The IPCC's Fifth Assessment Report

What's in it for Africa?

Climate & Development Knowledge Network

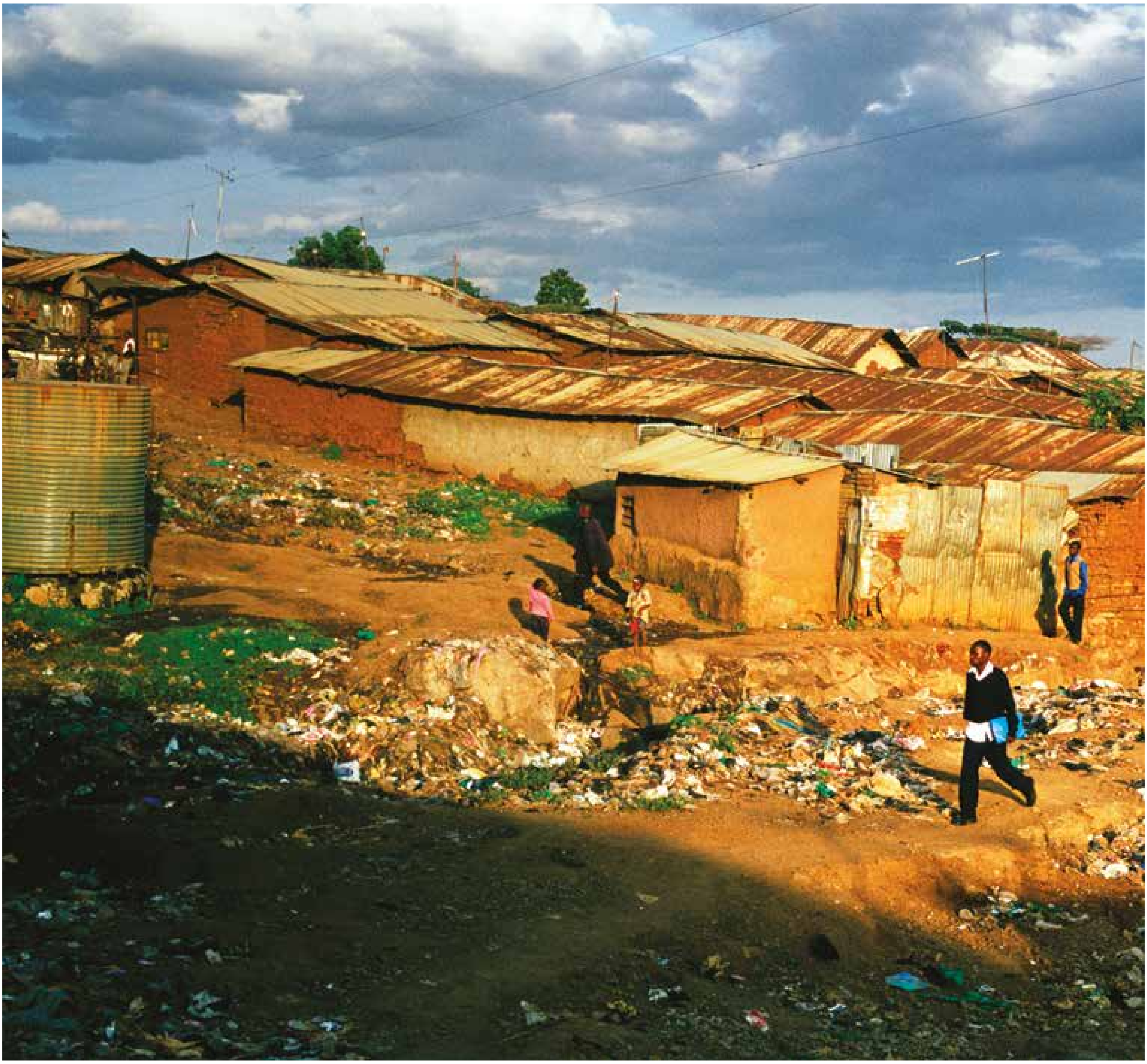

Image: © Jonas Bendiksen/Magnum Photos | Kibera, Nairobi, Kenya

Cover image:
Neil Palmer (CIAT) | A farmer in a maize field in Nyagatare, Rwanda

The IPCC's *Fifth Assessment Report* offers the following key messages for Africa:

1. Africa's climate is already changing and the impacts are already being felt
2. Further climate change is inevitable in the coming decades
3. Climate change poses challenges to growth and development in Africa
4. Adaptation will bring immediate benefits and reduce the impacts of climate change in Africa
5. Adaptation is fundamentally about risk management
6. Adaptation experience in Africa is growing
7. Some low-carbon development options may be less costly in the long run and could offer new economic opportunities for Africa
8. Africa stands to benefit from integrated climate adaptation, mitigation and development approaches
9. International cooperation is vital to avert dangerous climate change and African governments can promote ambitious global action

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Key messages from the *Fifth Assessment Report* for Africa

The IPCC's Fifth Assessment Report *offers the following key messages for Africa:*

Africa's climate is already changing and the impacts are already being felt

The *Fifth Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC) finds, beyond reasonable doubt, that the Earth's climate is warming.[1] Since the 1950s, the rate of global warming has been unprecedented compared to previous decades and millennia.[2] The IPCC finds with 95% certainty that human activity, by increasing concentrations of greenhouse gases in the atmosphere, has been the dominant cause of the observed warming since the mid-20th century.[3]

The *Fifth Assessment Report* presents strong evidence that warming over land across Africa has increased over the last 50–100 years.[4] Surface temperatures have already increased by 0.5–2°C over the past hundred years.[5] Data from 1950 onwards suggests that climate change has changed the magnitude and frequency of some extreme weather events in Africa already. The health, livelihoods and food security of people in Africa have been affected by climate change.[6]

Further climate change is inevitable in the coming decades

Regardless of future emissions, the world is already committed to further warming, largely due to past emissions and inertia in the climate system. The IPCC warns that if global society continues to emit greenhouse gases at current rates, the average global temperature could rise by 2.6–4.8°C by 2100 (according to the IPCC's highest emissions scenario[7]).

During this century, temperatures in the African continent are likely to rise more quickly than in other land areas, particularly in more arid regions.[8] Under a high-emissions scenario,[9] average temperatures will rise more than 2°C, the threshold set in current international agreements, over most of the continent by the middle of the 21st century.[10]

Climate change poses challenges to growth and development in Africa

Africa's recent development gains have been in climate-sensitive sectors. Economically, many Africans depend for food, fibre and income on primary sectors such as agriculture and fisheries, sectors which are affected by rising temperatures, rising sea levels and erratic rainfall.

The IPCC highlights the key risks to Africa of climate change as being stress on water resources, reduced crop productivity, and changes in the incidence and geographic range of vector- and water-borne diseases.[11]

While some environmental, economic and cultural systems across Africa are already at risk from climate change, the severity of the consequences increases with rising temperatures. Climate change challenges fundamental social and economic policy goals such as growth, equity and sustainable development.

> **"Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850."**
> IPCC[12]

Adaptation will bring immediate benefits and reduce the impacts of climate change in Africa

To manage the inevitable impacts of climate change that cannot be reduced through mitigation, Africa needs to adapt. Adaptation brings benefits both today and in the future. The IPCC emphasises that adaptation and development approaches can go hand-in-hand, and can in fact reinforce each other.

Even after taking action on adaptation, African societies may still have to deal with some climate-related risks. The intensity and frequency of future climate risks largely depends on the level of ambition of global mitigation actions. For this reason, the IPCC stresses the importance of integrating adaptation and mitigation strategies into long-term development planning.[13]

Adaptation is fundamentally about risk management

In Africa, the primary concern is adapting to the negative impacts of climate change. This means taking both short-and long-term approaches to managing climate risks. In the short term, integrating climate adaptation and disaster risk reduction will help withstand shocks to human security and economic development from which recovery can be costly. In the longer term, governments, businesses and communities need not only to prepare for the kinds of climate impacts experienced up to now but also for different and more intense climate impacts and extreme events.

"In many cases, we are not prepared for the climate-related risks that we already face. Investments in better preparation can pay dividends both in the present and for the future." Vicente Barros, Co-Chair, Working Group II

Adaptation experience in Africa is growing

The IPCC's findings accord with current directions in African development policy-making. Over the past decade, countries across Africa have adopted increasingly comprehensive development plans with ambitious social and economic development objectives. They have attempted to move beyond the narrow objective of poverty reduction to encompass wider objectives of accelerated growth, employment creation, and provision of water, sanitation, health and education needs within the framework of sustainable development. Further, several African governments, such as Ethiopia and Rwanda, have adopted national climate resilience strategies with a view to applying them across economic sectors. For the continent as a whole, development planning and practice must now reflect the reality of a changing climate, and ensure that investments take account of future climate conditions.[14]

African governments can help to promote ambitious global action on climate change mitigation

Ambitious climate mitigation at the global level must start now in order to limit the magnitude of long-term climate change and reduce the risks. The world's governments have pledged to limit warming to at least 2°C above pre-industrial levels. The need for deep cuts in emissions to limit warming to the 2°C threshold is a central theme of the section of the *Fifth Assessment Report* on climate mitigation.

The choices that global society makes today to curb greenhouse gas emissions will have a profound impact on the degree of warming during the second half of this century. It is widely recognised that urgent action is needed now to limit emissions at global level to mitigate the impacts of dangerous climate change in the longer term. Societies and ecosystems across the globe depend on such actions – and on their happening in a coordinated way.

Some low-carbon development options may be less costly in the long run and could offer new economic opportunities for Africa

The IPCC recognises that Africa (particularly sub-Saharan Africa but excluding South Africa) has low levels of emissions and that over time these emissions will increase moderately to meet pressing development needs.[15] In expanding economically and meeting their development needs, African countries have abundant opportunities to adopt clean, efficient low-carbon technologies and practices. They can side step the inefficient, fossil fuel-dependent infrastructure that more developed countries are 'locked into'.[16] The *Fifth Assessment Report* identifies many low-carbon opportunities and co-benefits.[17] Many of the measures to avoid greenhouse gas emissions provide generous gains in economic productivity, human development and quality of life. The adoption of a low-carbon pathway needs to fit into countries' specific national circumstances, which means that the nature of these pathways will depend on resources, capacities and governance realities.

Ambitious climate mitigation at a global level must start now to limit the magnitude of long-term climate change and reduce the risks.

The world can afford ambitious mitigation action, provided there is sufficient political will and cooperation among countries on technology transfer and finance. Indeed, the IPCC makes clear that it is relatively less expensive to adopt low-carbon choices now rather than react later when extensive institutional and infrastructure lock-in has taken place. Annual global consumption growth is estimated at 1.6–3% per year, and so adopting ambitious climate mitigation measures would reduce this consumption growth by around 0.06 percentage points per year this century.[19] Although Africa has contributed very little to historic greenhouse gas emissions, African countries stand to benefit from new, cleaner technologies, and these actions would enable African governments to play a proactive and leading role in promoting an ambitious global dialogue on climate change.

Africa stands to benefit from integrated climate adaptation, mitigation and development approaches

The IPCC points out that there are many complementarities among climate adaptation, mitigation and development.[19] Many sustainable development pathways combine adaptation, mitigation and development approaches. The *Fifth Assessment Report* provides policy-makers with a wealth of evidence from climate change adaptation and mitigation efforts around the world on what works and what does not work. The IPCC also highlights some of the trade-offs.

Unless carefully considered, some mitigation activities bring the risk of adverse consequences. For example, the adoption of new technologies or crops to reduce or sequester carbon can undermine the development opportunities and climate resilience of vulnerable social groups. The IPCC provides examples and recommends robust decision-making processes to avert these risks.

Climate mitigation activities, managed carefully so that they do not introduce new risks to development, can provide multiple benefits.

International cooperation is vital to avert dangerous climate change and African governments can promote ambitious global action

The IPCC's work shows that international cooperation is vital to avert dangerous climate change. Since the IPCC was formed in 1992, its work has given us a progressively improved understanding of climate science and provided a clearer picture of the range of vulnerabilities in different parts of the world. The *Fifth Assessment Report* provides the strongest warning yet.

In 2010, governmental Parties to the United Nations Framework Convention on Climate Change (UNFCCC) meeting in Cancun[20] pledged to reduce emissions to achieve the long-term goal of limiting global warming to 2°C above pre-industrial temperatures. The *Fifth Assessment Report* finds that the actual governmental pledges made at and since Cancun fall short of what is needed to achieve the long-term goal.

The *Fifth Assessment Report* recognises that climate change is a global commons problem – a problem that lies outside the political reach of any one nation state – and that it requires a collective, global response. For this reason, the IPCC's findings on sources of global greenhouse gas emissions and their impacts on climate provide African governments with an important knowledge base for formulating their positions in international climate change negotiations.

Ensuring the right choices now requires every government to participate in the global effort on climate change and to work towards an ambitious collective solution. African leaders have an important part to play – with all other international leaders – in forging this commitment.

About the IPCC's *Fifth Assessment Report*

The Intergovernmental Panel on Climate Change (IPCC) has produced the most comprehensive assessment of climate change ever. The *Fifth Assessment Report* (http://www.ipcc.ch), which IPCC is releasing in four parts between September 2013 and November 2014, is the work of 830 expert authors, from 85 countries. The report reviews the scientific evidence on the trends and causes of climate change, the risks to human and natural systems, and options for adaptation and mitigation. The IPCC aims to be – in its own words – "policy relevant but not policy prescriptive". Its findings further our understanding of humankind's interaction with our environment: how we are affecting the global climate and what we can do about it.

The IPCC Working Groups publish the reports comprising the *Fifth Assessment Report* (see Figure: How the IPCC works, page 70). These groups are: Working Group I (Physical Science of Climate Change), Working Group II (Impacts, Adaptation and Vulnerability) and Working Group III (Climate Change Mitigation). The final report is a synthesis of findings. Although the collected reports total many thousands of pages, each Working Group produces a *Summary for Policymakers,* which presents key findings in a more succinct form. Representatives of more than 190 governments review and negotiate the summaries in detail during a week-long event. Once governments have signed off on each *Summary*, the IPCC publishes it, together with the full scientific report.

The component parts of the *Fifth Assessment Report* may be accessed on the following websites:

Working Group I: The Physical Science
www.climatechange2013.org

Working Group II: Impacts, Adaptation and Vulnerability
www.ipcc.ch/report/ar5/wg2/

Working Group III: Mitigation of Climate Change
www.ipcc.ch/report/ar5/wg3/

About this report

This report is a guide to the IPCC's *Fifth Assessment Report* prepared for decision-makers in Africa by the Climate and Development Knowledge Network (CDKN) and Overseas Development Institute (ODI). The IPCC 's *Summaries for Policymakers* focus principally on global issues and trends. This report distils the richest material on what climate change means for Africa, and African experiences in adaptation and mitigation, from the thousands of pages of the *Fifth Assessment Report*. The publication has not been through the comprehensive governmental approval process that IPCC endorsement requires. However, the expert research team has worked under the guidance of IPCC Coordinating Lead Authors and Reviewers to ensure fidelity to the original (see *Acknowledgements*).

The research team has extracted the Africa-specific data, trends and analysis directly and solely from the *Fifth Assessment Report* for this short volume. In so doing, we hope to make the IPCC's important material more accessible and usable to African audiences. This report responds to wide demand among CDKN's Africa partner networks, for region-specific information.

Our publication is part of a suite of materials to aid understanding of the IPCC's *Fifth Assessment Report*. Companion volumes provide a digest of IPCC findings for: South Asia; Latin America; and Small Island Developing States.

Please visit www.cdkn.org/ar5-toolkit

1 Africa's climate is already changing and the impacts are already being felt

Scientists have observed changes in Africa's climate during the past century, with records showing increased warming over Africa's land mass. Climate change is already having negative effects on Africa. It is impacting the health of land and marine-based ecosystems, and the health and food security of many of the region's most vulnerable people.

1.1. Human activity is influencing the climate

The IPCC finds – beyond reasonable doubt – that the global climate has warmed since the 1950s. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea levels have risen. Concentrations of greenhouse gases in the Earth's atmosphere have increased and atmospheric concentrations of carbon dioxide, methane and nitrous oxide have now risen to levels unprecedented in at least the last 800,000 years.

According to the IPCC, there is 95% scientific certainty that human activities are responsible for these increased greenhouse gas concentrations. The primary sources of emissions are fossil fuel emissions and changes in land use, such as deforestation, to make room for agricultural expansion to meet food requirements for a growing population. These greenhouse gases do not only stay in the atmosphere, they are also absorbed by the oceans. About 30% of the carbon dioxide from human activities is absorbed by the oceans, which makes ocean waters more acidic and damages marine life.

Box 1: How the IPCC's *Fifth Assessment Report* defines scientific certainty[21]

The IPCC accords a degree of certainty to each of its key findings, based on the type, amount, quality and consistency of evidence (e.g. data, theory, models, expert judgment), and the degree of agreement among scientists. The terms to describe evidence are: limited, medium or robust; and to describe agreement: low, medium or high.

When the *Fifth Assessment Report* talks about 'confidence' in a finding, 'confidence' represents a synthesis of how much evidence there is, and how much scientific agreement exists. The levels of confidence used are: very low, low, medium, high and very high.

It is extremely likely that human activities have been the dominant cause of observed warming.

The likelihood of some outcome having occurred or occurring in the future can be described in terms of percentages as follows:

Virtually certain	**99% or more**
Extremely likely	**95% or more**
Very likely	**90% or more**
Likely	**66% or more**
More likely than not	**more than 50%**
About as likely as not	**33–66%**
Unlikely	**33% or less**
Very unlikely	**10% or less**
Extremely unlikely	**5% or less**
Exceptionally unlikely	**1% or less**

Using this scale, it is possible to see the very high level of certainty the world's leading scientists have in concluding that humans are the cause of global warming. In science, 95% certainty is often considered the 'gold standard' for certainty, the condition by which theories are accepted. For example, the theories of evolution, the Earth's age and the Big Bang theory have all achieved this standard of scientific certainty.

Image:
iStock | Seaweed farm at low tide, Zanzibar Island, Tanzania

1.2. Africa's climate is already changing

Observed temperature: The IPCC has reported that land surface temperatures across most of Africa have increased by 0.5°C or more during the last 50–100 years. There is strong evidence that observed temperature increases exceed natural climate variability and have been influenced by greenhouse gas emissions due to human influence.

Observed rainfall: Most areas of Africa lack sufficient observational data to draw conclusions about trends in annual rainfall over the past century. Where data are available, these indicate a very likely decrease in annual rainfall over the past century in parts of the western and eastern Sahel region in northern Africa and very likely increases over parts of eastern and southern Africa.

Observed extreme events: Based on data since 1950, evidence suggests that climate change has changed the magnitude and frequency of some extreme weather and climate events in some global regions already, although there is a general lack of data for Africa, as described in the sub-regional sections below.

Observed sea level rise: The rate of sea-level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (*high confidence*). Over the period 1901–2010, global mean sea level rose by 19 cm, and will continue to rise during the 21st century.

North Africa

Observed temperature: In recent decades, annual and seasonal observed trends in North Africa show overall warming in this region. Annual maximum temperatures are increasing.

Observed rainfall: Over the last few decades, the northern parts of North Africa have received much less rainfall in winter and early spring, and more dry days. In the Sahara Desert, there has been little seasonal change.

Observed extreme events: There is limited information about observed trends in the frequency of hot days, extreme rainfall or drought for this region. However, the northwestern Sahara has been shown to experience 40–50 heat wave days every year between 1989 and 2009.

East Africa

Observed temperature: The equatorial and southern parts of eastern Africa have experienced a significant increase in temperature since the early 1980s. Seasonal average temperatures have also risen in many parts of eastern

Figure 1: Change in annual average temperature in Africa, 1901–2012[22]

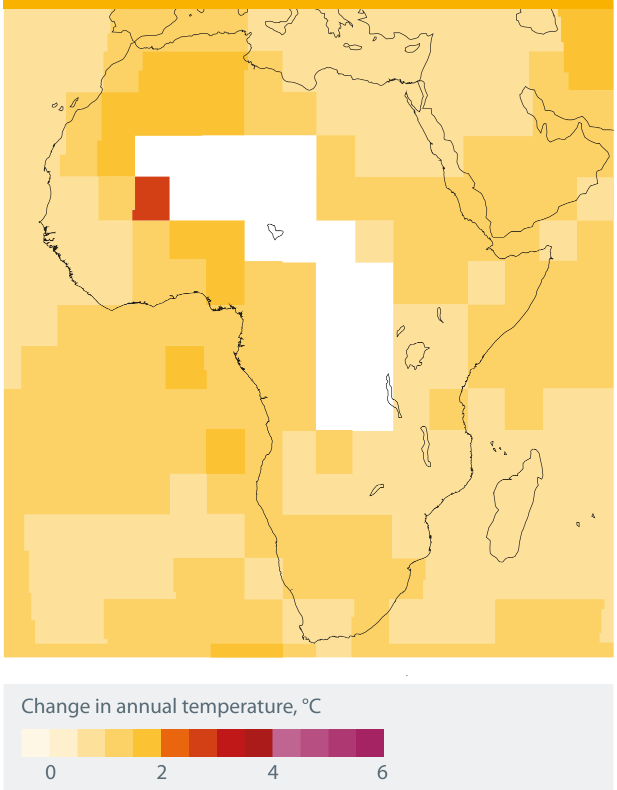
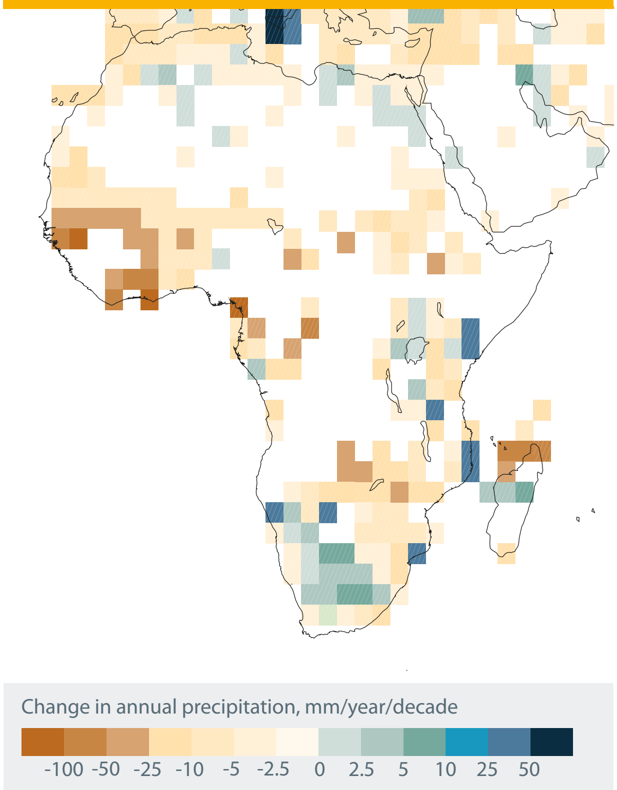


Figure 2: Change in annual average rainfall in Africa, 1951–2012[23]



Africa in the last 50 years. Countries bordering the western Indian Ocean experienced warmer temperatures and more frequent heat waves between 1961 and 2008.

Observed rainfall: Rainfall in eastern Africa is very variable in time and space. Several physical processes, including the El Niño Southern Oscillation, affect rainfall. Some models suggest that rapid warming of the Indian Ocean may be the cause of less rainfall over eastern Africa between March and May-June in the last 30 years. Summer monsoon rainfall declined throughout much of the Horn of Africa over the last 60 years.

Observed extreme events: There is a lack of evidence about trends in extreme temperature, extreme rainfall and drought in East Africa (*low confidence*). However, droughts and storms have been more frequent in eastern Africa in the last 30–60 years. Continued warming in the Indian Ocean has been shown to contribute to more frequent East African spring and summer droughts over the past 30 years. It is not clear whether these changes are due to anthropogenic influence or to natural climatic variability.

West Africa

Observed temperature: Temperatures across West Africa have risen over the last 50 years. There were fewer cold days and cold nights and more warm days and warm nights between 1970 and 2010.

Observed rainfall: Rainfall in the Sahel decreased overall in the 20th century, but recovered to previous levels in the 1980s and 1990s. The recovery may be due to natural climate variability or anthropogenic climate change. The many droughts in the Sahel in the 1970s and 1980s are well documented.

Observed extreme events: A significant increase in the temperature of hottest days and coolest days has been observed in some parts of West Africa (*medium confidence*) although there is insufficient information available in other parts to identify trends. There is likely to be an increase in the frequency of hot days in the future (*high confidence*). There has also been an observed increase in drought in the region, although the 1970s Sahel drought dominates this trend. Greater variation between years has been observed more recently (*high confidence*).

Southern Africa

Observed temperature: Since the mid-20th century, most of southern Africa has experienced an increase in annual average, maximum and minimum temperatures. The most significant warming has been during the last two decades. Minimum temperatures have risen more rapidly compared to maximum temperatures over inland southern Africa.

Observed rainfall: Western parts of southern Africa, from Namibia to Angola and the Congo, had less late summer rain in the second half of the 20th century. Botswana, Zimbabwe and western South Africa have also had modest decreases in rainfall. Seasonal rainfall patterns, such as the onset or duration of rains, frequency of dry spells and intensity of rainfall, as well as delays in the onset of rainfall, have changed. More frequent dry spells, coupled with more intense daily rainfall, have implications for surface water management and flood risk.

Observed extreme events: More hot days, hot nights and hotter days, and fewer cold days and cold nights in recent decades are consistent with overall warming. There has been a likely increase in the frequency of hot days in southern Africa (*high confidence*). There is also a likely increase projected for the future (*high confidence*). The probability of summer heat waves in South Africa increased 1981–2000 compared to 1961–1980. Heat waves were associated with a lack of rainfall during El Niño events.

