

**H** HEURISTICS

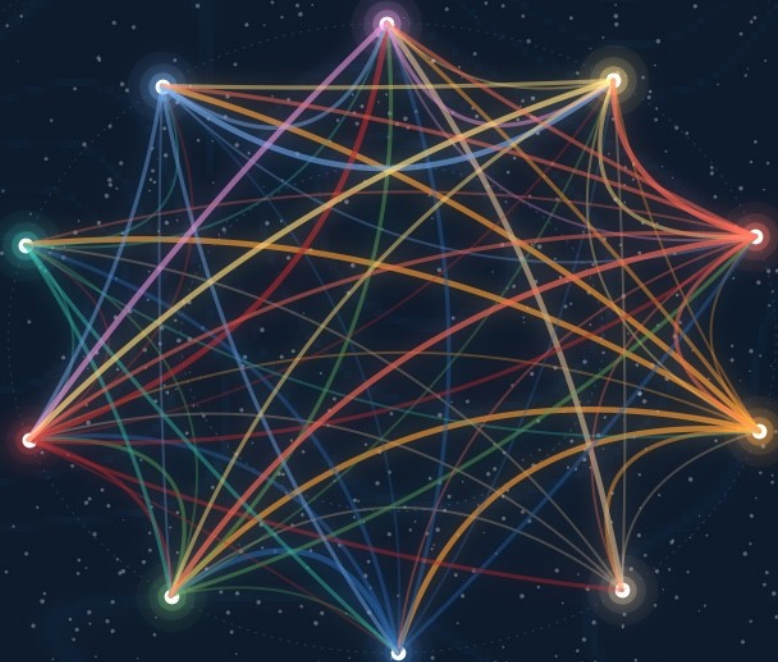
FLAGSHIP RESEARCH REPORT · OCTOBER 2026

# The Architecture of the Polycrisis Apocalypse

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Human Exposure, Interconnected Crises, and the  
Long-Term Survival Trajectory of Civilization

Exposure · Coupling · Cascades · Buffers · Persistence · Survivability · Prevention



**Hunter Hughes**

H Heuristics · Flagship Research Report

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# About This Report

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This report examines the polycrisis apocalypse: the possibility that humanity's gravest long-term danger is not one global catastrophe but a system of interacting pressures that wears down health, livelihoods, ecosystems and institutions over decades and centuries. It is the flagship statement of an argument that H Heuristics has developed across a series of studies. The monograph [The Architecture of the Polycrisis Apocalypse: Entropy, Cascading Failure, and the Long-Term Unraveling of Human Civilization](#) set out the thermodynamic and complexity-science case: civilizational decline begins when the overhead of maintaining complexity consistently exceeds the energy, capital and institutional capacity available to pay for it. The essay [The Polycrisis Apocalypse: Cascading Systemic Failure, Multi-Century Societal Regression, and the Thermodynamics of Civilizational Collapse](#) described the long-regression scenario in which that process runs unchecked. Earlier reports mapped [cascading risks](#), [human suffering](#), [the heat trap](#), [the geography of exposure](#) and [the architecture of civilization](#) itself.

This report brings those strands together and tests them. Its organizing idea is **compounding human exposure**. A hazard becomes a humanitarian problem when it reaches many people, lasts a long time and meets people who cannot protect themselves. The report therefore asks four questions. Which pressures expose the most people today? How do they interact, and when does interaction make the total harm larger than the sum of its parts? How will exposure change as warming, population growth, ageing and urbanization redraw the map of risk through 2100 and beyond? And where would preventive action protect the most people for the longest time?

The objective is not to declare humanity's future predetermined. Much of the popular literature on collapse moves from real trends to confident prophecy without showing its working. This report tries to show its working: it grades every major claim, separates established findings from scenarios, and presents nine original calculations whose assumptions are stated in full. It is written for researchers, policymakers, students and general readers, and assumes no technical background.

## How to read this report

Each section starts on a new page and can be read on its own. The report has four parts (Figure 1). Sections 1 to 3 define the polycrisis as a system, review the ideas it draws on, and rank ten pressures by how many people they reach. Sections 4 to 9 examine six clusters of pressure in turn: climate and pollution; poverty and inequality; water, food and ecosystems; biological and technological risks; economic and geopolitical fragility; and the demographic geography of risk. Sections 10 and 11 analyse the dynamics: the feedback loops, cascades and ratchets that make harm compound, and how the picture changes across centuries. Sections 12 to 14 build a framework for assessing human survivability, set out the prevention imperative and give the report's verdict.

## PART I · FRAMEWORK

|    |                                                                                                                |
|----|----------------------------------------------------------------------------------------------------------------|
| 01 | <b>The Polycrisis as a System</b><br>Definitions, thesis, exposure versus severity                             |
| 02 | <b>Intellectual Foundations</b><br>From Limits to Growth to the polycrisis literature                          |
| 03 | <b>The Global Human Exposure Baseline</b><br>Ten domains ranked by reach, persistence, severity, amplification |

## PART II · THE DOMAINS

|    |                                                                                                           |
|----|-----------------------------------------------------------------------------------------------------------|
| 04 | <b>The Climate and Pollution Nexus</b><br>Warming, extreme heat, air pollution and their loop             |
| 05 | <b>Poverty and Unequal Survivability</b><br>Why the same hazard harms the poor most                       |
| 06 | <b>Water, Food and Ecological Stability</b><br>Resource systems, ecosystem decline and hunger             |
| 07 | <b>Biological and Technological Pressures</b><br>Disease, antimicrobial resistance, cyber, AI, nuclear    |
| 08 | <b>Economic Fragility and Geopolitical Fragmentation</b><br>Debt, supply chains, conflict and cooperation |
| 09 | <b>The Demographic Geography of Risk</b><br>Where people will live, and what they will face               |

## PART III · DYNAMICS AND TIME

|    |                                                                                              |
|----|----------------------------------------------------------------------------------------------|
| 10 | <b>Feedback Loops and Cascade Dynamics</b><br>Loops, super-additivity, ratchets and cascades |
| 11 | <b>The Polycrisis Across Centuries</b><br>2025–2050, 2050–2100, 2100–2300 and beyond         |

## PART IV · RESPONSE

|    |                                                                                                 |
|----|-------------------------------------------------------------------------------------------------|
| 12 | <b>The Architecture of Human Survivability</b><br>Hazard × exposure × vulnerability; four tiers |
| 13 | <b>The Prevention Imperative</b><br>Interventions that cut many risks at once                   |
| 14 | <b>Conclusion</b><br>Answer, verdict and research agenda                                        |

**Figure 1. The structure of the report.** Three framework sections establish the thesis and the exposure baseline, six examine the principal domains of pressure, two analyse the dynamics of compounding and its time horizons, and three set out the survivability framework, the prevention agenda and the conclusions.

Source: *H Heuristics*.

Blue underlined text is a hyperlink. Where a specific scientific result is cited, the link goes to the DOI record of the peer-reviewed source; every DOI was checked against its registered title before publication, and the full list appears in the References. Where a statistic comes from an international agency, the link goes to the agency's report or release. Where a concept is introduced, the link may go to a reference article.

## Evidence grades

Claims are graded on the four-level scale used across H Heuristics reports. The grade describes the state of knowledge, not the importance of the claim.

**Table 1.** Evidence grades used in this report

| Grade                            | Meaning                                                                                              | Example from this report                                                                                          |
|----------------------------------|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| <b>A: Established</b>            | Confirmed by multiple independent lines of evidence and assessed as such by major scientific bodies. | Human influence has warmed the climate; air pollution is among the leading risk factors for death worldwide       |
| <b>B: Well supported</b>         | Strong evidence from several lines of work, with unresolved detail or some dissent.                  | Correlated harvest shocks across breadbaskets raise systemic food risk; thin buffers make coupled systems fragile |
| <b>C: Plausible or contested</b> | A credible argument and partial evidence; specialists disagree about size or mechanism.              | Climate change raises the risk of armed conflict; Earth-system tipping cascades could begin this century          |
| <b>D: Speculative</b>            | A scenario or hypothesis offered for evaluation, labelled as such wherever it appears.               | A global collapse followed by a regression lasting centuries                                                      |

*A single topic can carry several grades. That extreme heat is increasing is graded A; that it will make large regions uninhabitable for most people by 2100 is graded C; that it will end civilization is graded D.*

## A note on the figures and calculations

The report contains 29 figures and 22 tables. Nine figures chart published data, drawn from [Our World in Data](#) extracts of HadCRUT5 temperatures, atmospheric carbon dioxide, the UN World Population Prospects 2024, World Bank poverty estimates, FAO hunger estimates, the Living Planet Index, the EM-DAT disaster database and the Uppsala Conflict Data Program, or from figures stated in cited reports. Nine figures present original calculations written in Python for this report: a coupling matrix and network analysis of ten pressures; a model of super-additive harm when shocks coincide; a comparison of acute and chronic harm; a model of repeated shocks and recovery; the probability of simultaneous harvest failures under correlation; threshold cascades on networks with different buffers; the persistence of pollutants and committed sea-level rise; the multiplicative structure of risk; and a stylized Polycrisis Exposure Index to 2300. Each caption states what was computed and with which assumptions. These models are illustrative. They show how mechanisms behave, not what will happen. The remaining figures are diagrams drawn for this report.

## How to cite

Hughes, H. (2026). *The Architecture of the Polycrisis Apocalypse: Human Exposure, Interconnected Crises, and the Long-Term Survival Trajectory of Civilization*. H Heuristics Flagship Research Report. The report synthesizes published research and presents original calculations and propositions, which are labelled as such. It builds on Hughes, H. (2026), *The Architecture of the Polycrisis Apocalypse: Entropy, Cascading Failure, and the Long-Term Unraveling of Human Civilization*, figshare preprint, [doi:10.6084/m9.figshare.34856832](https://doi.org/10.6084/m9.figshare.34856832).

# Executive Summary

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## Abstract

Public imagination tends to picture the end of civilization as a single event: a nuclear exchange, an asteroid, an engineered pandemic. This report argues that the more probable and more insidious danger has a different shape. It is a **polycrisis apocalypse**: an interconnected system of environmental, biological, economic, demographic, technological and geopolitical pressures that reinforce one another and produce cumulative harm greater, or more persistent, than any single crisis would cause alone. The report develops this thesis in four steps. It defines the polycrisis as a system of root drivers, transmission pathways and human exposure. It ranks ten pressures by reach, persistence, severity and capacity to amplify others, and finds that warming and extreme heat, air pollution, and poverty and inequality form the system's core. It analyses six feedback loops and shows, with original calculations, how coupling, correlation and thin buffers convert separate shocks into compounding harm. And it traces exposure across time horizons from 2025 to the millennial scale. The report concludes that the polycrisis is real and already under way, but that its endpoint is not fixed. Collapse is neither inevitable nor instantaneous. The scale of future harm will depend less on any single hazard than on whether societies rebuild buffers, redundancy and adaptive capacity faster than compounding pressures erode them.

## The central thesis

**Central thesis.** The polycrisis apocalypse is not a single global catastrophe. It is an interconnected system of environmental, biological, economic, demographic, technological and geopolitical pressures that can reinforce one another, producing cumulative harm that is greater or more persistent than any individual crisis alone.

The thesis makes three testable claims. First, that the pressures are **coupled**: stress in one domain raises stress in others through identifiable mechanisms. Second, that coupling can make harm **super-additive**: when shocks coincide and buffers are thin, the combined damage exceeds the sum of the separate damages. Third, that harm can become **persistent**: some pressures, such as accumulated carbon dioxide, sea-level rise and biodiversity loss, outlast the generation that caused them, and repeated shocks can trap societies in states of low capacity from which recovery is slow. Each claim is examined against evidence and graded.

## The polycrisis in numbers

**Table 2.** Selected indicators of human exposure to the polycrisis

| Indicator                                                                 | Latest estimate                                     | Source                                               |
|---------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------------------------|
| Global surface temperature, 2024, above 1850–1900                         | about 1.55 °C, the first calendar year above 1.5 °C | <a href="#">WMO State of the Global Climate 2024</a> |
| People living in contexts highly vulnerable to climate change             | 3.3–3.6 billion                                     | <a href="#">IPCC AR6 Synthesis Report</a>            |
| Share of people breathing air above the WHO PM <sub>2.5</sub> guideline   | 99 per cent                                         | <a href="#">WHO</a>                                  |
| Deaths attributable to air pollution, 2023                                | 7.9 million                                         | <a href="#">State of Global Air 2025</a>             |
| Annual heat-related deaths, 2012–2021 average                             | about 546,000                                       | <a href="#">Lancet Countdown 2025</a>                |
| People in extreme poverty (below \$3 a day), 2025                         | about 808 million                                   | <a href="#">World Bank, via Our World in Data</a>    |
| Chronically undernourished people, 2024                                   | 673 million (8.2 per cent)                          | <a href="#">FAO SOFI 2025</a>                        |
| People lacking safely managed drinking water, 2024                        | 2.1 billion                                         | <a href="#">WHO/UNICEF JMP 2025</a>                  |
| Planetary boundaries transgressed                                         | 7 of 9                                              | <a href="#">Planetary Health Check 2025</a>          |
| Average decline in monitored wildlife populations since 1970              | 73 per cent                                         | <a href="#">WWF Living Planet Report 2024</a>        |
| State-based armed conflicts, 2025                                         | 65, the most since 1946                             | <a href="#">UCDP</a>                                 |
| People forcibly displaced, end of 2024                                    | 123.2 million                                       | <a href="#">UNHCR Global Trends</a>                  |
| People in countries spending more on interest than on health or education | 3.4 billion                                         | <a href="#">UNCTAD A World of Debt 2025</a>          |

*Estimates come from different years and methods and should not be summed: the same person can be exposed to several pressures at once, which is the point of the polycrisis framing.*

## Principal findings

- 1. The polycrisis is a system, not a list (Grade B).** The ten pressures examined are densely coupled. In the report's coupling matrix, 66 of 90 possible directed links between domains are active, 12 of them strong (Figure 18). Climate change and geopolitical fragmentation are the system's main transmitters of stress; poverty, ill health and food insecurity are where harm accumulates. This structure explains why single-sector responses so often disappoint.
- 2. Exposure is vast, chronic and unequal (Grade A).** Most of humanity already lives with at least one major pressure. Almost everyone breathes polluted air; about four billion people face severe water scarcity for at least one month a year; between 3.3 and 3.6 billion people live in contexts highly vulnerable to climate change (Figure 6). Exposure is concentrated where adaptive capacity is weakest.
- 3. Three pressures form the core of the system (Grade B).** Ranked by reach, persistence, severity and amplification, warming and extreme heat score highest (4.75 of 5), followed by air pollution and by poverty and inequality (4.20 each) (Figure 7). Warming is the system-wide driver; pollution has the broadest direct health burden; poverty decides who is harmed by every other hazard.
- 4. Coinciding shocks can be super-additive, but only when buffers are thin (Grade B).** In the report's ten-domain model, shocks that strike all domains at once caused 1.24 times the harm of the

same shocks arriving separately when buffers were thin, but only 1.01 times when buffers were deep, and exactly the sum when transmission was linear (Figure 21). Super-additivity is a property of thresholds and depleted slack, which means it can be designed against.

5. **Repeated shocks can ratchet capacity down (Grade B).** When damaging events arrive faster than societies recover from them, capacity does not oscillate around a stable level; it falls and stays low. In the report's model, with an eight-year recovery time, a society hit by a major shock every ten years kept a median capacity of 0.93, while one hit every five years fell to 0.07 within a century (Figure 23). This is the disaster–debt–resilience loop in quantitative form.
6. **Correlation is the hidden multiplier (Grade B).** If five major grain-producing regions each suffer a one-in-twenty-year harvest failure independently, three or more fail together about once in 902 years. If their shocks are moderately correlated ( $\rho = 0.4$ ), as shared climate patterns can make them, the same event recurs about once in 67 years, 13 times more often (Figure 12).
7. **Chronic harm can exceed catastrophic harm (Grade B).** A slow polycrisis that erodes capacity produces less dramatic harm in any year than an acute catastrophe, but in the report's illustration its cumulative harm overtook the catastrophe's total after about 112 years and reached three times that total within two centuries (Figure 2). The polycrisis apocalypse is dangerous precisely because it rarely looks like an apocalypse.
8. **The map of risk is being redrawn (Grade A–B).** World population is projected to peak at about 10.3 billion in the mid-2080s, with Africa growing from 1.51 billion today to 3.81 billion by 2100, 37 per cent of humanity (Figure 16). Most of the growth will occur in hot, rapidly urbanizing, lower-income regions, while ageing raises heat sensitivity everywhere. Demography, not only climate, decides how many people are exposed.
9. **Some harms are effectively permanent on human time scales (Grade A).** About 24 per cent of a pulse of carbon dioxide remains in the atmosphere after a thousand years, and sea level will keep rising for centuries: by 2 to 3 metres over two thousand years if warming is held to 1.5 °C, and 2 to 6 metres at 2 °C (Figure 24). Pollution of the air, by contrast, clears within days of emissions stopping. Persistence should shape priorities.
10. **A global collapse followed by multi-century regression is possible but not probable on current evidence (Grade D).** The report takes the long-regression scenario seriously as a tail risk but finds no basis for treating that scenario as a forecast. The evidence supports a narrower and more actionable claim: the polycrisis is already causing large, unequal, compounding harm, and the window for cheap prevention is now.

## The verdict

The polycrisis apocalypse is best understood as an architecture of compounding human exposure. Its foundations are energy systems, land use, consumption and governance; its load-bearing walls are warming, pollution and poverty; its weak joints are the buffers, reserves and institutions that absorb shocks. The architecture does not determine an outcome. It determines which interventions matter. Because risk is the product of hazard, exposure and vulnerability, reducing any one of them reduces the whole (Figure 11), and because the pressures are coupled, interventions that act on the system's core, such as clean energy, clean air, social protection, water security and early warning, reduce several risks at once.

**In one sentence.** The end of civilization, if it comes, is more likely to arrive as a long accumulation of interacting harms than as a single blow, and that is both the danger and the opportunity: what accumulates can also be interrupted.

## 01

## INTRODUCTION



# 1. The Polycrisis as a System

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## 1.1 Two images of the end

There are two ways to imagine the end of a civilization. The first is the image that dominates films, novels and much of the academic literature on [global catastrophic risk](#): a single, sudden event of overwhelming force. A nuclear war, an asteroid impact, a supervolcano or an engineered pathogen strikes, and within months the institutions that sustain billions of people stop working. The second image is slower and harder to see. No single event is decisive. Instead, a warming climate, polluted air, depleted aquifers, failing harvests, rising debt, ageing populations, fraying alliances and repeated disasters press on the same societies at the same time. Each pressure is survivable alone. Together they wear down the reserves, institutions and trust that allowed each previous crisis to be absorbed, until a shock that would once have been routine becomes unmanageable.

This report is about the second image, which it calls the **polycrisis apocalypse**. The word apocalypse is used deliberately but carefully. In its original sense it means an unveiling, and the report's purpose is to reveal the structure of a danger that is usually discussed one piece at a time. It does not mean that the outcome is fixed, or that the end is near. The central argument is that the second image describes a more probable path to severe and lasting harm than the first, and that it is more dangerous partly because it is less visible: it accumulates through chronic illness, lost income, abandoned schooling and deferred maintenance rather than through headline events.

Figure 2 illustrates the difference with a simple calculation. An acute catastrophe produces a spike of harm that decays as society recovers. A chronic polycrisis produces a lower but rising stream of harm, punctuated by shocks whose damage grows as adaptive capacity erodes. In the illustration, the polycrisis path never matches the catastrophe's peak, yet its cumulative harm overtakes the catastrophe's entire toll after about 112 years and reaches 3.0 times that toll after two centuries. The illustration is not a forecast. It shows why an accounting of risk that looks only at peak severity will systematically underweight slow, compounding harm.

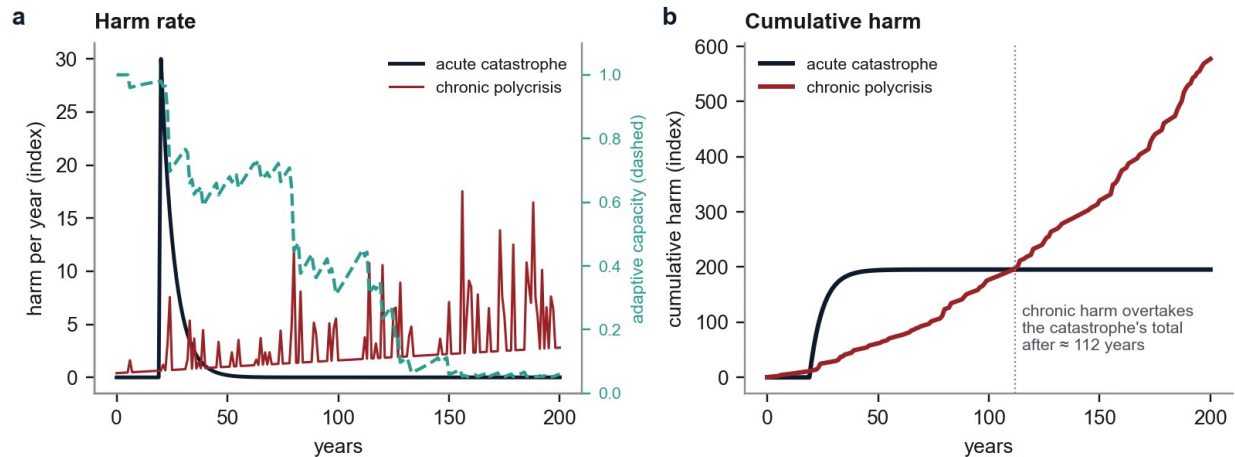


**Figure 2. An acute catastrophe versus a chronic polycrisis.** (a) Harm per year: the acute path (navy) is a single large shock followed by recovery; the polycrisis path (red) is a rising background of chronic harm plus shocks that arrive more often over time and do more damage as adaptive capacity (dashed) erodes. (b) Cumulative harm: the polycrisis overtakes the catastrophe's total after about a century.

Source: H Heuristics calculation. Shocks arrive at a rate rising from 0.15 to 0.45 per year with gamma-distributed severity; damage is amplified by up to 3.2 times as capacity falls; capacity recovers logistically. Arbitrary units; illustrative only.

**Table 3. Singular catastrophe and polycrisis apocalypse compared**

| Feature                    | Singular catastrophe                            | Polycrisis apocalypse                                                          |
|----------------------------|-------------------------------------------------|--------------------------------------------------------------------------------|
| <b>Trigger</b>             | One dominant event (war, impact, pandemic)      | Many interacting pressures; no single decisive event                           |
| <b>Onset</b>               | Sudden: days to months                          | Gradual with abrupt episodes: years to centuries                               |
| <b>Visibility</b>          | Unmistakable; generates immediate response      | Diffuse; harm is normalized and often uncounted                                |
| <b>Mechanism</b>           | Direct destruction of people and infrastructure | Coupling, cascades, correlated shocks and buffer exhaustion                    |
| <b>Who is harmed first</b> | Those near the event                            | Those with least adaptive capacity, wherever they are                          |
| <b>Recovery</b>            | Possible if core institutions survive           | Impeded because each shock arrives before recovery from the last               |
| <b>Persistence</b>         | Damage decays after the event                   | Some pressures (CO <sub>2</sub> , sea level, extinction) persist for centuries |
| <b>Prevention</b>          | Avoid or deflect the event                      | Reduce exposure and vulnerability across many systems at once                  |

The two are not exclusive. A polycrisis raises the probability of acute catastrophes, for example by increasing the risk of conflict, and an acute catastrophe would be far more damaging in a world already weakened by chronic pressures.

## 1.2 Defining the polycrisis

The term [polycrisis](#) was coined by the French philosopher Edgar Morin and Anne Brigitte Kern in *Homeland Earth* (published in French in 1993 and in English in 1999) to describe a planet whose problems, antagonisms and crises had become so intertwined that none could be understood or solved in isolation. It was revived in European politics in the 2010s, popularized by the historian Adam Tooze after 2022, and has since been given a more precise scientific definition. Lawrence and colleagues at the

Cascade Institute define a global polycrisis as the causal entanglement of crises in multiple global systems in ways that significantly degrade humanity's prospects ([Lawrence et al. 2024](#)). The key word is *causal*. A world with many simultaneous problems is not necessarily in a polycrisis. It is in one when those problems cause, amplify or prolong one another.

This report adopts that definition and extends it in three ways. It focuses on **human exposure**, the number of people a pressure reaches and how long they are exposed, rather than on the state of global systems alone. It extends the time horizon from the coming decades to centuries and, where physical processes allow, millennia. And it treats the polycrisis as an **architecture**: a structure of drivers, pressures, transmission pathways and buffers whose shape determines how harm flows and where it accumulates. The *polycrisis apocalypse* is then defined as the limiting case: a trajectory in which compounding pressures persistently outrun repair, so that harm becomes cumulative and capacity declines from generation to generation.

