health (and social) care (expert input)

KNOWLEDGE GAP A312.

Health care's contribution to other global environmental changes

- Calculating the environmental costs and benefits of discrete components of [health care] activity, which could be used to build models for estimating the impacts of different options and pathways (WHO)
- The effects of production and consumption of pharmaceuticals on health, via waste water and other media (expert input)

A32. RESEARCH THEME: PUBLIC HEALTH'S CONTRIBUTION TO GLOBAL ENVIRONMENTAL CHANGE

KNOWLEDGE GAP A321.

Effects of public health interventions on global environmental change

- Address sustainability aspects [of sanitation and safe drinking water,] such as carbon footprint and waste products (e.g. brine from desalination) to quantify environmental impacts of treatment alternatives and personal drinking water choices (e.g. bottled water) to promote sustainable personal choices (HERA)
- Assess environmental risks and benefits of public health interventions, e.g. promotion of physical exercise and use of disposable face-masks (expert input)

KNOWLEDGE GAP A322.

Feedback effects of population health on global environmental change

- How does human health, including inequities in health metrics, consequences of poverty, and societal impacts of disease outbreaks, feedback to affect air and water quality, resource use, and biodiversity? (NSF)
- [T]he ways in which the current health status of a population – itself a function of age structure, diets, health care systems, degree of 'underlying health issues' and their distribution in a society, poverty, and inequality – contribute to global environmental change and/or shape its effects (expert input)

A4. SUBAREA: OVERARCHING ANALYSES OF HEALTH IMPACTS OF GLOBAL ENVIRONMENTAL CHANGE

A41. RESEARCH THEME: GLOBAL ENVIRONMENTAL CHANGE AND HEALTH INEQUALITIES

KNOWLEDGE GAP A411.
Impacts of global environmental change on the health of vulnerable groups

- Identifying, elucidating and quantifying climate change effects on health with a focus on...vulnerable population groups (e.g. pregnant women, infants, elderly, and disadvantaged groups due to income or ethnicity) (HERA)
- Explore how the different risk-factors and their combinations (accumulation) in the [climate, environment and health] nexus affect people in different situations and how these factors and processes can produce and maintain social disadvantages and increase vulnerability. How does social disadvantage translate into environmental disadvantage (HERA)

KNOWLEDGE GAP A412.
Impacts of global environmental change on the health of different world regions

- Research on the climate impacts on human health have so far focused on global risks, with limited focus on regional risks and adaptation options at 1.5°C and 2°C (IPCC 1.5)
- The impacts of global and regional climate change at 1.5°C on...food distribution, nutrition,...are poorly understood, particularly for developing nations (IPCC 1.5)

A42. RESEARCH THEME: KEY DRIVERS OF GLOBAL ENVIRONMENTAL CHANGE AND HEALTH

KNOWLEDGE GAP A421.
Health impacts of economic drivers of global environmental change

- [Rising] consumption has been underlined as a common mechanism of...climate change, biodiversity loss, overload of the nitrogen and phosphorous cycles, freshwater depletion, ...[and is also a factor behind many modern health problems] (expert input)
- The role of commercial interests (e.g. companies involved in fossil fuel extraction) in driving both climate change and human health deterioration (expert input)

KNOWLEDGE GAP A422.
Health-related impacts of global environmental change on the economy

- Quantifiable human health effects can be taken into account as part of the economic analysis that goes into the decision-making process for policies affecting the environment and natural resource use (expert input)
- Climate change will also impact on global networks (trade, travel, infrastructure, welfare economy, etc.), affecting human health in various ways (expert input)

A43. RESEARCH THEME: INTEGRAL ANALYSES OF GLOBAL ENVIRONMENTAL CHANGE AND HEALTH

KNOWLEDGE GAP A431.

Impacts of global environmental changes on health (general, comparative quantification)

- How are accelerating anthropogenic changes to the Earth's natural systems – biodiversity loss, climate change, land use change, pollution of air, water, and soil, scarcity of resources, and altered biogeochemical cycles – threatening human health? (NSF)

- What is the scale of these threats? Which populations are at greatest risk and/or most vulnerable, and which dimensions of health are most impacted? (NSF)

KNOWLEDGE GAP A432.

Impacts of combinations of global environmental changes on health

- Assessment of interconnected pathways linking global environmental changes, e.g. environmental pollution, biodiversity loss, land-use change, climate change, …and their health impacts (HERA)

- How do the various direct and indirect impacts of global environmental change on human health interact? For example, will the likelihood or impact of emerging infectious diseases be stronger under conditions where people suffer from poor water and land quality? (expert input)

KNOWLEDGE GAP A433.

Complex interactions between natural and social systems involved in planetary health

- [S]ystems-based understanding of the interconnections and feedbacks [between natural and social systems and human health] to strategically address upstream drivers (Pongsiri)

- [U]nderstanding of how human-driven stressors, singly or in combination, lead to global and local environmental change and how this change affects human health (Pongsiri)

A5. SUBAREA: ANALYSING ETHICAL ISSUES RELATED TO GLOBAL ENVIRONMENTAL CHANGE AND HEALTH

A51. RESEARCH THEME: 'INTRA-SPECIES' ETHICAL ISSUES

KNOWLEDGE GAP A511.

Ethical reflection on health inequalities related to global environmental change

- Identify inequalities arising from environmental factors and their interaction with social and economic factors as well as approaches and solutions to address these issues and environmental justice (HERA)

- Evaluate the ethical and philosophical context of production and consumption patterns including the health effects of over-exploitation of resources, unsustainable food production and land-use, environmental injustice, migration and social displacement (HERA)

KNOWLEDGE GAP A512.

Ethical reflection on intergenerational aspects of global environmental change and health

- Questions of intergenerational justice are becoming key issues for the millennial and later generations (expert input)

- Develop research models that address the issue of responsibility towards future generations (HERA)

A52. RESEARCH THEME: 'INTER-SPECIES' ETHICAL ISSUES

KNOWLEDGE GAP A521.

Ethical reflection on impact of global environmental change on other species

- The ethical implications of our moral responsibilities towards animals and ecosystems (expert input)

- Develop a vision on the value of the health of humans, animals and nature, and on how these different values can be weighed (Meijboom)

AREA B:

DEVELOPING MITIGATION AND ADAPTATION STRATEGIES TO PROTECT HUMAN HEALTH AGAINST GLOBAL ENVIRONMENTAL CHANGE

B1. SUBAREA: DEVELOPING EFFECTIVE MITIGATION AND ADAPTATION STRATEGIES TO ADDRESS GLOBAL ENVIRONMENTAL CHANGES AND THEIR HEALTH IMPACTS

B11. RESEARCH THEME: CLIMATE CHANGE STRATEGIES AND HEALTH

KNOWLEDGE GAP B111.

