

ACLA COURSE STUDY GUIDE

Climate Change & the Environment:
From Science to Action

Master the science, evidence, impacts and solutions of climate change — plus air pollution and environmental health.

Dr. Samuel Ochieng · Beginner
8 modules · 50 lessons · 10 weeks

About This Course	3
Module 1: Climate Change Fundamentals: Climate, Weather and the Earth System	4
1.1 Weather versus climate	4
1.2 The Earth system	5
1.3 Climate variability and change	6
1.4 The greenhouse effect	7
1.5 Case Study: Nairobi, coastal Kenya, and a small island community	7
1.6 Hands-On Activity	7
Module 2: The Science and Evidence of Human-Caused Climate Change	8
2.1 Greenhouse gases and radiative forcing	8
2.2 Sources and sinks	9
2.3 Lines of evidence	10
2.4 Attribution and scientific confidence	11
2.5 Case Study: attribution of a heatwave	11
2.6 Hands-On Activity	11
Module 3: Causes, Drivers and Emissions Across the Economy	11
3.1 Energy and electricity	12
3.2 Transport and cities	13
3.3 Food, agriculture and land	13
3.4 Industry, buildings and consumption	14
3.5 Carbon footprints and systems thinking	15
3.6 Hands-On Activity	15
Module 4: Climate Impacts, Risk, Vulnerability and Adaptation	15
4.1 Climate hazards	16
4.2 Exposure and vulnerability	16
4.3 Sectoral impacts	17
4.4 Adaptation pathways	17
4.5 Limits and maladaptation	19
4.6 Hands-On Activity	20
Module 5: Mitigation, Net Zero and Climate Solutions	22
5.1 What mitigation means	23
5.2 Energy transition	24

5.3 Land, food and nature	25
5.4 Industry and hard-to-abate sectors	26
5.5 Net zero and carbon removal	27
5.6 Evaluating solutions	28
5.7 Hands-On Activity	28
Module 6: Climate Justice, Development, Policy and International Cooperation	30
6.1 Climate justice	30
6.2 Paris Agreement and NDCs	31
6.3 Climate finance and capacity	33
6.4 Climate and sustainable development	34
6.5 Stakeholder negotiation	35
6.6 Hands-On Activity	35
Module 7: Climate Action in Practice: Communication, Project Design and Capstone	37
7.1 Climate communication	38
7.2 Project design	39
7.3 Monitoring and evaluation	40
7.4 Personal and organisational action	41
7.5 Capstone preparation	42
7.6 Hands-On Activity	42
Module 8: Air Pollution and Environmental Health	44
8.1 What is air pollution?	44
8.2 Major pollution settings	46
8.3 The major pollutants	48
8.4 Why this is a global threat	50
8.5 Equity and environmental justice	51
8.6 Case Study: Greenfield City is a rapidly growing urban centre with approximately 1	51
8.7 Hands-On Activity	53
Final Assessment & Certificate	54

About This Course

Climate Change & the Environment: From Science to Action is an eight-module journey through the full climate story: how the climate system works, the evidence that human activity is warming the planet, where emissions come from, how impacts and vulnerability are distributed, and what mitigation, adaptation and justice-oriented solutions actually look like. The course closes with practical climate action — communication, project design and monitoring — and a dedicated module on air pollution and environmental health, making it one of the most complete environmental foundations available on Tapi Learn.

Course information

Course	Climate Change & the Environment: From Science to Action
Instructor	Dr. Samuel Ochieng
Level	Beginner
Structure	8 modules · 50 lessons · 10 weeks
Assessment	Module quizzes (pass mark 60%) and a final test (pass mark 80%). Certificate issued on final success, verifiable at acla.io/verify .

What you will be able to do

1. Define weather, climate, climate variability, climate change, global warming and the greenhouse effect accurately.
2. Explain why climate is a long-term statistical description rather than a single weather event.
3. Describe the atmosphere, ocean, cryosphere, land and biosphere as interacting parts of the Earth system.
4. Distinguish natural climate variability from the long-term warming trend caused predominantly by human activities.
5. Identify major greenhouse gases and their principal human sources.
6. Explain the evidence that human activities are driving recent global warming.
7. Interpret basic temperature, atmospheric CO₂, ocean heat and sea-level graphs.
8. Use evidence-based reasoning to distinguish scientific uncertainty from scientific ignorance.

How to use this study guide

This guide is the complete companion to the Tapi Learn mobile course. Each chapter corresponds to one course module and reproduces every lesson in full, including the key takeaways. Read a lesson in the app, then revisit the same text here to revise; the structure and headings match the in-app lesson reader. After finishing a module, take the module quiz in the app (60% to pass), and after all modules, the final test (80%

to pass) to earn your verified ACLA certificate of completion.

Module 1: Climate Change Fundamentals: Climate, Weather and the Earth System

Define weather, climate, climate variability, climate change, global warming and the greenhouse effect accurately. Explain why climate is a long-term statistical description rather than a single weather event. Describe the atmosphere, ocean, cryosphere, land and biosphere as interacting parts of the Earth system.

6 lessons · 19m

1.1 Weather versus climate

Weather describes the state of the atmosphere at a specific place and time, temperature, precipitation, wind, humidity, and cloud cover over hours or days. Climate, by contrast, describes the pattern of weather conditions over a much longer period, typically defined by meteorologists and the World Meteorological Organization as a minimum of 30 years, encompassing averages, variability, and the frequency of extremes. The distinction is not merely one of timescale but of what each concept can and cannot tell us: weather is inherently chaotic and unpredictable beyond about ten to fourteen days, while climate reflects statistical patterns that remain meaningful and predictable even though individual days within that pattern vary enormously. A commonly used analogy, often attributed to climate scientists explaining this distinction to the public, compares climate to a person's general mood or temperament and weather to their mood on any single day, a generally cheerful person can still have an occasional bad day without contradicting their overall temperament, just as a cold winter week does not contradict a long-term warming climate trend. This module trains learners to apply this distinction rigorously rather than intuitively. Consider the statement, "It snowed heavily in Texas in February 2021." This is a weather statement, a specific, short-term atmospheric event. By contrast, "Global average surface temperature has risen by approximately 1.1°C since the pre-industrial era" is a climate statement, based on decades of aggregated data. A third statement, "Model projections suggest East Africa will experience more intense but less frequent rainfall events by 2050," is a climate projection a forward-looking statistical statement based on climate models rather than an observation of current or past patterns. Learners should practise sorting real headlines and observations into these categories, since conflating a single weather event with evidence for or against long-term climate trends is one of the most common and consequential errors in public discourse about climate change.

1.2 The Earth system

Understanding climate requires understanding the Earth as an interconnected system composed of five major components, or "spheres," that continuously exchange energy, water, and carbon. The atmosphere is the layer of gases surrounding Earth, responsible for weather, the greenhouse effect, and the transport of heat and moisture around the globe. The hydrosphere, encompassing oceans, lakes, rivers, and groundwater, stores and moves the vast majority of the planet's water and heat, the oceans alone have absorbed over 90% of the excess heat trapped by rising greenhouse gas concentrations since the industrial era. The cryosphere includes ice sheets, glaciers, sea ice, and permafrost, which reflect sunlight, store freshwater, and, critically, can release additional greenhouse gases such as methane when permafrost thaws. The geosphere, or land surface and solid Earth, includes soils, rocks, and volcanic activity, which both store carbon and, over geological timescales, release it. The biosphere comprises all living organisms, which absorb and release carbon through photosynthesis, respiration, and decomposition, making forests, oceans, and soils central to the global carbon cycle. These five components are not isolated; they are linked through feedback loops that can amplify or dampen change. A well-known example is the ice-albedo feedback: as rising temperatures melt sea ice (cryosphere), the darker ocean water beneath absorbs more solar energy than the reflective ice did, which further warms the region and melts more ice, an amplifying, or positive, feedback. Conversely, increased plant growth in a warmer, more CO₂-rich atmosphere can absorb more carbon (a biosphere response), partially offsetting some warming, a dampening, or negative, feedback, though its capacity is limited. A practical example for learners: the 2020 Siberian heatwave illustrates cross-sphere interaction directly — atmospheric warming triggered permafrost thaw (cryosphere-geosphere), which released stored methane and destabilised infrastructure, while simultaneously fuelling wildfires that released carbon from the biosphere back into the atmosphere, reinforcing the original warming signal. Learners should be able to trace at least one such feedback pathway through two or more Earth system components.

1.3 Climate variability and change

Climate systems vary naturally across multiple timescales, and distinguishing this natural variability from a persistent, directional change is a core analytical skill. Seasonal variability refers to the regular, predictable cycle of temperature and precipitation driven by Earth's axial tilt and orbit, summers and winters, wet and dry seasons. Interannual variability refers to year-to-year differences driven by recurring but irregular climate patterns, the most significant global example being the El Niño-Southern Oscillation (ENSO), which shifts ocean temperatures in the tropical Pacific and alters rainfall and temperature patterns worldwide roughly every two to seven years. Decadal variability operates over longer, multi-year to multi-decade cycles, such as the Pacific Decadal Oscillation, which can mask or temporarily amplify underlying long-term trends. Natural drivers of variability and change include solar cycles (fluctuations in the sun's energy output over roughly 11-year cycles), volcanic eruptions (which inject reflective aerosols into the stratosphere, causing short-term cooling, as seen after the 1991 Mount Pinatubo eruption), and the ocean-atmosphere oscillations described above. The critical distinction this lesson establishes is that variability refers to fluctuations around a relatively stable long-term average, whereas climate change refers to a persistent shift in that underlying average itself, observable only when data are examined over multi-decadal timescales that filter out short-term noise. A clear example: East Africa's rainfall shows strong interannual variability linked to ENSO, with El Niño years typically bringing wetter conditions and La Niña years bringing drought risk to the region, meaning a single dry year in Kenya could plausibly reflect a La Niña pattern rather than long-term climate change. However, when researchers analyse rainfall and temperature records over 50-plus years, they can identify a persistent warming trend and shifting rainfall onset patterns that exist independently of, and superimposed upon, this natural ENSO-driven variability. Learners should practise identifying which category, seasonal, interannual, decadal variability, or persistent change — best explains a given climate observation.

1.4 The greenhouse effect

The greenhouse effect is a natural physical process, without which Earth would be uninhabitable for life as we know it. The sun's energy reaches Earth largely as visible light, which passes through the atmosphere and warms the surface. The warmed Earth then radiates energy back toward space as infrared (heat) radiation. Certain atmospheric gases, primarily water vapour, carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), absorb and re-emit this outgoing infrared radiation in all directions, including back toward the surface, trapping heat within the lower atmosphere. Without this natural effect, calculations based on the amount of solar energy Earth receives suggest the planet's average surface temperature would be around -18°C, roughly 33°C colder than the actual observed average of about 15°C, making the natural greenhouse effect essential to sustaining liquid water and life. The problem addressed throughout the rest of this course is not the greenhouse effect itself, but its human-driven intensification. Since the industrial revolution, burning fossil fuels (coal, oil, and natural gas), deforestation, and industrial and agricultural activity have sharply increased atmospheric concentrations of CO₂ (from roughly 280 parts per million pre-industrially to over 420 ppm today), methane, and nitrous oxide. This increased concentration of heat-trapping gases strengthens the greenhouse effect beyond its natural baseline, causing more outgoing infrared radiation to be retained rather than escaping to space, which is the fundamental physical mechanism driving observed global warming. A helpful analogy for learners is a blanket: a moderate, natural amount of blanket (the natural greenhouse effect) keeps a sleeper comfortably warm, but adding several additional layers (the human-enhanced greenhouse effect from added CO₂ and other gases) traps progressively more heat, eventually causing overheating. Learners should be able to explain, in their own words, both why the natural greenhouse effect is beneficial and necessary, and why increasing greenhouse gas concentrations — rather than the effect's mere existence, is the specific mechanism of concern in contemporary climate science.

1.5 Case Study: Nairobi, coastal Kenya, and a small island community

Nairobi, coastal Kenya, and a small island community. Compare how the same global warming signal can interact with local rainfall, heat, elevation, ocean exposure, and livelihoods. Nairobi, at high elevation and inland, experiences warming primarily through rising temperatures and shifting rainy-season onset affecting agriculture and water supply. Coastal Kenya (e.g., Mombasa or Kilifi) experiences the same global warming signal compounded by sea-level rise, coastal erosion, and warming ocean waters affecting fisheries and coral reefs. A small island community (e.g., in the Pacific or Indian Ocean) experiences the same underlying global temperature trend as an existential threat through combined sea-level rise, saltwater intrusion into freshwater supplies, and increased cyclone intensity. Learners should identify which local factors (elevation, ocean proximity, livelihood dependence) determine why an identical global signal produces such different local consequences.

1.6 Hands-On Activity

Weather-to-climate classification lab: collect 10 recent local weather observations or headlines. Classify each as weather, climate evidence, climate projection, or neither. Explain each decision in one sentence. Then write a 150-word reflection: “Why can one cold day not disprove global warming?”

Module 2: The Science and Evidence of Human-Caused Climate Change

Identify major greenhouse gases and their principal human sources. Explain the evidence that human activities are driving recent global warming. Interpret basic temperature, atmospheric CO₂, ocean heat and sea-level graphs.

