The IPCC's Fifth Assessment Report

What's in it for South Asia?

CDKN

Climate & Development Knowledge Network

Image: Panos I Wind farm, Tamil Nadu, India

Cover image:
Panos I Woman at well during extreme flooding, Satkhira district, Bangladesh

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

1. South Asia'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 South Asia
4. Adaptation will bring immediate benefits and reduce the impacts of climate change in South Asia
5. Adaptation is fundamentally about risk management
6. South Asia has many adaptation options
7. Some low-carbon development options may be less costly in the long run and could offer new economic opportunities for South Asia
8. South Asia stands to benefit from integrated climate adaptation, mitigation and development approaches
9. International cooperation is vital to avert dangerous climate change and South Asian governments can promote ambitious global action

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Key messages from the *Fifth Assessment Report* for South Asia

The IPCC's Fifth Assessment Report *offers the following key messages for the Asia region as a whole – with some findings which are specific to the South Asian countries of Afghanistan, Bangladesh, Bhutan, India, Maldives. Nepal, Pakistan and Sri Lanka:*[1]

South Asia'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.[2] Since the 1950s, the rate of global warming has been unprecedented compared to previous decades and millennia.[3]

Since the mid-19th century, the average increase in the temperature of the Earth's surface has been 0.85 degrees Centigrade (°C).[4] Globally, sea levels have risen faster than at any time during the previous two millennia – and the effects are felt in South Asia.[5] Changing patterns of rainfall or melting snow and ice are altering freshwater systems, affecting the quantity and quality of water available in many regions, including South Asia.[6] Warming has occurred, at a country scale, across most of South Asia over the 20th century and into the 2000s. South Asia suffered more temperature extremes (*high confidence*).[7] Even today, climatic risks threaten lives, food security, health and wellbeing across many parts of South Asia. There are clear signs that the impacts of climate change are already being felt.[8]

The IPCC finds with 95% scientific certainty that increasing concentrations of greenhouse gases in the atmosphere due to human activities have been the dominant cause of the observed warming since the mid-20th century.[9]

"Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850."
IPCC[10]

Further climate change is inevitable in the coming decades

Regardless of future emissions, we are already committed to further warming, largely due to past emissions and inertia in the climate system. These changes in climate will create new risks and will amplify existing risks for natural and human systems.[11] Meanwhile, 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[12]).

Total emissions since 1970 have continued to rise and, emissions between 2000 and 2010 have been the highest yet.[13]

Under a low-emissions scenario, average temperatures could rise average temperatures could rise by less than 2°C by 2100.[4] However, for a high-emissions scenario, the average temperature increase over most of South Asia's land area could be more than 2°C by the mid-21st century and could exceed 3°C. Under all scenarios, high latitudes will experience far greater average temperature increases.[15] The frequency of hot days in South Asia is likely to increase further in the future (*high confidence).*

Global mean sea level will continue to rise during the 21st century; under all emissions scenarios – low and high – the rate of sea level rise will very likely exceed that observed during the past three decades[16] and this will have consequences for South Asia's coastal settlements, as well as for coastal economies, cultures and ecosystems.[17] Low lying, densely populated coastal areas in South Asia, including in India and Bangladesh, will be at increased risk of storm surges.

Sea levels could rise from 26 cm–98 cm by the end of the 21st century, depending on global emissions levels.[18]

Climate change poses challenges to growth and development in South Asia

South Asia, reflecting Asia as a whole, is a rapidly urbanising region. Districts with poor infrastructure and rapid population growth are also the areas of maximum climate vulnerability. Extreme events are expected to be more catastrophic in nature for the people living in such districts.

Although rapidly urbanising, South Asia is still predominantly an agrarian society, where a majority of the population is dependent on agriculture for their livelihoods.[19] Climate-sensitive sectors such as agriculture and fisheries are affected by rising temperatures, rising sea levels, and changing rainfall patterns.

The *Fifth Assessment Report* identifies a set of key climate-related risks for Asia including South Asia.[20] These are: flood damage to infrastructure, livelihoods and settlements; food and water shortages; and heat-related mortality.[21]

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

To manage the inevitable impacts of climate change that cannot be reduced through mitigation, South Asia 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, South Asian 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.[22]

Adaptation is fundamentally about risk management

In South Asia, governments, businesses and communities will have to take 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. Much can be done to anticipate and reduce risk, rather than reacting after impacts have occurred. 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.

South Asia has many adaptation options

South Asian countries are already accumulating practical experience in adapting to climate change at the regional, national and local levels. Best practices from South Asia show the potential for effective climate adaptation approaches that can be enhanced and scaled up in the future, for example, the cultivation of different crops in different locations in the region. Policies for adapting to climate change could build on the local and indigenous coping strategies of farmers who have been adapting to climatic risks for generations. Breeding crop varieties suited to high temperatures could also be a promising option for adapting to climate change in South Asia.[23]

Donor agencies and international financial institutions have made significant progress in taking climate-change adaptation into account in loan and grant making processes.[24] Community-based approaches help identify adaptation strategies that address poverty and livelihoods issues.[25] Regional cooperation could be important in overcoming resource scarcities and conflicts related to climate change.[26]

Image: iStock | Paddy rice

South Asian 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.

Records indicate that there were more warm days and fewer cold days since 1950 and the frequency of heat waves has increased in South Asia.

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

In expanding economically and meeting their development needs, South Asian 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'.[27]

The *Fifth Assessment Report* identifies many opportunities and co-benefits of low-carbon policies.[28] Many of the measures to avoid greenhouse gas emissions provide generous gains in economic productivity, human development and quality of life. For example, the development of low-carbon mass transit systems can boost economic productivity, by reducing traffic congestion, and can improve air quality, thus benefiting public health.[29] This is a major opportunity.