**Table 4.** Key terms used in this report

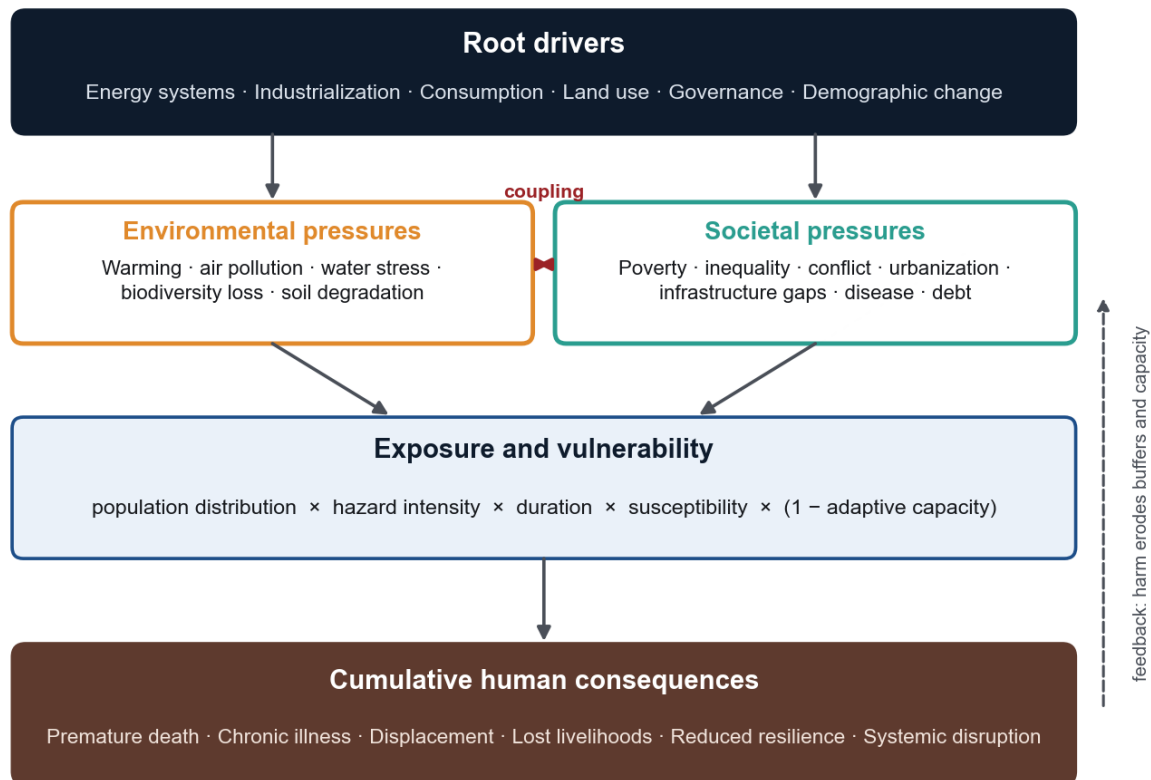
| Term                         | Meaning in this report                                                                                                                                     |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Pressure</b>              | A sustained source of potential harm, such as warming, pollution, poverty or debt. Pressures change slowly and set the background level of risk.           |
| <b>Shock</b>                 | A discrete, damaging event, such as a heatwave, flood, harvest failure, financial crisis or war, that tests a system's buffers.                            |
| <b>Hazard</b>                | The physical or social event or trend that could cause harm (IPCC usage).                                                                                  |
| <b>Exposure</b>              | The presence of people, livelihoods and assets in places and settings where a hazard can affect them.                                                      |
| <b>Vulnerability</b>         | The propensity to be harmed: susceptibility to damage combined with a lack of capacity to cope and adapt.                                                  |
| <b>Coupling</b>              | A causal link through which stress in one domain raises stress in another.                                                                                 |
| <b>Buffer</b>                | Slack that absorbs shocks before they are transmitted: savings, food stocks, spare capacity, redundant infrastructure, trust, fiscal space.                |
| <b>Super-additivity</b>      | The condition in which the harm of coinciding shocks exceeds the sum of their separate harms.                                                              |
| <b>Ratchet</b>               | A process in which repeated shocks lower capacity faster than it recovers, so that losses accumulate.                                                      |
| <b>Polycrisis apocalypse</b> | A trajectory in which coupled pressures persistently outrun repair, producing cumulative, persistent and unequal harm. A scenario class, not a prediction. |

*Hazard, exposure and vulnerability follow the risk framework of the [IPCC Sixth Assessment Report](#).*

## 1.3 The architecture of interconnected crises

The report organizes the polycrisis into four layers (Figure 3). At the base are **root drivers**: the energy systems, patterns of industrialization and consumption, land use, governance and demographic change that generate pressure in the first place. These produce two families of **pressures**. Environmental pressures include warming, air pollution, water stress, biodiversity loss and soil degradation. Societal pressures include poverty, inequality, conflict, rapid urbanization, gaps in infrastructure, disease and debt. The two families are coupled: environmental stress deepens poverty and conflict, while poverty and conflict deepen environmental stress, for example by forcing reliance on polluting fuels or delaying international cooperation.

Pressures harm people only through the third layer, **exposure and vulnerability**. The same heatwave can be a nuisance in a well-cooled city and a mass-casualty event in a crowded informal settlement. The report therefore treats risk as a product: population distribution, hazard intensity and duration, susceptibility, and the absence of adaptive capacity. The fourth layer is the **cumulative human consequence**: premature death, chronic illness, displacement, lost livelihoods, reduced resilience and systemic disruption. The architecture is closed by a feedback: consequences erode the buffers and capacity that determine vulnerability to the next shock. This loop, more than any single hazard, is what makes a polycrisis dangerous.



Conceptual framework, not a calibrated model. It follows the IPCC risk framing of hazard, exposure and vulnerability, extended to non-climatic pressures.

**Figure 3. The architecture of interconnected crises.** Root drivers generate coupled environmental and societal pressures; these become harm only through exposure and vulnerability; cumulative consequences then feed back to erode buffers and adaptive capacity.

Source: H Heuristics. Conceptual framework, not a calibrated model; follows the hazard–exposure–vulnerability framing of [IPCC AR6 Working Group II](#).

The report's most important analytical move is to connect the **prevalence of hazards to the distribution of people**. A dangerous environmental condition becomes a large humanitarian problem only when many people are exposed, especially people who lack the resources or infrastructure to protect themselves. This is why the report repeatedly returns to demography and to inequality. Over the coming century, the number of people exposed to dangerous heat will depend at least as much on where population growth occurs as on how much the planet warms.

## 1.4 Exposure is not the same as severity

Discussions of existential and catastrophic risk often rank threats by their worst plausible outcome. That is the right question for some purposes, but it is incomplete. The report distinguishes eight principal domains of pressure (Figure 4) and argues that they should not be ranked solely by perceived severity. Air pollution has exceptionally broad exposure: almost everyone on Earth breathes air that exceeds the World Health Organization's guideline, and it causes millions of deaths every year. Nuclear war has a different profile: potentially catastrophic consequences, including a nuclear winter that could threaten global food supply ([Xia et al. 2022](#)), but a far less certain probability and a much more event-dependent pattern of exposure.

Both profiles matter, and both appear in this report. But the polycrisis lens gives special weight to pressures that are broad, chronic and amplifying, because these are the ones that compound. A threat that harms a billion people a little every year, weakens their health and income, and makes them more vulnerable to the next shock can, over decades, produce more cumulative harm than a rarer and more spectacular event.

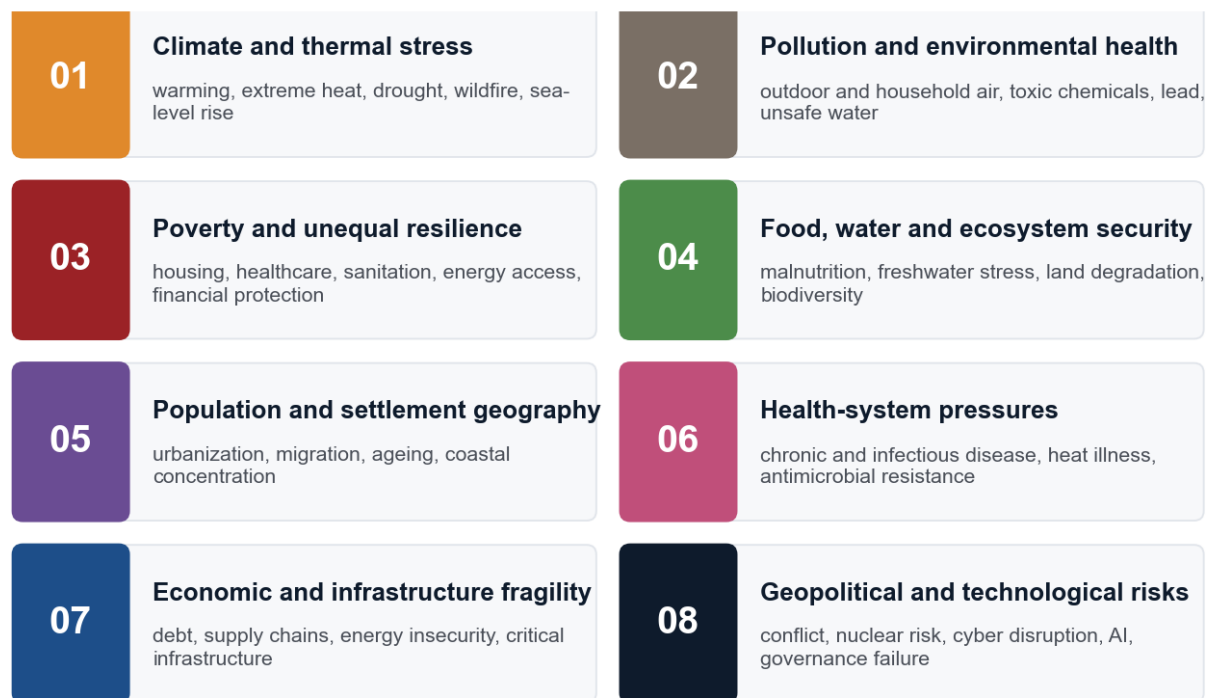


**Figure 4. The eight principal domains of pressure examined in this report.** Sections 4 to 9 take them in clusters; Section 3 ranks the ten specific pressures they contain.

Source: H Heuristics.

## 1.5 Three claims and how the report tests them

The central thesis rests on three claims. Each is examined with evidence and, where evidence is thin, with transparent calculations.

- **Coupling.** Pressures are causally linked. The report tests this by tracing specific mechanisms in Sections 4 to 9 and by assembling them into a coupling matrix of ten domains in Section 10, whose network structure identifies which pressures transmit stress and which accumulate it.
- **Super-additivity.** Coupled shocks can cause more harm together than apart. The report tests when this is true, and when it is not, using models of shocks on a coupled network, correlated harvest failures and threshold cascades (Section 10).
- **Persistence.** Some harms outlast their causes. The report distinguishes pressures that can be reversed within years from those that persist for centuries (Section 11), and models how repeated shocks can lower capacity faster than it recovers.

If the three claims hold, the polycrisis is more than the sum of its parts and must be addressed as a system. If they fail, the polycrisis is a useful label for a list of separate problems. The report finds that all three hold under identifiable conditions, and that those conditions, especially thin buffers and correlated exposure, are themselves things that policy can change.

## 1.6 What this report does not claim

Three cautions apply throughout. First, the report does not predict a sudden global collapse. The H Heuristics monograph on which it builds ([Hughes 2026](#)) explicitly concludes that collapse is neither inevitable nor instantaneous, and this report agrees. Second, it does not claim that every pressure will worsen everywhere. Extreme poverty has fallen dramatically since 1990, air quality has improved across much of Europe, North America and recently China, and hunger declined slightly in 2024. Prevalence is not destiny. Third, it does not present long-horizon scenarios as forecasts. Detailed predictions of populations or political systems centuries ahead would be too uncertain to be useful. For long horizons the report concentrates on durable physical processes and on conditional statements of the form 'if this pathway, then this range of exposure'.

The earlier H Heuristics essay on [the polycrisis apocalypse](#) described a severe scenario in which cascading failure leads to a regression lasting centuries. This report treats that scenario as the tail of a distribution, grades it D, and asks what evidence would be needed to move it up or down the scale. Its main focus is on the body of the distribution: the large, measurable, compounding harm that the polycrisis is causing now and is likely to cause through the rest of this century.

## 02

## LITERATURE REVIEW



## 2. Intellectual Foundations

### 2.1 Overshoot and limits

The idea that interlocking pressures could undermine industrial civilization is half a century old. In 1972 *\*The Limits to Growth\** used one of the first global computer models to explore how population, industrial output, food production, resource depletion and pollution interact. Its standard run did not predict a date of collapse, but it showed that in a coupled system with delays, growth could overshoot the planet's carrying capacity and then decline, and that solving one problem, such as resource scarcity, could simply shift the binding constraint to another, such as pollution. That insight, that the constraints are coupled and that relieving one can tighten another, is central to the polycrisis concept. Later models such as HANDY added inequality, showing that the separation of elites from the consequences of resource depletion can delay the response until it is too late ([Motesharrei et al. 2014](#)).

Biophysical economists extended the argument to energy. The [energy return on investment](#) of a fuel, the ratio of energy delivered to energy spent obtaining it, sets the surplus available to run everything else in a society. Early oil discoveries in the United States returned well over 100 units of energy for each unit invested; estimates for global oil and gas production in the mid-2000s were closer to 18:1 ([Hall et al. 2014](#)), and the return measured at the point of final use is lower still, at roughly 6:1 for fossil fuels ([Brockway et al. 2019](#)). The H Heuristics monograph argues that falling net energy and rising maintenance costs together squeeze the surplus available for adaptation. This report treats the argument as plausible (Grade C): estimates are sensitive to boundaries, and the falling cost of solar and wind power is changing the picture rapidly.

### 2.2 Complexity, coupling and collapse

A second tradition asks why complex systems fail. The sociologist Charles Perrow's *\*Normal Accidents\** (1984) argued that in systems that are both interactively complex and tightly coupled, failures will occur through unexpected combinations of small faults, and that adding safety features can add new pathways to failure. The anthropologist Joseph Tainter's *\*The Collapse of Complex Societies\** (1988) proposed that societies solve problems by adding complexity, in the form of bureaucracy, specialization and infrastructure, but that the returns on complexity eventually diminish. When the cost of maintaining complexity exceeds its benefits, collapse, understood as a rapid loss of complexity, becomes an economical response. The H Heuristics monograph builds on this idea: a society in which a growing share of resources goes to responding to recurring crises, rather than to building durable capacity, is approaching the point at which complexity no longer pays for itself.

Thomas Homer-Dixon and colleagues combined these ideas into a theory of **synchronous failure**: the convergence of multiple slowly building stresses with fast-moving triggers in a hyper-connected global system ([Homer-Dixon et al. 2015](#)). Resilience scientists have developed the dynamical side. Systems

approaching a critical transition often show early-warning signals such as slowing recovery from small perturbations ([Scheffer et al. 2009](#)), and the collapse of social–ecological systems can be understood as a loss of resilience across linked scales ([Cumming & Peterson 2017](#)). These ideas inform the report's treatment of buffers and ratchets in Section 10.

## 2.3 Risk society and networked risk

A third tradition concerns the nature of modern risk. The sociologist Ulrich Beck's *\*Risk Society\** (1986) argued that modern risks are manufactured by modernization itself and do not respect national borders or social classes, even though their burdens fall unequally. Complexity scientists later showed how global interconnection transforms risk. Dirk Helbing warned that hyper-connected systems, in finance, supply chains, information and infrastructure, can produce cascading failures that no single actor controls ([Helbing 2013](#)). Miguel Centeno and colleagues described the emergence of *global systemic risk*, in which the very efficiency and interconnection that create prosperity also create new channels for contagion ([Centeno et al. 2015](#)). Andrew Haldane and Robert May used ecological models to show why a banking system optimized for efficiency became fragile ([Haldane & May 2011](#)). The global financial crisis of 2008 and the supply-chain disruptions of 2020–2022 gave those warnings concrete form.

## 2.4 Earth-system science

The fourth and most quantitative tradition is Earth-system science. The [planetary boundaries](#) framework defines a safe operating space for humanity across nine Earth-system processes ([Steffen et al. 2015](#)). By 2023, six of the nine boundaries were assessed as transgressed ([Richardson et al. 2023](#)); the [Planetary Health Check 2025](#) added ocean acidification, making seven. A further step defined *safe and just* boundaries that also protect people from significant harm, and found that most are already exceeded ([Rockström et al. 2023](#)).

Climate science has meanwhile moved from single hazards to interactions. **Compound events**, combinations of drivers or hazards such as concurrent heat and drought, or storm surge combined with river flooding, can cause far more damage than either alone ([Zscheischler et al. 2018](#)). Assessments of **tipping elements**, such as ice sheets, the Atlantic overturning circulation and the Amazon rainforest, suggest several could be triggered within the range of warming expected this century ([Armstrong McKay et al. 2022](#)), and that tipping in one could raise the probability of tipping in others ([Wunderling et al. 2021](#)). The [IPCC Sixth Assessment Report](#) concluded with high confidence that climate and non-climatic risks will increasingly interact, creating compound and cascading risks that are more complex and difficult to manage.

## 2.5 From catastrophic risk to polycrisis

The study of [global catastrophic risk](#) has historically focused on discrete hazards. A turning point came when researchers began to classify risks not by their trigger but by the critical systems they threaten, the mechanisms by which harm spreads globally, and the failures of prevention and mitigation that allow it to spread ([Avin et al. 2018](#)). The 'Climate Endgame' paper called for systematic study of how climate change could contribute to catastrophic outcomes not directly but through cascades into famine, extreme weather, conflict and disease ([Kemp et al. 2022](#)). The polycrisis literature completes that shift. Lawrence and colleagues identify three causal pathways by which crises become entangled: **common stresses** that act on several systems at once, **domino effects** in which one crisis triggers another, and **inter-systemic feedbacks** in which crises amplify each other ([Lawrence et al. 2024](#)). Søgaaard Jørgensen and

colleagues describe 'Anthropocene traps': self-reinforcing dynamics, such as dependence on fossil fuels or short-term political horizons, that lock societies into harmful trajectories ([Søgaard Jørgensen et al. 2024](#)).



**Figure 5. The intellectual history of the polycrisis concept.** Four traditions, Earth-system science, the study of complexity and collapse, the theory of risk and the polycrisis literature itself, converge on the idea that interacting pressures can produce harm greater than their sum.  
*Source: H Heuristics, compiled from the works cited in Section 2.*

## 2.6 What the literature leaves open

The literature provides strong foundations but leaves four gaps that this report attempts to fill.

**Table 5.** Strands of the literature and the gaps this report addresses

| Strand                      | Core insight                                           | What it leaves open                                      | This report's response                                   |
|-----------------------------|--------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|
| Limits and overshoot        | Coupled constraints; relieving one can tighten another | How harm is distributed among people                     | Exposure-weighted ranking of pressures (Section 3)       |
| Complexity and collapse     | Tight coupling and rising overhead make failure normal | Measurable conditions for super-additive harm            | Models of coupling, buffers and correlation (Section 10) |
| Networked and systemic risk | Interconnection spreads contagion                      | Links between financial, ecological and social contagion | A ten-domain coupling matrix (Section 10)                |

| Strand               | Core insight                                                 | What it leaves open                            | This report's response                                    |
|----------------------|--------------------------------------------------------------|------------------------------------------------|-----------------------------------------------------------|
| Earth-system science | Boundaries, tipping points, compound events                  | Translation into human exposure over centuries | Persistence classes and time horizons (Section 11)        |
| Polycrisis studies   | Causal entanglement through stresses, dominoes and feedbacks | A framework for prioritizing prevention        | Survivability tiers and a prevention map (Sections 12–13) |

Each strand is graded in the text where it is used; most of the core insights are graded A or B.

The first gap is **distribution**: most systemic-risk analyses describe global systems rather than the people who live within them. The second is **conditions**: claims that crises amplify one another are common, but the conditions under which interaction is super-additive rather than merely additive are rarely specified. The third is **time**: most assessments end in 2050 or 2100, although some of the most consequential pressures persist for centuries. The fourth is **priority**: a list of interacting threats is paralysing unless it identifies where action would protect the most people for the longest time. The remaining sections address each gap in turn.

## 03

## EXPOSURE BASELINE



## 3. The Global Human Exposure Baseline

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### 3.1 How many people does each pressure reach?

The first step in mapping the polycrisis is to ask a simple question of each pressure: how many people does it reach today? Figure 6 assembles the most recent authoritative estimates. The pattern is striking. The pressures that reach the most people are not the ones that dominate news coverage. Almost the entire population of the planet, about 99 per cent according to the [World Health Organization](#), breathes air with fine-particle concentrations above the WHO guideline of 5 micrograms per cubic metre. About four billion people experience severe water scarcity for at least one month of the year ([Mekonnen & Hoekstra 2016](#)). The IPCC estimates that 3.3 to 3.6 billion people live in contexts highly vulnerable to climate change ([IPCC AR6 SYR](#)). About 3.4 billion lack safely managed sanitation and 2.1 billion lack safely managed drinking water ([WHO/UNICEF JMP 2025](#)). An estimated 2.6 billion people cannot afford a healthy diet ([FAO SOFI 2025](#)), and 1.81 billion live where a one-in-a-hundred-year flood would inundate them to a depth of more than 15 centimetres ([Rentschler et al. 2022](#)).

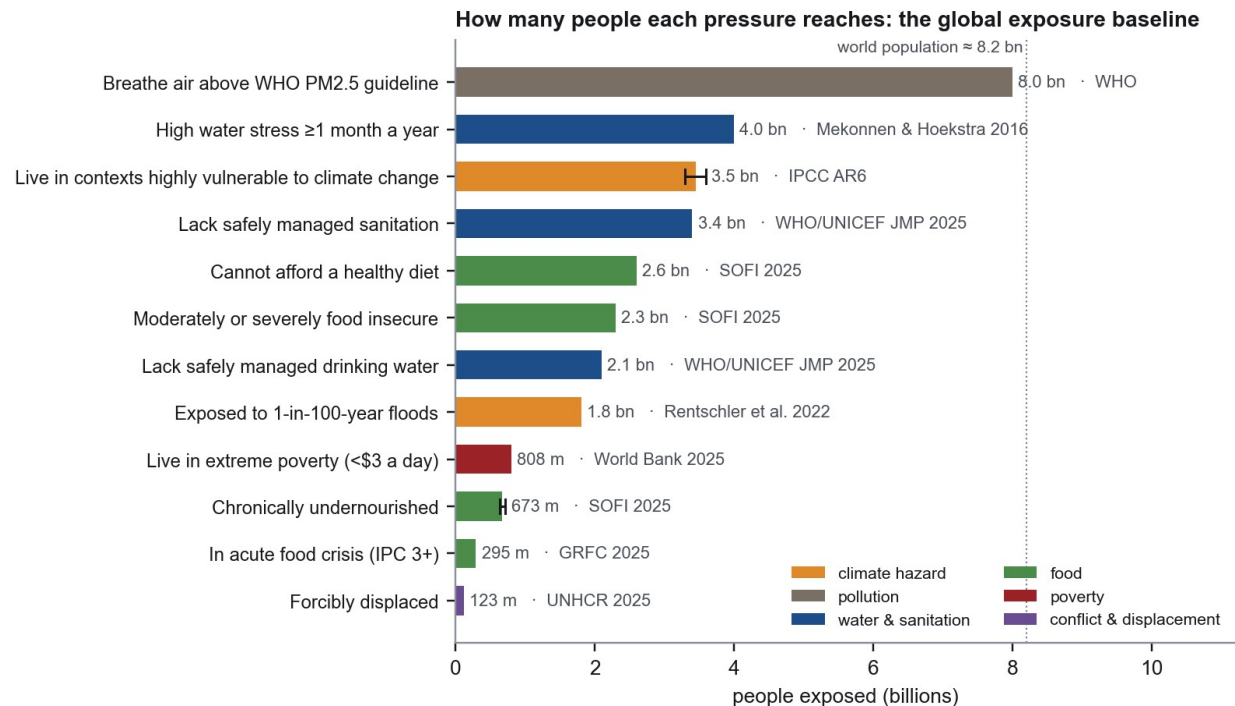


**Figure 6. The global exposure baseline.** Estimated number of people exposed to selected pressures, coloured by domain. The bars overlap heavily: many people face several pressures at once.

Sources: [WHO](#) (air quality); [Mekonnen & Hoekstra 2016](#) (water scarcity); [IPCC AR6 SYR](#) (climate vulnerability, range shown); [WHO/UNICEF JMP 2025](#) (water and sanitation); [FAO SOFI 2025](#) (diet affordability, food insecurity, undernourishment, range shown); [Rentschler et al. 2022](#) (floods); [World Bank, via Our World in Data](#) (poverty); [GRFC 2025](#) (acute food crisis); [UNHCR](#) (displacement).

At the narrow end of the distribution are the pressures with the most severe immediate consequences. About 808 million people live in extreme poverty on less than \$3 a day. About 673 million are chronically undernourished, and 295 million in 53 countries and territories faced acute food crisis in 2024, the sixth consecutive annual increase, with conflict the main driver for about 140 million of them ([Global Report on Food Crises 2025](#)). At the end of 2024, 123.2 million people had been forced from their homes by persecution, conflict and violence ([UNHCR](#)).

These numbers should not be added together. The same person may live in extreme poverty, breathe polluted air, lack safe water and live on a floodplain. That overlap is not a statistical inconvenience; it is the substance of the polycrisis. The people at the narrow end of the distribution are, overwhelmingly, the same people who are exposed at the broad end, and the pressures they face reinforce one another.

