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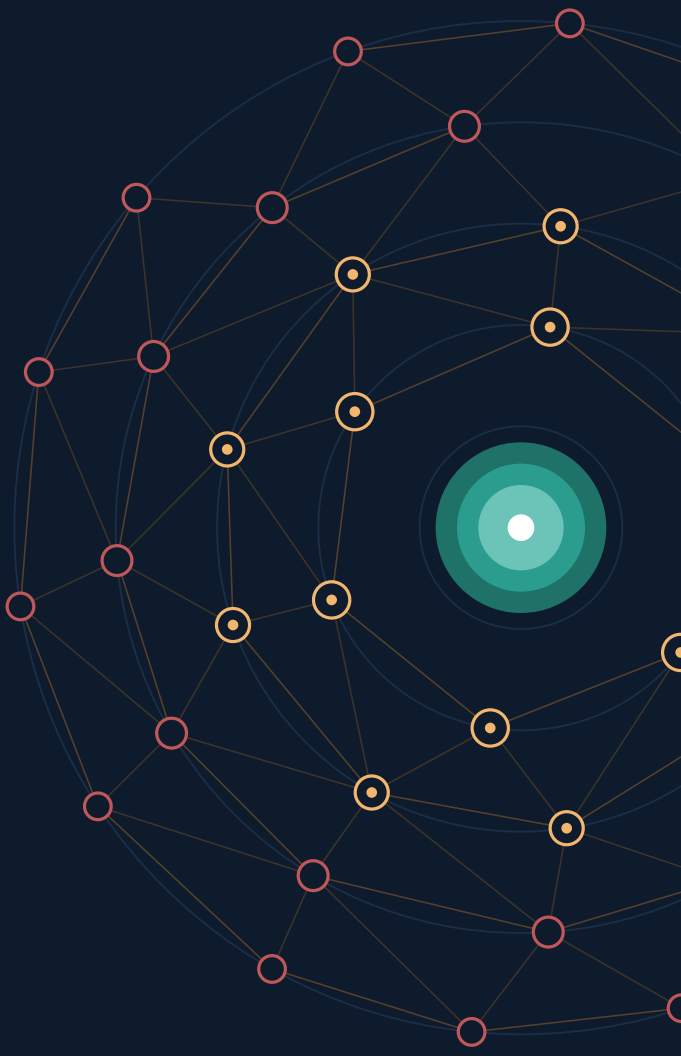
RESEARCH REPORT · NOVEMBER 2026

Polycrisis Resilience

A Research Report

The capacity to withstand, adapt to, recover from and reduce vulnerability to multiple interacting and compounding crises

Essential functions · Six scales · Five cascades · Seven objectives



Hunter Hughes
Founder, H Heuristics · A concept developed by Hunter Hughes

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About This Report

This report is a research study of **Polycrisis Resilience**, a concept developed by Hunter Hughes, Founder of H Heuristics. Polycrisis Resilience is the capacity of individuals, communities, societies, economies, institutions and interconnected systems to withstand, adapt to, recover from and reduce vulnerability to multiple interacting and compounding crises. It concerns the ability to maintain essential functions, manage systemic disruptions, adapt to changing conditions and strengthen long-term stability in a world of interconnected global risks.

It is the fourth report in the Polycrisis Resilience series. The founding report defined the concept and its six properties, the second examined the clean transition, and the third stated the development-oriented framework and tested it against data for 194 countries. This report asks what the definition means in practice, and tests it against what happens when crises collide.

What the report contributes

- **A plain statement of the concept**: the general definition, the four things resilience does, the seven core objectives, and the central idea that resilience is the reduction of vulnerability, not only the ability to recover (Chapters 1 to 3).
- **Essential functions, scales and failure patterns**: eight functions that must keep working and how they depend on one another; six scales from household to global system; four patterns by which crises compound (Chapters 4 to 6).
- **Five cascades examined against the definition**: Winter Storm Uri, the 2021 to 2023 price shock, the 2022 Pakistan floods, the 2022 Sri Lanka crisis and the 2024 CrowdStrike outage, with original analysis of the buffers that separated countries (Chapters 7 and 8).
- **Practice and measurement**: the seven objectives as actions and indicators, the economics of prevention, a scorecard by essential function, critiques and a research agenda (Chapters 9 to 13).

Evidence grades

Claims are graded on the four-level scale used across H Heuristics research. The grade describes the state of knowledge, not the importance of the claim. Analyses constructed by H Heuristics are always grade C or D.

Table 1. Evidence grades used in this report

Grade	Meaning	Example from this report
A: Established	Confirmed by multiple independent lines of evidence and assessed as such by leading scientific or statistical bodies.	Seven of nine planetary boundaries are assessed as transgressed.
B: Well supported	Strong evidence from several lines of work, with some unresolved detail or range.	The world death rate from disasters is far lower than a century ago, even as recorded disasters have multiplied.
C: Plausible or contested	A credible argument with partial evidence; specialists disagree on size or mechanism.	Energy and digital systems are the keystone dependencies of modern societies.
D: Speculative	A scenario or hypothesis offered for evaluation, labeled as such.	That a scorecard by essential function can predict which systems fail first.

Source: H Heuristics.

Data and methods are described in the Appendix. **How to cite.** Hughes, H. (2026). *Polycrisis Resilience: A Research Report.* H Heuristics Research Report, November 2026.

Executive Summary

The concept in one paragraph

Polycrisis Resilience is the capacity of individuals, communities, societies, economies, institutions and interconnected systems to withstand, adapt to, recover from and reduce vulnerability to multiple interacting and compounding crises. Its central idea is that resilience is not simply the ability to recover from crises. It is the ability to reduce the underlying vulnerabilities that make crises so damaging in the first place. A society with cleaner energy, stronger health systems, better infrastructure and more capable institutions is generally less vulnerable to many kinds of crisis at once.

15.7×
peak of the EU gas price in August 2022 against its 2019 average

−96%
fall in the world death rate from disasters, 2010s against 1900 to 1949

$2.3 tn
annual disaster cost once cascades are counted, against $202 billion of direct losses

1.1 vs 7.0
months of imports covered by reserves in 2022: Sri Lanka against India

Principal findings

- **Crises now arrive together.** Between 2020 and 2024 a pandemic, a Texas power failure, a canal blockage, a war, a global price shock, sovereign defaults, record floods and a software failure followed one another. Food prices peaked 67% above 2019 and European gas at 15.7 times (Chapter 1, grade A).
- **The decisive variable is vulnerability, not only the hazard.** The world death rate from disasters is about 96% lower than in 1900 to 1949 although recorded disasters have multiplied several times since 1970. What changed is the capacity of societies to absorb hazards (Chapter 3, grade B).
- **Eight essential functions carry the rest.** Energy and digital systems are the keystone dependencies: six of the other seven functions depend heavily on energy, and the digital layer is the second most depended-on. Food and health are the most exposed downstream (Chapter 4, grade C).
- **Resilience has six scales and four recurring failure patterns.** Gains at one scale can shift risk to another, as when export bans protected domestic markets and hurt importers. The patterns are depleted buffers, single points of failure, slow erosion followed by sudden shock, and responses that compound the crisis (Chapters 5 and 6, grade C).
- **Buffers separated the countries that bent from those that broke.** In 2022 Sri Lanka's reserves covered 1.1 months of imports and Pakistan's 1.4, against 7.0 for India. Sri Lanka's inflation averaged 49.7% and it defaulted. India's was 6.7% (Chapters 7 and 8, grade B for the data, C for the interpretation).
- **Prevention is under-financed relative to its returns.** Estimates put returns to resilience investment between 2:1 and 10:1, yet developing-country adaptation finance was $26 billion in 2023 against an estimated need of $310 to 365 billion a year by 2035 (Chapter 10, grade B).

What the concept asks of policy and practice

Four priorities follow. **Protect the keystones**: treat energy, digital systems and import finance as critical infrastructure with minimum service levels. **Build buffers before they are needed**: reserves, fiscal space, stocks and surge capacity. **Reduce vulnerability across hazards** by favoring measures that help against several crises at once. **Measure what matters**, with a scorecard by essential function that counts the weakest link.

PART I · THE CONCEPT

1. A World of Interacting Crises

IN BRIEF

- A polycrisis is a condition in which crises in different systems become causally entangled, so that the whole is worse than the sum of its parts.
- Between 2020 and 2024 the world experienced a sequence of linked shocks, visible in food, energy and gas prices and in events from Texas to Colombo to Sindh.
- The response to such a world cannot be organized hazard by hazard. It needs a concept of capacity that applies across crises.

1.1 What a polycrisis is

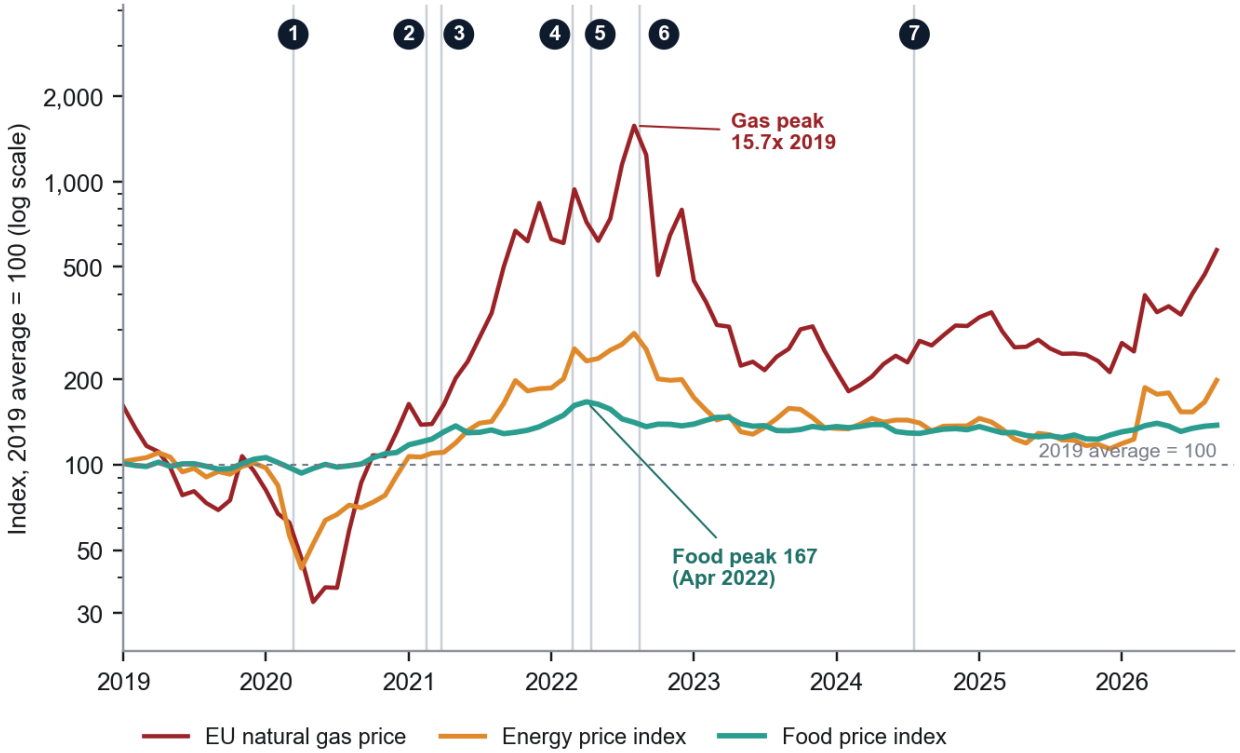
A **polycrisis** occurs when multiple crises interact in ways that amplify their combined consequences. The word was used by Edgar Morin and Anne Brigitte Kern in 1993 to describe the intertwined problems of the planet, and it returned to wide use after 2022, when the economic historian Adam Tooze applied it to the overlapping shocks of pandemic, war, inflation and climate extremes (Morin and Kern, 1999; Tooze, 2022). The World Economic Forum's Global Risks Report 2023 adopted the term for a cluster of related global risks with compounding effects, such that the overall impact exceeds the sum of each part (World Economic Forum, 2023).