The IPCC states, "…in rapidly growing and urbanising regions, mitigation strategies based on spatial planning and efficient infrastructure supply can avoid lock-in of high emission patterns".[30] Because South Asia is urbanising rapidly, urban adaptation provides opportunities for incremental and transformational adjustments towards resilient and sustainable systems. Reducing energy and water consumption through greening cities and recycling water, and developing resilient infrastructure systems can reduce the vulnerability of urban settlements in many parts of South Asia.[31]

Improvements in the performance and cost of renewable energy technologies are significant for South Asia: a growing number of renewable energy technologies have matured enough to enable deployment at significant scale.[32] Scaling up renewable energy systems in South Asia would help expand access to energy for those in energy poverty.[33]

Renewable energy technologies have demonstrated substantial performance improvements and cost reductions.[34]

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. The IPCC states clearly that it is relatively less expensive to adopt low-carbon choices now rather than react later when extensive lock-in to high-carbon infrastructure 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.[35] By embracing such opportunities, South Asian governments have the potential to play a proactive and leading role in promoting an ambitious global dialogue on climate change.

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

The IPCC finds many complementarities among climate adaptation, mitigation and development. Many sustainable development pathways combine adaptation, mitigation and development approaches. For example, decentralised renewable forms of power generation such as solar photovoltaic systems can prove more resilient to climate extremes like droughts and very high temperatures. Such climate extremes can have a negative effect on the performance of conventional power sources like large hydropower dams or large power stations reliant on water for cooling.

Climate mitigation measures can deliver benefits for public health and also for climate resilience. For example, sustainable cities with fewer fossil-fuel driven vehicles will have less overall damaging pollution (including soot particles which damage human health). Introducing cleaner household cooking methods will reduce greenhouse gas emissions but also to improve indoor air quality and respiratory and cardiac health among, in particular, women and children.[36] More green areas in cities can help sequester carbon while also reducing urban heat island effects. In rural areas, mangroves and peat swamp forest have soils with very high carbon storage potential: restoration of these ecosystems can build resilience to flood and storm damage along rivers and coasts, as well as lock up carbon.[37]

The IPCC also highlights some of the risks of poorly-planned climate mitigation activity. 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, unless carefully planned. The IPCC provides recommends robust decision-making processes to avert and manage the possible risks of mitigation activity.

Climate mitigation activities, managed carefully so that they do not introduce new risks to development, can provide multiple benefits.[38]

International cooperation is vital to avert dangerous climate change

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[39] 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 on climate adaptation and mitigation. For this reason, the IPCC's findings on sources of global greenhouse gas emissions and their impacts on climate provide South Asian governments with an important resource of knowledge and information 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. South Asian 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* (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* (How the IPCC works, page 80). These groups are: Working Group I (physical science of climate change), Working Group II (impacts, vulnerability and adaptation) and Working Group III (climate change mitigation). The fourth 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 South Asia by the Climate and Development Knowledge Network (CDKN) and Overseas Development Institute (ODI). The IPCC Summaries for Policymakers focus principally on global issues and trends. This report distils the richest material on sources of greenhouse gas emissions and experiences in adaptation and mitigation from the thousands of pages of the *Fifth Assessment Report* for South Asia – pulling out the South Asian-specific data and examples wherever possible. (Often, the IPCC presents data only for the larger Asia region, stretching from the Asia Pacific islands in the east to Afghanistan in the west, and including China, Japan and southeast Asia; in the text, we have distinguished between the larger Asia region and the smaller South Asia region of Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka where appropriate.) In so doing, we hope to make the IPCC's important material more accessible and usable to South Asian audiences. This report responds to wide demand among CDKN's Asian partner networks, for region-specific information.

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).

This report provides an overview of the changes in the climate already affecting South Asia – and the projected climate trends and risks for South Asia in the 21st century (Chapters 1–2). We provide highlights of South Asia's key opportunities and challenges for climate adaptation and mitigation, and summarise the IPCC's findings around some of the synergies and indeed, the trade-offs, among adaptation, mitigation and development goals (Chapters 3–7). We provide a summary for South Asian policy-makers of climate-smart policy options discussed by the IPCC for key economic sectors and policy-making areas such as: agriculture, forestry and fisheries; water and sanitation; energy; transport; industry; and urban areas (Chapter 8). The final chapter provides an overall summary of the IPCC's guidance on key issues that South Asian and other governments can pick up in multilateral and bilateral political negotiations – true to the IPCC's mission to avoid being policy prescriptive, but to stay policy relevant.

Image: Neil Palmer, CIAT | Traffic in Sangrur, India

"International cooperation is required to effectively mitigate greenhouse gas emissions and address other climate change issues … outcomes seen as equitable can lead to more effective cooperation." IPCC[40]

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

Climate change is already occurring, with negative impacts on South Asia. Warming occurred across most of the South Asian region over the 20th century and into the 2000s, and there were more temperature extremes. Rainfall trends have been highly variable. Already climate impacts such as flooding are causing loss of life and damaging people's health across the sub-region.

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 gases 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.

1.2. South Asia's climate is already changing

Observed temperature trends: The IPCC has reported that warming occurred across most of the South Asian region over the 20th century and into the 2000s, and that there were more temperature extremes (*high confidence*). Records indicate that there were more warm days and fewer cold days (Figure 1).[41]

Box 1: How the IPCC's *Fifth Assessment Report* defines scientific certainty[42]

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.

Observed rainfall trends: Most areas of the Asian region lack sufficient observational records to draw conclusions about trends in annual rainfall over the past century. Rainfall trends, including extremes, are characterised by strong variability, with both increasing and decreasing trends observed in different parts of Asia (Figure 2). Observations also show that there have been more extreme rainfall events and fewer weak rainfall events in the central Indian region.

Observed extreme events: The frequency of hot days in South Asia has increased (*medium confidence*). Observations also show that there have been more extreme rainfall events in India and in many other areas.