## 3.2 Ranking the pressures

Counting the people exposed is necessary but not sufficient. A pressure that reaches billions with mild effects is different from one that reaches millions with lethal effects, and a pressure that can be reversed in a decade is different from one that persists for centuries. The report therefore scores ten pressures on four criteria, each on a scale of 1 to 5:

- **Reach:** the number of people exposed now and projected to 2050.
- **Persistence:** how long the pressure would last after its causes were addressed, from days (air pollution) to millennia (carbon dioxide and sea level).
- **Severity:** the per-person harm in terms of mortality, morbidity and loss of livelihood.

- **Amplification:** the capacity of the pressure to raise stress in other domains, drawn from the coupling analysis in Section 10.

The composite score weights reach most heavily (0.35), severity next (0.25), and persistence and amplification equally (0.20 each), reflecting the report's focus on human exposure. The result is shown in Figure 7 and Table 6. It is a conceptual prioritization based on the judgement of H Heuristics, informed by the evidence reviewed in Sections 4 to 9. It is not a statistical measurement of future disasters.

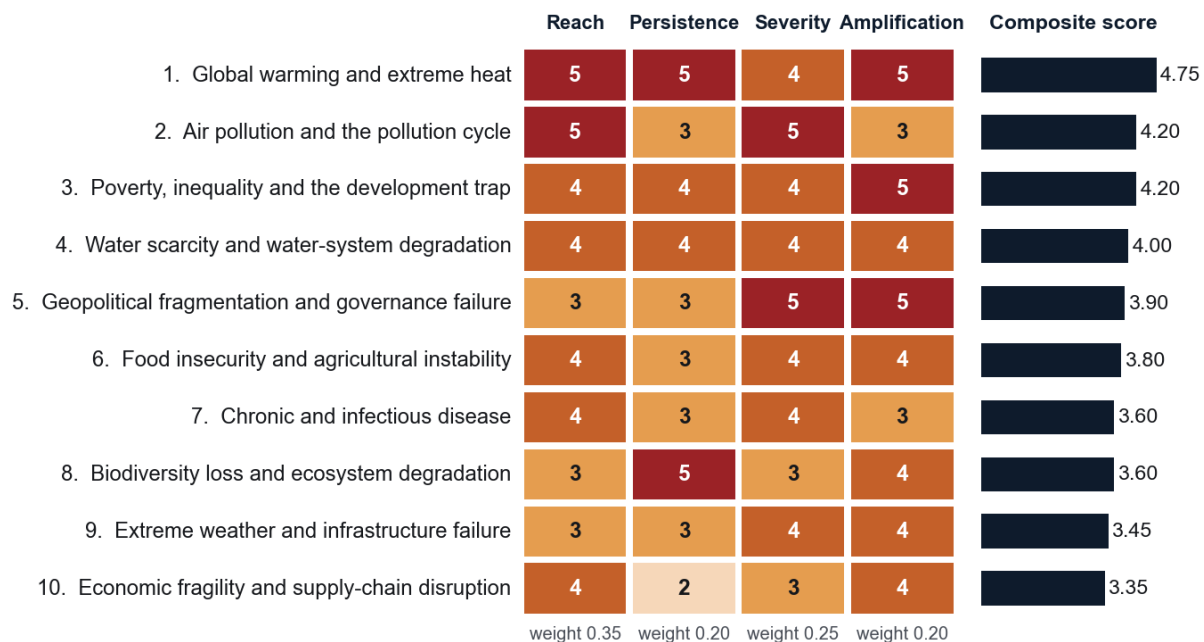


**Figure 7. The exposure ranking.** Ten pressures scored from 1 (low) to 5 (high) on reach, persistence, severity and amplification, with the weighted composite. Warming and extreme heat, air pollution, and poverty and inequality form the core of the system.

Source: H Heuristics assessment. Weights: reach 0.35, persistence 0.20, severity 0.25, amplification 0.20. Ties are ordered by reach.

Three findings stand out. First, **warming and extreme heat** rank first on every reasonable weighting. In a test that drew 20,000 random sets of weights centred on the base weights, it ranked first in 94 per cent of draws and in the top three in all of them. It is the system-wide driver: it reaches almost everyone, its causes persist for centuries, and it amplifies water stress, food insecurity, disease, infrastructure damage and air pollution. Second, **air pollution** and **poverty and inequality** form a close second tier, in the top three in 70 and 92 per cent of draws respectively. Pollution has the broadest direct health burden of any environmental risk; poverty determines who is harmed by every other hazard. Third, **geopolitical fragmentation** ranks fifth despite its lower reach, because its severity and capacity to amplify other crises are both maximal: wars destroy infrastructure, trigger famine and displacement, and delay the cooperation that every other problem requires.

**Table 6.** The ten pressures of the polycrisis: what they are and what they amplify

| Rank and pressure                                           | Principal components                                                                                                      | Amplifies                                                                                            | Outlook to 2050                              |
|-------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|----------------------------------------------|
| <b>1. Global warming and extreme heat</b>                   | Rising temperatures, heatwaves, shifting rainfall, drought, fire weather, ecosystem stress                                | Water scarcity, food insecurity, energy demand, infrastructure damage, disease, air pollution        | Increasing with further warming              |
| <b>2. Air pollution and the pollution cycle</b>             | PM <sub>2.5</sub> , ozone, industrial and transport emissions, household fuels, wildfire smoke                            | Cardiovascular and respiratory disease, cognitive harm, crop losses, warming (black carbon, methane) | Highly variable by region                    |
| <b>3. Poverty, inequality and the development trap</b>      | Low income, weak infrastructure, informal housing, limited services and financial protection                              | Exposure to every hazard, preventable illness, educational loss, limited adaptive capacity           | Slow decline; concentrated in fragile states |
| <b>4. Water scarcity and degradation</b>                    | Groundwater depletion, unreliable rainfall, contamination, ageing infrastructure, competing demand                        | Agricultural loss, sanitation failure, infectious disease, migration, regional tension               | Increasing in many vulnerable regions        |
| <b>5. Geopolitical fragmentation and governance failure</b> | Armed conflict, strategic rivalry, corruption, institutional weakness, failing cooperation                                | Food and energy insecurity, displacement, destruction, delayed climate and pollution action          | Uncertain, potentially cascading             |
| <b>6. Food insecurity and agricultural instability</b>      | Heat and water stress, floods, soil degradation, input costs, crop disease, distribution failure                          | Malnutrition, poverty, price inflation, political instability, displacement                          | Greater risk under compounding shocks        |
| <b>7. Chronic and infectious disease</b>                    | Disease burdens from pollution, heat, malnutrition and unsafe water; epidemic and pandemic risk; antimicrobial resistance | Health-system strain, lost productivity, household poverty                                           | Continued concern                            |
| <b>8. Biodiversity loss and ecosystem degradation</b>       | Habitat loss, deforestation, overexploitation, contamination, ocean warming and acidification                             | Loss of ecosystem services, fisheries and pollination; weaker natural carbon sinks                   | Persistent risk without stronger action      |
| <b>9. Extreme weather and infrastructure failure</b>        | Floods, storms, wildfire, coastal inundation, compound events affecting power, transport, health care                     | Economic loss, service interruption, outbreaks, displacement, supply-chain failure                   | Increasing overall                           |
| <b>10. Economic fragility and supply-chain disruption</b>   | Price shocks, concentrated production, energy insecurity, debt, trade restriction, logistics disruption                   | Inflation, unemployment, shortages, reduced funding for adaptation                                   | Uncertain, potentially cascading             |

*Integration can spread shocks but can also distribute supplies to affected regions; whether economic connection amplifies or damps a crisis depends on buffers and policy.*

### 3.3 The three pressures at the core

#### Warming and extreme heat: the system-wide driver

Global surface temperature in 2024 was about 1.55 °C above the 1850–1900 average, the first calendar year above 1.5 °C ([WMO 2025](#)). Warming is not a hazard in its own right so much as a multiplier of nearly every other hazard: it intensifies heat extremes, alters rainfall, extends fire seasons, raises sea level, stresses crops and ecosystems, and changes the geography of disease. The IPCC finds that climate

risks rise with every increment of warming, and that many are already larger than projected in earlier assessments. Section 4 examines the mechanisms in detail.

### Air pollution: the broadest direct burden

Air pollution was responsible for about 7.9 million deaths in 2023, roughly one in eight deaths worldwide, making it the second leading risk factor for early death after high blood pressure ([State of Global Air 2025](#)). Including unsafe water, lead and occupational toxins, pollution of all kinds causes about 9 million deaths a year ([Fuller et al. 2022](#)). It is especially important to the polycrisis because it is both a direct threat to health and a mechanism that reinforces wider environmental stress: the same combustion that produces particles produces carbon dioxide, and warming in turn increases ozone and wildfire smoke.

### Poverty and inequality: the determinant of harm

Poverty does not create hazards, but it decides what they do. Low incomes and weak infrastructure reduce people's ability to withstand heat, pollution, floods, disease and rising living costs. The same physical hazard can produce dramatically different outcomes depending on wealth, public services and state capacity. Extreme poverty has fallen from more than a third of humanity in 1990 to about a tenth today, but the remaining poor are increasingly concentrated in sub-Saharan Africa, where about 44 per cent of the population lived below \$3 a day in 2025, and in fragile and conflict-affected states, the places where climate and conflict risks are also highest.

## 3.4 What the ranking leaves out

The ten pressures provide a strong starting structure but not a complete one. Six further pressures are treated in this report as cross-cutting rather than ranked separately, because their exposure profiles are either diffuse or highly event-dependent:

- **Demographic change:** ageing, urbanization and the shifting distribution of population, treated in Section 9 as a modifier of exposure to every other pressure.
- **Antimicrobial resistance:** a slow-moving threat to modern medicine, treated with disease in Section 7.
- **Technological and cyber risks:** the vulnerability of digitized infrastructure and the uncertain trajectory of artificial intelligence (Section 7).
- **Nuclear and other catastrophic security risks:** low-probability, high-severity events whose likelihood the polycrisis may raise (Section 7).
- **Waste and chemical pollution:** plastics, persistent chemicals and other 'novel entities', one of the transgressed planetary boundaries (Section 4).
- **Space weather and other natural catastrophes:** geomagnetic storms, large volcanic eruptions and pandemics of natural origin, which would strike a more fragile world harder (Section 7).

## 3.5 Which pressures will become more prevalent?

The ranking describes the present. Table 7 gives the report's forward-looking assessment to 2050 and beyond. It is not a prediction that every pressure will worsen everywhere. Several are on improving trajectories in some regions, and the scale of future harm will depend on both physical change and human decisions.

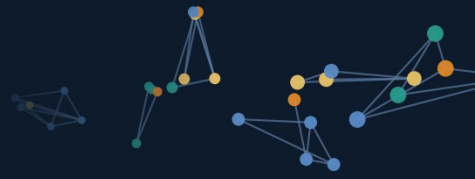
**Table 7.** Broad outlook for the principal pressures through 2050 and beyond

| Pressure                                | Broad outlook                         | Why it matters                                                                                                                                                           | Grade |
|-----------------------------------------|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| <b>Extreme heat</b>                     | Increasing with further warming       | Direct health impacts and stress on labour, sleep, infrastructure and energy systems                                                                                     | A     |
| <b>Climate-related compound hazards</b> | Increasing overall                    | Heat, drought, fire and flooding interact and coincide                                                                                                                   | A–B   |
| <b>Air pollution</b>                    | Highly variable by region             | Exposure depends on policy, energy, urbanization, wildfire and emissions; improving in many high-income countries and China, worsening in parts of South Asia and Africa | B     |
| <b>Water stress</b>                     | Increasing in many vulnerable regions | Interacts with food production, health and industry; groundwater depletion is accelerating in many aquifers                                                              | B     |
| <b>Food-system volatility</b>           | Greater risk under compounding shocks | Crop losses, price spikes and distribution failures, especially when shocks are correlated                                                                               | B     |
| <b>Ecosystem degradation</b>            | Persistent without stronger action    | Weakens natural systems and long-term resilience                                                                                                                         | A–B   |
| <b>Chronic health burdens</b>           | Continued concern                     | Pollution, heat, unsafe water and poor nutrition contribute; ageing raises susceptibility                                                                                | B     |
| <b>Economic and geopolitical shocks</b> | Uncertain, potentially cascading      | Can magnify existing humanitarian and environmental crises                                                                                                               | C     |

*The most important qualifier is that prevalence is not destiny. Air quality can improve substantially through regulation and cleaner technology; climate risks can be limited by emissions reductions and adaptation; poverty can fall even as some hazards intensify.*

## 04

## DOMAIN I · CLIMATE AND POLLUTION



## 4. The Climate and Pollution Nexus

### 4.1 A warming world

The scientific basis for the polycrisis begins with a single, established fact: human activities, principally the burning of fossil fuels, have warmed the planet. The IPCC's Sixth Assessment Report concluded that it is unequivocal that human influence has warmed the atmosphere, ocean and land ([IPCC AR6 WGI](#)). In the HadCRUT5 record charted in Figure 8, global surface temperature in 2024 was 1.53 °C above the 1861–1890 average; the World Meteorological Organization's consolidated estimate, relative to 1850–1900, is about 1.55 °C, the first calendar year above 1.5 °C ([WMO 2025](#)). A single year above 1.5 °C does not mean that the Paris Agreement's long-term goal, which refers to a multi-decade average, has been missed. But the long-term average, once year-to-year variability is removed, is now about 1.3 to 1.4 °C and rising by roughly 0.2 °C per decade. Atmospheric carbon dioxide reached about 426 parts per million in 2025, more than 50 per cent above its pre-industrial level.

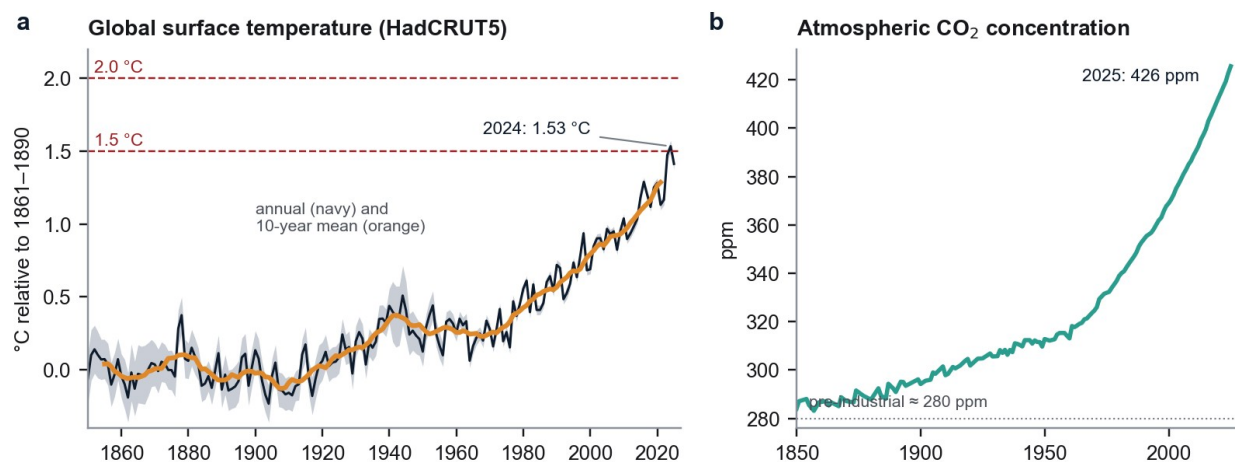


**Figure 8. The warming signal.** (a) Annual global mean surface temperature relative to 1861–1890, with 95 per cent uncertainty range and 10-year running mean. (b) Atmospheric carbon dioxide concentration.

Sources: Met Office Hadley Centre [HadCRUT5](#) and [NOAA/Scripps CO<sub>2</sub> records](#), via Our World in Data. Note that the HadCRUT5 baseline (1861–1890) differs slightly from the IPCC and WMO baseline (1850–1900).

Warming matters to the polycrisis not mainly because of the average but because of what the average does to extremes. A modest shift in the mean of a distribution produces a large increase in the frequency of its tails. Heat extremes that occurred once in fifty years in the pre-industrial climate now occur roughly five times as often, and at 2 °C of warming they would occur about fourteen times as often, according to the [IPCC](#). Heavy precipitation, agricultural and ecological drought, and fire weather all intensify in the same way. Every fraction of a degree avoided reduces the frequency of the events that trigger cascades.

## 4.2 Extreme heat and the limits of the human body

Heat is the most direct way in which warming harms people. The 2025 report of the [Lancet Countdown](#) estimated an average of about 546,000 heat-related deaths a year in 2012–2021, with the heat-related mortality rate 23 per cent higher than in the 1990s. Across 732 locations in 43 countries, about 37 per cent of warm-season heat-related deaths between 1991 and 2018 were attributable to human-caused climate change ([Vicedo-Cabrera et al. 2021](#)). Heat kills mainly by straining the heart and kidneys of people who are old, ill, very young, poor or working outdoors, which is why it is so closely tied to demography and inequality.

Beyond mortality lies a larger burden of lost function. Heat reduces the hours in which outdoor work is safe, disrupts sleep, impairs learning and raises violence and mental-health crises. The Lancet Countdown estimated that heat exposure cost about US\$1.09 trillion in potential labour income in 2024, almost 1 per cent of world output. Urban populations are especially exposed: the number of person-days of extreme heat in the world's cities roughly tripled between 1983 and 2016, through a combination of warming and urban population growth ([Tuholske et al. 2021](#)).

At the far tail is the question of physiological survivability. The human body cannot cool itself when the combination of heat and humidity is too high. A wet-bulb temperature of 35 °C has long been treated as the theoretical limit for a healthy, resting person, but laboratory work suggests that the real limit for young, healthy adults is lower, around 31 °C in humid conditions ([Vecellio et al. 2022](#)), and lower still for older people. Weather stations have already recorded brief exceedances of 35 °C wet-bulb in parts of the Persian Gulf and South Asia ([Raymond et al. 2020](#)). Over the longer term, researchers have described a 'human climate niche', the narrow band of mean annual temperature in which human populations have historically concentrated. With current policies, which imply about 2.7 °C of warming by 2100, a fifth to two-fifths of the projected world population could be pushed outside that niche ([Lenton et al. 2023](#); see also [Xu et al. 2020](#)). Being outside the niche is not the same as being unable to survive, but it marks a large increase in exposure to dangerous conditions. The H Heuristics report [The Heat Trap](#) examines this geography in detail.

## 4.3 Air pollution: the invisible medium

Air pollution is the largest environmental cause of disease and premature death in the world. Figure 9a breaks down the 7.9 million air-pollution deaths estimated for 2023 by the [State of Global Air 2025](#): about 4.9 million from ambient fine particles (PM<sub>2.5</sub>), 2.8 million from household air pollution caused by burning solid fuels for cooking and heating, and about 470,000 from ozone. Around 86 per cent of these deaths were from non-communicable diseases such as heart disease, stroke, lung cancer, chronic respiratory disease and diabetes. For the first time, the 2025 edition also estimated about 626,000 dementia deaths linked to air pollution, reflecting growing evidence that fine particles harm the brain as well as the heart and lungs.

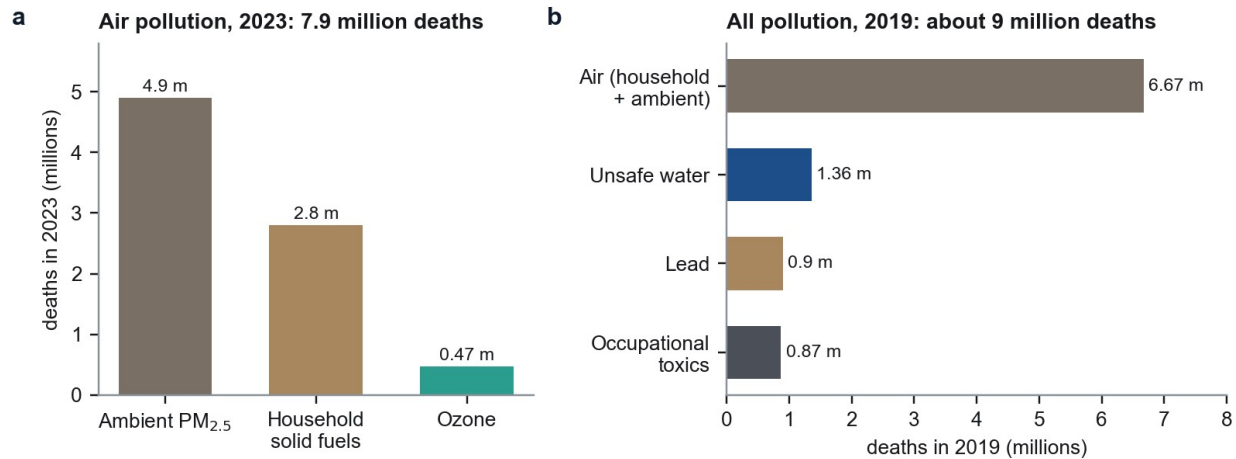


**Figure 9. The pollution burden.** (a) Deaths attributable to air pollution in 2023, by source. (b) Deaths attributable to all forms of pollution in 2019, by type: air pollution remains dominant, followed by unsafe water, lead and occupational exposure to toxic substances.

Sources: (a) [State of Global Air 2025](#), Health Effects Institute and IHME. (b) [Fuller et al. 2022](#), Lancet Commission on Pollution and Health update. Estimates use different years and methods and are not directly comparable.

Two features of air pollution make it central to the polycrisis. The first is its breadth. Almost everyone is exposed, and in large parts of South Asia annual mean PM<sub>2.5</sub> concentrations are ten times the WHO guideline ([WHO 2021 guidelines](#)). The H Heuristics report [Pollution, Climate Change, and Human Survivability](#) describes pollution as a continuous erosion of the 'human medium': the health and cognition on which every other form of development depends. The second is its inequality. About 2.1 billion people still cook with polluting fuels and technologies, almost all of them in low- and middle-income countries ([WHO](#)); women and children bear most of the exposure.

Pollution is also one of the most reversible pressures in the polycrisis. Fine particles leave the atmosphere within days to weeks of emissions stopping (Figure 24), and the health benefits of cleaner air begin almost immediately. Clean-air policies in the United States, Europe and, since 2013, China have produced some of the largest gains in life expectancy of any public-health intervention. This combination of breadth and reversibility makes air pollution one of the highest-value targets for prevention (Section 13).

#### 4.4 The pollution–climate feedback loop

Air pollution and climate change are usually managed by separate ministries and treaties, but physically they are one system. Most of both problems comes from the same activity: burning fossil fuels and biomass. Their interactions run in both directions and do not all have the same sign (Table 8).

**Table 8.** How air pollution and climate change interact

| Interaction                     | Direction                      | Mechanism                                                                                                            | Grade |
|---------------------------------|--------------------------------|----------------------------------------------------------------------------------------------------------------------|-------|
| <b>Shared sources</b>           | Both worsen together           | Coal, oil, gas and biomass combustion emit CO <sub>2</sub> and particles, nitrogen oxides and sulfur dioxide at once | A     |
| <b>Black carbon and methane</b> | Pollution warms                | Soot absorbs sunlight; methane is a potent greenhouse gas and a precursor of ground-level ozone                      | A     |
| <b>Sulfate aerosols</b>         | Pollution cools (masking)      | Sulfate particles reflect sunlight; cleaning them up removes part of the masking and accelerates near-term warming   | A     |
| <b>Climate penalty on ozone</b> | Warming worsens pollution      | Higher temperatures and stagnant air speed ozone formation in polluted regions                                       | B     |
| <b>Wildfire smoke</b>           | Warming worsens pollution      | Hotter, drier conditions lengthen fire seasons; smoke now drives PM <sub>2.5</sub> trends in parts of North America  | B     |
| <b>Cooling demand</b>           | Warming worsens pollution      | Heat raises electricity demand; where power is fossil-based, emissions of both pollutants and CO <sub>2</sub> rise   | B     |
| <b>Crop damage</b>              | Pollution and warming compound | Ozone and heat both cut yields of wheat, rice, soy and maize                                                         | B     |

Sources: [IPCC AR6 WGI](#); [Jacob & Winner 2009](#); [Burke et al. 2023](#); [Shindell et al. 2012](#).

The most important nuance concerns sulfate aerosols. Because they cool the planet, cutting sulfur emissions, which is essential for health, removes part of the 'mask' that has hidden some of the warming caused by greenhouse gases. This is not an argument for keeping air dirty; the health benefits vastly exceed the climate cost. It is an argument for cutting methane and black carbon at the same time, which reduces near-term warming while improving air quality ([Shindell et al. 2012](#)). It is also a clear illustration of the polycrisis principle that solving one problem in isolation can shift stress onto another.

The feedback that most concerns the polycrisis runs through heat and energy. As temperatures rise, demand for cooling rises; where electricity comes from fossil fuels, the response to heat adds both pollutants and greenhouse gases; and the resulting warming and smog raise the demand for cooling again. Section 10 treats this as one of six reinforcing loops. Where electricity is clean and cooling efficient, the loop is broken. The climate impact of adaptation depends on the energy system it runs on.

## 4.5 Chemicals, lead and novel entities

Air pollution is the largest but not the only form of pollution in the polycrisis. Lead remains a major and under-recognized burden: about 900,000 deaths a year are attributed to it ([Fuller et al. 2022](#)), and UNICEF estimates that around one in three children worldwide has elevated blood lead levels ([UNICEF 2020](#)), with lifelong consequences for cognition. Unsafe water causes about 1.4 million deaths a year. Beyond these known toxins lie 'novel entities', synthetic chemicals, plastics and other materials released faster than they can be assessed. Researchers concluded in 2022 that the production and release of novel entities has exceeded the planetary boundary ([Persson et al. 2022](#)). Their effects are slower and less certain than those of fine particles, but some, such as persistent fluorinated compounds, will remain in the environment for centuries.

