MSc Program in Public Health	
Digital Health for Climate Resilience	
Module number	PH-5
Person responsible	Prof. Kenesh Dzhusupov
Duration of the module	1 semester
Semester	2
Frequency of the module	Every semester
ECTS-Credits (CP)	5 CP
Semester hours per week, number of weeks	3
Workload	150 h (5 CP * 30 h) Contact hours: 48 Self-study: 102
Type of module	Mandatory
Required prerequisites for the module	Environmental health, Informatics, Epidemiology
Recommended prior knowledge for the module	Basic understanding of environmental science, familiarity with digital technologies
Teaching language	English
Competencies gained / Learning outcome	Upon completion of this module the student is able to: – Analyze linkages between greenhouse gases (GHGs), climate change, and the global burden of disease (GBD). – Assess health impacts of climate-sensitive diseases and extreme weather using real-world data (WHO/IHME dashboards). – Apply digital tools (satellite data, AI, Purple Air Quality network, AQI) for environmental monitoring and health surveillance. – Design climate-resilient health strategies, including digital health systems and low-carbon healthcare operations. – Develop risk communication frameworks and policy solutions for climate-health management. – Critically reflect on equity, ethics, and local applicability of climate-health interventions.
Content of the module	The module's core themes are climate change, health systems, digital innovation, policy governance. They are given in the following units: 1. GHGs & GBD: – GHG sources, climate-health pathways, GBD data analysis. 2. Climate-sensitive diseases & extreme weather: – Heatwaves, floods, vector-borne diseases; adaptation strategies. 3. Environmental monitoring technologies: – Remote sensing, air/water quality data platforms (AQI, Copernicus, NASA). 4. Digital health for climate adaptation: – Telemedicine, early warning systems, mHealth in emergencies.

	5. Carbon footprint of healthcare: – GHG emissions in health systems, sustainable procurement, green action plans. 6. AI & Big Data for health surveillance: – Predictive modeling, ethical AI, Google Earth Engine applications. 7. Risk communication & community engagement: – Crisis messaging, misinformation management, inclusive communication tools. 8. Policy & Governance: – Climate-resilient health systems, SDGs/Paris Agreement, policy advocacy.
Applicability of the module	*MSc program in Public Health* *MSc program in Health Management* MBBS in General Medicine
Requirements for the award of credit points **(Study and exam requirements)**	*Group projects - 40%: GBD analysis (20%) + Green action plan (20%).* *Individual diaries* - 40%: 8 reflective entries (5% each), applying INSERT technique. *Participation* - 20%: workshops, quizzes, peer feedback, roleplay. *Bonus* – 5-10%: Policy briefs/ infographics *Total: 100%* *Criteria*: Critical analysis, tool proficiency, local context application, collaboration
Learning and teaching types	Learning and teaching type: *Teaching will have blended format:* – Asynchronous pre-session work: readings (WHO/IPCC reports), videos (WHO/UNEP tutorials), and data exploration to build foundational knowledge before live sessions – Synchronous in-person or online workshops: lectures (theory), hands-on labs, group work, simulations (2-3 hours/sesion). *Active learning type:* – *Group work:* Case analyses (Unit 1: GBD data analysis; Unit 2: Pakistan floods and disaster response; Unit 4: Smart hospitals in SIDS; Unit 5: Green action plans), Unit 8: Policy brief development (students must apply frameworks to their home countries). – *Digital tools:* Hands-on labs with IHME/OurWorldInData, AI mock-ups, carbon calculators. – *Data Labs:* Unit 3: NASA/Copernicus dashboards; Unit 5: Carbon audits; Unit 6: AI model prototyping. – *Simulations:* Roleplay (Unit 2: Heat wave response scenarios; Unit 7: Crisis communication, Unit 8: Policy roundtables). – *Design challenges:* Unit 2: Infographics; Unit 4: Digital health dashboards; Unit 6: AI surveillance concepts. – *Reflections: 1)* Structured diaries using the INSERT technique to connect global concepts to local contexts and personalize learning. 2) Peer feedback with critiques of group work, policy briefs, and communication materials. *Collaborative platforms:* Padlet/Jamboard, Moodle.
Literature (latest editions) and other instruction material	**Core Resources:** – WHO reports on Climate Change & Health, Digital Health: ▪ https://cdn.who.int/media/docs/default-source/environment-climate-change-and-health/58595-who-cop29-special-report_layout_9web.pdf?sfvrsn=dd2b816_8; ▪ https://www.who.int/teams/environment-climate-change-and-health/climate-change-and-health/evidence-monitoring/country-profiles; ▪ https://www.who.int/docs/default-source/documents/gs4dhdaa2a9f352b0445bafbc79ca799dce4d.pdf; ▪ https://www.who.int/health-topics/digital-health.

	– IPCC AR6 Health Chapter (https://www.ipcc.ch/report/ar6/wg2/); – Lancet Countdown reports (https://lancetcountdown.org/); – HCWH's *Health Care's Climate Footprint (*https://global.noharm.org/sites/default/files/documents-files/5961/HealthCaresClimateFootprint_092319.pdf*).* **Digital Tools:** – Data visualization platforms: IHME GBD Compare (https://vizhub.healthdata.org/gbd-foresight/), Copernicus CDS 9 https://cds.climate.copernicus.eu/), NASA EarthData (https://search.earthdata.nasa.gov/), Google EarthData (https://earth.google.com/web), Tableau/Flourish, Canva/Piktochart – Collaboration: Miro/Jamboard (for mapping), Padlet (for idea sharing), Moodle (quizzes, forums). – AI/ML: Google Earth Engine, Kaggle datasets. – Simulation: Carbon calculators (Unit 5), SMS alert systems (Unit 7). – **Multimedia real-world dataset:** WHO/PAHO videos, Copernicus tutorials, OurWorldInData trends. **Frameworks:** WHO RCCE Toolkit, Smart Hospitals Guidelines.

Unit 1: Greenhouse Gases and Global Burden of Disease

Session duration: 6 academic hours, including:

- Lecture: 2 h,
- Workshop: 3 h,
- Q&A: 1h

Learning objectives:

By the end of this unit, students will be able to:

- Identify the primary greenhouse gases (GHGs) and their sources, both human and natural.
- Explain the mechanisms by which GHGs contribute to climate change and global warming.
- Analyze how climate change impacts the global burden of disease (GBD), including heat-related mortality, vector-borne diseases, malnutrition, and respiratory conditions.
- Use open-access data (WHO, GBD/IHME, OurWorldInData) to visualize GHG-related health trends.
- Critically assess climate-health interlinkages and propose mitigation or adaptation strategies.

Session format: Blended (In-class + online pre-study)

Digital innovation focus: Students learn to use GBD/WHO dashboards and interpret real-world datasets

Inclusivity & sustainability focus

- Includes climate justice aspects (e.g., vulnerable populations in LMICs),
- Promotes digital literacy for sustainability reporting,
- Encourages students to connect global concepts to their local/national context.

Discussion questions:

1. Which greenhouse gases have the strongest impact on climate change, and why?
2. What are the health effects associated with increasing concentrations of GHGs?
3. How does air pollution differ from greenhouse gas emissions in terms of health outcomes?
4. How does the global burden of disease (GBD) reflect the impact of climate change?
5. What populations are most vulnerable to GHG-related health risks?

The instructor:

- Presents key concepts (GHGs, CO_2 equivalents, IPCC basics, climate-health pathways).
- Demonstrates use of the GBD visualization tool and CO_2 data dashboard.
- Guides interactive group work and facilitates discussions

Students:

- Participate in an interactive quiz (via Kahoot or Moodle) on GHG types and sources.
- Work in groups to analyze a GBD dataset by country/region (provided in Excel or the WHO dashboard).
- Reflect on climate-health vulnerability in a short diary entry using the INSERT technique.
- Contribute to a collaborative Padlet or Jamboard on climate-sensitive diseases.

Assignments

Before the session: 1) Read assigned literature (see below); 2) Watch introductory video “Climate Change and Health” (WHO, 2023, 10 min: https://www.youtube.com/watch?v=d0yjb3HuyQw)

During the session: 1) Take part in group GBD case analysis (1 page summary + visualization, https://vizhub.healthdata.org/gbd-foresight/); 2) Engage in data interpretation of trends from IHME or OurWorldInData.

After the session: 1) Submit diary #1: “How do GHGs affect health in my country or region?” (2 pages max, with 1 citation)

Quiz questions

1. Quantitative attribution of climate change to health burdens. A policy brief states that "climate change is a major health threat." Which methodological approach provides the most robust quantitative evidence for this claim in the context of the Global Burden of Disease (GBD)?
a) Cross-sectional surveys comparing health outcomes in different climate zones.
b) Time-series analysis of mortality during extreme weather events.
c) *Comparative Risk Assessment (CRA) frameworks that estimate the attributable burden of disease for climate change relative to a baseline*.
d) Case studies documenting the health impacts of single extreme weather events.
Explanation: CRA is the established GBD methodology for quantifying the burden attributable to specific risk factors like climate change. It models the difference between current health outcomes and those expected under a counterfactual (e.g., pre-industrial climate) scenario, offering a comprehensive estimate beyond single events.

2. Mechanistic pathways from GHGs to health outcomes. Rising concentrations of tropospheric ozone (O_3), a potent greenhouse gas, are directly linked to increased morbidity and mortality through which primary physiological mechanism?
a) *Exacerbation of chronic respiratory diseases like asthma and COPD via oxidative stress and airway inflammation*.
b) Expansion of the geographic range of vector-borne diseases.
c) Increased risk of waterborne diseases following extreme precipitation.
d) Heat stress and heat stroke during extreme heat events.
Explanation: While climate change influences many health pathways, this question specifies the direct effect of a GHG (O_3). Tropospheric ozone is a powerful respiratory irritant. Its formation is accelerated by higher temperatures, directly linking GHG emissions to worsened respiratory health.

3. Epidemiological transition and climate vulnerability. Climate change acts as a "threat multiplier." In a middle-income country undergoing rapid epidemiological transition, what is the most significant dual burden of disease exacerbated by climate change?
a) A simultaneous increase in both HIV/AIDS and malaria.
b) *The persistence of infectious diseases (e.g., diarrheal diseases) alongside a rising burden of non-communicable diseases (e.g., cardiovascular stress from heat)*.
c) The complete replacement of communicable diseases by injuries from extreme weather events.
d) A decline in all diseases due to improved adaptation measures.
Explanation: This question addresses the complexity of the health transition. Climate change does not create a single new burden but amplifies existing vulnerabilities. In transitional economies, it simultaneously undermines control of infectious diseases (like diarrhea or malaria, which are climate-sensitive) while adding new pressures from NCDs and direct heat impacts.

4. Vulnerable populations and environmental justice. According to the GBD framework and environmental health research, the health impacts of greenhouse gas emissions are disproportionately borne by specific populations. This disparity is primarily driven by:
a) Genetic predispositions in certain ethnic groups.
b) *Higher baseline exposure and pre-existing health conditions in low-income and minority communities*.
c) A lack of international climate treaties.
d) The higher global warming potential of methane from agriculture in developing nations.
Explanation: This question focuses on health equity. Research consistently shows that vulnerable populations (e.g., low-income, communities of color) are more likely to live in areas with higher

pollution exposure (e.g., near highways or industrial zones) and have less access to adaptive resources (e.g., air conditioning, quality healthcare), compounding their climate-related health risks.

5. Food systems, malnutrition, and GHGs. How does the emission of greenhouse gases from the global food system create a feedback loop that exacerbates the global burden of malnutrition?
a) By directly reducing the caloric content of staple crops.
b) By increasing the efficiency of agricultural production.
c) *Through disruptions to supply chains and reduced crop yields, leading to food insecurity and higher prices, which disproportionately affect low-income populations*.
d) By improving the nutritional quality of food through carbon fertilization.
Explanation: GHG-driven climate change (extreme weather, shifting growing seasons) directly threatens food security. This indirect pathway is a major contributor to the global burden of disease, as malnutrition (both undernutrition and micronutrient deficiencies) increases susceptibility to other illnesses.

6. The "One health" approach to climate-sensitive diseases. The emergence and re-emergence of vector-borne diseases like malaria, dengue, and Lyme disease are linked to climate change. From a "One Health" perspective, this relationship is best understood as a consequence of:
a) The direct mutation of viruses due to higher temperatures.
b) *The impact of climatic and ecological changes on the behavior and geographic range of vectors, pathogens, and host species*.
c) The increased use of insecticides.
d) A decline in human immunity.
Explanation: A One Health approach recognizes the interconnection between human, animal, and environmental health. Climate change alters ecosystems: warmer temperatures allow mosquitoes to survive at higher altitudes, and changes in precipitation affect their breeding grounds, directly influencing disease transmission dynamics.

7. Mitigation vs. adaptation in public health policy. Distinguish between climate change mitigation and adaptation in the context of public health. Which of the following represents a primary public health adaptation strategy?
a) Transitioning a hospital's energy supply to solar power.
b) *Implementing a city-wide heat emergency response plan with early warnings and cooling centers*.
c) Enacting stricter fuel efficiency standards for vehicles.
d) Reforestation projects to sequester carbon.
Explanation: Mitigation aims to reduce the causes of climate change (e.g., reducing GHG emissions, as in a, c, and d). Adaptation aims to reduce the impacts of climate change that is already happening. Public health adaptation involves preparing for and managing the health risks, such as heatwaves.

8. Mental health burden of climate change. Quantifying the global burden of disease related to mental health is complex. How does climate change contribute to this burden?
a) It has no direct impact on mental health.
b) It only affects people with pre-existing psychiatric conditions.
c) *Through direct trauma from extreme weather events, chronic stress from displacement and livelihood loss, and eco-anxiety related to existential threats*.
d) It exclusively causes seasonal affective disorder.
Explanation: This question highlights a growing area of the GBD. The mental health impacts of climate change are significant and occur through multiple pathways: acute trauma from disasters, chronic stress from long-term environmental degradation and displacement, and the psychological distress of anticipating future threats ("eco-anxiety").