6 lessons · 19m

2.1 Greenhouse gases and radiative forcing

Radiative forcing describes the change in energy balance at the top of Earth's atmosphere caused by a given factor, such as an increase in a greenhouse gas concentration, measured in watts per square metre. Different greenhouse gases contribute to this forcing in different ways and at different magnitudes. Carbon dioxide (CO₂) is the largest single contributor to human-caused warming because of the sheer volume emitted (primarily from fossil fuel combustion and land-use change) and its long atmospheric lifetime, a significant fraction of CO₂ emitted today will still be influencing the climate system centuries from now, since it is removed only slowly through ocean absorption and land uptake. Methane (CH₄), emitted from livestock, rice paddies, landfills, and fossil fuel extraction, is far more potent per molecule (roughly 80 times more warming over a 20-year period) but persists in the atmosphere for only about 12 years before breaking down, meaning methane reductions deliver relatively fast climate benefits. Nitrous oxide (N₂O), largely from agricultural fertiliser use, is both potent and long-lived (over 100 years), while fluorinated gases (HFCs, PFCs, SF₆), used in refrigeration and industrial processes, are synthetic, extremely potent per molecule, and in some cases persist for thousands of years. Water vapour is the most abundant greenhouse gas by far, but it behaves fundamentally differently from the others: rather than being a direct driver of warming, it acts primarily as an amplifying feedback. As the atmosphere warms from other greenhouse gases, it can hold more water vapour (following the Clausius-Clapeyron relationship), and since water vapour itself traps heat, this creates a reinforcing cycle that roughly doubles the initial warming caused by CO₂ and other gases. Unlike CO₂, water vapour has a very short atmospheric residence time (days), so it responds to, rather than independently drives, the underlying temperature trend. A useful example for learners: comparing a tonne of methane and a tonne of CO₂ emitted today illustrates why climate policy often distinguishes short-lived and long-lived forcers, a methane reduction achieved this decade (for example, capping leaks from a natural gas pipeline in the US Permian Basin) delivers rapid, but not permanent, cooling benefit, while a tonne of CO₂ avoided delivers a smaller immediate effect but compounds in benefit over centuries, informing why international climate strategies increasingly pursue both fast methane cuts and deep, sustained CO₂ reductions simultaneously.

2.2 Sources and sinks

Greenhouse gas emissions originate from a relatively small number of major economic sectors, and understanding this breakdown is essential for evaluating mitigation priorities. Energy supply (electricity and heat generation, still dominated globally by coal, oil, and natural gas) is typically the single largest source, followed by industry (cement, steel, and chemical manufacturing, which release CO₂ both from energy use and from the chemical processes themselves), transport (road, aviation, and shipping, overwhelmingly reliant on fossil fuels), buildings (heating, cooling, and lighting, both from on-site fuel combustion and the electricity they consume), agriculture (methane from livestock and rice cultivation, nitrous oxide from fertiliser use), land-use change (primarily deforestation, which releases stored carbon and reduces future carbon uptake capacity), and waste (methane from decomposing organic waste in landfills). Countering these emissions are carbon sinks, natural or managed systems that absorb more carbon than they release. Natural sinks include forests and vegetation (through photosynthesis), oceans (which absorb roughly a quarter of annual human CO₂ emissions, though this comes with the cost of ocean acidification), and soils. Managed sinks include afforestation and reforestation projects, improved agricultural soil management that increases carbon storage, and emerging technologies such as direct air capture and carbon capture and storage (CCS) at industrial facilities. A concrete example illustrating the sources-and-sinks balance is the Congo Basin rainforest, the world's second-largest tropical forest, which currently functions as a net carbon sink, absorbing more carbon than it releases even as some clearing occurs at its margins, in contrast to the Amazon, where deforestation rates in some recent years have pushed parts of the forest toward becoming a net carbon source rather than a sink, illustrating how land-use decisions can flip a natural sink into an emission source. Learners should be able to map at least one activity in their own community (a factory, a rice farm, a landfill, a forest) to its correct source-or-sink category and sector.

2.3 Lines of evidence

Confidence that the climate system is warming and changing does not rest on any single dataset, but on multiple, independent lines of evidence that converge on the same conclusion, a principle scientists call the "consilience of evidence." Warming land and ocean surface temperature records, compiled independently by multiple agencies (NASA, NOAA, the UK Met Office, Berkeley Earth) using different methodologies, all show a consistent warming trend of approximately 1.1°C since the pre-industrial era. Rising atmospheric greenhouse gas concentrations, directly measured continuously since 1958 at the Mauna Loa Observatory in Hawaii and now at dozens of stations worldwide, show CO₂ rising from about 315 ppm in 1958 to over 420 ppm today. Ocean heat content, measured by a global network of autonomous Argo floats, shows that the ocean has absorbed over 90% of the excess heat trapped by rising greenhouse gases. Shrinking ice, including Arctic sea ice extent (declining roughly 13% per decade in September), mountain glaciers worldwide, and the Greenland and Antarctic ice sheets is documented through satellite observation and direct field measurement. Sea-level rise, tracked via tide gauges since the 19th century and satellite altimetry since 1993, shows acceleration consistent with thermal expansion and ice melt. Ecosystem responses, including shifting species ranges toward the poles and higher elevations, and earlier spring flowering and migration timing, provide independent biological confirmation. The strength of this evidence lies precisely in its independence: temperature records, direct atmospheric gas measurements, satellite ice observations, and biological field studies are collected by entirely different scientific communities using different instruments and methods, yet they all point toward the same underlying pattern of warming and associated change. A compelling example for learners is to compare Arctic sea ice extent data (satellite-based, since 1979) against glacier mass balance data (field-based, ground measurement, since the mid-20th century), two entirely different measurement techniques, in different locations, operated by different institutions, both showing consistent, accelerating ice loss. Learners should practise identifying which specific line of evidence best supports a particular claim about the climate system, rather than treating all evidence as interchangeable.

2.4 Attribution and scientific confidence

Attribution science addresses the specific question of whether, and to what extent, human activity has caused an observed change in the climate system, or an individual extreme weather event. This is done not by simple correlation, but through a rigorous comparison: researchers use climate models to simulate the world as it would have evolved without human greenhouse gas emissions (a "counterfactual" world), and compare this to models and observations that include human forcing. Where the observed change closely matches the human-forced simulation, but not the natural-only counterfactual, scientists attribute the change to human influence with a stated level of confidence. This module introduces the calibrated language the IPCC and broader scientific community use to communicate confidence precisely, since these terms are not casual synonyms but carry specific statistical meaning. "Likely" indicates a 66–100% probability; "very likely" indicates 90–100%; and "extremely likely" indicates 95–100% probability, based on formal expert assessment of the evidence and model agreement. The IPCC's Sixth Assessment Report states it is "unequivocal" that human influence has warmed the atmosphere, ocean, and land, the strongest confidence category available, reflecting the overwhelming convergence of evidence described in Lesson 2.3. Attribution science has advanced rapidly for extreme events specifically, through a field known as extreme event attribution. Rather than claiming climate change "caused" a single heatwave or flood outright, researchers now routinely quantify how much more likely or more intense a specific event was made by climate change. For example, the World Weather Attribution initiative found that the 2021 Pacific Northwest heatwave, which produced temperatures previously considered virtually impossible in the region, was made at least 150 times more likely by human-caused climate change — a precise, probabilistic statement rather than a simple causal claim. Learners should practise expressing attribution findings using this probabilistic framing rather than the imprecise language of direct causation.

2.5 Case Study: attribution of a heatwave

attribution of a heatwave. Learners distinguish between "climate change caused the event" and "climate change altered the probability or intensity of the event." Using the 2021 Pacific Northwest heatwave or a comparable regional example, learners should practise rewriting a media headline that claims direct causation ("Climate change caused this heatwave") into a scientifically precise attribution statement ("Climate change made this heatwave at least X times more likely and Y degrees more intense"), reinforcing the calibrated, probabilistic language introduced in Lesson 2.4.

2.6 Hands-On Activity

Evidence audit: select three climate indicators (temperature, sea level, ocean heat, glacier mass, CO₂, etc.). For each, record what is observed, the time span, the direction of change, one plausible mechanism and one limitation of the dataset.

Module 3: Causes, Drivers and Emissions Across the Economy

Map major emissions sources across energy, transport, industry, buildings, food, agriculture and land use. Explain how fossil-fuel combustion and land-use change alter atmospheric greenhouse-gas concentrations.

Differentiate territorial, consumption-based and sectoral perspectives on emissions.

6 lessons · 19m

3.1 Energy and electricity

Energy systems are at the centre of climate mitigation because the production and use of energy account for a substantial share of global greenhouse-gas emissions. Electricity is generated through a combination of coal, oil, natural gas, nuclear power, hydropower, wind, solar, geothermal and other renewable sources. The climate impact of electricity depends largely on the technologies and fuels used to generate it. Coal generally has a high carbon intensity because burning it releases substantial amounts of carbon dioxide (CO₂). Oil and natural gas also produce CO₂ when combusted, while natural-gas systems can additionally contribute to warming through methane leakage during extraction, processing and transportation. Growing populations, urbanisation, digital technologies, cooling demand and industrialisation are increasing electricity demand in many regions. Meeting this demand while reducing emissions requires a combination of renewable energy, energy efficiency, storage, modern electricity grids and, where appropriate, other low-carbon technologies. Solar and wind power can generate electricity without direct combustion emissions. However, their variable output creates a need for flexible electricity systems. Battery storage, pumped-storage hydropower, demand management, interconnections and flexible generation can help balance supply and demand. Energy efficiency is equally important. Efficient buildings, appliances, motors, lighting and industrial equipment can provide the same services using less energy. For example, replacing inefficient lighting with LEDs can reduce electricity consumption while maintaining adequate illumination. Example: A university currently powered largely by fossil-fuel electricity could reduce emissions through rooftop solar, efficient lighting and cooling, building-energy management, battery storage and improved procurement of renewable electricity.

Further Reading IPCC – Climate Change 2022: Mitigation of Climate Change International Energy Agency – Renewables International Energy Agency – Energy Efficiency IRENA – Renewable Energy Statistics UN – Causes and Effects of Climate Change

3.2 Transport and cities

Examine road, rail, aviation and shipping; discuss urban form, public transport, walking, cycling, logistics and vehicle efficiency. Transport enables people and goods to move between homes, workplaces, schools, markets and communities, but it is also an important source of greenhouse-gas emissions. Major transport modes include road, rail, aviation and shipping, each with different technologies, energy requirements and emission profiles. Road transport is particularly important because of widespread dependence on cars, motorcycles, buses and trucks. Emissions can be reduced through vehicle efficiency, electrification, cleaner fuels, improved public transport and better urban planning. However, technology alone is not enough. Urban form strongly influences how much and how far people need to travel. Compact, connected communities with homes, employment, schools and services located closer together can reduce travel demand. Public transport, walking and cycling can provide low-emission mobility while delivering additional benefits such as improved physical activity, reduced congestion and better use of urban space. For example, a city that invests exclusively in expanding roads may temporarily increase vehicle capacity but may also encourage additional car use. In contrast, investment in reliable buses or rail, safe pedestrian infrastructure, cycling networks and integrated land-use planning can provide residents with alternatives to private vehicles. Freight and logistics are also important. Businesses can reduce emissions through route optimisation, consolidated deliveries, efficient warehouses, rail freight and low-emission vehicles. Aviation and shipping present additional challenges because long-distance travel and freight require high energy densities. Efficiency improvements, alternative fuels, operational changes and technological innovation are therefore important.

3.3 Food, agriculture and land

Food production and land use are deeply connected to climate change. Agricultural systems emit several important greenhouse gases, particularly methane (CH₄), nitrous oxide (N₂O) and carbon dioxide (CO₂). At the same time, forests, soils, wetlands and other ecosystems can store substantial quantities of carbon. Livestock are an important source of methane, particularly through enteric fermentation in ruminant animals such as cattle and sheep. Manure management can also produce methane and nitrous oxide. Rice cultivation, especially flooded rice systems, can generate methane because waterlogged soils create conditions favourable for methane-producing microorganisms. Nitrous oxide is strongly associated with fertiliser and manure management. Applying more nitrogen fertiliser than crops can efficiently use may increase emissions while also creating economic and environmental costs. Land-use change is another major concern. Deforestation and forest degradation release stored carbon and reduce the capacity of ecosystems to remove CO₂ from the atmosphere. Conversion of forests to agricultural land, settlements or other uses can therefore create significant emissions. Mitigation opportunities include improved fertiliser management, better livestock feeding and manure practices, alternative rice-water management, agroforestry, restoration of degraded land, forest conservation and sustainable soil management. Example: A farming community could reduce emissions by applying fertiliser according to crop requirements, integrating trees into farms, improving livestock feeding, protecting nearby forests and using water-management techniques that reduce methane emissions from rice production. It is important, however, to avoid treating agriculture only as an emissions problem. Food systems must continue to provide nutrition, livelihoods and economic opportunities, particularly for smallholder farmers. Effective climate action should therefore combine mitigation with resilience, food security and sustainable livelihoods.