Health effects of climate disaster risk management

- Research is needed to advance the practice of disaster risk management, preparedness, response, and communication, including through event forecasting and early warning systems (Ebi)
- Understand the effectiveness of social safety nets for reducing vulnerability to extreme events, and the effectiveness of adaptation strategies in reducing health risks, particularly in vulnerable communities and regions (Ebi)

KNOWLEDGE GAP B112.

Health effects of climate change mitigation strategies

- What are the side effects (positive and negative) of climate mitigation measures in the fields of energy, agriculture, care (Green Deal 2.0), sustainability (circular economy)? (ZonMw)
- What are the health effects of negative emission technologies (i.e. removal of carbon dioxide from the atmosphere) and geo-engineering (i.e. to reduce solar radiation) (expert input)

KNOWLEDGE GAP B113.

Health effects of climate change adaptation strategies

- Research also is needed to understand the...effectiveness of adaptation strategies in reducing health risks (Ebi)
- What are the positive and/or negative health effects of climate adaptation measures (e.g. heat-resistant building, blue/green spaces, artificial wetlands, changes in agriculture)? What are the long-term health consequences? (ZonMw)

KNOWLEDGE GAP B114.

Health-related prioritisation of climate change mitigation and adaptation strategies

- Which (mix of) measures are most desirable / cost-effective? (ZonMw)
- [T]he paucity of evidence on both climate change mitigation and adaptation (alone and in combination) is of great concern, and unless urgently resolved will greatly limit the ability of governments to design evidence-based pathways to reduce the effects on health of climate change (Berrang-Ford)

B12. RESEARCH THEME: BIODIVERSITY LOSS STRATEGIES AND HEALTH

KNOWLEDGE GAP B121.

Health effects of biodiversity loss mitigation strategies

- Explore policies (including e.g. land-use planning, intensified agriculture, forestry sectors, urban development, human security, sustainable economy, sustainable production and consumption) and their capacities to support health promotion, resilience, biodiversity conservation and restoration and multiple synergies (HERA)

- More research is needed to assess the health impact of nature-based solutions... Urban blue infrastructure... City trees... Green school playgrounds... Wildlife provisioning... Forest bathing... (Aerts)

B13. RESEARCH THEME: GLOBAL POLLUTION STRATEGIES AND HEALTH

KNOWLEDGE GAP B131.

Health effects of air pollution mitigation strategies

- Develop air pollution mitigation strategies to reduce risks of air pollution-associated diseases of European citizens in outdoor and indoor environments (HERA)

KNOWLEDGE GAP B132.

Health effects of chemical pollution mitigation strategies

- Research to optimise development of substitutes for hazardous chemicals through "Safe and sustainable by design" (HERA)

- Develop innovative technologies for minimizing contamination [of drinking water] by chemical mixtures and micro-/nanoplastics (HERA)

KNOWLEDGE GAP B133.

Health effects of environmental decontamination strategies

- Identification of targeted cost-effective actions for decontamination, prioritised on the basis of critical health impacts, and research to develop guidelines for urban planning related to the redevelopment of contaminated sites for new functions (HERA)

- Prevent and minimize exposures from food, feed and soil contamination and their negative impacts on human and animal health and ecosystem services, including new solutions for decontamination (HERA)

KNOWLEDGE GAP B141.

Health effects of urban sustainability strategies

- European cities are actively improving the urban environment through applying better urban planning (e.g. new urban models such as Superblocks, 15-minute city), better transport planning (increasing cycling lane length), nature-based solutions (e.g. planting trees) and EU initiatives (e.g. carbon neutral cities), but robust data is missing of the effect on environmental exposures (e.g. air pollution, noise, heat, excessive light), lifestyle factors (e.g. food consumptions, physical activity) and health effects (e.g. mental and physical health), and overall effectiveness (HERA)

- [W]e do not understand... what effect slum-focused health interventions could have... improved uptake of vaccination... which types of [sanitary] installation are suitable for which types of slum... effects on education, wellbeing, and productivity in addition to those on health (Lilford)

KNOWLEDGE GAP B142.

Health effects of land degradation mitigation strategies

- Quantitative and comparative analysis of land degradation avoidance solutions and restoration options [including impact on ecosystem services] (IPBES 2)

- More information is needed to assess the linkages between the policies for poverty reduction and combating desertification (MEA)

KNOWLEDGE GAP B143.

Health effects of improved water management strategies

- While new approaches [to water treatment] are constantly under development, consideration of the health impacts of pathogen reduction by various methods and degrees would help to support decision-making (Setty)

- Ensuring the sustainability of water supplies for increasing water demand requires holistic optimisation...[which] should be broadened to include resource use and health (JPI)

B2. SUBAREA: DEVELOPING EFFECTIVE STRATEGIES TO ADDRESS IMPORTANT COMMON PATHWAYS BETWEEN GLOBAL ENVIRONMENTAL CHANGES AND HEALTH

B21. RESEARCH THEME: STRATEGIES FOR GLOBAL ENVIRONMENTAL CHANGE AND FOOD

KNOWLEDGE GAP B211.

Health effects of more sustainable food products

- [Assess nutritional quality of new] plant-based food products, including ultra-processed foods (WHO)
- Research is needed on risks, hazards and benefits of novel foods as well as people's perceptions and attitudes towards them and related technologies and solutions (HERA)

KNOWLEDGE GAP B212.

Guidelines for sustainable healthy diets

- Analyse and design what a sustainable European planetary health diet may look like (HERA)
- More research is needed to identify the most adequate healthy diets and their affordability and environmental sustainability across different contexts (UN)

KNOWLEDGE GAP B213.

Effective policies promoting adoption of sustainable healthy diets

- [Develop] food labelling covering both nutritional content and environmental sustainability, food profiling model for healthy and sustainable diets (WHO)
- [Develop] healthy digital food environments…this includes social media, online food retail, digital food marketing and food delivery apps (WHO)

KNOWLEDGE GAP B214.