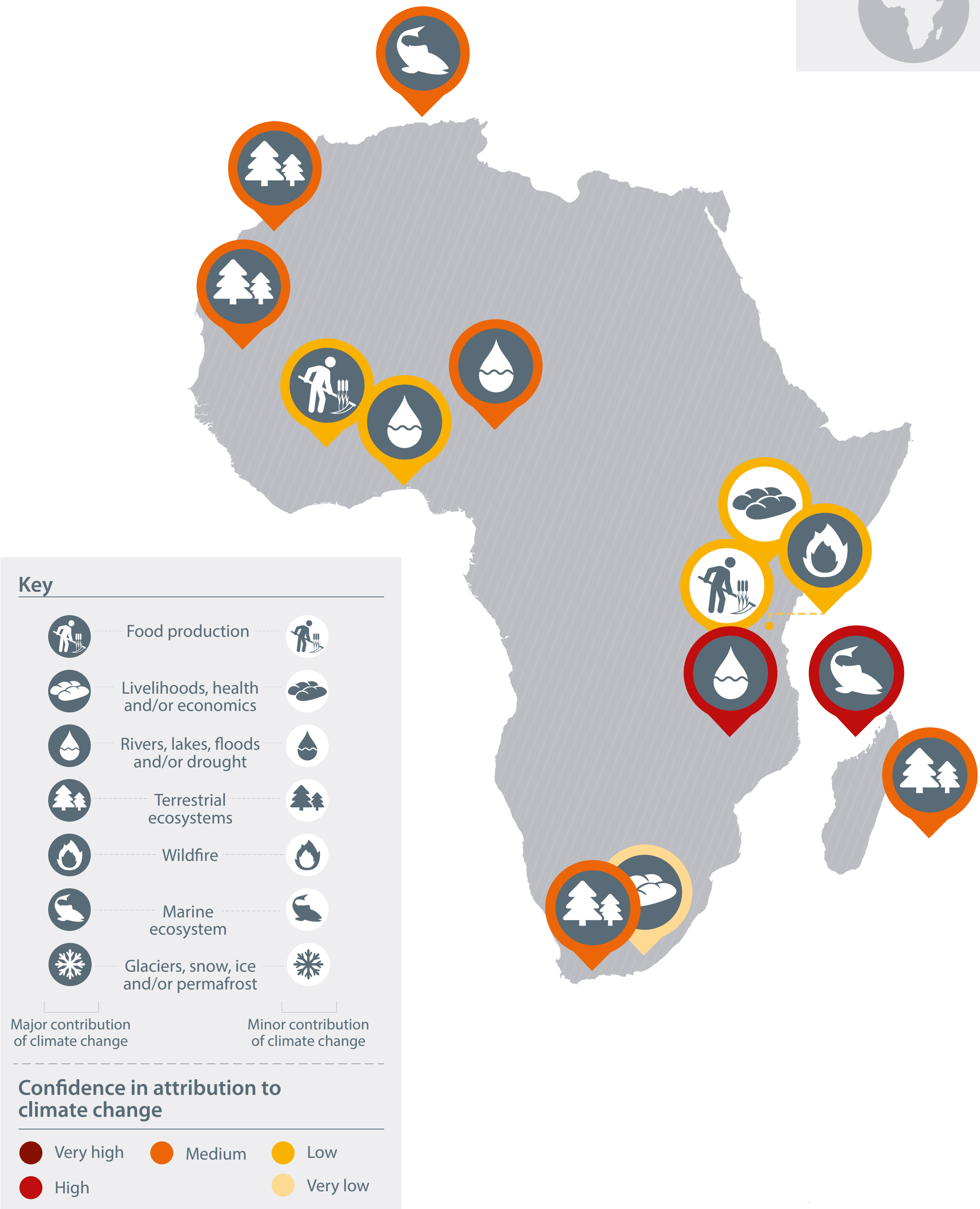
1.3. The impacts of climate change are already being felt

Even today, climatic risks threaten lives and prosperity across many parts of Africa and there are clear signs that the impacts of climate change are already being felt. The health, livelihoods and food security of people in Africa have been affected by climate change.[24] There is evidence that temperature changes have played a role in the increased incidence of malaria in parts of East Africa, and have already driven changes in the practices of South African farmers.[25] Production of wheat and maize in parts of Africa has been impacted by climate change, as has the productivity of fisheries of the Great Lakes and Lake Kariba and fruit-bearing trees in the Sahel.[26]

The impacts from recent weather-related extremes, such as heat waves, droughts, floods, cyclones and wildfires, reveal the exposure and vulnerability of some African people and economies to climate (Box 2).

Following droughts in the 1970s and 1980s, recurrent droughts and floods affected the Sahel in the 1990s and 2000s, often destroying crops and compounding food security problems.[27] Floods in the Zambezi River Valley displaced 90,000 Mozambicans in 2008. About 1 million people live in flood-affected areas and temporary displacement is taking on permanent characteristics.[28] The experiences of extreme weather events in different parts of Africa highlight the risks to human wellbeing. The *Fifth Assessment Report* expects such events to become more frequent and more intense as the climate changes, though with large regional variations and differing degrees of confidence depending on the type of climate event.[29] The economic losses due to extreme weather events are also rising with the increasing frequency of events and increasing exposure of assets.[30]

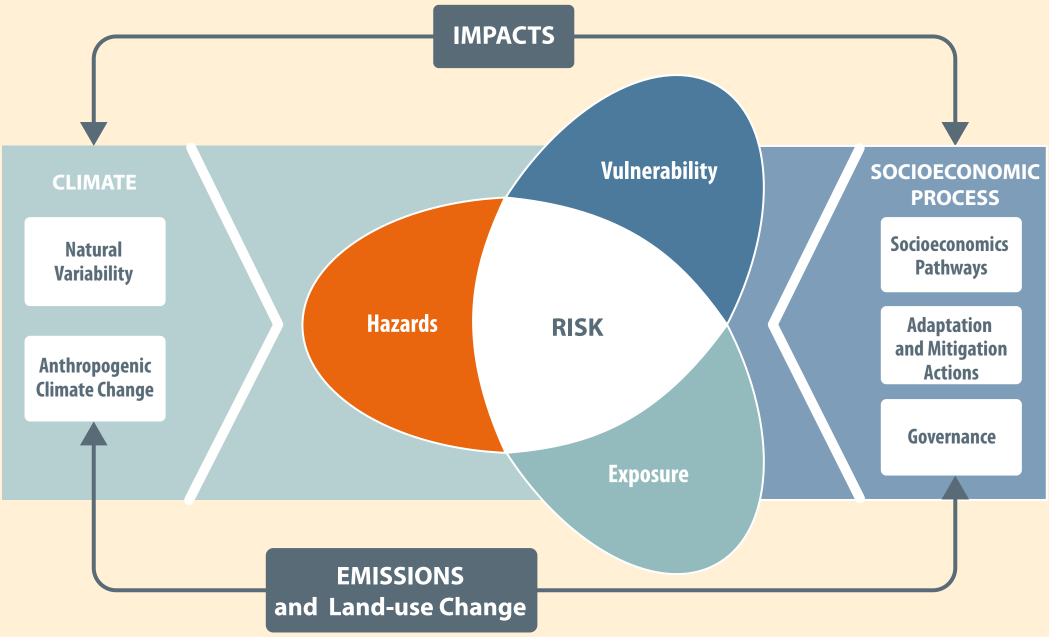
Figure 3: Impacts of climate change in Africa[33]



Box 2: Climate change poses risks to human and natural systems[34]

Risks related to climate change arise from climate-related hazards (climate trends and extremes) and the vulnerability of exposed societies, communities and systems (in terms of livelihoods, infrastructure, ecosystem services and governance). Effective measures to adapt to climate change and reduce the risks associated with climate change can address all three aspects of risk: hazard, vulnerability and exposure.

The vulnerability and exposure of societies and ecological systems to climate-related hazards vary constantly because of changes in economic, social, demographic, cultural, institutional and governance circumstances. For example, rapid and unsustainable urban development, international financial pressures, increases in socioeconomic inequality, failures in governance and environmental degradation affect vulnerability. These changes unfold in different places at different times, meaning that strategies to strengthen resilience and reduce exposure and vulnerability need to be locally or regionally specific. For example, countries that are rapidly urbanising are vulnerable to climate change if their economic development is slow. In other countries, urbanisation may present opportunities to adapt to climate change. Poverty is also a critical factor in determining vulnerability to climate change and extreme events. For example, vulnerability to drought in sub-Saharan Africa is closely linked to poverty in rural economies.[35]



The impacts of recent extreme weather events also demonstrate the vulnerability of some African ecosystems (Box 2). The geographic range, seasonal activities and migration patterns of many terrestrial, freshwater and marine species have shifted in response to ongoing climate change.[31] The abundance of species has changed, as have interactions among species. The pace of change has been rapid. Climate change has already led to changes in freshwater and marine ecosystems in eastern and southern Africa, and terrestrial ecosystems in southern and Western Africa (Figure 3).[32]

These examples from different parts of Africa highlight the risks of extreme weather events to human wellbeing in a part of the world where institutions are weak and the capacity to adapt barely exists. Communities across Africa have an inherent vulnerability to climate risks and extreme events, events which are expected to become more frequent and more intense in magnitude as the climate changes.

2 Further climate change is inevitable in the coming decades

African societies must prepare for inevitable changes in the climate during the next few decades, even as they join the global effort to limit greenhouse gas emissions and curb further warming. In Africa, climate change will amplify existing stresses on water availability and agriculture and will affect public health.

2.1. The world will continue warming until mid-century

The IPCC reports that total emissions have continued to rise since 1970, with larger absolute increases between 2000 and 2010.[36] Globally, the majority of greenhouse gas emissions due to human activities have come from a small number of countries – though the number is increasing. The IPCC warns that if global society continues to emit greenhouse gases at current rates and in the absence of robust climate mitigation policies, the average global temperature could rise by 2.6–4.8°C by 2100 (according to the IPCC's high-emissions scenario[37]). The implication of this scenario is that climate change will create new risks and amplify existing risks for human and natural systems, further challenging food, livelihoods and human security, and wellbeing.

Box 3 illustrates projected warming under a low-emissions scenario, a high-emissions scenario and two mid-range scenarios, and the temperature changes associated with each.[38] Regardless of future emissions, we are already committed to further warming largely due to past emissions and inertia in the climate system.[39] Whether global society continues to emit greenhouse gases at today's rate, or cuts greenhouse gas emissions sharply now, does not make

Box 3: What are the IPCC scenarios?

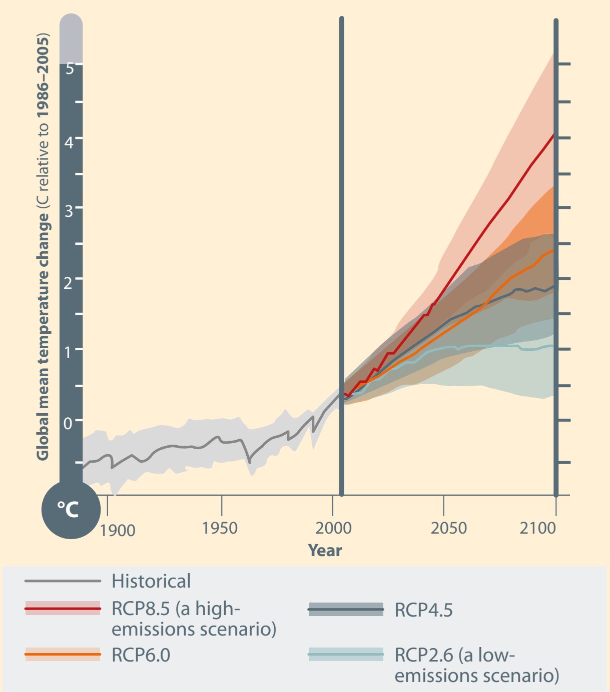
In assessing future climate change, the *Fifth Assessment Report* presents four scenarios, known as Representative Concentration Pathways (RCPs – see figure at right). The scenarios show the result of different levels of emissions of greenhouse gases, from the present day to 2100, on global warming. IPCC does not indicate which policy and behavioural choices[40] society could make that would lead to the scenarios.

In all scenarios, carbon dioxide concentrations are higher in 2100 than they are today. The low-emissions scenario[41] assumes substantial and sustained reductions in greenhouse gas emissions. The high-emissions scenario[42] assumes continued high-emissions. The two intermediate scenarios[43] assume some stabilisation in emissions.

In the next few decades, warming will be the same in all scenarios (see the overlap between the scenarios at right, and in Box 4). Regardless of action taken now to reduce emissions, the climate will change until around the middle of this century. In the longer term, in all except the low-emissions scenario, global warming at the end of the 21st century is likely to be at least 1.5°C.[44] In the two higher emissions scenarios, global warming is *likely* to be 2°C. In the second lowest emissions scenario, global warming is *more likely than not* to be 2°C.[45]

Warming will continue beyond 2100 under all emissions scenarios except the lowest and will continue to vary between years and between decades.

Observed warming and warming under IPCC scenarios



a big difference in terms of climate impacts in the next few decades.

Curbing emissions to maintain global temperatures below 2°C requires urgent action at global level. However, the benefits to the global climate – and societies and ecosystems that depend on it – will only emerge in the latter half of the century. The IPCC lists the many reasons why mitigation action must start now and the kinds of immediate benefits it can deliver (see page 34 onwards). In contrast, taking action on *adaptation* today delivers many immediate benefits. But, there are limits to adaptation. For this reason, both adaptation and mitigation are needed; they each deliver benefits but over different timeframes.[46]

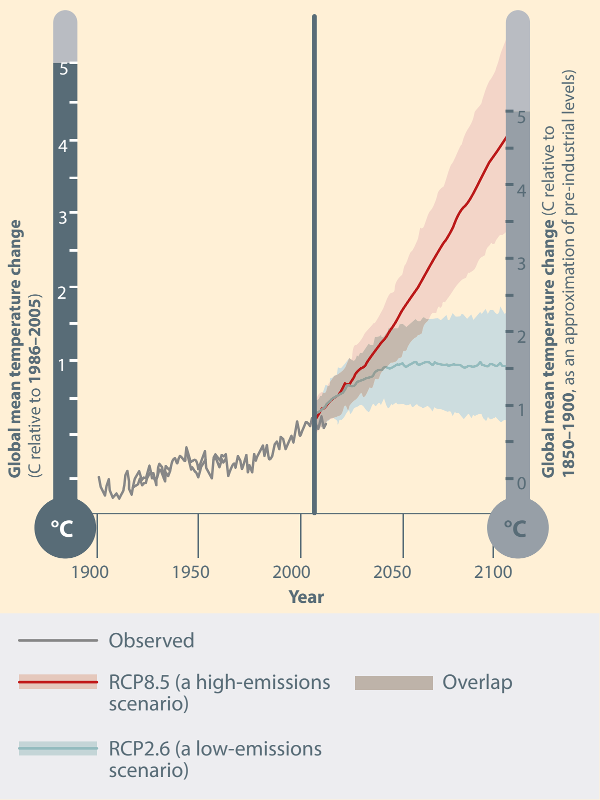
Climate change will create new risks and amplify existing risks for society and the natural environment.[47]

Box 4: Impacts of global warming[48]

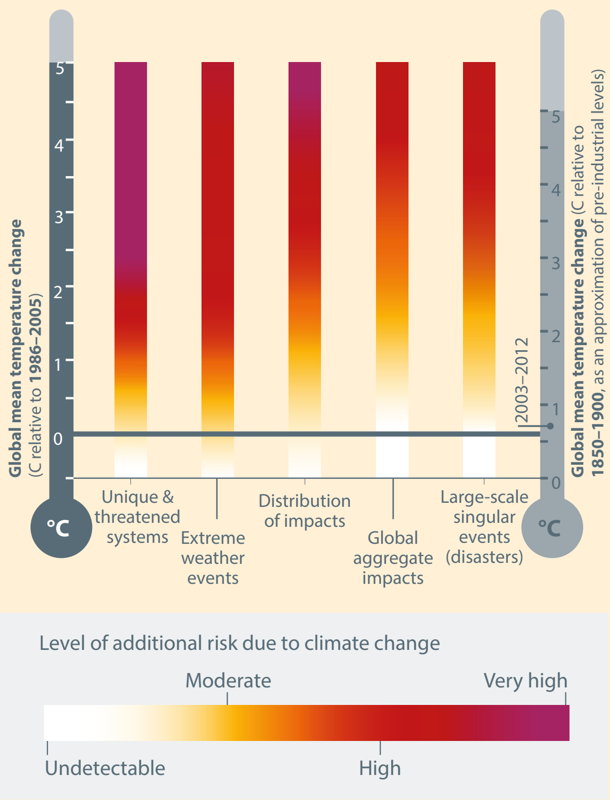
The diagram below shows global warming in the last century, and projected global warming to 2100 according to the IPCC's highest and lowest emissions scenarios. The IPCC identifies five main areas of concern as temperatures rise. The diagram on the right indicates the additional climate-related risks in these areas of concern when temperatures reach a certain level, are sustained at that level or exceeded. At even relatively low levels of warming of 1 to 2°C, many unique natural systems are threatened and food productivity, human health and water resources could be negatively impacted in some regions. The IPCC concludes that large-scale warming, of around 4°C or above, will increase the likelihood of severe, pervasive and irreversible impacts to which it will be difficult to adapt.

Climate change impacts across these areas of concern will increase risks of food insecurity and the breakdown of food systems, increase risks of loss of rural livelihoods and income due to insufficient access to drinking and irrigation water and reduced agricultural productivity, particularly for farmers and pastoralists with minimal capital in semi-arid regions. Risks due to extreme weather events leading to breakdown of infrastructure networks and critical services such as electricity, water supply, and health and emergency services are also linked to these areas of concern.

Observed and projected global annual average temperature



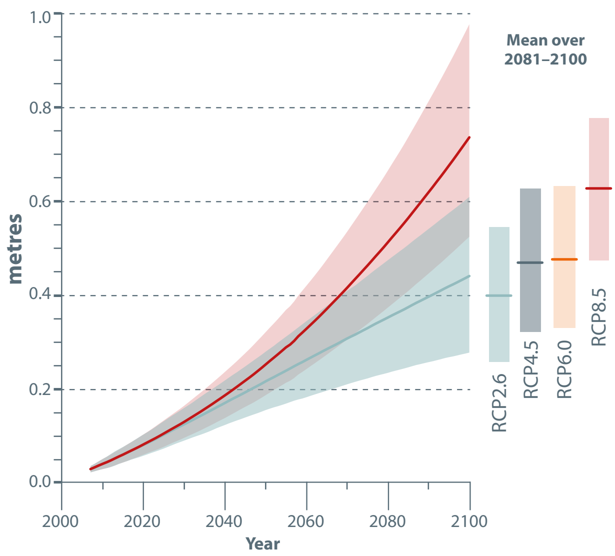
Global risks under increasing levels of climate change



"Extreme precipitation changes over Eastern Africa such as droughts and heavy rainfall have been experienced more frequently during the last 30–60 years." IPCC[49]

Risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development.

Figure 4: Global mean sea level rise[50]



2.2. Future climate trends for Africa[51]

Projected temperature trends: During this century, temperatures in the African continent are likely to rise more quickly than in other land areas, particularly in more arid regions. Increases in average temperatures are very likely in the mid- and late-21st century under both low- and high-emissions scenarios.

Under a high-emissions scenario, average temperatures will rise more than 2°C, the threshold set in current international agreements, over most of the continent by the mid-21st century. Average temperatures will rise more than 4°C across most areas by the late 21st century. Changes in average temperature are projected to be greater over northern and southern Africa and relatively smaller over central Africa. Under a low-emissions scenario, average temperature rises across Africa are projected to be less than 2°C by both the mid- and late-21st century.

Projected rainfall trends: Projections for rainfall are less certain than projections for temperature. Most areas of the African continent do not show changes in annual average rainfall under low-emissions scenarios. However, projections do show a very likely decrease in annual average rainfall over areas of southern Africa beginning in the mid-21st century, and expanding substantially by the late-21st century, under a high-emissions scenario. In contrast, likely increases in annual average rainfall are projected over areas of central and eastern Africa beginning in the mid-21st century for the same high-emissions scenario.

Projected extreme events: In the next two or three decades, the expected increase in climate extremes will probably be relatively small compared to the normal year-to-year variations in such extremes. However, as climate change impacts become more dramatic, their effect on a range of climate extremes in Africa, including heavy rainfall, heat waves and drought, will become increasingly important and will play a more significant role in disaster impacts.

Projected sea level rise: Under all emissions scenarios – low and high – the rate of sea level rise will very likely exceed that observed during the past three decades due to increased ocean warming and increased loss of mass from glaciers and ice sheets. Global mean sea level rise during the last two decades of the 21st century (as compared to sea level in 1986–2005) will likely be in the range 26–55 cm under a low-emissions scenario, but 45–82 cm for a high-emissions scenario – with total sea level rise of up to 98 cm by 2100 under this latter scenario. This magnitude of sea level rise by the century's end implies significantly increased risks for Africa's coastal settlements, as well as for coastal economies, cultures and ecosystems.

"In Africa, climate change will amplify existing stress on water availability and on agricultural systems, particularly in semi-arid environments." IPCC[52]

Image:
Shutterstock | Mother and child at medical clinic, Nairobi, Kenya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North Africa

Projected temperature: Both annual minimum and maximum temperatures are likely to rise further under a high-emissions scenario, with more of a rise in minimum temperatures. Projections indicate that temperatures will be higher during the northern hemisphere summer.

Projected rainfall: By the end of this century, it is very likely that northern Africa will receive less rainfall. Global and regional projections for the 21st century consistently indicate yearly and seasonal drying and warming over northern Africa under high-emissions scenarios.

Projected extreme events: Projections indicate that the number of heat wave days will increase over the 21st century. There is *high confidence* that there will be a likely increase in the frequency of hot days across the Sahara. The projections for extreme rainfall are inconsistent.

West Africa

Projected temperature: Projections indicate that temperatures in West Africa will rise by between 3°C and 6°C by the end of the 21st century under a range of scenarios. Regional-scale models support the range of change indicated by global models. Under a range of scenarios, the Sahel and West Africa are projected to be hotspots of climate change. Projections indicate that unprecedented changes in climate will occur earliest in these regions, by the late 2030s to early 2040s.

Projected rainfall: Variations in the results of global models mean that confidence in the robustness of projections of changes in regional rainfall is low to medium pending the availability of more regional data. However, many global models indicate a wetter main rainy season with a small delay in the onset of the rainy season by the end of the 21st century.

Projected extreme events: Projections of the risk of drought are inconsistent for this region. An increase in rainfall intensity has been observed (*medium confidence*), although projections indicate slight or no change in heavy rainfall in most areas (*medium confidence*). The results of regional modelling suggest an increase in more intense and more frequent extreme rainfall events over the Guinea Highlands and Cameroon Mountains.

East Africa

Projected temperature: Projections for medium- to high-emissions scenarios indicate that maximum and minimum temperatures over equatorial East Africa will rise and that there will be more warmer days compared to the baseline by the middle and end of this century. Climate models show warming in all four seasons over Ethiopia, which may result in more frequent heat waves.

Projected rainfall: In spite of the declining rainfall trend observed (page 11 above), global projections suggest that by the end of the 21st century, the climate in eastern Africa will be wetter, with more intense wet seasons and less severe droughts in October-November-December and March-April-May, a reversal of recent historical trends. Regional models suggest that most parts of Uganda, Kenya and South Sudan will be drier in August and September by the end of the 21st century. Projections indicate shorter spring rains in the mid-21st century for Ethiopia, Somalia, Tanzania and southern Kenya, and longer autumn rains in southern Kenya and Tanzania.

Projected extreme events: The IPCC's *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*[54] (SREX, 2012) indicates that there will likely be more heavy rainfall over the region with high certainty and more extremely wet days by the mid-21st century. There will also likely be an increase in the frequency of hot days in the future (*high confidence*), although a decreasing dryness trend over large areas is also projected (*medium confidence*).

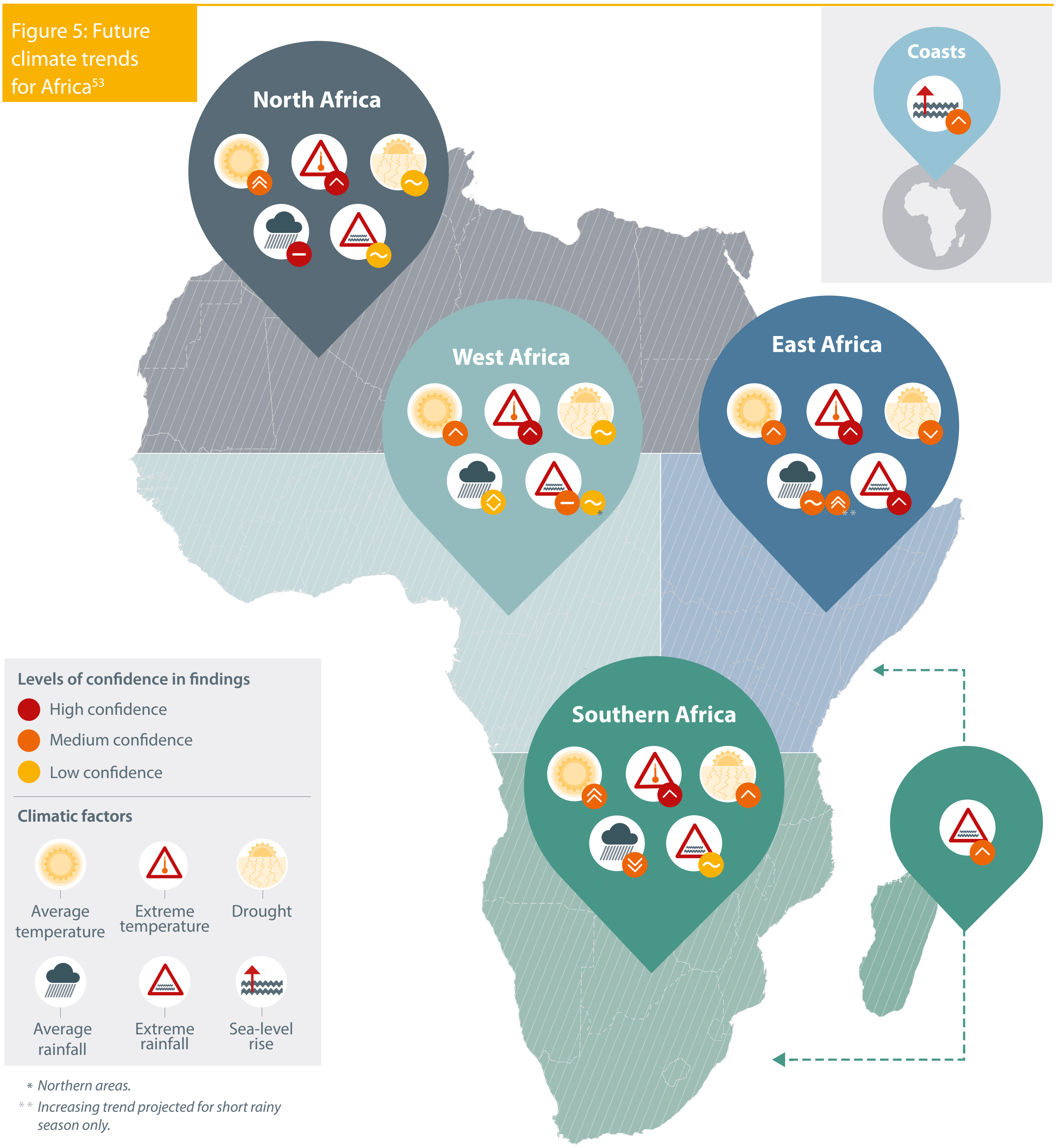
Southern Africa

Projected temperature: Warming in southern Africa in all seasons is likely to exceed average global warming. Towards the end of the 21st century, projections for high-emissions scenarios show warming of 3.4–4.2°C, far exceeding increases in temperature from natural climatic variability. Projections indicate rapid warming in semi-arid southwestern parts of southern Africa – northwestern South Africa, Botswana and Namibia.