9. Chronic vs. acute health impacts of air pollution from fossil fuels. Fossil fuel combustion is a major source of both GHGs and air pollutants. How do the health impacts of chronic exposure to fine particulate matter (PM2.5) differ from those of acute exposure?
a) They are identical.
b) *Chronic exposure is primarily linked to the development of cardiovascular and respiratory diseases over a lifetime, while acute exposure triggers immediate events like heart attacks and asthma exacerbations*.
c) Acute exposure is more dangerous than chronic exposure.
d) Chronic exposure only affects the elderly.
Explanation: This tests the understanding of exposure-response relationships. Acute toxicity refers to harm from a single, often high-dose exposure. Chronic toxicity, which contributes more significantly to

the GBD, results from repeated, long-term, low-dose exposures that lead to the gradual development of diseases like lung cancer, COPD, and ischemic heart disease.

10. The challenge of burden attribution in a complex system**.** Why is it methodologically challenging to precisely quantify the "additional" deaths directly caused by climate change within the GBD study?
a) Because there are too few deaths to measure.
b) *Because climate change rarely acts alone, it interacts with and exacerbates existing risk factors (e.g., poverty, malnutrition, baseline disease rates), making it difficult to isolate its unique contribution*.
c) Because all deaths are already counted in other categories.
d) Because climate models are unreliable.
Explanation: This question addresses a core scientific challenge. Climate change is a "risk multiplier." For example, a child dying from diarrhea during a flood in a region with poor sanitation dies from a disease with a long-standing burden, but the flood (made more likely by climate change) was the proximal trigger. Separating the climate-attributable fraction from the baseline burden is a complex epidemiological task.

Recommended reading & resources:

- WHO. (2023). Climate change and health: Key facts. https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health;
- IPCC AR6 Summary for Policymakers – Health Chapter (https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf),
- Prüss-Üstün, A., Corvalán, C. (2006). Preventing disease through healthy environments (https://apps.who.int/iris/bitstream/handle/10665/204585/9789241565196_eng.pdf),
- Max Roser & Hannah Ritchie. CO_2 and Greenhouse Gas Emissions. OurWorldInData.org (https://ourworldindata.org/co2-and-greenhouse-gas-emissions),
- IHME GBD Compare Tool: https://vizhub.healthdata.org/gbd-compare/,
- Copernicus Climate Change Service (https://climate.copernicus.eu/).

Evaluation criteria

Component	**Weight**
Participation in group discussion	10%
Group GBD analysis	20%
Diary #1 (INSERT reflection)	20%
Quiz (in-class or Moodle)	10%
Total:	60

Innovative/interactive tools

- Moodle LMS (assignments, quizzes)
- IHME GBD Visualization tool
- OurWorldInData CO_2 tracker
- Jamboard / Padlet for collaborative mapping
- Kahoot / Mentimeter for formative feedback

Unit 2: Climate-Sensitive Diseases and Extreme Weather Health Effects

Session duration: 6 academic hours, including:

- Lecture: 2 h,
- Workshop: 3 h,
- Reflection: 1h

Learning objectives:

By the end of this unit, students will be able to:

- Identify key diseases that are sensitive to climate factors such as temperature, rainfall, and humidity.
- Explain the direct and indirect health impacts of extreme weather events (heatwaves, floods, wildfires, storms).
- Analyze case studies of recent climate-related health crises (Dengue outbreaks, heatwave mortality, cholera after floods).
- Evaluate adaptation and early warning systems for climate-sensitive disease prevention.
- Apply knowledge to assess local vulnerabilities and resilience strategies.

Session format: Blended (In-class + online pre-study)

Focus: on real-time disaster response simulation and climate-adaptation strategy building.

Inclusivity & sustainability focus:

- Focus on climate justice, Indigenous populations, urban poor,
- Promotes communication tools for public awareness,
- Builds interdisciplinary teamwork and decision-making capacity.

Discussion questions:

1. What are examples of diseases directly influenced by temperature and precipitation?
2. How do extreme weather events cause both short- and long-term health consequences?
3. How do climate-sensitive diseases disproportionately affect vulnerable populations?
4. What are the most effective prevention and adaptation strategies for extreme heat and vector-borne diseases?
5. How can public health systems become more resilient to climate variability?

The instructor:

- Presents the WHO/CDC classification of climate-sensitive diseases and global data trends.
- Showcases case studies from recent climate disasters (2022 Europe heatwave, floods in Pakistan, wildfires in Canada).
- Leads a simulation exercise on designing a climate-adapted health alert system.

Students:

- Participate in a group mapping exercise on regional climate-health vulnerabilities.
- Analyze case studies and propose public health responses.
- Draft an infographic or factsheet on one climate-sensitive disease for public communication.
- Engage in peer review and feedback of proposed interventions.

Assignments

Before the session: 1) Read WHO: "Protecting health from climate change: A toolkit for adaptation", https://apps.who.int/iris/bitstream/handle/10665/104200/9789241564687_eng.pdf; 2) Watch short video: "Climate Change and Vector-Borne Diseases" (UNEP, 2022), https://www.youtube.com/watch?v=1uI0EjY38d8&pp=0gcJCfwAo7VqN5tD.

During the session: 1) Simulation: respond to an early warning alert for a climate-health emergency; 2) Group discussion and presentation: best practices in adaptation strategies.

After the session: 1) Submit Diary #2: "Local risks and adaptation strategies for climate-sensitive diseases in my region" (2 pages); 2) Optional: Share infographic on Moodle discussion board

Quiz questions

1. Defining climate-sensitive diseases. According to the latest scoping reviews on climate and health, which of the following best defines a "climate-sensitive disease"?
a) Any infectious disease that occurs in tropical regions
b) *Diseases whose transmission dynamics and geographic distribution are significantly influenced by climate factors such as temperature, precipitation, and humidity*
c) Only diseases that emerge during extreme weather events
d) Diseases that are exclusively vector-borne.
Explanation: Climate-sensitive diseases encompass a broad range of health conditions—including infectious diseases, respiratory and cardiovascular conditions, and mental health disorders—whose patterns are directly modulated by climatic variables. This definition extends beyond vector-borne diseases to include water-borne, food-borne, and non-communicable conditions affected by weather patterns.

2. Quantitative impacts of temperature on vector-borne diseases. A policymaker asks for evidence on how rising temperatures affect dengue fever transmission. Based on recent systematic review evidence, what is the most accurate quantitative estimate you can provide?
a) Dengue incidence decreases by 5% per 1°C rise
b) *Dengue incidence increases by 8–10% per 1°C rise*
c) Temperature has no measurable effect on dengue transmission
d) Dengue doubles with every 0.5°C rise.
Explanation: A comprehensive scoping review published in 2025 analyzing studies from 2000-2024 found that rising temperatures and variable rainfall patterns significantly increase the incidence of climate-sensitive infectious diseases. Specifically, malaria incidence can increase up to 50%, while dengue shows an 8–10% increase per 1°C rise in temperature.

3. Cardiovascular impacts of extreme heat. An increase in the number and intensity of extreme heat days has what documented effect on cardiovascular health?
a) No measurable effect on cardiovascular outcomes
b) *A direct impact on the number of deaths from cardiovascular disease*
c) Cardiovascular effects only occur in combination with air pollution
d) Only respiratory diseases are affected by heat.
Explanation: Research consistently demonstrates that extreme heat events directly contribute to increased cardiovascular mortality. Heat stress forces the cardiovascular system to work harder to maintain thermoregulation, which can precipitate heart attacks, strokes, and other acute cardiovascular events, particularly among vulnerable populations such as the elderly and those with pre-existing conditions.

4. Extreme weather events and respiratory disease burden. Following extreme weather events such as floods and hurricanes, what change in respiratory disease burden has been documented?
a) No change in respiratory disease incidence
b) *A 30% rise in respiratory diseases*
c) Respiratory diseases decrease due to improved air quality
d) Only asthma is affected, with no change in other respiratory conditions.
Explanation: Quantitative evidence from systematic reviews demonstrates that extreme weather events, including heatwaves and floods, contribute to a 30% rise in respiratory diseases. This occurs

through multiple mechanisms: flooding promotes mold growth, extreme heat increases ground-level ozone formation, and wildfires generate particulate matter that penetrates deep into lung tissue.

5. The concept of extreme weather-epidemic compound disasters (EWED). Recent scientific literature has introduced the concept of "Extreme Weather-Epidemic Compound Disasters" (EWED). What does this term specifically describe?
a) The simultaneous occurrence of two unrelated weather events
b) *Complex disaster systems where extreme weather events interact with infectious disease outbreaks, creating amplified health risks through non-linear effects*
c) The displacement of populations following weather disasters
d) Economic losses from weather events combined with healthcare costs.
Explanation: EWED represents an advanced conceptual framework recognizing that climate-related health threats are not simply additive but synergistic. When extreme weather events (floods, hurricanes, droughts) coincide with infectious disease transmission, they create cascading effects, flooding contaminates water sources, triggering water-borne diseases, while simultaneously destroying health infrastructure and displacing populations, which amplifies overall health impacts beyond what either stressor would cause alone.

6. Thunderstorm asthma: mechanisms and epidemiology. Following the 2016 Melbourne thunderstorm asthma event that overwhelmed emergency departments, what is the understood mechanism for this phenomenon?
a) Direct lightning strikes causing respiratory arrest
b) Cold air triggers bronchospasm in all exposed individuals
c) *Large pollen particles rupture due to moisture, releasing sub-particles small enough to penetrate deep airways and trigger acute asthma in susceptible individuals.*
d) Ozone formation during thunderstorms.
Explanation: Thunderstorm asthma represents a complex interaction between meteorological conditions and aeroallergens. During thunderstorms, pollen grains (typically too large to reach lower airways) absorb moisture and rupture, releasing hundreds of allergenic sub-particles that can penetrate deeply into lungs. This "pollen bomb" effect triggers acute, sometimes severe, asthma exacerbations in susceptible individuals, as dramatically demonstrated in the 2016 Melbourne event.

7. Geographic expansion of vector-borne diseases. Climate change is projected to alter the geographic distribution of vector-borne diseases. Which of the following outcomes is most consistent with current evidence?
a) Vector-borne diseases will disappear from equatorial regions
b) *Changes in climate will lengthen transmission seasons and expand geographic range, introducing diseases to regions where they have not previously occurred*
c) Vector-borne diseases will remain confined to their current geographic ranges
d) Only bacterial diseases will show geographic shifts.
Explanation: Warming temperatures and altered precipitation patterns allow disease vectors such as mosquitoes and ticks to survive at higher altitudes and latitudes where colder temperatures previously limited their distribution. This results in both extended transmission seasons within existing endemic areas and the introduction of diseases like dengue, chikungunya, and Lyme disease to previously unaffected regions. Europe, for example, now faces autochthonous dengue transmission due to established Aedes mosquito populations.

8. Health system disruption from extreme weather. Beyond direct health impacts, extreme weather events create indirect health burdens through which mechanism?
a) Only through economic losses
b) *Destruction of health facilities, disruption of supply chains for essential medicines, and displacement of populations, leading to treatment interruptions*
c) Temporary inconvenience to healthcare staff
d) Minimal impact on health systems in developed countries.
Explanation: The Global Fund's documentation of climate impacts highlights how floods can destroy health facilities and supplies, separating people from essential medicines needed to control chronic diseases like HIV, TB, and malaria. Extreme temperatures can compromise medication efficacy during storage and transport. Population displacement disrupts continuity of care, leading to increased disease transmission and potential drug resistance. These indirect pathways often cause greater long-term health burdens than the immediate injury toll.

9. Mental health effects of climate-related disasters. What mental health conditions are documented to increase following exposure to climate-related disasters?
a) Only mild anxiety without clinical significance
b) *PTSD, anxiety, and depression, with individuals exposed to climate-related disasters facing higher risks of all three conditions*
c) No mental health effects are documented
d) Only conditions requiring pre-existing psychiatric diagnoses.
Explanation: Systematic reviews of climate-sensitive health risks consistently identify mental health effects as a major category of climate-related morbidity. Exposure to climate-related disasters such as hurricanes, floods, and wildfires significantly increases risks of post-traumatic stress disorder (PTSD), anxiety disorders, and depression. These effects can persist long after the physical disaster has passed and affect both directly affected populations and those experiencing secondary stressors such as displacement or livelihood loss.

10. Vulnerable populations and differential impacts. According to research priorities identified by the National Academy of Medicine, which populations experience disproportionate health impacts from extreme weather events?
a) All populations are affected equally
b) Only elderly populations are affected
c) *Low-income communities, older adults, children, racial and ethnic minorities, and Indigenous populations experience disproportionate impacts*
d) Only populations in coastal areas.
Explanation: Research frameworks for climate and health emphasize that vulnerability to extreme weather events is not uniformly distributed. Low-income communities often reside in areas with poorer infrastructure and less access to cooling or healthcare. Older adults have reduced physiological capacity to thermoregulate. Children are more susceptible to dehydration and certain pollutants. Racial and ethnic minorities and Indigenous populations face historical inequities in housing, healthcare access, and political representation that compound climate vulnerability. Understanding these differential impacts is essential for equitable adaptation planning.

11. The attribution challenge in climate-health research. Why is it methodologically challenging to precisely attribute specific disease outbreaks to climate change rather than natural climate variability?
a) Climate data is unavailable for most regions
b) Diseases never follow predictable patterns
c) *Climate change interacts with numerous confounding factors, including land use change, population movement, infrastructure quality, and baseline health status, making it difficult to isolate the climate contribution*
d) There is no scientific consensus on climate change attribution.
Explanation: This question addresses a core scientific challenge in climate epidemiology. While climate change creates conditions favorable for disease transmission, outbreaks are rarely caused by climate alone. Deforestation brings humans into contact with novel vectors, urbanization creates breeding habitats, population movement introduces pathogens to naive populations, and health system strength determines outbreak severity. Sophisticated modeling approaches are needed to disentangle the climate-attributable fraction from these interacting determinants.