Health effects of sustainable food production

- [Develop] ways to sustainably boost [food] production to meet current and future food demands, protecting and using biodiversity through biophysical and ecological practices, rapid reduction of the use of pesticides in intensive crop production, of antibiotics and steroids, and protecting the agriculture- and forest-related genetic base (UN)
- Explore sustainable agriculture and aquaculture to uncover the benefits and risks on food, diets and health, in relation to the synergies with climate adaptation and mitigation (HERA)

KNOWLEDGE GAP B215.

Health effects of strategies to reduce food waste

- [S]caling up sustainable cold chain technology to make perishable foods (especially vegetables and fruits; potatoes) more available and affordable and at the same time reducing food loss and waste (UN)
- Accelerating the reduction of food waste and loss calls for developing food processing refrigeration, storage and warehouse technologies (UN)

B22. RESEARCH THEME: STRATEGIES FOR GLOBAL ENVIRONMENTAL CHANGE AND INFECTIOUS AGENTS

KNOWLEDGE GAP B221.

Effective prevention of the emergence of infectious diseases related to global environmental change

- Obtaining and disseminating critical data on the wildlife trade and disease risk (IPBES)
- Assessing economic cost and benefits of preventing pandemics (IPBES)

KNOWLEDGE GAP B222.

Effective non-pharmaceutical interventions against infectious diseases related to global environmental change

- There is a clear requirement to conduct large, pragmatic trials to evaluate the best combinations [of non-pharmaceutical interventions] in the community and in healthcare settings with multiple respiratory viruses and in different sociocultural settings (Jefferson)
- The use of facial masks in the community setting represents one of the most pressing needs to address, given the polarised opinions around the world (Jefferson)

KNOWLEDGE GAP B223.

Effective vaccination against infectious diseases related to global environmental change

- Innovative research on human and animal Prophylactic Vaccines (NCOH)
- Development of vaccines requires investment in the entire chain from protective antigen discovery, vaccine production, vaccine delivery to efficacy studies requiring basic knowledge about immunity (NCOH)

KNOWLEDGE GAP B224.

Effective treatment of infectious diseases related to global environmental change

- Delineate the mechanisms of resistance to infectious agents in certain species and implication for human therapeutics (HERA)
- Development of broadly-reactive antiviral drugs (NCOH)
- Knowledge gap B225. Effective general response against infectious disease outbreaks related to global environmental change
- Analysing behavioural risk in communities, co-designing programmes to reduce risk (IPBES)
- [Develop] novel, generic approaches to disease and pathogen detection, and a collaborative approach to outbreak response (NCOH)

KNOWLEDGE GAP B225.

Effective general response against infectious disease outbreaks related to global environmental change.

- Analysing behavioural risk in communities, co-designing programmes to reduce risk (IPBES)
- [Develop] novel, generic approaches to disease and pathogen detection, and a collaborative approach to outbreak response (NCOH)

B3. SUBAREA: DEVELOPING EFFECTIVE STRATEGIES TO REDUCE NEGATIVE AND INDUCE POSITIVE HEALTH SYSTEMS' CONTRIBUTIONS TO GLOBAL ENVIRONMENTAL CHANGE

B31. RESEARCH THEME: STRATEGIES FOR GLOBAL ENVIRONMENTAL CHANGE AND HEALTH CARE

KNOWLEDGE GAP B311.

Climate-resilient health care

- Develop climate adaptation measures for the health care sector (expert input)
- Incorporate climate change effects on climate-sensitive health risks into health care policies (Ebi)

KNOWLEDGE GAP B312.

Environmentally sustainable health care

- Development of climate mitigation measures and sustainable technology for the health sector (HERA)
- How to reduce medical waste/ toxic waste/plastic waste (expert input)

B32. RESEARCH THEME: STRATEGIES FOR GLOBAL ENVIRONMENTAL CHANGE AND PUBLIC HEALTH

KNOWLEDGE GAP B321.

Sustainable sanitation and drinking water practices

- A paradigm shift is needed from waste being disposed of far away to resource recovery and reuse.... Similar transitions are needed for sanitation (Ebi)
- Quantify environmental impacts of [water] treatment alternatives and personal drinking water choices (HERA)

KNOWLEDGE GAP B322.

Sustainable health promotion practices

- Shifting priorities in behavioral medicine from the study of traditional behaviors (e.g. a volume of physical activity) towards the promotion of a behaviors with higher mitigation potential and adaptive behaviors embodied in a climate change context (Chevance)
- Include indicators for sustainability...when studying health behaviors to uncover their joint benefits for humans and the planet (Konig)

KNOWLEDGE GAP B323.

Effective family planning practices

- [A]ssess...population policy as a component of [climate change] mitigation or adaptation responses, as well as its costs and benefits, implementation barriers, and links to SDGs (Bongaarts)
- [The] practice of integrating access to family planning with natural resource conservation should offer fertile ground for evidence that the linkage works in the real world (Engelman)

B4. SUBAREA: INTEGRAL ANALYSES OF STRATEGIES TO ADDRESS GLOBAL ENVIRONMENTAL CHANGES AND THEIR HEALTH IMPACTS

B41. RESEARCH THEME: INTEGRAL IMPACT ANALYSES OF STRATEGIES

KNOWLEDGE GAP B411.

Effects on health inequalities of policies addressing global environmental change

- Assess potential economic impacts of mitigation policies on disadvantaged groups (HERA)
- More attention needed for the energy transition and associated health risks, e.g. related to fuel poverty (expert input)

KNOWLEDGE GAP B412.

Cost-effectiveness of policies addressing global environmental change and health

- Investigate health-related economic effects of climate change mitigation and adaptation policies (HERA)
- Cost-benefit analysis of policies to reduce global environmental change [taking into account the health impacts] (expert input)

B42. RESEARCH THEME: HEALTH IMPACT OF INTEGRAL STRATEGIES

KNOWLEDGE GAP B421.

Health effects of circular economy strategies

- Identification of safe limits for recycling and safe reuse of products potentially containing toxic chemicals (HERA)
- Assess health risks of circular economy (expert input)

KNOWLEDGE GAP B422.

Health effects of integral strategies to address global environmental change

- Assess the contribution and impact of various environmental policies set by the European Commission (i.e. strategy and action plans related to the Green Deal) on global pollution and thus on health (HERA)
- Full characterisation of how policies to protect planetary health can cause a range of changes in the state of natural systems and can affect a range of critically important dimensions of human health in the long term…[including identification of] unintended adverse results… environment and human health co-benefits can justify integrated approaches to policy solutions across disciplines and sectors) (Lancet)

KNOWLEDGE GAP B431.