Projected rainfall: Over southern Africa, global model projections show drying in the southwest, extending northeast from the Namibia and Botswana deserts. During the southern summer months, global models project dry conditions in the southwest while regional models project wetter conditions in the southeast of South Africa and the Drakensberg Mountains. As in the *Fourth Assessment Report*, projections indicate drier winters over a large part of southern Africa by the end of the century.

Projected extreme events: Projections indicate that during the 21st century and beyond, the risk of severe droughts in southwestern regions will be high and there will be an increase in the area affected by drought (*medium confidence*). There is considerable uncertainty concerning projected changes in landfall of tropical cyclones originating in the southwest Indian Ocean. These cyclones led to intense flooding in the 20th century. More parts of southern Africa have observed increases in extreme rainfall than decreases, although trends vary over this area (*medium confidence*). Projections indicate that both extremely low rainfall and extremely high rainfall (e.g. in southeast regions) may become more common in the future, although there is lack of agreement for the region as a whole (*low confidence*).

Figure 5: Future climate trends for Africa[53]



Symbol	Rainfall	Temperature	Extreme rainfall, extreme temperature, sea-level rise
	up to 30% increasing trend	1–6°C increasing trend	–
	up to 10% increasing trend	1–4.5°C increasing trend	increasing trend
	both increasing and decreasing trends	–	both increasing and decreasing trends
	up to 10% decreasing trend	–	decreasing trend
	up to 30% decreasing trend	–	–
	inconsistent trend	inconsistent trend	inconsistent trend
	no or only slight change	inconsistent trend	inconsistent trend

3 Climate change poses challenges to growth and development in Africa

Much of Africa's economic growth is dependent on climate-sensitive sectors such as agriculture, forestry and fisheries, as are the livelihood prospects of a majority of the region's population. Climate change brings considerable risks to Africa's economic prospects, as well as to food security, freshwater availability and public health.

3.1. Climate change could undermine Africa's recent development progress

Sub-Saharan Africa is a rapidly developing region with a population of about 900 million, and wide ecological, climatic and cultural diversity. At present, six of the ten fastest growing economies in the world are in Africa. Growth in these economies started from a relatively low base so the current rate of economic growth needs to be seen against a background of three decades of poor development performance, conflict and economic marginalisation. Some of these problems remain. However, there are hopeful signs that a number of countries are turning a corner – for the better.

It is critical to recognise that Africa's growth is fragile. Real economic transformation has yet to take root. Part of Africa's vulnerability lies in the fact that recent development gains have been in climate-sensitive sectors. Economically, many Africans depend for food, fibre and income on primary sectors such as agriculture and fisheries, sectors which are affected by rising temperatures, rising sea levels and erratic rainfall. Demographic and economic trends in Africa mean that climate impacts will be acute. For example, growing populations will increase the demand for water and food but prolonged droughts will put additional pressure on already scarce water resources and will reduce crop yields.[55]

Already the region suffers from widespread, recurring risks to food production. Without adequate measures to adapt, these risks could become more intense under a changing climate.[56] For scenarios approaching 4°C warming, the risk to food security in Africa could be very severe, and there would be limited potential for reducing risk through adaptation.[57] The IPCC points out that some of the major crops in Africa are highly sensitive to changes in temperature.[58] For example, climate change is very likely to have an overall negative effect on yields of major cereal crops across Africa, though with strong regional variability in the degree of loss.[59] Estimated yield losses at mid-century range from 18% for southern Africa to 22% aggregated across sub-Saharan Africa, with yield losses for South Africa and Zimbabwe in excess of 30%.[60]

In a world that is 4°C warmer, the current cropping areas of crops such as maize, millet and sorghum across Africa could become unviable.[61] The adaptation challenges of a world that is 4°C warmer are not limited to agriculture, but extend to other critical sectors such as livestock, fisheries, tourism, health, water and energy.[62]

"In Africa, climate change will amplify existing stress on water availability and on agricultural systems, particularly in semi-arid environments." IPCC[63]

Health is an area of particular risk in Africa's changing climate. Already, people over much of the continent have insufficient access to safe water, good sanitation and adequate healthcare. The IPCC finds that because of this, climate change will exacerbate vulnerability to vector and water-borne diseases.[64] For example, more floods in areas with poor sanitation and waste management will spread disease. Warmer nights and days will allow disease-carrying insects to spread to new latitudes.[65]

The considerable threats could undermine the progress that African countries have made in tackling disease, malnutrition and early deaths in the past decades, together with gains in improving agricultural productivity.

Adaptation can reduce these risks and bring immediate benefits. But, even with significant resource and institutional investment on adaptation, for the most vulnerable there may be residual risks to food security, access to water, health and human security.[66] In the long term, there may be limits to adaptation and the only way to reduce these risks is through global action to reduce greenhouse gas emissions.

3.2. Climate change will have economic impacts in Africa

For most economic sectors, changes in population, age structure, income, technology, prices, lifestyle, regulation

Image: Neil Palmer/ CIAT | Irrigating farmland, East Africa

and governance are projected to have more impact than changes in climate (*high agreement, medium evidence*). The more global warming increases, the greater the economic losses will be, but little is known about aggregate economic impacts above 3°C.

Global economic impacts from climate change are difficult to estimate. Existing estimates vary in the sectors and factors they account for and depend on a large number of assumptions, many of which are disputable. So, while the impacts of climate change may lower productivity and slow economic growth, the degree to which this will happen is not clear (*high agreement, limited evidence*). However, changes in climate could be one of the reasons why some countries are trapped in poverty. There is evidence to suggest that erratic economic growth in sub-Saharan Africa can be explained in part by diminishing rainfall, increasing drought and more frequent extreme heat events. African economies and livelihoods are directly dependent on weather patterns, and so climate change and variability have direct implications.[67]

3.3. Climate change will exacerbate poverty in Africa

Climate change will exacerbate and further entrench poverty (*very high confidence*). Climate change and climate variability could worsen existing poverty, exacerbate inequalities, and trigger both new vulnerabilities and opportunities for individuals and communities. Climate change will create new poor between now and 2100 in low-, medium- and high-income countries. However, projections indicate that urban areas and some rural regions in sub-Saharan Africa will experience the most significant growth in new poor (*medium confidence*, based on medium evidence, medium agreement).[68]

Areas where projections indicate there will be more frequent extreme events coincide with zones of considerable poverty, although not all poor people will be at risk. Regions specifically at high risk are those exposed to sea level rise and extreme events, where there is multi-dimensional poverty. These high-risk areas include pockets of poor people in developing countries, and severely degraded dryland and coastal ecosystems in eastern and southern Africa.

Climate change threats could undermine the progress African countries have made in tackling disease, malnutrition and early deaths, and gains in agricultural productivity.

Image: Johanna Schwartz | Coastal fisheries, Ghana

4 Adaptation will bring immediate benefits and reduce the impacts of climate change in Africa

There are many synergies between action on climate adaptation and the achievement of human development objectives. This means that many actions can be taken to strengthen climate resilience which are 'no regrets' or 'low regrets'. Even in the face of uncertainty about exactly which climate impacts will strike and when, such investments will benefit human development.

4.1. Adaptation actions create many synergies with development

Further warming is inevitable in the next few decades, even if global society ceased to emit greenhouse gases today. Adaptation is the only effective option to manage the inevitable impacts of climate change that mitigation cannot reduce. The IPCC describes adaptation as "the process of adjustment to actual or expected climate and its effects".[69] Through adaptation, societies and communities can seek to moderate the harm of current and future climate risks or to take advantage of new opportunities.

Adaptation brings benefits both today and in the future. For example, Africa has much to gain from adaptation actions like disaster risk reduction and social protection that reduce the impacts of warming that are already being felt (Figure 6) and build resilience around critical sectors such as water, energy and agriculture. The IPCC emphasises that integrating adaptation into planning and decision-making can create many synergies with development.[70]

Effective adaptation strategies can, and should, strengthen livelihoods, enhance wellbeing and human security, and reduce poverty today. 'No regrets' or 'low regrets' measures such as increasing access to information and resources, improving health services, diversifying cropping systems, strengthening access to land, credit and other resources for poor and marginalised groups, and making water and land management and governance more effective are good for development, irrespective of changes in climate (Table 1; Boxes 4–5).[71]

Africa's urgent need to adapt to climate change stems from its sensitivity and vulnerability to climate change, together with low levels of capacity to adapt (adaptive capacity). Economic, demographic, health, education, infrastructure, governance and natural factors mean that Africa's overall adaptive capacity is low – and it varies within countries and across sub-regions. There are indications that adaptive capacity is higher in northern Africa. Individual or household level adaptive capacity depends on the ability to make informed decisions to respond to climatic and other changes, as well as on access to efficient institutions and assets.

The good news is that Africa has inherent strengths that will be important for climate adaptation. These include a wealth of natural resources and well-developed social networks. Local and indigenous knowledge underpin longstanding traditional practices for managing climate variability through, for example, diversifying crops and livelihoods, migration and small-scale enterprises. The extent to which such strategies will be sufficient to deal with future changes is uncertain. Since Africa is extensively exposed to a range of stresses that interact in complex ways with longer term climate change, adaptation needs are broad: they encompass institutional, social, physical and infrastructure needs, ecosystem services and environmental needs, and financial and capacity needs. In Africa, successful adaptation will depend upon developing resilience in the face of uncertainty.

4.2. Current development strategies must be climate-proofed

However, current development strategies are unable to deal with existing climatic risks. National policies can end up disregarding or undermining cultural, traditional and context-specific practices that aid local climate adaptation. Poorly conceived development programmes and adaptation strategies in one sector can lower resilience in other sectors or ecosystems. Incomplete, under-resourced and fragmented institutional frameworks translate into largely ad hoc projects, which are often donor driven. Overall, African countries' adaptive capacity to manage complex social and ecological change, especially at local government level, is weak.

The IPCC *Fifth Assessment Report* presents evidence that risks to Africa have already increased due to observed changes in the climate system, and will continue to increase, particularly under higher emissions scenarios. As the bars on the right-hand side of Figure 6 (page 26) illustrate, there is potential to significantly reduce some impacts through adaptation, which will require additional investment and effort. At the highest emission scenarios, with warming of 4°C or more, Africa will be facing severe risks that will be increasingly difficult to manage through climate change adaptation.

Box 5: Women, children and the elderly can be more vulnerable to climate change impacts[72]

Women often experience additional duties as labourers and caregivers as a result of extreme weather events and climate change, as well as from society's responses to climate change (e.g. male migration). They face more psychological and emotional distress, reduced food intake and adverse mental health outcomes due to displacement, and in some cases, increasing incidences of domestic violence.

Children and the elderly are often at higher risk due to narrow mobility, susceptibility to infectious diseases, reduced caloric intake and social isolation; young children are more likely to die from or be severely compromised by diarrheal diseases and floods. The elderly face disproportional physical harm and death from heat stress, droughts and wildfires.

Box 6: Action on climate change and development are inextricably linked[73]

The IPCC concludes:

- People who are socially, economically, culturally, politically, institutionally or otherwise marginalised in society are often highly vulnerable to climate change.
- Climate change impacts are projected to slow economic growth, make poverty reduction more difficult, further erode food security, and prolong existing and create new poverty traps, particularly in urban areas and emerging hotspots of hunger.
- Climate change poses an increasing threat to equitable and sustainable development. Sustainable development and equity provide a basis for assessing climate policies and addressing the risks of climate change.
- Business-as-usual development pathways can contribute to climate risk and vulnerability, and miss out on innovations and opportunities to build resilience in social and economic sectors.

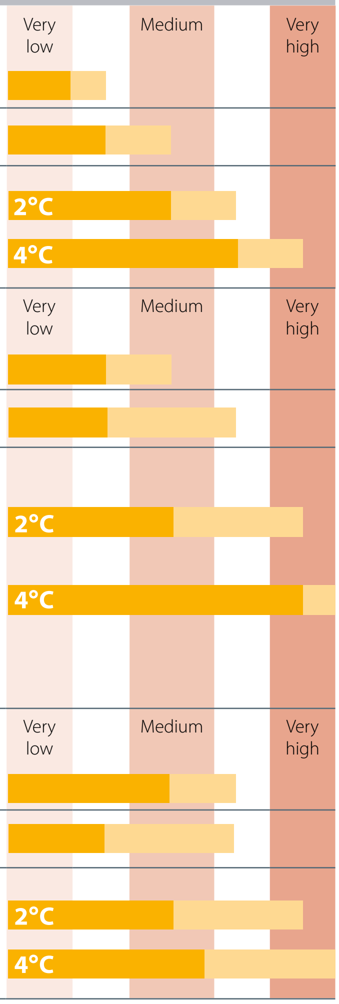
The IPCC underlines Africa's need to integrate climate action with inclusive and sustainable economic development.[74]

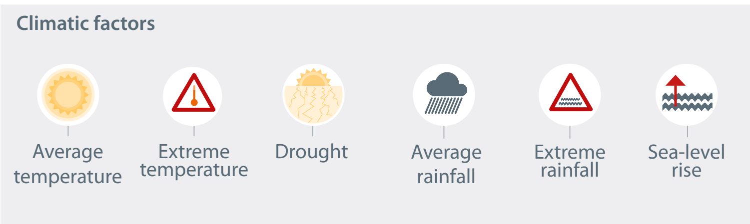
Table 1: Action on climate change adaptation can bolster development[75]

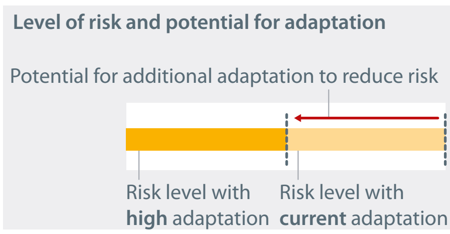
Overlapping approaches	Category	Examples
Vulnerability and exposure reduction through development, planning and practices including many low regrets measures **Adaptation including incremental and transformational adjustments** **Transformation**	Human development	Improved access to education, nutrition, health facilities, energy, safe housing and settlement structures, and social support structures; reduced gender inequality and marginalisation in other forms.
	Poverty alleviation	Improved access to and control of local resources; land tenure; disaster risk reduction; social safety nets and social protection; insurance schemes.
	Livelihood security	Income, asset and livelihood diversification; improved infrastructure; access to technology and decision-making fora; increased decision-making power; changed cropping, livestock and aquaculture practices; reliance on social networks.
	Disaster risk management	Early warning systems; hazard and vulnerability mapping; diversifying water resources; improved drainage; flood and cyclone shelters; building codes and practices; storm and wastewater management; transport and road infrastructure improvements.
	Ecosystem management	Maintaining wetlands and urban green spaces; coastal afforestation; watershed and reservoir management; reduction of other stressors on ecosystems and of habitat fragmentation; maintenance of genetic diversity; manipulation of disturbance regimes; community-based natural resource management.
	Spatial or land-use planning	Provisioning of adequate, housing, infrastructure and services; managing development in flood-prone and other high risk areas; urban planning and upgrading programmes; land zoning laws; easements; protected areas.
	Structural/physical	Engineered and built environment options: sea walls and coastal protection structures; flood levees; water storage; improved drainage; flood and cyclone shelters; building codes and practices; storm and wastewater management; transport and road infrastructure improvements; floating houses; power plant and electricity grid adjustments.
		Technological options: new crops and animal varieties; indigenous, traditional and local knowledge, technologies, and methods; efficient irrigation; water-saving technologies; desalinisation; conservation agriculture; food storage and preservation facilities; hazard and vulnerability mapping and monitoring; early warning systems; building insulation; mechanical and passive cooling; technology development, transfer and diffusion.
		Ecosystem-based options: ecological restoration; soil conservation; afforestation and reforestation; mangrove conservation and replanting; green infrastructure (e.g. shade trees, green roofs); controlling overfishing; fisheries co-management; assisted species migration and dispersal; ecological corridors; seed banks, gene banks and other ex situ conservation; community-based natural resource management.
		Services: social safety nets and social protection; food banks and distribution of food surplus; municipal services including water and sanitation; vaccination programmes; essential public services; enhanced emergency medical services.
	Institutional	Economic options: financial incentives; insurance; catastrophe bonds; payments for ecosystem services; pricing water to encourage universal provision and careful use; microfinance; disaster contingency funds; cash transfers; public-private partnerships.
		Laws and regulations: land zoning laws; building standards and practices; easements; water regulations and agreements; laws to support disaster risk reduction; laws to encourage insurance purchasing; defined property rights and land tenure security; protected areas; fishing quotas; patent pools and technology transfer.
		National and government policies and programmes: national and regional adaptation plans including mainstreaming; sub-national and local adaptation plans; economic diversification; urban upgrading programmes; municipal water management programmes; disaster planning and preparedness; integrated water resource management; integrated coastal zone management; ecosystem-based management; community-based adaptation.
	Social	Educational options: awareness raising and integration into education; gender equity in education; extension services; sharing indigenous, traditional and local knowledge; participatory action research and social learning; knowledge-sharing and learning platforms.
		Informational options: hazard and vulnerability mapping; early warning and response systems; systematic monitoring and remote sensing; climate services; use of indigenous climate observations; participatory scenario development; integrated assessments.
		Behavioural options: household preparation and evacuation planning; migration; soil and water conservation; storm drain clearance; livelihood diversification; changed cropping, livestock and aquaculture practices; reliance on social networks.
	Spheres of change	Practical: social and technical innovations, behavioural shifts, or institutional and managerial changes that produce substantial shifts in outcomes.
		Political: political, social, cultural and ecological decisions and actions consistent with reducing vulnerability and risk and supporting adaptation, mitigation and sustainable development.
		Personal: individual and collective assumptions, beliefs, values and worldviews influencing climate change responses.

Figure 6: Adaptation can reduce risk

Key risk	Adaptation issues and prospects	Climate drivers	Time frame	Risk and potential for adaptation
Compounded stress on water resources facing significant strain from overexploitation and degradation at present and increased demand in the future with drought stress exacerbated in drought-prone regions of Africa *(high confidence)*	• Reducing non-climate stressors on water resources • Strengthening institutional capacities for demand management, groundwater assessment, integrated water-wastewater planning, and integrated land and water governance • Sustainable urban development		Present Near-term (2030–2040) Long-term (2080–2100)	Very low / Medium / Very high 2°C 4°C
Reduced crop productivity associated with heat and drought stress, with strong adverse effects on regional, national and household livelihood and food security, also given increased pest and disease damage and flood impacts on food system infrastructure *(high confidence)*	• Technological adaptation responses (e.g. stress-tolerant crop varieties, irrigation, enhanced observation systems) • Enhancing smallholder access to credit and other critical production resources, diversifying livelihoods • Strengthening institutions at local, national and regional levels to support agriculture (including early warning systems) and gender-orientated policy • Agronomic adaptation responses (e.g. agroforestry, conservation agriculture)		Present Near-term (2030–2040) Long-term (2080–2100)	Very low / Medium / Very high 2°C 4°C
Changes in the incidence and geographic range of vector- and water-borne diseases due to changes in the mean and variability of temperature and precipitation, particularly along the edges of their distribution *(medium confidence)*	• Achieving development goals, particularly improved access to safe water and improved sanitation, and enhancement of public health functions such as surveillance • Vulnerability mapping and early warning systems • Coordination across sectors • Sustainable urban development		Present Near-term (2030–2040) Long-term (2080–2100)	Very low / Medium / Very high 2°C 4°C







5 Adaptation is fundamentally about risk management

Even with significant adaptation and only 2°C warming by the end of the 21st century, the risks to Africa from climate change could be high. Development planning and practice must reflect the reality of the changing climate and the uncertainty it brings. Placing risk management at the heart of decision-making will help Africa cope with climate change.

5.1. Short- and long-term approaches to climate risk management are needed

In Africa, the primary concern is adapting to the negative impacts of climate change. This means taking both short- and long-term approaches to managing climate risks. In the short term, integrating climate adaptation and disaster risk reduction will help withstand shocks to human security and economic development from which recovery can be costly. African governments, businesses and communities can do much to anticipate and reduce risk, rather than reacting after impacts have occurred. Support for effective disaster relief and recovery needs to continue, along with proactive efforts to reduce risk, such as integrating comprehensive risk assessments and risk reduction measures into national economic and development policy.

"Development planning and practice must reflect the reality of the changing climate."[76]

In the longer term, governments, businesses and communities need not only to prepare for the kinds of climate impacts experienced up to now but also for different and more intense climate impacts and extreme events in the future. Measures may include providing adequate housing, infrastructure or services, or mainstreaming climate change into planning processes (see Table 1).

There are good reasons to start now in the process of adapting to these longer-term risks. The IPCC cautions against overemphasising short-term outcomes or insufficiently anticipating consequences.[77] Given that climate change cuts across sectoral boundaries, poorly conceived development programmes or sector-specific adaptation strategies could lower resilience in other sectors or ecosystems. Some development pathways, like rapid urbanisation of coastal zones, can increase the vulnerability of certain groups to future climate change – known as 'maladaptation'. This is a particular challenge for Africa where economies are growing rapidly and societies are undergoing significant demographic shifts.[78]

More 'transformational' changes may be needed in situations where there are high levels of vulnerability and low capacity to adapt, as is often the case in Africa.[79] Such adaptations entail major economic, social, technological and political decisions and actions, rather than incremental changes to existing structures and processes, involving for example changing agricultural practices, integrating climate change into education, providing useful climate services, diversifying livelihoods or introducing social and technical innovations (see Table 1). Recent success stories from smallholder systems in Africa illustrate the potential for transforming degraded agricultural landscapes into more productive and sustainable systems by integrating trees into annual cropping systems.[80] However, it should be noted that transformational adaptation can result in both positive and negative outcomes. The level of investment and/or shift in fundamental values and expectations required for transformational change may create resistance.[81]

5.2. Options to reduce climate risks will be nationally and locally specific

There is no one-size-fits-all approach to adaptation. The IPCC stresses that no one single adaptation strategy will meet the needs of all communities and contexts in Africa.[82] Moreover, the characteristics of a community or society's capacity to adapt to climate change will differ from place to place, and depend largely on specific contexts. A range of actions that address underlying vulnerabilities, implement specific adaptation measures and instigate transformations may be necessary to reduce climate risks.[83]

There are challenges to adaptation. First, African countries lack climate data and information, which creates difficulties in assessing the overall risks and vulnerabilities triggered by climatic and non-climatic factors.[84] Data and information are vital for countries to develop robust climate-resilient strategies and policies, and national and sectoral development plans. In some cases, adaptation may require additional resources in terms of funding, skills and capacity beyond 'business as usual' development.

Image: Panos | Agriculture, Niger

Second, development planning tends to take place at a national scale and so may not take account of the impacts of climate change and variability in particular localities.[85] National policies can inadvertently disregard or undermine cultural, traditional and context-specific practices that support local adaptation to climate change.[86]

Third, interventions need to cross sectors. The cross-sectoral approach requires institutional integration and collaboration. The practice of working across sectors in Africa, and indeed in many parts of the world, does not come naturally, as it challenges entrenched institutional and sectoral behaviours. Overall, African countries' adaptive capacity and institutional frameworks to manage complex social and ecological change, especially at local government level, need strengthening.[87]

Risk assessment must be comprehensive so that development programmes and adaptation strategies in one sector do not lower climate resilience in another.[88]

6 Adaptation experience in Africa is growing

Poverty and other factors mean African societies' capacity to adapt to climate change is low – but development efforts can address this. In all African regions, national governments are putting in place systems for adapting and responding to climate change. Evolving institutions are working to coordinate the range of adaptation initiatives underway although they are not yet able to do so effectively (high confidence). *Countries have made progress on national and subnational policies and strategies, and have begun mainstreaming adaptation into sectoral planning. There are encouraging experiences in Mozambique, Ghana, Ethiopia, Rwanda and Tanzania.*

6.1. National Adaptation Plans of Action and other national adaptation policies are emerging in Africa

Regional, national and subnational bodies in Africa have made progress in developing policy, planning and building institutions for adapting to climate change. African governments have developed National Climate Change Response Strategies or, in least developed countries, National Adaptation Programmes of Action (NAPAs). Implementation and integration of climate resilient approaches with economic and development planning is limited but growing (*high confidence*). Adaptation measures in the action plans tend to focus on agriculture, food security, water resources, forestry and disaster management, and on projects, technical solutions, education and capacity development.

As yet, there is little integration of NAPAs with economic planning and poverty reduction policy processes. Only a few NAPA activities have been funded to date, although more funding is in the pipeline. Regional and transboundary policies and strategies for adaptation are still in their infancy. The Southern African Development Community and the Lake Victoria Basin Committee are forerunners in developing climate-change strategies and action plans.

Following the NAPAs and early experience with National Climate Change Response Strategies, there is some evidence that adaptation planning is evolving to become more integrated, multi-level and multi-sector (*medium confidence*). Ethiopia's Programme of Adaptation to Climate Change, for example, covers sectoral, regional, national and local community issues. Mali integrates adaptation into many sectors. Mainstreaming initiatives, like the twenty-country Africa Adaptation Programme, launched in 2008, foster cross-sectoral adaptation planning and risk management.

National climate-resilient development strategies include Rwanda's National Strategy on Climate Change and Low Carbon Development. Niger, Zambia and Mozambique are involved in the Pilot Program for Climate Resilience; and, Zambia's Sixth National Development Plan 2011–2015 and the new Economic and Social Investment Plan in Niger reflect some integration of climate resilience measures in national development plans.

Inter-sectoral climate risk management approaches are emerging in integrated water resources management, integrated coastal zone management, disaster risk reduction and land-use planning. In South Africa, design principles for climate change have been incorporated into existing biodiversity planning to guide land use.

In some African countries, the commitment to climate adaptation is reflected in broader policy frameworks, such as Namibia's National Policy on Climate Change, Zambia's National Climate Change Response Strategy and Policy, and South Africa's National Climate Change Response Policy White Paper. Lesotho's coordinated policy framework involves all ministries and stakeholders. Ten countries were developing new climate-change laws or formal policies in 2012. Gabon, for example, proposed a National Coastal Adaptation Law.