Observed sea level rise: Globally, the rate of sea level rise since the 1850s has been larger than the average rate during the previous 2,000 years (*high confidence*). Sea level rise can vary between regions, though. Shifting surface winds, the expansion of warming ocean water, and the addition of melting ice can alter ocean currents which, in turn, lead to changes in sea level that vary from place to place. Past and present variations in the distribution of land ice affect the shape and gravitational field of the Earth, which also cause regional fluctuations in sea level. Additional variations are caused by sediment and tectonics. Changes of sea level in the Indian Ocean have emerged since the 1960s, driven by changing wind patterns.

1.3. The impacts of climate change are already being felt

Even today, climatic risks threaten lives, food security, health and wellbeing across many parts of South Asia. There are clear signs that the impacts of climate change are already being felt.[45]

The Asia region as a whole experienced the most weather- and climate-related disasters in the world between 2000 and 2008 and suffered the second highest proportion (27.5%) of total global economic losses.[46]

The risk of deaths due to flooding is highly concentrated in Asia. At the same time as sea levels are rising, most Asian deltas are sinking as a result of groundwater extraction, floodplain engineering and trapping of sediments by dams.[47] Severe floods in Mumbai in 2005 have been attributed to both climatic and non-climatic factors, suggesting an interaction between climate change and other stressors.[48]

Extreme rainfall and flooding is causing illnesses, deaths, and mass displacement. In 2008, the embankments of the Kosi River, a tributary of the Ganges, broke, displacing over 60,000 people in Nepal and 3.5 million in India, and disrupting transport and power across large areas.[49]

Climate change is impacting on human health in several ways. Contaminated urban flood waters have caused exposure to disease and toxic compounds, for example,

Figure 1: Change in annual average temperature in South Asia, 1901–2012[43]

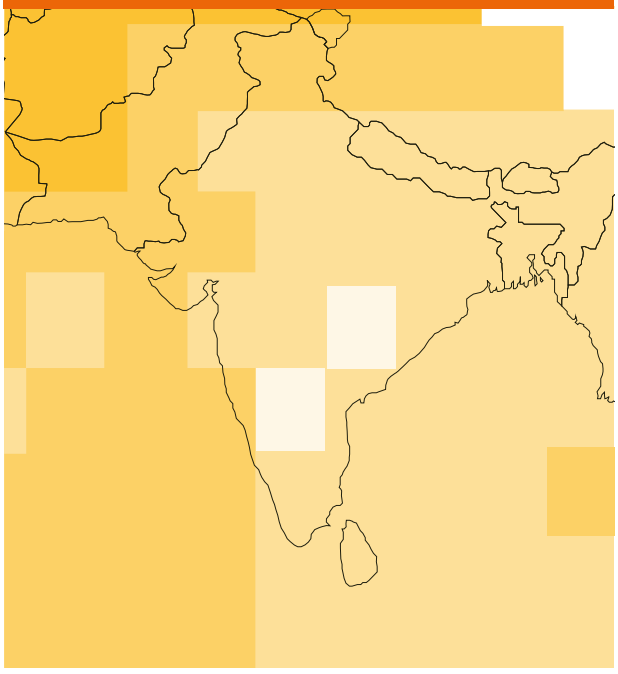
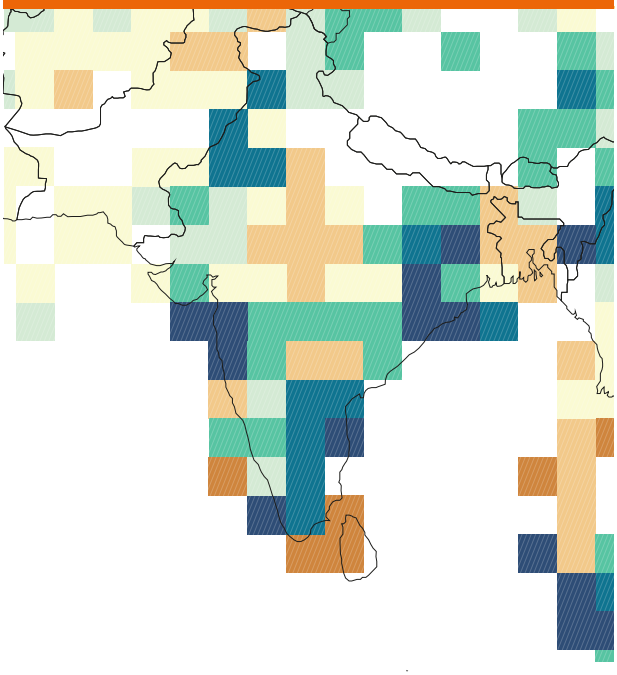


Figure 2: Change in annual average rainfall in South Asia, 1951–2012[44]



in India and Pakistan.[50] The incidence of many diseases increases at higher temperatures: the pathogens and parasites that cause disease multiply faster. Dengue and Japanese encephalitis outbreaks in South Asia have been associated with temperature and rainfall. Malaria prevalence in India and Nepal has been linked to rainfall patterns.[51]

Studies from South Asia have shown an association between diarrheal outbreaks and a combination of higher temperatures and heavy rainfall. Cholera outbreaks in coastal populations in South Asia have been associated with increased temperatures and algal blooms. Climate phenomena, such as the El Niño, have been associated with cholera epidemics in Bangladesh.[52] Also in Bangladesh, people have suffered from heat stress, a condition that often affects urban populations in low and middle income countries. In urban areas where child mortality is high, extreme temperatures have led to more deaths.[53] Mental disorders and post-traumatic stress syndrome have also been observed in disaster prone areas and in India, have been linked to age and gender.[54]

Climate change negatively impacts livelihoods and these impacts are directly related to natural resources affected by changes in weather and climate.[55] The impacts of recent climate trends and extreme weather events also demonstrate the vulnerability of some South Asian ecosystems.