Recommended reading & resources:

- WHO. (2021). Climate change and health: Overview and toolkit. https://www.who.int/teams/environment-climate-change-and-health/climate-change-and-health/capacity-building/toolkit-on-climate-change-and-health;
- IPCC AR6: Chapter on Health and Extreme Events,
- The Lancet Countdown on Health and Climate Change https://lancetcountdown.org/2024-report/;
- UNEP. Frontiers 2025. The Weight of Time (Climate-sensitive diseases and public health) https://www.unep.org/resources/frontiers-2025-weight-time;
- CDC: Climate Effects on Health – https://www.cdc.gov/climate-health/php/effects/index.html;
- OurWorldInData: Climate and Health interactive charts - https://ourworldindata.org/climate-change;
- WHO Heat-Health Action Plans - https://www.who.int/publications/i/item/9789289071918;

- Martinez GS, Kendrovski V, Salazar MA, de'Donato F, Boeckmann M. Heat-health action planning in the WHO European Region: Status and policy implications. *Environ Res*. 2022;214(Pt 1):113709. doi:10.1016/j.envres.2022.113709

Evaluation criteria:

Component	**Weight**
Group simulation & mapping presentation	15%
Diary #2 (INSERT reflection)	20%
Infographic or case summary	15%
Participation in workshop discussion	10%
Total:	60

Innovative/interactive tools:

- Climate Data Explorer (NASA or Copernicus)
- WHO Climate-Health Country Profiles
- Jamboard / Miro for mapping
- Moodle discussion forums
- Canva / Piktochart for infographics

Unit 3: Environmental Monitoring Technologies and Digital Tools

Session duration: 6 academic hours, including:

- Lecture: 2 h,
- Practical workshop: 3 h,
- Q&A: 1h

Learning objectives

By the end of this unit, students will be able to:

- Identify key technologies used in environmental monitoring (e.g., satellite imaging, remote sensors, IoT).
- Describe how digital tools support data collection, analysis, and visualization for environmental health.
- Access and interpret open datasets related to air quality, water safety, and climate indicators.
- Evaluate strengths and limitations of digital monitoring for health risk assessments.
- Apply digital platforms in designing a basic environmental health alert system.

Hybrid session format: self-paced digital prep + instructor-led in-person workshop

Focus: experiential data exploration and low-code digital visualization tools

Inclusivity & sustainability focus:

- Builds digital literacy and open-data fluency.
- Highlights technology accessibility gaps between regions.
- Encourages practical application for local policymaking and action.

Discussion questions:

1. What are the most important environmental parameters to monitor for public health?
2. How reliable and accessible are open-source climate and health data?
3. What is the role of satellite imagery in early warning systems?
4. How do IoT and mobile sensors contribute to real-time environmental health data?
5. What are ethical/privacy concerns in environmental data tracking?

The instructor:

- Demonstrates live examples using Copernicus, NASA EarthData, and AQICN air quality platforms.
- Explains data lifecycle: from sensors to public health dashboards.
- Guides practical exercise on mapping pollution trends using WHO/OurWorldInData.

Students:

- Conduct data queries on 2 different platforms (e.g., satellite + ground station data).
- Participate in group work: design a basic “Digital Health Dashboard” mock-up.
- Present dashboard prototype and justify the indicators chosen.
- Share and critique visualizations and interpretations from peers.

Assignments

Before the session: 1) Watch short tutorial: “Using Copernicus Climate Data Store” (ECMWF, 2023) - https://ecmwf-projects.github.io/copernicus-training-c3s/reanalysis-temp-record.html; 2) Review WHO Air Quality Database Overview - https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database/2022#:~:text=The%20WHO%20air%20quality%20database,a%20whole%2C%20rather%20than%20for.

During the session: 1) Complete hands-on exercise (data extraction, visualization); 2) Group task: build a mock-up of the Environmental Health Dashboard.

After the session: 1) Submit Diary #3: “How digital technologies enhance (or limit) environmental health action in my country” 2) Optional: Upload dashboard visuals to Moodle

Quiz questions

1. Core principles of IoT in Environmental Health. The Internet of Things (IoT) is increasingly deployed for environmental monitoring. Which of the following best describes the fundamental value proposition of IoT-based sensor networks compared to traditional monitoring approaches?
a) They completely eliminate the need for data quality assurance protocols.
b) They provide a one-time, high-precision snapshot of environmental conditions at a single point.
c) *They enable real-time, continuous data collection from distributed locations, revealing dynamic patterns and allowing for rapid response systems*.
d) They are exclusively used for outdoor air quality monitoring and cannot be applied to indoor settings.
Explanation: The core advantage of IoT is its ability to create a dense network of connected sensors that transmit data continuously. This allows researchers and public health officials to move beyond sparse, intermittent data and capture the true spatiotemporal variability of exposures (e.g., pollution hot spots, noise fluctuations) and to trigger real-time alerts (e.g., during a heatwave or a chemical leak).

2. Remote sensing for exposure assessment. A research team wants to estimate population-level exposure to PM2.5 in a large region of Sub-Saharan Africa with very few ground-based monitoring stations. Which of the following environmental monitoring technologies is most suitable for this task?
a) Deploying a network of low-cost sensors in the capital city only.
b) *Using satellite-based remote sensing data (e.g., aerosol optical depth) combined with modeling*.
c) Conducting a one-time mobile monitoring campaign with a single vehicle.
d) Relying solely on self-reported exposure from study participants.
Explanation: Satellite remote sensing provides a synoptic view and can estimate pollutant concentrations over vast, data-sparse regions. Algorithms convert satellite observations (like Aerosol Optical Depth) into surface-level PM2.5 estimates. This approach is a cornerstone of global exposure assessment for the Global Burden of Disease, especially where ground monitors are absent. Low-cost sensors (a) and mobile monitoring (c) are valuable but cannot provide the same regional coverage. Self-reporting (d) is highly subjective and unreliable for quantitative exposure assessment.

3. Calibration and validity of low-cost sensors. A community group wants to use low-cost particulate matter sensors to monitor air quality near a local industrial site. As an environmental health expert, what is the most critical limitation you would advise them to address?
a) These sensors are too expensive for community use.
b) *They require constant, expert-led calibration against reference-grade monitors to correct for environmental influences (humidity, temperature) and sensor drift, otherwise the data may be unreliable*.
c) They cannot measure any pollutants other than PM2.5.
d) They are illegal to use without a government permit.
Explanation: While low-cost sensors have democratized data collection, their accuracy is a major concern. They are susceptible to environmental factors, and their readings can drift over time. Robust field calibration against more accurate reference monitors is essential to ensure the data is scientifically valid and can be used for health studies or advocacy. Without it, the data can be misleading.

4. GIS and spatial analysis in disease mapping. A health department is investigating a cluster of pediatric leukemia cases. They are using Geographic Information Systems (GIS) to analyze potential

environmental risk factors. Which spatial analysis technique would be most appropriate to determine if the observed cases are closer to a point source of pollution (e.g., an industrial facility) than would be expected by chance?
a) Simple buffer analysis.
b) Proximity analysis using average distance to the facility.
c) *A spatial cluster detection method, such as Ripley's K-function or Kulldorff's spatial scan statistic*.
d) Creating a map with pins for each case and the facility.
Explanation: Simple mapping (d) and basic proximity analysis (a, b) are descriptive and can be misleading due to the underlying population distribution. Spatial cluster detection methods are statistical tests that account for the population at risk to determine if a clustering of cases around a point source is statistically significant, not just a visual artifact.

5. Mobile health (mHealth) for personal exposure monitoring. A study aims to link real-time environmental exposures to acute physiological responses (e.g., asthma symptoms, cardiac arrhythmias) in individuals. Which combination of digital tools would be most effective for this purpose?
a) A traditional paper diary and a stationary outdoor air quality monitor.
b) A GPS tracker and a retrospective questionnaire administered at the end of the study.
c) *A wearable sensor (e.g., smartwatch with heart rate monitor) paired with a personal, portable air pollution monitor and a mobile app for symptom logging*.
d) Satellite imagery of the city where participants live.
Explanation: This approach enables "personal exposure monitoring." It captures the dynamic interplay between where a person goes, what they are exposed to at that moment (using a personal monitor), and their immediate physiological response (using a wearable). This high-resolution data is far superior for causal inference than using static monitors or retrospective recall.

6. Machine Learning for Environmental Health Prediction. A researcher wants to develop a high-resolution model to predict daily noise levels across an entire city. They have data from a limited number of noise monitors, plus data on road networks, traffic patterns, building density, and land use. Which digital tool is best suited to integrate these diverse datasets and generate predictions for unsampled locations?
a) A simple linear regression model using distance to the nearest road as the only predictor.
b) *A machine learning algorithm, such as a random forest or gradient boosting model*.
c) A manual interpolation method drawing lines between monitoring points on a map.
d) A qualitative assessment by an urban planner.
Explanation: Machine learning (ML) models excel at finding complex, non-linear relationships between a target variable (noise) and multiple predictor variables (land use, traffic, etc.). They can be trained on the available monitor data and then used to predict noise levels across the entire city, creating high-resolution exposure maps ("land use regression" models) much more accurately than simple interpolation or single-variable models.

7. Digital tools for climate and health adaptation. A city is developing a heat action plan. Which digital tool would be most effective for identifying neighborhoods most vulnerable to extreme heat and targeting interventions like cooling centers?
a) A city-wide average temperature map.
b) *A geospatial vulnerability assessment map that integrates land surface temperature (from satellites), tree canopy cover, building age, and demographic data (e.g., percentage of elderly, low-income residents)*.
c) A list of all addresses in the city.
d) A social media sentiment analysis of the term "hot."
Explanation: Vulnerability is a function of both exposure (e.g., heat) and adaptive capacity (e.g., ability to afford AC, access to green space). By layering environmental data (exposure) with demographic and infrastructure data (sensitivity and adaptive capacity) in a GIS, public health officials can create a powerful tool to pinpoint the most at-risk communities and allocate resources equitably.

8. Citizen science and data quality. A state environmental agency is skeptical of air quality data collected by a community group using low-cost sensors. What is the most scientifically sound way for the agency to evaluate and potentially integrate this data into their official monitoring framework?
a) Dismiss the data entirely because it wasn't collected by the agency.
b) *Conduct a formal data quality assessment, including co-location studies where the community sensors are placed next to the agency's reference monitors for a period to compare measurements*.
c) Ask the community group to submit a report on their methods.

d) Use the data only from days when the pollution was very high.
Explanation: The rise of citizen science requires new frameworks for data integration. Co-location is a standard method for sensor calibration and validation. By running a formal comparison, the agency can quantify the bias and uncertainty in the community data. This allows them to either correct the data, use it with known confidence intervals, or identify specific conditions under which the data is reliable, thereby bridging the gap between community-generated and official data.

9. Unmanned aerial vehicles (UAVs/drones) in Environmental Health. A research team needs to map the spatial distribution of mosquito breeding habitats in a remote, swampy area to model disease risk. Which environmental monitoring technology offers the most practical combination of high-resolution imagery and accessibility for this task?
a) A manned aircraft.
b) A satellite with moderate-resolution imagery (e.g., Landsat).
c) *An unmanned aerial vehicle (UAV/drone) equipped with a multispectral camera*.
d) Ground-based visual inspection by a team of entomologists.
Explanation: Drones fill a critical niche between ground surveys (slow, dangerous in swamps) and satellites/satellites/aircraft (may lack resolution or be inaccessible on demand). They can be deployed quickly to fly below cloud cover and capture very high-resolution multispectral imagery that can be used to identify water bodies and vegetation signatures associated with mosquito breeding, even in difficult terrain.

10. The challenge of data integration. A major hurdle in using digital tools for environmental health is the "siloing" of data. What does this term refer to in this context?
a) The physical storage of data on isolated hard drives.
b) The practice of encrypting all health data for privacy.
c) *The existence of environmental, meteorological, health outcome, and demographic data in separate, often incompatible formats, managed by different agencies, making integrated analysis difficult*.
d) The tendency for sensors to stop transmitting data in remote areas.
Explanation: Data integration is a major technical and bureaucratic challenge. To understand the full picture of an environmental health issue, you need to link pollution data, weather data, hospital admission records, and census data. These are often held by different entities (environmental agencies, weather services, health ministries), use different identifiers, and have different spatial and temporal resolutions. Overcoming these "silos" is a critical step in harnessing the power of digital tools.

Recommended reading & resources:

- WHO Air Quality Guidelines, 2021 - https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines;
- Copernicus Climate Data Store: https://climate.copernicus.eu/climate-data-store;
- NASA EarthData: https://search.earthdata.nasa.gov/
- AQICN Real-time Air Quality Index - https://aqicn.org/map/world/
- WHO: “Digital Technologies and Health” Technical Brief, 2022: https://www.who.int/teams/health-product-and-policy-standards/assistive-and-medical-technology/digital-health-and-innovation---global;
- UNEP: Digital Transformations: https://www.unep.org/topics/digital-transformations;
- OurWorldInData.org: Environment section: https://ourworldindata.org/;

Evaluation criteria:

Component	Weight
Group dashboard design and presentation	20%
Diary #3 (INSERT reflection)	20%
Data interpretation (in class)	10%
Peer feedback participation	10%
Total:	60

Innovative/interactive tools:

- Copernicus CDS Viewer
- NASA Worldview
- OurWorldInData: Map Explorer
- WHO Climate & Health Country Profiles
- Excel, Tableau Public, or Flourish for visual dashboards

Unit 4: Digital Health Systems for Climate Adaptation

Session duration: 6 academic hours, including:

- Lecture: 2 h,
- Case-based workshop: 3 h,
- Q&A: 1h.