6.2. National and subnational levels must be linked effectively

Since the IPCC's *Fourth Assessment Report*, African countries have advanced subnational adaptation planning, but provincial and municipal authorities are mostly still developing adaptation strategies. Many local governments lack the capacity and resources for decentralised adaptation (*high confidence*). In Nigeria, Lagos State has a 2012 Adaptation Strategy. Ghana has mainstreamed adaptation into district development plans and Morocco has community climate resilience plans. Promising approaches for subnational strategies integrate adaptation and mitigation for low-carbon climate-resilient development, as in Delta State in Nigeria, and elsewhere. Many cities and

Image: istockphoto l Tea plantation, Rwanda

towns, including Lagos, Cape Town and Durban are building capacity. Notable examples are the specialised local government unit to implement climate change in Maputo, Mozambique, initiatives in ecosystem-based adaptation and improving city wetlands, and participatory skills development in integrating community-based disaster risk reduction and climate adaptation into local development planning in Ethiopia.

There is a pattern emerging in Africa for decision-making on adaptation, whereby there is limited inclusive governance at national level but greater involvement of vulnerable and exposed people in assessing and choosing adaptation responses at local level (*high confidence*). African leaders on climate change will be crucial in providing a wider political space for civil society institutions and communities in decision-making for adaptation, and in managing scientific evidence, projections and uncertainties within projections.

Tools that have been used in adaptation planning in Africa and that can be developed and taken further include assessing vulnerability, assessing risks, analysing costs and benefits, cost-effectiveness, multi-criteria analysis and participatory scenario planning. Monitoring and assessing adaptation is still relatively new in Africa. Few countries have national coordinating systems for collating data and synthesising lessons. Methods for assessing adaptation at local and regional levels, however, have been developed and there are positive examples of monitoring adaptation at project level.

Many studies show that under uncertain climatic futures, replacing hierarchical governance systems that operate within silos with more adaptive, integrated, multi-level, flexible governance approaches enhances adaptive capacity and the effectiveness of adaptation responses.

Box 7: Diversifying livelihoods

African households have long had several strings to their bow to cope with climate shocks. This recourse to diverse activities spreads risk and builds resilience for long-term climate change. Over the past 20 years, households in the Sahel that have diversified, particularly those that have diversified out of agriculture, have become less vulnerable and better off. In the Okavango Delta, Botswana, households are diversifying because of flooding. Schemes such as private and public insurance could help fishing communities in such areas rebuild after extreme events. Providing education and skills training would open up enable broader choices when fishing is no longer viable. Migration for work and remittances are established and important ways of lessening risk to climatic variability and other stresses, and recovering from climatic shocks. While diversification is an important adaptation strategy, new on-farm or specialised activities may replace formerly sustainable practices with negative results.

African leaders have a crucial role to play in providing a wider political space for civil society institutions and communities in decision-making for adaptation.

Regional institutions that focus on specific ecosystems, such as the Commission of Central African Forests, present an opportunity to strengthen the institutional framework for adaptation.

Box 8: The economics of climate adaptation[89]

Trade-offs: Where there are limited resources, adaptation choices will mean trade-offs among multiple policy goals (*high confidence*). Economics can offer valuable insights into these trade-offs and into the wider consequences of adaptation.

Evaluating and managing risk: Economic analyses are moving away from an emphasis on efficiency, market solutions, costs and benefits towards including consideration of non-monetary and non-market risks, inequities, barriers and limits. A narrow focus on costs and benefits can bias decisions against the poor and against ecosystems, and result in maladaptation. Risk-based approaches assess the potential opportunities, constraints and limits in adapting human and natural systems (*high agreement, medium evidence*). Risk management puts the consequences of climate change and adaptation in the context of values, objectives and planning horizons.

Effective areas for public expenditure: Public policies important for fostering adaptation include direct funding for technological research and development, environmental regulation, economic instruments and education. By providing direct and indirect incentives for anticipating and reducing the impacts of climate change, governments could reduce costs to the public purse.

Role of micro-finance: Finance and micro-credit schemes can provide rural communities with the means to adapt. Women taking part in these kinds of schemes build resilience. As well as credit, access to food storage on or off farm, means that families do not have to sell assets to buy food during lean periods but can store assets to sell when market prices are higher. In some parts of Africa, for example the Sudo-Sahelian region of West Africa, there is evidence that migration and trade, as opposed to subsistence agriculture, are important livelihood strategies.[90]

Public-private partnerships: Both private and public sectors have roles to play in developing and implementing adaptation measures (*high confidence*). The private sector alone often will not provide a desirable level of adaptation due to the costs, incentives and resource requirements of some types of action. This means the public sector will have to play a strong role to overcome barriers, develop technologies, and represent current and future equity concerns. Governments could further explore economic tools as a means to advance adaptation. Incentives to encourage adaptation in the private sector include sharing and transferring risk (e.g. insurance), loans, public-private financial partnerships, payments for ecosystem services, resource pricing (e.g. water markets), charges and subsidies (e.g. taxes), norms and regulations, and incentives to modify behaviour. These kinds of incentives offer useful possibilities but are tricky to implement effectively, especially in developing countries.

This less hierarchical approach shows that inclusive decision-making – adaptive governance and co-management – can operate successfully across multiple scales. Despite some progress on developing institutional frameworks for governing adaptation, there are significant problems with coordination and duplication, for disaster risk reduction for example. In fragile states, institutions for reducing climate risk and promoting adaptation may be extremely weak or almost non-existent. Linking institutions and coordinating responses across government, the private sector and civil society could enhance adaptive capacity. Resolving institutional challenges in natural resource management, including lack of coordination, monitoring and enforcement, would be a big step towards more effective climate governance. For example, it is critically important to develop organisational frameworks and strengthen institutional capacities for assessing and managing groundwater resources over the long term.

Global institutions, both within and outside the United Nations Framework Convention on Climate Change (UNFCCC), are critically important for Africa to move forward on adaptation. Regional institutions that focus on specific ecosystems, such as the Commission of Central African Forests, present an opportunity to strengthen the institutional framework for adaptation. National frameworks include institutions that cover all aspects of climate change, inter-ministerial coordinating bodies and institutions to manage climate finance.

6.3. African countries are developing specific strategies for managing climate disaster risk

Strategies to offset the risks associated with natural hazards to households, communities and economies include: early warning systems, schemes to transfer risk, social safety nets, budget contingency funds for disasters, diversifying livelihoods and migration.

National and local authorities are putting in place disaster risk reduction plans. There is also growing recognition of the synergies between disaster risk reduction and adaptation to climate change, although the focus is not yet on reducing vulnerability in the longer term.[91] Safety nets and social protection schemes for food security and nutrition can reinforce each other, promoting disaster risk reduction and adaptation.

Measures to reduce the risk of disasters at the community level tend to link food security, household resilience, environmental conservation, asset creation, infrastructure development and other benefits. Safety nets and social protection schemes for food security and nutrition can reinforce each other, promoting disaster risk reduction and adaptation. Uganda's Karamoja Productive Assets Programme is a good example. Programmes in Kenya, South Africa, Swaziland and Tanzania have also deployed local and traditional knowledge in preparing for disasters and managing risk. Donors have opportunities to learn lessons in building resilience from the 2011 famine in Somalia.

Ways to finance measures to reduce the risk of disasters could include contingency funds, agricultural and property insurance, sovereign insurance, reallocating programme expenditures, weather derivatives and bonds.

Early warning systems: Capacity to assess and monitor risks has grown. As a result, early warning systems are emerging. Regional systems such as the Permanent Inter-States Committee for Drought Control in the Sahel (CILSS), the Famine Early Warning System Network, and other national, local and community-based systems warn farmers and communities of potential crises. Some take a gendered approach, and may incorporate local knowledge systems for making decisions about farming and livestock, as in Kenya.

Assessing vulnerability: Participatory vulnerability assessment or screening to design adaptation strategies is common in projects. However, vulnerability assessment at local government level is often lacking, and assessments to develop national adaptation plans and strategies have not always been participatory.

Social protection: Social protection is a key element of the African Union social policy framework. Ethiopia, Rwanda, Malawi, Mozambique, South Africa and other countries have social protection schemes that build assets and increase the resilience of chronically and transiently poor households. In some cases, such as Ethiopia's Productive Safety Net Programme, social protection goes beyond immediate relief and addresses slow-onset climate impacts. Social protection helps reduce risks both before and after disasters and will become more important should the climate become more variable. There is less evidence that social protection is effective in reducing the risks associated with extreme climatic shocks projected for high-emissions scenarios. In high-emissions scenarios livelihoods would have to be less dependent on climate-sensitive activities. A better understanding of the structural causes of poverty, including political and institutional dimensions, would help in building adaptive capacity into social protection.

Social protection helps reduce risks both before and after disasters and will become more important should the climate become more variable.

Insurance: Family networks, community funds, and disaster relief and insurance provide help when there are droughts, floods and tropical cyclones, and concurrently reduce poverty and enhance adaptive capacity. Index-based insurance (Box 10) pays out in circumstances that could cause loss.

6.4. Africa faces barriers to climate adaptation – but has strategies to address the barriers

Growing understanding of the multiple interlinked constraints to increasing adaptive capacity is beginning to point to potential limits to adaptation in Africa (*medium confidence*). Changes in climate, together with environmental, social, political and technological changes, may overwhelm the ability of communities to cope and adapt, particularly in cases where the root causes of poverty and vulnerability are neglected. A growing body of evidence suggests that flexible, diverse development paths designed to reduce vulnerability, spread risk and build adaptive capacity can be effective. These paths put climate resilience, ecosystem stability, equity and justice at the centre of development efforts.

Funding, and technology transfer and support are needed to improve on the current level of adaptation in Africa, and to protect rural and urban livelihoods, societies and economies from climate change impacts.

Addressing climate risk, building adaptive capacity and implementing robust adaptation strategies requires significant financial resources, technological support and investment in developing institutions and capacity (*high confidence*). Funding, and technology transfer and support are needed to improve on the current level of adaptation in Africa, and to protect rural and urban livelihoods, societies and economies from climate-change impacts. Strengthening institutional capacities and governance mechanisms will enhance the ability of national governments and scientific institutions in Africa to absorb and effectively manage funds allocated for adaptation and ensure that adaptation initiatives are effective (*medium confidence*).

While economic plans are beginning to mainstream climate resilience, national planning documents often promote foreign direct investment and industrial competitiveness without putting in place measures to ensure that the ensuing activities support, rather than harm, the capacity of poor people to adapt. Poorly regulated business environments can impede foreign direct investment in their own right – but can also undermine climate resilience. Stakeholders in climate-sensitive sectors, for example Botswana's tourism industry, have yet to develop and implement adaptation strategies.

Box 9: Challenges in reducing the risk of disasters

The challenges in translating early warning into early action include political and institutional barriers in:

- Communicating information that is useful, and at appropriate scales;
- Communicating in local languages;
- Communicating in remote areas;
- Perception at national level that data collected locally is manipulated to leverage relief resources;
- Capacity of national meteorological centres; and
- Links between early warning, response and prevention.

Box 10: The value of index-based weather insurance

Malawi: Malawi's experience in piloting index-based weather insurance against drought for smallholders is promising. In the first year, 892 farmers bought insurance as part of a bundle that included a loan for inputs for groundnut production. The following year, the scheme took in maize farmers, bringing the total to 1,710 and stimulating interest among banks, financiers, processing and trading companies, and input suppliers.

Ethiopia: A pilot insurance project in Ethiopia pays claims based on the time lapse between lack of rain and actual losses. Farmers with this insurance do not need to sell assets to buy food, and can thus continue to farm in subsequent seasons, thereby lessening demand for humanitarian aid. Another insurance-for-work programme allows cash-poor farmers to pay insurance premiums in-kind by working on community projects, such as managing soil and improving irrigation, to reduce the risks of disasters. This kind of scheme means the most marginalised and resource-poor can afford insurance.

7 Low-emissions development offers opportunities for Africa

Africa has contributed little to historic greenhouse gas emissions. This means there is a tendency to think that Africa's priority lies in adaptation. However, this is a false direction to take. Effective climate policies can help protect development assets by building adaptive capacities, while at the same time, mobilising social and financial investments towards cost-effective mitigation technologies. The essence of climate-resilient development is to bring about holistic approaches to development and capitalise on new technical (and institutional) innovations. As they grow their economies and meet pressing development needs, there are abundant opportunities for African countries to adopt clean, efficient low-carbon technologies and measures directly. What is more, African decision-makers can make the most of climate adaptation, mitigation and development co-benefits while managing the trade-offs. The IPCC provides decision-makers with guidance for identifying the complementarities between – and managing the trade-offs among – climate adaptation, mitigation and development objectives.

7.1. Africa has low levels of historic emissions

In order to limit climate change, the world as a whole must act swiftly to reduce greenhouse gas emissions – and to sustain these reductions over time. The vast majority of African countries have contributed very little to historic emissions.

Most cumulative CO_2 emissions 1970–2010 were from the member states (as of 1990) of the Organisation for Economic Co-operation and Development (OECD 50% of cumulative CO_2 emissions), followed by transition countries (20%), and Asia (15%), while the remainder were from non-OECD African and Latin American countries (Figure 7).

In the *Fifth Assessment Report*, regional data for Africa is bundled together with the Middle East for 1970–2010; in this larger region (which extends beyond typical definitions of Africa) greenhouse gas emissions are rising inexorably. This region's emissions are the second lowest by volume globally but from 2000–2010 grew at the second highest rate after Asia.

Fossil fuel use: Most of the increase in emissions in the Middle East and Africa stems from an increase in the use of fossil fuel resulting from population and economic growth. Population and economic growth have a strong cumulative effect on emissions and counteract improvements in energy intensity – the ratio of energy per unit of gross domestic product – and per capita energy use.

Population: A key driver for the increase in emissions from the Middle East and Africa has been population growth. Between 1971 and 2010, population growth rates in the region were the highest in the world. However, although emissions in this region have increased because of the increase in the total number of people, per capita emissions have declined slightly.

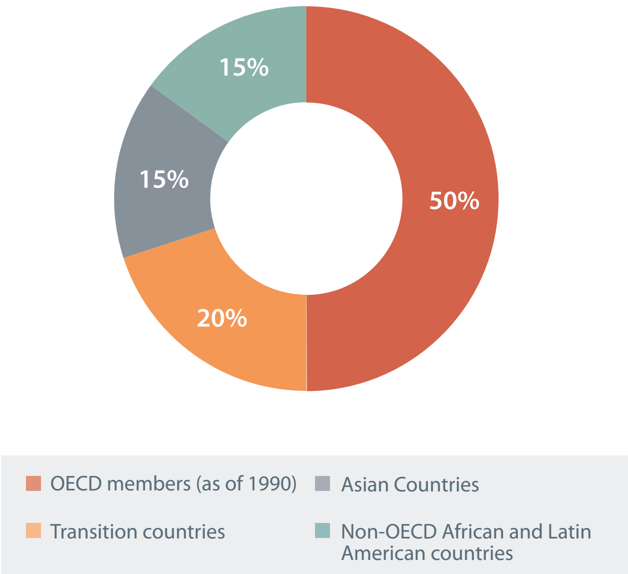
Urbanisation: Urbanisation also shapes emissions. Urban populations are responsible for more emissions than rural populations. Global urbanisation rates rose from 36% in 1970 to 52% in 2011. However, the relationship between urbanisation and emissions is complex and affected by economic factors, technologies and energy, as well growth patterns.

Population structure and household size: Overall, the effects on emissions of household size and age distribution within the population are not clear. The *Fifth Assessment Report* concludes that, overall, older populations, smaller households and urbanisation use more energy and cause more emissions than younger populations, larger households and non-urbanising societies.

Economic growth: Economic growth has also contributed to rising emissions from the Middle East and Africa. Research suggests a strong, historic, positive correlation between growth in gross domestic production and growth in CO_2 emissions. Per capita emissions correlate positively with per capita income. However, per capita emissions have declined in nearly all regions, including in the Middle East and Africa. In sub-Saharan Africa, per capita emissions have declined from 11.9 kt CO_2 eq (kilotonne CO_2 equivalent) in 1970 to 4.6 kt CO_2 eq in 2010 – a decrease of 61.3% with an average decade-on-decade decline of 20% in per capita emissions.

Between 1970 and 2010, gross domestic production per capita increased and emissions per capita decreased. This contradiction suggests that various factors may affect the link between the growth in gross domestic production and growth in emissions. How a country grows may determine its level of emissions (i.e. certain developing countries now

Figure 7: Cumulative CO_2 emissions 1970–2010 by source[92]



The data presented in section 7 follows the IPCC method and combines data from Sub-Saharan and Middle East and North African countries, defined as follows:

SSA (Sub-Saharan Africa): Angola, Benin, Botswana, Burkina Faso, Burundi, Central African Republic, Cameroon, Cape Verde, Chad, Comoros, Congo (The Democratic Republic of the), Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mayotte, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Saint Helena, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe

MNA (Middle East and North Africa): Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Lybia, Morocco, Palestinian Territory, Oman, Qatar, Saudi Arabia, South Sudan, Syrian Arab Republic, Tunisia, United Arab Emirates, Western Sahara, Yemen

Box 11: Africa's role in the global emissions landscape[93]

In 2010, governmental Parties to the United Nations Framework Convention on Climate Change (UNFCCC) made the 'Cancun Pledges'. The pledges specified a long-term global goal of limiting global warming to 2°C above pre-industrial temperatures, and considered revising this to 1.5°C. The IPCC's *Fifth Assessment Report* finds that the Cancun Pledges fall short of what is needed to limit emissions to achieve these goals.

Here lies an uncomfortable paradox for Africa. For large areas of Africa, average temperatures could exceed 2ºC by 2050 and rise by as much as 2.6–4.8ºC by the end of the century (under the medium- and high-emissions scenarios presented by the IPCC). Africa's historic contribution to the build-up of greenhouse gas emissions is small, and yet the cost of climate change on the region's ecosystems and human wellbeing is and will continue to be significant.

The IPCC also finds that mitigation efforts and the costs of mitigation vary between countries; developing countries have a significant proportion of the opportunities for low-cost mitigation. As such, African countries can play a role in global climate stabilisation efforts by taking advantage of low-carbon options where it is advantageous to do so, thereby avoiding future emissions. For example, there are opportunities to reduce deforestation by adopting sustainable practices, to plan innovative low-carbon towns and cities, and to develop land-use schemes that intensify agricultural practices and sustainably manage livestock. Such actions can bring large co-benefits beyond reducing the impacts of climate change.

Ethiopia's Climate-Resilient Green Economy strategy is a good example of an emerging vision in Africa on meeting multiple development goals while contributing to the global effort to mitigate climate change. However, it is also important to recognise that significant effort-sharing and substantial financial flows will be required to support mitigation actions in Africa.

The *Fifth Assessment Report* makes explicit that, because the atmosphere is a global commons, effective mitigation will not be achieved if individual countries advance their own interests independently. International cooperation is essential to effectively mitigate greenhouse gas emissions and address other climate change issues such as building resilience and capacity development in regions such as Africa.

Table 2: Mid-term scenarios for African emissions[94]

	OECD countries as of 1990	Asia	Latin America	Middle East & Africa
Scenario: 430–530 CO_2 ppm equivalent				
	OECD countries as of 1990	Asia	Latin America	Middle East & Africa
Peak year	2020	2030	2025	2030
Emission changes by 2030 compared to 2010	-32%	1%	-35%	-8%
Scenario: 530–650 CO_2 ppm equivalent				
	OECD countries as of 1990	Asia	Latin America	Middle East & Africa
Peak year	2025	2040	2030	2040
Emission changes by 2030 compared to 2010	-14%	34%	-9%	22%

use cleaner and more efficient productive technologies that increase productivity but also drive down emissions). The *Fifth Assessment Report* indicates that although economic growth could increase emissions, where cleaner technological change drives growth, then emissions could actually decrease.

Energy per capita: At the global level, energy use per capita increased by 31% overall between 1971 and 2010, but varied by region. Use of energy in transition economies and OECD90 countries rose by 14%. In other regions, the increase was much more dramatic. In the Middle East and Africa, per capita energy use increased by 90%, although per capita energy use is much lower than in OECD90 and transition countries.

Energy intensity: In the Middle East and Africa, energy intensity – the ratio of energy per unit of gross domestic product – is low, but has risen significantly in the last few decades. Energy intensity has fallen in the last decade but not enough to offset the overall increase in emissions because of the growth in gross domestic production. The relationship between the use of energy and gross domestic product is complicated, nevertheless, as incomes rise so the use of energy rises. Both rising incomes and larger populations contributed to the increase in global emissions between 1970 and 2010, including emissions from this region.

7.2. The IPCC maps future scenarios for African emissions

The mid-term scenarios to 2030 (Table 2) assume either stringent reductions in CO_2 to 430–530 CO_2 ppm (parts per million) equivalent (66% likely to keep temperature increases below 2°C by 2100) or slightly less stringent reductions in CO_2 to 530–650 CO_2 ppm equivalent (less likely to keep temperature increases below 2°C). In the more stringent mid-term scenario, emissions will peak in the Middle East and Africa by 2030 and there would be an 8% reduction in emissions. In the less stringent scenario, emissions peak by 2040 but emissions would increase by 22% by 2030.

7.3. Africa can capture the opportunities and manage the risks of low-carbon development

A fundamental issue for sustainable development is to avoid the negative social and environmental effects of climate change. However, climate change is only one issue that developing countries face. Other issues include providing the poor with reliable cheap energy and employment, limiting pollution and providing clean safe water.

A government policy or a measure intended to achieve one climate change objective (such as mitigation) will also affect other environment and development objectives (such as local air quality). Or, seen from a 'development first' perspective in Africa, where so much development infrastructure is still to be built in the years ahead, there are particular opportunities to invest in infrastructure and adopt development practices that are low-carbon from the outset, rather than polluting and fossil fuel-dependent. To the extent these side effects of climate policies are positive, they can be deemed 'co-benefits'; but sometimes they are negative, or 'adverse side effects'.

Mitigation can have many potential co-benefits and adverse side effects, which makes comprehensive analysis difficult. The direct benefits of climate policy include, for example, intended effects on global mean surface temperature, sea-level rise, agricultural productivity, biodiversity and health of global warming. The co-benefits and adverse side effects of climate policy could include effects on a partly overlapping set of objectives such as local air pollutant emissions and related health and environmental impacts, energy security, income distribution, efficiency of taxation, labour supply and employment, urban sprawl, and the sustainability of developing countries' growth. All these side effects, positive and negative, are important, as evaluating climate policies must look at the full picture, including all aspects of social welfare.

The IPCC's overall message is that mitigation involves both benefits and risks to development and that careful planning for and management of any down-side risks is necessary. The *Fifth Assessment Report* does not weigh up the risks and benefits because they are difficult to quantify and compare, and because different countries have different opportunities and development objectives. The *Fifth Assessment Report* finds that mitigation policies have more co-benefits than risks.

Because much of the urban space in Africa is yet to be developed, urban adaptation provides opportunities for incremental and transformational adjustments towards resilient and sustainable systems.[95]

7.4. Policy options for mitigation are wide-ranging

Understanding how the mitigation options set out in the *Fifth Assessment Report* could inform policy making in Africa is not simple. The mitigation options proposed by the IPCC are generalised for a global audience. The *Fifth Assessment Report* recommends policy options that could facilitate mitigation in three main categories: fiscal, regulatory and legal.

Fiscal policies deal with taxes and subsidies. These policies either put a cost on emissions (and their causes) or pay for avoided or reduced emissions (either directly or indirectly). Fiscal policies have effects that may not be obvious when first implemented, for example fiscal incentives to produce biofuels could lower food production and taxes on carbon could shift production to regions where carbon taxes are more lenient.

Regulatory policies limit what can be done in particular areas. For example, in the agricultural sector, regulations could apply to deforestation or biofuel targets, and in the energy sector to national renewable energy targets. Regulatory policies can affect other sectors and mitigation effects. For example, improving the energy efficiency of batteries may reduce transport emissions but producing them could increase manufacturing emissions and the use of material resources.

Legal frameworks provide governance – clarity, transparency, enforceability – for mitigation and how they operate determines the effectiveness of mitigation. In order to implement mitigation policies, laws need to be passed that facilitate or mandate mitigation measures and also ensure that mitigation measures are properly implemented, for example by enforcing afforestation regulations or energy-efficiency targets. Institutions need to have the capacity to create and implement appropriate legal frameworks, and judicial systems need to have the strength and independence to approve and enforce legal systems.

The *Fifth Assessment Report* stresses the importance of synergies among policies. Mitigation policy is not the be-all-and-end-all. Countries have other development objectives to consider. Mitigation policies could either benefit their development objectives or hinder them.

Industrial policy governs the development and growth of manufacturing. The amount of emissions from manufacturing and growth in the sector depend on the mix of goods produced. Policies to mitigate industrial emissions have been shown to have limited risks and multiple co-benefits. However, policies that encourage production of goods which require limited materials or limited energy to produce could still create more emissions if the goods have greater life-cycle emissions than goods requiring more materials or more energy. Understanding which goods provide the best compromise between positive development and emissions is important. Emphasising one aspect over the other could lead to either negative environmental outcomes or negative developmental outcomes.

Land and food policies determine the use of agricultural land (food or biofuel) and natural resources (conservation or use). As with most policies, balancing potentially conflicting objectives means clearly assessing where most long-term benefits lie.

Information campaigns on various aspects of mitigation, for example energy efficiency, the benefits of waste recycling, using less water or less energy-intensive transport systems (public transport) can reduce risks and enhance positive co-benefits. Providing information can also help people understand long-term perspectives and accept risks.

Renewable energy technologies have demonstrated substantial performance improvements and cost reductions.[96]

International policies can play a role in reducing emissions. Examples are regional carbon trading schemes such as the European Union Emission Trading Scheme, emissions reduction schemes such as the Clean Development Mechanism, access to international climate finance such as the Green Climate Fund and emission avoidance systems such as the United Nations reducing emissions from deforestation and degradation (REDD+) programme. Countries that meet eligibility criteria can access these programmes for help in reducing the cost of mitigating emissions.