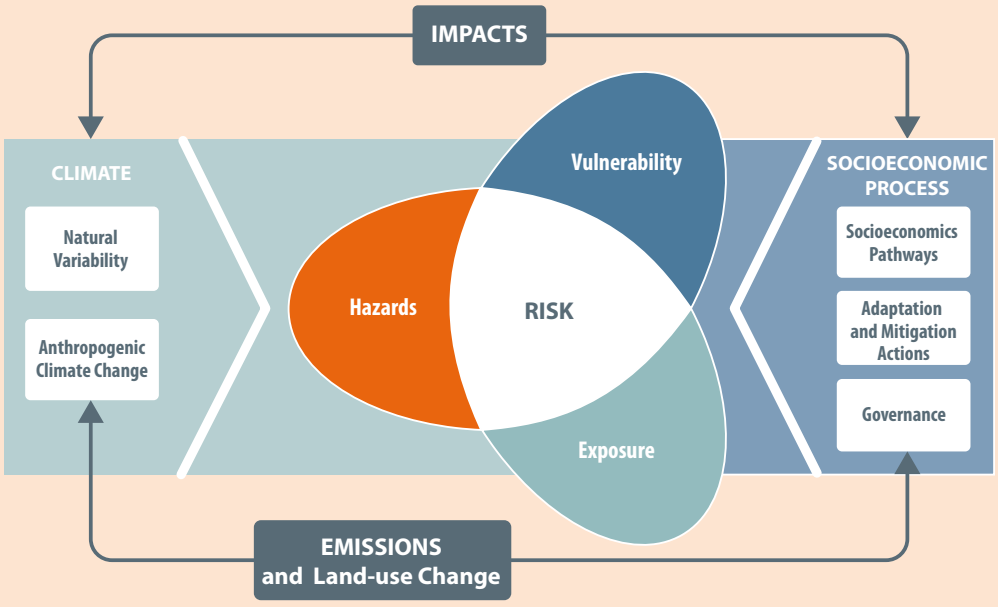
The geographic range, seasonal activities and migration patterns of many terrestrial, freshwater and marine species have shifted in response to ongoing climate change. The abundance of species has changed, as have interactions among species. The pace of change has been rapid. Permafrost degradation has been reported for parts of the Tibetan Plateau and earlier greening has been observed in the boreal forests of the Hindu-Kush-Himalayan region,[56] which could increase vulnerability to wildfires.[57] Coral reefs are bleaching with higher sea temperatures.[58]

Box 2: Climate change poses risks to human and natural systems[59]

Risks related to climate change arise from climate-related hazards (climate trends and extremes) and the vulnerability of exposed societies, communities or systems (in terms of livelihoods, infrastructure, ecosystem services and governance systems). 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 and poor rural economies.[60]



2 Further climate change is inevitable in the coming decades

South Asian 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 South Asia, 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.[61] 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[62]). 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, livelihood 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.[63] Regardless of future emissions, we are already

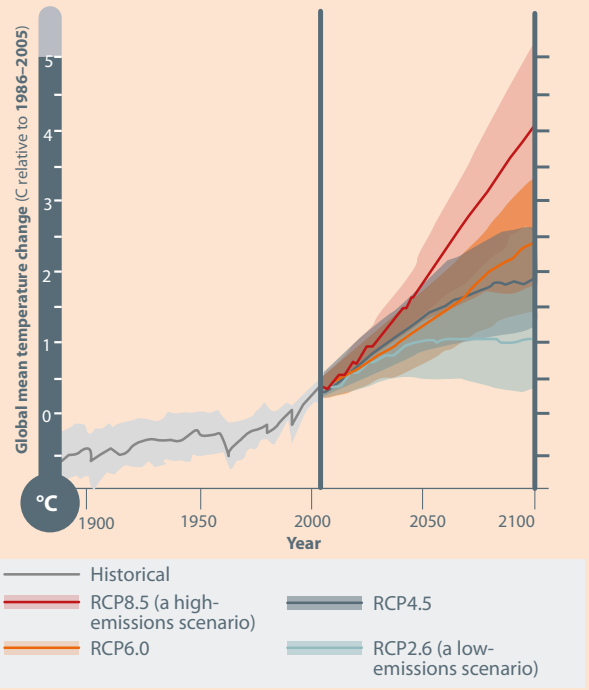
Box 3: What are the IPCC scenarios?

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 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 (RCP2.6) assumes substantial and sustained reductions in greenhouse gas emissions. The high-emissions scenario (RCP8.5) assumes continued high rates of emissions. The two intermediate scenarios (RCPs 4.5 and 6.0) 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, overleaf). 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. 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. Warming will continue beyond 2100 under all emissions scenarios except the lowest and will continue to vary between years and between decades.[65]

Observed warming and warming under IPCC scenarios



committed to further warming largely due to past emissions and inertia in the climate system.[64] Whether global society continues to emit greenhouse gases at today's rate, or cuts greenhouse gas emissions sharply now, does not make a big difference in terms of climate impacts in the next few decades.

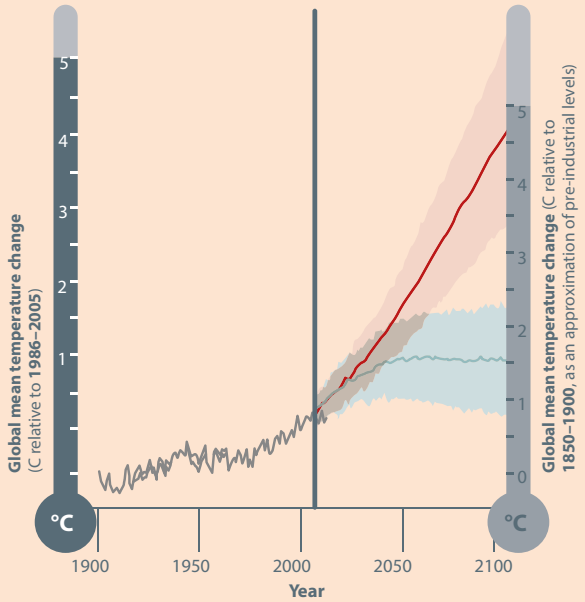
Curbing emissions to maintain global temperatures below 2°C would need urgent action at global level. However, the benefits to the global climate – and societies and ecosystems that depend on it – will only emerge in the latter half of the century. The IPCC lists the many reasons why *mitigation* action must start now and the kinds of immediate benefits it can deliver (see page 42). In contrast, taking action on *adaptation* today delivers many immediate benefits. But, there are limits to adaptation.[66] For this reason, both adaptation and mitigation are needed; they each deliver benefits but over different timeframes.[67]