## 4.6 Assessment

The climate–pollution nexus is the engine room of the polycrisis. Warming is the single largest amplifier of other pressures, and pollution is the single largest direct environmental burden on health. Their shared sources mean that the most effective responses address both at once. The report's grades are as follows. That human influence has warmed the climate, and that heat extremes are increasing, is established (A). That air pollution is among the leading risk factors for death worldwide is established (A). That warming worsens air quality through ozone, smoke and cooling demand is well supported (B). That warming of 2.5–3 °C would push a large share of humanity into conditions outside the historical human climate niche is well supported as a statement about exposure (B), while claims that large regions will become physically uninhabitable for most people this century remain contested (C).

**Key insight.** Pollution is the most widespread harm in the polycrisis and also the most reversible; warming is the most persistent. A strategy that cuts the shared sources of both buys immediate health gains and long-term climate stability at the same time.

## 05

## DOMAIN II · POVERTY AND INEQUALITY

## 5. Poverty and Unequal Survivability

### 5.1 The geography of deprivation

The polycrisis does not fall evenly. Its burden is shaped first and foremost by poverty. In June 2025 the World Bank raised its international extreme-poverty line from \$2.15 to \$3.00 a day, in 2021 purchasing-power-parity prices, to reflect updated price data and national poverty lines. On the new line about 808 million people, roughly 10 per cent of humanity, were projected to live in extreme poverty in 2025 ([World Bank, via Our World in Data](#)). Figure 10a shows the long decline: in 1990 more than 40 per cent of the world's population lived below the line. East Asia's share has fallen almost to zero and South Asia's has fallen steeply, but sub-Saharan Africa's has fallen only slowly, to about 44 per cent in 2025. Extreme poverty is becoming an African problem and, increasingly, a problem of fragile and conflict-affected states.

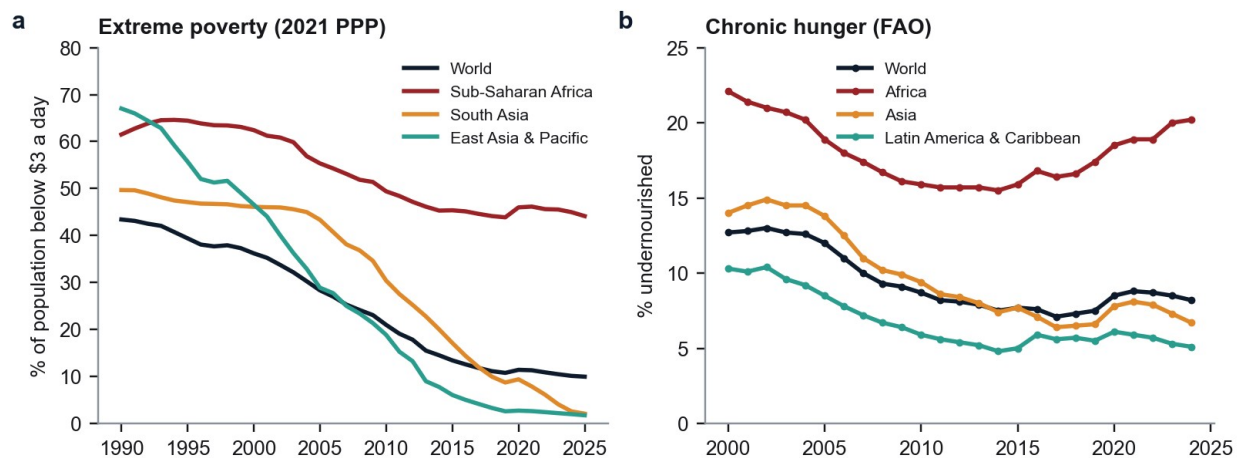


**Figure 10. Deprivation trends.** (a) Share of the population living below \$3 a day (2021 PPP), world and selected regions, 1990–2025, including World Bank nowcasts for recent years. (b) Prevalence of undernourishment, world and selected regions, 2000–2024.

Sources: (a) [World Bank Poverty and Inequality Platform](#), via Our World in Data. (b) [FAO](#), via Our World in Data.

This geography matters because it overlaps with the geography of physical hazard. The countries where extreme poverty is most persistent are, disproportionately, those that are hottest, most dependent on rain-fed agriculture, most exposed to drought and flood, and most affected by conflict. The H Heuristics study [The Geography of Resilience in the Global South](#) documents this overlap region by region.

## 5.2 Why the same hazard harms the poor most

Risk, in the IPCC's framing, is the product of hazard, exposure and vulnerability. Poverty raises the second and third terms. Figure 11a illustrates the consequence. Two cities can face the same heatwave; in a wealthy, well-cooled city the risk is modest, while in a poor city with informal housing, outdoor work and unreliable electricity it is several times larger. A third city with a milder hazard but high vulnerability can face more risk than the wealthy city with the severe hazard. Because the terms multiply, halving any one of them halves the risk, and halving two cuts it to a quarter (Figure 11b).

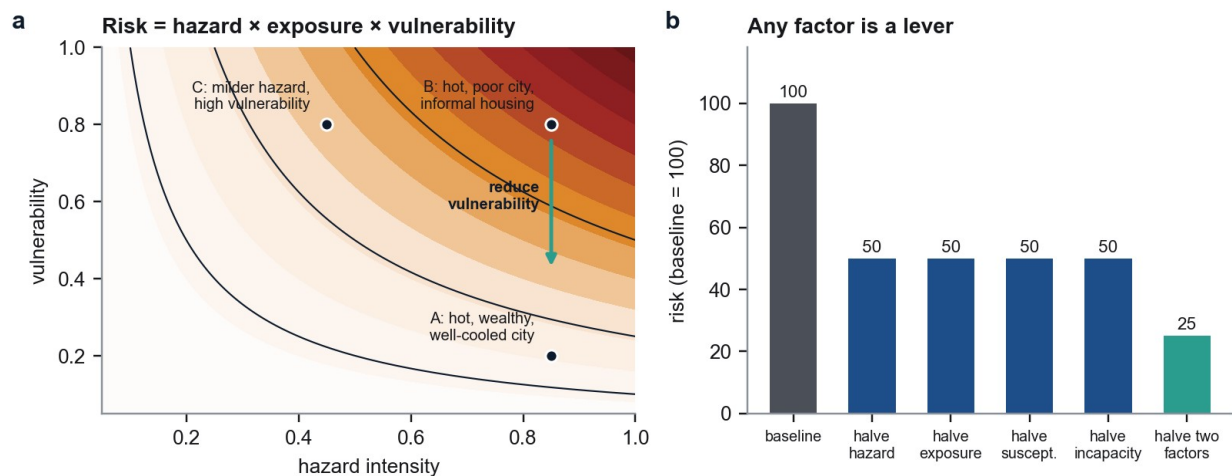


**Figure 11. The multiplicative structure of risk.** (a) Risk as the product of hazard intensity and vulnerability, for a fixed exposed population; contours show equal risk. Three archetypal settings are marked. (b) Starting from a baseline in which all four factors are high, halving any single factor halves risk; halving two cuts it to a quarter.

Source: H Heuristics calculation following the IPCC risk framework. Archetypes are illustrative; baseline factor values 0.8, 0.8, 0.7 and 0.7.

Poverty acts on each component of vulnerability (Table 9). Poor households are more likely to live on floodplains, unstable slopes and the urban fringe, because that is where land is cheap. They are more susceptible to harm because of malnutrition, untreated illness and housing that offers little protection from heat or water. They have less capacity to cope, because they lack savings, insurance and access to credit, and must often sell productive assets or withdraw children from school to survive a shock. And they have less capacity to adapt, because adaptation, from air conditioning to drought-resistant seed to relocation, costs money.

**Table 9.** How poverty acts on each component of vulnerability

| Component                | How poverty raises it                                                                                                       | Example indicators                                                                    |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| <b>Exposure</b>          | Low-cost land is often hazardous; informal settlements cluster on floodplains, slopes and coasts; outdoor and informal work | Share of population in informal settlements; outdoor workforce; flood-zone population |
| <b>Susceptibility</b>    | Malnutrition, chronic disease, poor housing, lack of cooling and clean water                                                | Child stunting; housing quality; access to electricity and cooling                    |
| <b>Coping capacity</b>   | No savings or insurance; reliance on selling assets, borrowing or cutting meals                                             | Household savings; insurance penetration; social-protection coverage                  |
| <b>Adaptive capacity</b> | Adaptation is costly; limited information, credit, land tenure and political voice                                          | Access to credit; tenure security; local government budgets                           |

| Component | How poverty raises it                                                                             | Example indicators                                |
|-----------|---------------------------------------------------------------------------------------------------|---------------------------------------------------|
| Recovery  | Losses are a larger share of wealth; recovery is slower; shocks recur before recovery is complete | Time to recover income; repeat-disaster frequency |

The components follow [IPCC AR6 WGII](#) and the World Bank's [Unbreakable](#) framework.

The World Bank's *Unbreakable* study estimated that natural disasters push about 26 million people into extreme poverty every year, and that because poor people lose a larger share of their wealth and recover more slowly, the losses in well-being from disasters are substantially larger than the losses in assets usually reported ([Hallegatte et al. 2017](#)). Climate change, by reducing crop yields, raising food prices, and increasing disease and disasters, acts on poverty through many channels at once ([Hallegatte & Rozenberg 2017](#)).

### 5.3 Inequality between countries

The polycrisis also widens inequality between countries. Economic productivity responds non-linearly to temperature, peaking at an annual mean of about 13 °C and declining steeply above it ([Burke et al. 2015](#)). Because many poor countries are already hot, further warming tends to depress their growth while having smaller or even positive effects in cool, rich countries. One analysis estimated that warming since 1960 has increased economic inequality between countries by about 25 per cent relative to a world without warming ([Differbaugh & Burke 2019](#)). Estimates of the aggregate economic damage from climate change remain highly uncertain. A prominent 2024 study that projected a 19 per cent loss in global income by 2050 was [retracted in December 2025](#) after its results were found to depend on flawed data for one country. That episode is a reminder that the distributional finding, that the poor are hit hardest, is more robust than any single estimate of the global total.

### 5.4 The development trap

Poverty is not only a condition but a dynamic. Scarcity consumes attention: experiments suggest that financial pressure measurably reduces cognitive performance ([Mani et al. 2013](#)), making long-term planning harder precisely for those who most need it. Repeated shocks deplete savings and health; depleted savings and health make the next shock more damaging; and the cost of each recovery crowds out investment in education and productive assets. At the national level, the same trap operates through public finance: governments that spend heavily on disaster recovery and debt service have less to spend on prevention. Section 10 models this ratchet explicitly, and Section 8 shows how rising debt is tightening it for billions of people.

### 5.5 Assessment

That poverty multiplies the harm caused by environmental hazards is established (A). That extreme poverty is increasingly concentrated in sub-Saharan Africa and fragile states, the regions where climate and conflict risks are also highest, is established (A). That warming has widened inequality between countries is well supported (B), though the size of the effect is debated. The implication for the polycrisis is direct: **the same physical hazard can produce dramatically different outcomes depending on wealth, public services and state capacity**, and poverty reduction is therefore not separate from risk reduction but one of its most powerful forms.

## 06

## DOMAIN III · WATER, FOOD, ECOSYSTEMS



## 6. Water, Food and Ecological Stability

### 6.1 Water: the first resource to fail

Water is where many of the polycrisis's pressures meet. It is needed for drinking, sanitation, agriculture, energy generation and industry; it is affected by warming, land use, pollution and governance; and its failure propagates quickly into health, food and economic crises. In 2024, 2.1 billion people still lacked safely managed drinking water, including 106 million who drank untreated surface water, and 3.4 billion lacked safely managed sanitation ([WHO/UNICEF JMP 2025](#)). Coverage of safely managed drinking water rose from 50 to 60 per cent between 2015 and 2024, real progress but far short of the universal access promised by the Sustainable Development Goals for 2030.

Scarcity is a separate problem from access. About four billion people experience severe water scarcity for at least one month a year ([Mekonnen & Hoekstra 2016](#)). Much of the world's irrigated agriculture depends on groundwater that is being extracted faster than it is replenished. Satellite gravimetry has revealed large changes in freshwater storage, with depletion concentrated in some of the world's most important farming regions ([Rodell et al. 2018](#)), and a global analysis of in-situ records found groundwater declines in most of the aquifers studied, accelerating in many of them in the twenty-first century ([Jasechko et al. 2024](#)). Water stress is driven by climate, but also by local governance, infrastructure, demand and pollution, which is why it is so often a polycrisis in miniature.

### 6.2 Food: a system optimized for efficiency

After decades of decline, chronic hunger rose sharply during the COVID-19 pandemic and the food-price shock that followed Russia's full-scale invasion of Ukraine. It has eased only slightly since: 673 million people, 8.2 per cent of the world's population, were undernourished in 2024, down from 8.5 per cent in 2023 ([FAO SOFI 2025](#)). The aggregate hides diverging trends (Figure 10b): hunger is falling in Asia and Latin America but rising in Africa, where more than 20 per cent of the population, 307 million people, was undernourished in 2024. About 2.3 billion people were moderately or severely food insecure.

Climate change has already slowed the growth of agricultural productivity. One estimate suggests that global farm productivity is about 21 per cent lower than it would have been without the warming since 1961 ([Ortiz-Bobea et al. 2021](#)). The deeper concern for the polycrisis is not the average but the tail: the possibility that several of the world's major grain-producing regions fail in the same year. The global food system is concentrated. A handful of countries supply most of the world's exported maize, wheat, rice and soybeans, and international trade is designed to move food efficiently from surplus to deficit regions, not to absorb a simultaneous shortfall in several of them ([Puma et al. 2015](#)).

That is why correlation matters. Figure 12 shows a simple calculation. Suppose five major breadbaskets each suffer a severe harvest failure, defined as a one-in-twenty-year event, and suppose their weather shocks are independent. Then three or more fail in the same year about once in 902 years. But

atmospheric patterns such as persistent jet-stream waves and the El Niño–Southern Oscillation can link weather across continents. With a moderate correlation of 0.4 between regions, the same event recurs about once in 67 years, about 13 times as often. Empirical studies find that the risk of simultaneous failure is rising with warming ([Gaupp et al. 2020](#); [Tigchelaar et al. 2018](#)), and that jet-stream patterns can synchronize low yields across Northern Hemisphere breadbaskets in ways that climate and crop models underestimate ([Kornhuber et al. 2023](#)).

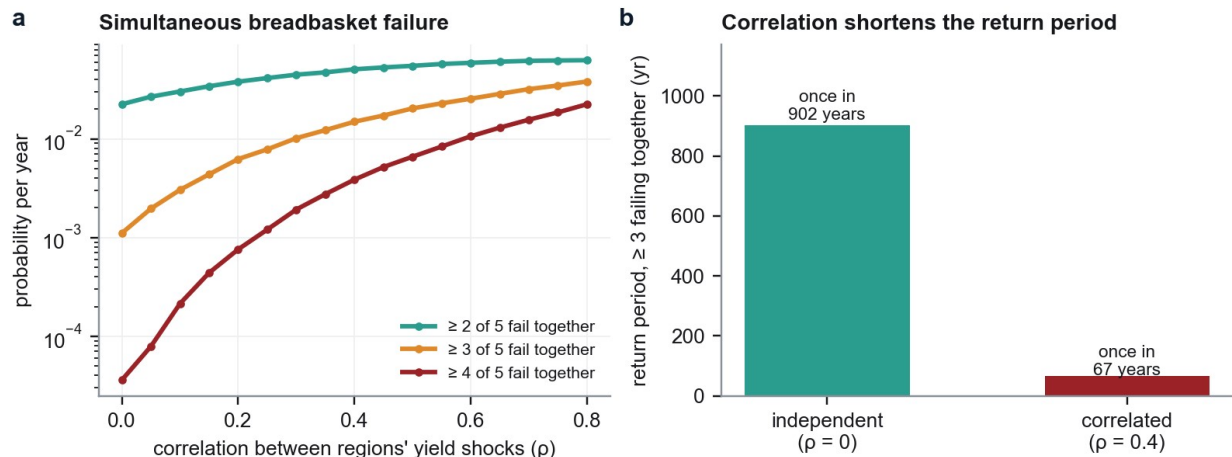


**Figure 12. Correlated harvest failure.** (a) Annual probability that two, three or four of five breadbaskets suffer a one-in-twenty-year harvest failure in the same year, as a function of the correlation between their yield shocks. (b) Return period of three or more simultaneous failures with independent and moderately correlated shocks.

Source: H Heuristics calculation. Gaussian-copula model with equal pairwise correlation  $\rho$ ; failure defined as a yield shock below the 5th percentile; one million simulated years per value of  $\rho$ . The independent case agrees with the binomial result (once in about 863 years).

Food shocks travel. Sharp rises in international food prices in 2007–2008 and 2010–2011 were followed by waves of unrest in import-dependent countries, and research has linked food-price spikes to the incidence of riots ([Bellemare 2015](#)). The 2010–2011 spike, partly driven by drought and export restrictions in Russia, is often cited as one of several contributing factors in the uprisings of the Arab Spring. Here the climate–food–poverty loop connects directly to the conflict–displacement loop.

### 6.3 Ecosystems: the slow foundation

Beneath water and food lies the living foundation on which both depend. The [Living Planet Index](#) records an average decline of 73 per cent in the size of monitored populations of vertebrate wildlife between 1970 and 2022 (Figure 13). The decline is steepest in Latin America and the Caribbean and in freshwater ecosystems. The index measures average change in population size, not the number of species lost, and is sensitive to how populations are weighted. But it is consistent with other evidence: the [IPBES Global Assessment](#) estimated that around one million animal and plant species are threatened with extinction, many within decades, and population losses are occurring even among species not yet considered endangered ([Ceballos et al. 2017](#)).

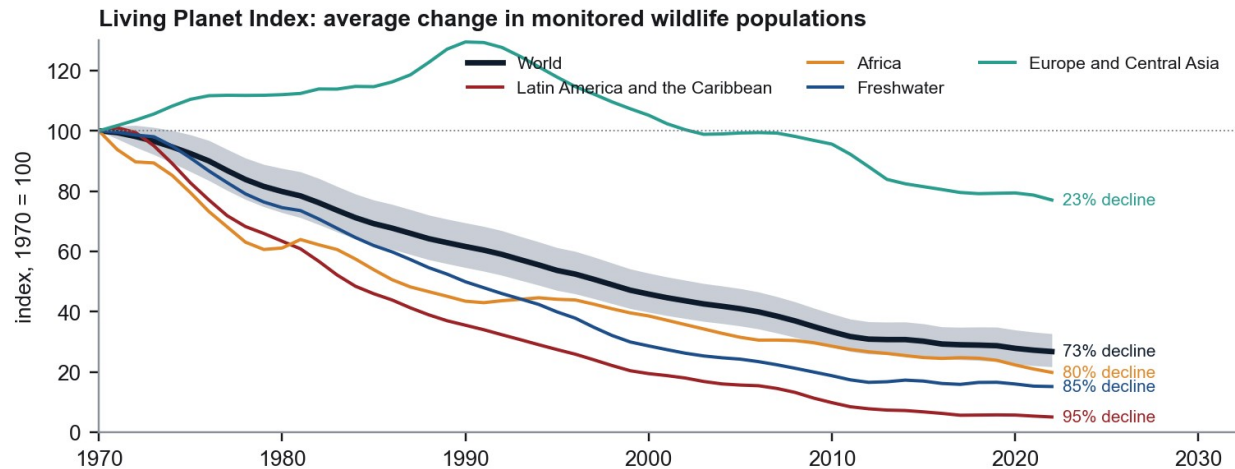


**Figure 13. The Living Planet Index, 1970–2022: average relative change in the size of monitored vertebrate populations, world (with confidence interval) and selected regions and systems.**

Source: WWF and ZSL, [Living Planet Report 2024](#), via [Our World in Data](#).

Biodiversity loss ranks lower than warming or pollution in the exposure ranking because its effects on people are mostly indirect and slow. But it scores maximally on persistence, since extinction is irreversible, and its amplifying effects run through every other domain. Ecosystems purify water, pollinate crops, protect coasts from storms, store carbon, regulate disease and support fisheries on which billions depend. The [Dasgupta Review](#) described nature as an asset that economic accounting has systematically depleted without recording the loss. Ecosystem degradation therefore makes climate adaptation harder: a degraded mangrove does not protect a coastline, a degraded watershed does not buffer a drought, and a degraded soil does not hold water.

## 6.4 The water–food–ecosystem nexus

**Table 10.** Couplings between water, food and ecosystems, and their links to other domains

| From       | To                   | Mechanism                                                                       | Typical time scale   |
|------------|----------------------|---------------------------------------------------------------------------------|----------------------|
| Water      | Food                 | Drought and groundwater depletion cut irrigated and rain-fed yields             | Seasons to decades   |
| Water      | Health               | Unsafe water and sanitation spread diarrhoeal disease, cholera and malnutrition | Days to years        |
| Water      | Energy               | Low river flows curtail hydropower and cooling of thermal power plants          | Weeks to seasons     |
| Food       | Ecosystems           | Agricultural expansion is the leading driver of habitat loss and deforestation  | Years to decades     |
| Food       | Poverty and conflict | Price spikes erode real incomes and can trigger unrest                          | Months               |
| Ecosystems | Water                | Forests and wetlands regulate flows, store water and filter pollutants          | Years to decades     |
| Ecosystems | Food                 | Pollinators, soil organisms and fisheries sustain production                    | Years to decades     |
| Ecosystems | Climate              | Degraded forests and soils release carbon and absorb less                       | Decades to centuries |

*These couplings are represented in the coupling matrix of Section 10.*

## 6.5 Assessment

Water, food and ecosystems are the polycrisis's resource base. Their coupling is established (A); the rising risk of correlated harvest failures is well supported (B); and the claim that ecosystem degradation weakens resilience to other shocks is well supported (B), though rarely quantified at global scale. The central lesson of this section is that a system optimized for efficiency, with concentrated production, lean stocks and long supply chains, performs well in normal years and poorly in correlated bad years. Restoring buffers, in the form of grain reserves, groundwater, diversified production and healthy ecosystems, is among the most direct ways of reducing the polycrisis's tail risk.

## 07

## DOMAIN IV · HEALTH AND TECHNOLOGY



## 7. Biological and Technological Pressures

### 7.1 Disease in a hotter, more crowded world

The polycrisis acts on human health through two routes. The first is the chronic burden already described: pollution, heat, unsafe water and poor nutrition each contribute to the growing toll of heart disease, stroke, respiratory illness, diabetes and infection. The second is the changing risk of epidemics. A systematic review found that 218 of 375 known infectious diseases affecting people, 58 per cent, have at some point been aggravated by climatic hazards such as warming, flooding, drought or storms ([Mora et al. 2022](#)). As species shift their ranges in response to warming, mammals that have never met will share viruses, creating new opportunities for spillover, with hotspots in densely populated parts of Africa and Asia ([Carlson et al. 2022](#)). Land-use change concentrates the species that most often host pathogens shared with people ([Gibb et al. 2020](#)), and emerging infectious diseases have historically originated disproportionately where human population density and wildlife diversity are both high ([Jones et al. 2008](#)).

COVID-19 showed how a biological shock propagates through every other system. The World Health Organization estimated about 14.9 million excess deaths in 2020 and 2021 alone ([Msemburi et al. 2023](#)). The pandemic also pushed tens of millions of people into extreme poverty, closed schools for more than a billion children, disrupted food and medical supply chains, increased public debt and deepened distrust between and within countries. It was, in the language of this report, a domino that toppled into the economic, food and governance domains, and its effects on learning, debt and trust are still being felt.

### 7.2 Antimicrobial resistance: a slow emergency

Antimicrobial resistance is a textbook polycrisis pressure: slow, diffuse, global and amplifying. In 2019 an estimated 1.27 million deaths were directly attributable to bacterial resistance and 4.95 million were associated with it ([Murray et al. 2022](#)). Forecasts suggest that, without stronger action, attributable deaths could rise to about 1.9 million a year by 2050, with almost 40 million cumulative attributable deaths between 2025 and 2050 ([Naghavi et al. 2024](#)). Resistance interacts with the rest of the polycrisis through poor sanitation, which spreads resistant bacteria; through overuse of antibiotics in agriculture; through conflict, which destroys health systems and creates conditions for resistant infections in the wounded; and through the potential loss of the antibiotics on which surgery, cancer treatment and childbirth safety depend ([WHO](#)).

### 7.3 Health systems under compound stress

Health systems are the polycrisis's last line of defence and are themselves exposed to it. Heatwaves increase hospital admissions at the same time as they strain the power supply on which hospitals depend; floods damage clinics and cut access roads; conflicts target health workers; and the fiscal squeeze described in Section 8 limits spending on prevention. The World Health Organization projects a

global shortfall of about ten million health workers by 2030, concentrated in low- and lower-middle-income countries ([WHO](#)). This is why health ranks high in the coupling analysis as a *receiver* of stress (Figure 18): nearly every pressure in the polycrisis ends, eventually, in a clinic or a hospital, or in the absence of one.