Table 3: Summary of mitigation options across sectors, from the *Fifth Assessment Report*[97]

The IPCC finds that systemic and cross-sectoral approaches to climate mitigation are expected to be more cost-efficient and more effective in cutting emissions than sector-by-sector policies. That is because there are inter-dependencies among sectors in a real, physical sense. In addition, many low-carbon energy supply technologies and their infrastructure requirements – as well as the adoption of the new technologies themselves – depend largely on public acceptance. This element of public acceptance or social psychology is another reason why efforts to embrace low-carbon technologies in one sector could have effects in other sectors. Until now, sector-specific policies have been more widely used than economy-wide, market based policies (and so the evidence still needs to be captured on how successful those economy-wide climate mitigation efforts will be). The following table presents a range of sector-specific policies that have been implemented.

Policy instruments	Energy	Transport	Buildings
Economic instruments – taxes (carbon taxes may be economy-wide)	• Carbon tax (e.g. applied to electricity or fuels)	• Fuel taxes • Congestion charges, vehicle registration fees, road tolls • Vehicle taxes	• Carbon and/or energy taxes (either sectoral or economy-wide)
Economic instruments – tradable allowances (may be economy-wide)	• Emission trading • Emission credit under CDM • Tradable Green Certificates	• Fuel and vehicle standards	• Tradable certificates for energy efficiency improvements (white certificates)
Economic instruments – subsidies	• Fossil fuel subsidy removal • Feed-in tariffs for renewable energy	• Biofuel subsidies • Vehicle purchase subsidies • Feebates • A fee on inefficient technology and a rebate on efficient vehicles	• Subsidies or tax exemptions for investment in efficient buildings, retrofits and products • Subsidized loans
Regulatory approaches	• Efficiency of environmental performance standards • Renewable portfolio standards for renewable energy	• Fuel economy performance standards • Fuel quality standards • Greenhose gas emission performance standards • Regulatory restrictions to encourage modal shifts (road to rail) • Restriction on use of vehicles in certain areas • Environmental capacity constraints on airports • Urban planning and zoning restrictions	• Building codes and standards • Equipment and appliance standards • Mandates for energy retailers to assist customers invest in energy efficiency
Information programmes		• Fuel labelling • Vehicle efficiency labeling	• Energy audits • Labeling programmes • Energy advice programmes
Government provision of public goods or services		• Investment in transit and human powered transport • Investment in alternative fuel infrastructure • Low-emission vehicle procurement	• Public procurement of efficient buildings and appliances
Voluntary actions	• Voluntary agreements		• Labeling programmes for efficient buildings • Product eco-labeling

Industry	AFOLU (agriculture, forestry and other land uses)	Human settlements and infrastructure
• Carbon tax or energy tax • Waste disposal taxes or charges	• Fertiliser or nitrogen taxes to reduce nitrous oxide	• Sprawl taxes, impact fees, exactions split-rate property taxes, tax increment finance, betterment taxes, congestion charges
• Emission trading • Emission credit under Clean Development Mechanism (CDM) • Tradable Green Certificates	• Emissions credits under CDM (Adam) • Compliance schemes outside Kyoto Protocol (national schemes) • Voluntary carbon markets	• Urban-scale cap-and-trade scheme for emissions
• Subsidies (e.g. for energy audits) • Fiscal incentives (e.g. for fuel switching)	• Credit lines for low-carbon agriculture, sustainable forestry	• Special Improvement of Redevelopment Districts
• Energy efficiency standards for equipment • Energy management systems (also voluntary) • Voluntary agreements (where bound by regulation) • Labeling and public procurement regulations	• National policies to support REDD+ including monitoring, reporting and verification • Forest law to reduce deforestation • Air and water pollution control greenhouse gas precursors • Land-use planning and governance	• Mixed use zoning • Development restrictions • Affordable housing mandates • Site access controls • Transfer development rights • Design codes • Building codes • Street codes • Design standards
• Energy audits • Benchmarking • Brokerage for industrial cooperation	• Certification schemes for sustainable forest practices • Information policies to support REDD+ including monitoring, reporting and verification	
• Training and education	• Protection of national, state, and local forests • Investment in improvement and diffusion of innovative technologies in agriculture and forestry	• Provision of utility infrastructure such as electricity distribution, district heating/cooling and wastewater connections, etc • Park improvements • Trail improvements • Urban rail
• Voluntary agreements on energy targets, adoption of energy management systems, or resource efficiency	• Promotion of sustainability by developing standards and educational campaigns	

Image: Panos | Biogas entrepreneur, Kenya

The policies described above indicate ways to incentivise reducing emissions and de-incentivise increasing emissions. Putting other 'back-end' policies in place and addressing other issues support the implementation of mitigation policy.

Efficient and effective policies balance mitigation and growth, gain from synergies and recognise the implications of the paths taken.

Education and human resources are important. Effectively implementing mitigation policies and measures depends on having people with the right skills to do so, and citizens that accept the risks and benefits. Education systems can be geared to provide the skills in mitigation technologies and to teach citizens about climate change and the risks of climate change.

Population growth is a major driver of emissions in Africa. Policies could encourage sustainable and equitable development by, for example, directing growth to areas where it can be sustained or redirecting urban expansion to more energy-efficient areas. Assessing and reforming related policies, such as healthcare, could also promote equitable and sustainable development.

Institutions may be hampered by limited technical capacity and limited human resources (staff shortages). Captured and vested interests may sway decisions. Institutions may be subject to external or internal pressure from those who could lose out or gain from mitigation. Other institutional barriers may be poor coordination (or cooperation) between institutions, or perceptions of a lack of relevance to institutions tasked with putting systems to mitigate emissions in place. Institutional reform could build human (technical) capacity, remove dis-incentives that promote inefficiency and strengthen capacity to implement policies.

Access to material resources such as capital (machinery) or resources (wind to power wind farms or rare earth minerals to produce solar photovoltaic panels) may not be assured. Policy-makers can assess whether resources are available within a country or if they need to be imported, whether there is capacity to use them, and the costs and benefits of access to resources. Understanding a country's natural assets helps assess its renewable energy potential and potential to invest in 'green' industries.

Governments have multiple policy systems and policy issues to consider. The most efficient and effective mitigation options, for Africa and countries worldwide, share similar traits. Efficient and effective policies balance mitigation and growth, gain from synergies and understand the implications of the paths taken.

8 Opportunities for low-carbon, climate-resilient development across sectors

Africa stands to benefit from integrated climate adaptation, mitigation and development approaches. The following sections summarise some of the key opportunities for integrated climate adaptation and mitigation action assessed in the Fifth Assessment Report*; they present the development benefits, possible adverse consequences and options for managing the trade-offs. The IPCC is careful to document the possible adverse consequences of mitigation actions and to discuss how they can be managed. Here, we present the headlines for the agriculture, forestry and fisheries, energy industry, transport and urban development policy areas.*

8.1. Opportunities in the agriculture, forestry and fisheries sectors

Africa's agriculture, forestry and fisheries sectors are vulnerable to climate change

Changes in climate, together with non-climate drivers and stresses, will exacerbate the vulnerability of African agricultural systems, particularly in semi-arid areas (*high confidence*). By mid-century, Africa will face significant challenges in adapting agriculture to projected changes in climate. Rising temperatures and changes in precipitation are very likely to reduce cereal crop productivity. Without adaptation, climate change will negatively impact production of major crops (wheat, rice and maize) under local temperature increases of 2°C or more, although individual locations may benefit.

By mid-century, Africa will face significant challenges in adapting agriculture to projected changes in climate.

Changes in the length of growing seasons are possible. The tendency will be towards shorter growing seasons, though in some areas the growing seasons may be longer. Farming systems may change, from mixed crop-livestock systems to systems dominated by livestock, where growing seasons for annual crops become shorter and crop failure becomes more common and frequent. Zones where projections indicate livestock will replace crops by 2050 include the West African Sahel, and coastal and mid-altitude areas in eastern and southeastern Africa, areas that now support 35 million people and are chronically food insecure.

Lower crop productivity due to heat and drought stress would have strong adverse effects on regional, national and household food security, also given increased pest and disease damage and flood impacts on food systems (*high confidence*). At present, the risk to crop productivity is medium and could be lowered through adaptation. In the near term (2030–2040), the risk is high but could be reduced to a low level through adaptation. In the long term (2080–2100), the risk is very high regardless of adaptation with 4°C warming, and very high with potential to reduce to a medium risk level through adaptation with 2°C warming.

Studies published since the *Fourth Assessment Report* confirm many of its findings, such as lower yields for all crops with over 3°C of local warming without adaptation and despite the benefits expected from more rainfall and the fertilising effect of more carbon dioxide. Relatively few studies have investigated the impacts on cropping systems for scenarios where global average temperatures increase by 4°C or more. The effects of climate change on crop productivity will alter land-use patterns, both in terms of the total area and geographic distribution of crops.

New evidence shows that perennial crops with a high economic value, such as tea, coffee and cocoa, could also suffer from rises in temperature (*medium confidence*). Pests, weeds and diseases are expected to affect crops and livestock to a greater extent than they do now as a result of changes in climate and other factors (*low confidence*). Rapid urbanisation and increasingly globalised food chains present new challenges that require a better understanding of the multiple stresses on food and livelihood security in both urban and rural Africa.

Floods, drought, shifts in the timing and amount of rainfall, and high temperatures associated with climate change could directly affect crop and livestock productivity.

Box 12: Projected impacts of climate change on Africa's farming systems[98]

Cereal crops: Climate change is very likely to lower yields of major cereal crops across Africa, although the degree to which yields will fall will vary significantly across regions. Research indicates that maize is the crop most vulnerable to climate change and that yields will drop across Africa. The region most affected by negative impacts on several important crops, including maize, is southern Africa. In eastern Africa, however, maize production may benefit from warming. Most maize grows at low altitudes so the distribution of maize may change. In dryland areas of eastern Africa, although projections indicate more rainfall, research shows crop yields are insensitive to more rainfall, since more rain is associated with warmer temperatures and warmer temperatures reduce yields.

Projections indicate that, across Africa, yields of wheat, sorghum and millet will fall by 2050. In West Africa, warming above 2°C may counteract the positive effects of more rain on millet and sorghum yields under a range of scenarios. The negative effects will be greater in savannah ecosystems and will affect improved crop varieties more than traditional varieties. In the Sahel, projections indicate millet yields will fall significantly under various scenarios.

Non-cereal crops: New research since the *Fourth Assessment Report* indicates that changes in climate will have a variable impact on non-cereal crops; both losses and gains in productivity are possible (*low confidence*). In eastern Africa, assuming that carbon dioxide has a fertilising effect, projections indicate that cassava yields will increase moderately up to the 2030s under a range of scenarios. Conditions for cassava may also improve in central Africa. Across sub-Saharan Africa, yields of bean will fall significantly with 5°C warming. In eastern Africa, projections indicate bean yields will decrease by mid-century. The effects of climate change on peanut yields are not clear; some research indicates yields will increase and other research shows it will decrease. In West Africa and lowland areas of East Africa, banana and plantain productivity could fall, whereas it could rise in highland areas of East Africa because of a rise in temperature. Further research will clarify the impacts on these non-cereal crops.

Perennial crops: Projections indicate that agro-climatic zones suited to economically important perennial crops will shrink significantly, largely because of rising temperatures. Under high-emissions scenarios, agro-climatic zones that are now very good to good for perennial crops may become marginal. Zones that are now marginal may become unsuitable by 2050. In equatorial East Africa, high-altitude zones may become more suitable for coffee and tea and low altitudes less suitable. In West Africa, high altitudes may become more suitable for cocoa and low altitudes less suitable. West Africa may also become less suitable for cotton and more suitable for cashew.

Livestock: The IPCC highlights that climate change could have an adverse effect on livestock production in Africa. Rising temperatures and changes in precipitation will bring more heat and water stress, and shift the distribution of pests and diseases. These changes will have adverse effects on pastoral livelihoods and rural poverty (*medium confidence*).

Projections indicate that, at present, the risk to livestock production is medium. Adaptation could reduce the risk level to low. In the near term (2030–2040), the risk level is high but could be lowered through adaptation. In the long term (2080–2100), the risk level is very high regardless of adaptation with 4°C warming, and very high with potential to reduce to a medium risk level through adaptation with 2°C warming.

Food security relates to the availability of food, access to food, and the use and stability of food supplies. There is strong consensus that climate change will negatively impact all these aspects of food security in Africa. Floods, drought, shifts in the timing and amount of rainfall, and high temperatures associated with climate change could directly affect crop and livestock productivity. Soil erosion caused by more frequent heavy storms, and the spread of pests and diseases affecting crops and livestock caused by warmer temperatures and other changes in climatic conditions, could indirectly affect food security. Access to food could be affected by the impacts of climate change on productivity in important cereal-producing regions, which in combination with other factors could raise food prices and erode the ability of the poor in Africa to buy food. Extreme events that affect transport and other food system infrastructure could also threaten access to food. Changes in climate could affect the use of food by allowing the spread of diseases that prevent the human body from absorbing nutrients. Warmer and more humid conditions caused by climate change could affect the availability and quality of food as fresh foods may spoil, and pests and pathogens may damage food in storage (e.g. cereals, pulses, tubers). The stability of food supplies could be affected by changes in availability and access linked to climatic and other factors.

Threats to food security in Africa stem from entrenched poverty, environmental degradation, rapid urbanisation, rapid population growth, and changes in climate and climatic variability. Markets and food security have emerged as important issues since the *Fourth Assessment Report*. Price spikes for globally traded food commodities 2007–2008, and price volatility and higher overall food prices in subsequent years, have undercut recent gains in food security across Africa. Among the groups most affected are the urban poor, who typically spend more than half of their income on food.

Projections indicate that northern and southern Africa will become drier with climate change, a particular concern for livestock production. Scarcity of water will have both direct and indirect effects on livestock production. In Botswana, for example, drier and warmer conditions by 2050 could raise the cost of pumping drinking water for livestock from boreholes by as much as 23%.[99] Scarcity of water will indirectly affect livestock because production of feed crops will fall. In East Africa, the availability of maize leaves and stems for feeding cattle could decrease by 2050.[100]

Temperature is an important limiting factor for livestock. Higher temperatures in lowland Africa could lead farmers to reduce stocks of dairy cows in favour of cattle, reduce cattle stocks in favour of sheep and goats, and decrease poultry production. In highland areas of East Africa, livestock keeping could benefit from warmer temperatures. In South Africa, dairy yields could decrease substantially by the mid- to late-21st century.

Pests and diseases: Understanding of how climate change may affect crop and livestock pests and diseases, and agricultural weeds has improved since the *Fourth Assessment Report*. Interactions between changes in climate and other environmental and production factors could intensify damage to crops from pests, weeds and diseases.

In the highlands of eastern Africa, warming could extend the reach of crop pests into areas where they are currently limited by cold. For example, the coffee berry borer may spread into areas that produce arabica coffee and the *Radopholus similis* nematode into banana-producing areas.[101] In western Africa (Angola and Guinea), higher minimum temperatures by 2020 may extend the range of Black Leaf Streak, a disease affecting banana crops.[102]

In lowland and dryland areas of Africa, climate change may alter the distribution of economically important pests (*low confidence*). For example, changes in temperature, rainfall and seasonality in central Africa may provide suitable habitats for the spread of the pernicious weed, *Striga hermonthica*, whereas its range may shrink in the Sahel. Striga is a major cause of low cereal yields in sub-Saharan Africa. The range of cassava pests, such as whitefly, cassava brown streak virus, cassava mosaic geminivirus and cassava mealybug, could shrink throughout Africa although projections indicate southeast Africa and Madagascar could become more susceptible.

Warming of more than 2°C and changes in precipitation may alter the distribution of the ticks that spread East Coast Fever in cattle.

Economic impacts of climate change on agriculture: Scenarios for Tanzania, where agriculture accounts for about half of gross domestic product and employs about 80% of the labour force, indicate that changes in climate could increase poverty and vulnerability. Scenarios for Namibia indicate that annual losses to the economy associated with the impacts of climate change on the country's natural resources could range between 1% and 4.8% of gross domestic product. Ghana's economy and agricultural sector are particularly vulnerable because cocoa is the single most important export product and because cocoa will be affected by changes in climate. Cocoa production is thus central in debates on development and poverty alleviation.

Looking forward, changes in climate could push up the price of basic cereals and this could have serious implications for food security in Africa. Moreover, as recent rises in food prices demonstrate, what happens in other regions has a profound effect on food security in Africa.

Africa is undergoing rapid urbanisation. At the same time, changes in food processing, marketing and patterns of food consumption are transforming food systems. Increasing reliance on purchased food in urban areas means that approaches to addressing the impacts of climate change on food security will need to consider field-to-table food systems (production, processing, transport, storage and preparation). Changes in climate may exacerbate weaknesses in food systems and result in more post-harvest losses. High temperatures increase spoilage. Floods damage transport infrastructure.

The degradation of coral reefs in Africa is a risk from climate change. Reefs are important for protecting coastal ecosystems and supporting fishery stocks (*medium confidence*). At present, the risk is medium and adaptation could reduce the risk to low. In the near term (2030–2040), the risk is high but adaptation could reduce the risk to medium. In the long term (2080–2100), the risk to coral reefs is very high with potential to reduce to high through adaptation with 4°C warming and high with potential to reduce to medium through adaptation with 2°C warming.

Projections also indicate that demand for fish will increase substantially in Africa over the next few decades. Angola, Mauritania, the Democratic Republic of the Congo and Senegal are most vulnerable to the impacts of climate change on fisheries. Coastal countries of West Africa may also experience significant negative impacts on fisheries.

The distribution and dynamics of all types of terrestrial ecosystems in Africa, deserts, grasslands, shrub lands, savannas, woodlands and forests, are changing (*high confidence*). The impacts of humans on forests are increasing, with conversion of forests for agricultural land, harvesting of wood for fuel and agroforestry practices. A complex shift in the spatial distribution of remaining natural vegetation has led to net decreases in woody vegetation in western Africa, and net increases in woody vegetation in central, eastern and southern Africa (*high confidence*).

Models show (*high agreement*) that changes in precipitation, temperature and levels of carbon dioxide associated with climate change are very likely to drive important changes in terrestrial systems throughout Africa (*high confidence*), primarily in the extent of woody vegetation. How the shift in ecosystem dynamics may affect economic activities such as forestry and agriculture is uncertain.

There are many adaptation options for African agriculture

Managing climate-related risks to livelihoods: Given that African economies depend largely on natural resources, most research on strengthening adaptive capacity in Africa has focused on rural livelihoods based on agriculture, forestry or fisheries, and has only recently extended to peri-urban and urban livelihoods.

Progress in managing risks to food production from current climate variability and near-term climate change will not be sufficient to address the long-term impacts of climate change (*high confidence*). Since the *Fourth Assessment Report,* Africa has taken a more livelihoods-based approach to managing risks to food production from multiple stresses, including rainfall variability. While these efforts could make agricultural systems in Africa more resilient over the near term, they would be insufficient for managing the risks associated with long-term climate change, which will vary across regions and farming systems. Nonetheless, collaborative, participatory research processes, warning systems and more flexible livelihood options are strengthening coping strategies for near-term risks in climate variability and could serve as foundations for strengthening adaptive capacities.

Technology: African countries have gained experience in climate-proofing infrastructure, and improving food storage and management to reduce post-harvest losses. A growing body of evidence shows that farmers are changing the technologies they use and their farming practices in response to food security risks linked to climate change and variability. For example, farmers plant cereal varieties adapted to shorter and more variable growing seasons, they build bunds to capture rainwater and reduce soil erosion, they use reduced tillage practices, manage crop residues to bridge dry spells when fodder is scarce and adjust planting dates to match shifts in rainfall patterns.

Conservation agriculture can both bolster food production and enable farmers to better manage climate risks (*high confidence*). Conservation or zero tillage, incorporating crop residues and green manures, building stone bunds, agroforestry, and afforestation and reforestation of croplands reduce run-off and protect soils from erosion. These practices capture rainwater and improve soil water-holding capacity, replenish soil fertility and increase carbon storage in agricultural landscapes.

Expansion of irrigation in sub-Saharan Africa holds significant potential for spurring agricultural growth while also managing water scarcity associated with climate change.

Expansion of irrigation in sub-Saharan Africa holds significant potential for spurring agricultural growth while also managing water scarcity associated with climate change. Planning at systems level could ensure that irrigation schemes benefit producers and avoid conflict. Inexpensive irrigation technologies such as low-pressure drip irrigation and small reservoirs could diversify production towards high-value horticultural crops. Strategic approaches to managing changing drought and rainfall patterns could include improving water- use efficiency in both rainfed and irrigated production, and embedding new irrigation schemes in rural development plans. Farmers need better access to agricultural inputs and markets, and packages that include technologies such as improved varieties, pest and disease control, soil fertility management, and in situ rainwater harvesting as well as access to irrigation in order to increase water productivity.

Reducing post-harvest losses through improved food storage, food preservation, greater access to processing facilities and better transport to markets is important to enhance food security. Low-cost on-farm storage, such as metal silos and triple-sealed plastic bags, reduces post-harvest losses from pests and pathogens. Better storage gives farmers more flexibility in when they sell their grain.

Barriers to adaptation: External interventions strengthen some coping and adaptive mechanisms and weaken others. Constraints faced by women, often cultural or legal, include limited access to land and natural resources, and limited access to information and new ideas. Few small-scale farmers across Africa are able to adapt to climatic changes, while others are restricted by a suite of overlapping barriers (*high agreement, robust evidence*).

In Kenya, South Africa, Ethiopia, Malawi, Mozambique, Zimbabwe, Zambia and Ghana constraints to adaptation have been found to be:

Table 4: Low-regrets entry points for adaptation in agriculture, forestry, fisheries and food security

Entry points for reducing vulnerability through development and planning
Poverty alleviation – livestock insurance, access to and control of local resources, land tenure, crop storage facilities
Livelihood security – infrastructure, access to technology and decision-making, cropping, livestock and aquaculture practices, social networks, livelihood diversification
Disaster risk management – early warning systems
Ecosystem management – genetic diversity, community-based natural resource management
Entry points for incremental and transformational adaptation
Technologies – new crop and animal varieties, traditional technologies and methods, efficient irrigation, water-saving technologies, conservation agriculture, food storage and preservation facilities, early warning systems
Ecosystems – ecological restoration, afforestation/reforestation, controlling overfishing, fisheries co-management, mangrove conservation and restoration, community-based natural resource management
Services – social safety nets, social protection, food banks, distribution of food surpluses
Economic – payment for ecosystem services, insurance, microfinance, disaster contingency funds, cash transfers
Laws and regulations – land zoning, easements, defined property rights, land tenure security, protected areas, fishing quotas, technology patents and transfer
Social – extension services, local and traditional knowledge, participatory action research, social learning, knowledge sharing, learning platforms, soil and water conservation, livelihood diversification, climate services, cropping, livestock and aquaculture practices, social networks
Transformation – social and technical innovation, behavioural shifts, institutional changes, changes in political, social, cultural and ecological systems and structures, changes in beliefs, worldviews

Source: See Table 1, above.

- Financial – poverty and a lack of cash or credit;
- Biophysical and infrastructural – limited access to water and land, poor quality soil, land fragmentation, poor roads, and pests and diseases;
- Institutional, technological and political – lack of access to inputs, shortage of labour, poor quality seed and inputs, insecure tenure and poor access to markets; and
- Informational – lack of information on agroforestry, afforestation, crop varieties, climate-change predictions and weather, and adaptation strategies.

Significant variability, lack of easy-to-use real-time weather information and information about the future climate, and poor local forecasts are commonly-cited barriers to adaptation at farm through to national level.

Africa's agriculture, forestry and land-use sectors are a source of greenhouse gas emissions

Food security and sustainable development depend on agriculture, forestry and other land use. Agriculture, forestry and other land use are important for mitigation because plants sequester carbon dioxide (CO_2) from the atmosphere into carbon stock pools such as biomass and soil. Plants also release greenhouse gases – CO_2, methane (CH_4) and nitrous oxide (N_2O) – through respiration, decomposition or combustion. Human land use alters natural sequestration and emissions and can either increase carbon sinks, for example through afforestation, or reduce carbon sinks, for example through deforestation.

Globally, the area of agricultural land increased by 7% (311 million hectares) between 1970 and 2010. The increase masks a decrease of about 53 million hectares between 2000 and 2010, which is attributed to a decline in cropland, permanent pasture and meadows. Improvements in farming technologies and techniques, and a 233% rise in the use of fertiliser, increased crop yields and doubled harvests of grain (to 2.5 billion tonnes per year) between 1970 and 2010. Livestock rearing also increased, contributing to a rise in methane emissions, particularly in Africa and Asia. Global daily per capita food availability also increased, and in Africa increased by 22% (to 10,716 kJ or 2560 kcal per person). Consumption of animal products increased globally but remained constant in Africa (8% of food consumption or 865 kJ) and decreased in OECD90 countries. Land is one of the most important resources in the agriculture, forestry and other land use sector because it provides food, fibre and fuel, and supports livelihoods. However, land is a finite resource and mitigation options in the agriculture, forestry and other land use sector may have positive or negative effects.

Between 1990 and 2010 the area of forest decreased in Africa and the area of pasture increased. The area of cropland has also increased. Africa now has the largest area of pasture and the third largest area of forest of all the continents. The use of fertiliser use is the lowest, well below global trends. Africa has the largest number of sheep and goats and is now third in cattle and buffalo rearing, overtaking OECD90 countries. Poultry farming is also increasing but is relatively less important than in most other regions.

Overall, there are benefits for mitigation action in Africa's agriculture and forestry sectors – and risks which must be managed carefully

Opportunities for mitigation in land and forestry involve supply-side changes, such as producing biomass, and improving agricultural efficiency; or demand-side changes, such as reducing food waste in production, distribution and by consumers, and reducing people's use of wood and forestry products.

As agriculture and forestry have major roles not only in mitigation, but also in achieving other development objectives, there are both significant benefits and risks.

Mitigation in agriculture, forestry and other land use could affect economic, social or institutional development objectives. The co-benefits and risks will depend on the development context as well as the extent of the mitigation intervention. Generalising the effects is difficult. Overall, there seem to be more economic and environmental benefits than risks. Maximising co-benefits, however, could make mitigation measures more efficient.

The social impacts will depend on the measures taken and the legal frameworks put in place, especially land rights. Mitigation measures that change land tenure and land-use rights could affect groups that depend on natural resources. A co-benefit of mitigation measures could be the clarification of land rights. A risk could be the removal of informal customary rights. Institutions that regulate and enforce land-use rights will determine the outcomes. Mitigation measures in agriculture, forestry and other land use could support certain sectoral policies but could also clash with others. Food security could be affected. Policies to reduce hunger by producing more food could clash with conservation measures or measures to increase biomass. Equity could be improved through social benefits or new technologies but could also be harmed by marginalisation of small farmers and forest users or land acquisition. The co-benefits and risks could be greater in Africa if mitigation through forestry measures takes priority. In Africa, capital may not be available to compensate or help groups such as forest users to diversify their livelihoods.