Learning objectives:

By the end of this unit, students will be able to:

- Explain the concept of digital health and its components (eHealth, mHealth, telemedicine, health informatics).
- Analyze how digital health systems contribute to climate resilience in health services.
- Evaluate the use of early warning systems, telehealth, and mobile health (mHealth) tools in climate-exposed regions.
- Explore the challenges of implementing digital health tools in low-resource settings.
- Propose climate-smart strategies using digital solutions in public health.

Case-based hybrid learning format: asynchronous case review + interactive group challenge.

Inclusivity & sustainability focus:

- Focus on digital equity and climate justice in digital access.
- Encourages localized solutions tailored to vulnerable groups.
- Strengthens students' policy communication and innovation skills.

Discussion questions:

1. How can telemedicine help reduce climate-sensitive exposure for vulnerable populations?
2. What are examples of successful digital health interventions in response to climate stressors?
3. What is the role of national health information systems in climate adaptation?
4. What barriers (technical, ethical, financial) exist for implementing digital tools in fragile health systems?
5. How can digital health reduce the carbon footprint of traditional healthcare systems?

The instructor:

- Presents examples of digital health systems in climate emergencies (mobile alerts for heatwaves, dengue reporting apps, remote triage).
- Guides case study analysis: WHO Smart Hospitals in Small Island Developing States.
- Leads group brainstorming on climate-smart digital innovations.

Students:

- Case study review and group presentation of lessons learned.
- Small group design challenge: “Create a Digital Health Response Plan for a Flood-Affected Community”
- Draft a one-page policy brief recommending a national strategy on digital health and climate adaptation.

Assignments

Before the session: 1) Read: a) Iyamu I, Gómez-Ramírez O, Xu AX, et al. Challenges in the development of digital public health interventions and mapped solutions: Findings from a scoping review. *Digit Health*. 2022;8:20552076221102255. Published 2022 May 26.

doi:10.1177/20552076221102255; b) Cummins N, Schuller BW. Five Crucial Challenges in Digital Health. *Front Digit Health*. 2020;2:536203. Published 2020 Dec 8. doi:10.3389/fdgth.2020.536203; 2) Watch: “Smart Hospitals” https://www.youtube.com/playlist?list=PL6hS8Moik7kt1EidZqxuvfgb6zylP9zLp (PAHO/WHO video, 5 min).

During the session: 1) Analyze digital climate-health response case (Bangladesh flood early warning, mHero Ebola response tool); 2) Collaborate on a Digital Health Response Plan

After the session: 1) Submit Diary #4: “Digital health for climate adaptation: risks and opportunities in my country”; 2) Submit policy brief (optional bonus +5 pts to final course grade)

Quiz questions

1. Defining digital health systems in the climate context. How should "digital health systems for climate adaptation" be most comprehensively defined?
a) The use of electronic health records to track climate-sensitive diseases in a single hospital
b) *A suite of interconnected digital technologies—including surveillance platforms, early warning systems, telemedicine, and data integration tools—deployed to anticipate, respond to, and build resilience against climate-related health threats at population and health system levels*
c) Mobile phone applications that provide weather forecasts to individual users
d) The digitalization of hospital administration to reduce paper waste.
Explanation: Digital health systems for climate adaptation encompass a broad ecosystem of tools working in concert. As outlined in recent frameworks, these include disease surveillance systems enhanced with climatic data, early warning mechanisms for extreme weather events, remote care delivery platforms that maintain service continuity during disruptions, and data integration architectures that enable predictive analytics. The definition emphasizes system-level functionality rather than isolated applications.

2. The DHIS2 climate app: addressing a fundamental barrier. The DHIS2 Climate App was developed by the HISP Centre at the University of Oslo. What specific barrier to climate-health analysis in low- and middle-income countries (LMICs) was it to address?
a) The high cost of purchasing climate data from meteorological agencies
b) The lack of trained healthcare workers to interpret climate information
c) *The difficulty in harmonizing disparate climate and health datasets that differ in spatial resolution, temporal scale, and geographic format*
d) The absence of any digital health infrastructure in most LMICs.
Explanation: A key lesson from early pilots, such as the 2017 Grenada project, revealed that while health data were registered by facilities, climate data (rainfall, temperature) were collected based on geographical points (villages, catchments). Harmonizing these datasets was a major technical hurdle. The Climate App solves this by using gridded datasets (e.g., ERA5-Land) that can be aggregated to any health region, automatically integrating them with DHIS2's existing health data structure.

3. Data sources for integrated climate-health surveillance. A Ministry of Health in a low-income country wants to integrate climate data into its national DHIS2 system, but has sparse, largely analog local weather stations. According to implementation experience from Uganda and other countries, what is the most practical initial approach?
a) Wait until the national meteorological agency digitizes all historical records
b) *Begin by making global gridded climate datasets (e.g., ERA5-Land, CHIRPS) available through a tool like the DHIS2 Climate App while simultaneously working on data-sharing agreements with the meteorological office*
c) Deploy hundreds of new automated weather stations before starting any analysis
d) Rely solely on qualitative community reports of weather patterns.
Explanation: This dual-track approach addresses immediate needs while building long-term capacity. Global products fill gaps where local data is missing and allow for immediate analytical work. In Uganda, this approach generated stakeholder engagement and demonstrated value, which in turn facilitated negotiations for data-sharing agreements between health and meteorological ministries. Global and local data are complementary, not mutually exclusive.

4. Malaria suitability mapping: translating climate data into action. In Uganda, the DHIS2 Climate App was used to develop a malaria suitability and risk mapping tool. What specific climate and

environmental variables are integrated to produce this indicator, and what was a key user-driven enhancement to the model?
a) Only temperature and rainfall; users requested no changes
b) *Precipitation, temperature, and relative humidity; users requested the addition of vegetation data (NDVI) to more accurately determine mosquito breeding habitat suitability*
c) Only historical malaria case data; users requested population density data
d) Ocean surface temperature and wind patterns; users requested altitude data.
Explanation: The initial model used standard climatic drivers of malaria transmission. However, during stakeholder engagement, the Uganda national malaria program noted that vegetation was essential for identifying actual mosquito breeding sites. This led to the integration of the Normalized Difference Vegetation Index (NDVI) into the app, demonstrating how iterative, user-centered design improves the utility of digital health tools for climate adaptation.

5. The dual role of digital health: mitigation and adaptation. Digital health technologies play a dual role in the climate-health nexus. Which of the following options correctly distinguishes between climate change *mitigation* and climate change *adaptation* in the context of digital health?
a) Mitigation: Using AI to predict malaria outbreaks; Adaptation: Reducing hospital energy consumption
b) *Mitigation: Reducing the carbon footprint of healthcare (e.g., via telemedicine); Adaptation: Strengthening health systems to manage climate-sensitive diseases (e.g., via integrated surveillance)*
c) Mitigation: Building cooling centers; Adaptation: Developing early warning apps for heatwaves
d) Mitigation: Disposing of e-waste safely; Adaptation: Manufacturing more wearable sensors.
Explanation: Mitigation addresses the causes of climate change by reducing GHG emissions. Digital health contributes through telemedicine (reducing travel), paperless records, and optimized energy use in facilities. Adaptation addresses the impacts of climate change. Digital systems for disease surveillance, early warning, and climate-informed health planning help populations and systems cope with the health effects that are already occurring.

6. Early warning systems for climate-sensitive health risks. The ISMED-CLIM project in the Mediterranean and the DHIS2 Climate & Health project in Africa/Asia both utilize digital tools for early warning. What is a key common element in the design of effective early warning systems for climate-sensitive health risks?
a) They rely exclusively on historical health data without climate inputs
b) *They are developed through participatory processes involving collaboration between health ministries, meteorological agencies, and local stakeholders to ensure tools meet local needs*
c) They are proprietary systems that cannot be modified by countries
d) They focus only on heat-related illness, excluding vector-borne diseases.
Explanation: Success factors documented across multiple projects emphasize that early warning systems must be grounded in national and local needs, aligned with existing policies, and co-designed with health and environmental stakeholders. The ISMED-CLIM project uses "Living Labs" for real-world testing, while the DHIS2 approach relies on direct collaboration between HISP groups, health programs, and meteorological offices.

7. The environmental paradox of digital health. A major scoping review on digital health and Planetary Health identified a fundamental paradox in deploying digital solutions for climate adaptation. What is this paradox?
a) Digital health tools are too expensive for low-income countries to afford
b) *While digital health can reduce healthcare's carbon footprint (e.g., through telemedicine), the digital infrastructure itself has significant environmental costs, including energy consumption, resource extraction for hardware, and electronic waste*
c) Patients prefer in-person visits despite the environmental benefits of telemedicine
d) Digital tools are effective for infectious diseases but not for NCDs.
Explanation: This is a critical tension. Digital health technologies offer substantial mitigation and adaptation benefits, but they are not environmentally neutral. Data centers consume large amounts of energy (and water for cooling), hardware manufacturing requires mining rare earth metals, and e-waste is the fastest-growing waste stream globally. Sustainable digital health requires life-cycle assessments and energy-efficient design.

8. Digital public infrastructure (DPI) for climate-resilient health. The concept of "Digital Public Infrastructure" (DPI) for climate-resilient health systems, as advanced by PATH and partners, refers to:
a) Building physical roads and railways to connect communities to hospitals

b) *A set of interoperable digital systems and foundational building blocks that enable the effective delivery of services, connecting people, information, and systems (like digital identity and data exchange platforms) to support climate adaptation*
c) A single software application that solves all climate-health problems
d) The privatization of all health data to encourage innovation.
Explanation: DPI is the foundational layer that allows different digital tools and datasets to work together. Just as physical infrastructure (roads, railways) enables commerce, DPI (interoperable platforms, data standards, digital identity) enables integrated climate-health action. It allows for the combination of weather forecasts, satellite imagery, disease surveillance, and community health data into predictive analytics and early warning systems.

9. Global goods for climate and health. The "Global Goods Guidebook Climate Services for Health Annex" identifies open-source digital tools that are adaptable across countries. Which of the following is a key characteristic of a "global good" in this context?
a) It is proprietary software owned by a single corporation
b) *It is an open-source tool that is mature, adaptable to different country contexts, and aligns with health and climate data standards to support climate-resilient health systems*
c) It is a hardware device that must be purchased from a specific vendor
d) It is a research paper published in a peer-reviewed journal.
Explanation: Global goods are digital health tools designed to be freely available, adaptable, and interoperable. Examples newly approved for climate and health include the DHIS2 Climate App (for data integration), EWARS-csd (for early warning of disease outbreaks), and GeoPrism Registry (for geospatial data linking). They are intended to be used and adapted by multiple countries rather than built from scratch each time.

10. Research gaps in digital health for climate adaptation. A systematic review of policy-driven digital health interventions published in 2025 identified a major gap in the evidence base. What was this gap?
a) There are no studies showing any health benefits of digital health
b) *Most studies focus solely on health impacts, while environmental sustainability metrics are rarely included, and only 12% of studies evaluated the full life-cycle impact of digital technologies*
c) There are too many studies and no need for further research
d) Digital health only works in high-income countries.
Explanation: The review found that 71% of studies focused exclusively on health impacts (e.g., improved access, disease management), while only a small fraction assessed environmental outcomes like reduced emissions or energy savings. Furthermore, life-cycle assessments that account for the full environmental cost of digital tools (manufacturing, energy use, disposal) are rare. This represents a critical evidence gap for truly sustainable digital health.

Recommended reading & resources:

1. Iyamu I, Gómez-Ramírez O, Xu AX, et al. Challenges in the development of digital public health interventions and mapped solutions: Findings from a scoping review. *Digit Health*. 2022;8:20552076221102255. Published 2022 May 26. doi:10.1177/20552076221102255;
2. Cummins N, Schuller BW. Five Crucial Challenges in Digital Health. *Front Digit Health*. 2020;2:536203. Published 2020 Dec 8. doi:10.3389/fdgth.2020.536203;
3. Smart Hospitals video https://www.youtube.com/playlist?list=PL6hS8Moik7kt1EidZqxuvfgb6zylP9zLp
4. WHO. (2021). Smart Hospitals Toolkit. https://www.who.int/publications/m/item/smart-hospitals-toolkit
5. UNEP. (2022). Digital Transformations for Climate Action: https://www.unep.org/topics/digital-transformations
6. GSMA. mHealth and Mobile for Development Reports: http://draft-content.gsmaintelligence.com/AR/assets/8784352/Role%20of%20VAS%20Vendors%20in%20M4D%20FINAL%20web.pdf
7. The Lancet Digital Health journal (selected articles): https://www.thelancet.com/journals/landig/home
8. Digital Health Atlas: https://dha.akuko.io/

Evaluation criteria:

Component	Weight
Case study group presentation	15%
Diary #4 (INSERT reflection)	20%
Climate Response Plan prototype (group work)	15%
Participation in workshop	10%
Optional: Policy brief (Bonus)	5%
Total:	60

Innovative/interactive tools:

- WHO Smart Hospital Case Bank
- Digital Health Atlas (by WHO)
- Miro Board for collaborative design
- Heat Alert SMS templates
- Google Docs for shared policy brief development

Unit 5: Carbon Health Footprint of Healthcare Systems

Session duration: 6 academic hours, including:

- Lecture: 2 h,
- Group workshop: 3 h,
- Reflection / Q&A: 1h.

Learning objectives:

By the end of this unit, students will be able to:

- Define the concept of carbon footprint in the context of healthcare systems.
- Identify the main sources of GHG emissions in hospitals, supply chains, pharmaceuticals, and waste.
- Evaluate strategies for greening healthcare operations, logistics, and procurement.
- Analyze international tools and benchmarks for tracking carbon emissions in health.
- Propose local or institutional interventions for reducing healthcare's environmental impact.