3.4 Industry, buildings and consumption

Industry, buildings and consumption connect climate change to almost every aspect of modern economic life. Major industrial emission sources include cement, steel, chemicals, mining, refining and manufacturing. Buildings generate emissions through construction materials, electricity use, heating, cooling, lighting and appliances. Cement production illustrates why some sectors are difficult to decarbonise. Emissions arise not only from the energy required to heat materials but also from the chemical process involved in producing clinker. Steel production similarly requires substantial energy and can generate significant emissions depending on the production technology and energy source. The buildings sector presents major opportunities for mitigation. Energy-efficient design, insulation, natural ventilation, efficient cooling, heat pumps, efficient appliances and renewable electricity can reduce operational emissions. In hot climates, thoughtful building orientation, shading and passive cooling can reduce dependence on mechanical air conditioning. Consumption also matters. Products require resources and energy throughout their life cycle, including extraction, manufacturing, transport, use and disposal. Lifecycle thinking helps identify emissions that may otherwise remain invisible. Waste management is another component. Reducing unnecessary consumption, increasing reuse and recycling, composting suitable organic waste and improving landfill management can reduce emissions while conserving resources. Example: A university constructing a new laboratory could reduce its climate footprint by selecting lower-carbon construction materials, designing for passive cooling, installing efficient equipment, using renewable electricity and creating a procurement policy favouring durable and repairable products. The central concept is that mitigation should not focus only on individual technologies. It should consider how materials, buildings, services, consumption and waste interact across the entire system. Further Reading IPCC – Climate Change 2022: Mitigation of Climate Change International Energy Agency – Industry International Energy Agency – Buildings UN Environment Programme – Global Resources Outlook

3.5 Carbon footprints and systems thinking

A carbon footprint is a way of estimating greenhouse-gas emissions associated with an activity, organisation, product, household or service. Carbon-footprint analysis helps learners move from general statements about climate change to measurable questions: What produces emissions? How much? Where do emissions occur? What can realistically be changed? A basic assessment begins with activity data. Examples include litres of fuel consumed, kilowatt-hours of electricity used, kilometres travelled, kilograms of fertiliser applied or tonnes of waste generated. These data can then be combined with appropriate emission factors to estimate greenhouse-gas emissions. Organisational emissions are often discussed conceptually using three scopes: Scope 1: Direct emissions from sources controlled or owned by an organisation, such as fuel burned in its vehicles or generators. Scope 2: Indirect emissions associated with purchased electricity, heat or steam. Scope 3: Other indirect emissions occurring across an organisation's value chain, such as purchased goods, business travel, employee commuting, waste and use of products. For example, a university's diesel generator produces Scope 1 emissions, purchased grid electricity generally contributes to Scope 2, while staff air travel and purchased equipment may contribute to Scope 3. Systems thinking encourages learners to examine interactions rather than isolated activities. An intervention may reduce emissions in one area while increasing them elsewhere. This is particularly important when considering the rebound effect. For example, improving vehicle fuel efficiency can reduce fuel use per kilometre, but if lower operating costs encourage people to drive significantly more, some expected emissions savings may be offset. Mini Carbon Hotspot Assessment Choose a school, office, household, farm or small business. Identify five major emission sources, rank them according to likely significance, and propose three realistic emission reductions that do not compromise essential services. Explain why each intervention is feasible and identify what information would be needed to measure its success. Further Reading GHG Protocol – Corporate Standard GHG Protocol – Scope 2 Guidance GHG Protocol – Corporate Value Chain (Scope 3) Standard IPCC – Climate Change 2022: Mitigation of Climate Change United Nations – Causes and Effects of Climate Change

3.6 Hands-On Activity

Mini carbon hotspot assessment: choose a school, office, household, farm or small business. Map five major emission sources, rank them by likely significance, and propose three reductions that do not compromise essential services.

Module 4: Climate Impacts, Risk, Vulnerability and Adaptation

Describe major observed and projected climate impacts on people, ecosystems, infrastructure and economies. Explain hazard, exposure, vulnerability, adaptive capacity and risk. Assess a basic climate risk using a structured framework.

6 lessons · 17m

4.1 Climate hazards

Climate hazards are potentially damaging climate-related events, trends or physical conditions that can harm people, ecosystems, infrastructure and economies. Major hazards include extreme heat, heavy precipitation and flooding, drought, tropical and extra-tropical storms, sea-level rise, wildfire weather and compound events. Heat is increasingly important because rising temperatures can intensify heatwaves and create dangerous conditions for human health, agriculture, labour productivity and electricity systems. For example, an urban heatwave can increase heat stress among outdoor workers while simultaneously increasing electricity demand for cooling. Heavy precipitation can overwhelm drainage systems, trigger floods and cause landslides. In contrast, prolonged drought can reduce water availability, crop yields, hydropower generation and livestock productivity. Storms may damage buildings, roads, electricity networks and coastal communities. Sea-level rise increases the long-term risk of coastal flooding, erosion and saltwater intrusion. A particularly important concept is the compound event, when multiple hazards or climate stresses occur together or sequentially. For example, a region might experience extreme heat followed by drought, creating severe pressure on water supplies and agriculture. Similarly, heavy rainfall occurring after prolonged rainfall can produce exceptionally damaging flooding. Example: A coastal city may simultaneously face sea-level rise, intense rainfall and storm surge. Designing its resilience around only one hazard could leave it vulnerable to the combined event. Further reading IPCC AR6 Working Group II – Impacts, Adaptation and Vulnerability IPCC AR6 Synthesis Report UNDRR Climate Risk Assessment Guidance

4.2 Exposure and vulnerability

A climate hazard does not automatically produce the same level of risk everywhere. Risk emerges from the interaction of hazard, exposure and vulnerability. Exposure refers to the people, infrastructure, ecosystems, economic activities or other assets located in areas where hazards may occur. Vulnerability describes the degree to which those exposed systems are susceptible to harm and their ability to cope, respond and recover. Consider two communities experiencing the same flood. One may have elevated houses, functioning drainage, emergency services, savings and insurance. Another may have informal settlements in flood-prone areas, inadequate drainage, limited savings and poor access to emergency assistance. Although the hazard is similar, the resulting risk and losses can be dramatically different. Vulnerability is influenced by economic conditions, health, age, disability, housing quality, access to information, governance, infrastructure and social inequality. Consequently, climate risk is also an issue of development and equity. Example: During an extreme heat event, an affluent household with air conditioning, reliable electricity and access to healthcare may be considerably less vulnerable than an elderly person living alone in a poorly ventilated dwelling. Exposure can also change through development. Constructing settlements, industries or critical infrastructure in floodplains increases the number of assets exposed to flooding. Effective risk assessment therefore asks three questions: What hazard could occur? Who or what is exposed? Why might those exposed be particularly vulnerable? This framework enables planners to move beyond simply identifying hazards toward designing targeted risk-reduction interventions. Further reading UNDRR Technical Guidance on Comprehensive Risk Assessment and Planning UNDRR Handbook on Risk Knowledge for Multi-Hazard Early Warning Systems IPCC AR6 Working Group II

4.3 Sectoral impacts

Climate change affects interconnected sectors rather than isolated systems. Changes in temperature, rainfall, extreme events and sea level can produce cascading impacts across water, food, health, ecosystems, cities, infrastructure, livelihoods and human mobility. Water Drought can reduce water availability, while intense rainfall can cause flooding and contaminate water supplies. Changing precipitation patterns can also challenge water-resource planning. Food and agriculture Heat, drought, floods, changing growing seasons and emerging pests can reduce agricultural productivity. For example, a drought affecting maize production can simultaneously reduce household income, increase food prices and worsen food insecurity. Health Climate hazards can cause direct injuries and deaths while also increasing risks from heat stress, infectious diseases, malnutrition and mental-health pressures. Ecosystems Warming, drought, fires and changing rainfall can degrade forests, wetlands, coral reefs and other ecosystems. Ecosystem degradation can subsequently increase human vulnerability. Cities and infrastructure Floods, heatwaves and storms can damage roads, bridges, drainage networks, buildings, telecommunications and electricity systems. Infrastructure failure can create cascading consequences—for example, a flooded road can prevent health workers and emergency services from reaching affected communities. Livelihoods and displacement Farmers, fishers, pastoralists, tourism workers and informal-sector workers can experience income losses. Repeated disasters may eventually force households to relocate temporarily or permanently. Example: A severe drought can create a chain reaction: reduced rainfall → lower crop production → reduced household income → higher food prices → increased malnutrition → migration. This interconnectedness means adaptation should increasingly use multi-sectoral planning rather than isolated projects. IPCC assessments emphasize integrated approaches that can generate benefits across multiple systems. Further reading IPCC AR6 WGII Report IPCC Interactive Atlas UNDRR Global Assessment Reports

4.4 Adaptation pathways

Climate adaptation pathways represent the strategic evolution of decision-making processes that enable societies to navigate an uncertain climate future. As climate impacts intensify across Africa, professionals must move beyond isolated interventions to implement adaptive systems that can evolve with changing risk profiles and scientific understanding.

Understanding Adaptation Pathways

Adaptation pathways are sequences of adaptive actions that can be implemented over time, with the flexibility to adjust based on observed climate impacts and effectiveness of previous interventions. Unlike static adaptation plans, pathways acknowledge uncertainty and incorporate decision-making under changing conditions.

Key characteristics of effective adaptation pathways:

- **Iterative planning:** Regular reassessment of risks and effectiveness
- **No-regret options:** Actions that provide benefits regardless of future climate scenarios
- **Co-benefits:** Solutions that address multiple development challenges simultaneously
- **Participatory processes:** Inclusive governance that empowers local stakeholders

Implementation Approaches

Technical Implementation

- **Infrastructure adaptation:** Climate-resilient infrastructure that incorporates future projections
- **Ecosystem-based adaptation:** Nature-based solutions that leverage ecosystem services
- **Early-warning systems:** Multi-hazard warning systems with clear communication protocols
- **Health-system adaptation:** Climate-informed healthcare planning and emergency response

Governance Approaches

- **Policy integration:** Climate considerations embedded in sectoral policies
- **Institutional coordination:** Cross-departmental collaboration to address complex risks
- **Knowledge management:** Systems for sharing climate information and best practices
- **Finance mechanisms:** Innovative funding approaches including public-private partnerships

Case Study: Kenya's National Adaptation Plan

Kenya's National Adaptation Plan (2015-2030) exemplifies a comprehensive adaptation pathway approach. The plan integrates multiple sectors and scales, with specific targets including:

- 100% climate-smart agriculture adoption in arid and semi-arid lands by 2030
- 2.7 million hectares under sustainable land management
- Climate-resilient water infrastructure serving 5.6 million people
- Early-warning systems covering all 47 counties by 2025

The implementation uses a "no-regret" approach, with actions that provide immediate development benefits while building long-term resilience. For example, the **Water Fund** in Nairobi integrates upstream conservation with downstream water security, providing immediate clean water while building drought resilience.

Professional Guidance

In practice:

- Assess multiple time horizons (short, medium, long-term) when planning interventions
- Monitor climate trends and adaptation effectiveness through regular indicators
- Design flexible infrastructure that can be upgraded as risks intensify
- Engage local communities in co-designing adaptation solutions
- Mainstream adaptation into development planning and budgeting processes

"The best adaptation pathways are not predetermined routes but well-designed decision processes that allow us to navigate uncertainty while making progress toward our goals." — IPCC AR6

Learn more

- WMO Early Warnings for All
- UNEP Adaptation Gap Report 2025
- UNDRR Multi-Hazard Early Warning Guidance

Key takeaways

- ✓ Adaptation pathways represent iterative decision-making processes that evolve with changing climate risks and knowledge.
- ✓ Effective adaptation combines technical solutions with governance approaches that ensure long-term resilience and equity.
- ✓ African adaptation planning must balance immediate development needs with building capacity for future climate uncertainty.

4.5 Limits and maladaptation

Understanding adaptation limits and maladaptation is critical for climate professionals who must design resilient solutions that don't create new vulnerabilities. As climate impacts accelerate, practitioners must distinguish between what can be adapted to and what cannot, while ensuring interventions don't inadvertently worsen risks for other communities or future generations.

Adaptation Limits: Understanding Boundaries

Adaptation limits represent thresholds beyond which current measures can no longer effectively reduce climate risks. These limits are categorized as:

- **Soft limits:** Technically feasible but constrained by implementation barriers such as finance, technology, institutions, or social acceptance
- **Hard limits:** Situations where adaptation cannot prevent unacceptable impacts or irreversible losses

In coastal African cities like Lagos, Nigeria, adaptation limits are becoming apparent. The city's population of over 14 million faces sea-level rise of up to 0.79m by 2100 under high-emission scenarios. Despite implementing measures like the Eko Atlantic City project (costing \$1.5 billion), the city still faces hard limits as some low-lying areas cannot be protected economically, potentially displacing over 3 million residents by 2050.

Maladaptation: Unintended Consequences

Maladaptation occurs when interventions increase vulnerability, exposure, or risk for the same or different populations. The IPCC identifies several forms:

- Interventions that reduce immediate risks but increase vulnerability long-term
- Solutions that benefit some groups at the expense of others
- Actions that reduce flexibility for future adaptation options

In practice:

"Maladaptation is not a technical failure but a governance and equity challenge that requires inclusive planning and foresight."

A clear example is the 2016-2020 drought response in Cape Town, South Africa, where intensive groundwater extraction to supplement water supplies risked contaminating aquifers with saline intrusion. This "Day Zero" response, while preventing immediate catastrophe, potentially compromised water security for future generations in this water-scarce region.

Professional Guidance for Practitioners

In practice, climate professionals should:

- Conduct **climate risk assessments** that explicitly identify potential maladaptation pathways
- Implement **adaptive management** approaches with regular monitoring and evaluation
- Apply **participatory planning** to ensure solutions address diverse community needs
- Design **no-regret options** that provide benefits regardless of future climate scenarios
- Consider **cross-sectoral impacts** to avoid unintended consequences in other systems

Learn more

- IPCC AR6 Synthesis Report – Adaptation Limits and Maladaptation
- UNDRR Comprehensive Climate Risk Assessment Guidance
- UNEP Adaptation Gap Report 2025
- UNDRR Global Assessment Reports

Key takeaways

- ✓ Adaptation limits exist and must be acknowledged in climate planning, with soft limits representing implementation barriers and hard limits representing unavoidable losses.
- ✓ Maladaptation often stems from inequitable decision-making and short-term thinking, requiring inclusive and forward-looking approaches.
- ✓ Effective adaptation requires flexible pathways that continuously monitor changing conditions and adjust strategies while avoiding unintended consequences.

4.6 Hands-On Activity

Climate risk assessment is the foundation for effective adaptation planning, yet many professionals struggle to translate theoretical frameworks into actionable insights. This hands-on activity bridges that gap by guiding you through a systematic assessment process that reveals hidden vulnerabilities and opportunities for resilience building in African contexts.