## 7.4 Technological fragility

Digital technology is one of humanity's great tools for managing risk, enabling early warning, weather forecasting, disease surveillance, mobile money and remote work. It is also a new source of systemic fragility. Modern infrastructure, from electricity grids to hospitals to ports, now depends on software and networks that can fail together. The [NotPetya](#) malware of 2017, aimed at Ukraine, spread worldwide and caused an estimated US\$10 billion in damage, halting operations at one of the world's largest shipping companies. In July 2024 a single faulty software update from a cybersecurity firm crashed millions of computers, grounding flights and disrupting hospitals and banks across the world ([2024 CrowdStrike outage](#)). These events were not catastrophes, but they demonstrated how tightly coupled, efficient systems can convert a small fault into a global disruption, exactly as Perrow predicted.

Natural hazards can strike the same vulnerabilities. A geomagnetic storm on the scale of the [Carrington Event](#) of 1859 would today threaten satellites, navigation and high-voltage transformers, which take months or years to replace. Artificial intelligence adds a further layer of uncertainty. The first [International AI Safety Report](#), published in 2025, grouped the risks of general-purpose AI into malicious use, malfunctions and systemic risks, including effects on labour markets, information ecosystems and the concentration of power. Within the polycrisis, AI acts in both directions. It could strengthen early warning, accelerate clean-energy innovation and improve the targeting of social protection; it could also amplify misinformation, which the World Economic Forum's surveys have ranked among the most severe short-term global risks, and introduce new correlated failures into critical systems.

## 7.5 Nuclear and catastrophic security risks

Nuclear war is the clearest example of a risk whose profile differs from the polycrisis's chronic pressures. Its probability in any year is low and impossible to estimate precisely, but its consequences would be global. Modelling suggests that soot injected into the stratosphere by firestorms after a nuclear exchange could cut sunlight and global harvests enough that more than two billion people could die from a regional war between India and Pakistan, and more than five billion from a war between the United States and Russia ([Xia et al. 2022](#)). The architecture of arms control that limited these risks during and after the Cold War has eroded; New START, the last treaty limiting the strategic arsenals of the United States and Russia, reached the end of its term in February 2026.

The connection to the polycrisis runs through probability rather than mechanism. A world in which climate stress, economic fragility, mass displacement and geopolitical rivalry are all rising is a world in which the conditions for miscalculation multiply, and in which the institutions for crisis management are already overstretched. The same is true of engineered pandemics and other deliberate catastrophic risks. The polycrisis does not cause these events, but it can raise their likelihood and would magnify their consequences.

**Table 11.** Biological, technological and security risks: profiles and interactions with the polycrisis

| Risk                                        | Onset                   | Exposure profile                                     | Interaction with the polycrisis                                                               | Grade                       |
|---------------------------------------------|-------------------------|------------------------------------------------------|-----------------------------------------------------------------------------------------------|-----------------------------|
| <b>Climate-sensitive infectious disease</b> | Gradual, with outbreaks | Broad; concentrated in the tropics and poor settings | Warming, flooding and poor sanitation expand transmission; malnutrition raises susceptibility | A–B                         |
| <b>Pandemic of zoonotic origin</b>          | Sudden                  | Global                                               | Land-use change and range shifts raise spillover risk; fragile health systems slow response   | B                           |
| <b>Antimicrobial resistance</b>             | Slow                    | Global; highest burden in low-income regions         | Poor sanitation, conflict and agricultural overuse accelerate resistance                      | A                           |
| <b>Cyber and digital failure</b>            | Sudden                  | Event-dependent; potentially global                  | Tight coupling of critical infrastructure; conflict raises the threat                         | B                           |
| <b>Geomagnetic storm</b>                    | Sudden                  | Event-dependent; potentially continental             | Dependence on grids and satellites; long transformer replacement times                        | B                           |
| <b>Advanced AI</b>                          | Uncertain               | Uncertain                                            | Could strengthen resilience or amplify misinformation, concentration and correlated failure   | C                           |
| <b>Nuclear war</b>                          | Sudden                  | Global through climate effects                       | Geopolitical stress raises the probability; a weakened world would recover more slowly        | B (impact), D (probability) |

*Grades refer to the existence and direction of the interaction, not to the probability of the event, except where stated.*

## 7.6 Assessment

Biological and technological pressures differ from the climate–pollution core in their timing: they are more often sudden. Their importance to the polycrisis lies in two facts. First, the chronic pressures raise their probability or their impact: warming expands disease, conflict erodes arms control, fragile health systems turn outbreaks into epidemics. Second, a sudden shock arriving in a world already weakened by chronic pressures would do more damage and leave a longer legacy than the same shock in a resilient world. The polycrisis is the background against which every acute catastrophe would be played out.

08

DOMAIN V · ECONOMY AND GEOPOLITICS

## 8. Economic Fragility and Geopolitical Fragmentation

### 8.1 The fiscal squeeze

If the climate–pollution nexus is the engine of the polycrisis, public finance is its transmission. Global public debt reached a record of about US\$102 trillion in 2024, of which about US\$31 trillion was owed by developing countries ([UNCTAD A World of Debt 2025](#)). Developing countries' net interest payments on public debt reached about US\$921 billion in 2024, and a record 61 countries spent 10 per cent or more of government revenue on interest. About 3.4 billion people now live in countries that spend more on interest payments than on either health or education.

This matters for the polycrisis because fiscal space is a buffer. A government with room to borrow can fund disaster relief, social protection and reconstruction after a shock; a government already spending a large share of its revenue on interest cannot, or can only by cutting the investments in health, education and infrastructure that reduce vulnerability to the next shock. Disasters themselves are growing more costly (Figure 14). Part of the apparent rise in recorded events reflects better reporting, especially before 2000, and part of the rise in damage reflects more assets in harm's way. But both trends point to the same conclusion: the bill for absorbing shocks is rising faster than the capacity of many states to pay it.

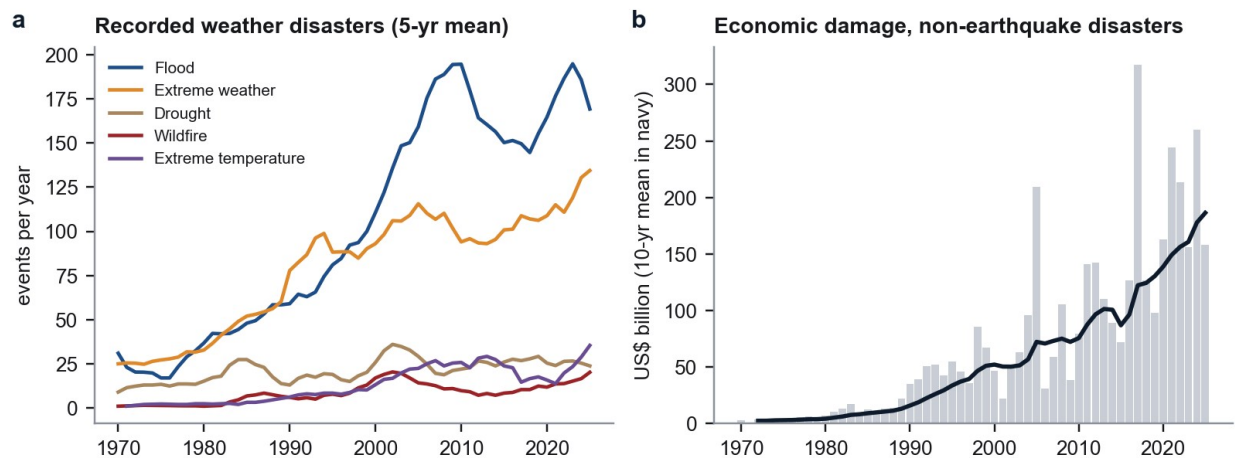


**Figure 14. Recorded disasters and their cost.** (a) Number of recorded weather-related disasters per year by type, five-year running mean, 1970–2025. (b) Recorded economic damage from all non-earthquake disasters, with ten-year running mean.

Source: [EM-DAT](#), CRED/UCLouvain, via Our World in Data. Trends in recorded events are affected by improvements in reporting, especially before 2000; damage is in current US dollars and is not adjusted for growth in exposed assets.

Insurance is the private equivalent of fiscal space, and it too is under strain. As losses from floods, wildfires and storms rise, insurers in exposed regions raise premiums or withdraw, leaving households and businesses uninsured. The H Heuristics monograph identifies this process, rising **uninsurability**, as one of the key mechanisms by which chronic climate pressure becomes financial fragility: uninsured assets lose value, mortgage markets come under stress, and the losses are eventually transferred to public budgets that are already stretched.

## 8.2 Efficient, concentrated and fragile supply chains

The global economy's supply chains are marvels of efficiency, but efficiency is often achieved by eliminating slack. Just-in-time inventories, concentrated production and long shipping routes minimize costs in normal times and maximize exposure to correlated disruption. The COVID-19 pandemic, the blockage of the Suez Canal by the container ship *Ever Given* in 2021, attacks on shipping in the Red Sea from late 2023, and the drought that forced the [Panama Canal](#) to restrict transits in 2023 each demonstrated how a disruption at a single chokepoint can propagate worldwide. The Panama Canal case is particularly instructive: a climate-related water shortage became a constraint on global trade.

The general principle is shown by the threshold-cascade model in Figure 22, discussed in Section 10. In a network where each node fails if a sufficient fraction of its partners fail, lean systems with little tolerance for disruption experience system-wide cascades over a wide range of connectivity, while buffered systems absorb the same initial failures. More connection is not always more fragility: in a buffered network, connection spreads load and supports recovery. What makes connection dangerous is connection without slack.

## 8.3 The return of war

After a long decline following the end of the Cold War, armed conflict has risen sharply. The Uppsala Conflict Data Program recorded 65 state-based armed conflicts in 2025, the highest number since its records began in 1946 (Figure 15); 61 were active in 2024 ([UCDP](#); [PRIO Conflict Trends](#)). The number of conflicts between states has also risen, and wars causing at least 1,000 battle deaths a year rose to eleven in 2024. At the end of 2024, 123.2 million people were forcibly displaced, one in every 67 people on Earth; Sudan had become the world's largest displacement crisis, with 14.3 million refugees and internally displaced people ([UNHCR](#)).

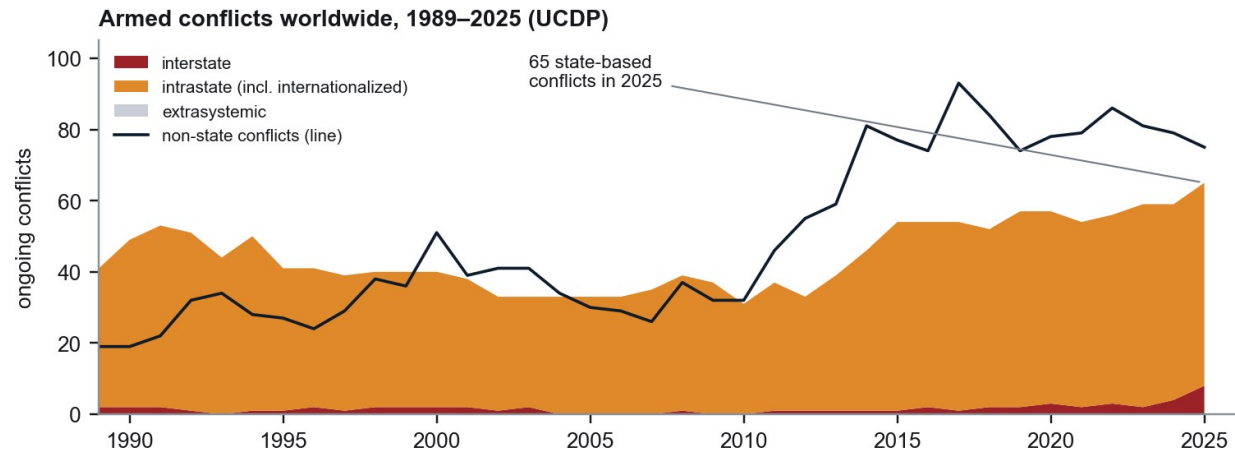


**Figure 15. Armed conflict, 1989–2025.** Ongoing state-based armed conflicts by type (stacked areas) and non-state conflicts (line). The count of state-based conflicts in 2025 is the highest in the UCDP record.

Source: [Uppsala Conflict Data Program](#), via *Our World in Data*. Counts are revised as new information becomes available; figures in this chart may differ slightly from those in UCDP press releases.

Conflict is the single largest driver of acute food insecurity, affecting about 140 million people in 20 countries and territories in 2024 ([GRFC 2025](#)). It destroys infrastructure that takes decades to rebuild, displaces populations into neighbouring states that are often fragile themselves, and diverts public spending from development to defence. In the coupling matrix of Section 10, geopolitics is the second strongest transmitter of stress in the entire system.

## 8.4 Does climate change cause conflict?

The link between environmental stress and conflict is one of the most debated questions in the polycrisis literature, and it deserves a careful answer. A widely cited meta-analysis found that deviations toward hotter temperatures or extreme rainfall systematically increase the risk of interpersonal violence and intergroup conflict ([Hsiang et al. 2013](#)). An expert elicitation published in *Nature* concluded that climate has affected organized armed conflict within countries, but that its influence so far has been small relative to other drivers such as low socioeconomic development, weak state capacity, intergroup inequality and recent violent conflict; the experts judged that between 3 and 20 per cent of conflict risk over the previous century had been influenced by climate ([Mach et al. 2019](#)). The influence is expected to grow with warming.

The report therefore grades the claim that climate change raises conflict risk as C: plausible and partly supported, but modest, conditional and contested. Environmental stress can compound conflict risks, but it does not automatically cause war. Its effect runs through the same vulnerabilities, poverty, weak institutions and inequality, that the polycrisis framework identifies everywhere else. This is an encouraging conclusion: the conditions that turn environmental stress into violence are themselves amenable to policy.

## 8.5 Fragmentation and the erosion of cooperation

The most dangerous geopolitical pressure may not be war but the erosion of cooperation. Nearly every pressure in the polycrisis, from emissions to pandemics to debt, requires collective action across borders. The World Economic Forum's [Global Risks Report 2026](#) ranked geoeconomic confrontation as the most severe risk for 2026 and over the following two years, and found that environmental risks had fallen down

the short-term rankings even though they remain at the top over a ten-year horizon. Official development assistance fell in 2024, humanitarian funding declined again in 2025 as needs rose, and trade restrictions have multiplied. A world that cooperates less is a world with thinner buffers in every domain at once.

**Table 12.** How economic and geopolitical fragility transmits stress

| Channel               | Mechanism                                                                     | Domains affected                 | Buffer that breaks it                               |
|-----------------------|-------------------------------------------------------------------------------|----------------------------------|-----------------------------------------------------|
| <b>Debt service</b>   | Interest payments crowd out health, education and adaptation spending         | Poverty, health, infrastructure  | Debt relief, concessional finance                   |
| <b>Uninsurability</b> | Rising losses lead insurers to withdraw; risk shifts to households and states | Economy, housing, public finance | Risk pools, catastrophe bonds, land-use planning    |
| <b>Chokepoints</b>    | Disruption at a single route or supplier propagates globally                  | Food, energy, medicine, industry | Diversified routes and suppliers, strategic stocks  |
| <b>Price shocks</b>   | Food and energy spikes erode real incomes and trigger unrest                  | Food, poverty, governance        | Social protection, grain reserves                   |
| <b>War</b>            | Destruction, displacement, famine, diversion of spending                      | All domains                      | Conflict prevention, mediation, humanitarian access |
| <b>Fragmentation</b>  | Loss of cooperation on emissions, health, finance and trade                   | All domains, especially climate  | Multilateral institutions, minilateral coalitions   |

Source: H Heuristics, drawing on [UNCTAD](#), [GRFC 2025](#) and the works cited in this section.

## 8.6 Assessment

Economic and geopolitical fragility rank lower in direct exposure than warming or pollution, but they are among the most powerful amplifiers in the system. That rising debt service is reducing fiscal space for health, education and adaptation in many developing countries is established (A). That armed conflict has risen to its highest level since 1946 is established (A). That climate change contributes modestly and conditionally to conflict risk is contested (C). That geopolitical fragmentation reduces the capacity to manage every other pressure is well supported (B). The common thread is buffers: fiscal space, insurance, inventories, diversified supply and the institutions of cooperation are all forms of slack, and all are under pressure at the same time.

## 09

## DOMAIN VI · DEMOGRAPHY

## 9. The Demographic Geography of Risk

### 9.1 Why demography decides exposure

A hazard's humanitarian significance depends on how many people live in its path. That simple observation makes demography one of the most important and most neglected dimensions of the polycrisis. Over the rest of this century, the number of people exposed to dangerous heat, water scarcity and coastal flooding will depend at least as much on where population grows, how it ages and where it settles as on how much the planet warms. The report calls this the **demographic geography of survivability**.

### 9.2 Peak population and where growth will occur

According to the [UN World Population Prospects 2024](#), the world's population, about 8.2 billion in 2024, is projected to reach 9.7 billion in 2050 and to peak at about 10.3 billion in 2084 before declining slightly to 10.2 billion by 2100 (Figure 16a). The headline masks a profound redistribution. Asia's population is projected to peak in the mid-2050s at about 5.3 billion and fall to 4.61 billion by 2100. Europe's is already declining. Africa's is projected to grow from 1.51 billion in 2024 to 2.47 billion in 2050 and 3.81 billion in 2100, when it would account for 37 per cent of humanity. Projections this far ahead are uncertain, and some alternative models project an earlier and lower peak ([Vollset et al. 2020](#)), mainly because they assume faster declines in fertility as education and contraception spread. But the direction of the shift is robust.

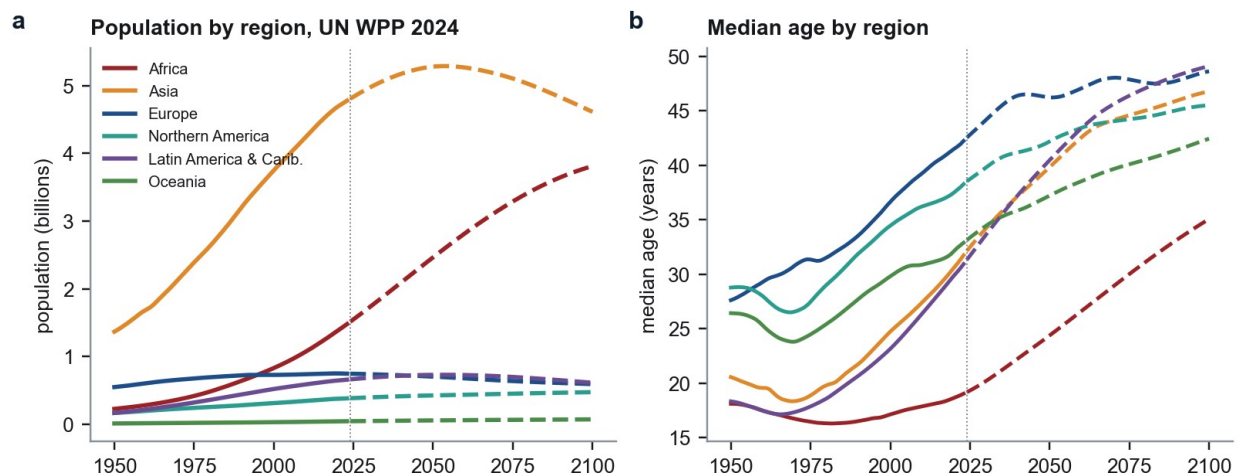


**Figure 16. The demographic shift.** (a) Population by region, 1950–2100: estimates (solid) and UN medium-variant projections (dashed). (b) Median age by region over the same period.

Source: [UN World Population Prospects 2024](#), via [Our World in Data](#). Regions follow UN definitions.

The significance for the polycrisis is that the fastest population growth will occur in the regions that are already hottest, most water-stressed, most dependent on rain-fed agriculture, least served by infrastructure and, on current trends, least able to finance adaptation. Sub-Saharan Africa, which is projected to account for most of the world's population growth this century, faces some of the steepest increases in dangerous heat and some of the largest gaps in cooling, electricity and health care. Even with no further warming, demographic growth alone would increase the number of people exposed to today's climate hazards in these regions.

### 9.3 Ageing: a rising sensitivity

At the same time, humanity is ageing (Figure 17a). The share of the world's population aged 65 and over is projected to rise from about 10 per cent in 2024 to about 16 per cent in 2050 and 24 per cent in 2100. Europe's share is already above 20 per cent; Latin America's and Asia's will roughly triple by 2100. Ageing raises sensitivity to almost every environmental pressure. Older people are far more likely to die during heatwaves, more susceptible to the cardiovascular effects of air pollution and more dependent on functioning health systems and electricity. The Lancet Countdown has found that heat-related deaths of people over 65 have risen sharply in recent decades, driven by both warming and the growing number of older people. Ageing also changes the economics of adaptation: shrinking working-age populations and rising pension and health costs reduce the fiscal space available for prevention.

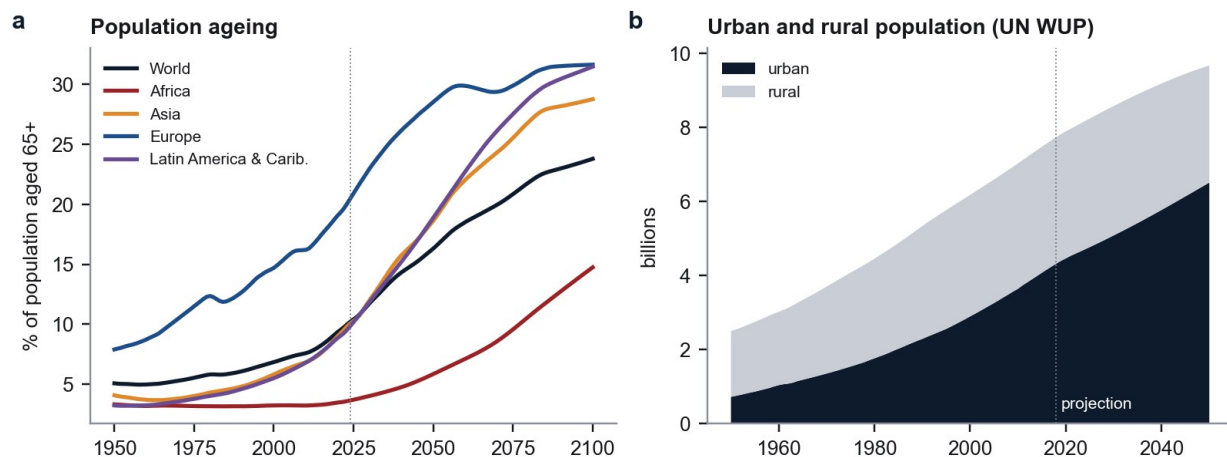


**Figure 17. Ageing and urbanization.** (a) Share of the population aged 65 and over, world and selected regions, 1950–2100, with UN medium-variant projections after 2023. (b) Urban and rural population of the world, 1950–2050.

Sources: (a) [UN World Population Prospects 2024](#), via [Our World in Data](#). (b) [UN World Urbanization Prospects](#), via [Our World in Data](#); projections after 2018.

### 9.4 Urbanization and the coast

By 2050 about 67 per cent of the world's people are projected to live in urban areas (Figure 17b). Cities concentrate both risk and the means to manage it. They amplify heat through the urban heat-island effect, concentrate air pollution, and in rapidly growing regions often expand through informal settlements on land exposed to floods and landslides. But they also offer economies of scale in water, sanitation, health care and early warning that dispersed rural populations cannot match. Whether urbanization reduces or increases exposure depends overwhelmingly on planning and investment.

Coastal concentration is a particular concern because of its persistence. Improved elevation data suggest that land currently home to about 300 million people could fall below the elevation of an average annual

coastal flood by 2050 ([Kulp & Strauss 2019](#)). Satellite observations show that the share of the world's population living in flood-exposed areas has been rising, as settlement expands into floodplains faster than population grows elsewhere ([Tellman et al. 2021](#)). Because sea-level rise will continue for centuries (Section 11), decisions about where to build today shape exposure for many generations.

## 9.5 Migration: adaptation and its limits

Migration is one of humanity's oldest responses to environmental change, and it will be part of the response to the polycrisis. The World Bank's *Groundswell* analysis projected that, in its most pessimistic scenario, climate change could force up to 216 million people to move within their own countries by 2050, mainly in sub-Saharan Africa, South Asia and East Asia and the Pacific ([Clement et al. 2021](#)). Migration can be a successful adaptation, diversifying household income and moving people out of harm's way. It can also be distress migration into precarious urban settlements that are themselves exposed. And some of the most vulnerable people will be unable to move at all: 'trapped populations' who lack the resources to leave places that are becoming more dangerous. Most climate-related movement is, and is likely to remain, internal and regional rather than international.