Box 4: Impacts of global warming[68]

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

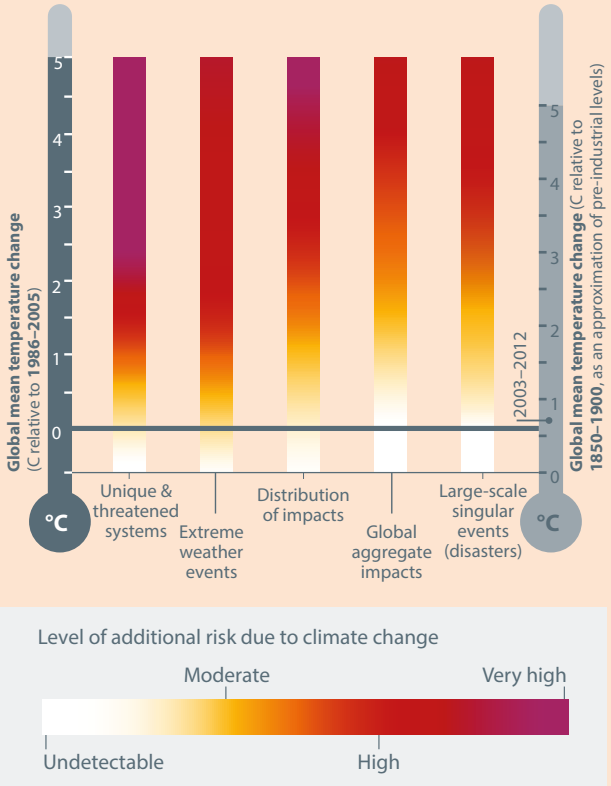


Image:
Neil Palmer, CIAT | Planting wheat, Southeast Punjab, India

Climate change will create new risks and amplify existing risks for society and the natural environment[69]

2.2. Future climate trends for South Asia

Projected temperature trends: Projections indicate that, compared to the average in the 20th century, average annual temperatures could rise by more than 2°C in South Asia by the mid-21st century and exceed 3°C by the late-21st century under a high-emissions scenario. Under RCP2.6, average temperatures could rise by less than 2°C in the 21st century, except at higher latitudes, which could be up to 3°C warmer. Oceans in subtropical and tropical regions of Asia could warm under all emissions scenarios and would warm most at the surface. Projections indicate that the oceans in subtropical and tropical regions of Asia will warm under all emissions scenarios and will warm most at the surface.[70]

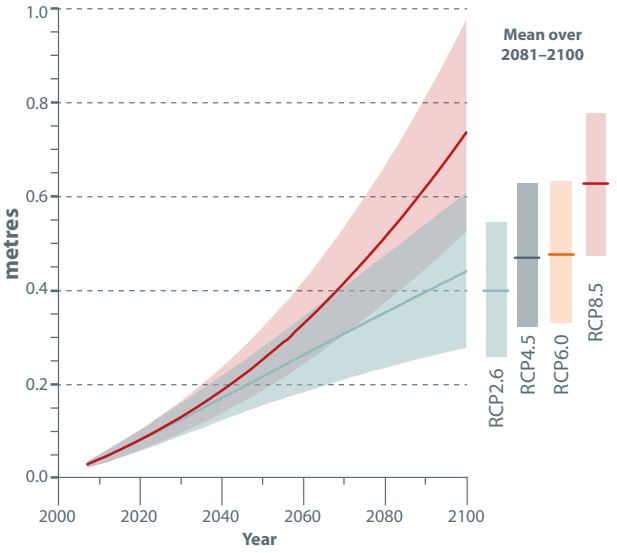
Projected rainfall trends: Projections also indicate that more rainfall will be *very likely* at higher latitudes by the mid-21st century under a high-emissions scenario and over southern Asia by the late-21st century. Under a low-emissions scenario, more rainfall at higher latitudes will be *likely* by mid-century but changes in rainfall are *not likely* at low latitudes.[71]

Extreme temperature and rainfall trends: 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. 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 South Asia will become increasingly important and will play a more significant role in disaster impacts.

The frequency of hot days is likely to increase further in the future (*high confidence*). More frequent and heavy rainfall days are projected over parts of South Asia (*low confidence*). Extreme rainfall events will be *likely* to occur where the centres of tropical cyclones make landfall in South Asia. An increase in extreme rainfall events related to monsoons will be *very likely* in the region.[72]