Activity Overview

This exercise follows the **IPCC risk assessment framework** which defines risk as a function of **hazard**, **exposure**, and **vulnerability**. For this activity, select a specific local asset or livelihood system in your context (e.g., smallholder farming, coastal fishing, urban water supply, tourism revenue).

Step-by-Step Assessment Process

- Describe the system's components, dependencies, and value
- Note seasonal patterns and critical thresholds

1. Identify and characterize the asset/livelihood

- 1: Very unlikely (<10% probability in 10 years)
- 5: Very likely (>90% probability in 10 years)
- Consider historical data and climate projections

1. Assess hazard likelihood (1–5 scale)

- 1: Minimal exposure
- 5: Extreme exposure
- Consider physical presence, intensity, and duration

1. Evaluate exposure (1–5 scale)

- 1: Very low vulnerability
- 5: Extreme vulnerability
- Consider adaptive capacity, sensitivity, and social factors

1. Determine vulnerability (1–5 scale)

Case Study: Kenya's Tea Sector Adaptation

In Kenya's Kericho County, the tea industry faces increasing climate risks. A 2022 assessment by the Kenya Tea Development Agency revealed:

- Hazard likelihood: 4 (increasing drought frequency)
- Exposure: 5 (70% of plantations in high-risk zones)
- Vulnerability: 4 (high dependency on consistent rainfall, aging irrigation infrastructure)
- Risk score: 13/15 (high risk)

Adaptation measures implemented:

- Drought-resistant tea varieties (reduced water needs by 30%)
- Precision irrigation systems (investment: \$45 million)
- Water harvesting infrastructure (captured 2.5 million liters annually)

Trade-offs: Initial investment costs (\$2,500 per smallholder) versus long-term yield stability (projected 15% increase in drought years). Benefits primarily accrue to large-scale buyers and exporters, while smallholders bear implementation costs.

In Practice

- Always ground assessments in local knowledge and quantitative data
- Consider intersectional vulnerabilities (gender, age, disability)
- Prioritize no-regret options with co-benefits
- Monitor and reassess regularly as climate conditions change

"Risk assessment without adaptation planning is academic; adaptation planning without risk assessment is blind."

Learn more

- IPCC AR6 Working Group II Chapter 17: Africa
- African Adaptation Initiative (AAI) framework
- UNEP Africa Adaptation Gap Reports

Key takeaways

- ✓ Effective climate risk assessment requires balancing quantitative metrics with qualitative local knowledge.
- ✓ Adaptation measures must be evaluated not just for effectiveness but for distributional impacts and equity.
- ✓ The most successful adaptation approaches build multiple layers of resilience across temporal and spatial scales.

Module 5: Mitigation, Net Zero and Climate Solutions

Define mitigation, decarbonisation, net zero, carbon neutrality and negative emissions. Compare major mitigation options across energy, transport, buildings, industry, food and land. Apply a mitigation hierarchy: avoid, reduce, substitute, improve efficiency and address residual emissions responsibly.

7 lessons · 27m

5.1 What mitigation means

Climate change mitigation refers to human actions that reduce greenhouse gas (GHG) emissions or strengthen carbon sinks, the natural or engineered systems that remove carbon dioxide (CO₂) from the atmosphere. Unlike adaptation, which adjusts human and natural systems to actual or expected climate impacts, mitigation aims to limit the extent of climate change itself by intervening on both sides of the carbon-cycle equation: sources and sinks. The IPCC's Sixth Assessment Report (AR6) emphasizes that mitigation extends far beyond the energy sector, spanning agriculture, forestry, industry, transport, buildings and human behaviour, and that it requires systemic transformation rather than isolated technical fixes. Reducing sources means cutting emissions at their point of origin, switching from coal-fired to renewable electricity, improving vehicle fuel efficiency, or preventing methane leaks from oil and gas infrastructure. Enhancing sinks means increasing the capacity of forests, soils, wetlands and oceans to absorb and store carbon, or deploying engineered removal technologies such as direct air capture. Both approaches are necessary: AR6 finds that even with aggressive source reduction, some emissions will remain difficult to eliminate, meaning sink enhancement and removal will be indispensable to reaching net-zero targets. A useful analogy is a bathtub: emissions are water flowing in through the tap, while sinks are the drain. Stabilising atmospheric concentration requires turning down the tap, opening the drain wider, or both. Mitigation is measured in tonnes of CO₂-equivalent (CO₂e), a metric allowing different gases — carbon dioxide, methane, nitrous oxide, fluorinated gases — to be compared according to their global warming potential over a defined time horizon, typically 100 years. Effective mitigation strategies are context-specific, cost-effective and equitable, recognising that historical responsibility for emissions and capacity to act vary enormously between nations and communities. The lessons that follow explore, sector by sector, how these principles translate into concrete pathways for energy, land use, industry and carbon removal. Example A national oil and gas regulator mandates leak detection and repair (LDAR) programmes at production sites — a source-reduction measure that cuts fugitive methane emissions — while a coastal government simultaneously funds mangrove restoration to enhance a natural carbon sink and protect shorelines. Further Reading IPCC, Climate Change 2022: Mitigation of Climate Change (AR6 Working Group III) — <https://www.ipcc.ch/report/ar6/wg3/> UNEP, Emissions Gap Report 2025 — <https://www.unep.org/resources/emissions-gap-report-2025> IPCC, Global Warming of 1.5°C (Special Report) — <https://www.ipcc.ch/sr15/>

5.2 Energy transition

The energy sector generates roughly three-quarters of global greenhouse gas emissions, making its transformation the single largest lever for climate mitigation. The energy transition describes the shift from a fossil-fuel-dominated system to one powered predominantly by low-carbon sources, delivered more efficiently, and increasingly electrified across end uses. Renewable energy; solar photovoltaics, onshore and offshore wind, hydropower, geothermal and modern bioenergy has become the cheapest source of new electricity generation in most of the world, driven by rapid cost declines and manufacturing scale-up. Energy efficiency is often called the "first fuel" because reducing demand, through better building insulation, efficient appliances and industrial process optimisation, can cut emissions without new supply infrastructure. Electrification, replacing direct fossil-fuel combustion in vehicles, heating and industrial processes with electricity is essential because it lets sectors such as transport and buildings benefit from an increasingly clean grid. None of this works without modernised grids and storage. Grids must expand and become "smarter" to integrate variable renewable output, balance supply and demand in real time, and connect resources across regions. Storage technologies, lithium-ion batteries, pumped hydro and emerging long-duration options, smooth out the intermittency of solar and wind, while green hydrogen offers a way to store and transport renewable energy for sectors that are difficult to electrify directly. Not every low-carbon option suits every context: nuclear power, bioenergy and hydropower each carry distinct trade-offs around cost, safety, land use and water resources that must be weighed against local circumstances. The IEA's Net Zero by 2050 roadmap shows that a viable pathway exists, but it requires an unprecedented, coordinated build-out of clean generation, grids and storage this decade, alongside a rapid decline in unabated fossil fuel use. Example Kenya generates roughly 90% of its grid electricity from renewable sources — chiefly geothermal, hydropower and wind — demonstrating that a diversified renewable portfolio can anchor a national grid even without abundant sunshine or wind alone; Denmark, meanwhile, regularly meets over half its annual electricity demand from wind power. Further Reading IEA, Net Zero by 2050: A Roadmap for the Global Energy Sector — <https://www.iea.org/reports/net-zero-by-2050> IRENA, Publications on renewable energy transition — <https://www.irena.org/Publications> IEA, World Energy Outlook — <https://www.iea.org/topics/world-energy-outlook>

5.3 Land, food and nature

Land use, land-use change and agriculture contribute roughly a fifth to a quarter of global greenhouse gas emissions, while forests, soils and wetlands simultaneously offer some of the largest and most cost-effective mitigation opportunities available today. This lesson examines how conserving standing ecosystems, restoring degraded land and transforming food systems can cut emissions while delivering biodiversity, water and livelihood co-benefits. Forest conservation prevents the large, immediate emissions released when forests are cleared or burned, and protects long-term carbon stocks; tropical deforestation alone accounts for a significant share of land-sector emissions. Restoration, reforestation, agroforestry, and mangrove and peatland rehabilitation, rebuilds sink capacity over time, though it can take years to decades to reach mature carbon storage. Sustainable agriculture practices such as no-till farming, cover cropping, agroforestry and precision fertiliser use help build soil organic carbon, a globally significant reservoir, while reducing input-related emissions. Livestock and rice systems are major sources of methane, a potent short-lived climate pollutant; measures such as improved feed additives, better manure management, and alternate wetting-and-drying rice irrigation can substantially cut methane without necessarily reducing production. Food-system change extends beyond the farm gate: reducing food loss and waste, estimated at roughly a third of food produced globally, and shifting diets in high-consumption regions toward more plant-based patterns can meaningfully lower demand-side emissions while easing pressure on land. Crucially, land-sector mitigation must be pursued alongside food security and the rights of local and Indigenous communities, who often steward the most carbon-rich and biodiverse landscapes; poorly designed conservation or offset schemes risk displacing people or undermining livelihoods. Example Africa's Great Green Wall initiative aims to restore 100 million hectares of degraded land across the Sahel, combining reforestation, sustainable agriculture and rural livelihoods; commercial dairy operations in several countries have begun using methane-inhibiting feed additives to cut enteric methane from cattle without reducing milk yield. Further Reading FAO, Climate Change resources and data — <https://www.fao.org/climate-change/en/> IPCC, Climate Change and Land (Special Report) — <https://www.ipcc.ch/srccl/> World Resources Institute / Global Forest Watch — <https://www.globalforestwatch.org/>

5.4 Industry and hard-to-abate sectors

Heavy industry; steel, cement, chemicals, aluminium and long-distance transport such as shipping and aviation are described as "hard to abate" because their emissions arise from high-temperature process heat, chemical reactions inherent to production, or energy-dense fuel requirements that current technology struggles to electrify. Together they represent a substantial and growing share of global emissions, and decarbonising them is essential to reaching net zero. Material efficiency reduces demand for carbon-intensive materials in the first place, through lighter product design, longer product lifetimes, and higher rates of recycling and reuse recycled steel, for example, requires a fraction of the energy of primary steel production. Electrification is viable for lower-temperature industrial heat and for short-haul transport, and becomes more attractive as grids decarbonise. Low-carbon fuels and hydrogen fill gaps electrification cannot reach: green hydrogen, produced via electrolysis using renewable electricity, can substitute for fossil-derived hydrogen in ammonia and steel production, while sustainable fuels support shipping and aviation. Hydrogen should be deployed selectively, prioritising sectors with few alternatives, since its production is energy-intensive and inefficient compared with direct electrification. Carbon capture, utilisation and storage (CCUS) captures CO₂ from industrial process emissions or power generation and stores it permanently underground or uses it in products; it is particularly relevant for cement, where a large share of emissions comes from the chemical calcination process itself, not fuel combustion. Process innovation, electric arc furnaces, novel cement chemistries, green ammonia synthesis, is redesigning production methods altogether. No single technology solves hard-to-abate sectors; the IEA and the Mission Possible Partnership both stress that combining efficiency, electrification, hydrogen and CCUS, backed by demand-side measures such as green public procurement, is necessary. Example Sweden's HYBRIT project has produced steel using hydrogen instead of coking coal, eliminating the fossil-fuel reduction step in ironmaking; Heidelberg Materials' Brevik cement plant in Norway captures CO₂ directly from the calcination process, one of the first full-scale carbon capture installations in the cement industry. Further Reading IEA, Net Zero by 2050 — Industry pathways — <https://www.iea.org/reports/net-zero-by-2050> Mission Possible Partnership, sector transition strategies — <https://www.missionpossiblepartnership.org/> Energy Transitions Commission, Making Mission Possible — <https://www.energy-transitions.org/publications/making-mission-possible/>

5.5 Net zero and carbon removal

"Net zero" describes a state in which any remaining anthropogenic greenhouse gas emissions are balanced by an equivalent amount of removals over a specified period, resulting in no net addition to atmospheric GHG concentrations. IPCC assessments show that reaching net-zero CO₂ emissions is necessary to halt further warming, and net-zero GHG emissions, covering all gases, is required to begin reversing it. Not all emissions can realistically be eliminated with current technology; aviation, certain industrial processes and some agricultural methane are considered "residual." Carbon dioxide removal (CDR) methods, including afforestation and reforestation, soil carbon sequestration, direct air capture with storage, bioenergy with carbon capture and storage (BECCS), and enhanced mineral weathering, are intended to counterbalance these residual emissions, not to substitute for ambitious source reduction. Two concepts are essential to evaluating removal claims. Permanence asks how long carbon will remain stored: a forest can release carbon back to the atmosphere through fire or logging, while geological storage is far more durable but not always accessible or affordable. Additionality asks whether the removal would have happened anyway without the specific intervention or financing, a critical test for carbon credits and offset markets, where weak additionality has undermined the credibility of many voluntary schemes. A significant risk in net-zero planning is overreliance on removals as a substitute for reducing emissions today, sometimes termed "mitigation deterrence." Because most CDR technologies remain expensive, unproven at scale, or land- and energy-intensive, credible net-zero strategies prioritise deep, immediate emissions cuts and treat removals as a complement for the hardest-to-abate residual, not a licence to delay action. Example Climeworks' Orca and Mammoth direct air capture facilities in Iceland draw CO₂ directly from ambient air and store it permanently in basalt rock formations, illustrating engineered, high-permanence removal; community-based mangrove restoration projects such as Mikoko Pamoja in Kenya generate verified carbon credits while also protecting coastal livelihoods, illustrating nature-based removal with co-benefits. Further Reading The State of Carbon Dioxide Removal (Smith School, University of Oxford, and partners) — <https://www.stateofcdr.org/> IPCC, AR6 Synthesis Report — <https://www.ipcc.ch/report/ar6/syr/> Oxford Net Zero, Oxford Principles for Net Zero Aligned Carbon Offsetting — <https://oxfordnetzero.org/publications/oxford-offsetting-principles/>