Researchers at the Cascade Institute have given the term a sharper meaning. In their account a global polycrisis is a set of causally entangled crises in multiple global systems that interact so as to harm humanity's prospects significantly more than the sum of the separate crises would (Janzwood and Homer-Dixon, 2022). They identify three kinds of causal mechanism behind such entanglement: common causes that drive several stresses at once, direct interactions between stresses, and feedback loops through which a crisis returns to worsen its own causes (Lawrence et al., 2024). Earlier work on systemic risk had already shown how interdependence turns local failures into global ones (Helbing, 2013; Centeno et al., 2015).

1.2 The shock calendar, 2019 to 2026

The easiest way to see the problem is to look at the world's prices. **Figure 1** plots three monthly indices, rebased so that the 2019 average equals 100: food, energy and the European natural gas price. Seven events from this period are marked. The pandemic caused a collapse in energy demand and prices in 2020, followed by a sharp rebound. Then, between early 2021 and August 2022, the energy index rose from about 107 to 291 and gas prices rose to 15.7 times their 2019 average. Food prices peaked in April 2022 at 67% above 2019. By September 2026 the food index stood at 38% above its 2019 level, the energy index at 99% above and the gas index at 5.7 times.

Figure 1. Food, energy and gas prices, 2019 to September 2026 (2019 average = 100, log scale)



Source: H Heuristics calculation from IMF global price indices for food and energy and the IMF EU natural gas price (PFOODINDEXM, PNRGINDEXM, PNGASEUUSDM), via FRED. Events: 1 WHO declares COVID-19 a pandemic (11 March 2020); 2 Winter Storm Uri (February 2021); 3 Suez Canal blockage (March 2021); 4 Russia's full-scale invasion of Ukraine (24 February 2022); 5 Sri Lanka suspends external debt payments (12 April 2022); 6 Pakistan floods at their height (August 2022); 7 CrowdStrike outage (19 July 2024).

The chart does not show causes, and the events are not all related to prices. Its point is the density of the sequence. In the five years after 2020 there was no period in which a household, a firm or a government could assume that the system had returned to normal before the next shock arrived. That is the practical meaning of a polycrisis: the interval between crises shrinks below the time needed to recover from them.

1.3 The state of the polycrisis

Table 2 collects headline indicators for the main stress domains. They are not a ranking of danger. They show that the stresses are large, that they are measured by many independent bodies, and that several of them, including debt, climate and food insecurity, bear most heavily on the same countries.

Table 2. Headline indicators of interacting stresses

Domain	Indicator	Source	Grade
Climate	2025 was about 1.43 °C above the 1850–1900 baseline; 2015–2025 was the warmest eleven-year period on record.	WMO, 2026	A
Ecosystems	Seven of nine planetary boundaries are transgressed; ocean acidification was added in 2025.	Steinert et al., 2025	A
Health and pollution	Air pollution was linked to about 7.9 million deaths in 2023. COVID-19 was associated with about 14.9 million excess deaths in 2020 and 2021.	HEI, 2025; WHO, 2022	A/B
Debt	Global public debt reached about $102 trillion in 2024; 3.4 billion people live in countries that spend more on interest than on health or education.	UNCTAD, 2025	B

Domain	Indicator	Source	Grade
Food	295 million people in 53 countries and territories faced acute food insecurity in 2024, the sixth annual rise.	GRFC, 2025	B
Poverty	About 808 million people are estimated to live below the $3.00-a-day line in 2025.	World Bank, 2025	B
Disasters	Disaster costs exceed $2.3 trillion a year once cascading and ecosystem effects are counted, against about $202 billion in direct losses.	UNDRR, 2025	B
Adaptation	Developing countries need an estimated $310 to 365 billion a year for adaptation by 2035; international public flows were $26 billion in 2023.	UNEP, 2025	B

Sources as shown. The 2025 poverty headcount is a nowcast and varies by source.

1.4 Why a concept is needed

Most institutions are organized by hazard or by sector. There are ministries and agencies for floods, for pandemics, for energy security and for financial stability, each with its own plans, metrics and budgets. This is sensible for managing known risks. It is poorly suited to a world in which the hazards interact, because the failure that matters often lies between the plans. Three gaps follow.

- **The silo gap.** Plans for each hazard assume that other systems keep working. The Texas freeze of 2021 showed what happens when the electricity plan assumes gas supply and the gas system assumes electricity.
- **The recovery gap.** Much of the language of resilience is about bouncing back. A system that recovers fully to a condition that was vulnerable has restored the vulnerability along with the service.
- **The development gap.** Resilience is often treated as a specialist add-on to development programs rather than as a product of development itself, so the long-run foundations that reduce vulnerability to many crises at once are not counted as resilience.

A shared concept of Polycrisis Resilience is intended to close these gaps. It gives planners one question that applies across hazards and sectors: does this action leave people and systems better able to withstand, adapt to, recover from and, above all, be less vulnerable to the next set of interacting shocks?

PART I · THE CONCEPT

2. Defining Polycrisis Resilience

IN BRIEF

- The definition has four verbs (withstand, adapt, recover, reduce vulnerability), six scales and three outcomes: essential functions maintained, systemic disruptions managed, long-term stability strengthened.
- Of the four verbs, reducing vulnerability is the one that distinguishes the concept: it works before the shock and across hazards.
- Seven core objectives translate the definition into direction for policy and investment.

2.1 The definition

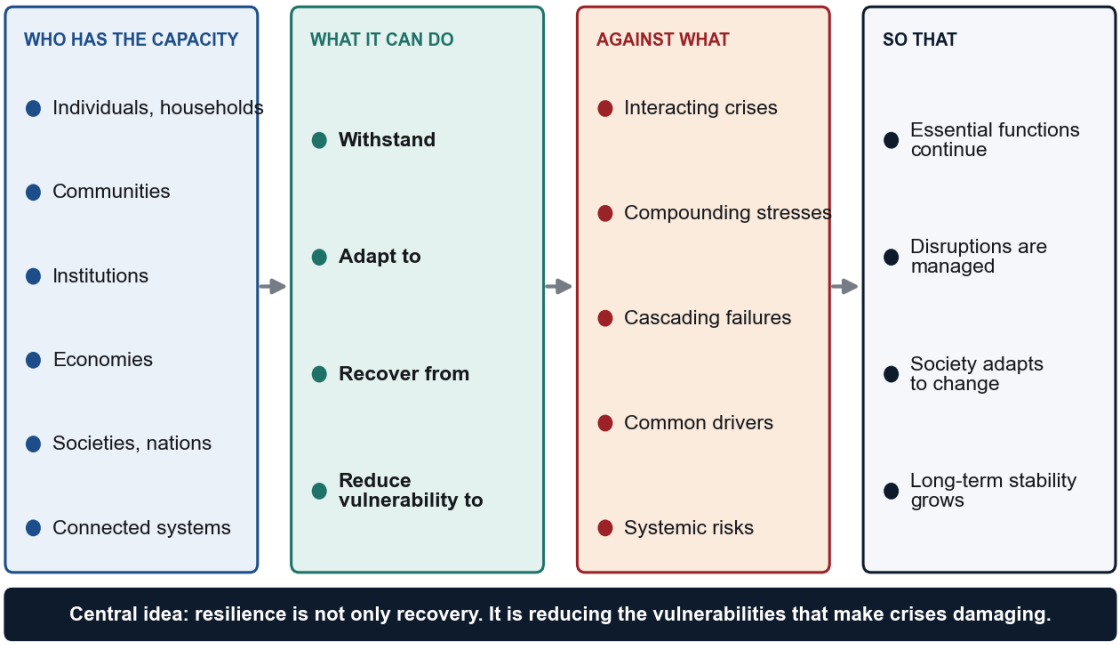
Polycrisis Resilience

GENERAL DEFINITION

Polycrisis Resilience is the capacity of individuals, communities, societies, economies, institutions and interconnected systems to withstand, adapt to, recover from and reduce vulnerability to multiple interacting and compounding crises.

It concerns the ability to maintain essential functions, manage systemic disruptions, adapt to changing conditions and strengthen long-term stability in an environment characterized by interconnected global risks.

Figure 2. The anatomy of the definition



Source: H Heuristics. Conceptual diagram.

Where a shorter formulation is needed, the concept can be stated as the capacity to reduce vulnerability to multiple interconnected crises through coordinated improvements in economic development, technology, infrastructure, environmental sustainability, institutional capacity and human development. Its central principle is the strengthening of the foundations of society to reduce vulnerability in an increasingly interconnected and crisis-prone world.

2.2 Four things resilience does

The definition names four verbs. They are often blurred together, but they operate at different moments and call for different investments. **Table 3** separates them.

Table 3. The four functions of Polycrisis Resilience

Function	Meaning	Timing	Example	Typical indicator
Withstand	Absorb a shock without losing essential function.	During the shock	A hospital keeps operating through a blackout on backup power.	Hours of service continuity under stress
Adapt	Change practices, assets or location as conditions change.	Before, during and after	Farmers shift to drought-tolerant crops; a utility relocates a substation.	Share of assets adjusted to projected hazards
Recover	Restore service and livelihoods quickly after loss.	After the shock	Reconstruction financed within a year; insurance pays out.	Time to restore service; share of cost financed
Reduce vulnerability	Lower the underlying susceptibility to harm so that future shocks do less damage.	Mostly before, and in rebuilding	Universal clean power, health coverage, reserves, diversified supply.	Loss per unit of hazard; share of people lacking buffers

Source: H Heuristics, drawing on Bruneau et al. (2003), Folke (2006) and Hallegatte et al. (2017).

2.3 Three outcomes

The definition ends with three outcomes against which any resilience effort can be judged.

- **Maintain essential functions.** Energy, water, food, health care, payments, communications, transport and governance must continue at some minimum level through a crisis. Chapter 4 maps these.
- **Manage systemic disruptions.** When a failure does spread, its path and speed matter. Resilience includes the ability to contain, isolate and reroute, so that a local failure does not become a general one.
- **Adapt to changing conditions and strengthen long-term stability.** A resilient system is one that is better prepared after a crisis than before it. Stability here means the capacity to keep developing, not merely to stay still.

2.4 Seven core objectives

The concept is made operational through seven core objectives. They state what Polycrisis Resilience aims to achieve, and Chapter 9 turns each into mechanisms and indicators.

Table 4. The seven core objectives of Polycrisis Resilience

	Objective	What it means
1	**Reduce vulnerability**	Strengthen the ability of populations and systems to withstand interconnected risks.
2	**Strengthen development**	Improve economic conditions, institutional capacity, infrastructure and human capabilities.
3	**Accelerate technological diffusion**	Expand access to technologies that improve productivity, health, environmental conditions and resilience.
4	**Advance the clean transition**	Reduce environmental pressures while supporting sustainable economic development.
5	**Promote convergence**	Reduce development gaps between economies and expand access to the capabilities necessary for resilience.
6	**Improve adaptive capacity**	Enable societies to anticipate, absorb and respond to changing conditions.
7	**Strengthen long-term stability**	Reduce the likelihood that individual crises develop into cascading systemic disruptions.