Health effect of transformative changes to the economy to address global environmental change

- Exploration of new economic models (circular, green, wellbeing, doughnut etc.) [and their health impacts] (expert input)

- There is a growing group of economic scientists who claim that a fundamental change of the economic system is required in order to bring humanity in balance with its environment. The health effects of such a fundamental change of economic system are completely unexplored (expert input).

KNOWLEDGE GAP B432.

Health effects of transformative societal changes to address global environmental change

- The effect of multiple transitions (energy, diet, health care, …) on human health (expert input)

B5. SUBAREA: ANALYSING ETHICAL ISSUES RELATED TO POLICIES ADDRESSING GLOBAL ENVIRONMENTAL CHANGE AND HEALTH

B51. RESEARCH THEME: POLICIES AND 'INTRA-SPECIES' ETHICAL ISSUES

KNOWLEDGE GAP B511.

Ethical reflection on policies addressing global environmental change and human health

- What ethical principles should guide the choice of specific climate change policy objectives, including but not limited to, maximum human-induced warming and atmospheric greenhouse gas targets? (Rock)

- [On what ethical principles should economic analyses of climate change policies, such as cost-benefit analyses, be based?] (Rock, reformulated)

KNOWLEDGE GAP B512.

Ethical reflection on the distribution of responsibility for policies addressing global environmental change and human health

- Who is ethically responsible for the [health] consequences of climate change, that is, who is liable for the burdens of [adaptation] or paying for unavoided damages (Rock)

- A 'just transition' sits at the heart of planetary health, and there are questions about what this means in every domain (expert input)

B52. RESEARCH THEME: POLICIES AND 'INTER-SPECIES' ETHICAL ISSUES

KNOWLEDGE GAP B521.

Ethical reflection on the impact of policies on the health of other species

- Ethical principles in relation to the effect/impact of policies on animals and ecosystems (expert input)

- The ethical implications of our moral responsibilities towards animals and ecosystems (expert input)

KNOWLEDGE GAP B522.

Ethical framework for planetary health, including the interests of other species

- Develop a new more holistic conceptual framing which defines a culture of ethical sustainability, including equality and vulnerable population groups and which shifts social institutions, societal norms and governance systems towards a deeper ecological philosophy (HERA)

- Develop an ethical framework [for planetary health] which has an eye for the interests of animals and nature in addition to those of humans (Meijboom)

AREA C: PROMOTING THE IMPLEMENTATION OF MITIGATION AND ADAPTATION STRATEGIES TO PROTECT HUMAN HEALTH AGAINST GLOBAL ENVIRONMENTAL CHANGE

C1. SUBAREA: DEVELOPING EFFECTIVE STRATEGIES FOR CHANGING BEHAVIOUR RELATED TO GLOBAL ENVIRONMENTAL CHANGES AND HEALTH

C11. RESEARCH THEME: CHANGING CITIZEN BEHAVIOUR

KNOWLEDGE GAP C111.

Determinants of citizen behaviour related to global environmental changes and health

- We need to identify which cognitive, motivational, social, cultural, physical, and institutional factors influence the adoption of different sustainable innovations and technologies by individuals, households, and organisations (Steg)

- More research is needed into biases that may inhibit adequate judgements and optimal decisions related to energy behaviour of various actors (Steg)

KNOWLEDGE GAP C112.

Improving citizen understanding of the health impacts of global environmental change

- Investigating the most relevant tools and (participatory) approaches for a balanced education of citizens in the environment and health field (HERA)

- What are effective methods for informing citizens about risks and encouraging measures and prevention (sun-safe behaviours, different consumption patterns)? How can this be better linked to existing processes? Which ICT technologies can be used to reach target groups? (ZonMW)

KNOWLEDGE GAP C113.

Contextual approaches to changing citizen behaviour related to global environmental change and health

- The identification of effective economic (including changing behavioural incentives)... approaches to promote planetary health...; develop and implement appropriate taxes and subsidies that promote sustainability, improve health, and reduce inequities...; support local sustainable development initiatives; and regulate harmful activities (Lancet)

- We need to better understand the psychological and behavioural effects of contextual changes that aim to make sustainable energy behaviour more attractive or feasible (Steg)

KNOWLEDGE GAP C114.

Inequalities in citizen behaviour related to the health impact of global environmental change

- What are success and failure factors [of climate adaptation measures] (especially in relation to behaviour) and how is this distributed among the different population groups? (ZonMw)

- Which actors, communities, and stakeholders have been excluded from participation in environmental and human health research and decision-making, and how can these barriers be overcome? (NSF)

C12. RESEARCH THEME: CHANGING POLICYMAKERS' BEHAVIOUR

KNOWLEDGE GAP C121.

Determinants of institutional and policymakers' behaviour related to global environmental change and health

- We [also] need a better understanding of factors influencing sustainable energy use...of organisations, firms, industry and governments (Steg)

- [A] better understanding of factors influencing (un) sustainable energy behaviour in developing and emerging countries is critical (Steg)

KNOWLEDGE GAP C122.

Understanding barriers to implementing policies addressing the health impacts of global environmental change

- [D]efining approaches and tools for translating and implementing scientific evidence into policies and profound societal and behavioural transformational change processes and technological innovations supporting sustainability and green transition on national and local level, taking benefit of living labs, testbeds or other relevant approaches and platforms (HERA)

- To analyse causes of the poor translation of recommendations into policy and action. How can research better capture the barriers to policy and behaviour change? (Lancet)

KNOWLEDGE GAP C123.

Improving policymakers' understanding of the health impacts of global environmental change

- Evaluate the effectiveness of knowledge translation of innovative methods and approaches to reduce harmful exposures in urban environments (HERA)

- There is a need to investigate especially the science-to-policy interface to improve the translation of research results into policy. Research is also needed on how to best include stakeholder communication and input in a broader risk governance framework (HERA)

KNOWLEDGE GAP C124.

Harnessing public support for policies related to global environmental change and health

- It is crucial to better understand which factors affect support for energy policies, energy system changes, energy infrastructure and innovations, and how to address public concerns so that broader positive societal outcomes can be achieved (Steg)

- [L]ittle is known about which factors affect perceived legitimacy and fairness of policies and how this in turn affects the support for energy policies and system changes (Steg)

KNOWLEDGE GAP C131.