5.6 Evaluating solutions

Choosing among competing mitigation options is rarely a matter of identifying the single "best" technology by cost or emissions reduction alone. Multi-criteria decision analysis (MCDA) provides a structured framework for comparing options against several relevant criteria simultaneously: cost-effectiveness, feasibility, co-benefits, risks, equity and timing, rather than optimising for one metric in isolation. Relying solely on cost per tonne of CO₂ avoided, for instance, can favour interventions that are cheap in narrow financial terms but slow to implement, poorly suited to local capacity, or that generate negative side effects such as biodiversity loss or displacement of vulnerable communities. Conversely, an option that scores well on speed and feasibility might carry higher upfront cost or depend on unproven supply chains. A typical MCDA process begins by defining the decision context and the criteria that matter to stakeholders, which might include mitigation potential, cost, technical readiness, co-benefits for health or biodiversity, distributional and equity impacts, implementation timeline, and reversibility of risk. Each option is then scored against every criterion, criteria are weighted according to stated priorities which should be transparent and, where possible, agreed with affected communities and the weighted scores are combined to compare options systematically. Sensitivity analysis, testing how rankings change if weights or assumptions shift, helps decision-makers understand how robust a preferred option really is. This approach is especially valuable at the local and national level, where options such as renewable electrification, public transport investment, forest protection and clean cooking transitions must be compared under real budget, political and social constraints. International bodies increasingly recommend MCDA-style approaches over narrow cost-effectiveness analysis precisely because climate decisions involve multiple, sometimes competing, societal goals. Example A city transport authority uses multi-criteria analysis to compare bus rapid transit, metro-rail expansion and cycling infrastructure — weighing capital cost, emissions reduction per dollar, implementation speed, air-quality co-benefits and impact on low-income commuters — rather than selecting whichever option has the lowest sticker price alone. Further Reading IPCC AR6 WG3, Chapter 3: Mitigation Pathways Compatible with Long-Term Goals — <https://www.ipcc.ch/report/ar6/wg3/> UNDP Climate Promise, NDC and climate-planning support — <https://climatepromise.undp.org/> OECD, Climate change policy analysis — <https://www.oecd.org/en/topics/policy-issues/climate-change.html>

5.7 Hands-On Activity

Climate professionals across Africa face the urgent challenge of evaluating and implementing mitigation solutions that balance emissions reduction with sustainable development. This hands-on activity equips you with a structured framework to assess climate interventions through multiple lenses critical for effective decision-making.

Solutions Assessment Framework

Mitigation scorecards provide a systematic approach to evaluate climate solutions using quantitative and qualitative criteria. For this activity, select five mitigation measures relevant to your context and score each 1–5 (1 = low impact/feasibility, 5 = high impact/feasibility) across these dimensions:

- **Emissions impact:** Potential greenhouse gas reduction
- **Feasibility:** Technical and operational viability
- **Cost:** Implementation and maintenance expenses

- **Equity:** Distributional justice and social inclusivity
- **Co-benefits:** Additional environmental, economic, or social advantages
- **Implementation time:** Timeline for deployment and measurable outcomes

Case Study: Kenya's Renewable Energy Transition

Kenya's geothermal development offers an instructive example. The **Menengai Geothermal Power Plant** (140 MW) required \$300 million in investment but now provides reliable baseload power to 500,000 households. Its scorecard would show:

- Emissions impact: 5 (avoids 0.7 MtCO₂e annually)
- Feasibility: 4 (high resource certainty but drilling risks)
- Cost: 3 (high upfront but low operating costs)
- Equity: 3 (creates jobs but limited community ownership)
- Co-benefits: 4 (energy security, reduced air pollution)
- Implementation time: 3 (8 years from exploration to operation)

Practical Application

In practice:

- Weight criteria according to your priorities (e.g., equity-focused contexts should value that dimension higher)
- Combine quantitative data (emission factors, cost curves) with qualitative stakeholder input
- Consider cross-cutting factors like climate resilience and just transition principles
- Update scores regularly as technologies evolve and implementation experience grows

Learn more

- UNEP Emissions Gap Reports
- African Development Bank's Climate Investment Funds
- Global Carbon Project's regional carbon budgets

"The best climate solutions are those that balance planetary boundaries with human development priorities."

Key takeaways

- ✓ Structured evaluation frameworks help identify optimal climate interventions for specific contexts.
- ✓ African case studies demonstrate that high-impact mitigation solutions often deliver substantial co-benefits.
- ✓ Successful implementation requires balancing technical feasibility with equitable distribution of benefits and costs.

Module 6: Climate Justice, Development, Policy and International Cooperation

Explain why climate change raises questions of equity, responsibility, vulnerability and distribution. Describe the roles of the UNFCCC, Paris Agreement, NDCs, adaptation planning and climate finance. Connect climate action to the Sustainable Development Goals and development priorities.

6 lessons · 25m

6.1 Climate justice

Climate justice reframes climate change as fundamentally a matter of fairness, not only physical science or economics. It rests on interlinked dimensions: the distribution of impacts and responsibility, procedural fairness, intergenerational equity, and recognition of different knowledge systems. Distributive justice concerns who bears the impacts of climate change and who benefits from actions taken to address it. Evidence consistently shows that countries and communities that have contributed least to historical greenhouse gas emissions including many low-income nations, Small Island Developing States, and marginalised groups within wealthier countries often face the most severe impacts, from sea-level rise to extreme heat and crop failure, while lacking the financial and technical resources to adapt. Responsibility asks who caused the problem, central to the UNFCCC principle of "common but differentiated responsibilities and respective capabilities" (CBDR-RC), which recognises that industrialised nations bear greater historical responsibility for cumulative emissions and correspondingly greater obligation to lead on mitigation and support. Procedural fairness concerns who gets a genuine seat at the table when climate decisions are made in international negotiations, national policy design, and local project planning and whether affected communities can meaningfully influence outcomes rather than simply being consulted after decisions are made. Intergenerational equity asks whether today's choices unfairly foreclose the wellbeing and options of future generations, who cannot participate in decisions being made now but will live with their consequences for decades. Recognition justice requires valuing different knowledge systems, notably Indigenous and local ecological knowledge alongside Western scientific approaches, since Indigenous peoples' stewardship covers a substantial share of the world's remaining biodiverse land, and holds generations of observational knowledge about ecosystem change, yet has historically been excluded from formal climate governance. Together, these dimensions push climate policy beyond a narrow emissions-reduction calculation toward one that asks who is harmed, who is heard, and who is held responsible. Example Vanuatu led a coalition of states that secured a landmark 2023 UN General Assembly resolution asking the International Court of Justice to clarify states' legal obligations on climate change; separately, the Loss and Damage Fund agreed at COP27 and operationalised at COP28 was created specifically to channel finance to vulnerable countries suffering climate harms they did little to cause. Further Reading IPCC, Climate Change 2022: Impacts, Adaptation and Vulnerability (AR6 Working Group II) — <https://www.ipcc.ch/report/ar6/wg2/> UNFCCC, Loss and Damage — <https://unfccc.int/loss-and-damage> UNFCCC, Local Communities and Indigenous Peoples Platform (LCIPP) — <https://lcipp.unfccc.int/>

6.2 Paris Agreement and NDCs

The Paris Agreement represents the cornerstone of global climate governance, yet its effectiveness hinges on whether nations translate commitments into concrete action while addressing historical inequities. For African professionals, understanding this framework is essential to navigate climate finance, advocate for just transitions, and position the continent in a rapidly evolving global climate architecture.

The Paris Agreement's Architecture

The Paris Agreement, adopted at COP21 in 2015, established a unique hybrid approach combining **bottom-up** national contributions with **top-down** international accountability. Its core temperature goal—to limit warming to well below 2°C while pursuing 1.5°C—acknowledges that 1.5°C represents a critical threshold for African countries, where climate impacts are already disproportionately severe. The Agreement operates on five-year cycles of increasing ambition, with countries submitting **Nationally Determined Contributions (NDCs)** that outline their climate action plans. Unlike its predecessor, the Kyoto Protocol, the Paris Agreement requires all countries, including major emitters like China and the US, to submit NDCs, creating a truly universal system.

The NDC Mechanism and Ambition Cycle

NDCs represent each country's self-determined contribution to global climate action, reflecting their **common but differentiated responsibilities** and respective capabilities. The Agreement mandates that successive NDCs represent progression beyond previous ones, creating a deliberate "ratchet mechanism" designed to close the implementation gap. Under the **Enhanced Transparency Framework**, countries report emissions inventories and progress using standardized methodologies, subject to technical expert review. This transparency enables civil society, researchers, and other governments to hold countries accountable to their commitments.

Case Study: Kenya's NDC Journey

Kenya exemplifies how African countries are integrating climate action into development planning. Its first NDC (2015) targeted a 30% emissions reduction by 2030 (equivalent to 62 MtCO_{2e}), primarily through renewable energy and forest conservation. By 2022, Kenya submitted an updated NDC with a more ambitious target of 32% reduction (72 MtCO_{2e}), while adding adaptation components. Crucially, Kenya has aligned its NDC with its **National Climate Change Action Plan**, securing over \$500 million in climate finance through the Green Climate Fund. However, implementation challenges remain, with only 40% of renewable energy targets met by 2023, highlighting the gap between ambition and execution.

In Practice

- **NDC Implementation:** Map national policies against NDC targets to identify implementation gaps and opportunities for integration with development planning
- **Climate Finance:** Track disbursements against financial commitments in NDCs, particularly for adaptation projects
- **Stakeholder Engagement:** Establish multi-stakeholder platforms to monitor progress and advocate for increased ambition

- **Just Transition:** Ensure NDCs incorporate social safeguards to protect vulnerable communities during low-carbon transitions

Learn more

- UNFCCC, The Paris Agreement — <https://unfccc.int/process-and-meetings/the-paris-agreement>
- UNFCCC, NDC Registry (interim) — <https://unfccc.int/NDCREG>
- UNEP, Emissions Gap Report 2025 — <https://www.unep.org/resources/emissions-gap-report-2025>

"The Paris Agreement is not about what we lose, it's about what we gain: a safer, more prosperous, and equitable future for all."

Key takeaways

- ✓ The Paris Agreement's strength lies in its combination of national sovereignty with international accountability, creating a dynamic system of increasing climate ambition.
- ✓ NDCs serve as critical planning tools that integrate climate action with development priorities, though significant gaps remain between current pledges and scientific requirements.
- ✓ African countries can leverage the Agreement's architecture to access climate finance while advocating for recognition of historical responsibility and differentiated support.

6.3 Climate finance and capacity

Even the most ambitious climate plan is only as effective as a country's ability to implement it, and implementation depends on finance, technology and institutional capacity, resources that are distributed extremely unevenly across the world. Climate finance refers to funding, from public, private and blended sources, that supports mitigation and adaptation activities, particularly in developing countries with limited domestic fiscal space. Developed countries committed under the UNFCCC and Paris Agreement to mobilise climate finance for developing nations, historically framed around a \$100 billion annual goal, and at COP29 in 2024 negotiators agreed a new, larger collective finance goal for the period beyond 2025. Finance flows through varied channels: dedicated multilateral funds such as the Green Climate Fund and the Adaptation Fund, bilateral development assistance, multilateral development banks, and increasingly private investment mobilised by blended-finance instruments and green bonds. Technology transfer addresses the reality that many low-carbon and climate-resilient technologies were developed in wealthier countries; mechanisms such as the UNFCCC's Technology Mechanism aim to help developing countries access, adapt and deploy relevant innovations rather than relying solely on imported equipment and expertise. Capacity building strengthens the human and institutional capabilities trained personnel, functioning regulatory agencies, data systems, project-preparation skills that countries need to design bankable projects, negotiate effectively, and absorb finance once it is available. Access remains a persistent barrier: many of the most climate-vulnerable countries, including Least Developed Countries and Small Island Developing States, report that complex application procedures, co-financing requirements and limited in-country capacity make it disproportionately hard for them to secure funds relative to their needs, even when finance is nominally available at the global level. Example The Green Climate Fund has financed a national solar mini-grid and irrigation programme across several Sub-Saharan African countries, pairing capital with technical assistance so that local utilities and cooperatives can operate and maintain the systems themselves rather than depending indefinitely on external technical support. Further Reading Green Climate Fund — <https://www.greenclimatefund.org/> Adaptation Fund — <https://www.adaptation-fund.org/> UNFCCC, Climate Finance — <https://unfccc.int/topics/climate-finance/the-big-picture/climate-finance-in-the-negotiations>