Session format: Workshop-based simulation and decision-making session focused on operational strategy and sustainability metrics

Inclusivity & sustainability focus:

- Encourages systems thinking in green innovation,
- Focus on public vs. private health sector capacity,
- Teaches practical skills for environmental impact measurement and climate-smart operations.

Discussion questions:

1. What are the key contributors to carbon emissions in healthcare systems?
2. How does energy use in hospitals compare to emissions from pharmaceuticals and transport?
3. What are the best practices in sustainable procurement in the health sector?
4. Can a hospital be both technologically advanced and climate neutral?
5. What barriers exist for implementing low-carbon initiatives in healthcare?

The instructor:

- Presents data and visualizations from Health Care Without Harm and NHS England.
- Guides walk-through of a carbon calculator for hospitals.
- Facilitates debate on trade-offs in low-emission health services.

Students:

- Calculate and interpret the carbon footprint of selected hospital activities.
- Group project: develop a "Green Action Plan" for a public hospital.
- Peer-review sustainability strategies proposed by other groups.
- Participate in roleplay: hospital administrator defending carbon reduction investments.

Assignments:

Before the session: 1) Read: "Health Care's Climate Footprint" (HCWH, 2019) – Executive Summary; 2) Watch: NHS Greener NHS Case Study video (https://www.youtube.com/playlist?list=PL6IQwMACXkj0uTw3zFxz3XAiJjBYK_F3t)

During the session: 1) Complete carbon audit exercise in groups; 2) Present a mini Green Action Plan.

After the session: 1) Submit Diary #5: “Reducing emissions in the health sector: My vision for our local system” (2 pages); 2) Optional: Upload Action Plan presentation to Moodle.

Quiz questions

1. Healthcare's global climate contribution. If the global healthcare sector were a country, how would it rank in terms of greenhouse gas emissions, and what is its approximate percentage contribution to global net emissions?
a) It would rank 10th, contributing approximately 1.5% of global emissions.
b) *It would rank 5th, contributing approximately 4.4% of global emissions*.
c) It would rank 1st, contributing approximately 15% of global emissions.
d) It would not rank significantly, contributing less than 1% of global emissions.
Explanation: Multiple authoritative sources, including Health Care Without Harm and The Lancet Countdown, have consistently estimated that the global healthcare sector accounts for approximately 4.4% of net global greenhouse gas emissions. If aggregated as a single entity, this would make healthcare the fifth-largest emitter on the planet, ahead of entire countries like Brazil or Germany in terms of national emissions.

2. Understanding scope classifications in healthcare carbon accounting. According to the Greenhouse Gas Protocol and Health Care Without Harm's classification system, which of the following correctly categorizes the three emission scopes for a hospital?
a) Scope 1: Patient travel; Scope 2: Pharmaceutical production; Scope 3: Hospital electricity
b) *Scope 1: Direct emissions from hospital operations (anaesthetic gases, on-site fuel combustion); Scope 2: Indirect emissions from purchased electricity, steam, and heating; Scope 3: Supply chain emissions including production and transport of goods and waste disposal*
c) Scope 1: Building construction; Scope 2: Medical equipment manufacturing; Scope 3: Staff commuting
d) Scope 1: Waste incineration; Scope 2: Refrigerant leaks; Scope 3: On-site renewable energy.
*Explanation:*vThe Scope framework is fundamental to carbon accounting in healthcare. Scope 1 covers direct emissions from sources owned or controlled by the healthcare facility, including anaesthetic gases and on-site fuel combustion (approximately 17% of healthcare emissions). Scope 2 covers indirect emissions from purchased energy (approximately 12%). Scope 3, the largest category, includes the full supply chain—production, distribution, and disposal of pharmaceuticals, medical devices, and other purchased goods.

3. The challenge of scope 3 emissions in pharmaceutical carbon footprinting. A recent systematic review of carbon footprint studies for medical devices and pharmaceuticals published in ScienceDirect revealed a significant methodological gap. What was the primary finding regarding the quality of pharmaceutical carbon footprint studies?
a) Pharmaceutical studies consistently achieve higher methodological quality than medical device studies.
b) *Only 29% of drug studies considered a full "cradle-to-grave" life cycle perimeter, and only 11% included end-of-life waste treatment, largely due to industrial secrecy limiting access to emission factors*.
c) Over 90% of pharmaceutical studies included comprehensive supply chain data due to mandatory industry reporting.
d) The review found no significant difference in methodological quality between drug and medical device studies.
Explanation: The systematic review of 1,096 articles found that methodological quality was insufficient, particularly for pharmaceuticals. While 80% of medical device studies considered a full cradle-to-grave perimeter, only 29% of drug studies did so. End-of-life waste treatment was included in just 11% of drug studies. The review identified industrial secrecy and lack of transparency in emission factors as primary barriers to accurate pharmaceutical carbon footprinting.

4. Hospital-level carbon hotspots: dynamic life cycle assessment evidence. A 2025 study published in *Building and Environment* conducted a dynamic life cycle assessment of a hospital emergency complex in Shanghai. What did the study identify as the largest contributor to the hospital's total carbon footprint, and what percentage did it represent?
a) Building construction materials, accounting for 62.4% of total emissions

b) *The operation stage, accounting for 73.1% of total emissions, with medical equipment systems contributing 43.3% of that*
c) Waste management and incineration, accounting for 58.7% of total emissions
d) Staff and patient transportation, accounting for 67.2% of total emissions.
Explanation: The Shanghai hospital study employed a novel dynamic assessment model integrating Building Information Modeling (BIM) and four dynamic factors. The results demonstrated that the operation stage dominated the life cycle carbon footprint at 73.1%. Within this, medical equipment systems (MRI, CT, X-ray, etc.) accounted for 43.3% of operational emissions, while conventional energy-consuming systems (HVAC, lighting) contributed over 50%.

5. The "minimally invasive ≠ low-carbon" paradox. A 2025 study in *Scientific Reports* examining the carbon footprint of minimally invasive axillary osmidrosis surgery challenged a common assumption in surgical practice. What was the key finding that created this paradox?
a) Minimally invasive surgery requires longer operating times, doubling energy consumption.
b) *Despite being less invasive clinically, the procedure generated 50.48 kgCO_2e per surgery, with facility operations (43.5%) and disposable consumables (21.7%) as primary hotspots, demonstrating that clinical minimalism does not guarantee environmental minimalism*.
c) The study found that minimally invasive surgery had a zero carbon footprint due to efficiency gains.
d) Patient travel accounted for 80% of emissions, unrelated to the surgical technique.
Explanation: The study systematically uncovered the environmental burden of minimally invasive surgery through life cycle assessment. Facility operations (HVAC, lighting) dominated at 43.5%, followed by disposable consumables at 21.7% (sterile drapes and gloves alone accounting for 78.8% of consumable emissions). This challenges the intuitive assumption that less invasive clinical approaches automatically equate to lower environmental impact.

6. OECD analysis: hospital contribution and decarbonization potential. According to the 2025 OECD report on decarbonising health systems, what percentage of healthcare emissions are attributable to hospitals, and what reduction potential exists through addressing inappropriate care?
a) Hospitals account for 15% of emissions, with minimal reduction potential
b) *Hospitals represent approximately 30% of healthcare emissions, and reducing inappropriate care and hospital stay duration could cut hospital-related emissions by up to 25% on average across OECD countries*
c) Hospitals account for 60% of emissions, but no reduction is feasible
d) Hospitals represent 5% of emissions, with primary care accounting for the majority.
Explanation: The OECD's comprehensive analysis found that highly resource-intensive care settings, particularly hospitals, contribute disproportionately to health sector emissions—approximately 30% on average across OECD countries. Importantly, the analysis demonstrated that policies promoting appropriate care and reducing low-value care and hospital length of stay could reduce hospital-associated emissions by as much as a quarter.

7. Anaesthetic gases and inhalers: high-impact clinical choices. Clinical products, including anaesthetic gases and metered-dose inhalers, represent a unique opportunity for rapid decarbonization. What is the basis for this opportunity, and what scale of impact do these products represent?
a) They represent less than 0.1% of emissions and are not worth addressing.
b) *Anaesthetic gases and inhalers account for approximately 1% of healthcare's global climate footprint (0.6% from anaesthetics, 0.3% from inhalers), and clinically equivalent lower-emission alternatives are readily available for many applications*.
c) They represent 25% of healthcare emissions but have no viable alternatives.
d) They are significant only in low-income countries and irrelevant in high-income settings.
Explanation: While representing a relatively small percentage of total healthcare emissions, these products are "low-hanging fruit" for decarbonization because alternatives exist. Desflurane, for example, has a global warming potential many times higher than sevoflurane. For inhalers, dry powder inhalers have significantly lower carbon footprints than metered-dose inhalers using hydrofluorocarbon propellants. Spain's Ministry of Health established a "Green Anaesthesia" working group in 2025 to develop best practices.

8. The supply chain challenge: transboundary emissions. The OECD's analysis of health system emissions using a country-of-origin framework revealed a critical challenge for national decarbonization strategies. What did this analysis find?
a) All healthcare emissions originate within the country where care is delivered.

b) *On average, half of health sector emissions originate from sources outside the country in which healthcare was delivered, meaning domestic policy alone cannot fully decarbonize health systems*.
c) Supply chain emissions are negligible, accounting for less than 5% of total healthcare emissions.
d) Only pharmaceutical emissions cross borders, while all other emissions are domestic.
Explanation: This finding has profound policy implications. Because medical supply chains are globalized, emissions from manufacturing pharmaceuticals, medical devices, and other products often occur in different countries than where they are consumed. This means that even if a country decarbonizes its domestic healthcare operations completely, it may only address half of its consumption-based healthcare footprint. This underscores the need for international cooperation, green procurement policies, and supply chain engagement.

9. ULT freezers: A case study in behavioral carbon reduction. Recent initiatives in Catalonia and other regions have targeted Ultra-Low Temperature (ULT) freezers for carbon reduction. What simple intervention has been demonstrated to significantly reduce emissions without compromising sample integrity?
a) Replacing all ULT freezers with refrigerators
b) *Increasing the temperature set point from -80°C to -70°C, which can reduce energy consumption by approximately 30-40% without affecting most biological samples*
c) Discontinuing the use of freezers entirely
d) Moving all freezers outdoors to use ambient cooling.
Explanation: ULT freezers are energy-intensive pieces of laboratory equipment essential for storing biological samples and medicines. The IDIBELL research institute in Catalonia implemented a policy to increase freezer temperatures from -80°C to -70°C, upgrading 10 freezers to cut 4.2 tons of CO_2 annually, equivalent to nearly 5 households. This simple behavioral and operational change demonstrates how low-cost interventions can yield significant emissions reductions.

10. Methodological innovation: dynamic life cycle assessment. Traditional Life Cycle Assessment (LCA) in healthcare has been criticized for static assumptions. A 2025 study introduced a dynamic assessment model incorporating four dynamic factors. Which of the following was NOT one of the dynamic factors identified as significantly affecting hospital carbon footprint estimates?
a) Changes in energy mix over time (grid decarbonization)
b) Changes in vehicle mix for transportation
c) Changes in unit energy consumption of equipment due to efficiency improvements
d) *Changes in patient willingness to pay for green healthcare*.
Explanation: The dynamic assessment model integrated four factors that change over a hospital's long lifespan (often 50+ years): energy mix evolution, vehicle mix changes, unit energy consumption improvements, and other technical parameters. The study demonstrated that incorporating these dynamics changed the carbon footprint estimate by 48% compared to static assessment. Patient willingness to pay, while relevant for policy acceptance, is not a direct technical parameter in carbon footprint quantification.

11. The healthcare-emission paradox. Healthcare systems face a fundamental ethical paradox regarding their carbon footprint. What is this paradox?
a) Healthcare systems are too small to matter in climate discussions
b) *Healthcare systems exist to protect health, yet their emissions contribute to climate change—the greatest health threat of the 21st century—creating a conflict between immediate care delivery and long-term population health*
c) Only private hospitals contribute to emissions; public hospitals are carbon neutral
d) The paradox only exists in high-income countries.
Explanation: This ethical tension is increasingly recognized in the literature. The WHO's Director-General has explicitly stated: "Health sector facilities are the operational heart of service delivery, protecting health, treating patients, and saving lives. Yet health sector facilities are also a source of carbon emissions, contributing to climate change. Places of healing should be leading the way, not contributing to the burden of disease". This paradox drives the movement toward "climate-smart healthcare" that balances clinical priorities with climate action.

Recommended reading & resources:

- Health Care Without Harm. (2019). Health Care's Climate Footprint Report: https://global.noharm.org/media/4361/download?inline=1#:~:text=%E2%80%A2-,Health%20care's%20climate%20footprint%20is%20equivalent%20to%204.4%25%20of%20gl

obal,gigatons%20of%20carbon%20dioxide%20equivalent).&text=The%20global%20health%20care%20climate,514%20coal%2Dfired%20power%20plants.

- NHS England. Greener NHS Programme: https://www.england.nhs.uk/greenernhs/
- WHO Guidance for climate resilient and environmentally sustainable health care facilities, 2020: https://www.who.int/publications-detail-redirect/9789240012226.
- WHO New guidance for safe, climate-resilient and environmentally sustainable healthcare, 2024: https://www.who.int/publications/i/item/B09119.
- UNDP: Sustainable Procurement in the Health Sector (SPHS): https://www.undp.org/eurasia/sustainable-procurement.
- Institute of Medicine (US) Roundtable on Environmental Health Sciences, Research, and Medicine. Green Healthcare Institutions: Health, Environment, and Economics: Workshop Summary. Washington (DC): National Academies Press (US); 2007. 2, Sustainable Healthcare Facilities. Available from: https://www.ncbi.nlm.nih.gov/books/NBK54143/

Evaluation criteria:

Component	Weight
Group Green Action Plan presentation	20%
Diary #5 (INSERT reflection)	20%
Carbon audit activity (group)	10%
Peer feedback and roleplay	10%
Total:	60

Innovative/interactive tools:

- Health Care Without Harm Carbon Calculator.
- NHS Carbon Hotspots Map.
- WHO Facility Assessment Tool.
- Miro / Canva for action plan visualization.
- Moodle forum for peer strategy feedback.