**Table 13.** The demographic geography of risk: regional shifts and their implications for exposure

| Region                             | Population 2024 → 2050 → 2100 (bn) | Aged 65+ 2024 → 2100 | Implication for exposure                                                                                            |
|------------------------------------|------------------------------------|----------------------|---------------------------------------------------------------------------------------------------------------------|
| <b>Africa</b>                      | 1.51 → 2.47 → 3.81                 | 3.6% → 14.7%         | Largest growth in the hottest, least-served region; heat, water and food exposure rise even without further warming |
| <b>Asia</b>                        | 4.81 → 5.28 → 4.61                 | 10.1% → 28.8%        | Peak and decline; South Asian heat and pollution exposure stays very high; rapid ageing raises sensitivity          |
| <b>Europe</b>                      | 0.75 → 0.70 → 0.59                 | 20.5% → 31.6%        | Oldest population; heat mortality is concentrated among the elderly; shrinking fiscal base                          |
| <b>Latin America and Caribbean</b> | 0.66 → 0.73 → 0.61                 | 9.8% → 31.5%         | Rapid ageing; highly urban; exposed to storms, drought and ecosystem loss                                           |
| <b>Northern America</b>            | 0.39 → 0.43 → 0.47                 | 18.1% → 28.5%        | Continued growth through migration; wildfire, heat and coastal exposure; high adaptive capacity                     |
| <b>World</b>                       | 8.16 → 9.66 → 10.18                | 10.2% → 23.8%        | Growth concentrated where risk is rising; ageing raises sensitivity everywhere                                      |

Source: H Heuristics calculation from [UN World Population Prospects 2024](#) medium variant, via *Our World in Data*.

## 9.6 Assessment

That population growth this century will be concentrated in hot, lower-income regions is established as a projection (A–B). That ageing will raise sensitivity to heat and pollution is established (A). That climate change will drive large-scale internal migration is well supported (B), but the numbers are highly scenario-dependent. The key insight of this section is that **exposure can rise even if hazards do not**. A strategy for the polycrisis that ignores demography will underestimate future risk in Africa and South Asia, and underestimate the importance of preparing health and social-protection systems for older populations everywhere.

## 10

## MECHANISMS OF COMPOUNDING



## 10. Feedback Loops and Cascade Dynamics

### 10.1 The coupling network

Sections 4 to 9 described each cluster of pressures and the ways it affects others. This section assembles those links into a single structure and asks what the structure does. Figure 18a shows the coupling matrix: an assessment, by H Heuristics, of how strongly sustained stress in each of ten domains raises stress in each of the others, on a scale from 0 (no meaningful link) to 3 (strong link). Each entry corresponds to a mechanism documented earlier in this report. For example, climate strongly raises stress on water, food, ecosystems and infrastructure; poverty strongly raises stress on health; and geopolitics strongly raises stress on food and the economy.

The matrix is dense. Of 90 possible directed links between different domains, 66 (73 per cent) are active, and 12 are strong. To identify the system's structure, the report computed each domain's total influence, counting indirect paths as well as direct ones with a discount for each step (Figure 18b). Two domains stand out as **transmitters**, sources of stress that radiate through the system: climate and heat, and geopolitics and governance. Four stand out as **receivers**, the places where harm accumulates: poverty and inequality, health and disease, food, and the economy. Water occupies an intermediate position as a conduit, receiving stress from climate and transmitting it to food, health and conflict.

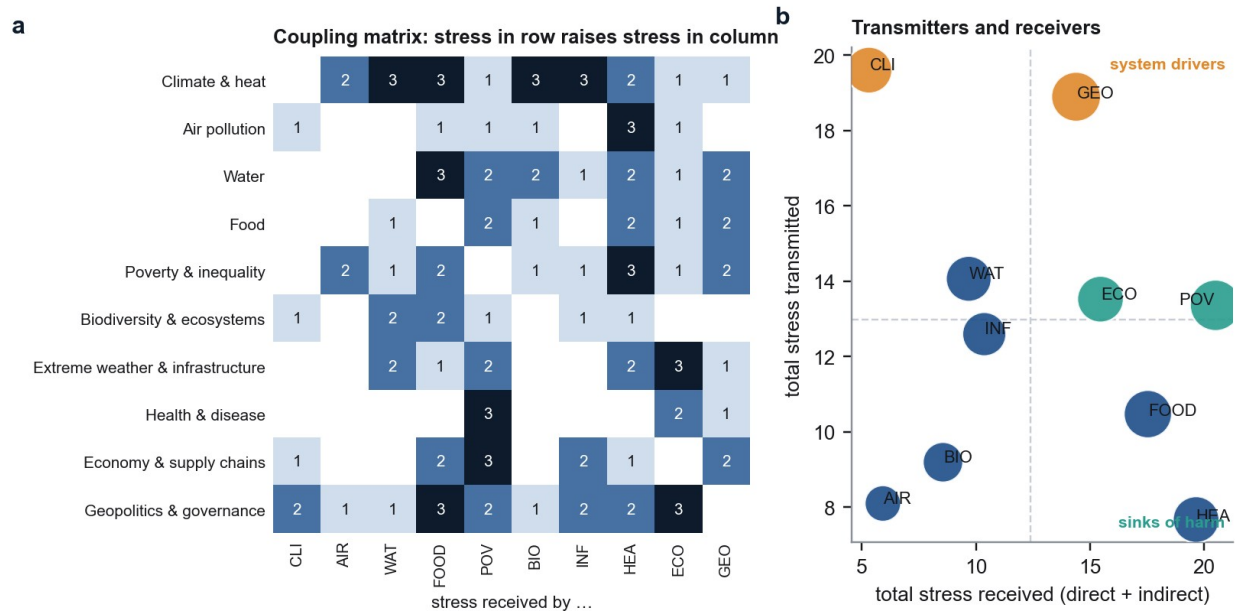


**Figure 18. The coupling network.** (a) The ten-domain coupling matrix: each cell scores how strongly sustained stress in the row domain raises stress in the column domain (0–3). (b) Each domain's total stress transmitted and received, including indirect paths (Katz-type centrality, discount 0.25 per step); bubble size reflects total direct links.

Source: H Heuristics assessment of the mechanisms documented in Sections 4–9 and calculation. The scores are judgements, not measurements; the network structure is robust to changing any single score by one point.

This structure has a practical implication. Interventions at transmitters, such as cutting emissions or preventing conflict, reduce stress across the whole system. Interventions at receivers, such as social protection or health care, reduce the harm that stress causes. Both are necessary, but they do different jobs, and a portfolio that does only one will be less effective than one that does both.

## 10.2 Six reinforcing loops

Coupling becomes dangerous when it closes into loops. A feedback loop is a chain of causes that returns to its starting point, so that the consequence of a shock amplifies the shock itself. The report identifies six loops that are central to the polycrisis (Figure 19).

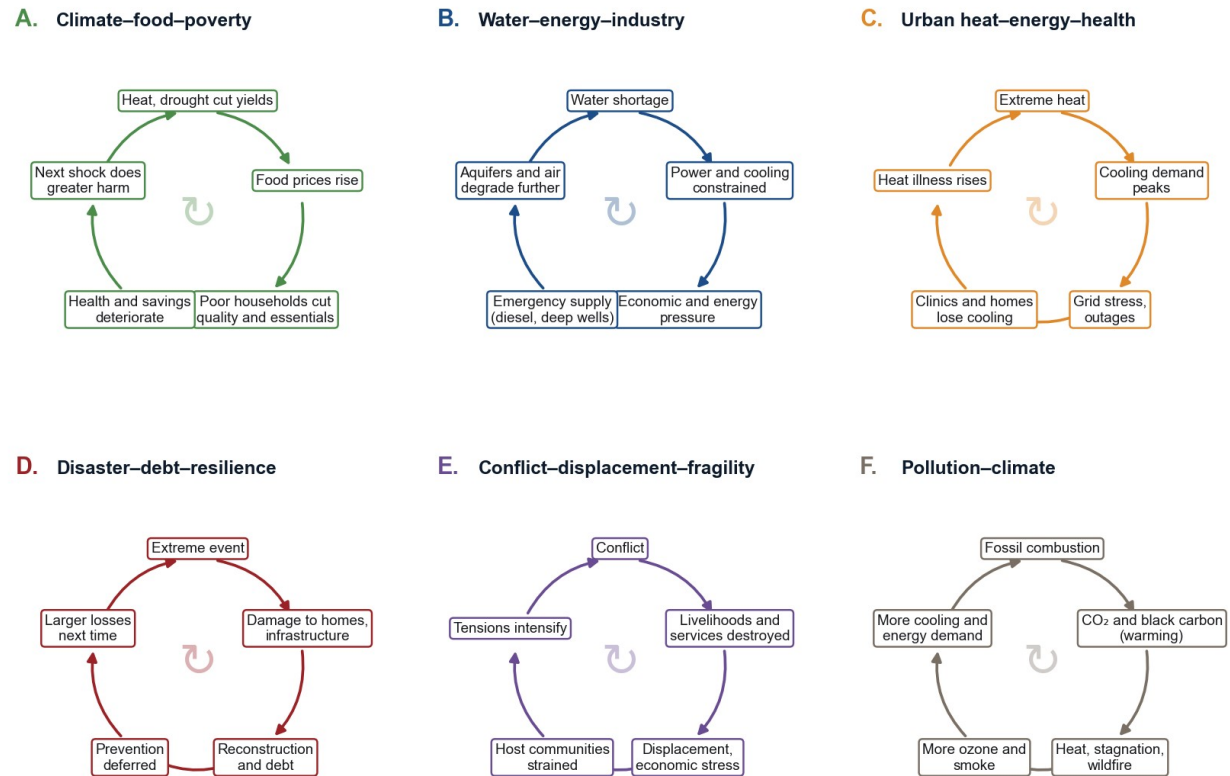


**Figure 19. Six reinforcing feedback loops of the polycrisis.** Each loop is a chain of causes that returns to its origin, so that harm amplifies the conditions that produce it.

Source: H Heuristics. Mechanisms documented in Sections 4–9.

**Table 14.** The six loops: how they work, where they are strongest and what breaks them

| Loop                                      | How it reinforces                                                                                                                                 | Where strongest                                           | What breaks it                                                      |
|-------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|---------------------------------------------------------------------|
| <b>A. Climate–food–poverty</b>            | Heat and drought cut yields; prices rise; poor households cut food quality and essentials; health and savings fall; the next shock does more harm | Rain-fed farming regions; import-dependent poor countries | Social protection, crop insurance, grain reserves, resilient seed   |
| <b>B. Water–energy–industry</b>           | Water shortages constrain power, cooling and manufacturing; emergency supply (diesel, deep wells) worsens pollution and depletion                 | Arid regions; hydropower-dependent grids                  | Water storage and reuse, diversified clean power, demand management |
| <b>C. Urban heat–energy–health</b>        | Heat raises cooling demand; grids fail at peak load; clinics and homes lose cooling; heat illness rises                                           | Fast-growing hot cities with weak grids                   | Efficient cooling, clean power, passive design, heat-health plans   |
| <b>D. Disaster–debt–resilience</b>        | Disasters damage assets; reconstruction and debt absorb resources; prevention is deferred; future losses grow                                     | Small islands, low-income states with high debt           | Risk finance, debt relief, building back better                     |
| <b>E. Conflict–displacement–fragility</b> | Conflict destroys livelihoods and services; displacement strains host communities and institutions; tensions intensify                            | Sahel, Horn of Africa, Middle East                        | Mediation, humanitarian access, support to host communities         |

| Loop                        | How it reinforces                                                                                    | Where strongest                            | What breaks it                                               |
|-----------------------------|------------------------------------------------------------------------------------------------------|--------------------------------------------|--------------------------------------------------------------|
| <b>F. Pollution–climate</b> | Combustion warms the climate; heat increases ozone, smoke and energy demand; more combustion follows | Fossil-based economies; fire-prone regions | Clean energy, methane and black-carbon cuts, fire management |

Loops A–E follow the H Heuristics feedback analysis; loop F is described in Section 4.4. The outcomes of each loop depend heavily on governance and humanitarian support.

### 10.3 A cascade in motion

Loops describe recurring dynamics; cascades describe how a single shock travels. Figure 20 traces a stylized cascade that begins with a multi-year drought. Falling reservoirs curtail hydropower and raise the cost of energy-intensive inputs such as fertilizer and irrigation. Harvests fail and food prices spike. Hunger, illness and distress migration follow. Municipal and national budgets come under strain as revenues fall and relief spending rises, adding to debt. Unrest and weaker governance reduce the capacity to prepare for the next drought, closing the loop. No single link is extraordinary; each has been observed many times. What makes the cascade dangerous is the sequence, and the absence of a buffer at any point that could stop it.

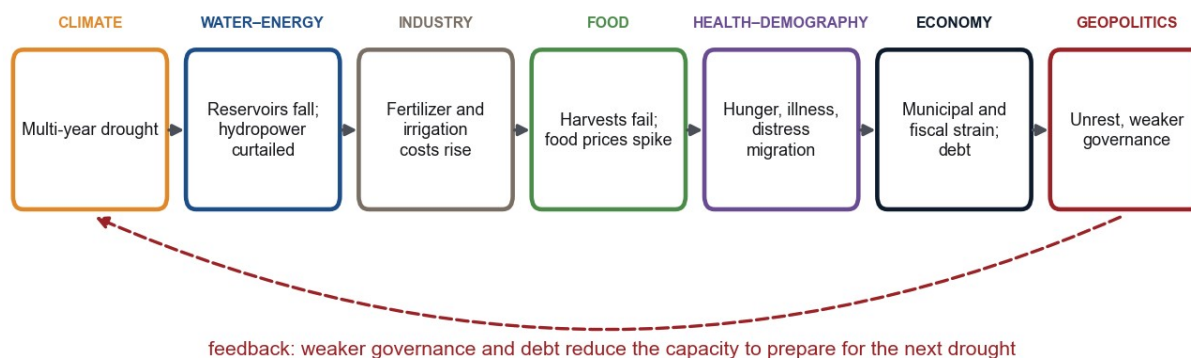


**Figure 20. A stylized cascade.** A multi-year drought propagates through water, energy, industry, food, health, the economy and governance; weaker governance then reduces preparedness for the next drought.

Source: H Heuristics, adapting the cascade described in the H Heuristics essay [The Polycrisis Apocalypse](#).

### 10.4 When is harm super-additive?

The central thesis claims that interacting pressures can produce harm greater than the sum of their parts. This claim is often asserted and rarely tested. The report tests it with a simple model of the coupling network. Each domain carries a level of stress that decays over time as the system recovers. A shock adds stress to one or more domains. Stress is transmitted along the links of the coupling matrix, but only the part that exceeds a domain's **buffer**: stress below the buffer is absorbed locally. The model compares two experiments: shocks to all ten domains at once, and the same shocks delivered to each domain separately, with the separate harms added up.

The results, in Figure 21, are instructive because they show both when the thesis holds and when it does not. With no buffers, transmission is linear and the joint harm is exactly the sum of the separate harms: interaction spreads harm but does not multiply it. With deep buffers, most stress is absorbed and joint

harm exceeds the sum by only 1 per cent. But with **thin buffers**, the coinciding shocks push many domains past their buffers at once, every one of them begins transmitting, and the joint harm reaches 1.24 times the sum of the separate harms, rising further as coupling strengthens toward the point at which the system can no longer recover at all.

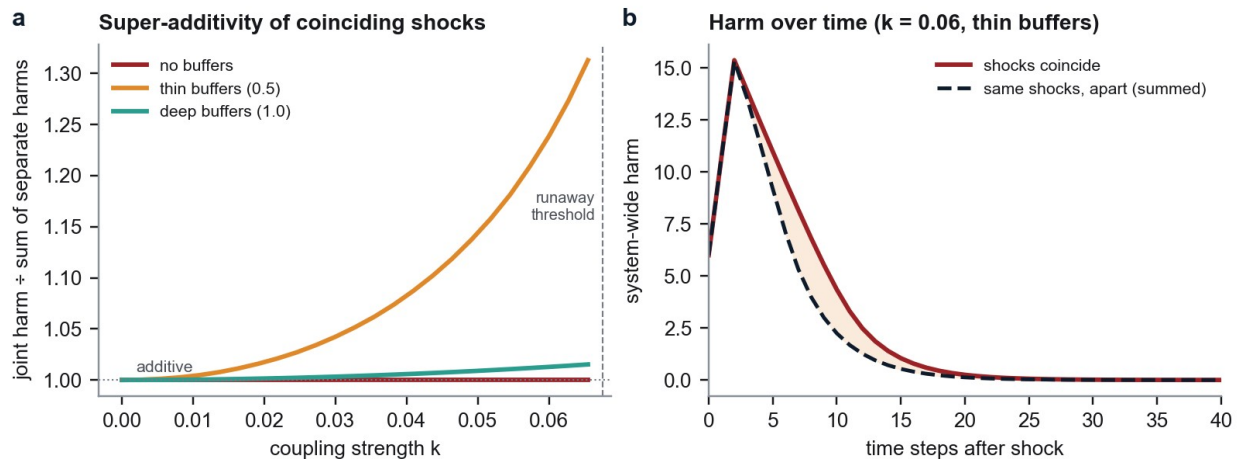


**Figure 21. Super-additivity in the ten-domain model.** (a) Ratio of the harm caused by simultaneous shocks to all domains to the sum of the harms when the same shocks arrive separately, as coupling strength increases, for three buffer depths. (b) System-wide harm over time with thin buffers: coinciding shocks (red) versus the summed effect of separate shocks (dashed).

Source: H Heuristics calculation. Stress decays at 25 per cent per step; transmission along the coupling matrix of Figure 18 is proportional to stress above the buffer; shocks of 0.6 units for three steps. The runaway threshold is the coupling at which a fully unbuffered system can no longer recover.

Three lessons follow. First, super-additivity is not automatic; it is a property of **thresholds** and **depleted slack**. Second, the same coinciding shocks can be nearly additive in a well-buffered society and strongly super-additive in a depleted one, which means that the polycrisis is most dangerous precisely where previous crises have already consumed reserves. Third, and most hopefully, super-additivity can be designed against. Buffers are things that can be built: savings, stocks, spare capacity, redundant infrastructure, fiscal space and social trust.

## 10.5 Buffers and the efficiency trap

Modern economies have spent decades removing slack in the name of efficiency. The threshold-cascade model in Figure 22, a standard model of how failures spread through networks (Watts 2002), shows the consequence. In a network of 3,000 nodes, each node fails when a given fraction of its partners have failed. Three initial failures are introduced. In a **lean** network, where nodes fail when just 12 per cent of their partners fail, system-wide cascades occurred in more than half of trials across a wide range of connectivity, from about two to eleven connections per node. In a **buffered** network, where nodes tolerate failure of up to 26 per cent of their partners, the same three failures never spread.

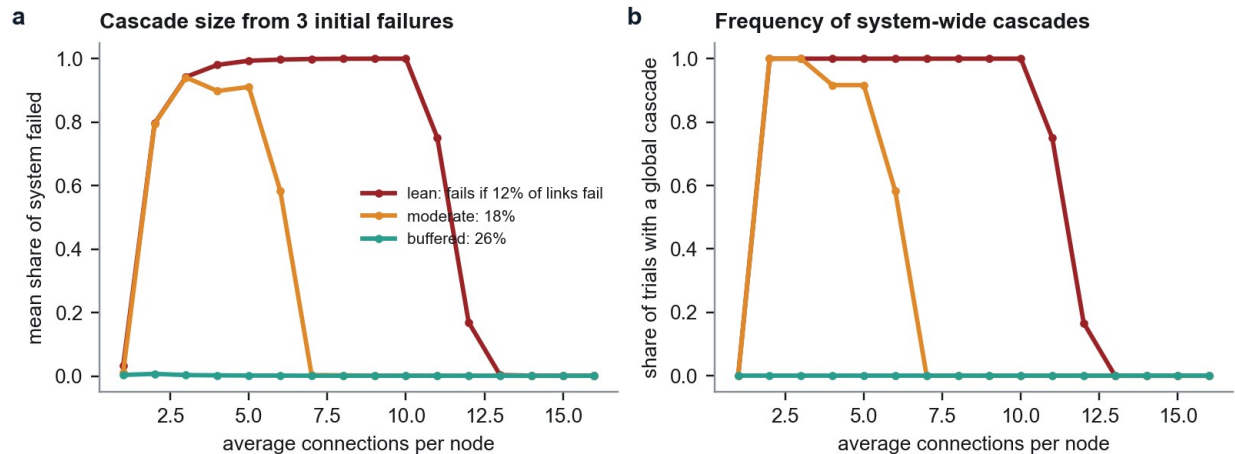


**Figure 22. Lean versus buffered networks.** (a) Average share of a 3,000-node random network that fails after three initial failures, by average number of connections, for three failure thresholds. (b) Share of trials producing a system-wide cascade (more than half of nodes failing).

Source: H Heuristics calculation using the threshold-cascade model of [Watts 2002](#); Erdős–Rényi networks; 12 trials per point.

The model also shows a subtler point. In the lean network, cascades are most likely at intermediate connectivity. Very sparse networks cannot carry a cascade far; very dense networks spread each failure across so many partners that no single one is pushed over its threshold. The danger zone is a world that is connected enough to transmit shocks but not buffered enough to absorb them, which is a fair description of many of today's supply chains, financial systems and infrastructure networks.

## 10.6 Ratchets: when recovery cannot keep up

The most important dynamic for the long-term trajectory of the polycrisis is the ratchet. A society struck by a major shock loses capacity, in the form of assets, health, savings, institutions and trust, and then recovers over a period of years. If the next shock arrives after recovery is complete, capacity oscillates around a stable level. If it arrives before, capacity ratchets downward. And because damaged capacity makes each subsequent shock more damaging, as the disaster–debt–resilience loop describes, the ratchet can accelerate.

Figure 23 models this process. A society's capacity recovers with a characteristic time of eight years, and each major shock does more damage the lower capacity already is. When major shocks arrive about once a decade, median capacity after a century remains high, at 0.93. When they arrive once every five years, median capacity collapses to 0.07; at three shocks a decade it falls to 0.03. The transition is sharp (Figure 23b): it occurs close to the point at which the average interval between shocks equals the recovery time. This is the quantitative core of the polycrisis apocalypse. A society does not need to suffer an unprecedented catastrophe to enter long-term decline. It needs only to suffer ordinary shocks slightly more often than it can recover from them.

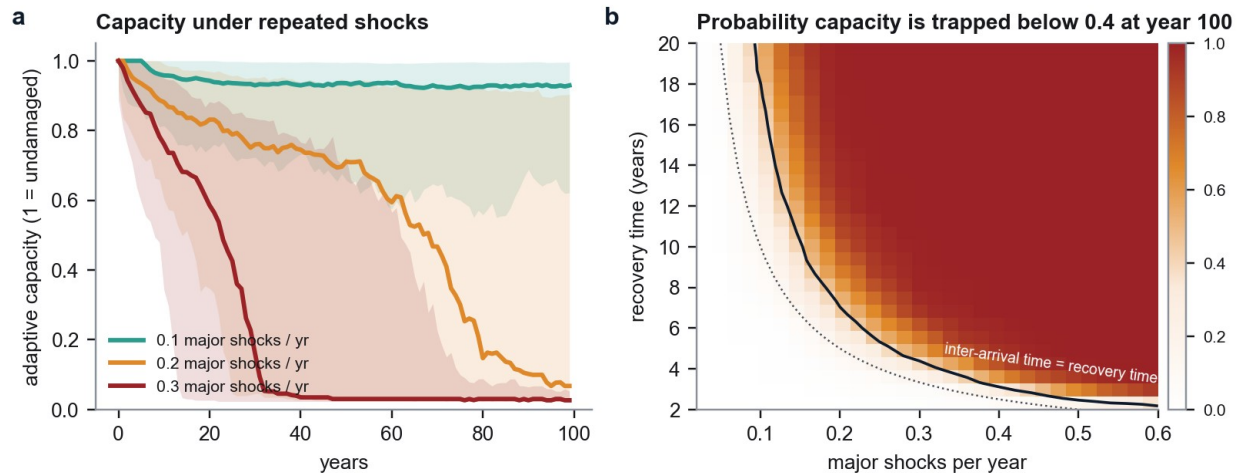


**Figure 23. The recovery ratchet.** (a) Adaptive capacity over a century for societies experiencing 0.1, 0.2 and 0.3 major shocks per year, with a recovery time of eight years: medians and 10th–90th percentile ranges of 400 simulations. (b) Probability that capacity is trapped below 0.4 after a century, by shock frequency and recovery time; the black contour marks 50 per cent, and the dotted line marks where the average interval between shocks equals the recovery time.

Source: H Heuristics calculation. Shocks arrive as a Bernoulli process with gamma-distributed severity; damage is amplified by up to 2.5 times as capacity falls; recovery is logistic. Illustrative only.

The ratchet also identifies the two levers that keep a society on the safe side of the threshold: reducing the frequency and severity of shocks, through mitigation, prevention and conflict avoidance, and shortening the recovery time, through risk finance, social protection, insurance and the capacity to rebuild quickly. Shifting either lever moves a society away from the cliff.

## 10.7 Earth-system cascades

The loops and cascades above operate in human systems over years to decades. Earth-system scientists have warned of a slower and potentially larger class of cascade. Several tipping elements, including the Greenland and West Antarctic ice sheets, warm-water coral reefs, boreal permafrost and the Atlantic Meridional Overturning Circulation, may cross thresholds within the range of warming expected this century ([Armstrong McKay et al. 2022](#)). Their interactions could produce cascades in which tipping one element raises the probability of tipping others ([Wunderling et al. 2021](#); [Lenton et al. 2019](#)), and in the most extreme hypotheses, a self-reinforcing trajectory toward a much hotter 'hothouse' state ([Steffen et al. 2018](#)). The existence of tipping elements is well supported; the timing, thresholds and strength of their interactions remain highly uncertain. The report grades the claim that Earth-system tipping cascades will begin this century as C. Their importance for the polycrisis is that they would add a persistent, largely irreversible source of stress to every human system at once.