Determinants of health care professionals' behaviour related to global environmental change

- We need to identify which cognitive, motivational, social, cultural, physical, and institutional factors influence the adoption of environmentally sustainable health care practices (expert input)

- [Understand environmentally relevant] decisions in health care, most of which are taken by autonomous health professionals, not by citizens, managers, or policymakers. For instance, they tend to prioritise (individual) patient safety over everything else (expert input)

KNOWLEDGE GAP C132.

Understanding barriers to implementing health care policies related to global environmental change

- Conducting research focused on supporting implementation, for example, understanding the barriers to change or assessing the co-benefits of sustainable approaches (WHO)

- The challenge remains how to weigh (individual) patient benefits against climate impacts and how to communicate that to the public (expert input)

KNOWLEDGE GAP C133.

Promoting implementation of sustainable health care practices

- [R]esearch on effective ways leading to better incorporation of environmental health and health prevention as an integral part of the healthcare ecosystem (HERA)

- Embedding environmental sustainability in wider health research, with environmental costs and benefits treated as an outcome measure or a dimension of quality akin to access or equity (WHO)

C2. SUBAREA: DEVELOPING EFFECTIVE GOVERNANCE FOR IMPLEMENTATION OF MITIGATION AND ADAPTATION STRATEGIES

C21. RESEARCH THEME: LEGAL INSTRUMENTS TO ADDRESS GLOBAL ENVIRONMENTAL CHANGE AND HEALTH

KNOWLEDGE GAP C211.

Effective national laws to address global environmental changes and health

- Largely absent from the past decade of [climate] adaptation law reform is evaluation of effectiveness (Jefferson)

- The design of [climate adaptation] laws must (1) be responsive to change; (2) address equity dimensions of climate change; (3) implement innovative solutions; (4) maximize co-benefits; and (5) establish processes for managing trade-offs (Jefferson)

KNOWLEDGE GAP C212.

Effective international laws to address global environmental changes and health

- [Develop] textual and operational reforms [to increase the effectiveness of WHOs] International Health Regulations (Gostin)

- Higher standards and more effective compliance are necessary for international law [i.e., trade law, food security law, environmental law, humanitarian law, and refugee law] to realize its full potential to safeguard the world's population (Garcia)

KNOWLEDGE GAP C213.

Effectiveness of litigation in addressing global environmental changes and health

- [There is] very little evidence of the extent to which the growing number of [climate change litigation] cases...are either driving action to address climate change or creating awareness of the issue (Setzer)

- Another aspect to consider is the potentially negative impacts that can result from [climate change litigation] lawsuits (Setzer)

C22. RESEARCH THEME: GOVERNANCE STRUCTURES AND PRACTICES TO ADDRESS GLOBAL ENVIRONMENTAL CHANGE AND HEALTH

KNOWLEDGE GAP C221.
Effective local governance to address global environmental change and health

- How can climate and health policies be best organized at the local/regional level? What are effective governance processes in this context? Where does the responsibility lie for vulnerable groups, for example? (ZonMW)

- There is a need to develop knowledge to understand the operational pathways and institutional structures for governance that effectively supports climate action in different urban contexts (IPCC 2)

KNOWLEDGE GAP C222.
Effective national governance to address global environmental change and health

- The identification of effective... governance approaches to promote planetary health, including how best to reduce and recycle harmful subsidies; develop and implement appropriate taxes and subsidies that promote sustainability, improve health, and reduce inequities; support local sustainable development initiatives; and regulate harmful activities. (Lancet)

- [Develop] good resource management practices for soil and water that contribute to promoting sustainable food systems, with payments for ecosystem services as an option (UN)

KNOWLEDGE GAP C223.
Effective international governance to address global environmental change and health

- In terms of governance, a global management system for water is needed, specifically a negotiation system, as well as a global water strategy (JPI)

- Strengthen [Common Agricultural Policy] related governance research in order to better integrate environment, biodiversity, climate change and health issues into agriculture policy and the related food systems (HERA)

C3. SUBAREA: ENABLING TRANSFORMATIVE CHANGE TO COUNTER GLOBAL ENVIRONMENTAL CHANGE AND PROTECT HEALTH

C31. RESEARCH THEME: DISCOVERING MECHANISMS FOR TRANSFORMATIVE CHANGE

KNOWLEDGE GAP C311.
Mechanisms for transformative change (general)

- Study the underlying, direct and indirect drivers of transformational change in behaviour, policy, economy, and technology to reveal leverage points to bring about the conservation, restoration and sustainable use of biodiversity, while taking into account human and planetary health (HERA)
- We call on both social and natural sciences to engage more intensively in collaborative interdisciplinary research to understand rapid social transformations, social tipping elements, and their interactions (Otto)

KNOWLEDGE GAP C312.
Historical precedents for transformative change

- [Use historical analysis] to increase understanding about the constraints of, and opportunities for, long-term change processes (Kanger)
- Historical analysis of path dependencies that need to be overcome to realise transformational change (expert input)

C32. RESEARCH THEME: DEVELOPING METHODS FOR TRANSFORMATIVE CHANGE

KNOWLEDGE GAP C321.
Methods to promote transformative change (general)

- A key area is the interactions between enabling conditions such as finance, behaviour, and innovation and how they can accelerate transitions (expert input)
- Developing effective methods for citizen engagement (expert input)

KNOWLEDGE GAP C322.
Methods to promote transformative change of specific subsystems

- [E]mpirical and modelling efforts to better understand the potentials of harnessing social tipping dynamics for climate change mitigation (Otto)
- Develop, redesign and apply research on the food system transformation in order to provide healthy nutrition for European urban and rural populations while staying within planetary boundaries and also safeguarding natural capital for the future (HERA)

AREA D:
ENABLING RESEARCH ON GLOBAL ENVIRONMENTAL CHANGE AND HEALTH

D1. SUBAREA: IMPROVING DATA AND METHODS FOR RESEARCHING AND MONITORING GLOBAL ENVIRONMENTAL CHANGES AND HEALTH

D11. RESEARCH THEME: DATA INFRASTRUCTURE

KNOWLEDGE GAP D111.

Climate change and health information systems

- Develop health and climate-related information systems to guide the development of adaptation measures and provide scientific evidence (HERA)
- Develop innovative health climate-related services including an integrated early warning system (HERA)

KNOWLEDGE GAP D112.