Source: H Heuristics.

2.5 What the concept is not

- **It is not toughness.** Resilience is not a call for individuals or poor countries to endure more. A framework that asks the vulnerable to cope better without reducing what they are vulnerable to has missed the point (Béné et al., 2012).
- **It is not a replacement for prevention.** Cutting emissions, ending conflict and preventing pandemics remain essential. Resilience addresses what prevention cannot: the shocks that arrive anyway and the vulnerabilities that make them costly.
- **It is not a single score.** The concept describes a set of capacities at several scales. Measurement, discussed in Chapter 11, needs a profile and not a ranking.
- **It is not a prediction.** The claim is not that any given crisis will occur, only that a more resilient society will suffer less when crises of any kind do.

Table 5. Polycrisis Resilience and neighboring concepts

Concept	Focus	What Polycrisis Resilience adds
Disaster risk reduction	Hazards that cause disasters; exposure and vulnerability to them.	Interactions across hazard types, and non-disaster crises such as debt and technology failure.
Climate adaptation	Adjusting to actual or expected climate change.	Climate as one driver among several, and the interplay with economic and technological stress.
Sustainable development	Meeting present needs without compromising the future.	An explicit test: does development leave people less exposed to compounding shocks?
Business continuity and risk management	Keeping an organization running through disruption.	Society-level and cross-scale effects, including those that firms externalize.
Systemic risk	The risk that failure spreads through a connected system.	A capacity, and not only a risk: what builds the ability to resist spread.

Source: H Heuristics.

PART I · THE CONCEPT

3. From Recovery to Vulnerability Reduction

IN BRIEF

- Resilience has several scientific traditions. Early ones stressed bouncing back; later ones stressed adaptation and transformation.
- Risk is a product of hazard, exposure and vulnerability. Recovery acts after loss, while vulnerability reduction acts before it and across hazards.
- The long-run fall in disaster deaths, while recorded disasters rose, is the clearest evidence that vulnerability can be reduced.

3.1 Four traditions of resilience

The word resilience has been used in several scientific traditions with different meanings. Polycrisis Resilience draws from each but follows the later ones in treating resilience as more than return to the previous state. **Table 6** summarizes them.

Table 6. Four traditions of resilience thinking

Tradition	What resilience means	Main reference	Limit for a polycrisis
Engineering	Speed of return to equilibrium after disturbance; resistance and recovery time.	Holling (1973, 1996)	Assumes a single stable state and a known disturbance.
Ecological	Capacity to absorb disturbance and persist; avoid crossing thresholds into another regime.	Holling (1973); Scheffer et al. (2009)	Describes thresholds but not human choices or fairness.
Social-ecological	Persistence, adaptability and transformability of linked human and natural systems.	Folke (2006); Walker et al. (2004); Folke et al. (2010)	Rich but hard to measure and apply to policy.
Disaster and community	Robustness, redundancy, resourcefulness and rapidity of recovery; community capacities.	Bruneau et al. (2003); Cutter et al. (2008); Aldrich (2012)	Often scoped to one hazard and one scale.

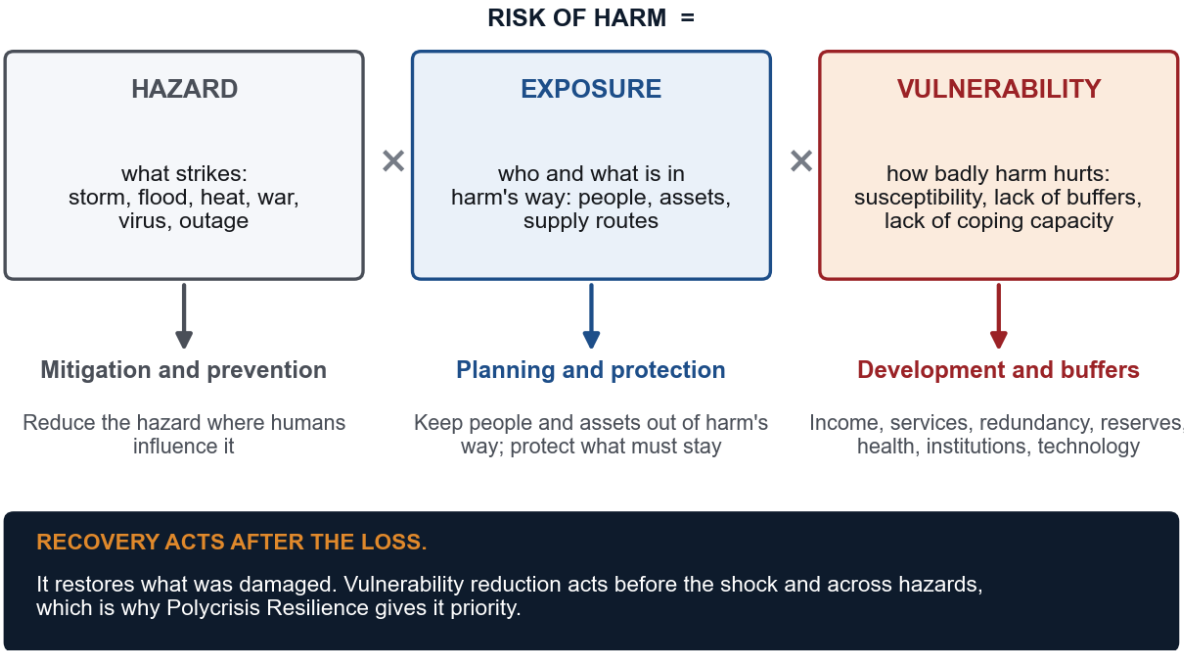
Source: H Heuristics.

The field's own history points in one direction. Holling's original distinction between the speed of recovery and the ability to persist through change already implied that the best response to a shock is not always to return to the old state. The social-ecological school added adaptability and transformability, and critics of resilience policy added that unless vulnerability itself is addressed, resilience can become a way of asking the poor to absorb risk (Béné et al., 2012; Pelling, 2011; Kates et al., 2012). Polycrisis Resilience takes that critique as its starting point.

3.2 Hazard, exposure and vulnerability

The standard decomposition used in climate and disaster science treats the risk of harm as arising from the interaction of three things: the hazard (what strikes), exposure (who and what is in the way) and vulnerability (how badly the harm hurts, given susceptibility and the capacity to cope). This is the framing used by the Intergovernmental Panel on Climate Change and by the Sendai Framework (UNDRR, 2015). **Figure 3** shows the three terms with the lever that acts on each.

Figure 3. Risk of harm as hazard, exposure and vulnerability, and the lever on each



Source: H Heuristics, adapting the risk framing of IPCC and UNDRR (2015). Conceptual diagram.

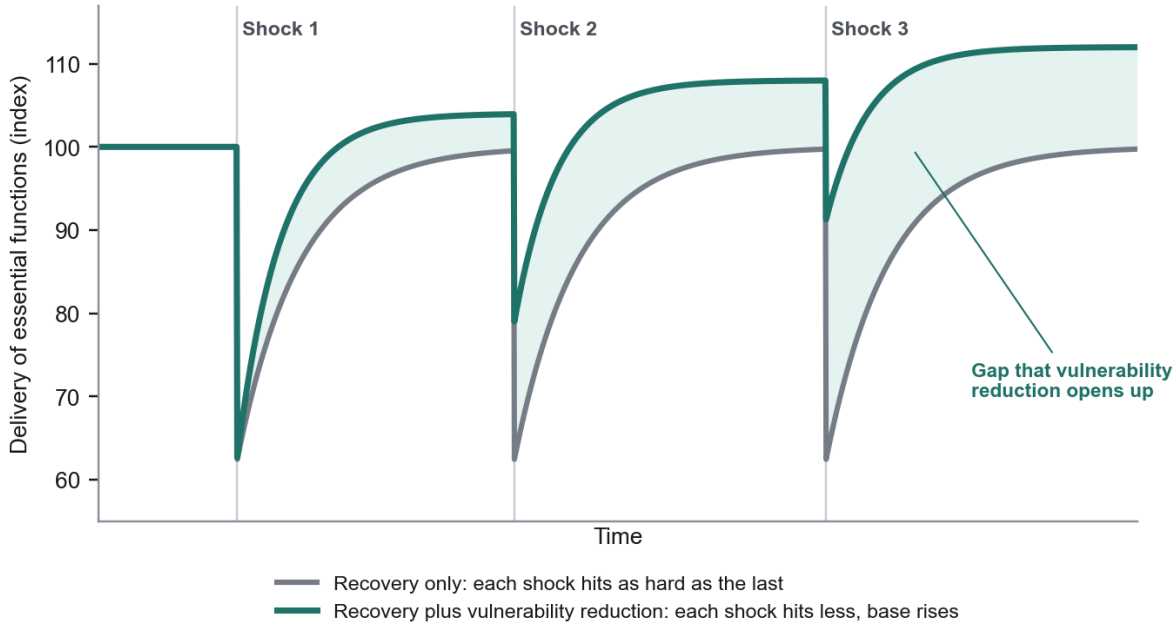
Each lever matters. Mitigation reduces hazards that humans influence, notably climate change. Planning and protection keep people and assets out of the way. Development and buffers reduce vulnerability: the income, services, redundancy, reserves, health and institutions that determine how much harm a given event does. Recovery sits outside the equation, because it restores what has already been lost. Polycrisis Resilience does not reject recovery. It insists that recovery alone leaves the multiplicative term, vulnerability, untouched.

Vulnerability has a further property that makes it central to a polycrisis. A hazard is specific to a domain: a flood is a flood. Vulnerability is general. A household without savings, a clinic without backup power and a government without fiscal space are exposed to many different hazards. Reducing vulnerability therefore protects against crises that have not yet been imagined, which is exactly what a polycrisis requires.

3.3 Why before is better than after

Figure 4 illustrates the argument with a stylized pair of systems. Both suffer three shocks of equal size. The first can only recover: it returns to its starting level each time and takes the same hit from the next shock. The second also reduces its vulnerability between shocks, so each shock hits less and the base level of service rises. The gap between the two grows with each cycle. The figure is an illustration, not a forecast, and its parameters are arbitrary (grade D). Its message is structural: recovery sets the pace of return, while vulnerability reduction sets the depth of the next fall.