## 10.8 The conditions for compounding

**Table 15.** When pressures compound: conditions, evidence and levers

| Condition                               | What it does                             | Evidence                                            | Policy lever                                    |
|-----------------------------------------|------------------------------------------|-----------------------------------------------------|-------------------------------------------------|
| <b>Coupling</b>                         | Spreads stress from one domain to others | Mechanisms in Sections 4–9; coupling matrix         | Decouple critical systems; act on transmitters  |
| <b>Thresholds and thin buffers</b>      | Make coinciding shocks super-additive    | Figure 21; financial and ecological network studies | Build reserves, spare capacity and fiscal space |
| <b>Correlation</b>                      | Makes 'independent' failures coincide    | Figure 12; breadbasket studies                      | Diversify sources, routes and crops             |
| <b>Tight connectivity without slack</b> | Allows small failures to become systemic | Figure 22; supply-chain and cyber incidents         | Redundancy, modularity, circuit breakers        |
| <b>Shocks faster than recovery</b>      | Ratchets capacity downward               | Figure 23; repeat-disaster studies                  | Prevention plus faster recovery finance         |
| <b>Persistent pressures</b>             | Lock in stress for generations           | Section 11; CO <sub>2</sub> and sea level           | Early mitigation; long-horizon planning         |

*Each condition is graded B: well supported in theory and in specific cases, but not yet measured systematically across the global polycrisis.*

The answer to the question 'does the polycrisis produce harm greater than the sum of its parts?' is therefore: yes, under specific and identifiable conditions. Those conditions, coupling, thin buffers, correlation, connectivity without slack, shocks faster than recovery, and persistence, are widespread today. But every one of them is also a target for policy. The architecture that makes harm compound is the same architecture through which prevention can work.

## 11

## TIME HORIZONS



# 11. The Polycrisis Across Centuries

## 11.1 Kinds of persistence

The defining feature of this report is its time horizon. Most assessments of global risk end in 2050 or 2100. Yet some of the most consequential pressures in the polycrisis will last far longer than that, while others could be eliminated within a few years. A long-horizon analysis should not simply extend today's trends into the distant future. It should distinguish between kinds of persistence.

Figure 24a makes the distinction concrete. Fine particles leave the atmosphere within about a week; if emissions stopped tomorrow, the air would clear within weeks. Methane has an atmospheric lifetime of about twelve years, so cutting methane emissions reduces warming within a generation. Carbon dioxide is different. Using the impulse-response function of the Bern carbon-cycle model ([Joos et al. 2013](#)), about 41 per cent of a pulse of CO<sub>2</sub> remains in the atmosphere after a century and about 24 per cent after a thousand years. Warming caused by carbon dioxide is therefore, on any human time scale, effectively permanent unless the gas is actively removed. Sea level responds more slowly still, because the deep ocean and the great ice sheets take centuries to millennia to adjust (Figure 24b). Over the next 2,000 years, global mean sea level is projected to rise by about 2 to 3 metres if warming is limited to 1.5 °C, 2 to 6 metres if limited to 2 °C, and 19 to 22 metres with 5 °C of warming ([IPCC AR6 WGI](#)).

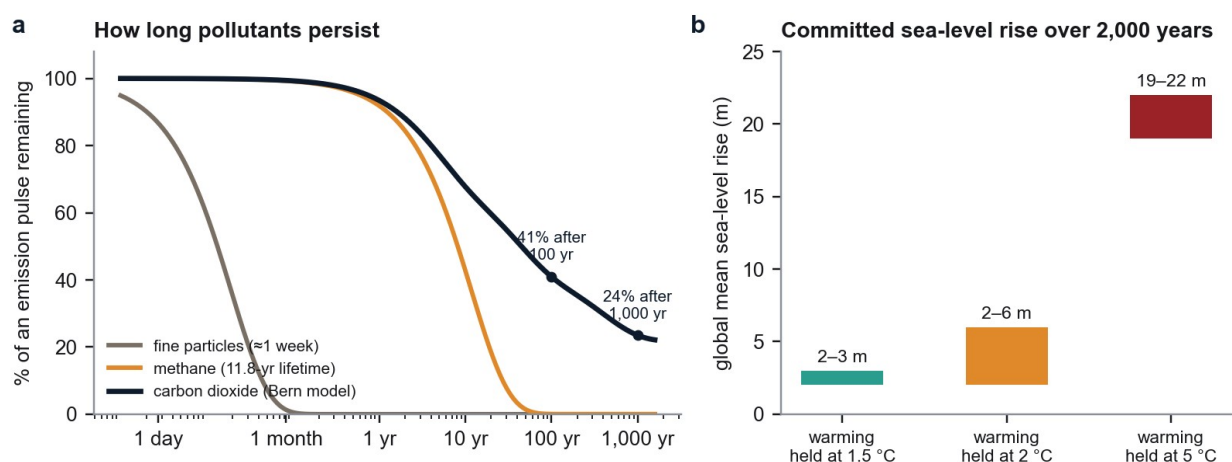


**Figure 24. How long the polycrisis lasts.** (a) Fraction of an emission pulse remaining in the atmosphere over time for fine particles, methane and carbon dioxide. (b) Committed rise in global mean sea level over the next 2,000 years for three levels of sustained peak warming.

Sources: (a) H Heuristics calculation: CO<sub>2</sub> from the Bern-model impulse response of [Joos et al. 2013](#) as used in IPCC AR5; methane lifetime 11.8 years ([IPCC AR6](#)); fine-particle residence time of about one week. (b) [IPCC AR6 WGI Summary for Policymakers](#), statement B.5.4.

**Table 16.** Persistence classes of the polycrisis

| Class               | Typical duration after causes stop | Examples                                                                                    | Implication                                                                             |
|---------------------|------------------------------------|---------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| <b>Fast</b>         | Days to years                      | Air pollution, many price shocks, acute food crises                                         | Large, rapid benefits from action; no excuse for delay                                  |
| <b>Generational</b> | Years to decades                   | Methane, poverty traps, stunting, lost schooling, damaged infrastructure, conflict legacies | Benefits accrue within a lifetime; early childhood and institutions are leverage points |
| <b>Centennial</b>   | Decades to centuries               | Degraded soils and aquifers, ocean heat, settlement patterns, long-lived infrastructure     | Decisions today constrain options for several generations                               |
| <b>Millennial</b>   | Centuries to millennia             | CO <sub>2</sub> concentration, sea-level rise, ice-sheet loss, ocean acidification          | Stabilization is urgent because reversal is impractical                                 |
| <b>Irreversible</b> | Permanent on human time scales     | Species extinction, loss of unique ecosystems and cultures                                  | Precaution is the only effective strategy                                               |

Source: H Heuristics classification.

## 11.2 2025–2050: the immediate exposure transition

The first period is defined by existing populations and existing hazards (Figure 25). Most of the people who will be exposed to the polycrisis by 2050 are already alive, and most of the warming that will occur by 2050 is already determined by past emissions and the inertia of energy systems. The focus of this period is therefore on exposure: rising heat risk, pollution-related illness, water and food insecurity, urban vulnerability and gaps in essential infrastructure. It is the period in which preventive policy has the greatest leverage, because many exposure reductions can be achieved quickly and cheaply through cleaner energy, pollution controls, heat-health measures, sanitation and better housing. H Heuristics has argued in earlier work that the years to 2030 are the cheapest build window of the century, because every year of delay raises the complexity and cost of the response.

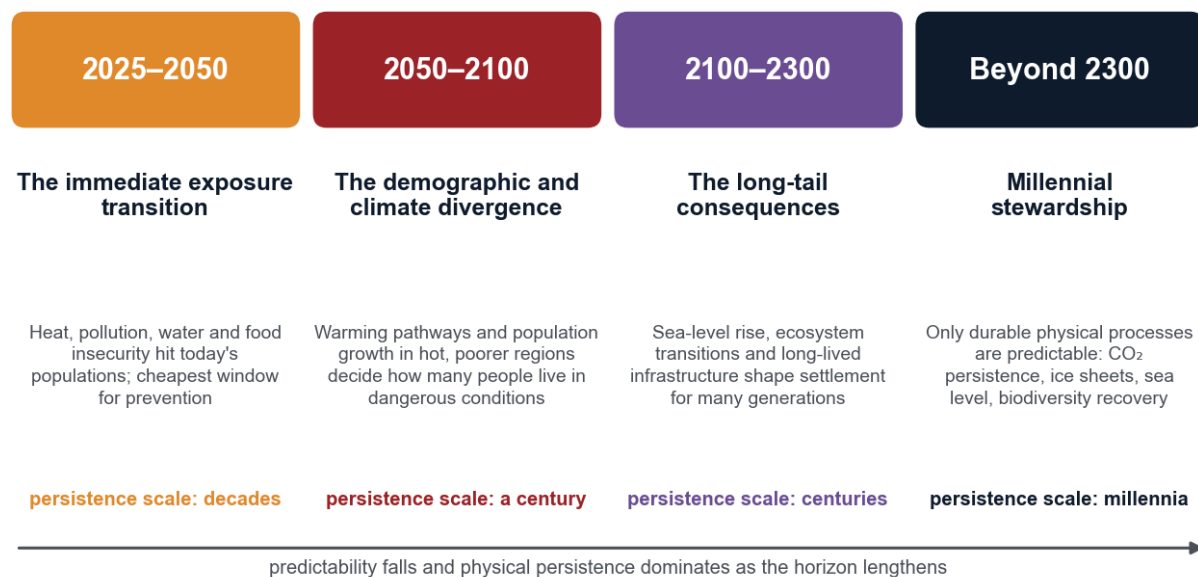


**Figure 25. Time horizons of the polycrisis.** Each period has a different focus, a different balance between human decisions and physical inertia, and a different kind of persistence.

Source: H Heuristics.

### 11.3 2050–2100: the demographic and climate divergence

The second period is where pathways diverge. By the second half of the century, the warming pathway the world has chosen, the distribution of population, the pace of ageing and urbanization, and the extent of development will together determine how many people live in increasingly hazardous environments. This is the core period for comparing high- and low-warming scenarios and for assessing how socioeconomic development changes vulnerability. The IPCC projects that compound and cascading risks will increase as climate and non-climate pressures interact, and that risks rise sharply between 1.5 °C and 3 °C of warming.

Figure 26 illustrates the divergence with a stylized **Polycrisis Exposure Index**. The index combines the UN's population projection, a hazard term that rises with the square of warming, a slow coastal term driven by cumulative warming, and a vulnerability term that falls as development proceeds but rises again when hazards outrun adaptation. Three pathways are compared. Under **reactive drift**, warming reaches about 2.4 °C by 2100 and continues to rise, and vulnerability falls only slowly; the index reaches 309 by 2100 (2025 = 100). Under a **managed transition**, warming peaks near 2.1 °C and development is moderate; the index peaks at about 190 around 2100 and then declines. Under **proactive resilience**, warming peaks below 1.8 °C, adaptation and development are rapid, and the index rises only to about 122 by 2050 before falling back to 98 by 2100.

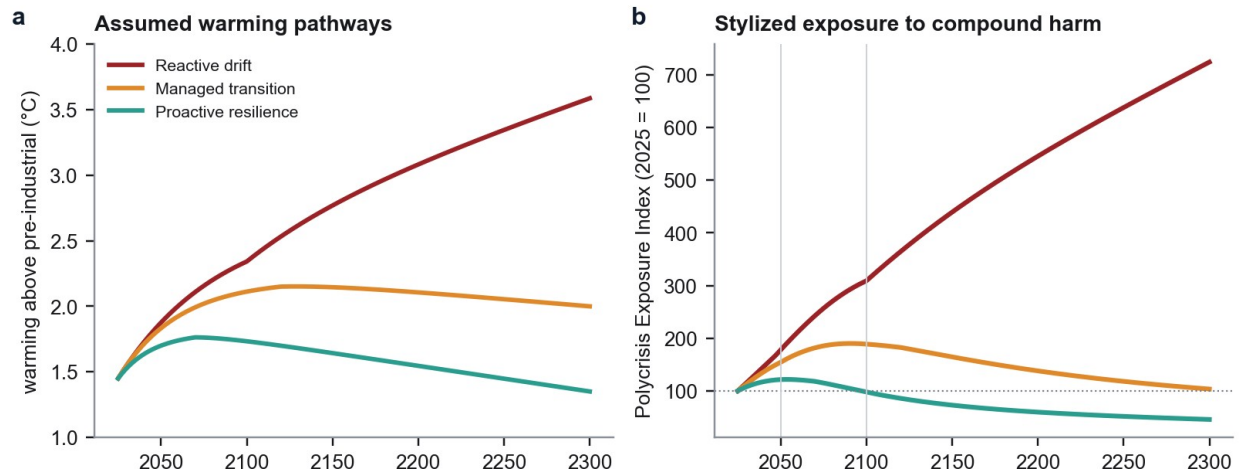


**Figure 26. A stylized Polycrisis Exposure Index to 2300.** (a) Assumed warming pathways. (b) The resulting index (2025 = 100) combining population, hazard, coastal exposure and vulnerability.

Source: H Heuristics calculation. Population: UN WPP 2024 medium variant to 2100, then an assumed slow decline. Hazard = (warming / 1.45 °C)<sup>2</sup>; coastal term proportional to cumulative warming; vulnerability declines at 0.2, 0.8 and 1.6 per cent a year in the three pathways and rises when hazard exceeds 1.6 times today's level. The index is illustrative and is not a forecast.

The index is not a forecast, and its absolute values depend on assumptions that are deliberately simple. Its purpose is to show the shape of the choice. The differences between pathways are small in 2030 and large by 2100, and they keep widening long afterwards. Under reactive drift the index continues to rise for centuries, to about 724 by 2300, because warming and sea level continue to increase and vulnerability rises once hazards outrun adaptation. Under proactive resilience it falls below today's level. Most of the difference is created by decisions made before 2050.

## 11.4 2100–2300: the long-tail consequences

The third period is governed increasingly by physical inertia. Even if emissions fall, some consequences, above all sea-level rise, will continue for centuries. By 2300, global mean sea level is projected to rise by roughly 0.3 to 3.1 metres under a very low-emissions pathway and by 1.7 to 6.8 metres under a very high-emissions pathway, with rises of up to about 15 metres not ruled out if ice-sheet processes that are poorly understood come into play ([IPCC AR6 WGI](#)). The extent of future harm in this period will depend on cumulative emissions, ice-sheet responses, adaptation and future settlement choices. It will also depend on decisions about long-lived infrastructure: ports, cities, power plants and transport networks built in the coming decades will still be in use, or abandoned, in the twenty-second century.

This period also brings ecosystem transitions. Forests, coral reefs and permafrost that cross tipping points this century may continue to change for centuries afterwards. Biodiversity, once lost, does not return on human time scales: after the great extinctions of the geological past, the diversity of life took millions of years to recover. The long tail of the polycrisis is therefore not a continuation of today's crises but a different kind of problem: managing settlement, infrastructure and ecosystems in a world whose physical baseline is still moving.

## 11.5 Beyond 2300: millennial stewardship

For millennial horizons, the report concentrates on durable physical processes, conditional climate scenarios, ecosystem persistence and long-term stewardship. Detailed forecasts of future populations or political systems over thousands of years would be too uncertain to present as reliable predictions. What

can be said is conditional. If carbon dioxide concentrations are stabilized at a moderate level, the climate will settle into a warmer but stable state, sea level will rise slowly for millennia, and human societies, given time and wealth, can adapt to that. If concentrations continue to rise, the eventual commitment, measured in metres of sea level and degrees of warming, grows with every decade, and the burden falls on generations that had no part in the decision. Millennial stewardship is ultimately about one variable more than any other: how much carbon dioxide the present century leaves in the atmosphere.

## 11.6 The long-regression scenario

The H Heuristics essay [The Polycrisis Apocalypse](#) and the [monograph](#) on which this report builds describe a severe scenario: a multi-century regression in which cascading failure dismantles industrial civilization and successor societies struggle to rebuild it. The report takes the scenario seriously as a tail risk. It identifies five mechanisms that would drive it:

1. **Buffer exhaustion.** Repeated shocks consume savings, stocks, fiscal space and trust until ordinary shocks become unmanageable, as in the ratchet of Section 10.
2. **Financial contagion and uninsurability.** Rising losses make assets uninsurable, credit contracts, and public budgets absorb private losses until they too fail.
3. **Complexity overhead.** An increasing share of resources goes to maintaining existing systems and responding to recurring crises, leaving too little for renewal, the condition Tainter associated with collapse.
4. **The energetic moat.** Rebuilding an industrial base after a collapse could be harder than building it the first time, because the most accessible high-return fossil fuels have been used and modern energy technologies require an existing industrial and knowledge base.
5. **Loss of institutional memory.** Prolonged contraction erodes universities, archives, professional skills and the tacit knowledge needed to operate complex systems.

Each mechanism is plausible and has historical precedents at regional scale: the end of the Bronze Age palace economies of the eastern Mediterranean, the fragmentation of the western Roman Empire and the decline of the Classic Maya cities each involved combinations of environmental stress, economic disruption, conflict and loss of complexity, followed by centuries of lower population and output in the affected regions. But four considerations weigh against treating a *global* long regression as probable. First, historical collapses were regional, and a globally distributed civilization has redundancy that no ancient state possessed. Second, knowledge is now stored in forms and places far more numerous and durable than ever before. Third, the energetic moat is narrowing: solar panels, wind turbines and batteries can deliver energy without high-return fossil fuels, and their costs have fallen dramatically. Fourth, the indicators that would mark the onset of a long regression, such as sustained declines in global life expectancy, food production per person or scientific output, are not yet visible at global scale.

The report therefore grades the long-regression scenario D. It is a scenario to be prevented, not a forecast to be planned around. Specific quantitative projections for such a scenario, for example of population contraction over several centuries, cannot be derived from current evidence and are not adopted here. The value of the scenario is diagnostic: it identifies the mechanisms, buffer exhaustion, contagion, overhead, energy and memory, that a resilience strategy must address, and it identifies early-warning indicators that should be monitored.

## 11.7 Assessment

That carbon dioxide and sea-level rise make some consequences of the polycrisis persist for centuries to millennia is established (A). That the coming decades will largely determine exposure for the rest of the century and beyond is well supported (B). That the world faces a multi-century civilizational regression is speculative (D). The key insight of this section is that **persistence should shape priority**. Pressures that are fast to reverse, such as air pollution, offer the quickest gains. Pressures that are slow to reverse, such as carbon dioxide and biodiversity loss, are the most urgent to stop, because every year of delay adds to a debt that cannot be repaid on human time scales.

## 12

## THE SURVIVABILITY FRAMEWORK



## 12. The Architecture of Human Survivability

### 12.1 From hazard to survivability

The preceding sections described the polycrisis from the perspective of pressures. This section turns the perspective around and asks what it would take for people to remain safe within it. The report uses the term **survivability** for the capacity of a population to maintain health, livelihoods and dignity under compound stress over long periods. Survivability is not a binary property of places, as the word 'uninhabitable' suggests. It is a gradient that depends on the combination of hazard, exposure and vulnerability, and it can be raised or lowered by human decisions.

Three principles follow from the analysis so far. First, survivability is **cumulative**: it is eroded by chronic harms long before it is threatened by catastrophic ones. Second, it is **conditional**: a place that is survivable with reliable electricity, cooling and health care may not be survivable without them. Third, it is **unequal**: the same environment can be safe for one household and lethal for its neighbour.

### 12.2 Four tiers of survivability risk

H Heuristics has proposed a four-tier model of how survivability risk accumulates (Figure 27). The tiers are ordered by severity per person, which rises, and by the share of humanity currently exposed, which falls.

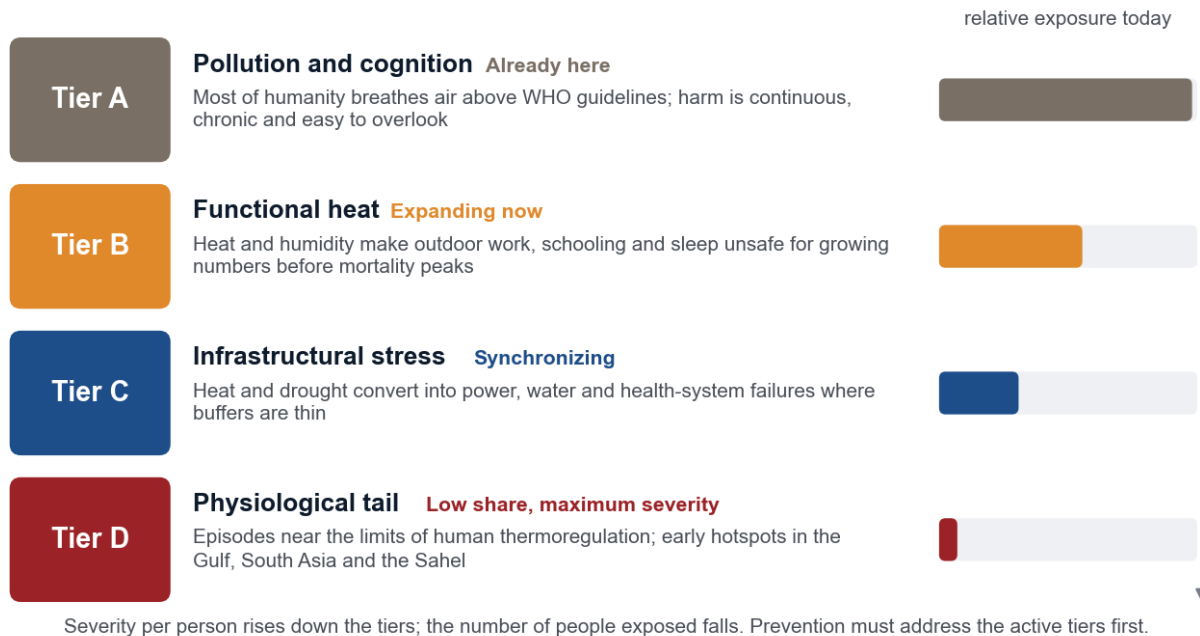


**Figure 27. Four tiers of survivability risk.** Risk accumulates in layers: people lose health and cognition before they lose physiological viability, and labour and infrastructure systems fail before regions are abandoned. Bars indicate the relative share of humanity exposed today.

Source: H Heuristics. Relative exposure shares are indicative.

- **Tier A: pollution and cognition (already here).** Almost all of humanity breathes air above WHO guidelines. The harm is continuous and chronic, and it erodes health and cognition, the human medium on which every other form of development depends. Tier A rarely looks like catastrophe, which is why it is so often underweighted.
- **Tier B: functional heat (expanding now).** Heat and humidity make outdoor work, schooling and sleep unsafe for growing numbers of people before mortality becomes extreme. The near-term damage is to labour, productivity and learning rather than sudden depopulation.
- **Tier C: infrastructural stress (synchronizing).** Heat and drought convert into failures of power, water and health systems where buffers are thin, as in the urban heat–energy–health loop. Whether buffers hold determines whether Tier B becomes Tier D.
- **Tier D: the physiological tail (low share, maximum severity).** Episodes near the limits of human thermoregulation, in which people without cooling cannot survive. Exposure is small today but concentrated in early hotspots such as the Persian Gulf, the Indus and Ganges plains and parts of the Sahel, and grows on high-warming pathways.

The tiered model has a direct implication for policy: prevention should address the active tiers first. Tier A and Tier B are where most people are being harmed now, and where action is cheapest and fastest. Tier C is where the polycrisis concentrates its compounding effects. Tier D is where the stakes per person are highest, but it is reached mainly through failures in Tiers B and C.

## 12.3 A framework for regional assessment

To assess survivability in a given region, the report proposes six groups of indicators (Table 17). The first three describe the hazard and who is exposed; the last three describe the capacity to withstand it. The framework is designed to be multiplicative, in keeping with the structure of risk described in Section 5,

and to capture coupling: a region where several hazards coincide and buffers are thin is more at risk than the sum of its separate scores suggests.

**Table 17.** A survivability assessment framework: indicator groups and examples

| Indicator group             | What it captures                                      | Example indicators                                                                              | Data sources                                             |
|-----------------------------|-------------------------------------------------------|-------------------------------------------------------------------------------------------------|----------------------------------------------------------|
| <b>Hazard</b>               | Intensity, frequency and duration of physical hazards | Days above wet-bulb thresholds; PM <sub>2.5</sub> concentration; drought frequency; flood depth | Climate reanalyses; satellite products; IPCC projections |
| <b>Exposure</b>             | People and assets in harm's way                       | Population in heat, flood and coastal zones; outdoor workforce                                  | UN WPP; gridded population; census data                  |
| <b>Sensitivity</b>          | Susceptibility to harm                                | Share aged 65+; child stunting; chronic disease; housing quality                                | WHO; DHS surveys; UN-Habitat                             |
| <b>Coping capacity</b>      | Ability to absorb a shock                             | Savings; insurance; social-protection coverage; health-system capacity                          | World Bank; ILO; WHO                                     |
| <b>Adaptive capacity</b>    | Ability to adjust over time                           | Electricity and cooling access; fiscal space; governance quality; education                     | IEA; IMF; World Bank governance indicators               |
| <b>Coupling and buffers</b> | Likelihood of compounding                             | Number of coinciding hazards; debt service; food-import dependence; conflict risk               | UNCTAD; FAO; UCDP                                        |

Source: H Heuristics framework. The [Polycrisis Risk Reduction Index](#) applies a related approach at national level.