Biodiversity and health information systems

- Implement longitudinal research, which builds on existing and novel data sets and registers, measuring tools and artificial intelligence to better characterise, monitor and model biodiversity and health related pathways and related indicators to improve monitoring (HERA)

KNOWLEDGE GAP D113.

Pollution and health information systems

- Developments in digital health and large-scale as well as dedicated cohort studies are needed to monitor immediate to long-term impacts of air pollutants as well as their mixture (HERA)
- Innovative approaches are needed to ensure linkage and interoperability of different data sources (e.g. air pollution and waste water monitoring systems, disease registries) and access to information updated in real time, coupled with HIA and modelling platforms (HERA)

KNOWLEDGE GAP D114.

Sustainable and healthy diet information systems

- Data platform for modelling healthy and sustainable dietary patterns (WHO)
- Set up a monitoring system to assess the status of food environments, and to measure progress on achieving the goals of nutrition and health plans (Food-EPI)

KNOWLEDGE GAP D115.

Infectious disease information systems

- Implement ecological health observatories in hot spots of disease emergence (HERA)
- Effective surveillance for known and potential zoonoses (and diseases that threaten livestock and wildlife) in the wildlife trade is crucial (IPBES)

KNOWLEDGE GAP D116.

Integrated planetary health information systems

- Many information systems already exist. What is missing is the ability to integrate information from different systems (expert input)
- Simultaneously monitoring population and planetary health is critical for understanding the causal pathways between environmental parameters (including weather/climate, atmosphere, land use and crop yields, biodiversity) and the health and well-being of populations, taking into account the multiple drivers of adverse health outcomes (Ebi)

D12. RESEARCH THEME: MEASUREMENT METHODS

KNOWLEDGE GAP D121.

Measurement of exposure to biodiversity

- Novel methods are needed to accurately quantify...exposures to different dimensions of biodiversity (Aerts)

- Quantitative indicators defining the relationships between biodiversity and human and planetary health/well-being to inform and support transformational change pathways in economy, policy and planning are not sufficiently developed (HERA)

KNOWLEDGE GAP D122.

Measurement of exposure to global pollution

- Novel approaches in monitoring technologies, techniques and reporting of air quality are needed for an assessment of the new WHO guideline implementation. In addition, also novel approaches for the monitoring of ultrafine particulate air pollution is needed e.g. of desert dust in PM (HERA)

- Linking human biomonitoring of exposure and effect biomarkers to citizen-science by making sampling easier, cheaper, less invasive (HERA)

KNOWLEDGE GAP D123.

Measurement of early health effect markers of global environmental change

- Develop advanced approaches for incorporation of early effect markers in the environmental burden of disease assessments (HERA)

D13. RESEARCH THEME: ANALYTIC METHODS

KNOWLEDGE GAP D131.

Attribution of health effects to global environmental change

- A very recent scientific development is the possibility of attributing specific extreme weather events to climate change. As a follow-up to that, one may explore the possibility of attributing certain health effects to a specific type of extreme weather event (expert input)

- Improve methods for attribution of health effects to climate change, with special attention for combined exposures of environmental stressors (exposome: temperature, air pollution, pollen etc.) and linkage between environmental, socio-economic and health data (HERA)

KNOWLEDGE GAP D132.

Health systems' contribution to global environmental change

- Developing standard metrics and research methods for assessing the environmental costs and benefits of health system activities (WHO)

KNOWLEDGE GAP D133.

Complex interactions between exposures

- Development of analytical tools that are able to handle high levels of complexity, e.g. interactions and feedback loops between climate change, biodiversity loss, and global pollution, and how these affect human health (expert input)

- Development of new methods, such as the 'exposome', to identify interrelationships between global environmental change entities that relate to human health (expert input)

KNOWLEDGE GAP D134.

Integration of evidence on the health effects of global environmental change

- Development of methodologies that take stock of multiple lines of evidence coupling epidemiological evidence from human cohort studies and toxicological data (HERA)
- Develop a unified EU approach on quality of life and burden of disease related to climate change measures (HERA)

KNOWLEDGE GAP D135.

Trade-offs between the short-term and long-term health effects of policies addressing global environmental change

- The assessment of trade-offs between short-term gains and longer-term benefits can support transparent decision making. (Lancet)
- How can current and future effects be mapped in a comparable manner? (ZonMw)

KNOWLEDGE GAP D136.

Economic valuation of the health effects of global environmental change

- [W]e still know little about the marginal value of biodiversity (i.e. value associated with changes in the variation of genes, species, and functional traits) in the production of [ecosystem] services (Cardinale)
- [E]fforts must be made to embrace the true value of food. External costs associated with climate change, biodiversity loss, and adverse health effects need to be considered (UN)

KNOWLEDGE GAP D137.

Integral health impact assessment of policies addressing global environmental change

- Develop and apply methods to evaluate and monitor the (cumulative) health impacts of mitigation and adaptation measures in an integrated and harmonized way within or across sectoral policies (HERA)
- Development of quantitative impact assessment of air and water quality guidelines and global flow of materials and goods regulations (HERA)

D14. RESEARCH THEME: QUANTITATIVE MODELS

KNOWLEDGE GAP D141.

Models forecasting the health effects of climate change and climate-related policies

- Develop integrated forecast models and tools for health impacts of climate change, including epidemiological models and socio-economic trajectories of exposure and vulnerability (HERA)
- [Forecasting the health effects of climate change and climate-related policies] demands the explicit incorporation of projections of future demographics and population health parameters (expert input)

KNOWLEDGE GAP D142.

Models forecasting health effects of biodiversity loss and biodiversity-related policies

- We also need sets of models and statistical tools that help us move from experiments that detail local biological processes to landscape-scale patterns where management and policy take place (Cardinale)
- Ideally, predictions arising from landscape-level models would be 'ground-truthed' by assessing their ability to predict the outcome of real restoration projects, or other management scenarios where policy actions are being taken to protect ecosystem services (Cardinale)

KNOWLEDGE GAP D143.

Models forecasting the health effects of global pollution and pollution-related policies

- Further development of exposure modelling linking sources to internal exposure ultimately leading to improved prediction of body burden based on environmental data (HERA)

- Development of harmonised approaches for modelling frameworks relevant for human health risk assessment,development of a harmonised protocol for models that should be used in a regulatory context (HERA)

KNOWLEDGE GAP D144.