Unit 6: AI and Big Data for Environmental Health Surveillance

Session duration: 6 academic hours, including:

- Lecture: 2 h,
- Data lab workshop: 3 h,
- Reflection / Q&A: 1h.

Learning objectives:

By the end of this unit, students will be able to:

- Understand basic concepts of AI, machine learning (ML), and big data as applied to public and environmental health.
- Explore the use of AI-driven models for predicting disease outbreaks related to environmental changes.
- Use open big data platforms (e.g., Google Earth Engine, GBD, Copernicus) to identify health trends.
- Evaluate the risks and ethical challenges of AI use in climate-health surveillance.
- Collaborate on designing a concept model of an AI-based surveillance solution for environmental health issues.

Session format: Data lab format with exploration of real datasets, group AI model ideation, and ethical reflection.

Inclusivity & sustainability focus:

- Emphasizes responsible and ethical AI use
- Addresses global inequality in data access and infrastructure
- Promotes student collaboration in digital innovation for health equity

Discussion questions:

- What types of data are most valuable for predicting health risks related to climate?
- How can machine learning enhance early warning systems for vector-borne or air pollution–related illnesses?
- What are the risks of bias or misinformation in AI-based health prediction models?
- How accessible are AI and big data tools for low-resource settings?
- Can AI-based systems replace traditional public health surveillance?

The instructor:

- Explains how big data sources (satellite, weather, health records) are integrated for modeling.
- Presents case examples: BlueDot (pandemic prediction), Google Flu Trends (lessons learned), IBM AI for air quality.
- Demonstrates use of simple dashboards (e.g., Kaggle datasets + notebooks, Earth Engine visualizations).

Students:

- Participate in guided exploration of real-time data dashboards.
- Form teams to develop a concept for an AI-based tool for tracking a climate-sensitive disease.
- Present prototype (paper-based or digital mock-up) and explain logic/inputs/outputs.
- Reflect on trade-offs between innovation, equity, and reliability.

Assignments:

Before the session: 1) Read: “Ethics and governance of artificial intelligence for health” (WHO, 2021); 2) Watch: Short demo on Google Earth Engine for environmental health.

During the session: 1) Explore and evaluate one AI-powered public health tool or dataset; 2) Create an AI concept solution in groups.

After the session: 1) Submit Diary #6: “AI in public health: empowering or replacing the human role?”; 2) Optional: Share group mock-up model (presentation or PDF)

Quiz questions

1. Defining the scope of AI and Big Data in Environmental health surveillance. At an MSc level, how should "AI and Big Data for environmental health surveillance" be most comprehensively defined?
a) The use of spreadsheet software to organize pollution data from a single monitoring station
b) *The integration of massive, diverse datasets (e.g., satellite imagery, electronic health records, wearables, genomics) with machine learning algorithms to detect patterns, predict health risks, and enable proactive public health interventions related to environmental exposures*
c) The replacement of all public health workers with automated systems
d) The collection of environmental samples without any computational analysis.
Explanation: This definition captures the essence of the field—the synthesis of high-volume, high-velocity data from multiple sources (the "big data" component) with advanced computational techniques (the "AI" component) to derive insights that would be impossible with traditional methods. The goal is to shift from reactive to predictive and proactive surveillance.

2. The MOSSAIC and EHRLICH projects: Integrating exposomics with clinical data. Dr. Heidi Hanson's MOSSAIC and EHRLICH projects at Oak Ridge National Laboratory represent a significant advancement in environmental health surveillance. What key innovation do these projects enable through the use of exascale supercomputing?
a) They replace all clinical diagnoses with automated algorithms
b) *They create AI-ready platforms like the Centralized Health and Exposomic Resource (C-HER) that link geocoded residential histories from cancer registries with environmental exposure datasets, enabling large-scale exposomic research*
c) They focus exclusively on genetic data, ignoring environmental factors
d) They only work with data from a single city.
Explanation: The MOSSAIC and EHRLICH projects leverage DOE supercomputing to overcome historical barriers in exposomics research. C-HER unifies area-based and environmental exposure datasets with population health data, including geocoded residential histories for cancer cases from SEER registries linked to environmental datasets. This enables investigations into how environmental factors affect cancer incidence, treatment response, and survival over the life course.

3. Wastewater surveillance enhanced by AI: A paradigm shift. Traditional wastewater surveillance for pathogens typically required prior knowledge of a variant's genetic makeup and relied on clinical data from patients who had already tested positive. How does AI-enhanced wastewater surveillance fundamentally change this paradigm?
a) It makes wastewater surveillance unnecessary
b) *AI algorithms can detect emerging pathogens and variants without prior knowledge by identifying unique genomic signatures, potentially identifying outbreaks before the first patient enters a clinic*
c) AI only works for COVID-19 and cannot be applied to other pathogens
d) It requires more clinical testing, not less.
Explanation: A UNLV-led study published in Nature Communications demonstrated that AI-driven algorithms can scan wastewater to detect budding influenza, RSV, mpox, and other pathogens without prior knowledge of their genetic makeup. This represents a shift from reactive to proactive surveillance, identifying threats before clinical cases emerge.

4. Machine learning for source tracking in sewer networks. A research team at Vrije Universiteit Amsterdam combined hydraulic modeling with machine learning to trace pathogen sources in sewer networks. What critical limitation did this study identify for real-world implementation?
a) The machine learning models were completely inaccurate

b) *The approach requires high time-resolution monitoring data and is highly sensitive to the sewer system's physical layout, flow velocity, and sampling procedures, and currently available sensor systems cannot provide the necessary high-frequency, contaminant-specific data*
c) Sewer networks are too simple to require modeling
d) The method only works for chemical pollutants, not pathogens.
Explanation: The study demonstrated promising results for back-tracing pathogen sources using only outlet sampling, but emphasized that real-world implementation requires technological advances in high-frequency, contaminant-specific sensors that are not currently available. This highlights the gap between algorithmic potential and practical deployment.

5. Geospatial artificial intelligence (GeoAI) for exposure assessment. According to a comprehensive narrative review published in *Current Environmental Health Reports*, what are the two major recent shifts in geospatial data and analytic methods for environmental epidemiology?
a) The complete abandonment of traditional GIS methods and exclusive use of drones
b) *First, novel methods combining geospatial analysis with machine learning (GeoAI) enable scalable exposure assessment; second, widespread adoption of smartphones and wearables with GPS allows passive data collection at finer spatial and temporal scales than ever before*
c) The elimination of all privacy concerns and the end of need for validation datasets
d) The shift from satellite to balloon-based monitoring and from computers to manual calculation.
Explanation: The review identifies these two transformative trends: GeoAI methods that can process vast geospatial data at scale for exposure assessment, and the explosion of passively collected personal data from mobile devices that capture exposures across individuals' activity spaces rather than just at residential locations.

6. Airborne microbe surveillance in Bangladesh: data fusion for pandemic preparedness. A study in Dhaka, Bangladesh, integrated multiple data sources to predict airborne pathogen risks. Which of the following represents the comprehensive data fusion approach used in this research?
a) Only temperature and humidity data
b) *Integration of microbial air burdens (Influenza A, SARS-CoV-2, Dengue), environmental factors (PM2.5, humidity, rainfall), health markers (hospitalizations), and socio-economic drivers (poultry outbreaks, rice harvest seasons) using deep learning architectures*
c) Exclusive use of social media trends
d) Reliance on a single weather station.
Explanation: The study created a combined dataset (2000-2023) integrating microbial, environmental, health, and socio-economic data. Using deep architectures including autoencoders and CNNs, the researchers detected that elevated dengue RNA titers preceded hospitalization peaks, and COVID-19 waves were associated with mobility shifts and PM2.5 exposure. The AI system compressed outbreak detection cycles from weeks to days with >85% predictive accuracy.

7. Automated robotics and AI for Mpox prediction. A study from Shenzhen developed an integrated system combining automated wastewater sampling robots with AI prediction models. What level of predictive accuracy did this system achieve, and what important caveat was noted?
a) 50% accuracy with no caveats
b) *The AI model predicted mpox cases with remarkable precision, capturing 87% of the data's variability, though this may be related to the high-frequency data acquisition and relatively non-mobile isolated hospital environment*
c) 100% accuracy, making clinical testing obsolete
d) The system failed and was abandoned.
Explanation: The study demonstrated a strong correlation between wastewater MPXV concentrations and clinically confirmed cases, with the AI stacking ensemble model capturing 87% of the variability. However, the authors noted that this high precision might be influenced by the specific study setting, a hospital with high-frequency sampling and relatively non-mobile populations, highlighting the importance of context in evaluating AI performance.

8. Environmental justice and AI-powered monitoring in South Africa. The AI_r project in South Africa's Gauteng province combines low-cost monitors with AI to address air quality issues. What dual breakthrough does this project represent for environmental health surveillance in low- and middle-income countries?
a) It only monitors indoor air quality
b) *It reduces monitor production costs by a factor of 2.5 (to approximately USD $100) while simultaneously empowering communities with real-time, publicly available data that can be used for advocacy and personal protection (e.g., mask-wearing during predicted pollution spikes)*

c) It replaces all government monitoring systems
d) It focuses exclusively on industrial emissions without community engagement.
Explanation: The AI_r project demonstrates that technological innovation (low-cost, locally manufactured hardware) combined with AI-powered prediction and public data dashboards can democratize access to environmental information. This addresses both the technical challenge of granular monitoring and the social justice dimension of environmental health, enabling communities to advocate for change based on evidence.

9. Linking climate phenomena to disease dynamics with AI. Research on Vibriosis in coastal environments demonstrates how AI can link large-scale climatic phenomena to local disease risk. What specific climate pattern was integrated with satellite data and machine learning to predict disease outbreaks?
a) The Indian Ocean Dipole only
b) *The El Niño-Southern Oscillation (ENSO), demonstrating how changes in coastal water systems influenced by this climate pattern affect the spatio-temporal dynamics of Vibrio outbreaks*
c) Solar cycles
d) Lunar phases.
Explanation: The University of Florida research used high-resolution satellite data with GeoAI and machine learning to understand environmental conditions favorable for Vibrio species. A key finding was establishing a direct link between ENSO and Vibrio outbreak dynamics, showing how global climate patterns can be translated into local, actionable risk predictions through AI.

10. Ethical and methodological challenges in AI-powered surveillance. Despite the promise of AI and big data for environmental health surveillance, significant challenges remain. According to the GeoAI narrative review, which of the following represents a critical concern that researchers must address?
a) There are no challenges; AI solves all problems
b) *Participant privacy, representativeness of collected data, curation of high-quality validation sets for training algorithms, and understanding the assumptions made by these models*
c) AI is too simple and doesn't provide enough data
d) Only computational speed is a concern.

Explanation: The review emphasizes that while GeoAI approaches enable more rapid, higher-quality exposure measures, they pose significant challenges: privacy concerns with passively collected personal data, questions about whether these data represent the broader population, the need for high-quality "gold standard" data to train algorithms, and the importance of understanding model assumptions rather than treating AI as a "black box".

11. The ENHANCE project's One Health approach. The EU-funded ENHANCE project combines Copernicus Marine data, citizen science, and AI to address coastal management. What makes this project innovative from a "One Health" perspective?
a) It ignores human health entirely
b) *It develops products to analyze urban, agricultural, and climate extremes pressures in coastal areas and their impacts on biodiversity, public health, and the environment simultaneously, recognizing the interconnectedness of ecosystem and human health*
c) It only studies fish populations
d) It focuses exclusively on tourism revenue.

Explanation: The ENHANCE project exemplifies the One Health approach by integrating data and analysis across environmental, human, and ecosystem health domains. By developing products that assess impacts of multiple pressures on both biodiversity and public health, it creates tools for holistic coastal management that recognize the fundamental links between environmental degradation and human health outcomes.

Recommended reading & resources:

- WHO. (2021). Ethics and Governance of Artificial Intelligence for Health: https://www.who.int/publications/i/item/9789240029200, https://www.who.int/publications/i/item/9789240084759
- WHO (2024). Action framework advances multi-source surveillance. https://www.who.int/westernpacific/newsroom/feature-stories/item/world-health-organization-and-partners-across-asia-and-the-pacific-explore-new-frontiers-for-public-health-surveillance.

- Enoch, Olanite. (2024). AI for Public Health Surveillance. https://www.researchgate.net/publication/384732109_AI_for_Public_Health_Surveillance
- Jane M. Kunberger, Melanie R. Colón, Ashley M. Long. Using Google Earth Engine to develop interactive mapping tools for conservation planning. Journal for Nature Conservation, Volume 87, 2025, 126997, https://doi.org/10.1016/j.jnc.2025.126997.
- Google Earth Engine Tutorials; https://earthengine.google.com/, https://www.numberanalytics.com/blog/google-earth-engine-environmental-monitoring;
- Short demo on Google Earth Engine for environmental health: https://www.youtube.com/watch?v=2i6cw7nTbhI
- IHME: Global Burden of Disease: https://vizhub.healthdata.org/gbd-foresight/
- Copernicus Open Access Hub: https://www.copernicus.eu/en/access-data/conventional-data-access-hubs
- UNEP AI for Good: https://aiforgood.itu.int/about-us/un-ai-actions/unep/

Evaluation criteria:

Component	Weight
Group AI Concept Presentation	20%
Diary #6 (INSERT reflection)	20%
Dashboard exploration participation	10%
Peer feedback on prototypes	10%
Total:	60

Innovative/interactive tools:

- Google Earth Engine
- Copernicus Climate Monitoring API
- Kaggle public health datasets
- Tableau or Flourish for visual summaries

Unit 7: Risk Communication and Community Engagement in Climate-Health Crises

Session duration: 6 academic hours, including:

- Lecture: 2 h,
- Roleplay and Design Lab: 3 h,
- Reflection / Q&A: 1h.