## 12.4 A regional typology

Combining hazard with capacity yields four broad types of region, each facing a different version of the polycrisis (Table 18). The typology is deliberately coarse; within every region there are wide differences between rich and poor households and between well-planned and unplanned settlements. The H Heuristics study [The Future of Global Habitability](#) develops a more detailed regional assessment.

**Table 18.** Four types of regional exposure to the polycrisis

| Type                                  | Characteristics                                                                                   | Illustrative regions                                            | Principal risk                                     | Priority response                                            |
|---------------------------------------|---------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------------------|--------------------------------------------------------------|
| <b>High hazard, low capacity</b>      | Rising heat, water stress and food insecurity; rapid population growth; thin buffers              | Sahel, Horn of Africa, parts of South Asia, small island states | Compounding of Tiers A–C; ratchets                 | Social protection, water, clean energy access, early warning |
| <b>High hazard, high capacity</b>     | Extreme heat managed through engineered systems; high energy dependence                           | Arabian Gulf, US Southwest, northern Australia                  | Tier C: failure of cooling, power or water systems | Redundancy, clean power, passive design                      |
| <b>Moderate hazard, ageing</b>        | Rising heat in ageing societies; shrinking workforce; fiscal pressure                             | Europe, East Asia                                               | Heat mortality among the elderly; fiscal squeeze   | Heat-health systems, adaptation of buildings and care        |
| <b>Lower hazard, growing pressure</b> | Milder climates; potential destinations for migration; new risks from fire, permafrost and storms | Northern Europe, Canada, parts of Russia and South America      | Wildfire, permafrost thaw, migration management    | Planning, infrastructure and integration capacity            |

Source: H Heuristics. Regions are illustrative, not exhaustive.

## 12.5 What a survivability assessment should quantify

The most useful contribution of a survivability framework would be an integrated set of exposure estimates and long-term scenarios. Table 19 sets out the research outputs that H Heuristics proposes as the agenda for this work.

**Table 19.** Research outputs for an integrated assessment of the polycrisis

| Research output                              | Purpose                                                                         | Status in this report                            |
|----------------------------------------------|---------------------------------------------------------------------------------|--------------------------------------------------|
| <b>Global exposure ranking</b>               | Identify the most widespread persistent hazards                                 | Developed (Section 3)                            |
| <b>Human exposure atlas</b>                  | Map people exposed to multiple hazards simultaneously                           | Proposed; requires gridded data                  |
| <b>Pollution–climate feedback analysis</b>   | Estimate how environmental pressures reinforce one another                      | Qualitative (Section 4); quantification proposed |
| <b>Demographic vulnerability projections</b> | Identify where future population distribution may increase or reduce exposure   | Regional (Section 9); gridded version proposed   |
| <b>Century-scale scenario comparisons</b>    | Compare outcomes under alternative climate and development pathways             | Stylized index (Section 11)                      |
| <b>Survivability risk assessment</b>         | Identify regions with concentrated risks and limited adaptive capacity          | Framework and typology (Section 12)              |
| <b>Prevention opportunity analysis</b>       | Estimate potential reductions in exposure, illness, mortality and economic loss | Prevention map (Section 13); costing proposed    |

*For millennial horizons, the assessment should focus on durable physical processes, conditional scenarios and stewardship rather than detailed forecasts.*

## 12.6 Assessment

That survivability risk accumulates in tiers, with chronic and functional harms preceding catastrophic ones, is well supported (B). That the same hazard produces very different outcomes depending on capacity is established (A). The typology and indicator framework are offered as tools for analysis rather than findings. Their central message is that the polycrisis is not one problem for the world but several different problems for different places, and that the response must be matched to the tier and type of exposure that each place faces.

## 13

## PREVENTION AND RESILIENCE



## 13. The Prevention Imperative

### 13.1 Principles

If the polycrisis is an architecture, prevention is a matter of structural engineering: strengthening the load-bearing elements, adding redundancy at weak joints and removing the couplings that let failure spread. Five principles emerge from the analysis.

1. **Act on the core.** Warming, pollution and poverty are the system's core. Interventions that address them reduce stress across many domains at once.
2. **Reduce every factor of risk.** Because risk is the product of hazard, exposure and vulnerability, reducing any factor reduces the whole; the cheapest factor to reduce is often vulnerability.
3. **Rebuild buffers.** Super-additivity and cascades depend on thin buffers. Reserves, redundancy, fiscal space, insurance and social trust are not inefficiencies; they are protection against the polycrisis.
4. **Let persistence set urgency.** Stop the pressures that persist longest, carbon dioxide and biodiversity loss, as early as possible; exploit the pressures that reverse fastest, such as air pollution, for rapid gains.
5. **Keep recovery faster than shocks.** The ratchet of Section 10 is avoided by reducing the frequency of shocks and by shortening the time to recover.

### 13.2 The prevention map

Figure 28 places thirteen categories of intervention on two axes: the breadth of risks each reduces, and its difficulty in terms of cost, time and political effort. The assessment is a judgement by H Heuristics based on the evidence reviewed in this report. The upper left of the map, broad and comparatively easy, contains the no-regret options: early-warning systems, social protection and climate-resilient agriculture, together with heat-health action plans and disaster risk finance as targeted quick wins. The upper right contains the transformational options that address the system's core: the clean energy transition, air-quality regulation and clean cooking, and conflict prevention and international cooperation.

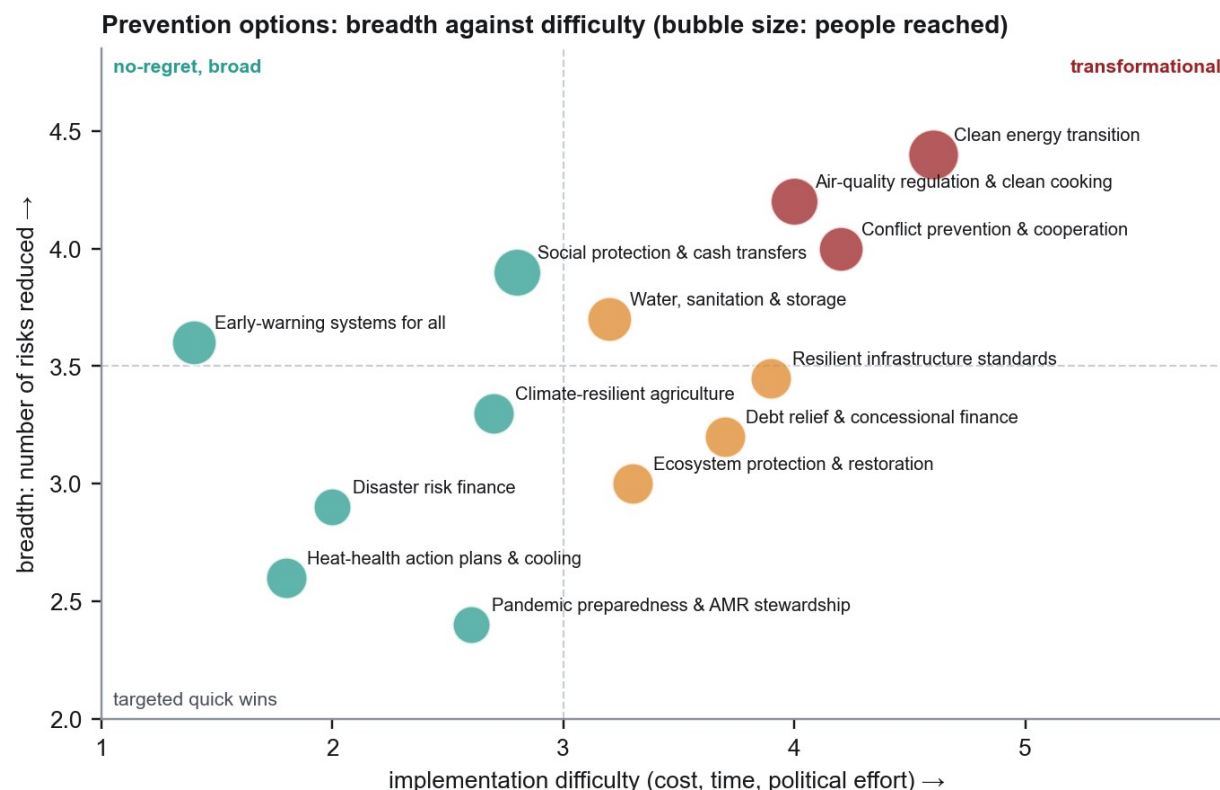


**Figure 28. The prevention map.** Thirteen intervention categories by implementation difficulty and breadth of risks reduced; bubble size indicates the relative number of people reached. No-regret options are upper left; transformational options upper right.

Source: H Heuristics assessment based on Sections 4–12 and the sources in Table 20.

**Table 20.** A prevention portfolio for the polycrisis

| Intervention                                    | Risks reduced                                        | Evidence of effectiveness                                                                                                                                                                                         | Grade |
|-------------------------------------------------|------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| <b>Clean energy transition</b>                  | Warming, air pollution, energy insecurity, water use | Cuts the shared sources of warming and pollution; solar, wind and battery costs have fallen dramatically                                                                                                          | A     |
| <b>Air-quality regulation and clean cooking</b> | Air pollution, chronic disease, cognitive harm       | Health benefits of the US Clean Air Act estimated at more than 30 times its costs ( <a href="#">EPA</a> ); rapid gains in China after 2013                                                                        | A     |
| <b>Methane and black-carbon cuts</b>            | Near-term warming, ozone, crop loss                  | Reduces warming within decades while improving air quality ( <a href="#">Shindell et al. 2012</a> )                                                                                                               | A     |
| <b>Early warning for all</b>                    | Extreme weather, disasters, disease outbreaks        | Warnings even 24 hours ahead can substantially cut damage; benefit–cost ratios among the highest of any adaptation ( <a href="#">Global Commission on Adaptation</a> ); UN <a href="#">Early Warnings for All</a> | A–B   |
| <b>Social protection and cash transfers</b>     | Poverty, food insecurity, disaster losses            | Adaptive social protection speeds recovery and prevents asset sales ( <a href="#">Hallegatte et al. 2017</a> )                                                                                                    | A–B   |
| <b>Water, sanitation and storage</b>            | Disease, food insecurity, drought impacts            | Among the most cost-effective health investments; storage buffers drought ( <a href="#">JMP</a> )                                                                                                                 | A     |

| Intervention                                            | Risks reduced                                             | Evidence of effectiveness                                                                                | Grade |
|---------------------------------------------------------|-----------------------------------------------------------|----------------------------------------------------------------------------------------------------------|-------|
| <b>Heat-health action plans and efficient cooling</b>   | Heat mortality, urban heat loop                           | Warning systems and cooling centres reduce deaths; efficient cooling breaks the heat–energy loop         | B     |
| <b>Climate-resilient agriculture and grain reserves</b> | Food insecurity, correlated harvest failure               | Diversification and reserves reduce exposure to correlated shocks                                        | B     |
| <b>Ecosystem protection and restoration</b>             | Biodiversity, water, coastal protection, carbon           | Mangroves, wetlands and forests reduce flood and storm damage and store carbon ( <a href="#">IPBES</a> ) | B     |
| <b>Disaster risk finance and insurance</b>              | Disaster–debt loop, uninsurability                        | Pre-arranged finance shortens recovery; catastrophe bonds and risk pools spread losses                   | B     |
| <b>Debt relief and concessional finance</b>             | Fiscal squeeze, underinvestment in prevention             | Frees fiscal space for health, education and adaptation ( <a href="#">UNCTAD</a> )                       | B     |
| <b>Pandemic preparedness and AMR stewardship</b>        | Epidemics, antimicrobial resistance                       | Surveillance, vaccines, sanitation and antibiotic stewardship reduce burden ( <a href="#">WHO</a> )      | B     |
| <b>Conflict prevention and cooperation</b>              | Conflict, displacement, acute food crises, delayed action | Mediation and peacekeeping reduce violence; cooperation is a precondition for global public goods        | B     |

*Grades refer to the evidence that the intervention reduces the risks listed, not to its political feasibility.*

### 13.3 The Antifragile Development Engine

The H Heuristics [monograph](#) proposes that the answer to the polycrisis lies in an **Antifragile Development Engine**: a development model that grows stronger under stress rather than merely enduring it. Its components map directly onto the conditions for compounding identified in Section 10.

- **Decentralized infrastructure**, such as distributed solar power, mini-grids and local water storage, which reduces dependence on single points of failure.
- **Modular resilience**, in which systems are designed as loosely coupled modules that can fail without bringing down the whole, the opposite of the lean network in Figure 22.
- **Clean energy deployment**, which addresses the system's largest transmitter of stress and narrows the energetic moat.
- **Catastrophe finance**, which shortens recovery and breaks the disaster–debt loop.
- **Early-warning systems**, which reduce the damage of each shock and buy time for response.
- **Polycentric governance**, in which overlapping local, national and international institutions provide redundancy, experimentation and learning ([Ostrom 2010](#)).

The central idea is to prioritize **buffers, redundancy, repair and adaptive learning** over hyper-efficient but fragile systems. This does not mean abandoning efficiency. It means pricing fragility correctly, so that the value of slack in a world of coupled, correlated shocks is recognized.

### 13.4 Leverage points

The systems thinker Donella Meadows observed that the most powerful [places to intervene in a system](#) are rarely its parameters, such as taxes and subsidies, and more often its feedback loops, information flows, rules and goals. The polycrisis suggests three high-leverage interventions of this kind. The first is **information**: making compound exposure visible through integrated monitoring, so that chronic harms

are counted alongside headline disasters. The second is **rules**: building resilience requirements into infrastructure standards, financial regulation and procurement, so that buffers are not competed away. The third is **goals**: shifting the objective of development from maximizing output to maximizing the capacity to sustain wellbeing under stress.

## 13.5 Sequencing to 2050

Prevention has a time structure. The years to 2030 are the cheapest build window: most of the infrastructure that will be in use in 2050 has not yet been built, and decisions made now determine whether it locks in or breaks the polycrisis's loops. The 2030s are the decade in which the transition must scale, with emissions falling steeply, clean air spreading to South Asia and Africa, and social protection and early warning reaching universal coverage. The 2040s are when the benefits compound: if the earlier decades succeed, the danger window of the mid-century, when population growth, warming and ageing all peak in their pressure on vulnerable regions, can be passed with exposure falling rather than rising. If they fail, the same decade becomes the one in which ratchets engage.

## 13.6 Monitoring the polycrisis

The long-regression scenario of Section 11 is graded D partly because its warning signs are not yet visible. That judgement should be revisited regularly. Table 21 proposes a set of indicators that would signal whether the polycrisis is compounding or being contained.

**Table 21.** Early-warning indicators of a compounding polycrisis

| Indicator                                  | Signal of compounding                                                        | Signal of containment          | Source               |
|--------------------------------------------|------------------------------------------------------------------------------|--------------------------------|----------------------|
| <b>Global mean temperature trend</b>       | Acceleration beyond 0.25 °C per decade                                       | Peak and stabilization         | WMO, Copernicus      |
| <b>Air-pollution deaths</b>                | Rising in South Asia and Africa                                              | Falling everywhere             | State of Global Air  |
| <b>Extreme poverty and hunger</b>          | Sustained increases                                                          | Renewed decline                | World Bank, FAO      |
| <b>Simultaneous harvest failures</b>       | More frequent multi-region failures                                          | Stable yields, rising reserves | FAO, AMIS            |
| <b>Debt service versus social spending</b> | More people in countries where interest exceeds health or education spending | Falling                        | UNCTAD, IMF          |
| <b>Armed conflict and displacement</b>     | Continued records                                                            | Sustained decline              | UCDP, UNHCR          |
| <b>Global life expectancy</b>              | Sustained decline outside pandemic years                                     | Continued rise                 | UN WPP               |
| <b>Insurance protection gap</b>            | Widening; insurer withdrawal from regions                                    | Narrowing                      | Industry, regulators |

*A sustained adverse signal across several indicators at once would be evidence that the polycrisis is entering a compounding phase.*

## 13.7 Assessment

The prevention imperative rests on well-established evidence. Many of the most effective interventions, including clean air, clean energy, water and sanitation, early warning and social protection, are proven

and affordable (A–B). What the polycrisis framing adds is a way to choose among them: favour interventions that act on the system's core, that reduce several risks at once, that rebuild buffers and that keep recovery faster than shocks. In the report's stylized scenarios, a proactive resilience pathway keeps the Polycrisis Exposure Index at or below today's level through 2100. That pathway is not guaranteed. But the architecture of the polycrisis makes clear that it is available.

## 14

## CONCLUSION



## 14. Conclusion

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### 14.1 The answer to the central question

This report set out to describe the architecture of the polycrisis apocalypse and to test its central thesis: that humanity's gravest long-term danger is not a single global catastrophe but an interconnected system of environmental, biological, economic, demographic, technological and geopolitical pressures that reinforce one another, producing cumulative harm greater or more persistent than any individual crisis alone.

The evidence supports the thesis, with important qualifications. The pressures are coupled: the report's coupling analysis finds that most possible links between domains are active, with climate change and geopolitical fragmentation transmitting stress through the system and poverty, ill health and food insecurity accumulating it. Interaction can make harm super-additive, but only under identifiable conditions, above all thresholds, thin buffers, correlated exposure and connectivity without slack. Harm can become persistent, both physically, because carbon dioxide and sea-level rise last for centuries, and socially, because repeated shocks that arrive faster than recovery ratchet capacity downward. The polycrisis is therefore real, already under way, and more dangerous than a list of its parts would suggest.

The qualifications matter as much as the confirmation. Prevalence is not destiny: extreme poverty has fallen, air quality has improved in much of the world, and the costs of clean energy have collapsed. Super-additivity is not automatic: well-buffered systems absorb coinciding shocks with little amplification. And a global collapse followed by a regression lasting centuries, while possible as a tail risk, is not supported as a forecast. The architecture of the polycrisis shapes the range of possible futures; it does not choose among them.

### Evidence map: the broader the claim, the weaker the evidence

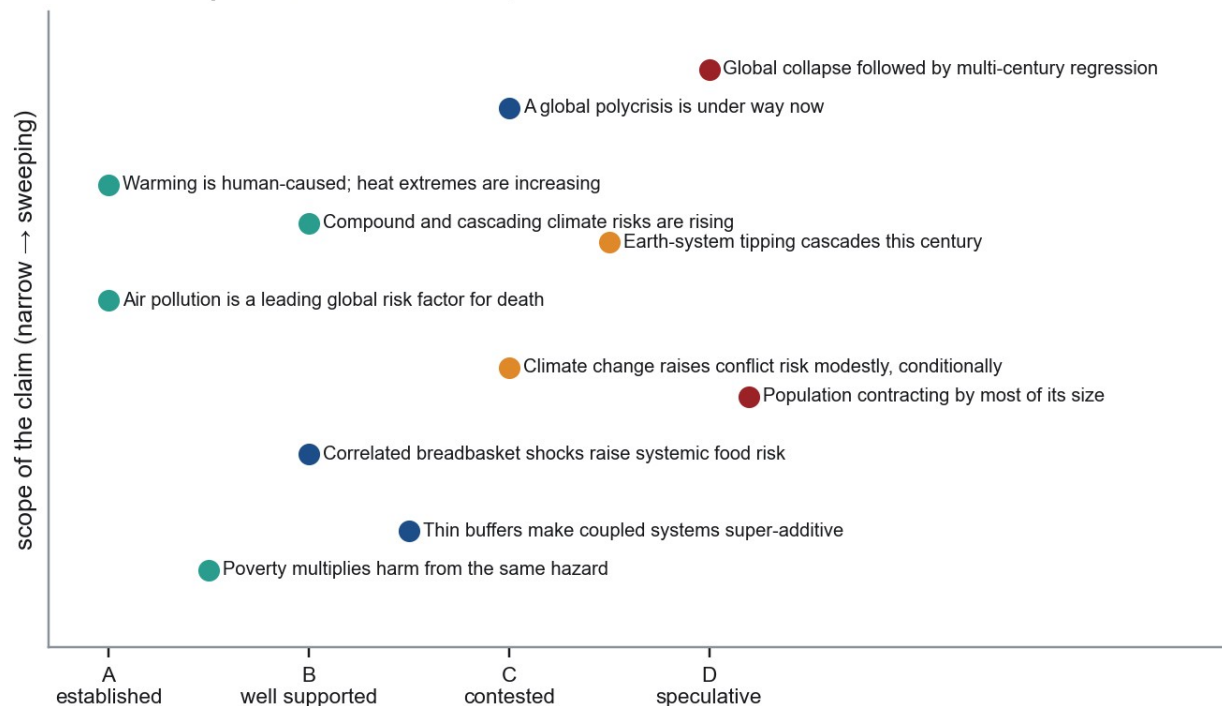


**Figure 29. The report's evidence map.** Each point is a claim, placed by its evidence grade and by the sweep of its scope. Narrow claims about mechanisms and current exposure are well established; sweeping claims about collapse and long regression are speculative.

Source: H Heuristics assessment based on Sections 1–13.

## 14.2 What is established, contested and open

**Table 22.** What the report establishes, what remains contested and what is open

| Established or well supported                                                         | Contested                                                    | Open                                                                    |
|---------------------------------------------------------------------------------------|--------------------------------------------------------------|-------------------------------------------------------------------------|
| <b>Human-caused warming is intensifying heat and other extremes</b>                   | How much climate change contributes to armed conflict        | Whether a global long regression is possible in practice                |
| <b>Air pollution is among the leading causes of death worldwide</b>                   | Whether large regions will become uninhabitable this century | The strength of interactions between Earth-system tipping elements      |
| <b>Poverty multiplies the harm of every hazard</b>                                    | The size of aggregate economic damages from warming          | How to measure super-additivity across the global system                |
| <b>Correlated shocks and thin buffers make coupled systems fragile</b>                | The net effect of advanced AI on systemic risk               | How fast adaptive capacity can be built in the most exposed regions     |
| <b>Population growth this century will concentrate in hot, lower-income regions</b>   | The energy return of the future energy system                | Whether early-warning indicators can detect a compounding phase in time |
| <b>CO<sub>2</sub> and sea-level rise commit the world to change lasting centuries</b> | Exact thresholds for human heat tolerance across populations | How future generations will value and govern a still-changing planet    |

The columns correspond broadly to grades A–B, C and D in the terms of Table 1.

## 14.3 Ten propositions

The report's findings can be condensed into ten propositions, each of which can be tested and, if necessary, revised.

1. The polycrisis is best measured by human exposure, not by the state of global systems alone.
2. Warming, air pollution and poverty form the core of the polycrisis; interventions on the core reduce stress across the whole system.
3. Climate change and geopolitical fragmentation are the system's principal transmitters of stress; poverty, health and food are its principal receivers.
4. Coinciding shocks are super-additive when buffers are thin and close to additive when buffers are deep.
5. Correlation between regions converts rare independent failures into recurring systemic ones.
6. A society enters long-term decline not through unprecedented catastrophe but through ordinary shocks that arrive faster than it can recover.
7. Demographic change can raise exposure even if hazards do not.
8. Persistence should set urgency: stop the longest-lived pressures first and exploit the fastest-reversing ones for rapid gains.
9. Buffers, redundancy and repair are not inefficiencies but the core of resilience in a coupled world.
10. The polycrisis apocalypse is a trajectory, not a destination; what accumulates can be interrupted.

## 14.4 Limitations

The report has five main limitations. Its exposure ranking and coupling matrix are expert judgements, informed by evidence but not derived from a single dataset; different analysts would assign different scores, although the report's sensitivity test suggests that the core of the ranking is robust. Its models are deliberately simple and illustrative; they demonstrate how mechanisms behave rather than predicting outcomes. Its exposure estimates come from different sources, years and methods and cannot be combined into a single total. Its long-horizon analysis relies on physical projections whose uncertainties grow with time, particularly for ice sheets. And it treats the world in broad regions, while the most important differences in exposure are often between households in the same city. Each limitation points to the research agenda set out in Section 12.

## 14.5 How this informs the H Heuristics research programme

This report connects the H Heuristics series on the polycrisis to its series on the architecture of complex systems. Like [The Architecture of Civilization](#) and [The Architecture of Entropy](#), it treats a large-scale phenomenon as a structure whose behaviour follows from its parts and their connections. Like [The Cascading Risk Atlas](#) and [How Many Lives Could Polycrisis Resilience Save This Century?](#), it is concerned with how local shocks become global and how prevention can save lives. Its main contribution to the programme is a common framework, drivers, pressures, coupling, exposure, vulnerability, buffers and persistence, within which each of those studies can be located and compared.

## 14.6 Closing

The word apocalypse has always carried two meanings: catastrophe and revelation. This report has tried to keep both in view. The catastrophe is real, but it is not the sudden, cinematic event of popular imagination. It is a slow accumulation of harm that falls hardest on the poor, the old and the young; that hides in polluted air and lost schooling and deferred maintenance; that compounds when shocks coincide and buffers are thin; and that, in its slowest components, will outlast everyone now alive. The revelation is that this accumulation has an architecture, and that architectures can be redesigned. The same couplings that spread harm can spread protection. The same persistence that makes carbon dioxide so dangerous makes clean infrastructure so valuable. And the same arithmetic that makes risk the product of hazard, exposure and vulnerability means that every one of those factors is a lever.

**Final verdict.** The polycrisis apocalypse is not a prophecy but an architecture of compounding human exposure. Its outcome will be decided less by any single hazard than by whether humanity rebuilds buffers, redundancy and adaptive capacity faster than interacting pressures erode them, and the decisive decades for that choice are the ones now beginning.

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