Figure 4. Recovery alone against recovery plus vulnerability reduction (stylized)



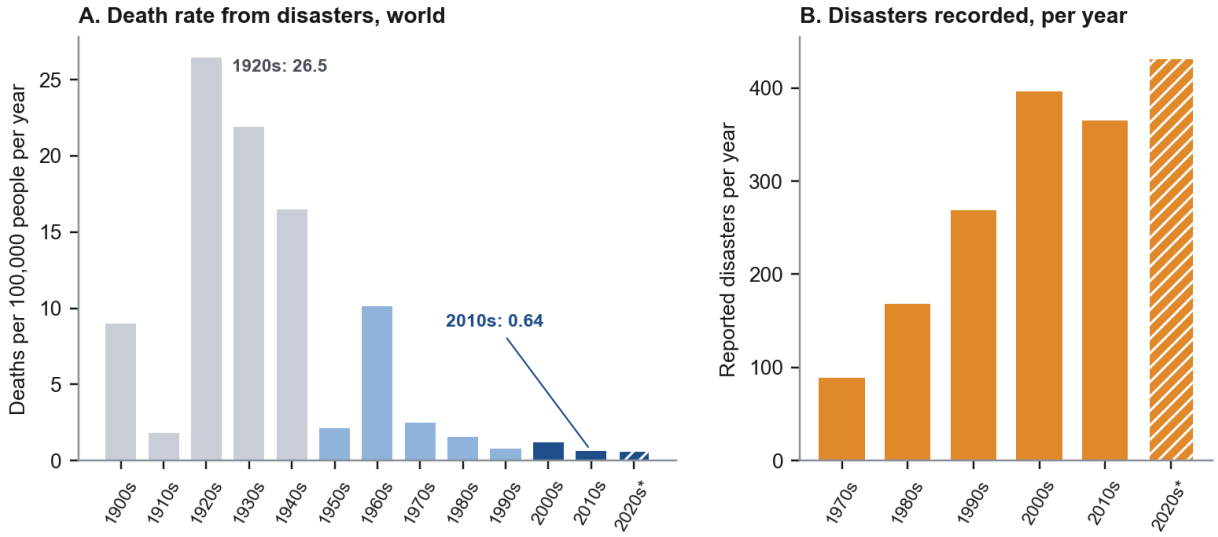
Source: H Heuristics. Stylized illustration (grade D). Each shock removes a share of service proportional to current vulnerability; the second system lowers vulnerability by one third after each shock and gains a small increment of base capacity.

3.4 The evidence that vulnerability can fall

Is vulnerability reduction more than an assertion? The longest evidence comes from disaster mortality. **Figure 5** shows the world death rate from disasters by decade since 1900, alongside the number of disasters recorded per year since 1970. The death rate in the 2010s was 0.64 per 100,000 people a year. The average for 1900 to 1949 was 15.1. That is a fall of about 96%, and it is a fall in a rate, so it is not an effect of a larger population. Over the same period the number of recorded disasters rose from about 89 a year in the 1970s to between 365 and 433 a year since 2000.

The interpretation needs care. Early records are incomplete and dominated by a few famine and drought catastrophes, so the exact size of the fall is uncertain, and the growth in recorded events partly reflects better reporting. But the direction is robust and is documented by Our World in Data from the EM-DAT record, which describes a decline of more than 90% over the century. Most analysts attribute it to a set of vulnerability-reducing changes: early warning and forecasting, sturdier housing and infrastructure, better health care and food distribution, and richer, better-governed states (grade B for the decline, C for the attribution).

Figure 5. Death rate from disasters (A) and recorded disasters (B) over time



*Source: H Heuristics calculation from EM-DAT (CRED/UCLouvain) as published by Our World in Data. Panel A: decadal average deaths per 100,000 people, including missing persons, all natural disasters. Panel B: average number of recorded disasters per year. *2020s covers 2020 to 2025 only.*

The figure also carries a warning. In the 2020s heat has become the largest recorded killer: extreme temperature accounts for about 56% of the 2020 to 2025 disaster death rate in this series, and in 2022 to 2024 the recorded rate for the high-income group exceeded that of every other income group, driven by heat-wave deaths. Vulnerability falls where it is addressed and rises where it is not. A society that was resilient to the hazards of the twentieth century can be vulnerable to those of the twenty-first.

The same pattern appears in the poverty literature. Hallegatte and colleagues (2017) estimate that natural disasters cost the world about $520 billion a year in lost consumption and push roughly 26 million people into poverty annually, and that the poor lose a larger share of their wealth than the rich because they are more exposed, more susceptible and less able to cope. The losses that matter most are borne by people who have the least to lose, which is why the report treats vulnerability, and not only asset damage, as the target.

PART II · STRUCTURE

4. Essential Functions: What Must Keep Working

IN BRIEF

- The definition asks resilience to maintain essential functions. Eight can be named: energy, water, food, health, finance, digital systems, transport and trade, and governance.
- They are not equally connected. Energy and digital systems are the keystones that most others depend on; food and health are the most exposed downstream.
- Resilience planning should define a minimum service level for each function and protect the dependencies that support it.

4.1 Why start with functions

Crises are experienced as the loss of something essential: light, water, food, care, money, communication, movement, order. A resilience concept that starts from the hazard has to be repeated for every hazard. One that starts from the functions society cannot do without applies to all of them, including those not yet foreseen. Critical-infrastructure policy in many countries already works this way, with national lists of vital sectors and requirements for continuity, and the engineering literature on interdependent infrastructure has long shown that these sectors cannot be protected one at a time (Rinaldi et al., 2001).

H Heuristics groups the essential functions into eight, listed in **Table 7**. The grouping is a working choice rather than a standard. It combines what national lists usually separate, and it adds finance and governance, because the case studies in Part III show that crises often travel through the ability to pay and the ability to coordinate.

Table 7. Eight essential functions

Function	What it delivers	Illustrative minimum service	Typical single point of failure
Energy	Electricity, gas, liquid fuels, heat	Power for hospitals, water pumping and communications; fuel for emergency transport	Grid operators; gas supply and processing; fuel import terminals
Water and sanitation	Safe drinking water and sewage treatment	Enough safe water per person per day; no uncontrolled sewage release	Pumping stations that need grid power; treatment chemicals
Food	Production, storage and distribution of staples	Staple availability and affordability for every region	Ports; fertilizer supply; cold chains; import dependence
Health	Emergency and routine care, medicines, public health	Emergency and critical care continues; essential medicines in stock	Backup power; medical supply chains; clinical IT systems
Finance and payments	Payments, credit, foreign exchange, public finance	Wages and imports can be paid; essential public spending continues	Payment switches; foreign-exchange reserves; sovereign debt
Digital and information	Networks, cloud services, data, alerts	Emergency communications and public alerts continue	Software and cloud monocultures; cables; shared update channels
Transport and trade	Ports, roads, rail, shipping and aviation	Movement of food, fuel, medicine and responders	Chokepoints such as canals and major ports

Function	What it delivers	Illustrative minimum service	Typical single point of failure
Governance and security	Public order, emergency management, courts, coordination	Authority to act, fiscal capacity, and public trust are maintained	Fiscal space; institutional legitimacy; early-warning systems

Source: H Heuristics.

4.2 How strongly the functions depend on one another

Figure 6 scores how strongly each function depends on each other function: none, low, moderate or high. The scores are the author's judgments from the literature on infrastructure interdependency and from the case studies in this report, so they are grade C and should be read as a hypothesis to be tested, not as measurements. They are most useful for the pattern they reveal.

Figure 6. Dependency matrix of the eight essential functions (qualitative)



Source: H Heuristics. Scores assigned by the author from Rinaldi et al. (2001), Buldyrev et al. (2010) and the cases in Chapter 7 (grade C). Row depends on column; the bottom line sums each column to show how much the other functions rely on it.

Three patterns stand out.

- **Energy is the master dependency.** Six of the other seven functions depend on it highly and the seventh moderately, for a column total of 20 out of a possible 21. Water pumping, food processing and cold storage, hospital operation, payment systems, data centers and fuel-based transport all stop without it.
- **The digital layer is the second keystone.** Its column total is 16. Health, finance and governance depend on it highly, and the energy, water and transport sectors use it to control their own operations. The 2024 CrowdStrike outage, discussed in Chapter 7, showed how far a failure in one software component can reach.
- **Food and health are the most exposed downstream.** Their row totals are 13 and 15, the highest in the matrix. They depend on almost everything, and almost nothing depends on them. This is why the human consequences of a failure elsewhere so often show up as hunger, untreated illness and avoidable death.

4.3 Minimum service levels and graceful degradation

A resilience plan that says that a function must always work is not credible. One that says what must work, for whom and for how long can be tested. For each essential function a **minimum service level** defines the least that must be maintained through a crisis, such as emergency power for hospitals and water pumping, a guaranteed supply of staples, or the continued processing of wage and import payments. Between full service and the minimum lies a controlled path of **graceful degradation**: a defined order in which less essential demands are shed so that essential ones survive. Systems that degrade gracefully fail partially. Systems that do not fail completely.

Three design principles support this. **Redundancy** keeps a spare route, supplier or source for critical inputs. **Modularity** lets a system break into self-sufficient islands, as when a clinic or a village keeps running on local solar power and storage while the main grid is down. **Diversity** avoids the single supplier, single standard or single technology whose failure takes everything with it. Each has a cost in everyday efficiency, which is why Chapter 12 returns to the trade-off.

4.4 Functions that statistics miss

Official lists of critical systems omit much that keeps societies functioning in a crisis. Informal care, unpaid household work, neighbors who share food and shelter, and local knowledge of who needs help are all functions in the sense used here. Research on disasters finds that social capital strongly affects recovery (Aldrich, 2012). A resilience assessment that counts only the formal systems will understate the capacity of communities that are well connected and overstate that of communities that depend on a service with no local fallback.

PART II · STRUCTURE

5. Six Scales of Resilience

IN BRIEF

- The definition spans individuals and households, communities, institutions, economies, societies and nations, and interconnected global systems.
- Each scale has its own capacities and its own characteristic failures.
- The scales interact. Resilience gained at one scale can be lost, or shifted onto others, at another, so a polycrisis response must work across scales.

5.1 What resilience means at each scale

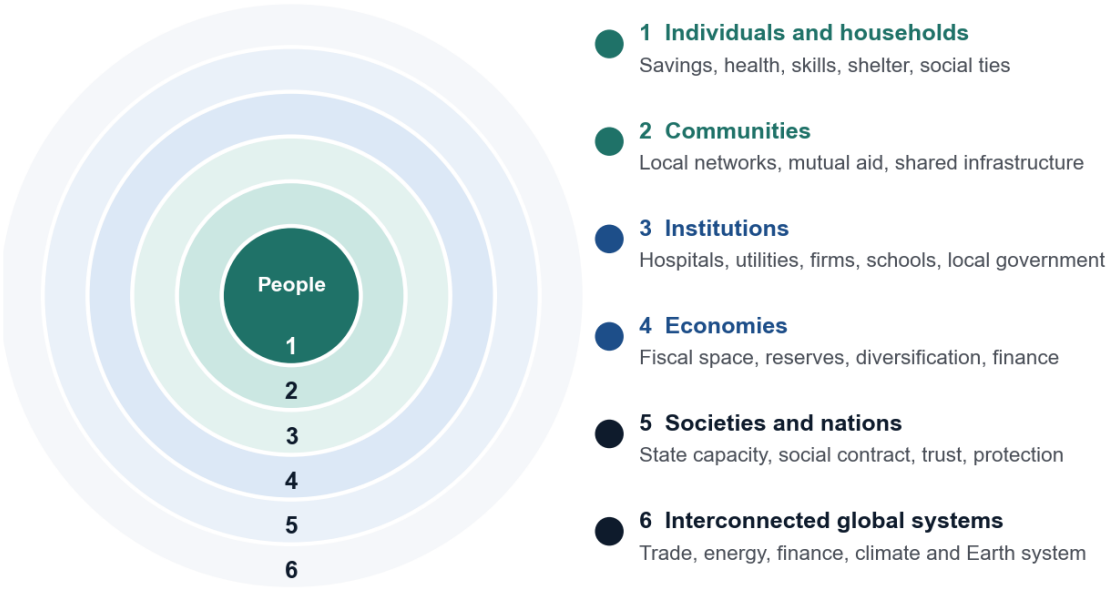
Figure 7 shows the six scales as nested layers around people, and Table 8 sets out what resilience means at each, the capacities it draws on, how it typically fails and how it might be tracked.