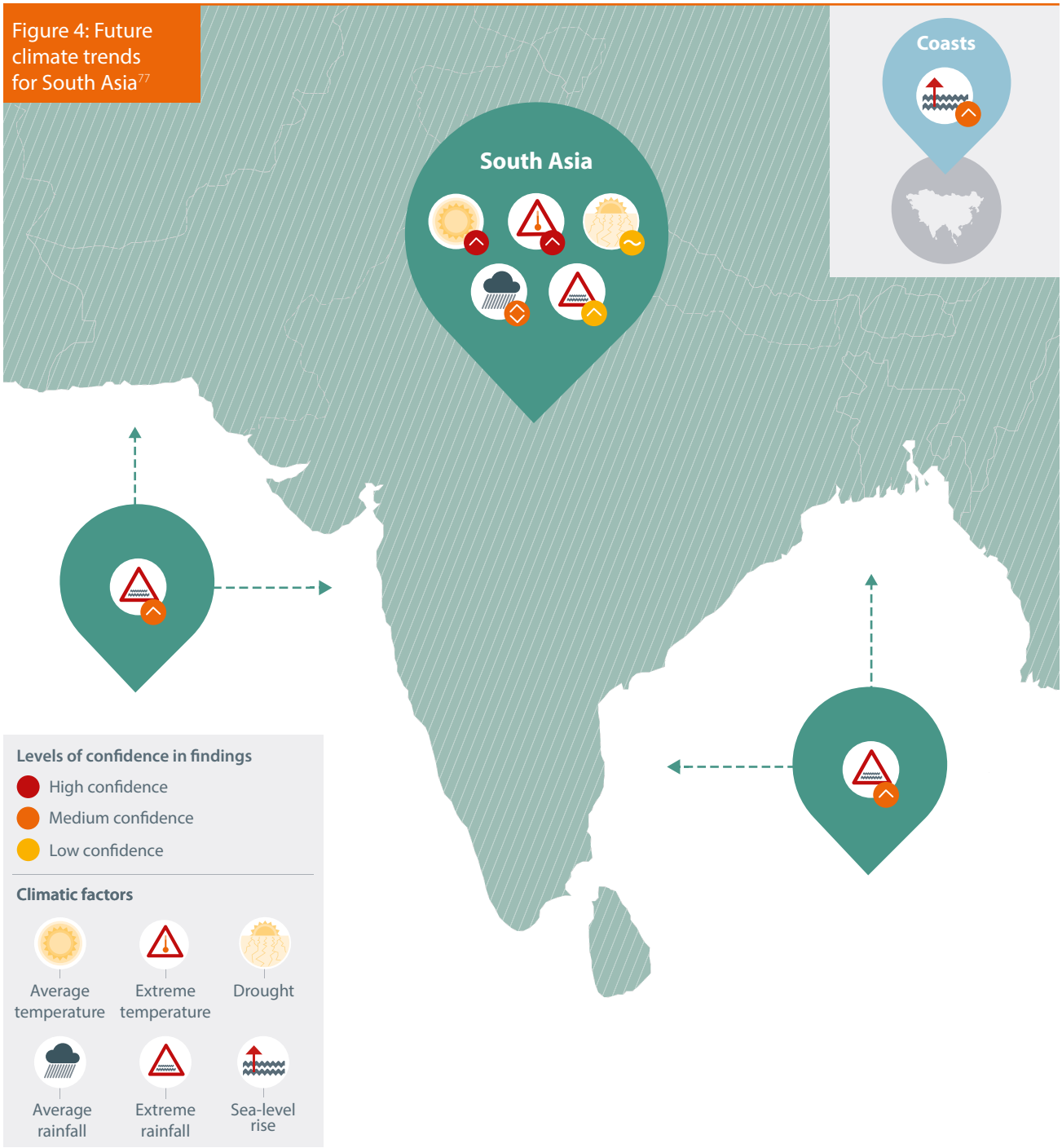
Projected sea level rise: Global mean sea level will continue to rise during the 21st century; under all emissions scenarios – low and high – the rate of sea level rise will *very likely* exceed that observed during the past three decades due to increased ocean warming and increased loss of mass from glaciers and ice sheets. Global mean sea level rise by the last two decades of the 21st century (as compared to sea levels in 1986–2005) will likely be in the ranges of 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.[73] This magnitude of sea level rise by the century's end implies significantly increased risks for South Asia's coastal settlements, as well as for coastal economies, cultures and ecosystems. Projections indicate that the average height of waves in Indian Ocean monsoons will not change greatly.[74]

Figure 3: Global mean sea level rise[75]



"Key risks for Asia are increased riverine, coastal and urban flooding, leading to widespread damage to infrastructure, livelihoods and settlements (*medium confidence*), increase risk of heat-related mortality (high confidence) and increased risk of drought-related water and food shortage causing malnutrition (*high confidence*)"
IPCC[76]

Figure 4: Future climate trends for South Asia[77]



Symbol	Rainfall	Temperature	Extreme rainfall, extreme temperature, sea-level rise
	up to 30% increasing trend	1–5 °C increasing trend	increasing trend
	both increasing and decreasing trends	–	both increasing and decreasing trends
	up to 30% decreasing trend	–	decreasing trend
	inconsistent trend	inconsistent trend	inconsistent trend
	no or only slight change	no or only slight change	no or only slight change

3 Climate change poses challenges to growth and development in South Asia

Climate change poses risks to South Asian growth and development. Even with significant adaptation and only 2°C warming by the end of the 21st century, the risks to South Asia from climate change could be high. Development planning and practice must reflect the reality of the changing climate and the uncertainty it brings.

3.1. Climate change could undermine South Asia's recent development progress

Climate change and development goals are inextricably linked. A changing climate will affect the natural resource base on which human society depends: for basic food, water and shelter, and also for economic prosperity. Climate impacts, including the impacts of extremes and disasters, will also affect the infrastructure that delivers vital development services, such as energy and transport infrastructure. Climate change and extremes will have direct and indirect effects on human health and security.[78]

Changes in climate may hamper progress towards the Millennium Development Goals and post-2015 development goals.[79] By the same token, slow progress in attaining most Millennium Development Goals will hold back the abilities of South Asian citizens, communities, states and nations to adapt to climate change. South Asian societies that meet their people's basic development needs are better prepared to cope with climate impacts.

Climate change poses a moderate threat to current sustainable development and a severe threat to future sustainable development (*high confidence, high agreement, medium evidence*).[80] Some climate-related impacts on development are already evident, changes in agriculture and increasing coastal vulnerability for instance. Added to other stresses such as poverty, inequality or disease, the effects of climate change will make sustainable development objectives such as food and livelihood security, poverty reduction, health and access to clean water more difficult to achieve in many environments and societies.