Learning objectives

By the end of this unit, students will be able to:

- Define key principles of risk communication and community engagement (RCCE) in public health.
- Identify communication challenges during climate-related emergencies (e.g., heatwaves, floods, epidemics).
- Design culturally appropriate communication strategies for vulnerable populations.
- Use digital tools for risk alerts, misinformation monitoring, and social media engagement.
- Evaluate real-world examples of RCCE during climate-health crises.

Session format: Roleplay and scenario-based workshop to build real-time communication and engagement skills.

Inclusivity & sustainability focus:

- Focus on reaching marginalized and linguistically diverse groups
- Emphasis on building public trust and shared decision-making
- Supports participatory approaches to resilience and climate justice

Discussion questions:

1. What makes communication effective during a climate-related health crisis?
2. How do we tailor messages to different cultural and literacy contexts?
3. What is the role of social media in spreading or preventing misinformation?
4. How can communities be meaningfully engaged in emergency preparedness and response?
5. What tools and platforms can improve RCCE in resource-limited settings?

The instructor:

- Presents the WHO RCCE framework and real cases (COVID-19, Pakistan floods, EU heatwave alerts).
- Guides students in designing a communication strategy for addressing the climate crisis.
- Leads scenario-based roleplay: public health official briefing the community during a disaster.

Students:

- Participate in simulation (press conference, SMS alert writing, infographic design).
- Collaborate on creating a community engagement plan.
- Critique communication materials for inclusivity, clarity, and trustworthiness.
- Reflect on barriers to communication and engagement in their region.

Assignments

Before the session: 1) Read: WHO (2021) RCCE Action Plan Guidance for COVID-19 Preparedness and Response; 2) Watch: Heat Alert Messaging in the EU (short video case).

During the session: 1) Participate in RCCE roleplay and debrief; 2) Design a communication product (infographic, alert message, radio script).

After the session: 1) Submit Diary #7: “My experience communicating climate-health risks in my community”; 2) Optional: Post a sample message or product to the Moodle discussion board.

Quiz questions

1. Defining risk communication and community engagement in climate-health contexts. At an MSc level, how should "risk communication and community engagement" be most comprehensively defined within the context of climate-health crises?
a) The one-way broadcast of weather warnings from meteorological agencies to the general public through mass media
b) *A strategic, iterative process of exchanging information, building trust, and fostering collaborative partnerships between authorities, experts, and affected communities to enable informed decision-making, protective behaviors, and co-designed adaptation strategies before, during, and after climate-related health emergencies*
c) The exclusive domain of public relations departments within health ministries
d) The distribution of pamphlets about heatwave safety during the summer months.
Explanation: This definition captures the full scope of RCCE, which extends beyond simple information transmission to include dialogue, trust-building, and genuine partnership with communities. As emphasized in the WHO's operational framework for climate-resilient health systems, effective communication must translate science into locally relevant language and empower communities as active participants in resilience-building. It is a dynamic process that spans the entire disaster management cycle, not just emergency response.

2. The Extended Parallel Process Model (EPPM): balancing threat and efficacy. The Extended Parallel Process Model (EPPM) has been applied to climate change communication to address the psychological barrier of "doom-and-gloom" framing. According to experimental research testing the EPPM for climate messaging, what is a critical finding regarding the combination of threat and efficacy appeals?
a) High-threat messages alone are most effective at motivating behavior change
b) Low-threat messages consistently outperform all other combinations
c) *Defeatist messaging—whether low-threat with negative efficacy or high-threat with positive efficacy—can reduce perceived self-efficacy compared to saying nothing, while messages emphasizing low threat with positive efficacy can increase behavioral intentions*
d) Threat level has no impact on message effectiveness; only efficacy matters.
Explanation: Research applying the EPPM to climate change communication found that participants exposed to no message had significantly higher perceived self-efficacy than those exposed to low-threat/negative-efficacy or high-threat/positive-efficacy messages. This suggests that "defeatist" messaging can backfire. However, both no message and low-threat/positive-efficacy messages produced higher behavioral intentions to mitigate climate change than low-threat/negative-efficacy messages. These findings underscore the importance of balancing threat with genuine efficacy appeals and avoiding messaging that leaves audiences feeling powerless.

3. Co-constitutive risk (CCR) messaging and One Health communication. The concept of "Co-Constitutive Risk" (CCR) messaging has been proposed as part of a One Health Communication approach. What does CCR messaging specifically entail, and what effect has been observed among climate change skeptics?
a) CCR messaging focuses exclusively on personal health risks while ignoring environmental factors, and it decreases support among all audiences
b) *CCR messaging combines the risks of climate change and infectious disease (e.g., dengue fever) into a single intervention, and among individuals skeptical of human-caused climate change, it shows suggestive evidence of increasing support for climate mitigation policies*
c) CCR messaging only works for collectivist cultures and does not affect individualists
d) CCR messaging is identical to traditional fear appeals and produces no unique effects.
Explanation: CCR messaging is an innovative approach that frames climate change and infectious disease risks as interconnected—recognizing that climate change exacerbates disease threats. In a nationally representative US study, researchers found that while CCR messages were generally effective at increasing support for pharmaceutical interventions (like vaccines), the effects on climate policy support were more nuanced. Notably, post hoc exploratory analyses suggested that CCR

messaging resonated with individuals who expressed doubts about human-caused climate change, potentially by making abstract climate consequences more tangible through concrete health threats.

4. Cultural cognition and audience segmentation. According to Cultural Cognition Theory of Risk and research on climate-health messaging, why is audience segmentation based on cultural worldviews essential for effective risk communication?
a) Because all audiences respond identically to the same messages
b) *Because individuals with individualist orientations may respond more positively to messages emphasizing personal consequences, while communitarians may be more receptive to framing that emphasizes collective impacts, and mismatched framing can produce "boomerang effects" where risks are downplayed*
c) Because cultural worldviews only matter in non-Western contexts
d) Because communicators should only target audiences that already agree with them.
Explanation: Cultural Cognition Theory posits that their cultural values and group identities shape people's perceptions of risk. Research on Zika virus messaging demonstrated this dynamic: when Zika risk was linked to climate change, hierarchist-individualists downplayed the danger compared to when it was framed solely as a public health issue. Conversely, egalitarian-communitarians showed consistent concern across both frames but underestimated the threat when Zika was linked to immigration. This demonstrates how interconnected risks can significantly influence perceptions across different cultural groups, necessitating tailored communication strategies.

5. Global evidence on public perceptions of climate and health. A comprehensive global literature review (2000-2023) synthesized findings from 93 studies on public engagement with climate change and health. What was a key pattern identified regarding public awareness, particularly in the United States?
a) Americans have consistently demonstrated comprehensive knowledge of climate-health linkages since 2000
b) *While many Americans believe climate change poses health threats, few possess specific knowledge of how it harms health or who is most vulnerable, though awareness of specific risks like wildfire smoke has increased in recent years*
c) Americans are completely unaware of any connection between climate and health
d) Public awareness in the US has decreased steadily since 2010.
Explanation: The review found a consistent pattern: surveys from 2010 and 2015 showed that majorities of Americans acknowledged climate change as a health threat, but few could name specific health consequences or vulnerable populations in open-ended questions. However, more recent data shows improved recognition—for example, the percentage of Americans expecting increased health risks from wildfire smoke in their community rose from 26% in 2014 to 54% in 2020. This suggests that concrete, personally relevant experiences may bridge the gap between general concern and specific knowledge.

6. Health professionals as trusted communicators. The WHO has developed specific toolkits to empower health professionals in climate communication. What rationale underpins this investment in health worker capacity building?
a) Health professionals have no unique role in climate communication
b) *Health professionals are among the most trusted sources of health information, and their direct engagement with communities positions them uniquely to translate climate science into locally relevant health advice, advocate for policy changes, and model climate-smart behaviors*
c) Health professionals should only focus on treating disease, not prevention
d) Climate communication is best left to meteorologists and environmental scientists.
Explanation: The WHO's toolkit for health professionals emphasizes that health and care workers play a key role in addressing climate change as a health crisis. Their unique position—grounded in trust and direct community relationships—enables them to raise awareness, advocate for policy changes, and empower communities to mitigate and adapt. However, many health workers feel ill-equipped to discuss climate change, creating a capacity gap that these toolkits aim to address. The Zanzibar initiative similarly trained health personnel as facilitators to multiply climate-health knowledge across the workforce.

7. Community-based participatory research in climate-health adaptation. A scoping review on community involvement in climate and health research identified several rationales for engaging communities, including Indigenous groups, in research. What was a key benefit documented from such participatory approaches?
a) Community engagement slows down research and produces less relevant findings

b) *Co-produced adaptation strategies that respond appropriately and effectively to priority health hazards, generated through equitable partnerships between scientists and communities*
c) Communities prefer not to be involved in research that affects them
d) Participatory research is only relevant for infectious diseases, not climate adaptation
Explanation: The review demonstrated that involving communities through approaches like community-based participatory research and citizen science generates tangible benefits, including adaptation strategies that are culturally appropriate and responsive to locally identified health priorities. This aligns with principles of social justice and ensures that research addresses the needs of those most affected by climate change, particularly marginalized populations.

8. Practical tools for campaign development: The MOUNTADAPT toolkit. The MOUNTADAPT project, a Horizon Europe initiative, developed a campaign toolkit for climate risk preparedness. What makes this toolkit particularly accessible for diverse users and contexts?
a) It is only available to government agencies with high budgets
b) *It includes specific strategies for designing campaigns at low, moderate, and high budgets, making it adaptable across different resource contexts and user types, including citizen groups, local healthcare providers, and NGOs*
c) It requires professional communication training to use effectively.
d) It focuses exclusively on mountain regions and cannot be adapted elsewhere.
Explanation: The MOUNTADAPT toolkit, developed by Health Care Without Harm Europe, is designed for a wide range of users—from citizen groups to public health agencies. Its budget-conscious approach provides tailored guidance for different resource levels, each section offers real-world examples, and it includes guiding questions to support campaign development. This democratizes access to evidence-based communication strategies, enabling community-level action regardless of financial resources.

9. Ethical considerations in community engagement. Research on community involvement in climate-health research has identified potential ethical challenges. Which of the following represents a documented risk that requires careful mitigation?
a) Communities are always eager to participate and never experience engagement fatigue
b) *The risk of reinforcing stereotypes, uneven geographic distribution of participatory efforts, and the potential for engagement to place additional burdens on already marginalized communities*
c) Community engagement has no ethical dimensions
d) Only researchers face risks in participatory projects; communities face none.
Explanation: Ethical community engagement requires acknowledging potential harms. The literature identifies risks, including the reinforcement of stereotypes (e.g., assuming Indigenous communities have homogeneous views), the tendency for participatory efforts to cluster in accessible areas while neglecting remote populations, and the burden placed on community members who may be asked to participate repeatedly in research without adequate compensation or benefits. These challenges necessitate dynamic, adaptive, and genuinely respectful engagement designs.

10. The "Paradox of awareness" in climate-health communication. Synthesis of global research reveals a paradox in public awareness of climate-health linkages. What is this paradox, and what implications does it have for communication strategies?
a) People are either fully aware or completely unaware, with no middle ground
b) *While general concern about climate change as a health threat is relatively high in many populations, specific knowledge about mechanisms, vulnerable groups, and protective actions remains low—creating a gap between concern and capacity to act*
c) Awareness is highest in populations least affected by climate impacts
d) There is no relationship between awareness and action.
Explanation: This paradox—high general concern coexisting with low specific knowledge—appears across multiple countries and contexts. For example, while majorities acknowledge climate health threats, few can name specific health consequences or vulnerable populations. This suggests that communication strategies must move beyond simply raising concern to providing actionable, concrete information about risks, protective behaviors, and the efficacy of potential actions. The goal is to translate diffuse worry into informed and empowered preparedness.

11. Translating science for community resonance. The WHO-supported initiative in Zanzibar emphasized the importance of "translating science into simple, locally relevant language that resonates with vulnerable communities." What specific participatory methods were employed in this project to achieve this translation?
a) Exclusive use of scientific publications and technical reports

b) *Role-play, group work, and storytelling, combined with the development of locally adapted training materials by community health workers themselves*
c) Lecture-based training with no interactive components
d) Distribution of pre-printed materials developed externally without community input
Explanation: The Zanzibar project used participatory methods to ensure that climate-health information would resonate with local communities. By training health personnel as facilitators through interactive techniques, and by having participants develop locally adapted materials for future use, the project operationalized the principle that effective risk communication must be co-created with those who will deliver and receive it. This approach builds workforce capacity while ensuring cultural and contextual relevance.

Recommended reading & resources:

- WHO RCCE Frameworks and Toolkits: https://www.who.int/publications/i/item/9789240092501.

- WHO (2021) RCCE Action Plan Guidance for COVID-19 Preparedness and Response: https://hlh.who.int/docs/librariesprovider4/hlh-documents/rcce-action-plan-guidance-covid-19-preparedness-and-response.pdf

- UNICEF: Risk Communication and Community Engagement for Climate Emergencies: https://www.corecommitments.unicef.org/rcce

- CDC: Crisis and Emergency Risk Communication Manual: https://www.cdc.gov/cerc/php/cerc-manual/index.html

- Internews: Humanitarian Communication in Disaster Response: https://internews.org/wp-content/uploads/2021/02/Internews_SIPA_communicating_disastes_2013-09.pdf

- WHO: Myth-busting and Infodemic Management: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/myth-busters; https://apps.who.int/iris/bitstream/handle/10665/334287/9789240010314-eng.pdf.