Table 8. Capacities and failures at six scales

Scale	Resilience means	Key capacities	Typical failure	Example indicator
1. Individuals and households	Keeping health, income, shelter and food through a shock	Savings, insurance, health, skills, access to services	Forced sale of assets; children leave school; debt spiral	Share of households with three months of expenses saved
2. Communities	Collective ability to share risk and act together	Networks, mutual aid, local organizations, shared infrastructure	Fragmentation; no local fallback when services fail	Share of people with a trusted source of help
3. Institutions	Hospitals, utilities, schools, firms and local governments continue to operate	Continuity plans, backup supply, trained staff, spare capacity	Single points of failure; no surge capacity	Hours of operation under grid or network loss
4. Economies	Absorbing shocks without losing output, jobs or solvency	Fiscal space, reserves, diversified production and trade, deep finance	Balance-of-payments crisis; debt distress	Months of imports covered by reserves; debt service to exports
5. Societies and nations	State capacity to protect, coordinate and maintain legitimacy	Government effectiveness, social protection, trust, early warning	Loss of public trust; slow or uneven response	Government effectiveness; share covered by social protection
6. Interconnected global systems	Stability of the networks that link everything else	Diverse supply, open trade, financial safety nets, climate stability	Chokepoints; export bans; cascading finance and trade disruption	Supplier concentration; share of trade under restrictions

Source: H Heuristics.

Figure 7. Six nested scales of Polycrisis Resilience



Source: H Heuristics. Conceptual diagram.

5.2 How the scales interact

The scales are connected in both directions. A household's resilience depends on the services of its community and institutions, which depend on the economy's ability to pay for them, which depends on the stability of global trade and finance. Failure also travels upward: a wave of household distress becomes unrest and fiscal pressure, and local failures can combine into national ones. The theory of panarchy describes such cross-scale linkages, in which fast, small cycles can trigger change in slower, larger ones, and large, slow structures constrain what small ones can do (Gunderson and Holling, 2002; Pescaroli and Alexander, 2016). Work on interdependent networks adds a warning: coupling two networks that are each robust can create a system that is far more fragile, because failure in one propagates into the other (Buldyrev et al., 2010).

The practical consequence is that resilience at one scale is not enough and may be harmful. A firm that cuts its risk by shifting it to suppliers, a country that protects its markets by restricting exports, or a city that protects itself by diverting floodwater downstream has raised its own resilience while lowering that of others. The export restrictions of 2022 are the clearest example: they eased pressure on the exporting countries and added to prices for the importing ones (Chapter 7). Critics of resilience policy make a related point about distribution: where resilience is delegated downward to households and communities without resources, it becomes a transfer of risk to those least able to bear it (Béné et al., 2012).

A working principle: build low, back up high

Capacity should be built at the lowest scale that can use it effectively, and backed by the next scale up. A household should have savings and a clinic should have its own power, but both depend on a community, a state and a financial system that stand behind them. This is a version of the principle of polycentric governance, in which several overlapping centers of decision-making share the work of managing a shared risk (Ostrom, 2010). It also implies that a resilience investment should be judged by what it does at the scales above and below it, and not only at the scale where it is made.

PART II · STRUCTURE

6. How Crises Compound: Four Failure Patterns

IN BRIEF

- Crises compound through common drivers, direct interactions and feedback loops (Lawrence et al., 2024). In practice four failure patterns recur.
- Each pattern points to a specific kind of resilience investment.

6.1 From mechanisms to patterns

If one reads the major recent cascades, four patterns recur, and each can be tied to a capacity that resilience should provide. They are not exhaustive or mutually exclusive, and most cases show several together. They are the patterns the five cases in Chapter 7 most clearly display, and so they are grade C.

Table 9. Four failure patterns and the capacities that answer them

Pattern	How it works	Where it appears	Resilience response
1. Depleted buffers	Reserves, stocks, fiscal space and spare capacity are run down before the shock, so a moderate shock becomes a crisis.	Sri Lanka and Pakistan entered 2022 with about one month of import cover.	Build and protect reserves, fiscal space, stocks and surge capacity in good times.
2. Single points of failure	A function depends on one supplier, one technology, one route or one vendor, so one failure takes down many dependents.	CrowdStrike (one software component); Uri (gas supply for power); canals and ports.	Diversify and modularize; test dependencies; separate critical systems.
3. Slow erosion, then sudden shock	Gradual deterioration of infrastructure, finances or ecosystems lowers the threshold at which a shock becomes a failure (Scheffer et al., 2009).	Unwinterized plants after earlier cold events; rising debt service before 2022.	Monitor slow variables; treat early-warning indicators as triggers for action.
4. Responses that compound the crisis	Actions to protect one part of a system raise risk elsewhere, or policy errors create a new shock.	Export bans in 2022; abrupt fertilizer import restrictions in Sri Lanka.	Coordinate across sectors and borders; stress-test policies for side effects.

Source: H Heuristics.

Why averages mislead. Climate science calls the physical version of these patterns compound events, in which combined drivers or hazards produce an impact larger than any alone (Zscheischler et al., 2018), and complex risk assessment must also weigh the response options that may themselves create risk (Simpson et al., 2021). A system that copes with the average winter, price spike or outage may still fail in the event that combines them, which is why Chapter 11 stresses weakest-link measures.

PART III · EVIDENCE

7. Five Cascades Examined

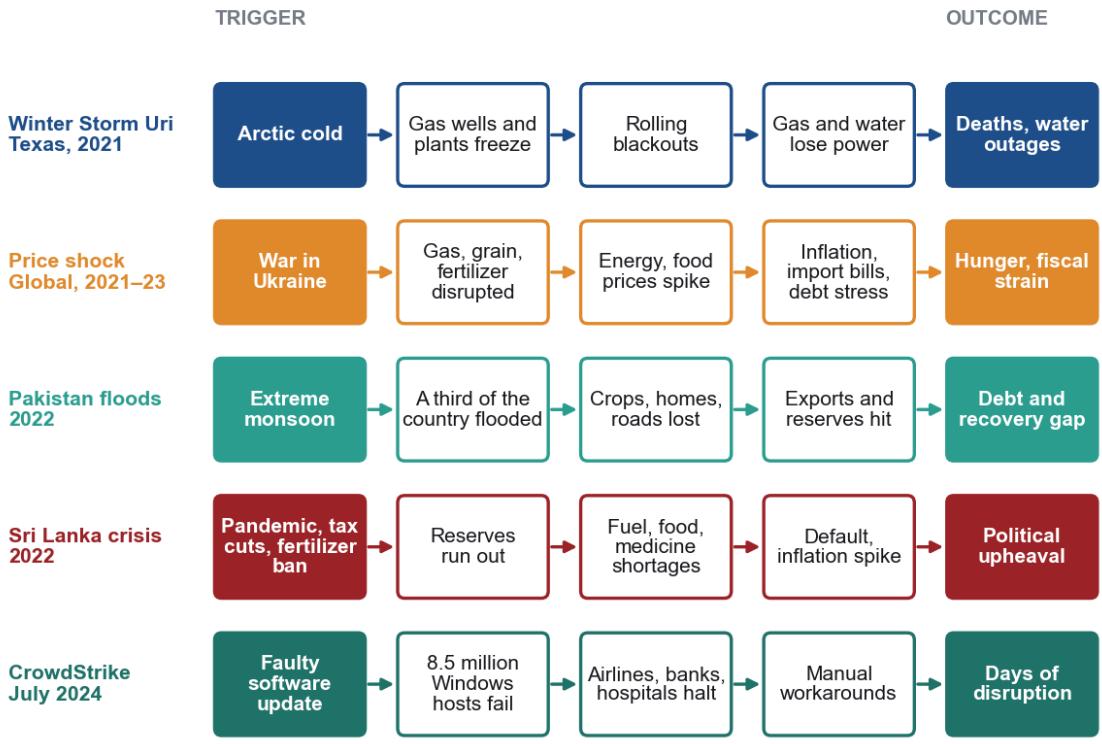
IN BRIEF

- Five recent events show how different triggers move through the essential functions: a freeze in Texas, a global price shock, floods in Pakistan, a balance-of-payments crisis in Sri Lanka and a software failure that spanned the world.
- Each shows the failure patterns of Chapter 6, and each shows what separated systems that held from those that did not.
- Comparing Sri Lanka, Pakistan, India and Bangladesh through 2022 shows the importance of buffers held before the shock.

7.1 Why these five

The cases span the main kinds of trigger (weather, conflict, flood, financial, technological) and the scales of the definition, from a regional power system to the global price system. They are not a random sample. COVID-19 is treated as the background to all five rather than as a case, because it would need a study of its own. **Figure 8** sets out the chain of each cascade, and **Table 10** compares them.

Figure 8. Five cascades, from trigger to outcome



Source: H Heuristics, summarizing the sources cited in Sections 7.2 to 7.6. Conceptual diagram; links are simplified.

Table 10. The five cascades compared

Case	Trigger	Keystone function hit	Buffers before the shock	What distinguished outcomes
Winter Storm Uri, Texas, 2021	Extreme cold	Energy (power and gas); water; health	Thin reserve margin in a grid with limited outside connection; plants not winterized	Whether plants and gas facilities were prepared for cold
Price shock, 2021–23	War; gas and grain supply disruption	Energy; food; finance	Highly variable; low-income importers had least fiscal space	Fiscal space and supplier diversity; export restrictions
Pakistan floods, 2022	Extreme monsoon	Food; housing; transport; finance	1.4 months of import cover; debt service 42% of exports	Reserves and fiscal space; recovery finance
Sri Lanka, 2022	Reserve exhaustion	Finance; energy; food; health	1.1 months of import cover; debt service 38% of exports (2020)	Buffers; policy sequencing; external financing
CrowdStrike, 2024	Faulty software update	Digital; health; transport; finance	Single vendor, single update channel; limited manual fallback	Fallback procedures; speed of manual recovery

Source: H Heuristics, from the sources cited in Sections 7.2 to 7.7. World Bank data for import cover and debt service.

7.2 Winter Storm Uri, Texas, February 2021

In mid-February 2021 an Arctic outbreak brought record cold to Texas. From 15 February the grid operator ordered rolling outages, and at the peak about 4.5 million homes and businesses had no power. A University of Houston survey found that about 69% of Texans lost power and about half lost water service, with an average outage of around 42 hours (Hobby School of Public Affairs, 2021). The state's final count of storm-related deaths was 246, and some independent analyses estimate more (Texas Department of State Health Services, 2022).

The joint inquiry by the federal energy regulator and the national reliability council found that the blackouts had two intertwined causes: generating units that tripped or could not start because their equipment froze, and a collapse in natural gas supply, with Texas production falling by about 70% from its January average (FERC, NERC and Regional Entities, 2021). Gas wells and processing plants lost power, and the loss of gas then caused further power plant failures. Water systems lost pumping power and treatment capability. The inquiry made 28 recommendations and noted that earlier cold events, including February 2011, had exposed the same weaknesses.

What it shows. The case displays the first and third failure patterns. Electricity and gas were each dependent on the other without a plan that covered both, and a known vulnerability to cold had been identified and left unaddressed. The consequences fell hardest on the functions at the bottom of the dependency matrix: water, health and heat for people in their homes.