Mitigation measures in agriculture, forestry and other land use could increase food supplies but reduce the amount of water available for other uses. Decision-makers would be faced with evaluating this kind of trade-off. Mitigation measures in agriculture, forestry and other land use could support biological diversity, for example through conservation, but undermine biodiversity through changes in land use. Changes in forest management, afforestation and reforestation or production of biomass for biofuels could alter the availability of water.

Table 5: Climate mitigation policy in the agriculture, forestry and land-use sectors: co-benefits and risks[103]

Policy	Benefits	Risks
Economic	• Diversification of production as goods such as biofuels or biomass for energy production is increased • Additional income sources as production is diversified and additional income towards sustainable landscape management • Access to innovative financing mechanisms for sustainable resource management • Improved energy security • Technology innovation and transfer	• Potential to use less labour intensive technologies in agriculture
Social	• Increased food/crop production as efficiency improves • Conservation or creation of cultural habitats and recreational areas • Better human health through reduced use of chemical fertilisers and pesticides • Potential to increase security in land-use rights	• Decrease in food production if displaced by biofuels • Increased air pollution through increased burning of biomass • Potential to shift land rights towards more 'productive' users and away from traditional users
Environmental		• Increased land-use competition i.e. between conservation and production and between food crops and biomass for energy

Box 13: Bioenergy

Bioenergy could help stabilise changes in climate and has significant potential to reduce emissions. Best practice production of biomass, coupled with efficient cooking stoves and biogas plants, could reduce emissions and improve the lives of rural inhabitants. Moreover, Africa has opportunities to integrate bioenergy into food production.

Biomass residue and waste, from sugar production for example, can be converted to ethanol, energy and biogas. Agricultural and forestry residues are also low-cost feedstock for bioenergy. The inedible parts of food plants, wood and certain types of grass also hold substantial potential for bioenergy.

Large-scale development of bioenergy is, however, controversial. Developing bioenergy may threaten food security in Africa. Releasing carbon into the atmosphere by burning bioenergy reduces carbon stocks. Shifting land use from forests to biofuel production could threaten biodiversity.

Eight countries in Africa have set bioenergy targets. These countries are developing bioenergy in order to meet a range of development objectives – rural development, energy security and mitigating climate change. Achieving bioenergy targets, especially through biofuels, involves tackling policies and legislation relating to land registration, land-use planning and governance. Achieving biofuel targets also involves trade-offs, for example between forests and biofuel production, or between commodities such as vegetable oil and food and biofuel. Among the concerns are competition for land and water between fuel and food crops, adverse impacts of biofuels on biodiversity and the environment, contracts and regulations that expose farmers to legal risks, and changes in land tenure. The spread of biofuel crops could also restrict access to land and reduce livelihood opportunities for women, pastoralists and nomadic farmers. Research evidence does not yet provide a full understanding of the socioeconomic and environmental trade-offs associated with biofuel production in Africa.

Developing biofuels can also lead to international trade disputes. Some countries have already limited imports of biofuels and some subsidise national biofuel production.

Box 14: The land use sector offers opportunities for combined adaptation-mitigation approaches

Mitigating emissions from agriculture and forestry could either enhance or diminish climate resilience. The many competing pressures on land mean that land use decisions driven by mitigation objectives could affect adaptive capacity in agriculture as well as development objectives in other sectors. In some cases there may be clear synergies between adaptation and mitigation, for example, slowing or reversing deforestation could provide benefits by conserving biodiversity, which could bolster climate resilience.

Land-baesd approaches to mitigation such as reforestation need to consider the effects of changes in climate. For example, reforestation relying on one tree species would be more susceptible to climate change than reforestation involving several species. Monocultural forestry introduces other problems for climate adaptation and development, too: forest plantations of non-native species, although they may fix more carbon than mixtures of native species, support less biodiversity and contribute less to ecological services. In such cases, compromises that favour biodiversity-rich carbon storage would be preferable.

Adaptation measures could support mitigation; for example, a project to prevent fires or restore degraded forests would also prevent the release of greenhouse gases. Adaptation measures that add biomass and soil carbon, such as ecosystem protection and reforestation, could also help mitigate climate change by sequestering carbon.

Box 15: Low-regrets opportunities

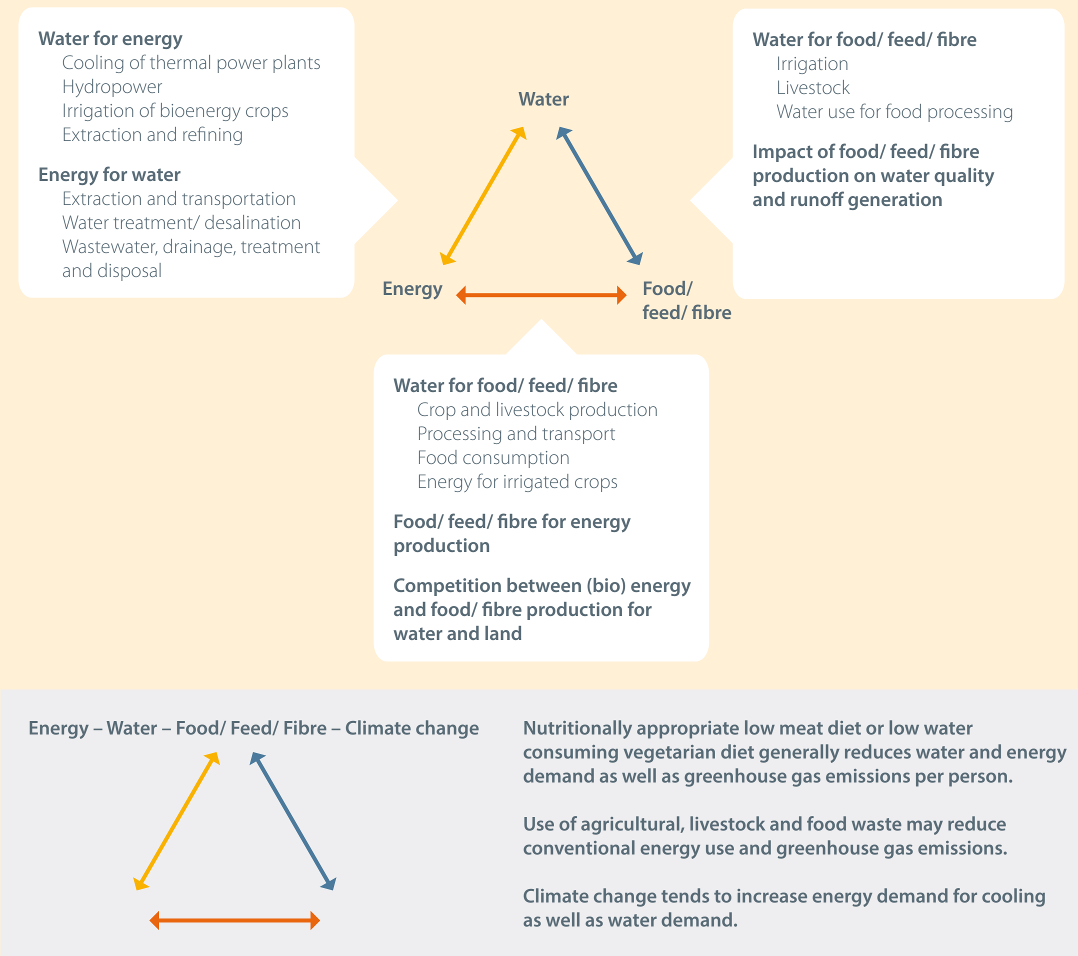
Evidence from smallholder farms in Africa shows that planting trees among annual crops can transform degraded farmland. In Zambia and Malawi, for example, planting nitrogen-fixing *Faidherbia* trees and fertilising them with small doses of minerals has replenished soil fertility. Yields of maize have doubled, food security has improved and incomes have risen.

Natural regeneration, a tradition among farmers and herders of selecting and protecting small trees until they grow to maturity has, perhaps for centuries, maintained extensive tracts of *Acacia albida* (winter thorn) in Senegal, *Adansonia digitata* (baobab) in western and southern Africa, and *Butyrospermum parkii* (Shea butter) in Burkina Faso. Recent work on natural regeneration has, depending on the type of soil, led to a denser tree cover and richer mix of species in Burkina Faso and Niger. In southern Niger, farmer-managed natural regeneration of *Faidherbia albida* and other field trees starting in the late 1980s, has increased tree cover across 4.8 million hectares and made production systems less sensitive to drought, compared to other regions in Niger.

Box 16: The water-energy-food/feed/fibre nexus and climate change[105]

The interactions among water, energy, food, feed and fibre are multi-dimensional. These interactions affect and are affected by changes in climate. Energy technologies (biofuels, hydropower, thermal power plants), transport and food production (from irrigated crops for example) use significant amounts of water. In irrigated agriculture, factors such as climate, technologies, the choice of crops and yields determine the water requirements per unit of crop produced. Producing, refrigerating, transporting and processing food require a great deal of energy. Another significant link between food and energy related to climate change is the competition for land and water (*robust evidence, high agreement*). Using food and crop waste, and wastewater as sources of energy saves not only non-renewable fuels, but also the water and energy that would have been used to process, treat and dispose of the wastes. By-products of sugar cane, for example, now fuel power stations. Such approaches bring both economic benefits and mitigate emissions of greenhouse gases.

The interactions between food, fibre, water, land use, energy and climate change are becoming more and more important in policies for adaptation and mitigation. For example, mitigation scenarios, as described in the IPCC's *Special Report on Renewable Energy Sources and Climate Change Mitigation* (IPCC, 2011) indicate up to 300 exajoule (EJ) a year of biomass primary energy by 2050 under increasingly stringent mitigation measures. (Energy use in the United States per year is roughly 94 EJ.) Such high levels of biomass energy production, in the absence of changes in technologies, processes, management and operations, would have significant implications for land use, water and energy, as well as for food production and prices. A consideration of the links between energy, food, feed, fibre, water, land use and changes in climate is increasingly recognised as being critical to making decisions on climate-resilient pathways (*medium evidence, high agreement*). Tools to support local and regional assessments and decision-making, however, are limited.



Beyond the *Fifth Assessment Report*: Agroforestry for stable livelihoods, carbon capture and climate resilience[104]

Zambia, like much of Africa, is reliant on maize for food security. However, maize yields average only about 1 tonne per hectare (ha), so even a moderate decline in harvests can be devastating for food security. Climate change is a critical concern, with declining or more erratic rainfall likely to result in lower production and less predictable harvests. Also, current production methods leave the soil deplete of nutrients, leading to land degradation which further threatens livelihoods and food security. Since the mid-1990s, Zambia's Conservation Farming Unit (CFU) and the World Agroforestry Centre have been pioneering 'evergreen agriculture' solutions to address these problems.

Evergreen agriculture combines agroforestry with the principles of conservation farming, by integrating particular tree species into annual food crop systems. By sustaining a green cover on the land throughout the year, the intercropped trees have several key benefits including:

- maintaining vegetative soil cover;
- bolstering nutrient supply through nitrogen fixing and nutrient cycling;
- generating greater quantities of soil organic matter;
- improving soil structure and water infiltration;
- producing additional food, fodder, fibre and income;
- enhancing carbon storage both above and below ground; and
- allowing more effective conservation of above- and below-ground biodiversity.

Zambia is using evergreen agriculture in two practices: maize agroforestry and conservation agriculture with trees. Both of these systems tackle the need to replenish soils in affordable ways using natural fertilisers – in short, re-employing age-old indigenous knowledge practices.

Image: Neil Palmer/ CIAT | Farming, Kenya

While these practices have great potential in mitigating the impacts of climate change and promoting climate-compatible development, there is a need for more support, as well as research and testing. There is also potential for 'nationally appropriate mitigation schemes' (NAMAs) to integrate evergreen agriculture, which could mobilise international finance for these practices in Zambia, and in other African countries.

Box 17: Removing barriers to conservation agriculture

Conservation agriculture practices strengthen the resilience of agro-ecosystems to extreme events and diversify livelihoods, while also advancing adaptation (*high confidence*). African farmers are adopting practices such as agroforestry, farmer-managed forest regeneration, conservation tillage, contouring, terracing and mulching. These practices strengthen the resilience of land resources to extreme events and diversify livelihoods, both important in managing and adapting to changes in climate. Removing barriers to broader adoption of these practices, such as by stabilising land tenure and usufruct, encouraging peer-to-peer learning, orienting extension services to cater for gender, widening access to credit and markets, and eliminating perverse policy incentives could help adaptation.

8.2. Opportunities in the energy sector

Climate vulnerabilities should be a consideration for decision-makers in Africa's energy sector

The extent to which changes in climate will affect energy will depend on the resource (e.g. water, wind, solar radiation), the technology (e.g. cooling) and the location (e.g. coastal, floodplain) (*high agreement, robust evidence*). Gradual changes in climate (e.g. in temperature, rainfall, windiness, cloudiness etc.) and changes in the frequency and intensity of extreme weather events will have a progressive effect. Changes in the availability and temperature of water for cooling are the main concern for thermal and nuclear power plants, and may push up costs. Changes in climate may also affect the integrity and reliability of pipelines and electricity grids (*medium agreement, medium evidence*).

Solar energy: All solar energy technologies are sensitive to changes in sunlight. For example, if cloud cover increases, the intensity of solar radiation and hence the output of heat or electricity will decrease. Solar power systems are also vulnerable to harsh weather conditions.

Thermal energy: Rising temperatures and decreasing water availability will lower the efficiency of thermal power generation. For example, in southern Africa less water may be available for thermoelectric power and drinking water, with associated impacts on local and regional economies.

Hydropower: Assessing the impacts of climate change on hydropower is complicated. Competition for water because of changes in population and economic activities (especially irrigation) is difficult to predict. For example, in Ethiopia capital expenditure in climate change adaptation for hydropower facilities through 2050 may either decrease under extreme wet scenarios or increase under severe dry scenarios in order to maintain output. In the Zambezi river basin, less hydropower could be generated by mid-century under the driest scenario. Upstream power stations on the Zambezi are likely to generate less power and downstream stations more.

Non-renewable energy: Hazards related to climate and weather in the oil and gas sectors include the potentially severe effects of tropical cyclones on off-shore platforms and on-shore infrastructure.

Africa's energy-related emissions are low, but increasing fast

Industrial, transport, construction and other sectors use electricity, heat, refined petroleum and other forms of energy derived from primary sources of energy such as coal, oil or gas. However, in generating energy, the energy sector uses more energy than any other sector. Major inefficiencies in converting, transmitting and distributing energy (generating power from fossil fuel is only 37% efficient) mean there are significant opportunities for saving energy.

Between 2001 and 2010, the world's total primary energy supply grew by 27% or 2.4% a year. Globally, the highest rate of growth over this period was in Asia (79%) but growth rates were also high (47%) in Africa and the Middle East. Growing energy demand in Africa has raised consumption of both conventional and non-conventional oil. Rising oil prices and the security of oil supplies are concerns for countries where demand for oil is growing. Rates of growth in the consumption of natural gas were highest in Africa and Asia.

Box 18: Energy sector terminology

Primary energy use: Primary energy (also referred to as energy sources) is the energy stored in natural resources (e.g. coal, crude oil, natural gas, uranium and renewable resources).

Final energy use: Primary energy is transformed into secondary energy by cleaning, refining or by converting it into electricity or heat. When secondary energy is delivered to the end-user it is called final energy (e.g. electricity at the wall outlet), where it becomes usable energy in supplying services (e.g. light).

Life-cycle emissions assessment: Refers to compiling and evaluating all the inputs, outputs and potential environmental impacts of a production system (e.g. a coal power plant or a photovoltaic panel) throughout its life cycle, including construction, use (outputs) and end of use.

Levelised costs of energy: A measure assessing the long-run average cost of a unit of energy provided by a technology.

Carbon intensity: The amount of carbon by weight emitted per unit of energy consumed.

Energy source: A source from which useful energy can be extracted or recovered either directly or by means of a conversion or transformation process (e.g. solid fuels, liquid fuels, solar energy, biomass).

Energy carrier: Energy carriers are produced by the energy sector using primary energy sources.

By 2010, renewable energy contributed 13.5% of total global primary energy supply. In 2012, renewable energy accounted for 21% of total electricity production, ranking third after coal and gas. Between 2005 and 2012 there was a five-fold growth in wind power and a 25-fold growth in solar photovoltaic power, mostly in OECD90 countries and Asia.

Growth in greenhouse gas emissions from the energy supply sector was faster 2001–2010 than in any previous period. Between 1991 and 2000, emissions increased by 1.7% a year and between 2001 and 2010 they increased by 3.1% a year. Between 2010 and 2012 there was a 6% rise in greenhouse gas emissions, of which most (43%) were from coal, followed by oil (36%) and gas (20%).

The rise in energy emissions is partly due to population growth. The *Fifth Assessment Report* indicates that population growth accounts for 39.7% of additional emissions. The slow rate of decarbonisation of global energy led to the paradox whereby the decade 2001–2010 saw carbon mitigation policies put in place at the same time as emissions of carbon were growing at the fastest rate for 30 (or so) years. While carbon intensity (the amount of carbon by weight emitted per unit of energy consumed) fell in OECD90 countries, there was little or no decarbonisation in developing countries (average decline of about 0.4% a year).

Greenhouse gas emissions from the energy supply sector in Africa increased by 3.38 times between 1970 and 2010. Emissions from producing electricity and heat, and from petroleum refining grew the most quickly, although fuel production and transmission continued to be significant. That said, African emissions start from a low base. Per capita emissions in Africa in 2010 were the second lowest globally (1.46 t/CO_2e/yr) and increased by 1.05 times between 1980 and 2010. Africa had the second highest rate of growth in total emissions 2001–2010 (3.66%), lower only than Asia (7.89%). High rates of growth and an increase in the use of fossil fuel are the main causes of the rise in greenhouse gas emissions from the energy sector in Africa.

Fossil fuel is not a fixed resource but is a 'dynamically evolving quantity' because of uncertainty about the amount available. Estimates indicate that coal will be available for the next 100 years at current rates of production. Production of conventional oil will soon or may already have peaked. Production of non-conventional oil will only extend supplies by about two decades and will depend on price rises in order to make extraction profitable. Overall, oil production is expected to decline in the long term. Discoveries of natural gas have far outpaced production. Reserves are large and have a greater global distribution than oil. Reserves of unconventional gas are estimated to be greater than reserves of conventional gas. If all reserves of fossil fuel were used to produce energy, estimates indicate that emissions would raise temperatures above the 2°C warming threshold.

Africa has options to invest in clean energy and avoid emissions

Mitigating emissions in the energy sector will involve reducing life-cycle greenhouse gas emissions. This will mean replacing fossil fuel by renewable or nuclear energy, and reducing emissions from extracting, transporting and converting fossil fuel into energy. Without mitigation, CO_2 emissions from the energy sector will continue to rise. As African countries are still to make significant investments in energy infrastructure to meet their development needs, there is a major opportunity to avoid fossil fuel dependency and invest up front in cleaner, more efficient technologies.

As African countries are still to make significant investments in energy infrastructure to meet their development needs, there is a major opportunity to avoid fossil fuel dependency and invest up front in cleaner, more efficient technologies.

Scaling out renewable energy technologies: Significantly reducing greenhouse gas emissions from the energy sector in Asia would require investment in renewable energies such as hydropower, bioenergy and ocean energy. Most renewable energy technologies emit less greenhouse gas over their life cycle than fossil fuel technologies.

Life-cycle emissions for renewable energy (see Figure 8) are:

- Photovoltaic panels 5–217 gCO_2eq/kWh,
- Nuclear energy 1–220 gCO_2eq/kWh,
- Geothermal energy 6–79 gCO_2eq/kWh, and
- Ocean energy 2–23 gCO_2eq/kWh.

Emissions from non-renewable energy are:

- Coal 410–650 gCO_2eq/kWh
- Natural gas 710–950 gCO_2eq/kWh

Africa uses only a fraction of its renewable energy resources. Renewable energy can be large-scale, as in industrial-sized solar farms, or distributed, for example household solar panels. Decentralised renewable energy could be significant in Africa given its geography and settlement patterns.

African countries already generate some electricity from large and decentralised photovoltaic systems. Life-cycle emissions from hydropower plants vary widely depending on the construction materials used. Large hydropower schemes would emit more than small run-of-the-river dams.

The cost and performance of many renewable energy technologies have improved significantly in recent years. Better manufacturing processes, lower costs of hardware and changing market conditions have brought down prices. Globally, between 2009 and 2012, the levelised cost of photovoltaic energy fell by 57%, wind energy by 15%, gas from waste by 16% and biomass gas by 26%. Lower levelised costs mean that wind, solar and geothermal energy are becoming more competitive. Although scarcity of inputs, rare earth minerals for photovoltaic panels for example, may raise prices in the short term, the long-term trend is for costs to fall.

Other technologies are at different stages of development, for example different types of bioenergy differ in their efficiency and cost-effectiveness. Also, the levelised costs of energy can vary according to location. For example, the cost of producing biofuel in certain parts of Africa will differ from the cost of producing the same fuel elsewhere, as will the cost of infrastructure.

The distribution of renewable resources, capacity to invest and competition for the resources may limit the extent to which they can be deployed. For example, many renewable energy technologies are geographically constrained as they need to be located at the source of energy: wind farms need to be located in windy areas and geothermal plants in geothermally active areas. Economic factors, public acceptance and the need for investment in infrastructure could also limit exploitation of the technical potential of renewable resources. Policies and publicly-sponsored research and development could play an important role in scaling-out renewable energy.

New technology: Hydraulic fracturing and horizontal drilling technologies (fracking) in the gas sector have increased supplies. The new technologies have led to a switch from coal to gas and have reduced emissions in countries with abundant non-conventional gas reserves. Tapping non-conventional gas or more natural gas could reduce emissions in Africa.

Preventing fugitive emissions: Fugitive emissions contribute to air pollution and climate change. Reducing fugitive emissions, especially of methane, would include for example, preventing leaks in gas pipelines.

Improving transmission and distribution: Losses in transmission vary by country, but are considerably higher in developing countries, where losses are around 20%, than in OECD90 countries, where they are 6.5%. Shorter connections and high-voltage transmission systems help decrease losses and related emissions because less electricity needs to be produced and electricity generated is better distributed.

Infrastructure: Reducing emissions in the energy sector will require large-scale investment in infrastructure. In Africa, demand for power often outstrips supply, hindering economic and social progress. Production of renewable energy, wind power for example, fluctuates and means that energy systems will need to link several sources of energy in order to deliver reliable supplies. Storing energy could be important in balancing supply and demand, for example storage dams in hydropower systems – although dam construction and maintenance can create trade-offs with development goals that must be very carefully managed.

Existing infrastructure would need to be made more robust and efficient in order to transmit and distribute renewable energy. In Africa, decentralised renewable energy may be technically and economically more feasible than centralised supply systems. Gases generated from biomass and waste could be distributed through existing natural gas pipelines. Existing natural gas systems could also be used to transport hydrogen for short distances.

Costs and benefits of mitigation approaches in Africa's energy sector

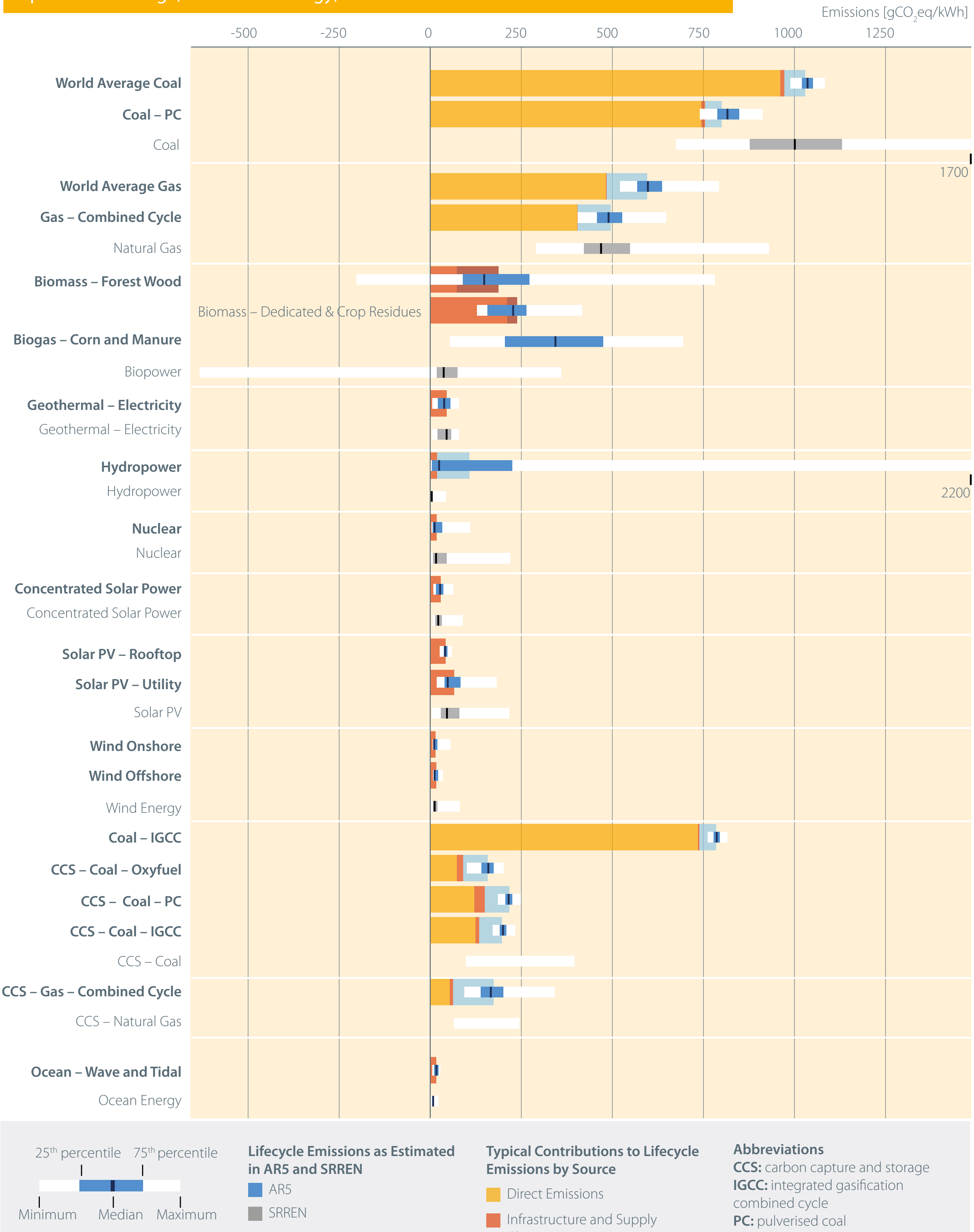
From an energy supply and security perspective, the co-benefits and risks of mitigation action are hard to resolve. Replacing fossil fuels with renewable energy may improve energy security. Conversely, if investments in renewable energy are too slow to meet suppressed demand and take place at the expense of investments in fossil fuels), then there could continue to be a shortage of energy in the short to medium-term. A further number of socioeconomic, environmental and health risks and benefits merit consideration:

Socioeconomic benefits of clean energy: The potential for creating jobs in renewable power plants, or in manufacturing, distributing and researching technologies to mitigate emissions in the energy sector is good although the cost of creating jobs may be high. Creating a new job in photovoltaics in Germany, for example, costs US$257,400. Mitigation measures could improve energy security by generating more energy locally or by efficiency savings that reduce imports. Benefits to rural development could include wider access to energy through decentralised renewable energy systems. Developing biofuels could also stimulate rural growth.