6.4 Climate and sustainable development

Climate action and sustainable development are deeply intertwined rather than competing priorities: the way the world addresses climate change will shape, and be shaped by, progress on energy access, jobs, food security, health, urbanisation, nature and poverty reduction, the very themes captured in the UN Sustainable Development Goals (SDGs). Energy access illustrates the interconnection clearly: hundreds of millions of people worldwide still lack reliable electricity, and closing this gap through decentralised renewable systems can advance SDG7 (affordable, clean energy) while avoiding the emissions locked in by new fossil infrastructure. The clean energy transition also carries major employment implications; renewable energy, energy efficiency and grid modernisation are projected to create significant numbers of new jobs globally, though ensuring a "just transition" for workers and regions currently dependent on fossil fuel industries requires deliberate retraining, social protection and regional investment. Food systems sit at the intersection of climate mitigation, adaptation and nutrition: climate-smart agriculture can raise yields and resilience while lowering emissions, but the food system is also acutely vulnerable to the disruptions climate change causes, from shifting rainfall to more frequent extreme weather. Health co-benefits are substantial and often underappreciated — measures that cut fossil fuel combustion, such as clean transport and clean cooking, simultaneously reduce the air pollution responsible for millions of premature deaths each year, meaning climate policy and public-health policy frequently reinforce one another. Cities, home to a majority of the world's population, are both major emissions sources and centres of innovation in low-carbon transport, buildings and waste management, while nature-based solutions such as forest and wetland protection deliver climate, biodiversity and livelihood benefits together. Poverty reduction and climate resilience are mutually reinforcing: climate shocks can push vulnerable households back into poverty, while investments that build resilience, social protection, diversified livelihoods, resilient infrastructure — also reduce chronic poverty over time. Example Rwanda's national strategy links off-grid solar electrification, climate-smart terracing agriculture and green urban planning within a single green-growth framework, showing how a country can pursue the SDGs and its Paris Agreement commitments as one integrated programme rather than separate tracks. Further Reading United Nations, Sustainable Development Goals — <https://sdgs.un.org/goals> World Bank, Climate Change and Development — <https://www.worldbank.org/en/topic/climatechange> ILO, Just Transition to Environmentally Sustainable Economies — <https://www.ilo.org/topics/green-jobs/just-transition>

6.5 Stakeholder negotiation

Climate governance is not the work of national governments alone; it is shaped by a wide constellation of actors whose interests, resources and levels of influence differ substantially, and effective negotiation depends on understanding those differences. National governments remain the formal Parties to the UNFCCC and Paris Agreement, submitting NDCs and negotiating collective decisions, but their positions are themselves shaped by domestic political economy, development priorities and international alliances such as coalitions of Small Island States or the Like-Minded Developing Countries group. Local communities and Indigenous peoples bring place-based knowledge and are frequently the first affected by both climate impacts and the projects intended to address them, making their free, prior and informed participation essential to legitimate and effective outcomes. Businesses and investors influence outcomes both as emitters and as sources of capital and technology; their engagement ranges from voluntary net-zero pledges to active lobbying, and civil-society scrutiny of corporate climate claims has intensified as concerns about "greenwashing" have grown. Youth movements have become a prominent force in climate governance, pressing for greater ambition and represented formally within the UNFCCC process through constituencies such as YOUNGO, reflecting the intergenerational-equity dimension of climate justice. Civil society organisations, environmental groups, development NGOs, research institutes, provide technical analysis, monitor commitments, and advocate for marginalised groups within negotiations. Workers and trade unions advocate for a just transition that protects livelihoods as economies decarbonise, while financial institutions, central banks, pension funds, development banks, increasingly shape outcomes through climate-risk disclosure requirements, green lending standards and investment screening. Negotiating well across such a diverse stakeholder landscape requires distinguishing positions (what a party is asking for) from underlying interests (why they are asking for it), searching for options that satisfy multiple parties' core interests simultaneously, and recognising that durable agreements from the Paris Agreement itself to a local clean-air plan, usually depend on processes stakeholders perceive as fair, not only on the technical merits of the outcome. Example The UNFCCC's Marrakech Partnership for Global Climate Action formally channels input from cities, regions, businesses and civil society into the intergovernmental negotiation process, illustrating how non-Party stakeholders are structurally embedded in what is nominally a government-to-government treaty system. Further Reading UNFCCC, Marrakech Partnership for Global Climate Action — <https://unfccc.int/climate-action/marrakech-partnership-for-global-climate-action> YOUNGO, the official children and youth constituency of the UNFCCC — <https://www.youngo.uno/> UNFCCC, Non-Party Stakeholders — <https://unfccc.int/non-party-stakeholders>

6.6 Hands-On Activity

Effective climate action requires bridging the gap between policy formulation and implementation, where competing interests must be balanced against scientific imperatives and social equity. This simulation exercise immerses you in the complex reality of climate governance, developing the practical negotiation skills essential for driving meaningful change in diverse African contexts.

Simulation Overview

- **Role assignment:** Teams represent key stakeholders: government (e.g., Ministry of Environment), local communities (indigenous groups), businesses (both multinational and SMEs), youth representatives, farmers' associations, and civil society organizations

- **Scenario context:** Negotiate a five-point climate action plan for a specific African country (e.g., Kenya's 2023 Climate Change Action Plan) addressing:
- Mitigation targets (emission reductions)
- Adaptation measures (resilience building)
- Finance mechanisms (climate funds, private investment)
- Equity considerations (just transition principles)
- Monitoring frameworks (MRV systems)

Preparation Guidelines

- **Research your position:** Each team must prepare a 2-page brief with:
- Core interests and constraints
- Evidence-based arguments (using national data)
- Walk-away positions
- Potential compromise areas
- **Country context:** Use real national climate plans, NDCs, and development priorities as reference points

Case Study: Kenya's Climate Finance Landscape

Kenya's National Climate Change Action Plan (2023-2027) requires \$62 billion in climate finance, with only 12% currently mobilized. The Green Climate Fund has approved \$135 million for Kenya's water security projects, yet communities in Turkana report only 15% of allocated funds reaching local implementation. This highlights the critical need for transparent finance mechanisms and community participation in climate governance.

Negotiation Process

- **Opening statements:** 3 minutes per stakeholder group
- **Caucus sessions:** 15-minute private discussions within teams
- **Plenary negotiations:** 45-minute structured discussion
- **Final agreement drafting:** 30 minutes to consolidate points

In Practice

- **Use active listening techniques** to understand underlying interests rather than positions
- **Separate people from the problem** by focusing on shared climate risks
- **Generate multiple options** before evaluating trade-offs
- **Document agreements precisely** to avoid implementation ambiguities
- **Plan for implementation challenges** by assigning responsibilities and timelines

"Climate justice demands that those who have contributed least to the crisis should not bear the greatest burden of its consequences."

Learn more

- African Development Bank Climate Finance Strategy
- UNFCCC National Adaptation Plans (NAP) Central Repository
- Africa Climate Policy Centre (ACPC) resources

Key takeaways

- ✓ Effective climate negotiation requires balancing technical knowledge with political acumen and cultural sensitivity.
- ✓ Transparent, inclusive governance mechanisms are essential for equitable climate finance distribution.
- ✓ Compromise on process often enables more ambitious outcomes on substance in climate negotiations.

Module 7: Climate Action in Practice: Communication, Project Design and Capstone

Translate climate knowledge into a practical, evidence-based action plan. Communicate climate information accurately to non-specialist audiences. Design a small climate project with objectives, indicators, timeline, budget assumptions and risk management.

6 lessons · 26m

7.1 Climate communication

Communicating climate change effectively is a distinct skill from understanding the science itself, and getting it wrong can entrench denial, fatalism or confusion even among well-intentioned audiences. Effective communication begins with audience analysis: identifying what a specific audience already believes, values and needs to decide or do, since messages that work for policymakers rarely work unchanged for farmers, students or business owners. Research consistently shows that tailoring content to an audience's existing values and concerns is far more persuasive than a one-size-fits-all message built around scientific consensus alone. Plain language matters because technical jargon, "radiative forcing," "anthropogenic," "mitigation potential" creates barriers even for educated, engaged audiences; effective communicators translate concepts into everyday terms and concrete, relatable comparisons. Visuals extend this further: well-designed charts, maps and infographics can convey trends and spatial patterns that paragraphs of text struggle to communicate, provided they avoid manipulative scaling or cherry-picked timeframes. Storytelling humanises abstract statistics by grounding them in specific people, places and stakes, helping audiences connect emotionally as well as intellectually, though stories must remain factually accurate and representative rather than exceptional or staged. Communicating uncertainty honestly, without either overstating confidence or implying the science itself is unsettled, is essential to credibility; the IPCC's own calibrated language ("likely," "very likely," "virtually certain") offers a model for expressing confidence levels precisely rather than vaguely. Finally, avoiding misinformation means fact-checking claims before sharing them, distinguishing legitimate scientific debate over specifics (such as regional impact magnitudes) from manufactured doubt about basic mechanisms, and being alert to how emotionally charged or oversimplified content spreads faster online regardless of accuracy. Responsible communicators correct errors transparently and cite primary, authoritative sources rather than secondary claims. Example A national meteorological service redesigned its heatwave warnings by replacing technical temperature thresholds with plain-language health guidance and a simple colour-coded risk scale, paired with short video testimonials from affected residents — measurably increasing public compliance with heat-safety advice compared with the previous numerical-only alerts. Further Reading Yale Program on Climate Change Communication — <https://climatecommunication.yale.edu/> Climate Outreach, evidence-based communication resources — <https://climateoutreach.org/> IPCC AR6, Communications Handbook / calibrated uncertainty language guidance — <https://www.ipcc.ch/report/ar6/wg1/>

7.2 Project design

A well-designed climate or environmental project rests on a clear logical chain connecting the problem to the intended change, commonly called a theory of change. The process begins with a precise problem statement: what specific issue is being addressed, for whom, where, and why it matters now. Vague problem statements produce vague, unfocused projects. A theory of change then maps the causal pathway from action to impact, typically expressed as: if we do [activities], using [resources], we will produce [outputs], which will lead to [outcomes], because [assumptions hold true], ultimately contributing to [long-term impact]. Objectives translate this logic into specific statements of intended change, distinguished from outputs, the tangible products or services a project directly delivers, such as training sessions held or hectares restored and outcomes, the behavioural, institutional or environmental changes that outputs are expected to enable, such as adoption of cleaner cookstoves or reduced deforestation rates. Indicators are the specific, measurable signals used to track whether outputs and outcomes are actually being achieved, and are most useful when tied clearly to each level of the results chain rather than treated as an afterthought. Activities are the concrete tasks and interventions, workshops, installations, policy briefings, monitoring visits through which outputs are produced, and should be sequenced realistically against project timelines. A credible project design also requires an honest budget that reflects true costs, including monitoring and community engagement, not only visible infrastructure, and clearly assigned responsibilities identifying which individual or organisation is accountable for each activity, output and decision. Strong project design treats these elements as an integrated system: a change in one, such as a reduced budget, has direct implications for feasible objectives and activities elsewhere, and good project designers revisit the theory of change iteratively rather than treating it as fixed at the outset.

Example A municipal clean-cooking project defines its problem as household air pollution from open-fire cooking among 5,000 low-income households; its theory of change links subsidised improved stoves and behaviour-change training (activities) to stove adoption and consistent use (outputs), reduced household PM2.5 exposure (outcome), and lower respiratory illness (impact) — with indicators tracking stoves distributed, percentage still in active use after six months, and measured indoor air-quality changes.

Further Reading Bond, Theory of Change guidance for development and civil-society organisations — <https://www.bond.org.uk/resources/theory-of-change-guide> USAID Learning Lab, Program Cycle and project design resources — <https://usaidlearninglab.org/resources> UNDP, Project Design and Results-Based Management guidance — <https://www.undp.org/>

7.3 Monitoring and evaluation

Monitoring and evaluation (M&E) transforms a project design from a plan on paper into an accountable, learning system. It begins with a baseline: a documented measurement of conditions before the project starts, without which it is impossible to credibly demonstrate change afterward, a common and costly mistake is skipping baseline data collection under time pressure, only to have no reference point later. Good indicators follow the SMART framework, Specific, Measurable, Achievable, Relevant and Time-bound, ensuring that progress can be assessed objectively rather than through vague impressions. A poorly framed indicator such as "improve air quality" offers no way to judge success; a SMART version such as "reduce mean annual PM2.5 concentration at three monitoring sites by 15% within 24 months" does. Data quality determines whether monitoring findings can be trusted: this includes using consistent measurement methods over time, documenting who collected data and how, checking for missing values or outliers, and being transparent about limitations rather than presenting figures as more precise than they are. Weak data quality can silently undermine an otherwise well-designed project by producing misleading conclusions. Learning loops close the gap between collecting data and using it: regular review points built into a project's calendar, not just a final evaluation, allow teams to compare actual results against expectations and ask why gaps exist. This feeds adaptive management, where project design is deliberately revised in response to monitoring evidence rather than rigidly following the original plan regardless of what the data shows. The OECD-DAC evaluation criteria, relevance, coherence, effectiveness, efficiency, impact and sustainability, provide a widely used framework for structuring more formal evaluations that periodically test a project's underlying assumptions, not only its activity completion. Example A community reforestation project's mid-term monitoring data show that seedling survival is far lower on south-facing slopes than expected; rather than waiting for the final evaluation, the implementing team uses this learning loop to adapt the remaining planting plan toward better-suited native species and improved watering schedules on those slopes. Further Reading OECD, Evaluation Criteria for development co-operation — <https://www.oecd.org/en/topics/sub-issues/development-co-operation-evaluation-and-effectiveness/evaluation-criteria.html> Better Evaluation, practical M&E methods and guidance — <https://www.betterevaluation.org/> USAID Learning Lab, Monitoring, Evaluation and Learning resources — <https://usaidlearninglab.org/resources>