7.3 The price shock of 2021 to 2023

Figure 1 in Chapter 1 shows the shape of this cascade. After the pandemic rebound, energy prices climbed through 2021. Russia's full-scale invasion of Ukraine on 24 February 2022 disrupted the trade of commodities for which Russia and Ukraine were leading exporters: by FAO's estimate the two countries supplied about a quarter of world wheat exports in 2021, they dominated sunflower oil, and Russia was Europe's largest source of natural gas and an important fertilizer exporter. Fertilizer production depends on gas, so the energy shock reached the food system twice. The World Bank described the result as the largest commodity shock since the 1970s (World Bank, 2022). In the data used here the IMF food index peaked at 67% above its 2019 average in April 2022, the energy index at almost three times in August 2022, and the European gas price at 15.7 times.

Governments responded in ways that sometimes made matters worse. Indonesia banned palm oil exports from 28 April 2022 and India banned wheat exports from 13 May 2022, and at the peak about 17% of the calories traded internationally were subject to export restrictions (IFPRI, 2022). Both bans were later eased, but the episode showed how national protective action can aggravate a global shock. Importing countries with thin reserves and high debt were left with the highest bills and the least room to subsidize. By 2024, 295 million people in 53 countries and territories faced acute food insecurity, although armed conflict, and not prices, was the principal driver of that number (Food Security Information Network, 2025).

What it shows. The case displays the second and fourth patterns: concentrated supply and responses that compound the crisis. It also shows a cascade crossing three scales: a regional war, global prices, and national and household budgets.

7.4 The Pakistan floods, 2022

Monsoon rains and flooding from June to October 2022 submerged about a third of Pakistan and affected 33 million people, and more than 1,700 people died. The government's Post-Disaster Needs Assessment, prepared with the World Bank, the United Nations, the European Union and the Asian Development Bank, estimated damage of more than $14.9 billion and economic losses of about $15.2 billion, with reconstruction needs of at least $16.3 billion (Government of Pakistan et al., 2022). Housing ($5.6 billion), agriculture and livestock ($3.7 billion) and transport and communications ($3.3 billion) bore the largest damage, and the province of Sindh bore about two-thirds of the damage and losses.

The floods struck an economy with almost no buffers. World Bank data show that Pakistan's reserves covered 1.4 months of imports in 2022, its external debt service absorbed about 42% of export earnings, and consumer price inflation reached an annual average of 19.9% in 2022 and 30.8% in 2023. The economy contracted by 0.4% in 2023. In 2023 the IMF approved a $3 billion standby arrangement that helped Pakistan avoid default. Press reports in 2024 put financing pledged or received at about $10.9 billion, against reconstruction needs of about $16 billion, so that the recovery was only partly funded (Dawn, 2024).

What it shows. The case displays depleted buffers. A flood is a hazard, but its macroeconomic consequences were a product of the condition the country was in when it arrived: low reserves, heavy debt service and high inflation. It also shows the recovery gap between rebuilding costs and available money.

7.5 The Sri Lanka crisis, 2022

In April 2022 Sri Lanka announced that it would halt payments on its external debt, saying it needed its remaining dollars for food and fuel. In the months before, shortages of fuel, cooking gas, medicines and many foods had spread, and the rupee had fallen by over 30% after a devaluation in March. Consumer price inflation (the Colombo index) reached a record 69.8% in September 2022, and food inflation was reported above 90% in August 2022 (later series differ). World Bank data show a fall in output of 7.3% in 2022 and annual average inflation of 49.7%. The president resigned in July after mass protests. In March 2023 the IMF approved a four-year program of about $3 billion.

Analysts disagree on the weight of the causes. The commonly cited list includes the loss of tourism and remittance income in the pandemic, tax cuts in 2019, a heavy burden of foreign debt, the rise in global fuel and food prices after the invasion of Ukraine, and the abrupt ban on chemical fertilizer imports in April 2021, which was reversed within months. What the data show clearly is the condition of the buffers. Sri Lanka's reserves covered 3.4 months of imports in 2019, 1.6 in 2021 and 1.1 in 2022, and in 2020 its external debt service absorbed about 38% of exports.

What it shows. The case displays all four patterns, with depleted buffers at the center. The cascade ran from finance to energy and food imports, to health, and to the government itself.

7.6 The CrowdStrike outage, July 2024

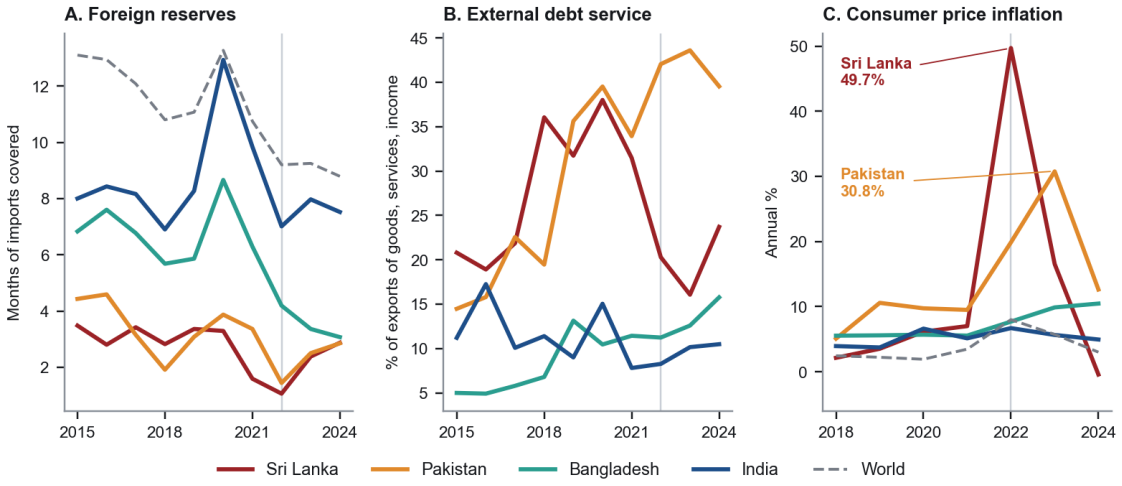
On 19 July 2024 a faulty content update to a widely used endpoint security product caused Windows computers running it to crash and fail to restart. Microsoft estimated that about 8.5 million Windows devices were affected, less than 1% of all Windows machines, but they included machines at airlines, hospitals, banks, broadcasters and public agencies. Recovery required many machines to be fixed by hand, and more than 97% of the affected sensors were back within five days (CrowdStrike, 2024; Microsoft, 2024). The insurer Parametrix estimated direct losses for the US Fortune 500 firms, excluding Microsoft, at $5.4 billion, with health care the hardest hit at about $1.9 billion, then banking at $1.2 billion and airlines at $0.9 billion. It estimated that insurance would cover only $0.5 to 1.1 billion of this (Parametrix, 2024).

What it shows. The case displays the second pattern in its purest form: one component, one vendor and one update channel shared across sectors. It was not an attack. It shows that the digital layer, the second keystone of the dependency matrix, can fail through the ordinary process of maintaining it, with effects at once in health, finance and transport, and that private insurance covered only a fraction of the system-wide exposure.

7.7 Same shocks, different buffers

Figure 9 uses World Bank data to compare four South Asian economies and the world average through the shocks of 2020 to 2024. All four faced the same global price movements but entered them with different buffers. Panel A shows the foreign reserves that finance imports, in months of import cover. India held between 7 and 13 months through the period and Bangladesh between 3 and 9. Sri Lanka and Pakistan held between about 1 and 5 months and fell to 1.1 and 1.4 in 2022. Panel B shows the share of export earnings that went to service external debt: for Pakistan it was 42% in 2022 and for Sri Lanka 38% in 2020, against 8% for India in 2022. Panel C shows the result: annual average consumer price inflation peaked at 49.7% in Sri Lanka and 30.8% in Pakistan, against 6.7% in India in 2022 and 9.9% in Bangladesh in 2023.

Figure 9. Reserves, debt service and inflation in four South Asian economies, 2015 to 2024



Source: H Heuristics calculation from World Bank World Development Indicators (FI.RES.TOTL.MO, DT.TDS.DECT.EX.ZS, FP.CPI.TOTL.ZG). The vertical line marks 2022. Inflation is the annual average, which understates the monthly peaks (Sri Lanka's reached 69.8% in September 2022).

The comparison is suggestive and not conclusive. The four countries differ in trade structure, exchange-rate regime, policy choices and exposure to the specific shocks, and a buffer is only one difference among many. India, too, saw its reserves fall by almost half from their 2020 peak, which was inflated by pandemic-era import compression. But the contrast is large and consistent with the idea that buffers built before the shock, and not the shock itself, did most to determine how bad the outcome was (grade B for the data, C for the interpretation).

PART III · EVIDENCE

8. What the Cases Teach

IN BRIEF

- Because the cases are a purposive sample, the lessons are hypotheses supported by evidence, not general laws (grade C).

1. Buffers decide outcomes

Countries that held a few months of reserves absorbed the same shocks that pushed others into default. A buffer works for every hazard, and **Figure 9** is the strongest single piece of evidence here that a country's condition on the eve of a crisis matters more than the crisis.

2. Keystone functions deserve keystone protection

Energy and digital systems support nearly everything else, as Uri and CrowdStrike show. They deserve explicit minimum service levels, tested fallbacks and independent redundancy, in proportion to what depends on them.

3. Known weaknesses are fixed late

The 2021 Texas inquiry found weaknesses that earlier cold events had exposed. The gap between knowing and fixing is itself a vulnerability, so mandatory standards and public reporting of fixes matter as much as technical knowledge.

4. Cascades run through finance and the state

In Pakistan and Sri Lanka the shock mattered because it met a balance of payments and a budget that could not absorb it. Resilience policy that ignores public finance misses the channel by which many crises become human ones.

5. Responses can become the next shock

The 2022 export restrictions and the Sri Lankan fertilizer ban protected one part of a system and made the whole more fragile. Resilience measures should be stress-tested for their effects on other scales and actors before adoption.

6. Diversity and modularity limit the blast radius

CrowdStrike hit a small share of machines but a large share of critical functions because so many shared one tool. Supplier diversity, staged rollouts and the ability to run in isolation shrink any single failure, at some cost in efficiency.

7. Recovery finance arrives late and short

Pakistan's reconstruction needs outran the money pledged by a wide margin, inviting the next shock to find the same weaknesses. Pre-arranged finance, such as contingent credit and risk pooling, shortens recovery.

Reading the lessons against the definition. Buffers and diversity serve the capacity to **withstand**. Stress-tested responses and learning from known weaknesses serve the capacity to **adapt**. Pre-arranged finance and fallbacks serve the capacity to **recover**. All are forms of **reducing vulnerability**, and all were done, or not, before the crisis began: the outcome of a crisis is largely set before it starts.

PART IV · PRACTICE AND MEASUREMENT

9. The Seven Core Objectives in Practice

IN BRIEF

- Each core objective works through specific mechanisms and can be tracked with indicators.
- The objectives reinforce one another: development provides the means, technology and the clean transition spread the capability, convergence extends it and adaptive capacity and long-term stability protect it.
- The test of any investment is whether it advances several objectives and leaves vulnerability lower across several crisis domains.

9.1 From objectives to mechanisms and indicators

Table 11 turns each of the seven objectives into a mechanism, an illustrative action and an indicator. The indicators are examples, drawn from public sources where possible, to show that each objective can be monitored. They are not a finished measurement system, which Chapter 11 discusses.