Environment and health benefits: No energy supply chain, including for renewable energy, has zero impact on the environment. Emissions from fossil fuels are pollutants that affect human health and can lead to many diseases. Reducing combustion of fossil fuel can help reduce pollution with benefits to human health and biodiversity. Small renewable energy systems have less ecological impact than large systems such as hydropower dams. The health and environmental risks associated with mitigation measures, such as the risks of meltdown, waste disposal and uncontrolled proliferation associated with nuclear energy, may outweigh the benefits.

Barriers to clean energy: The main barriers to mitigation in the energy sector are technological and financial. Investment in renewable energy in developing countries fell by 29% in 2012. Capital markets for financing energy are

Figure 8: Comparative life-cycle greenhouse gas emissions from electricity supplied by currently commercially available technologies (fossil fuels, renewable and nuclear power) and pre-commercial technologies (advanced fossil systems with carbon capture and storage, and ocean energy)[106, 107]



Lifecycle Emissions as Estimated in AR5 and SRREN

- AR5
- SRREN

Typical Contributions to Lifecycle Emissions by Source

- Direct Emissions
- Infrastructure and Supply Chain Emissions
- Biogenic CO_2 and Albedo
- Methane

Abbreviations

CCS: carbon capture and storage
IGCC: integrated gasification combined cycle
PC: pulverised coal
PV: photovoltaic
SRREN:[108] IPCC (2011). IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation.

not well developed. Human capacity is also a constraint. Education systems are not delivering sufficient skilled personnel for research, production and investment in energy mitigation technologies. The lifespan of existing energy capital stock could also be a barrier. There is little incentive to invest in new energy infrastructure if the existing infrastructure is still commercially and technically viable.

A range of policy options can support clean energy development: most are just beginning to be tested in Africa

Policies to stabilise greenhouse gas concentrations combine economic, regulatory and informational measures. Many of these have been tested in industrialised countries such as in northern Europe and to only a very limited degree in Africa – although there is some important African experience beyond the scope of the *Fifth Assessment Report*, which is captured in the boxes below.

Economic policies: Greenhouse gas trading schemes and taxes on emissions deal with market externalities associated with emissions. Trading schemes allow emitters to reduce their emissions and sell spare capacity. Taxes allow emitters to save money by cutting emissions.

Regulations: Rules setting targets for low-carbon technology allow companies to assess whether investment is worthwhile and to plan for the long term. More investment in low-carbon technology would make technologies both cheaper and more efficient. The success of policies would depend on robust legal frameworks and stable regulations.

Information campaigns: Raising awareness, building capacity and disseminating information are important in encouraging uptake of renewable energy technologies. Transparency improves both public and private decision-making processes and catalyses public acceptance of mitigation activities in the energy sector.

Technology investments: Publicly-funded research and development could advance renewable energy technologies. There has been significant public expenditure on research and development in nuclear energy. However, technologies such as carbon capture and storage have not received much support. More public support would not only improve renewable energy technologies but might also be an incentive for private investment.

Voluntary action: The success of voluntary agreements has been mixed, improving energy efficiency significantly but only reducing emissions slightly.

Beyond the *Fifth Assessment Report* – Voluntary carbon footprinting in Kenya's flower sector[109]

Kenya's flower sector contributed over US$500 million to the national economy in 2011. The sector accounts for over 35% of all cut flower sales in the European Union (EU). However, heightened awareness of climate change among EU consumers is increasing the demand for sustainably sourced, carbon efficient horticultural produce. In response to this the Horticultural Crops Development Authority and Kenya Flower Council are strengthening Kenya's competitive position in global markets by developing accounting and management solutions for greenhouse gas emissions, energy efficiency and water use. They have developed a sectoral greenhouse gas management tool, the Carbon Reduction, Resources and Opportunities Toolkit (CaRROT). The toolkit is an easy-to-use Microsoft Excel spreadsheet that integrates energy and water trackers with a carbon calculator. The features have been designed with local context in mind, providing disaggregated tracking for various sources of energy and water, including grid electricity, diesel and kerosene, municipal water, boreholes, lakes and water harvesting, among others.

Ten farms supplied the initial data to build the preliminary tool and an additional ten farms assisted in the pre-testing phase. It was found that many of the larger farms, especially those with an international corporate presence, are already tracking their carbon footprint through either internal structures or subcontractors. In this regard, the biggest push for the uptake of the toolkit has come from medium and small-scale farms. The final toolkit was approved in February 2014. The focus for the Kenya Flower Council and partners now shifts towards dissemination.

Image: Panos | Commercial flower farm, Kenya

The project contributed to the implementation of Kenya's National Climate Change Action Plan by highlighting financing opportunities for improvements in energy efficiency and small-scale renewable energy generation – and by including efficient water resource use.

Beyond the *Fifth Assessment Report*: Kenya's geothermal power development[119]

Kenya's heavy reliance on hydroelectricity has made the country vulnerable to climate change impacts, such as drought and erratic rainfall patterns. Kenya needs to develop a more resilient and stable supply of electricity, while rapidly developing its base load of electricity production to meet growing demand. Although the path of least resistance would be to expand its fossil fuel-based thermal production, Kenya's Vision 2030 strategy places priority on low-carbon development including renewable energy source development – with geothermal energy playing a critical role.

Kenya has relied on hydroelectricity as a key low-carbon energy source and a way of expanding energy services. However, droughts and erratic rainfall have made hydropower unreliable, reducing the country's adaptive capacity. Nearly 77% of Kenyans still lack access to modern energy services, which impedes development efforts.

An expanded and diversified range of renewable electricity sources is critical, and geothermal energy is at the forefront of low-carbon options. Geothermal energy is readily available and is not affected by climatic variability.

Image: Caption

Kenya has catalysed a productive geothermal sector by establishing a specialist government institution, the Geothermal Development Company, which shoulders some of the financial risk for the private sector in the exploration, appraisal and drilling stages. Kenya has accessed previously unattainable funding sources by aligning further investments in geothermal energy with climate change and development objectives (e.g. carbon/climate finance, donor funding and local public finance).

Energy sector reforms in Kenya are beginning to stimulate and fast-track the country's geothermal industry in line with the country's vision of climate-compatible development. The country is finding ways to overcome constraints within the sector and obtain project financing. This is supported by several enabling factors and concrete measures taken by the Government of Kenya, with the aim of creating a viable and sustainable national geothermal industry.

Beyond the *Fifth Assessment Report*: Tanzania's small power producers[111]

Lack of reliable access to electricity is a significant barrier to economic development and job creation in Tanzania. Currently, only 14% of the population has access to electricity; in rural areas the electrification rate hovers around 2%. Power outages are frequent – especially during droughts, which cripple the hydroelectric power on which most of the country depends.

Tanzania's Small Power Projects (SPP) programme was designed by the Government of Tanzania – with very limited financial resources – to support renewable energy deployment. As a result, decentralised renewable energy solutions are contributing to Tanzania's climate-compatible development by:

- Supporting economic development through improved access to reliable electricity;
- Reducing greenhouse gas emissions; and
- Lessening vulnerability to fossil fuel price shocks and to drought-related hydropower shortages.

The programme does not cost the electricity company or consumers more than conventional power sources, which is appropriate for this low-income country.

Low tariffs and difficult financing conditions currently limit the programme's reach, but have enabled Tanzania to build a regulatory framework and gain experience. As a next step, the programme could be scaled up, if sufficient funds can be secured.

Image: Panos | Decentralised solar power

Tanzania's renewable energy policy-making and implementation has benefitted from intensive South-South exchange with Thailand and Sri Lanka.

Table 6: Energy mitigation policy co-benefits and risks[112]

Policy	Benefits	Risks
Economic	• Increased energy security • Improved employment opportunities • Avoids lock-in to fossil fuel-based systems	• Potentially reduced energy supply as energy moves to renewables
Social	• Reduced health risks – less air pollution • Contributes to energy security and access in the long run	• Safety and waste issues • Energy technology risks (i.e. nuclear risks) • Carbon capture and storage may cause CO_2 leakages with associated health concerns
Environmental	• Less air pollution	• Impacts on habitats where renewables are located

8.3. Opportunities in the transport sector

Transport systems can be vulnerable to climate change, but the IPCC does not report Africa-specific data

The *Fifth Assessment Report* makes some generic observations about the robustness of transportation systems in a changing climate. These generic observations are worth consideration by decision-makers and planners in Africa's transport sector.

Climate change will affect transport both positively and negatively depending on the location and the nature of local transport systems. Adapting a transport system to changes in climate could either complement or counteract mitigation efforts. However, little is known about the relationship between mitigation and adaptation in the transport sector.

Changes in sea or river levels may affect shipping routes. Where routes become shorter there could be a positive effect on emissions but where they become longer the effect could be negative. New routes could also be subject to pollution if emissions are not regulated. Climate change will shift agricultural production, which means that freight routes will also change. Food chains could be shorter or longer.

Higher temperatures and humidity could affect vehicle emissions and the interaction of emissions with the atmosphere. As global average temperatures rise, demand for cooling systems for both private and public vehicles will also rise. Similarly, more cold spells will increase demand for heating in vehicles. Both heating and cooling systems reduce vehicle fuel efficiency.

Transport infrastructure may also be affected. Climate-proofing transport will depend on changes in demand but will most likely increase the cost of infrastructure. Changes in climate will add to maintenance costs. Resources that could be used to expand existing transport networks could be diverted to climate-proof existing infrastructure. An increase in extreme weather events could also influence modes of transport, for example as storms become more frequent ships or aircraft may become less safe.

Conventional transport systems that are fossil fuel-intensive are a fast-growing source of emissions for Africa

Globally, transport emissions from non-OECD90 countries will probably be twice as much as transport emissions from OECD90 countries by 2050. Emissions from personal transport will likely stay at lower levels in non-OECD90 countries than in OECD90 countries. Most transport emissions in developing countries will be from public systems. Emissions from the transport sector have doubled since 1970 and, in 2012, accounted for 27.4% of final energy use. Road vehicles are responsible for 80% of emissions. Reducing emissions from transport will be difficult given growing demand and existing investment in vehicles and infrastructure.

The potential for the transport sector to grow in Africa is significant. Currently, 10% of the world's population account for 80% of transport, measured in passenger kilometres. Emissions from transport in Africa (here signifying the IPCC's Africa-Middle East region) grew from 0.07 Mt CO_2 eq in 1970 to 0.57 Mt CO_2 eq in 2010, an eight-fold increase in 40 years. This region has the second highest growth rate in emissions from transport. Most African emissions are now from road traffic. Other sources of emissions barely register. The pattern in Africa is not unique. Emissions from road traffic dominate in all other regions.

Mitigation action in Africa's transport sector offers significant development benefits, including for public health

In the transport sector, opportunities for mitigation include:

- Reducing fuel carbon intensity, for example by changing to electric engines or hydrogen powered engines;
- Shifting transport preferences away from personal vehicles to public transport; and
- Reducing commuting and freight times and distances.

The co-benefits of mitigation in the transport sector significantly outweigh the risks:

- More energy security as demand for energy from the transport sector falls;
- Improved productivity as travel times for goods and people, and the associated costs, fall;
- Better health because of less pollution; and
- Potential for positive technological spillovers, such as more efficient engines and batteries.

The risks are mainly environmental. Manufacturing more efficient transport may need more primary resources or may open previously relatively untouched areas to vehicles.

Urban transport systems can be planned to minimise emissions, by giving priority to pedestrians, cyclists and public transport for example. In emerging economies, developing mass-transit and low-carbon transport infrastructure could avoid future lock-in to carbon-intensive transport.

Technological advances in motor vehicle efficiency, spurred by regulations in the European Union, the United States and Japan, indicate that there is considerable scope to reduce emissions by improving combustion engines and by developing hybrid vehicles.

Currently, most vehicles run on petrol or diesel engines. Replacing petrol or diesel engines with new electric or hybrid motors could help to reduce emissions. Low-carbon fuels derived from electricity, biofuel, natural gas and hydrogen could directly help reduce CO_2 emissions. Compressed methane can substitute for petrol in light vehicles and replace diesel in heavier vehicles. In liquid form, methane could also fuel heavy-duty vehicles and ships. Compressed natural gas could reduce tailpipe emissions by 25% compared to petrol or diesel, or 10% to 15% over a life cycle. The reduction in emissions would depend on how electricity to power vehicles was generated. Producing hydrogen from biomass or natural gas is relatively expensive at present but could become commercially feasible in the future.

Liquid and gas biofuels produced from crops are relatively energy-dense and are mostly compatible with existing fuel distribution infrastructure. Blends of ethanol and biodiesel with petrol can fuel unmodified combustion engines or slightly modified engines when the proportion of biofuel in the blend is higher. Biofuels emit 30%–90% less greenhouse gases than petrol or diesel. However, indirect emissions from changes in land use and agriculture could lead to greater total emissions. Successfully promoting the use of more efficient vehicles, new technologies and more efficient fuels requires changes in behaviour. These changes include:

- **Purchasing:** In order to encourage people to buy efficient vehicles, policy-makers could set fuel economy standards and lower taxes on efficient vehicles.
- **Fuel economy and eco-driving:** Poor driving and traffic congestion can lower fuel economy. Policy-makers could improve traffic management, set up intelligent transport systems and promote eco-driving, especially for large, long-haul vehicles.
- **Rebound effects:** Low travel costs create demand. In the USA, elasticity in fuel prices means that a reduction of 50% results in a 2.5% to 15% increase in travel. The rebound effect is higher where fuel prices represent a high proportion of household income, such as in developing countries.

Planning infrastructure to reduce emissions could avoid lock-in to potentially high-emission systems. Emissions from building and operating infrastructure could be reduced by using low-carbon materials and low-carbon fuels.

Low-density development with extensive road networks creates a greater demand for vehicles than high-density development. Many people in high-density urban areas in developing countries walk or cycle but inadequate infrastructure often makes these modes of travel dangerous. Urban population density inversely correlates with emissions from land transport. Non-motorised transport becomes more feasible as density increases but employment density, street design and connectivity are also important factors.

8.4. Opportunities in the industrial sector

The vulnerability and climate adaptation potential of African industries is largely unknown

Little is currently known about the effects of mitigation on industry, its potential and costs. Little is also understood about the potential synergies or trade-offs in reducing or increasing emissions from industry. Many adaptation measures could raise demand for industrial products and lead to more emissions, for example improving flood defences may increase emissions from manufacturing cement to build barricades.

Box 19: How much does it cost to switch to lower-carbon transport options?

The costs of reducing emissions in the transport sector vary according to the region, the country and the type of mitigation. The approach to mitigation will depend on emission targets. Successful mitigation will depend on shifting existing transport, infrastructure and behaviour to lower emission options.

Vehicles: Light vehicles could be 50% more efficient by 2030 compared to 2010 at either low or negative social cost. Reducing emissions associated with electric vehicles depends on how the electricity they use has been generated. If generation is high carbon, emissions saved by electric vehicles are minimal. If generation is very low carbon, the mitigation costs are US$200/t CO_2. Better batteries in electric cars indicate mitigation costs ranging between US$0/t CO_2 and US$100/t CO_2.

Aircraft and ships: New aircraft are more efficient than older types and already reduce CO_2 emissions at negative social cost over 10 to 15 years. Further 30%–40% reductions in CO_2 by 2030 could be achieved with aircraft now being developed but the mitigation potential is uncertain. In shipping emissions could be reduced by 50%.

Rail: Reductions in emissions from rail transport could come from electrification and switching to low-carbon electricity.

Substitute fuel: In all modes of transport, reducing emissions by switching to another fuel depends on the type of substitute fuel. Some biofuels have the potential to reduce CO_2 emissions. The CO_2 emissions avoided by using biofuel depend on the net CO_2 reduction, the cost of biofuel compared to regular fuel, and the cost of altering vehicles to use biofuels or biofuel blends.

Table 7: Climate mitigation policies in the transport sector: co-benefits and risks[113]

Policy	Benefits	Risks
Economic	• Improved energy security as less fossil fuels are used • Positive technology spillovers for example improved batteries • Improved productivity as transport times decrease	
Social	• Reduced air pollution improves health in urban areas • Less noise pollution • Increased road safety • Health benefits as people use less motorised vehicles	• Quieter vehicles could increase road risks
Environmental	• Less urban pollution	• Increased material use for new technology production • Potential creation of new transport routes in otherwise unused areas

Industrial emissions can be very significant at a country level, depending on the structure of the economy

Industrial emissions accounted for 30% of global greenhouse gas emissions in 2010, more than emissions from transport and building. Direct industrial emissions from Africa were low but grew at 4.3% per year from 1970 to 2010, above the average world growth rate (of 3.6%).

Industrial CO_2 emissions include emissions from energy used in mining and quarrying. Although mining and quarrying use only 2.7% of global industrial energy they can be quite significant emitters at the national level. In Botswana and Namibia emissions from energy used in mining and quarrying account for 80% of national emissions from industrial use of energy, in Zimbabwe 18.6% and in South Africa 15%. Manufacturing accounts for 98% of all direct CO_2 emissions. Developing countries made the most progress in reducing energy intensity in manufacturing 1995–2008 because they used more energy-efficient practices and technologies, and because the type of goods they produced changed.

Africa has abundant opportunities to adopt efficient industrial processes that reduce or avoid emissions

Reducing emissions from industry requires more than using carbon and materials efficiently, recycling and re-using materials, reducing demand, and becoming economically and environmentally efficient. There are various options for mitigating greenhouse gas emissions from industry.[114]

Energy efficiency: Although industry has made great strides in energy efficiency over the last four decades, there is still scope for improvement. Industrial processes such as heating, refrigeration and combustion could be more energy efficient. Better insulation, using excess heat for secondary processes and recycling would also help reduce demand for energy and so reduce emissions.

Emissions efficiency: Switching the fuels used by industry, for example from coal to natural gas, would help reduce emissions. Carbon capture and storage could also play a significant role in reducing CO_2 emissions from industry. Decarbonising power generation, coupled with more use of electricity by industry, could further reduce emissions.

Efficient use of resources: Industries could reduce emissions by using materials more efficiently, cutting down on waste and recycling.

Efficient product design. Less material could be used in manufacturing many products without any detriment to performance. The high cost of labour relative to materials currently makes optimising design and production systems unfeasible except in industries such as aerospace.

Reducing demand: Reducing demand for products is another way of reducing industrial emissions. Behaviour change campaigns could reduce demand for processed products such as food where significant proportions are currently wasted. Durable goods could be engineered to last longer, thus requiring fewer to be produced.

Collaboration by clusters of companies and cross-sector collaboration could also help reduce consumption of materials by industries and contribute to reducing greenhouse gas emissions. The clustering of companies, for example in industrial parks, can encourage growth and competitiveness as well as help reduce greenhouse gas emissions. Benefits to companies include opportunities to exchange by-products (e.g. heat), share infrastructure (e.g. transport) and pool resources to invest in more energy-efficient technologies. Cooperation could help lessen cumulative environmental impacts, for example through recycling materials.

There are opportunities to mitigate emissions by co-locating industries, for example, the cement industry could use urban waste in some of its products and urban areas could use industrial exhaust for heating.

Mitigation in non-industrial sectors could affect mitigation efforts in industry. For example, demand for energy-efficient technologies such as high-efficiency batteries could raise emissions from the industries that produce them. Conversely, demand for more efficient products such as lighter vehicles could lower emissions.

Co-benefit and risk analysis shows that there are many co-benefits associated with these opportunities and very limited risks.

Climate mitigation approaches confer advantages in competitiveness and in cutting costs. Improving energy efficiency can be profitable, conserve natural resources, reduce demand for fuel and save energy. Since industries need energy security, improving energy efficiency could reduce dependency on imported energy, maintain stability and competitiveness, and lead to co-benefits such as better health because of less pollution. Reducing emissions also has multiple benefits – less pollution, less damage to ecosystems, better health and lower emissions-related taxes. Capturing and storing carbon could provide environmental co-benefits. Reducing the use of materials could lower production costs. Mitigation associated with co-benefits such as improving local environmental quality can make such activities more socially acceptable. The only real risk identified by the *Fifth Assessment Report* was the possibility of lower production because of changing consumer demand, which could reduce demand for goods or primary resources.

Information on the costs of mitigation in industry is limited. Mitigation options that have been costed use different methods and the results are not comparable. Mitigation options are estimated to be profitable when emissions are reduced within a range of 0–20 US$/$tCO_2$eq. To reduce emissions to zero, longer-term investments such as carbon capture and storage would be needed. These investments

Table 8: Industry mitigation policy co-benefits and risks[115]

Policy	Benefits	Risks
Economic	• Improved competitiveness and productivity • Increased energy efficiency leading to improved energy security • Positive employment impacts due to new or expanded industries such as waste recycling • Technological spillovers into other sectors • New or improved infrastructure for industry	• Potential for lower tax revenue as demand for goods decreases
Social	• Fewer health risks due to decreased pollution • More employment opportunities • Better water availability and quality • Better worker safety conditions	
Environmental	• Less pollution and better water conservation • Reduced use of materials through recycling	

would increase costs to 50–150 US$/t$CO_2$eq. Costs vary regionally, and by country and site.

Non-financial barriers to mitigation in industry are technological (maturity, reliability, safety), physical (geography, infrastructure) and cultural (public acceptance, human resources).

Barriers to improving energy efficiency in industry include a failure to recognise the positive impacts (competitiveness, lower costs), the long-term nature of return on investment in energy efficiency, behavioural issues and access to capital. Economic, regulatory, social and political barriers could also discourage industry from taking measures to improve energy efficiency and emissions efficiency, and to switch to other fuels. The communication skills needed to convey the benefits of recycling or preventing waste, which would lead to less industrial production and fewer emissions, might also be lacking. Products that have been redesigned in order to use materials more efficiently might not be acceptable to consumers.

8.5. Opportunities for urban areas

African towns and cities are very vulnerable to climate change

The urban population in Africa is projected to triple by 2050, increasing by 0.8 billion. African countries have some of the world's highest urbanisation rates. Many of Africa's evolving cities are unplanned, surrounded by informal settlements and poverty, and have inadequate housing and basic services.

Climate change is among many drivers of rural-urban migration. This means that changes in climate could affect rural and urban settlements in Africa. Most migration caused by changes in the environment is within countries.

African cities and towns are very vulnerable to climatic changes and climate variability. Rapid urbanisation calls for significant investment to create jobs, and provide infrastructure and services. Basic infrastructure services lag behind urban growth. Slums and poor areas typically have neither flood protection nor the wherewithal to manage floods when they happen.

Infrastructure and services: Small- and medium-sized cities have limited capacity to deal with current or future climatic risks. Although cities are usually better serviced than rural areas, for example with piped water, sanitation, schools and healthcare, and people on average generally live longer than in rural areas, poor infrastructure may shorten life spans under changes in climate. Many cities in sub-Saharan Africa not only have inadequate piped water, sewers and drains, but also have very limited capacity to invest in improving services. The amount required to adapt existing water infrastructure may be US$1–2.7 billion a year. More would be required to deal with deficient infrastructure. Another US$1–2.6 billion a year would be required for new water storage, wastewater treatment and electricity plants to counter changes in climate.

Floods: Low-lying deltaic cities, Alexandria on the River Nile, and Benin City, Port Harcourt and Aba on the River Niger, are particularly vulnerable to flooding caused by a rise in sea level as a result of changes in climate. Floods also affect many cities and towns across Africa. Floods and mudslides caused by heavy rain in East Africa in 2002 forced tens of thousands of people to leave their homes in Rwanda, Kenya, Burundi, Tanzania and Uganda. Serious floods affected Port Harcourt and Addis Ababa in 2006.

A rise in sea level could disrupt economic activities such as tourism and fisheries in coastal towns and cities. Over a quarter of Africa's population lives within 100 km of the coast. Urban areas account for half the population living in low-lying coastal zones (see Box 21, coastal flooding threats to African cities).

Image:
Panos | Solar training course, Kenya

Box 20: How could transformation look in African countries' industrial sectors?[116]

The scenarios for emissions projected to 2100 assume economic growth as well as growth in the industrial sector. Scenarios to 2050 indicate that Africa will produce more iron, steel and cement. All scenarios indicate that the demand for energy from industry will rise. By 2100, however, projections indicate that the link between demand for energy from industry and CO_2 emissions could be weak because of improvements in energy productivity. The scenarios show that the demand for energy from industry could be highest in Asia, followed by Africa, and that growth in demand could slow in the last decade of the century.

Scenarios for Africa show little variation in demand for energy from industry by 2100. If Africa takes opportunities for mitigation now the same amount of energy could be generated for lower CO_2 emissions.

After 2050, projections indicate that emissions from industry could be very low under certain scenarios. Emissions from energy consumed by industry could decrease up to 2100, especially where there are measures to capture and store carbon, and where there is a shift to low-carbon energy. Mitigating emissions in the industrial sector will require significant investment. However, Africa has opportunities to leapfrog unsustainable growth and go straight to technologies that use less energy and materials, and generate fewer emissions. Opportunities for green growth are greatest where industries are growing.

Box 21: Coastal flooding threats to African cities

Western Africa: There are few economic assessments of the risks posed by climate change to coastal cities in western Africa. Many cities, industries, infrastructure and tourist facilities, for example in Cotonou, Lagos and Dakar, will be hard to protect. Large areas of these and other important economic centres in the Gulf of Guinea, including Abidjan and Port Harcourt, are close to mean sea level, and very vulnerable to erosion and rising sea level. Rapid construction, destruction of mangrove swamps and inadequate refuse management compound the risks posed by climate change.