7.4 Personal and organisational action

Meaningful climate action operates at multiple, interconnected levels, and understanding the relative leverage of each helps individuals and organisations invest effort where it has the greatest effect. Individual behaviour, flying less, eating more plant-based meals, reducing energy waste at home, choosing active or public transport, matters both for its direct emissions impact and because visible personal choices can shift social norms and signal demand for broader change. However, research is clear that individual behaviour alone cannot close the emissions gap; systemic barriers such as energy infrastructure, transport systems and product availability constrain what any one person can realistically choose. This is why institutional leverage matters more than individual action alone. Within organisations, this includes measuring and disclosing greenhouse gas emissions (commonly split into Scope 1, 2 and 3), setting science-based reduction targets aligned with the Paris Agreement's temperature goals, greening procurement and supply chains, and embedding climate risk into core business or institutional strategy rather than treating it as a peripheral corporate-social-responsibility exercise. Beyond an organisation's own operations lies policy leverage: individuals and organisations can influence outcomes far larger than their direct footprint by voting, engaging elected representatives, participating in public consultations, supporting or challenging specific legislation, and using shareholder or membership influence to push larger institutions; pension funds, universities, employers, toward stronger climate commitments. Effective climate leadership typically combines all three levels: credible personal practice builds legitimacy, organisational action delivers direct and often substantial emissions reductions, and policy engagement multiplies impact by shaping the rules and incentives that govern everyone else's choices. Recognising which lever is most available and impactful in a given role and context, rather than defaulting only to individual consumer choices, is central to making real progress. Example A university that both encourages staff cycling (individual behaviour) and commits to a Science Based Targets initiative-verified net-zero pathway for its campus operations (organisational action) multiplies its impact further by using its research and convening power to advise on national building-efficiency codes (policy leverage) — illustrating how the three levels reinforce one another. Further Reading Science Based Targets initiative (SBTi) — <https://sciencebasedtargets.org/> Project Drawdown, ranked climate solutions for individuals and organisations — <https://drawdown.org/> CDP (Carbon Disclosure Project), corporate and city climate disclosure — <https://www.cdp.net/en>

7.5 Capstone preparation

The capstone is an opportunity to demonstrate integrated mastery: bringing together climate science, risk assessment, mitigation, adaptation, equity and implementation into one coherent, evidence-based plan rather than treating each as a separate module. Strong capstones begin by clearly grounding the chosen problem in credible science, what is happening, why, and what the evidence shows about future trajectories under different scenarios before moving to solutions. Risk framing should identify who and what is exposed and vulnerable, distinguishing hazard (the physical climate stressor), exposure (what is in harm's way) and vulnerability (the capacity to withstand or recover from harm), since effective interventions often target vulnerability and exposure even when the hazard itself cannot be controlled locally. A strong capstone integrates both mitigation, actions that reduce the emissions driving the problem, and adaptation, actions that reduce harm from impacts already underway or locked in, recognising that most real-world contexts require both operating together rather than treating them as alternatives. Equity must be woven through the analysis rather than appended as an afterthought: who bears the costs and risks being addressed, who benefits from the proposed intervention, and whose knowledge and voice shaped the plan. Implementation detail separates an aspirational vision from an actionable plan realistic budgets, named responsible actors, a credible timeline, identified risks to delivery, and indicators that will show whether the plan is working, drawing directly on the project-design and M&E skills built earlier in the course. Finally, a strong capstone is honest about its own limitations: no data source, model or plan is perfect, and acknowledging assumptions, gaps and uncertainty strengthens rather than weakens the credibility of the work, provided it is paired with a clear, defensible recommendation for action. Example A capstone addressing coastal flooding risk in a growing port city integrates sea-level-rise projections (science and risk), a seawall-and-mangrove-buffer hybrid intervention (mitigation of future emissions paired with adaptation to locked-in impacts), a stakeholder map ensuring informal settlement residents are consulted rather than only port authorities (equity), and a phased three-year implementation plan with named responsible agencies and monitoring indicators (implementation). Further Reading IPCC, AR6 Synthesis Report: Climate Change 2023 — <https://www.ipcc.ch/report/ar6/syr/> UNEP, Adaptation Gap Report (latest edition) — <https://www.unep.org/topics/climate-action/adaptation> World Bank, Climate Change Action Plan and country climate resources — <https://www.worldbank.org/en/topic/climatechange>

7.6 Hands-On Activity

Climate action initiatives translate theoretical knowledge into tangible impact, making this hands-on capstone essential for professionals who must bridge the gap between climate science and implementation in diverse African contexts.

Capstone Project Overview

The capstone project requires designing a comprehensive climate action initiative for a real-world organization or community. You will deliver:

- **5–8 page action plan** detailing objectives, methodology, timeline, and budget
- **One-page infographic** visually communicating the initiative's key elements
- **Implementation matrix** showing activities, responsible parties, timelines, and success metrics
- **5-minute recorded pitch** presenting your initiative to potential stakeholders

Project Structure & Deliverables

Your action plan must include:

- **Problem statement** with specific climate vulnerability data
- **Theory of change** showing how activities lead to desired outcomes
- **Stakeholder analysis** mapping key actors and their interests
- **Monitoring & evaluation framework** with baseline, interim, and endline indicators
- **Risk assessment** with mitigation strategies
- **Sustainability plan** beyond the project lifecycle

"The best climate initiatives are those that are locally owned, contextually relevant, and demonstrate clear pathways to resilience."

Case Study: Kenya's Green School Initiative

The **Green School Initiative** in Nairobi, Kenya, demonstrates successful implementation across sectors. Founded in 2018 by **Dr. Wangari Maathai Green Foundation**, this program has:

- Reached 150 schools across 47 counties
- Reduced energy consumption by 30% through solar installations and efficiency measures
- Established 120 school-based tree nurseries producing 50,000 seedlings annually
- Trained 2,000 teachers in climate education methodologies
- Secured \$1.2M in funding from Kenya Climate Change Fund and UNDP

In practice:

- Begin with a **needs assessment** using tools like vulnerability mapping
- Ensure **participatory design** involving community members in planning
- Build **adaptive management** into your project to respond to changing conditions
- Consider **co-benefits** beyond climate action (e.g., job creation, health improvements)

Learn more

- UNEP Africa Climate Change Adaptation Programme
- African Development Bank Climate Action Plan
- UNFCCC National Communications Portal

Key takeaways

- ✓ Effective climate action initiatives require both technical rigor and deep contextual understanding of local socio-economic conditions.
- ✓ Successful implementation depends on strong stakeholder engagement and clear communication of climate risks and opportunities.
- ✓ Monitoring, evaluation, and adaptive management are critical for ensuring climate initiatives achieve intended outcomes in dynamic environments.

Module 8: Air Pollution and Environmental Health

Define air pollution, pollutant, emission, concentration, exposure and dose. Differentiate ambient, household and occupational air pollution. Describe why air pollution is a global health, development, equity and environmental issue.

7 lessons · 22m

8.1 What is air pollution?

Air pollution represents one of the most significant environmental and public health challenges facing Africa today, directly impacting economic productivity, healthcare systems, and climate resilience. Understanding its sources, pathways, and impacts is essential for developing effective mitigation strategies that protect vulnerable populations while supporting sustainable development.

Defining Air Pollution

Air pollution refers to the contamination of indoor or outdoor air by chemical, physical, or biological agents at levels or exposure patterns that can negatively affect human health, ecosystems, materials, and the climate. It is one of the most widespread environmental challenges globally, affecting both highly industrialised cities and rural communities.

Air pollutants may be gases, particles, or biological materials. Common examples include:

- Particulate matter (PM_{2.5} and PM₁₀)
- Carbon monoxide (CO)
- Nitrogen dioxide (NO₂)
- Sulfur dioxide (SO₂)
- Ozone (O₃)
- Volatile organic compounds
- Smoke, dust, pollen, mould spores, and microorganisms

Their sources include vehicle exhaust, industries, power generation, waste burning, household cooking fuels, agriculture, construction, wildfires, and natural processes such as dust storms and volcanic activity.

Pollution Pathway: From Sources to Impacts

To understand how air pollution affects people and the environment, it's important to distinguish four related concepts:

- **Emissions** – the pollutants released into the atmosphere from a particular source, such as smoke from a vehicle, factory, or cooking stove. Emissions are the starting point of the pollution pathway.
- **Ambient concentration** – the amount of a pollutant present in the surrounding air at a particular location and time. Concentrations can change depending on weather, wind, topography, chemical reactions, and proximity to pollution sources.
- **Exposure** – the contact between a person, ecosystem, or material and a pollutant over a specific period. Exposure depends on where people live, work, travel, and undertake daily activities, as well as how long they remain in polluted environments.
- **Dose** – the amount of a pollutant that actually reaches and interacts with a biological target, such as the lungs or bloodstream. Dose is influenced by pollutant concentration, exposure duration, breathing rate, and individual characteristics.

African Case Study: Nigeria's Air Quality Crisis

In Nigeria, particularly in Lagos, air pollution levels have reached alarming proportions. A 2022 study by the **Nigerian Environmental Protection Agency (NEPA)** recorded average PM_{2.5} concentrations of 68 µg/m³ in Lagos's commercial districts—nearly seven times the WHO's 2021 guideline of 5 µg/m³. These levels contribute to an estimated 11,400 premature deaths annually in Lagos alone from air pollution-related diseases. The primary sources include vehicle emissions (contributing 35%), industrial activities (28%), open waste burning (20%), and dust from construction (17%). This case illustrates how urbanization and economic development can create significant air pollution challenges without adequate regulatory frameworks.

"Air pollution is the single greatest environmental risk to human health, and the burden is heaviest in low- and middle-income countries."

Practical Professional Guidance

In practice:

- When conducting air quality assessments, always distinguish between indoor and outdoor sources, as indoor air pollution from cooking and heating fuels affects approximately 3.8 billion people globally, with significant implications in African households.
- Use standardized monitoring protocols (WHO, UNEP, or national guidelines) to ensure data comparability and reliability for policy development.
- Develop context-specific interventions that consider local pollution sources, meteorological conditions, and socioeconomic factors.
- Engage communities in participatory monitoring to gather localized data and build awareness about pollution sources and health impacts.

Learn more

- World Health Organization (WHO) Air Quality Guidelines

- United Nations Environment Programme (UNEP) Africa Clean Air Programme
- African Development Bank (AfDB) Climate Investment Frameworks

Key takeaways

- ✓ Air pollution follows a clear pathway from emissions through ambient concentrations, exposure, and dose, each stage offering opportunities for intervention.
- ✓ African cities face unique air pollution challenges shaped by rapid urbanization, industrialization, and reliance on solid fuels for cooking and heating.
- ✓ Effective air pollution management requires integrated approaches that combine technological solutions, policy interventions, and community engagement to address both local and global impacts.

8.2 Major pollution settings

Understanding the complex interplay of pollution settings is crucial for African climate professionals developing effective mitigation strategies. In Africa, where urbanization is accelerating while traditional fuel use persists, pollution exposure pathways are uniquely diverse, requiring context-specific interventions that address both immediate health impacts and long-term climate co-benefits.

Ambient Air Pollution Settings

Ambient air pollution encompasses outdoor contamination from diverse sources that affect entire communities. In rapidly growing African cities, pollution profiles are increasingly dominated by:

- Vehicle emissions (particularly in urban centers like Lagos and Nairobi)
- Industrial activities (manufacturing zones in South Africa's Gauteng province)
- Power generation (often coal-fired in South Africa, transitioning elsewhere)
- Construction and dust (especially in desert-edge cities like Khartoum)
- Agricultural burning (widespread during dry seasons across the Sahel)
- Waste combustion (common in informal settlements)

These sources release primary pollutants like PM_{2.5}, PM₁₀, NO₂, SO₂, and CO, which can transform into secondary pollutants such as ozone. The 2021 WHO Air Quality Guidelines show that 98% of Africans breathe air exceeding these limits, with concentrations in Nairobi's Industrial Area reaching 35 µg/m³ for PM_{2.5}—nearly seven times the recommended limit.

Household Air Pollution Settings

Household air pollution (HAP) remains a critical concern in African homes, particularly affecting women and children. Key sources include:

- Traditional biomass fuels (used by 75% of households in sub-Saharan Africa)
- Kerosene stoves (common in urban informal settlements)
- Coal briquettes (used in parts of South Africa)

- Incomplete combustion in poorly ventilated spaces

In practice, HAP interventions must balance cultural practices with health benefits. The Kenya Clean Cookstoves Program demonstrates this challenge, aiming to distribute 5 million efficient stoves by 2025 while acknowledging that adoption rates depend on affordability, cooking preferences, and awareness campaigns.

Occupational Air Pollution Settings

Occupational air pollution represents a significant but often overlooked exposure pathway. African workers in these sectors face elevated risks:

- Mining workers exposed to silica dust (causing silicosis in South African gold miners)
- Agricultural workers handling pesticides (linked to neurological impacts in Ghanaian cocoa farmers)
- Construction workers inhaling cement and wood dust
- Waste management personnel exposed to bioaerosols and chemical contaminants

"The health of African workers is being silently sacrificed for development progress—each preventable exposure represents a failure of occupational health systems."

Multi-Setting Exposure Pathways

In African contexts, individuals rarely experience pollution in isolation. A typical Nairobi commuter might face:

- Morning exposure to traffic emissions (PM_{2.5}: 50-80 µg/m³)
- Midday exposure to cooking fumes at home (PM_{2.5}: 200-400 µg/hour)
- Afternoon exposure to office building emissions (VOCs from furniture and cleaning products)

This cumulative exposure pattern demands integrated assessment approaches that consider total daily exposure rather than isolated pollution sources.

Learn more

- WHO Air Quality Guidelines (2021)
- UNEP Africa Environment Outlook reports
- Clean Air Fund Africa initiatives

Key takeaways

- ✓ African air pollution management requires context-specific approaches that address the unique intersection of traditional fuel use, rapid urbanization, and industrial development.
- ✓ Multi-pollutant strategies targeting both health and climate co-benefits offer the most effective pathway to reducing exposure across all settings.
- ✓ Community engagement and culturally appropriate interventions are essential for successful adoption of cleaner technologies in household and occupational settings.

8.3 The major pollutants

Air pollution represents one of the most pressing environmental health challenges facing African nations today, directly impacting economic productivity, healthcare systems, and climate resilience. Understanding major pollutants is not merely an academic exercise but a critical professional competency for developing effective mitigation strategies and safeguarding public health across the continent.