Models forecasting the food-mediated health effects of global environmental changes and related policies

- The same ambitious methods used in the past decade to model future climates and agricultural impacts must be matched by modelling the economics of diets, and the multidirectional relationships among diet, human health and planetary boundaries (GlobPan)

KNOWLEDGE GAP D145.

Models forecasting infectious diseases related to global environmental changes and related policies

- The modelling of disease risks and pathogen evolution to adapt prevention and mitigation strategies and anticipate the evolutionary potential of pathogens that may threaten treatment and vaccination strategies (HERA)

- Many of the modeling efforts that explore the links between environmental change and infectious disease are still theoretical...In order to advance predictive modeling, there is a need for linked, long-term data at multiple spatial and temporal scales to support assessments of functionality within and across ecological and human behavioral systems, and over time (NSF)

KNOWLEDGE GAP D146.

Integrated models forecasting the health effects of global environmental change and related policies

- Studies focused on understanding, assessing, and responding to multiple hazards have been limited, ...predominantly focused on two hazards rather than the complex multitude of stressors that simultaneously affect socioenvironmental systems. [We need new models] for exploring overlapping stressors spatially through simulation of future scenarios (NSF)

- Various modelling approaches, e.g. spatially explicit land-use models and ecosystem services models, [must be] integrated in a single framework of analysis to identify possible side-effects and synergies emerging from policy implementation (Pongisir)

D2. SUBAREA: CREATING CONDITIONS CONDUCIVE TO RESEARCH ON GLOBAL ENVIRONMENTAL CHANGES AND HEALTH

D21. RESEARCH THEME: RESEARCH PRACTICES

KNOWLEDGE GAP D211.

More interdisciplinary and transdisciplinary research

- [U]niversities and research institutes need to find new ways to encourage transdisciplinary research teams to investigate scientific questions of societal importance and to develop, reward, and promote academic staff pursuing a research agenda informed by the planetary health framework (Lancet)
- Strengthening the interactions among scientists specializing in food systems, health, climate, and energy will make it possible to generate the required expertise (UN)

KNOWLEDGE GAP D212.

More science-policy dialogue

- Improve dialogue and understanding between science, stakeholders and policy by effective and comprehensive communication of results and solutions as well as risks and uncertainty to various audiences across disciplines and stakeholder types to foster trustworthiness, counter misinformation and build capacities and skills (HERA)
- [M]ore [food-related] research needs to be driven by the specific needs of policy makers (GlobPan)

KNOWLEDGE GAP D213.

More participatory research

- Innovative, interdisciplinary, people-centered, participatory research to foster crucial trust and transform people's perception of risk and their risk-reduction behaviors and communicate prevention (Ebi)
- Utilise participatory research with under-represented groups to address societal needs through citizen science where the public contributes to data gathering to monitor local environments, in order to address environmental injustice where there is disproportionate exposure of certain populations to environmental hazards (HERA)

KNOWLEDGE GAP D214.

More implementation research

- [P]rioritise translational research and implementation science to address the on-the-ground realities of what is feasible and relevant in the settings facing the greatest threats (Lancet)
- Rigorous implementation research is needed to strengthen the fit-to-context design delivery of [food systems] programs (UN)

KNOWLEDGE GAP D215.

More evidence synthesis

- [N]eed for capacity strengthening to develop a global collaborative effort analogous to the Cochrane Collaboration, which oversees the co-coordination of systematic reviews that link health and environmental sustainability (Lancet)
- Establish inter-governmental and global institutional mechanisms to better forge credible and authoritative consensuses on scientific evidence, resolving controversies surrounding new [food systems-related] research (GlobPan)

D22. RESEARCH THEME: TRAINING OF SCIENTISTS AND PRACTITIONERS

KNOWLEDGE GAP D221.

More educational content related to global environmental change and health

- Advanced educational programs at all levels (research scientists, professionals, citizens) combining the science areas relevant for addressing environment, climate and health, promoting trans-disciplinary science and holistic perspectives (HERA)

- What knowledge does practice (care, health services, construction, various governments) need? How can this be integrated into existing curricula? (ZonMw)

KNOWLEDGE GAP D222.

More interdisciplinary and transdisciplinary education

- Beyond the challenge of building complex, interdisciplinary research teams, there are structural challenges to performing such work. One such challenge, at the university level, is that training of young scientists tends to be focused within disciplines and there are few incentives for scientists to work across health and environmental disciplines (NSF)

- We need to encourage trans-disciplinary science education and develop advanced educational programs at the undergraduate and graduate levels bridging and connecting several domains together (chemistry, biology, physics, public health, statistics, informatics etc.) in order to address environmental health challenges (HERA)

Literature

Abbreviation used in Knowledge gaps	Complete Reference
Aerts	Aerts R et al. (2018) *Biodiversity and human health: mechanisms and evidence of the positive health effects of diversity in nature and green spaces.* British Medical Bulletin 2018;127:5–22. https://academic.oup.com/bmb/article/127/1/5/5051732 .
Berrang-Ford	Berrang-Ford, L. (2021) *Systematic mapping of global research on climate and health: a machine learning review.* The Lancet 2021, Vol. 5, Iss. 8, E514-E545. https://doi.org/10.1016/S2542-5196(21)00179-0
Bongaarts	Bongaarts J and O'Neill BC (2018). *Global warming policy: Is population left out in the cold?* Science 2018; 361 (6403), 650-652. DOI: 10.1126/science.aat8680.
Cardinale	Cardinale BJ et al. (2012). *Biodiversity loss and its impact on humanity.* Nature 2012; 486,7401:59-67. http://dx.doi.org/doi:10.1038/nature11148.
Chevance	Chevance G et al. (2021). *Thinking health-related behaviours in a climate-change context: a narrative review.* Preprint http://dx.doi.org/10.31219/osf.io/pb8vc
Coffey	Coffey Y et al. (2021). *Understanding Eco-anxiety: A Systematic Scoping Review of Current Literature and Identified Knowledge Gaps.* The Journal of Climate Change and Health 2021; 3, 100047 https://doi.org/10.1016/j.joclim.2021.100047 .
EASAC	EASAC policy report 38 (2019). *The imperative of climate action to protect human health in Europe.*
Ebi	K.L. Ebi et al (2020), *Transdisciplinary Research Priorities for Human and Planetary Health in the Context of the 2030 Agenda for Sustainable Development, Int.* J. Environ. Res. Public Health 17(23), 8890. https://doi.org/10.3390/ijerph17238890
Engelman	Engelman R et al. (2016). *Family Planning and Environmental Sustainability: Assessing the Science*, Washington, DC: Worldwatch Institute, 2016. https://paa.confex.com/paa/2016/mediafile/ExtendedAbstract/Paper3509/FPESA%20final%20paper%20PAA%202016.pdf
Food-Epi	Djojosoeparto, S.K. et al. (2021) on behalf of the JPI-HDHL Policy Evaluation Network. *The Healthy Food Environment Policy Index (Food-EPI): European Union.* Utrecht, Utrecht University, The Netherlands, 2021. https://www.jpi-pen.eu/images/reports/Food-EPI_EU_FINAL_20210305.pdf
Garcia	Garcia, K.K. and Gostin, L.O (2012). *One Health, One World— One Health, One World—The Intersecting Legal Regimes of Trade, Climate Change, Food Security, Humanitarian Crises, and Migration.* Laws 1 (1), 4-38. https://doi.org/10.3390/laws1010004
Glob Pan	Global Panel on Agriculture and Food Systems for Nutrition (2020). *Future Food Systems: For people, our planet, and prosperity.* London, UK. https://foresight.glopan.org/
Gostin	Gostin, L.O. and Katz, R. (2016). *The International Health Regulations: The Governing Framework for Global Health Security.* Milbank Q. 2016 Jun; 94(2): 264–313. https://dx.doi.org/10.1111%2F1468-0009.12186
HERA	HERA Consortium. *EU Research Agenda for the Environment, Climate and Health* 2021-2030.Final draft (2021). www.heraresearcheu.eu
IPBES	IPBES (2018): *The IPBES assessment report on land degradation and restoration.* Montanarella, L., Scholes, R., and Brainich, A. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. https://doi.org/10.5281/zenodo.3237393
IPBES2	IPBES (2019): *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.3831673.