Evaluation criteria:

Component	**Weight**
Roleplay participation & communication task	20%
Diary #7 (INSERT reflection)	20%
Group engagement strategy or product	10%
Peer critique and feedback	10%
Total:	60

Innovative/interactive tools:

- WhatsApp/SMS alert simulations
- Canva for infographics and posters
- WHO Myth-Buster Toolkit
- Moodle Forum for feedback
- Telegram/Signal broadcast bots (demo)

Unit 8: Policy and Governance for Climate-Resilient Health Systems

Session duration: 6 academic hours, including:

- Lecture: 2 h,
- Workshop: 3 h,
- Reflection / Q&A: 1h.

Learning objectives:

By the end of this unit, students will be able to:

- Understand the role of governance, policy, and leadership in promoting climate-resilient health systems.
- Analyze national and global frameworks (WHO, UNFCCC, Paris Agreement, SDGs).
- Evaluate climate-health integration in national adaptation plans and health policies.
- Propose context-relevant strategies for policy advocacy and cross-sectoral collaboration.
- Apply systems thinking to policy design in environmental public health.

Session format: Policy lab format combining theory, systems thinking, and real-time simulation of cross-sectoral governance

Inclusivity & sustainability focus:

- Builds leadership and advocacy capacity for health professionals.
- Encourages equity-centered and evidence-informed policymaking.
- Promotes systemic thinking for resilient and sustainable health systems.

Discussion questions:

1. What policy instruments are most effective for climate-health governance?
2. How can ministries of health work with other sectors (e.g., transport, energy, agriculture)?
3. What is the role of international agreements like the Paris Accord or Sendai Framework?
4. How do we ensure accountability and implementation at the local level?
5. What does good leadership look like in building climate-resilient health systems?

The instructor:

- Presents case studies from countries with successful climate-health policy integration.
- Leads a mock inter-ministerial roundtable on climate-health priorities.
- Shares policy mapping templates and advocacy tools.

Students:

- Roleplay: health policy advisor presenting to government committee.
- Group task: analyze one national climate-health policy and identify gaps.
- Design a 1-page policy brief targeting a real public health authority.
- Reflect on their role as future leaders in climate-resilient governance.

Assignments

Before the session: 1) Read: WHO Operational Framework for Climate-Resilient Health Systems; 2) Watch: SDG 13 & Health – United Nations explainer video.

During the session: 1) Participate in roundtable simulation and peer feedback; 2) Begin development of group policy brief.

After the session: 1) Submit Diary #8: “Building a climate-resilient health system: policy gaps and my role”; 2) Finalize and submit group policy brief (graded with bonus +10 pts to course total).

Quiz questions

1. Defining a climate-resilient health system (CRHS). At an MSc level, how should a "climate-resilient health system" be most comprehensively defined within a governance and policy framework?
a) A health system with backup generators to maintain power during extreme weather events
b) *A system that can anticipate, respond to, cope with, recover from, and adapt to climate-related shocks and stresses, while continuously transforming to meet evolving health needs and reducing its own carbon footprint*
c) A network of hospitals located outside of flood-prone areas
d) A national health insurance scheme that covers treatment for climate-sensitive diseases
Explanation: The WHO's operational framework defines climate-resilient health systems through multiple interconnected dimensions—governance, leadership, health workforce, information systems, service delivery, financing, and technologies—that together enable systems to not only withstand climate impacts but also transform in response to them. This definition encompasses both adaptation (building resilience) and mitigation (reducing healthcare's carbon footprint) as integrated responsibilities.

2. Institutional architecture: the case of Mauritius. In 2025, Mauritius validated a gap analysis and institutional framework for climate-resilient health systems with WHO support. What was the central governance mechanism proposed to address the identified systemic gaps?
a) Complete privatization of all health services
b) *Establishment of a dedicated Climate and Health Technical Unit (CHTU) within the Ministry of Health and Wellness, with a mandate for multisectoral coordination, data systems strengthening, and capacity building*
c) Relocation of all coastal health facilities to inland areas
d) Creation of a standalone Ministry of Climate and Health
Explanation: The multisectoral stakeholder validation process in Mauritius identified five critical systemic gaps, including the absence of a dedicated coordination unit and a lack of climate budget tagging. The proposed solution was a CHTU with well-defined functions: coordinating multisectoral action, strengthening early warning mechanisms, building health workforce capacity, and developing partnerships. This represents a typical governance innovation for embedding climate resilience within existing health structures.

3. Federalism as barrier and opportunity: evidence from Argentina. Research on Argentina's climate and health policy implementation, drawing on 31 key informant interviews, revealed a paradoxical finding about federal governance structures. What was this finding?
a) Federalism consistently accelerates national policy implementation
b) *Argentina's federal structure allows provinces and municipalities to advance climate and health initiatives independently during periods when national political will is withdrawn—representing either a barrier or an opportunity depending on context*
c) Federalism has no impact on health system resilience
d) All climate and health action in Argentina occurs exclusively at the national level
Explanation: Despite Argentina being the first Latin American country to integrate health into its Nationally Determined Contributions and establish a National Strategy for Climate and Health, implementation faces significant barriers, including fluctuating political will. However, federalism creates space for subnational innovation. Interviewees noted that "in a context where political will at the national level is withdrawn, federalism becomes an opportunity, as each province, municipality and territory have a certain autonomy." Technical teams and personal networks sustain progress when higher-level political support wavers.

4. Social determinants of policy implementation: Thailand's experience. Thailand's experience implementing the GREEN and CLEAN hospitals policy and the National Health Adaptation Plan revealed that, beyond formal policy frameworks, certain social factors critically influenced outcomes. What were these factors?
a) Strict enforcement mechanisms and financial penalties for non-compliance

b) *Strong leadership and a sense of shared ownership among stakeholders*
c) Complete reliance on international donor funding
d) Replacement of all existing health staff with climate specialists
Explanation: Research examining Thailand's climate and health policies found that while adaptation and mitigation planning were well-developed at the government level, "social values such as strong leadership and a sense of shared ownership significantly influenced initiative outcomes." This finding underscores that governance for climate-resilient health systems depends not only on institutional architecture but also on the human and relational dimensions of policy implementation.

5. The implementation gap: heat-health governance in Western Cape, South Africa. A 2025 study examining heat-health governance in South Africa's Western Cape province identified a critical disconnect between national policy and local action. What was the primary reason for this implementation gap?
a) Complete absence of any national heat-health policy
b) *Subnational and local actors were not involved in developing the national Heat-Health Action Guidelines, limiting their applicability and ownership at the local level*
c) Health workers refused to implement any heat-related measures
d) The national guidelines were legally unenforceable
Explanation: Despite South Africa's 2020 National Heat-Health Action Guidelines and recognition among Western Cape decision-makers of heat-related health risks, implementation remained fragmented. The study found that "subnational and local actors were not involved in developing the Heat-Health Action Guidelines, limiting their applicability at the local level." This top-down development process, without engagement of those responsible for implementation, created a governance gap that undermined effectiveness.

6. Multisectoral coordination mechanisms: the Pan-European protocol on water and health. The Pan-European Protocol on Water and Health, celebrating its 20th anniversary in 2025, represents a distinctive model of governance for climate-resilient health systems. What makes this instrument unique?
a) It is a voluntary industry self-regulation scheme
b) *It is a legally binding international agreement that legally binds sectors, health, environment, and water, around regional targets, directly supporting climate resilience and health system adaptation*
c) It applies only to European Union member states
d) It focuses exclusively on recreational water quality
Explanation: The Protocol is a unique, legally binding instrument that brings together health, environment, and water sectors to achieve regional targets. It supports climate resilience through risk-based water safety planning (now used by over 30 countries), health facility assessments in 10 countries, and evidence-based guidance on pathogens like Legionella. Its legally binding nature creates accountability mechanisms absent from voluntary frameworks.

7. The role of frontline health workers as governance intermediaries. Research from Thailand highlighted the critical governance function performed by sub-district public health officials. What specific role do these frontline workers play in climate-resilient health systems?
a) They exclusively deliver clinical services with no governance role
b) *They serve as crucial intermediaries between government and local communities, translating national policies into locally relevant action*
c) They have no involvement in climate-related health activities
d) They replace all higher-level governance structures
Explanation: The Thailand study found that "sub-district public health officials also served as crucial intermediaries between the government and local communities." These frontline actors represent the "street-level bureaucracy" that ultimately determines how national policies translate into practice. Their role in bridging governance levels is essential for the effective implementation of climate adaptation measures.

8. Health information systems governance: data integration challenges. Argentina's experience with climate and health governance revealed persistent challenges in health information systems. What specific governance barriers were identified regarding data?
a) Argentina has no health data collection systems
b) *Climate and health data are scattered across various sources and formats, lack interoperability protocols, and data ownership issues create reluctance to share sensitive information*
c) All climate data is classified as secret
d) Health workers refuse to record any data

Explanation: Interviewees in Argentina described "difficulties in sharing data without a defined protocol," data scattered across sources "hindering data interoperability," and "data ownership" issues creating reluctance to share. Additionally, mortality data crucial for assessing the effects of extreme weather "often takes time to consolidate, delaying timely decision-making." These governance challenges around data systems fundamentally undermine the evidence base for climate-resilient health policy.

9. Financing mechanisms for climate-resilient health systems. Mauritius's institutional framework for climate-resilient health systems identified a critical gap related to financing. What specific financial governance mechanism was proposed to address this gap?
a) Complete reliance on out-of-pocket payments from patients
b) *Development of a financing strategy combining domestic resources and international climate funds, including climate budget tagging in the health sector*
c) Elimination of all health spending
d) Exclusive reliance on private insurance companies
Explanation: Mauritius identified "lack of climate budget tagging in the health sector" as a critical systemic gap. The proposed institutional framework included "development of a financing strategy combining domestic resources and international climate funds." Climate budget tagging—tracking climate-relevant expenditures within health budgets—is essential for accountability, resource mobilization, and demonstrating fiscal commitment to climate resilience. Haiti's National Health Adaptation Plan similarly emphasizes "mobilizing resources for implementation," including submissions to the Green Climate Fund.

10. The "implementation gap" in climate-health governance. Across multiple country case studies, South Africa, Argentina, and Thailand, a consistent governance challenge emerges. What is this "implementation gap," and what drives it?
a) The complete absence of any climate-health policies
b) *The disconnect between well-developed national policy frameworks and their translation into tangible action at subnational and local levels, driven by factors including lack of local engagement in policy design, insufficient funding, fragmented data systems, and fluctuating political will*
c) The refusal of international organizations to support national action
d) The absence of any scientific evidence linking climate and health.
Explanation: Across diverse contexts, the pattern repeats: South Africa's national Heat-Health Guidelines exist, but local actors weren't involved in their development; Argentina has policy instruments, but "translating regulatory and institutional frameworks into concrete actions is a challenging task"; Thailand has strong national planning, but adaptation "could be strengthened at the organizational level". Bridging this implementation gap requires governance approaches that engage subnational actors, ensure sustained financing, build data interoperability, and maintain momentum through political transitions.

11. The Africa CDC strategic framework's guiding principles. The Africa CDC's 2025 Strategic Framework for Climate Change and Health explicitly names several guiding principles essential for governance. Which set of principles does the framework identify as critical for building climate-resilient health systems in Africa?
a) Profit maximization, market competition, and deregulation
b) *One Health Approach, Partnerships & Collaborations, Sustained Investment, Advanced Technology & Infrastructure, Community Engagement, Accountability & Transparency, and Equity & Inclusion*
c) Centralized decision-making, secrecy, and exclusion of civil society
d) Reliance on a single source of funding and exclusive focus on curative care
Explanation: The Africa CDC framework explicitly states that "Key to the success of this framework are the guiding principles it upholds, including the One Health Approach, Partnerships & Collaborations, Sustained Investment, Advanced Technology & Infrastructure, Community Engagement, Accountability & Transparency, and Equity & Inclusion." These principles recognize that climate-resilient health systems require multisectoral collaboration, sustained resources, technological innovation, community participation, accountability mechanisms, and explicit attention to equity, particularly crucial given that Africa faces disproportionate climate health impacts despite minimal historical emissions.

Recommended reading & resources:

- WHO. Operational Framework for Building Climate Resilient Health Systems (2015): https://www.who.int/publications-detail-redirect/operational-framework-for-building-climate-resilient-health-systems.
- SDG 13& Health – UN explainer video: https://www.youtube.com/watch?v=P2UpV5jvu7E;
- UNFCCC Health and Climate Country Profiles: https://www4.unfccc.int/sites/nwpstaging/pages/item.aspx?ListItemId=28604&ListUrl=/sites/NWPStaging/Lists/MainDB&SearchId=982a1557-64be-f535-662e-fe7f86a214dc; https://www.who.int/teams/environment-climate-change-and-health/climate-change-and-health/evidence-monitoring/country-profiles.
- The Lancet Countdown Policy Briefs (Global and Country-level): https://www.thelancet.com/countdown-health-climate/about; https://lancetcountdown.org/.
- UNEP: Climate Action. https://www.unep.org/topics/climate-action; https://sdg.iisd.org/news/unep-who-launch-partnership-on-environmental-health/.
- SDG 3 & 13 Implementation Toolkits: https://www.oecd.org/cfe/oecd-toolkit-for-a-territorial-approach-to-the-sdgs-291
- WHO Action Plan for Healthy Lives and Well-being for All. https://www.who.int/initiatives/sdg3-global-action-plan#:~:text=Frequently%20asked%20questions-,The%20Global%20Action%20Plan%20for%20Healthy%20Lives%20and%20Well%2Dbeing,action%20and%20progress%20in%20countries.

Evaluation criteria:

Component	**Weight**
Policy brief development (group)	30%
Diary #8 (INSERT reflection)	20%
Participation in policy roundtable	10%
Bonus points for excellence in policy brief	+10
Total:	60

Innovative/interactive tools:

- WHO Health and Climate Country Profiles Dashboard.
- UN SDG Dashboard.
- Canva for brief and poster design.
- Shared Google Docs for co-editing briefs.
- Policy simulation tools (WHO eLearning modules).