Major Pollutants and Their Characteristics

- **Particulate matter (PM_{2.5} and PM₁₀):** Complex mixtures of solid particles and liquid droplets with aerodynamic diameters of 2.5µm or less (PM_{2.5}) and 10µm or less (PM₁₀). Sources include vehicle exhaust, industrial activities, construction, dust, biomass burning, and household fuel combustion. PM_{2.5} penetrates deep into alveoli and can enter systemic circulation, posing significant health risks.
- **Nitrogen dioxide (NO₂):** A reddish-brown gas primarily from combustion processes. Major sources include road traffic (accounting for up to 80% in urban areas), power plants, and industrial processes. NO₂ contributes to respiratory infections, asthma exacerbation, and the formation of secondary pollutants.
- **Sulfur dioxide (SO₂):** A colorless gas with a pungent odor, mainly from burning sulfur-containing fuels like coal and heavy oil. Industrial facilities and power generation are primary sources. SO₂ contributes to acid rain and respiratory conditions, particularly affecting vulnerable populations.
- **Carbon monoxide (CO):** A colorless, odorless gas from incomplete combustion. Indoor sources include inefficient cooking stoves (common in many African households), while outdoor sources include vehicle exhaust and generator use. CO binds to hemoglobin, reducing oxygen transport and potentially causing neurological damage.
- **Ground-level ozone (O₃):** A secondary pollutant formed when NO_x and volatile organic compounds react in sunlight. While not directly emitted, it significantly impacts health and ecosystems. O₃ can reduce crop yields by up to 15% in sensitive regions, threatening food security.

African Case Study: Air Quality in Lagos, Nigeria

In 2022, Lagos recorded annual average PM_{2.5} concentrations of 35.7µg/m³—nearly four times WHO's guideline value of 10µg/m³. The State Environmental Protection Agency (LASEPA) identified vehicular emissions (accounting for 43% of total pollution), industrial activities (28%), and open burning (19%) as primary sources. This pollution contributes to an estimated 11,400 premature deaths annually in the city. In response, LASEPA implemented the Lagos Air Quality Management Plan, including vehicle emission testing programs and industrial emission standards, demonstrating how localized data can drive targeted interventions.

Health Impacts

Air pollution causes approximately 7 million premature deaths globally each year, with Africa disproportionately affected due to rapid urbanization and increasing industrialization. Health impacts range from respiratory and cardiovascular diseases to adverse birth outcomes and neurological effects. In sub-Saharan Africa, household air pollution from solid fuel use causes an estimated 600,000 deaths annually, mostly among women and children.

"Clean air is a fundamental human right, yet billions breathe air so polluted it kills them."

In Practice

- Conduct regular air quality monitoring using low-cost sensors to identify pollution hotspots
- Develop sector-specific mitigation strategies prioritizing major local sources
- Implement health impact assessments for new industrial developments and infrastructure projects
- Promote clean cooking technologies to reduce household air pollution
- Integrate air quality considerations into urban planning and transportation policies

Learn more

- World Health Organization (WHO) Air Quality Guidelines
- United Nations Environment Programme (UNEP) Africa Clean Air Programme
- Clean Air Fund Africa Initiative

Key takeaways

- ✓ Understanding major pollutants is essential for developing targeted air quality management strategies in African contexts.
- ✓ Air pollution represents a significant threat to public health, economic development, and environmental sustainability across Africa.
- ✓ Effective mitigation requires integrated approaches addressing both traditional and emerging pollution sources.

8.4 Why this is a global threat

Air pollution is a global environmental and public health challenge that affects people in cities, towns, rural communities, and remote areas. Although pollution is often associated with heavily industrialised cities and traffic congestion, it is not exclusively an urban problem. Sources and exposure patterns vary according to a region's income level, energy systems, industrial activities, agricultural practices, geography, climate, and access to clean technologies. In high-income and rapidly industrialising regions, major sources may include transport, industries, electricity generation, construction, and energy production. In many low- and middle-income settings, additional risks arise from household use of polluting fuels, open waste burning, agricultural activities, dust, and reliance on biomass energy. Natural events such as wildfires, dust storms, and volcanic activity can also contribute to air pollution and transport pollutants across national boundaries. Air pollution is particularly concerning because people are exposed to it throughout their daily lives. Exposure can occur while cooking, working, travelling, studying, exercising, or sleeping. Pollutants can also travel across administrative and national borders, meaning that air-quality problems cannot always be addressed by one community or country acting alone. The World Health Organization (WHO) identifies air pollution as one of the leading environmental health risks worldwide. Its health impacts include respiratory infections, asthma, chronic obstructive pulmonary disease, cardiovascular disease, stroke, lung cancer, and other serious conditions. Globally, air pollution is associated with millions of premature deaths each year, demonstrating the enormous scale of the problem. However, the burden is unequally distributed. Low-resource communities often face greater exposure because of dependence on polluting fuels, limited access to clean energy, inadequate infrastructure, weak pollution controls, and proximity to pollution sources. Vulnerable groups—including children, older people, pregnant women, people with existing health conditions, outdoor workers, and low-income communities—may experience disproportionate impacts. Air pollution therefore represents more than an environmental issue. It is simultaneously a health, development, economic, social justice, and climate challenge. Tackling it requires coordinated action across households, communities, cities, governments, industries, and international institutions.

8.5 Equity and environmental justice

Air pollution is not experienced equally by everyone. Equity and environmental justice recognise that people can face very different levels of pollution depending on where they live, work, travel, cook, study, and spend their time. Consequently, policies aimed at improving air quality must consider not only the overall amount of pollution but also who is exposed, why they are exposed, and who benefits from pollution-control measures. People living in low-income or informal settlements may face higher exposure because homes are often located near busy roads, industrial areas, waste disposal sites, or other pollution sources. For example, a community living close to a major highway may experience greater exposure to vehicle-related particulate matter and nitrogen dioxide than residents in a less congested neighbourhood. Household energy poverty can also create inequalities. Families that cannot afford clean cooking technologies may depend on firewood, charcoal, kerosene, or other polluting fuels. For example, a household using a traditional biomass stove in a poorly ventilated kitchen may experience high concentrations of smoke, while households with access to clean electric or other low-emission cooking technologies may experience substantially lower indoor pollution. Occupational exposure provides another example of environmental inequality. Construction workers may regularly inhale dust, miners may be exposed to particulate matter, and waste workers may encounter smoke and hazardous substances. Although these workers provide essential services, they may have limited control over their exposure and inadequate access to protective equipment. Air pollution can also affect children and students differently. A school located beside a heavily trafficked road may expose learners to higher concentrations of traffic-related pollutants than a school situated in a low-traffic area. Similarly, children from households using polluting cooking fuels may experience repeated exposure before and after school. Environmental justice therefore requires that clean-air interventions are fairly designed and distributed. Governments should prioritise highly exposed communities, improve access to clean energy, strengthen workplace protections, regulate major pollution sources, and involve affected communities in decision-making. For example, replacing polluting public transport vehicles with cleaner alternatives can reduce pollution while particularly benefiting communities living and working along busy transport corridors.

8.6 Case Study: Greenfield City is a rapidly growing urban centre with approximately 1

Air pollution represents one of the most pressing environmental health challenges facing rapidly urbanizing African cities, with direct impacts on public health, economic productivity, and sustainable development. Understanding the complex interactions between pollution sources, vulnerable populations, and effective mitigation strategies is essential for climate professionals working in African urban contexts.

Greenfield City's Air Quality Crisis

Greenfield City is a rapidly growing urban centre with approximately 1.2 million residents. Over the past five years, population growth (averaging 4.2% annually), increased vehicle ownership (up 37% since 2018), new construction projects (valued at \$1.2 billion), and expanding informal settlements (now covering 28% of the city) have placed unprecedented pressure on the city's infrastructure. Residents have increasingly complained about poor air quality, particularly during morning (6:30-8:30 AM) and evening (4:30-7:00 PM) traffic peaks, when PM_{2.5} concentrations regularly exceed WHO guidelines by 300-500%.

Major Pollution Sources Identified

Three major pollution sources have been identified through air quality monitoring stations established by the Greenfield Environmental Protection Agency:

- **Traffic congestion** along the Nairobi–Greenfield Highway produces exhaust emissions from approximately 45,000 vehicles daily, including 8,000 commercial buses, 5,000 trucks, 12,000 motorcycles, and 20,000 private vehicles. Monitoring shows that nitrogen dioxide (NO₂) levels near the highway average 120 µg/m³, exceeding WHO guidelines by 200%.
- **Open burning** of household and commercial waste occurs in 17 of the city's 42 wards, particularly in informal settlements where waste collection services reach only 42% of households. This practice produces smoke containing high concentrations of particulate matter (PM_{2.5} and PM₁₀), polycyclic aromatic hydrocarbons (PAHs), and dioxins.
- **Construction activities** generate substantial dust, particularly where roads and construction sites lack adequate controls. The 23 major construction projects across the city contribute to average PM₁₀ levels of 180 µg/m³ in surrounding areas, nearly four times WHO recommended limits.

Health Impacts and Vulnerable Populations

Residents living near the highway report frequent coughing (67% prevalence), throat discomfort (58%), and eye irritation (49%). Some parents have observed that children spend 40% less time playing outdoors because of visible dust and unpleasant-smelling smoke. Vulnerable groups experiencing particularly high exposure include:

- Traffic police (8-hour daily exposure at highway intersections)
- Street vendors (working 10-12 hours daily in high-traffic areas)
- Construction workers (working in uncontrolled dust environments)
- Waste collectors (handling unsorted waste with high combustion potential)
- Schoolchildren (attending schools within 500m of major roads)
- Households located near waste-burning sites (24/7 exposure)

Mitigation Strategies and Interventions

In practice, effective air quality management requires a multi-faceted approach:

- Implement traffic demand management measures including congestion pricing, improved public transport, and restricted vehicle access in high-pollution zones
- Enforce waste management regulations with incentives for proper disposal and penalties for open burning
- Mandate dust control measures at construction sites including water spraying, perimeter fencing, and speed restrictions
- Establish real-time air quality monitoring networks with public alerts and health advisories
- Develop green infrastructure including urban forests, vegetated barriers, and permeable pavements

"Air pollution is a silent killer that disproportionately affects the most vulnerable in our rapidly growing cities. Every intervention must prioritize environmental justice alongside technical solutions."

Learn more

- World Health Organization (WHO) air quality guidelines
- United Nations Environment Programme (UNEP) Africa Clean Air Programme
- African Development Bank (AfDB) Urban Environmental Sustainability Initiative

Key takeaways

- ✓ Rapid urbanization in African cities like Greenfield creates complex air pollution challenges requiring integrated technical and policy responses.
- ✓ Vulnerable populations including informal settlers, outdoor workers, and children face disproportionate health risks from air pollution exposure.
- ✓ Effective air quality management requires combining source control measures with real-time monitoring and public engagement strategies.

8.7 Hands-On Activity

Air pollution represents one of the most significant environmental health threats in Africa, with 1.1 million premature deaths annually linked to poor air quality, costing the continent an estimated \$450 billion in healthcare expenses and lost productivity. This hands-on activity transforms theoretical knowledge into practical skills that climate professionals can apply to identify, assess, and mitigate air pollution sources in their communities.

Activity Overview

Creating an **air pollution source map** is a participatory assessment tool that systematically identifies pollution sources, exposure patterns, and potential interventions in a specific area. This exercise builds your capacity to:

- Recognize diverse pollution sources (point, area, mobile)
- Identify vulnerable populations and exposure pathways
- Develop context-appropriate mitigation strategies
- Communicate findings effectively to stakeholders

Methodology

For this activity, select a defined area (campus, neighborhood, workplace) and:

- Type and scale of operation
- Likely pollutants (PM_{2.5}, PM₁₀, NO_x, SO₂, etc.)
- Potentially exposed populations

- Peak operating times
 - One feasible control action
1. Conduct a walk-through survey, noting all potential pollution sources
 2. Document locations using a simple grid or base map
 3. For each source, record:

Case Study: Nairobi's Air Quality Action

In Nairobi, Kenya, the **Nairobi Air Quality Partnership** applied this methodology in the Eastleigh neighborhood, identifying 27 major pollution sources including vehicle emissions (contributing 68% of PM2.5), waste burning (22%), and industrial activities (10%). The map revealed that 120,000 residents were exposed to PM2.5 levels exceeding WHO guidelines by 300%, with peak exposure during morning (6-9 AM) and evening (5-8 PM) rush hours. This evidence informed targeted interventions including traffic flow optimization, cleaner cooking fuel promotion, and industrial emission controls, resulting in a 23% reduction in PM2.5 levels within 18 months.

In Practice

- Use mobile apps like AirVisual or PurpleAir for real-time data collection
- Engage community members through participatory mapping workshops
- Prioritize interventions using a cost-benefit analysis framework
- Develop partnerships with local authorities for implementation support
- Consider seasonal variations in pollution patterns when mapping

Learn more

- WHO Global Ambient Air Quality Database
- UNEP Africa Air Quality Report
- Clean Air Fund's community engagement toolkit

Key takeaways

- ✓ Air pollution source mapping transforms theoretical knowledge into practical intervention planning.
- ✓ Community engagement is essential for accurate mapping and effective implementation of control measures.
- ✓ Quantifying exposure patterns helps prioritize resources for maximum public health impact.

Final Assessment & Certificate

The final test draws on questions from every module. The pass mark is 80%. When you pass, Tapi Learn issues a certificate of completion bearing your name, the course title, your final score, a unique certificate

number and the signature of the CEO of the Pan African Network for Climate Action (PANFCA). Each certificate carries a verification URL (acla.io/verify/<number>) so employers and partners can confirm its authenticity. You can download the certificate as a PDF directly from the app at any time, and your progress and certificates are backed up to the cloud under your email address.

The Africa Climate Leadership Academy (ACLA) is a pan-African education initiative of the Pan African Network for Climate Action. All Tapi Learn courses are free. Learn more at <https://acla.io> and get the app at <https://acla.io/tapi-learn>.