Abbreviation used in Knowledge gaps	Complete Reference
IPCC1.5	Ebi, K. et al (2018). I*PCC The 1.5 Health Report*, https://ghhin.org/resource-library/
IPCC2	Prieur-Richard, A.H. et al.(2018). *IPCC Extended version: Global Research and Action Agenda on Cities and Climate Change Science.* https://www.ipcc.ch/site/assets/uploads/2019/07/Research-Agenda-Aug-10_Final_Long-version.pdf.
Jefferson	Jefferson T et al. (2008). *Physical interventions to interrupt or reduce the spread of respiratory viruses.* BMJ 2008;336:77 doi: https://doi.org/10.1136/bmj.39393.510347.BE.
JPI	Water JPI (2020). Strategic research and innovation agenda 2025
Kanger	Kanger, L. and Schot. J. (2019). *Deep transitions: Theorizing the long-term patterns of socio-technical change. Environmental Innovation and Societal Transitions*, 2019, Vol. 32, p.7-21. https://doi.org/10.1016/j.eist.2018.07.006
Konig	Konig L and Araújo-Soares V. (2022). *Will the Farm to Fork strategy be effective in changing food consumption behavior? A health psychology perspective.* Appl Econ Perspect Policy, 2022;1–18. https://doi.org/10.1002/aepp.13220 .
Lancet	Whitmee S et al. (2015) *Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation–Lancet Commission on Planetary health.* The Lancet 2015, 386: 1973–2028 https://doi.org/10.1016/S0140-6736(15)60901-1
Lilford	Lilford R et al. (2016) *The health of people who live in slums 2.* The Lancet 2016; 10068. https://DOI:10.1016/S0140-6736(16)31848-7.
MEA	Millennium Ecosystem Assessment (MEA), 2005. *Ecosystems and Human Well-being: Desertification Synthesis.*
Meijboom	Meijboom, F.L.B and Nieuwland, J. (2017). *Gezondheid in meervoud, Over ethische aspecten bij One Health en de noodzaak tot samenwerking binnen de ethiek.* Preadvies voor de Nederlandse Vereniging voor Bio-ethiek.
NCOH	NCOH research themes infographic and Strategic research agenda 2021. Research Themes - NCOH. https://ncoh.nl/research/research-themes
NSF	*Environmental and Human Health: Research Priorities* (2021), National Science Foundation, The public health and environmental research and education subcommittee
Otto	Otto IM et al. (2020). *Social tipping dynamics for stabilizing Earth's climate by 2050.* Proc Natl Acad Sci U S A, 2020; 117(5):2354-2365. https://doi.org/10.1073/pnas.1900577117
Paudel	Paudel S et al. (2021) *Nexus between water security framework and public health: A Comprehensive Scientific Review.* Water 2021, 13(10), 1365; https://doi.org/10.3390/w13101365 .
Pongsiri	Ponsiri, M.J. et al (2017). *The need for a systems approach to planetary health.* Lancet Planet Health. 2017, e257-e259. https://doi.org/10.1016/s2542-5196(17)30116-x
Rock	Brown, D. et al (2013). *White paper on the ethical dimensions of climate change.* Widener Law School Legal Studies Research Paper No. 13-58. https://ssrn.com/abstract=2304401
SAPEA	A Scientific Perspective on Microplastics in Nature and Society (2019). Science advice for policy by European Academies (SAPEA). ISBN 978-3-9820301-7-3. https://doi.org/10.26356/microplastics
Setty	Setty K et al. (2019). *Faster and Safer: Research Priorities in Water and Health.* Int J Hyg Environ Health 2019; 222(4): 593–606. doi: https://doi.org/10.1016/j.ijheh.2019.03.003.
Setzer	Setzer J and Vanhala LC. (2019). *Climate change litigation: A review of research on courts and litigants in climate governance.* WIRE Climate Change 2019; 10(3). https://doi.org/10.1002/wcc.580.
Steg	Steg L et al. (2021). *A research agenda to better understand the human dimensions of energy transitions.* Front. Psychol. 2021; https://doi.org/10.3389/fpsyg.2021.672776 .
UN	Braun J von, Afsana K, Fresco LO, Hassan M (editors) (2021). *Science and Innovations for Food Systems Transformation and Summit Actions.* UN Food Summit Science and Innovations 2021. https://sc-fss2021.org/wp-content/uploads/2021/09/ScGroup_Reader_UNFSS2021.pdf.
WHO	WHO Environmentally sustainable health systems: a strategic document. (2017) WHO/Europe | Public health services.
ZonMW	Huynen M et al. (2019). Kennisagenda Klimaat en Gezondheid. Den Haag: ZonMw, 2019.