Table 11. The seven objectives: mechanism, action and indicator

Objective	How it reduces vulnerability	Illustrative action	Illustrative indicator
1. Reduce vulnerability	Lowers the harm any given hazard does, across hazards	Protect keystone functions; build buffers; extend social protection	Loss per unit of hazard; share of households without buffers
2. Strengthen development	Raises income, services and institutional capacity that underlie every capacity to cope	Universal access to power, water, health and education; capable public institutions	Access rates; government effectiveness; poverty headcount
3. Accelerate technological diffusion	Spreads tools that raise productivity, improve health and enable warning and response	Open standards; affordable digital access; technology transfer and local capacity	Internet use; adoption lag for proven technologies
4. Advance the clean transition	Cuts pollution and fuel-import exposure while adding distributed, low-cost energy	Clean power, clean cooking, electrified transport and industry	Clean share of energy; air-pollution deaths; fuel import share
5. Promote convergence	Narrows the gaps that leave some populations far more exposed than others	Concessional finance; trade and investment in lower-income economies	Growth in lower-income economies against high-income; gaps in access
6. Improve adaptive capacity	Lets societies anticipate, absorb and respond as conditions change	Early warning; adaptive social protection; flexible public finance; learning systems	Early-warning coverage; time to disburse relief
7. Strengthen long-term stability	Reduces the chance that single crises escalate into cascades	Cross-sector stress tests; diversified supply; coordinated policy	Dependency concentration; frequency of cascading events

Source: H Heuristics.

9.2 How the objectives fit together

The objectives are a system. **Strengthening development** (objective 2) supplies the base: income, infrastructure, institutions and human capabilities. **Technological diffusion** (3) and the **clean transition** (4) are two of the main channels by which capability spreads and environmental pressure falls, and the second report of this series examines the latter in detail. **Convergence** (5) ensures that the capability reaches the places where vulnerability is greatest. **Adaptive capacity** (6) lets societies adjust as conditions change, and **long-term stability** (7) is the outcome that reduces the likelihood of cascades. **Reducing vulnerability** (1) is the aim to which all the others contribute.

This ordering clarifies priorities. A measure that improves one objective at the cost of another, for example a fast expansion of energy supply that adds to pollution or fiscal strain, has not necessarily advanced resilience. A measure that advances several, for example distributed clean power that lowers pollution, cuts fuel imports and keeps clinics running through a grid failure, scores on each of the seven.

Worked example: a clinic with solar and storage

Consider a rural health clinic equipped with solar panels and batteries. In ordinary times it cuts the cost of power and the clinic's exposure to fuel prices (objectives 2 and 4). In a grid failure it keeps vaccines cold and the lights on in the delivery room (1, 6). It also shows how technology spreads when a local technician learns to maintain it (3). If clinics like it become common, they narrow the gap between a district and a capital (5) and reduces the chance that a regional power failure becomes a regional health crisis (7). No single hazard plan would have been written for all of this. Because it reduces vulnerability across many hazards, the investment counts as Polycrisis Resilience.

PART IV · PRACTICE AND MEASUREMENT

10. The Economics of Prevention

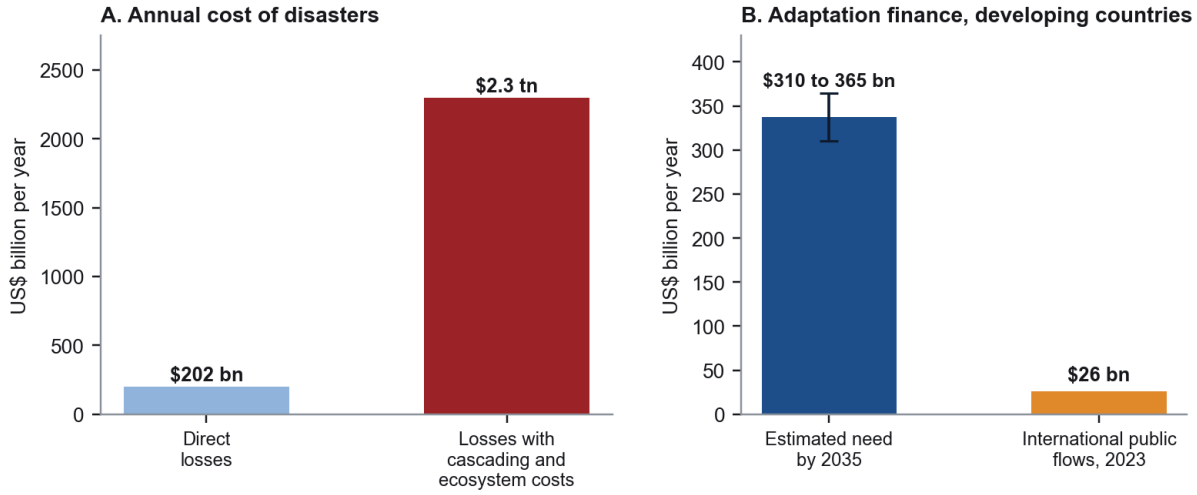
IN BRIEF

- Disaster costs are roughly eleven times larger once cascading and ecosystem effects are counted: about $2.3 trillion a year against $202 billion in direct losses.
- Studies find returns to resilience investment of between 2:1 and 10:1, and benefits that arrive in good times as well as bad.
- Finance does not follow the economics: adaptation finance for developing countries in 2023 was about a tenth of the estimated annual need.

10.1 The cost of cascades

The 2025 Global Assessment Report of the UN Office for Disaster Risk Reduction estimates average direct disaster losses at about $202 billion a year. Once cascading effects and ecosystem losses are included, the total exceeds $2.3 trillion a year (UNDRR, 2025). The gap between the two figures is the price of interaction: what falls outside conventional loss accounting because it moves through supply chains, health systems, public budgets and ecosystems. Panel A of **Figure 10** shows the difference. The report also finds that only about 2% of development aid goes to disaster risk reduction.

Figure 10. The cost of disasters, and the adaptation finance gap



Source: UNDRR (2025), Global Assessment Report 2025 (Panel A); UNEP (2025), Adaptation Gap Report 2025 (Panel B; the bar shows the midpoint of the $310 to 365 billion range).

10.2 The returns to resilience

The evidence on returns points in a consistent direction (**Table 12**). The Global Commission on Adaptation (2019) estimated that $1.8 trillion invested over 2020 to 2030 in five areas, early warning systems, resilient infrastructure, dryland agriculture, mangrove protection and water resource management, could generate $7.1 trillion in net benefits, with benefit-cost ratios between 2:1 and 10:1. The World Bank's analysis of infrastructure estimated about $4 of benefit for each $1 invested in more resilient infrastructure in low- and middle-income countries, for a net benefit of about $4.2 trillion (Hallegatte et al., 2019). Tanner and colleagues (2015) described a **triple dividend** of avoided losses, economic gains from reduced risk and social and environmental co-benefits, and Rodin (2014) argued that the dividend arrives in good times as well as bad.

Table 12. Estimated returns to resilience

Source	Finding	Scope	Grade
Global Commission on Adaptation (2019)	$1.8 trillion invested over 2020–2030 yields $7.1 trillion in net benefits; benefit-cost ratios of 2:1 to 10:1	Five adaptation areas, global	B
Hallegatte et al. (2019), Lifelines	About $4 of benefit per $1 invested in resilient infrastructure; net benefit about $4.2 trillion	Infrastructure in low- and middle-income countries	B
Hallegatte et al. (2017), Unbreakable	Disasters cost about $520 billion a year in lost consumption and push about 26 million people into poverty each year	Global, welfare-based	B
Tanner et al. (2015)	Triple dividend: avoided losses, economic gains, and social and environmental co-benefits	Disaster risk management	B/C

Source: as cited. Estimates carry wide uncertainty and depend on assumptions about discount rates, hazard frequency and counterfactuals.

These figures come from studies of particular kinds of investment, usually against single hazards. They probably understate the return to resilience as the concept defines it, because conventional benefit-cost accounting counts the benefits within one system at a time. An investment that lowers pollution, reduces fuel imports and keeps clinics running delivers value across several systems, and only a cross-system accounting will capture it (grade C).

10.3 The finance gap and who bears the risk

Panel B of **Figure 10** shows the mismatch in funding. The UN Environment Programme's Adaptation Gap Report 2025 estimates that developing countries will need $310 to 365 billion a year for adaptation by 2035, against international public adaptation finance of $26 billion in 2023 (UNEP, 2025). The countries least able to pay are also those with the least access to private insurance and the most exposure to debt distress. Debt service absorbed about 42% of Pakistan's export earnings in 2022, and 3.4 billion people live in countries that spend more on interest than on health or education (UNCTAD, 2025). The CrowdStrike case shows the same gap in a rich-country setting: the insured share of the loss was a fraction of the whole.

The economics support a straightforward conclusion: the cheapest resilience is the one built before the shock, and the cost of failing to build it is borne disproportionately by those who can least afford it. A policy that treats resilience as a cost to be minimized misreads the evidence. It is an investment with a return, and the return is highest in the places where vulnerability is greatest.

PART IV · PRACTICE AND MEASUREMENT

11. Measuring Polycrisis Resilience

IN BRIEF

- Resilience cannot be measured by a single number. It needs a profile across essential functions and scales.
- Indicators should combine leading measures (buffers, redundancy) and lagging ones (loss, recovery time), and should be aggregated so that the weakest link counts.
- Stress tests that run cross-sector scenarios give information that no static indicator can.

11.1 Principles

- **Measure vulnerability and capacity, not only outcomes.** Losses show what happened. Buffers and dependencies show what is likely to happen, and they are the better guide to action. The review literature finds a wide variety of definitions and measures of system resilience, and few that combine them (Hosseini et al., 2016).
- **Use a profile, not a rank.** A country with strong power and weak finance is not the same as one with the reverse, even if the averages match. A profile shows where the weakness lies.
- **Aggregate by the weakest link.** If scores are combined at all, use a rule that penalizes low values, such as a geometric mean or a minimum, so that strength in one function cannot offset a fatal weakness in another.
- **Test, do not only count.** Stress tests, tabletop exercises and cross-sector scenarios reveal dependencies that no dataset records. Financial regulators have used stress tests for years. Equivalent exercises across energy, water, digital and finance functions are rare.
- **Report uncertainty and gaps.** Many of the most important dependencies are not measured at all. A resilience scorecard should say what it cannot see.

11.2 A scorecard by essential function

Table 13 proposes candidate indicators for each essential function, with a leading and a lagging measure for each. The indicators are suggestions for a design stage, and many require data that are not yet collected consistently. The scorecard is grade D as a measurement tool, though its individual indicators are mostly well established.

Table 13. Candidate scorecard by essential function

Function	Leading indicator (capacity)	Lagging indicator (outcome)
Energy	Reserve margin; share of distributed supply; fuel and gas storage days	Outage hours per customer; unserved energy in extreme events
Water and sanitation	Share of utilities with backup power; storage days	Days without safe water in events
Food	Stocks-to-use ratio; import and fertilizer supplier concentration	Price spikes; share of people food insecure
Health	Surge capacity; hospitals with backup power; essential medicine stocks	Excess mortality in events
Finance and payments	Months of imports covered by reserves; debt service to exports; fiscal space	Time in arrears; inflation volatility

Function	Leading indicator (capacity)	Lagging indicator (outcome)
Digital and information	Share of critical systems with multi-vendor and offline fallbacks; recovery time objectives	Hours of critical-service downtime
Transport and trade	Supplier and route concentration; port and chokepoint redundancy	Delay and cost in disruptions
Governance and security	Government effectiveness; early-warning coverage; social protection coverage	Time to disburse relief; trust in institutions

Source: H Heuristics. Illustrative; grade D as a measurement system.