Eastern Africa: In eastern Africa, an assessment of the impact of coastal flooding on Kenya due to a rise in sea level found that 10,000–86,000 people could be affected by 2030. The economic cost could be between US$7 million and US$58million.[117] Detailed assessments have also been made of the impact of extreme events on some coastal cities, including Mombasa and Dar-es-Salaam. In Mombasa, by 2030, 170,700–266,300 people and assets worth US$0.68–1.06 billion could be at risk In Dar-es-Salaam, by 2030, 30,300–110,000 inhabitants and assets worth US$35.6–404.1 million could be at risk.[118] Both assessments consider three population growth scenarios and four sea-level rise scenarios. The sea-level rise scenarios were also used in a broader assessment of risks to the coast of Kenya. The scale of damage projected for specific cities highlights the risks from extreme events coupled with a rise in sea level. Mombasa may need significant capital investment to redesign and rebuild ports, protect cement plants and oil refineries, and relocate industries inland. However, projects such as the rehabilitation of 220 hectares of old quarries – now the Haller Park attracting more than 150,000 visitors a year – show that adapting to climate change can have positive effects.

Southern Africa: In southern Africa, Durban, Cape Town and the uMhlathuze local municipality have assessed the risks from climate change impacts. The risk assessments covered business, tourism, air quality, health, food security, infrastructure, services, biodiversity and water resources.

Northern Africa: Risks are similar to the risks to eastern and southern Africa. By the end of the 21st century, about 23%, 42% and 49% of the coastal governorates of the Nile Delta would be susceptible to inundation under low, medium and high warming scenarios. Most of these areas are now either wetland or undeveloped.[119] A study assessing the economic impact of a rise in sea level on the Nile Delta suggested that damage to housing and roads would be 1–2 billion Egyptian Pounds (EGP) in 2030 and 2–16 billion EGP in 2060 under medium and high-emissions scenarios and the current trend in the rise of sea level.[120]

Table 9: Low-regrets actions in urban climate adaptation[121]

Reducing vulnerability through development and planning (low-regrets measures)
Human development – safe settlements
Disaster risk management – improve drainage, flood and cyclone shelters, building codes, storm and wastewater management, and transport and road infrastructure
Ecosystem management – maintain and improve urban green spaces
Spatial or land-use planning – provide housing, infrastructure and services, manage development in flood prone and other high-risk areas, upgrade urban areas
Incremental and transformational adaptation
Engineered and built environment – build sea walls and coastal protection structures, flood levees, improve drainage, flood and cyclone shelters, building codes, storm and wastewater management, transport and road infrastructure, and build floating houses
Technologies – building insulation, mechanical and passive cooling, and water-saving technologies
Ecosystems – green infrastructure including shade trees and green roofs
Services – municipal services including water and sanitation
Laws and regulations – building standards, define property rights and land tenure security
Government policies and programmes – urban upgrading programmes, municipal water management programmes, and disaster planning and preparedness
Social – prepare households, evacuation and migration plans

African cities have the potential to embrace more systematic adaptation approaches

Since 2007, African countries have conceptualised, planned and begun to implement and support adaptation activities at local to national level and across a growing range of sectors. However, across the continent, most adaptation to climate variability and change is reactive, short term, at the individual or household level, and is not supported by government stakeholders and policies.

Rapidly urbanising countries in Africa have the most opportunities for climate mitigation

Rapidly urbanising countries have the most opportunities for mitigation:

Macro scale: Regional strategies and plans could help minimise the effects of urbanisation on the environment and maximise the effectiveness of large infrastructure projects. Urban containment and live-work developments could encourage cities to grow inwards and upwards.

Meso scale: Development of 'districts' or 'corridors'.

Micro scale: Urban regeneration, making cities compact and cycle and pedestrian friendly, 'transit-oriented development' where neighbourhoods are hubs of city-wide public transport systems, and pedestrian and car-restricted zones. In rapidly developing cities, there are opportunities to integrate planning for urbanisation and infrastructure. In established cities, there are opportunities for retrofit.

Opportunities for urban mitigation vary according to urban development trajectories. Policies are more effective when bundled together. Policy options include:

Land-use regulations and redesigning urban areas: Regulations for land use and other aspects of urban development could promote either low or high-density development. Restrictions could spell out what land can or cannot be used for, for example residential, commercial or industrial use. Policies could co-locate residential and employment areas. Regulations on density could stipulate the minimum or maximum density for residential units, and the size and height of buildings. Building codes could specify the energy efficiency of buildings and parking regulations could help limit vehicular use.

Land management and acquisition: Land management and acquisition policies could shape development by landowners and direct new developments to areas where development would be desirable. Policies that expand green spaces and urban carbon sinks could help sequester urban carbon emissions.

Market instruments: Taxes such as property taxes could promote compact urban areas by taxing large plots of lands. Development taxes could help control urban growth by internalising externalities associated with urban land development. Pricing policies for fuel and transport could make using personal vehicles less attractive and encourage use of public transport.

Box 22: Urban-rural interaction

Rural and urban areas have always been closely connected but, in recent decades, new relationships have emerged. The boundaries between rural and urban areas are now less defined than previously and new types of land use and economic activity are appearing. These changes are important for understanding the impacts of climate change, vulnerabilities and opportunities for adaptation.

Climate extremes in rural areas can have an impact on urban areas: Migration and movement of resources between rural and urban areas mean that climate extremes that affect water supplies, agriculture and the habitability of rural areas have ripple effects on cities. For example, water shortages in Bulawayo, Zimbabwe, in the last few decades are attributed to droughts in rural areas.

Rural-urban interface: Changes in agricultural potential, economic marginalisation and human health can be overlooked because they are neither in the rural nor in the urban domain. For example, in Tanzania and Malawi, agricultural extension services do not reach peri-urban farmers. However, developing peri-urban areas could build resilience to climate shocks. For example, good transport connections could provide access to jobs and improve access to education, thus reducing risks associated with disasters.

Integrated infrastructure and services: Interdependent rural and urban systems can put rural areas at risk. Urban demands often take preference in the allocation of resources. Rural areas can suffer resource shortages or other disruptions in order to sustain cities.

Box 23: Climate-change adaptation in Cape Town[122]

Cape Town's climate change framework (2009) aims to reduce emergencies and prepare for climate change, by regulating informal housing for example. Community partnerships such as the partnership between the Cape Flats Nature Project and the parastatal South African National Biodiversity Institute work to conserve biodiversity. Schools and organisations taking part in the project explore flood risk management and restoring wetlands.

Cape Town has also taken action to safeguard future water supplies. Studies of water management commissioned by the city identified the need to plan for climate change, and population and economic growth. During the 2005 drought, local authorities raised water tariffs to encourage efficient use of water. Other measures that may be taken include water restrictions, re-using grey water, educating consumers and introducing technologies such as low-flow or dual-flush toilets.

Box 24: Green infrastructure in Durban[123]

Durban recognises that services provided by biodiversity and ecosystems can reduce vulnerability to changes in climate and has made these services part of its climate change adaptation strategy. In the Community Restoration Programme, communities raise seedlings of native trees for restoring forests. The approach taken by Durban shows the value of tapping into local knowledge to enhance existing protected areas and land-use practices. These kinds of local initiatives can also provide job and business opportunities, and develop skills.

Table 10: Urbanisation mitigation policies co-benefits and risks[124]

Policy	Benefits	Risks
Economic	• Innovation and efficient resource use in cities • Commuters save time and money • Higher rents	• Higher rents
Social	• Better health from more physical activity • More social interaction and better mental health	
Environmental	• Preservation of urban open spaces • Better air quality and lower ecosystem impact	

Where authorities are successful in channelling funds into urban climate mitigation activities, these can yield significant co-benefits, including saving public funds, preventing pollution, and improving health and productivity:

Urban air quality: Urban planning that promotes for example cleaner fuels, public transport and energy efficiency can help improve air quality. Such planning could be particularly beneficial in Africa as there are various urban zones where air pollution is significant.

Energy security: Urban mitigation measures that shift transport away from fossil fuel could help decrease reliance on imported fuels and improve energy security.

Health benefits: Cities that provide infrastructure to encourage walking and cycling could improve the health of their populations. Reducing urban traffic could also improve cardiovascular health and reduce sleep disturbances.

Africa is exposed to many stresses that coupled with climate change mean that adaptation needs to consider institutions, social issues, infrastructure, ecosystems, the environment, investment and capacity. Overall, the benefits of mitigation in urban areas seem to be greater than the risks. The effectiveness of mitigation measures in urban areas, however, depends on strategies in other sectors, particularly transport and energy.

Barriers to urban climate change mitigation are mainly in governance and financing

Political will influences the extent to which opportunities to mitigate emissions can be taken and appropriate policies enacted. The capacity of national and government institutions responsible for urban development determines the extent to which urban mitigation policies can be implemented. Weak local government creates and exacerbates problems such as: lack of appropriate regulations and mandates; poor or no planning; lack of or poor data; lack of disaster risk reduction strategies; poor services and infrastructure (particularly waste management and drainage); uncontrolled settlement in high-risk areas such as floodplains, wetlands and coastal zones; ecosystem degradation; competing development priorities and timelines; and lack of coordination among government agencies.

Financing for urban infrastructure originates from many sources leading to difficulties in earmarking financing for mitigation. Cities in developing countries that have secured financing for mitigation have tended to tap international climate change finance. Local taxes could help raise funds for mitigation, but taxes on urban development may push new developments to rural areas where there are no taxes.

Image: Panos | Masai women on solar training course, Kenya

9 The way forward

Since the IPCC's formation in 1992, its work has given us a better understanding of climate science, provided us a better picture of the range of vulnerabilities in different parts of the world, and reviewed the range of potential policy options and their implementation in a range of country contexts. The Fifth Assessment Report *provides the strongest warning yet that the scientific evidence of climate change is firmer than ever. The report also indicates that waiting or doing nothing is no longer an option, and makes a compelling case that the world needs to act now on climate change.*

African governments can promote ambitious global action

Ambitious climate mitigation at the global level must start now in order to limit the magnitude of long-term climate change and reduce the risks. Delaying action on mitigation will not only mean that adaptation costs will rise, but will substantially increase the difficulty of transitioning, globally, towards a low-emissions development pathway as countries invest in low-cost but potentially carbon-intensive infrastructure.[125] Between 15% and 40% of emitted carbon dioxide will remain in the atmosphere for more than 1,000 years. This creates a major intergenerational challenge in terms of rights and responsibilities to act on climate change. The *Fifth Assessment Report* provides a global carbon budget: it says that for the world to limit average global warming to less than 2°C, total emissions from human activity should not exceed 800–1,000 gigatonnes of carbon dioxide equivalent. To date, human activity has released 500 gigatonnes.[126]

The world's governments have pledged to limit warming to 2°C above pre-industrial levels. Above the 2°C warming threshold, climate change impacts become severe and unmanageable. Deep cuts in greenhouse gas emissions would limit warming to 2°C relative to pre-industrial levels and avoid dangerous climate change. The IPCC states that under this ambitious scenario, emissions would peak in Africa by 2030 then decline.[127] The need for deep cuts in emissions to limit warming to the 2°C threshold is a central theme of the section of the *Fifth Assessment Report* on climate mitigation. Warming of 2°C alone would pose a significant threat to economic growth and human development in Africa (see page X). The African Common Position on Climate Change promotes a 1.5°C warming threshold as more appropriate for Africa.

In 2010, governmental Parties to the United Nations Framework Convention on Climate Change (UNFCCC) meeting in Cancun[128] pledged to reduce emissions to achieve the long-term goal of limiting global warming to 2°C above pre-industrial temperatures. The *Fifth Assessment Report* finds that the actual governmental pledges made at and since Cancun fall short of what is needed to achieve the long-term goal.

Here lies an uncomfortable paradox. Africa's historic contribution to the build-up of greenhouse gas emissions has been relatively small but the cost of climate change it will face to human wellbeing and ecosystems in the region is, and will continue to be, large. Over large parts of Africa, warming could exceed 2°C by 2050 and rise by as much as 2.6–4.8°C by the end of the century (under the medium and high-emissions scenarios).[129]

To be cost-effective on a global scale, most mitigation needs to take place in countries projected to have the highest emissions in the future. But it is important to recognise that, although deep cuts in greenhouse gas emissions are technically possible, making such cuts will entail substantial technological, economic, institutional and behavioural changes.

The IPCC also finds that mitigation efforts and the costs of mitigation vary between countries; developing countries have a significant proportion of the opportunities for low-cost mitigation.[130] As such, African countries can play a role in global climate stabilisation efforts by taking advantage of low-carbon options where it is advantageous to do so, thereby avoiding future emissions. For example, there are opportunities to reduce deforestation by adopting sustainable practices, plan innovative low-carbon towns and cities, and develop land-use schemes that intensify agricultural practices and sustainably manage livestock. Such actions can bring large co-benefits beyond reducing the impacts of climate change. Nevertheless, it is also important to recognise that Africa will need substantial financial support for mitigation and that it will have to be a shared effort.

The *Fifth Assessment Report* explicitly states that, because the atmosphere is a global commons, we will not achieve effective mitigation if individual countries advance their interests independently. International cooperation is essential to limit greenhouse gas emissions effectively and to address other climate change issues such as building resilience and capacity in regions such as Africa.[131]

A robust case for adaptation action now

Throughout the 21st century, climate-change impacts are projected to slow down economic growth and make poverty reduction more difficult. Africa as a whole is one of the most vulnerable continents to the impacts of climate change due to its high exposure and low adaptive capacity. The IPCC's assessment of significant impacts in a 2°C world at the end of the 21st century shows that, even under high levels of adaptation, there could be very high levels of risk for Africa. To manage these risks, climate adaptation and mitigation actions must be taken without delay.

Adaptation is place and context specific, with no single approach for reducing risks appropriate across all settings (*high confidence*). Effective risk reduction and adaptation strategies consider the dynamics of vulnerability and exposure and their linkages with processes, sustainable development and climate change.

Adaptation planning and implementation can be enhanced through complementary actions across levels of government. National governments can coordinate adaptation efforts of local and subnational governments, for example by protecting vulnerable groups, by supporting economic diversification, and by providing information, policy and legal frameworks, and financial support. Local government and the private sector are increasingly recognised as critical to progress in adaptation, given their roles in scaling up adaptation of communities, households and civil society, and in managing risk information and financing.

Exploiting the opportunities of mitigation action for Africa, and managing the trade-offs

The IPCC's Working Group III (Mitigation) Co-Chairs have categorised the array of mitigation options as a map; across which each country's policy-makers, and the collective global community, must use the political process to navigate. When the report says that investment in zero or low-carbon energy will have to treble or quadruple globally to meet the global mitigation requirement, it also says that countries will have to choose which particular zero and low-carbon technologies are most appropriate for them.

African policy-makers must address widespread, suppressed demand for energy services to meet their societies' development needs. The *Fifth Assessment Report* provides an evidence base on zero and low-carbon solutions, some of which are proven in the African context, others of which are proven elsewhere and are yet to be tested at scale in Africa. The *Fifth Assessment Report* also emphasises the need for sequestration of carbon at a global scale to redress the 'mitigation gap' that global society has created through its unsustainable emissions to date.

The IPCC's call for a much wider embrace of land- based mitigation solutions such as reforestation and reducing emissions from deforestation and forest degradation (REDD) provides an opportunity for African countries – where such activities are tied to increased sources of funding and can deliver multiple co-benefits for human development. The calls upon scarce land resources to contribute to climate mitigation solutions also illustrate the tensions between mitigation and development approaches. It will take strong institutions and governance for African countries to identify the trade-offs, opportunities and risks of mitigation activities such as these and steer a course that is environmentally sound – and fair.

Paying for climate action

Developed countries have committed to a goal of jointly mobilising US$100 billion per year from various sources by 2020 for adaptation and mitigation in developing countries.

As yet, there is no agreement on how these funds should be allocated between mitigation and adaptation, nor between developing countries and regions. What is clear is that Africa needs the resources to build viable adaptation frameworks and capabilities, and to develop critical infrastructures for development. Provision of climate finance through the Global Climate Fund or other schemes is one way of mobilising resources to support adaptation and mitigation action in Africa.

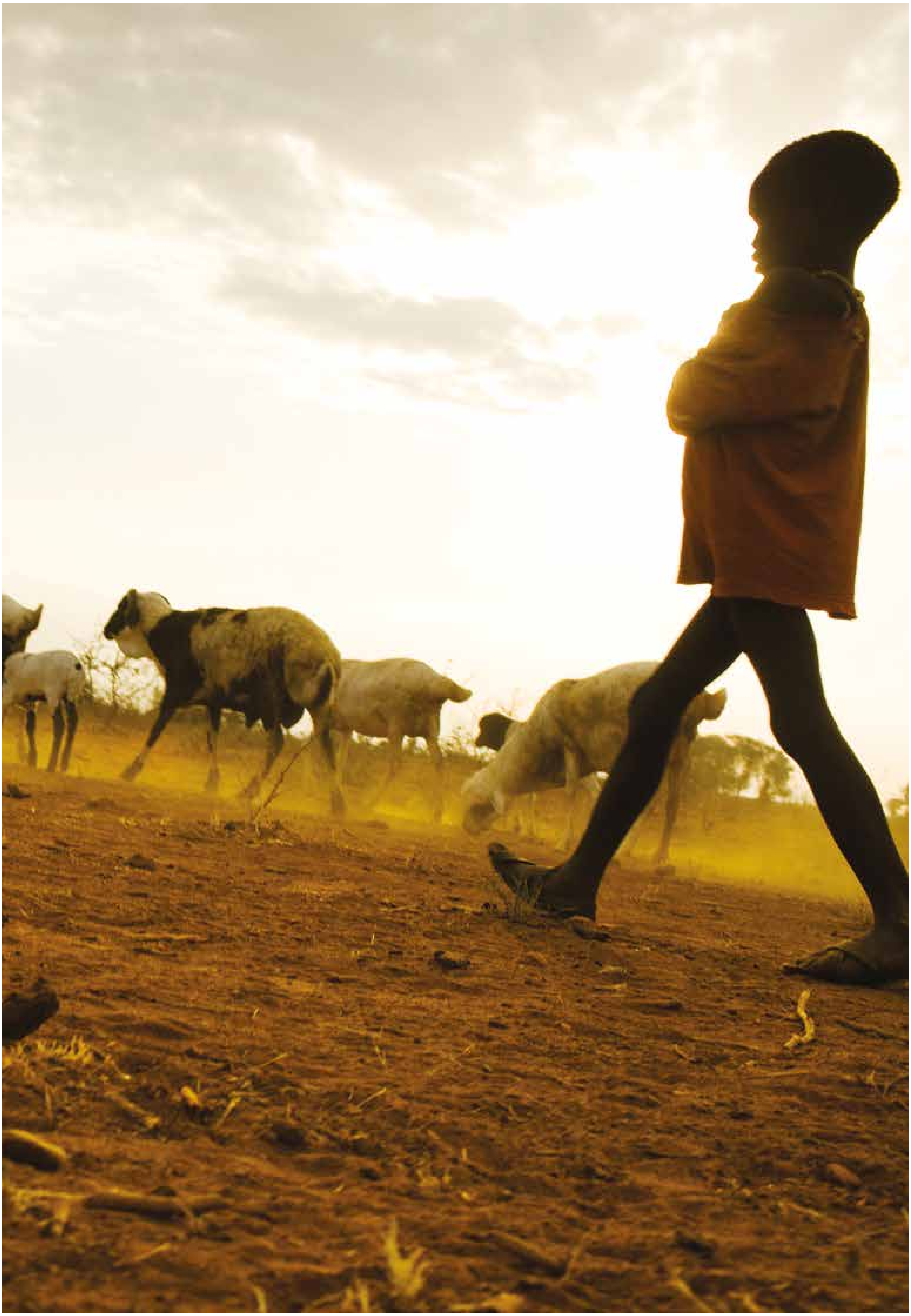
What's next for African voters and leaders

The *Fifth Assessment Report* is clear that the global community must commit to far higher ambition in cutting greenhouse gas emissions. However, the 'policy relevant but not policy prescriptive' IPCC does not offer guidance on the relative burden that different countries should bear with regard to their mitigation commitments. This is the realm of ethics and value judgments, with which politicians and voters must engage.

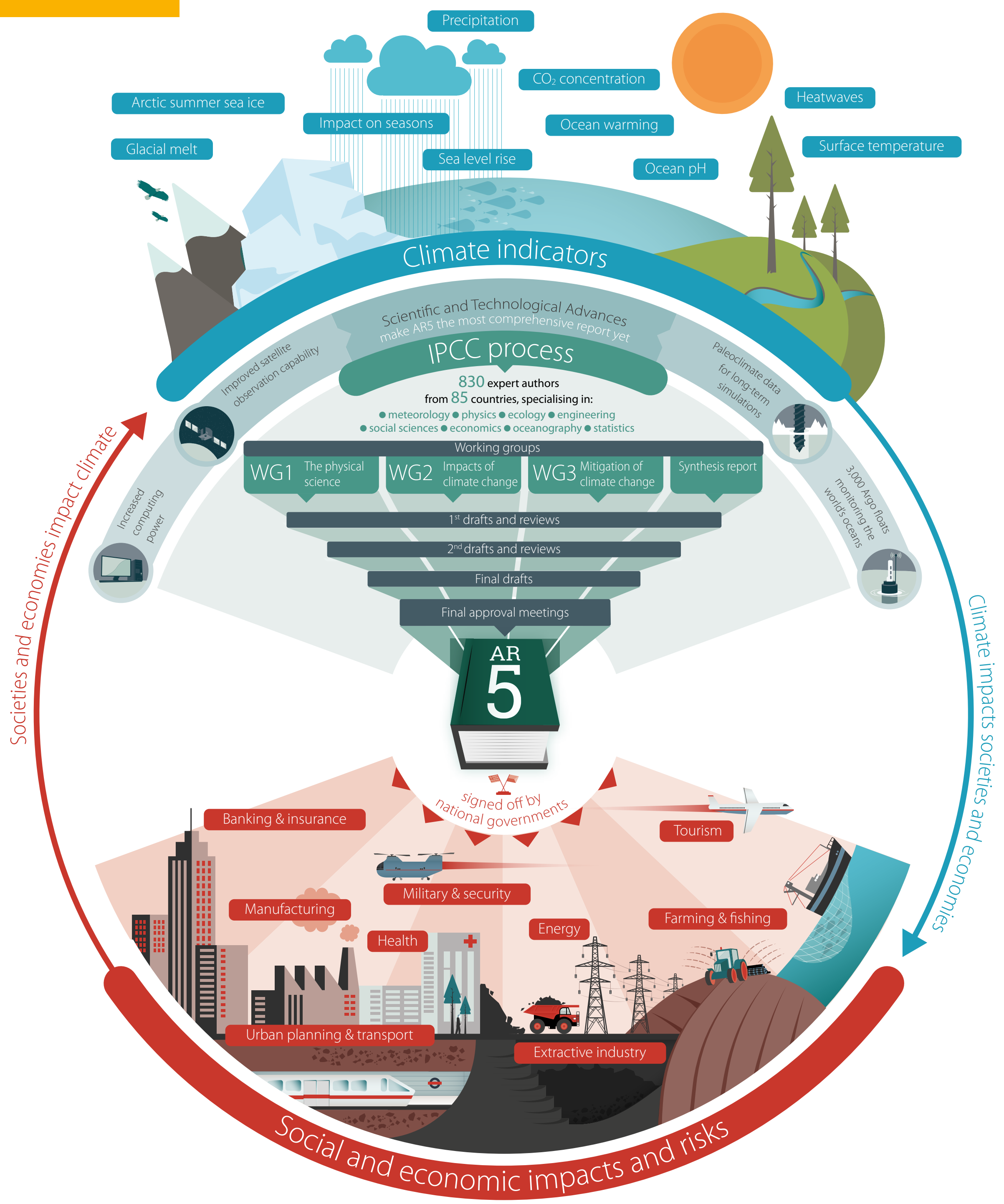
The IPCC's key messages provide crystal clear implications for the global climate negotiations process. The IPCC states categorically that the Cancun pledges for emissions reduction by 2020 are insufficient,[132] but could be the basis for something more ambitious. This is what the international process must deliver.

African leaders have an important part to play – with all other international leaders – in forging this commitment to ambitious, collective action. An important part of reaching a global agreement is ensuring that the cooperative spirit is in place, effort-sharing is recognised and financial resources are made available to invest in adaptation programmes and low-emissions infrastructure.

Image:
Panos | Goat herder, Nakapelimen, Uganda



How the IPCC works



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Glossary

Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Greenhouse gas: Greenhouse gases are those gaseous constituents of the atmosphere, both natural and caused by human activity. Greenhouse gases trap energy from the sun in the atmosphere causing it to warm. Water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere; while hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) are also of concern. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as halocarbons and other chlorine- and bromine-containing substances.

Maladaptive actions (or maladaptation): Actions that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future.

Mitigation (of climate change): A human intervention to reduce the sources of greenhouse gases or enhance the sinks (those processes, activities, or mechanisms that remove a greenhouse gas from the atmosphere).

Representative concentration pathways (RCPs): Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use and land cover. The word 'representative' signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics (i.e., greenhouse gas-related warming). The term 'pathway' emphasises that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome.

Resilience: The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganising in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

Scenario: A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g. rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are useful to provide a view of the implications of developments and actions.

Social protection: In the context of development aid and climate policy, social protection usually describes public and private initiatives that provide income or consumption transfers to the poor, protect the vulnerable against livelihood risks, and enhance the social status and rights of the marginalised, with the overall objective of reducing the economic and social vulnerability of poor, vulnerable, and marginalised groups.

Transformation: A change in the fundamental attributes of a system, often based on altered paradigms, goals, or values. Transformations can occur in technological or biological systems, financial structures, and regulatory, legislative, or administrative regimes.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Source: IPCC Working Group II, Fifth Assessment Report (http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Glossary_FGD.pdf). The definition for 'greenhouse gas', above, has been shortened from the IPCC's much longer version. Readers are encouraged to reference the IPCC's original source document for a full technical definition of 'radiative forcing' and other scientific terms.

Endnotes

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34 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summary for Policymakers* (Figure TS.1, p.60).
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37 During the decade 2000–2010, emissions have been higher "than any previous decade since 1750" and "between 2000–2010, greenhouse gas emissions grew on average 2.2% per year compared to 1.3% per year over the entire period 1970–2000." IPCC (2014) *Climate Change 2014: Mitigation of Climate Change. Technical Summary* (pp.9–10).
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