Although low income South Asian countries such as Nepal and Bangladesh contribute little to the build-up of greenhouse gas emissions, they experience disproportionate impacts of climate change because they rely on climate-sensitive sectors such as agriculture and fisheries, which are affected by rising temperatures, rising sea levels, and changing rainfall patterns. Development planning and practice must reflect the reality of the changing climate.

3.2. Water and food shortages, flood damage and heat-related deaths pose key climate-related risks to Asia, including South Asia

The IPCC identifies three key risk areas related to climate change for the Asia region as a whole (for the IPCC's definition of the Asia region, see endnote 1), and these apply to South Asia. These three risk areas are widespread damage to infrastructure, livelihoods and settlements from flooding, increases in heat-related mortality and drought-related water and food shortage leading to malnutrition.

The *Fifth Assessment Report* suggests that the risks to Asia from climate change could rise but that adaptation measures could lower risks even with warming of up to 4°C by the end of the 21st century. Projections indicate that more frequent extreme climatic events could affect human health, security, livelihoods and the prevalence of poverty, although the type and magnitude of impact would vary across Asia (*high confidence*).[81] More frequent and intense heat waves in Asia could increase mortality and the incidence of disease in vulnerable groups. More rain and higher temperatures could increase the risk of diarrheal diseases, dengue fever and malaria. More frequent floods and droughts in parts of South Asia could lower rice harvests and lead to higher food prices and living costs, exacerbating rural poverty.

Food and water shortages: A key risk identified for Asia is that more frequent droughts – due to rising temperatures, drying trends and extreme temperatures – could lead to malnutrition caused by water and food shortages (*high confidence*). At present, the risk of drought-related water and food shortages is '*low*' regardless of adaptation. In the near term (2030–2040), the risk level is '*medium*' but could be reduced to '*low*' through adaptation. In the long term (2080–2100), the risk is '*high*' but could be reduced to '*medium*' through adaptation with 4°C warming, and '*medium*' but could be reduced to '*low*' through adaptation with 2°C warming.

Flood damage to infrastructure, livelihoods and settlements: The *Fifth Assessment Report* indicates that

Image: Panos | Flooding, Sindh province, Pakistan

riverine, coastal and urban floods linked to extreme rainfall events, rising sea level and cyclones could cause widespread damage to infrastructure, livelihoods and settlements (*medium confidence*). At present and in the near term (2030–2040), projections indicate that the risk of flood damage is '*medium*' but could be reduced by adopting adaptation measures. In the long term (2080–2100), the risk of flood damage could be '*very high*' but could be reduced to '*high*' by adaptation under 4°C warming, and '*high*' but could be reduced to '*medium*' by adaptation under 2°C warming.

The risk of floods – and loss of life and property associated with floods – is highest in India and Bangladesh. By the 2070s, the *Fifth Assessment Report* indicates that the Asian port cities that could be most at risk, in terms of population and assets exposed to coastal flooding, will be Kolkata, Mumbai (Box 5) and Dhaka. The *Fifth Assessment Report* shows that floods and storms have caused disease epidemics in India and Pakistan.

Box 5: Flooding in Mumbai causes extensive damage

The 2005 floods in Mumbai led to injuries, deaths and damage to property. The floods also seriously affected city services, which shut down for five days. The city was without rail, road or air transport. Overloaded telecommunications networks also ceased to work, as there was no power and no diesel for back-up generators. By upgrading drainage in Mumbai, losses associated with a 1-in-100 year flood event could fall by as much as 70%. By extending insurance to most of the population, the indirect effects of flooding could halve, speeding recovery significantly.

"Climate change will cause declines in agricultural productivity in many subregions of Asia, for crops such as rice (*medium confidence*)" IPCC[82]

Heat-related mortality: Another key risk identified for Asia is increased mortality due to rising temperatures and extreme temperatures (*high confidence*). At present, the risk of heat-related mortality is '*medium*' with potential to be reduced to '*low*' through adaptation. In the near term (2030–2040), the risk level is '*high*' but could be reduced to '*medium*' through adaptation. In the long term (2080–2100), the risk is *'very high*' regardless of adaptation with 4°C warming, and '*very high*' but could be reduced to '*high*' through adaptation with 2°C warming.

The potential of adaptation to reduce each of these climate-related risks is represented graphically on page 23; and adaptation options are explored in greater depth in Chapter 4.

Image: Shutterstock | Sacred Lake and peaks near Gokyo in Himalayas, Nepal

3.3. Climate change will have economic impacts in South Asia

While changes in climate may lower productivity and slow economic growth, the degree to which this will happen is not clear (*high agreement, limited evidence*).[83] Although economic growth has been impressive in recent decades, there are still gaps in development to be addressed and these will be affected by climate change.

For most economic sectors, changes in population, age structure, income, technology, prices, lifestyle, regulation and governance are projected to have large impacts compared to the impacts of climate change (*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.

Rapid urbanisation, industrialisation and economic development will compound stresses caused by climate change (*high confidence*).[84] Projections indicate that climate change could adversely affect sustainable development in most Asian developing countries because changes in climate would aggravate pressure on natural resources and the environment. In South Asia, developing sustainable cities with low-carbon transport, trees and greenery would have a number of co-benefits, including improvements in public health.

3.4. Climate change will exacerbate poverty in South Asia

Climate change will exacerbate and further entrench poverty (*very high confidence*).[86] Changes in climate could be one of the reasons why some countries may not be able to escape the poverty trap. Climate change and climate variability could 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.

"Some low-lying developing countries and small island states are expected to face very high [climate change] impacts that, in some cases, could have associated damage and adaptation costs of several percentage points of GDP"
IPCC[85]

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. Bangladesh is among the countries that will be most at risk from extreme events.[87] A rise in sea level will put low lying, densely populated coastal areas in India and Bangladesh at risk of storm surges. Projections indicate that in India the population at risk from a rise in sea level will increase by 80%. The mega-deltas of Bangladesh, watersheds in the Himalayas and drylands will also be at risk.