11.3 Three levels of measurement

A practical program would work at three levels. A **national profile** would draw on existing international data, such as reserves, debt service, government effectiveness, energy and health indicators, to give a comparable view across countries. A **sector assessment** would use utility and operator data to compare dependencies and fallbacks across an essential function. A **local assessment** would combine household and community data with exercises, to test how a particular place would cope with a combined shock. Each feeds the one above, and the whole is only as reliable as its weakest data.

PART IV · PRACTICE AND MEASUREMENT

12. Trade-offs, Critiques and Limits

IN BRIEF

- Resilience has costs, and the concept has fair critics. The most serious objection is that it can shift the burden of risk onto people with the least power to carry it.
- Some risks cannot be made manageable by resilience alone, and prevention remains essential.

12.1 Critiques and responses

Table 14. Eight objections to Polycrisis Resilience, and responses

Objection	Response
Resilience shifts responsibility onto the vulnerable. It asks people to cope rather than asking institutions to protect them (Béné et al., 2012).	The concept puts vulnerability reduction ahead of coping. It treats a plan that asks individuals to absorb risk without reducing their exposure as a failure, and it treats distribution as a condition of effectiveness.
It is too broad to be useful. A concept that covers everything explains nothing.	The definition is anchored in four functions, three outcomes and eight essential functions, and in testable claims: buffers predict outcomes; keystones fail hardest. The measurement program tests it.
It costs efficiency. Redundancy and buffers are waste in normal times (Taleb, 2012).	True in a narrow accounting. The returns evidence suggests net benefits in most settings, and the dividend arrives in ordinary times as well. Redundancy should be targeted at keystones, not spread everywhere.
It risks maladaptation. Protective actions can raise risk elsewhere or later.	Chapter 8 draws this lesson from the cases. Measures should be stress-tested across scales and time, and a measure that moves risk to others should not count as resilience.
Development raises emissions. Greater capability goes with higher carbon use.	That is why the clean transition is one of the seven objectives. Development without decarbonization raises the hazard term of the risk equation, and the concept does not endorse it.
The evidence is case-based and correlational.	Agreed in part. The five cases are a purposive sample and the cross-country comparisons are not causal. Chapter 13 sets out a research agenda to test the claims more rigorously.
Resilience invites complacency. If societies can cope, prevention seems less urgent.	The concept treats prevention and resilience as complements. Some risks, including tipping points in the Earth system, cannot be adapted to and have to be prevented (Armstrong McKay et al., 2022).
Resilience for whom? Gains may accrue to the already secure.	The concept's convergence objective and its focus on the most exposed address this directly, and the indicator profiles should be disaggregated by income, place and group.

Source: H Heuristics.

12.2 Limits

Three limits deserve emphasis. **Resilience is not a substitute for prevention**: reducing the likelihood of climate change, pandemics and conflict is cheaper and safer than coping with them. **Some risks exceed any resilience**: beyond certain Earth-system thresholds adaptation cannot compensate, and several planetary boundaries have already been passed (Rockström et al., 2009; Steinert et al., 2025). **The knowledge base is incomplete**: the dependency matrix is a hypothesis, the scorecard a design, and the cases few.

PART IV · PRACTICE AND MEASUREMENT

13. Strategic Priorities, Research Agenda and Conclusion

IN BRIEF

- Governments, financial institutions, operators, firms, communities and researchers each have a distinct role.
- Ten research questions would test and sharpen the concept.
- The central idea stands: the aim is not only to recover from crises but to reduce the vulnerabilities that make them so damaging.

13.1 Priorities by actor

Table 15 summarizes what each group can do. The common thread is to name the essential functions, fund the buffers and fix the known weaknesses before the next shock.

Table 15. Priority actions by actor

Actor	Priority actions
National governments	Define minimum service levels for the eight essential functions; hold fiscal and reserve buffers; extend adaptive social protection; run cross-sector stress tests; publish and track fixes to known weaknesses.
Finance ministries and central banks	Treat external balance and debt service as resilience variables; arrange contingent financing and risk pooling before shocks; avoid policy responses that shift risk onto neighbors.
Multilateral and development institutions	Scale up prevention and adaptation finance toward the estimated need; finance cross-cutting investments that reduce vulnerability to several crises; support recovery finance that arrives fast.
Infrastructure operators and regulators	Map interdependencies; set and enforce standards for keystone systems; require diversity, staged rollouts and manual fallbacks for critical digital services; share incident data.
Firms and investors	Disclose dependency concentrations; invest in redundancy for keystone inputs; price systemic risk, not only firm-level risk.
Communities and civil society	Strengthen local networks, shared infrastructure and local fallbacks; hold governments to account for distribution of protection.
Researchers	Test the dependency matrix and the buffer hypothesis; build scorecards and datasets; document cases, including those where resilience held.

Source: H Heuristics.

13.2 A research agenda

Table 16. Ten research questions

	Question
1	Can the dependency matrix of the essential functions be measured empirically, for example from outage data, and do the keystones hold?
2	How well do pre-shock buffers (reserves, fiscal space, stocks) predict the severity of outcomes across a large sample of shocks, controlling for the size of the shock?
3	What is the return to cross-cutting investments that reduce vulnerability across hazards, once benefits in all affected systems are counted?
4	Which design features of resilience policy cause maladaptation, and how can they be detected before adoption?
5	How do resilience gains at one scale transmit, positively or negatively, to other scales?
6	What minimum service levels are appropriate for each function, and what do they cost?
7	How can cross-sector stress tests be designed so that they are credible, comparable and repeated?
8	Does a weakest-link scorecard predict cascade risk better than an average?
9	How does vulnerability to new hazards, such as extreme heat, evolve in societies that were resilient to older ones?
10	What governance arrangements make it likely that identified weaknesses are fixed, and fixed in time?

Source: H Heuristics.

13.3 Conclusion

The decade from 2020 has shown what a polycrisis looks like in practice: a pandemic that led to supply-chain strain, a war that led to an energy and food price shock, floods that met a country with no reserves, a debt crisis that spread to fuel and medicine, and a software update that stopped aircraft and hospital systems. In each case the trigger was different and the pattern was similar. Outcomes depended less on how large the shock was than on the condition in which it found people and systems.

Polycrisis Resilience is a concept for acting on that observation. It asks for essential functions to be named and protected, for buffers to be built before they are needed, for dependencies and single points of failure to be found and reduced, for responses to be stress-tested for side effects, and for the work to be done where vulnerability is greatest. It also asks for humility: much remains untested, and the claims of this report are graded accordingly.

> **THE CENTRAL IDEA**
>
> Resilience is not simply the ability to recover from crises. It is the ability to reduce the underlying vulnerabilities that make crises so damaging in the first place.

APPENDIX

Appendix: Data, Methods and Exhibits

The data figures in this report use public sources, retrieved in November 2026. All calculations are by H Heuristics, and the scripts that produce them (analysis.py and figs.py) are kept with the report so that every number can be reproduced. Case facts come from official assessments where they exist. Where sources disagree, as with the death toll of Winter Storm Uri or the peak of Sri Lankan food inflation, the report says so or uses the more conservative figure.

Table 17. Data sources and their use

Source	Series	Used for
IMF global price indices, via FRED (Federal Reserve Bank of St. Louis)	Food price index (PFOODINDEXM); energy price index (PNRGINDEXM); EU natural gas price (PNGASEUUSDM); monthly, rebased to the 2019 average	Figure 1 and the price figures in Chapters 1 and 7
EM-DAT (CRED/UCLouvain) as published by Our World in Data	Decadal average death rates from natural disasters; number of recorded disasters per year	Figure 5 and the mortality figures in Chapter 3
World Bank World Development Indicators (API)	Reserves in months of imports; external debt service as % of exports; consumer price inflation; GDP growth	Figure 9 and the case figures in Chapter 7
UNDRR, UNEP, UNCTAD, WMO, WHO, HEI, FSIN and others	Published headline estimates, as cited	Table 2, Figure 10 and Chapter 10
Official case assessments	FERC-NERC staff report (Uri); Pakistan PDNA; Texas DSHS; Microsoft, CrowdStrike and Parametrix (CrowdStrike); IMF and Central Bank of Sri Lanka releases	Chapter 7

Source: H Heuristics.

Illustrative exhibits and their grades

Figures 2, 3, 7 and 8 are conceptual diagrams by H Heuristics; Figure 8 summarizes the documented chain of events in each case and simplifies the links. Figure 4 is a stylized illustration of a mechanism, not a forecast (grade D); its parameters are arbitrary. Figure 6 rests on qualitative scores assigned by the author from the literature on infrastructure interdependency and from the cases in this report (grade C), and the scores have not been validated against outage data. The scorecard in Table 13 is a design proposal (grade D). Every other figure reports data from the cited source.

Limits of the evidence

- **Five cases are a purposive sample.** They were chosen to span triggers and scales, not drawn at random, and cases in which resilience held are under-represented. Lessons from them are hypotheses (grade C).
- **The buffer comparison is descriptive.** It compares four economies on three World Bank indicators. It does not control for trade structure, policy or exposure, and it does not establish causation.
- **Disaster mortality records are imperfect.** EM-DAT coverage improved over the century, early records are dominated by a few famine and drought events, and the 2020s figure covers only 2020 to 2025.
- **Price indices describe global averages.** They do not show the prices paid in any particular country, which depend on exchange rates, subsidies and trade barriers.

Glossary

Adaptive capacity	The ability of people, institutions and systems to adjust to changing conditions, take advantage of opportunities and cope with consequences.
Buffer	A reserve, stock, margin or spare capacity that lets a system absorb a shock without failing, such as foreign-exchange reserves, fiscal space or backup power.
Cascade	The propagation of failure or stress from one system to others through dependencies.
Common driver	A single stress that affects several systems at the same time (Lawrence et al., 2024).
Compound event	A combination of drivers or hazards that together produce a larger impact than any would alone (Zscheischler et al., 2018).
Essential function	A service that society cannot do without during a crisis. This report names eight: energy, water, food, health, finance, digital systems, transport and trade, and governance.
Exposure	The presence of people, assets and systems in places where they could be adversely affected by a hazard.
Graceful degradation	A controlled reduction of service in which less essential demands are shed so that essential ones survive.
Hazard	A potentially damaging physical event, trend or disturbance, such as a flood, heat wave or outage.
Keystone function	An essential function on which many others depend, so that its failure has outsized effects. In this report, energy and digital systems.
Maladaptation	Action intended to reduce vulnerability that increases it elsewhere or later.
Minimum service level	The least delivery of an essential function that must be maintained through a crisis.
Polycrisis	A condition in which crises in multiple systems become causally entangled in ways that worsen overall prospects.
Polycrisis Resilience	The capacity of individuals, communities, societies, economies, institutions and interconnected systems to withstand, adapt to, recover from and reduce vulnerability to multiple interacting and compounding crises (H Heuristics).
Single point of failure	A component, supplier, route or technology whose failure disables the function that depends on it.
Systemic risk	The risk that failure in one part of a connected system spreads to cause widespread failure.
Vulnerability	The propensity to be adversely affected, shaped by susceptibility to harm and lack of capacity to cope and adapt.
Weakest-link aggregation	A way of combining scores that penalizes low values, such as a geometric mean or a minimum.

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