South Asia has made significant progress in eradicating poverty in the past decade. Much of this has been the result of migration, and rapid growth in the agricultural and urban sectors. Changes in weather and climate affect natural resources, and the livelihoods of people who depend on them. Poor yields, soil erosion, natural calamities, poor water quality and land degradation affect the sustainability of agriculture, and make rural communities vulnerable to droughts, floods and typhoons associated with climate change.

Although rapidly urbanising, South Asia is still predominantly agrarian. People in rural areas depend on natural resources, which are subject to the vagaries of weather and climate.

Agriculture is a key driver of economic growth in Asia including in South Asia. Projections indicate that floods, droughts and changes in seasonal rainfall patterns could negatively affect crop yields, food security and livelihoods in vulnerable areas. Projections indicate that rural poverty in South Asia could continue to be more widespread than urban poverty for decades to come. Indeed, rural poverty in parts of South Asia could rise because of poor rice harvests, and high food prices and living costs.

Climate change could affect poverty in different countries and social groups in different ways. For example, countries such as Bangladesh could experience 15% more poverty by 2030. The effects could also differ within food exporting countries, with farm labourers suffering disproportionately.

Climate change could also affect South Asia's urban poor. The urban poor could experience rises in food prices, as happened in 2007–2008. Certain categories of urban dwellers, such as urban wage labourers, could be particularly vulnerable.[88]

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

There are many synergies between action on climate adaptation and the achievement of growth and development objectives. This means that many investments can be made to strengthen climate resilience which pose 'no regrets' or 'low regrets'. Even in the face of uncertainty about exactly how climate impacts will strike and when, such investments will benefit economic growth and 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. The IPCC describes adaptation as "the process of adjustment to actual or expected climate and its effects".[89] Through adaptation, societies and communities can seek to moderate the harm of current and future climate risks or to take advantage of new opportunities.

In South Asia, rapid population growth, urbanisation, economic growth and changes in land use could interact with climate change to increase vulnerabilities.[90] The effects of climate change depend as much on the inherent vulnerability of social and ecological systems as on the magnitude of climatic changes. Adapting to foreseeable change will be important in securing the health and prosperity of South Asian nations and the region as a whole.

Strengthening the links between development and building resilience could help to improve the level of adaptation in Asia and reduce the risk of 'maladaptation' or causing unintended adverse consequences (*high confidence – for 'maladaptation' see Glossary*).

Effective adaptation strategies can, and should, strengthen livelihoods, enhance wellbeing and human security, and reduce poverty today (Figure 5). 'No regrets' or 'low regrets' adaptation 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 6–7).[91]

Adaptation brings benefits both today and in the future. South Asia 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 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 (Table 1).[92]

Levels of capacity to adapt (adaptive capacity) in South Asia are low – although this varies within and across countries of the region. Societies' capacity to adapt to climate change impacts is influenced by economic, demographic, health, education, infrastructure, governance and natural factors. Many aspects of development, such as improving education and health, facilitate adaptation to a changing climate.

On the whole, 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 sectoral adaptation strategies 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, South Asian countries' adaptive capacity to manage complex social and ecological change, especially at local government level, is weak.

South Asia 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.[93]

In South Asia, successful adaptation to climate change will depend upon developing resilience in the face of uncertainty.

Figure 5: Adaptation can reduce risk[94]

Key risk	Adaption issues & prospects	Climate drivers	Time frame	Risk & potential for adaptation
Increased riverine, coastal, and urban flooding leading to widespread damage to infrastructure, livelihoods and settlements in Asia. *(medium confidence)*	• Exposure reduction via structural and non-structural measures, effective land-use planning, and selective relocation • Reduction in the vulnerability of lifeline infrastructure and services (e.g., water, energy, waste management, food, biomass, mobility, local ecosystems, telecommunications) • Construction of monitoring and early warning systems; measures to identify exposed areas, assist vulnerable areas and households, and diversify livelihoods • Economic diversification		Present Near-term (2030–2040) Long-term (2080–2100)	Very low / Medium / Very high 2°C 4°C
Increased risk of heat-related mortality *(high confidence)*	• Heat health warning systems • Urban planning to reduce heat islands; improvement of the built environment; development of sustainable cities • New work practices to avoid heat stress among outdoor workers		Present Near-term (2030–2040) Long-term (2080–2100)	Very low / Medium / Very high 2°C 4°C
Increased risk of drought-related water and food shortage causing malnutrition *(high confidence)*	• Disaster preparedness including early-warning systems and local coping strategies • Adaptive/integrated water resource management • Water infrastructure and reservoir development • Diversification of water sources including water re-use • More efficient use of water (e.g., improved agricultural practices, irrigation management, and resilient agriculture)		Present Near-term (2030–2040) Long-term (2080–2100)	Very low / Medium / Very high 2°C 4°C

Climatic factors

Average temperature · Extreme temperature · Drought · Cyclone · Average rainfall · Extreme rainfall · Sea-level rise

Level of risk and potential for adaption

Potential for additional adaption to reduce risk

Risk level with **high** adaption · Risk level with **current** adaption

Box 6: Women, children and the elderly can be more vulnerable to climate change impacts[95]

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 7: Action on climate change and development are inextricably linked[96]

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 South Asia's need to integrate climate action with inclusive and sustainable economic development.

Table 1: Action on climate change adaptation can bolster development[97]

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.

5 Adaptation is fundamentally about risk management

Placing risk management at the heart of decision-making will help South Asia cope with climate change, but both short- and long-term approaches to climate risk management will be required.

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

Both short- and long-term approaches to managing climate risks are needed. 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. South Asian 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.[98]

There is no one-size-fits-all approach to adaptation.

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. 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' (see Box 10 for definition). This is a particular challenge for South Asia where economies are growing rapidly and societies are undergoing significant demographic shifts.

More 'transformational' changes may be needed in situations where there are high levels of vulnerability and low capacity to adapt, as is the case in parts of South Asia. 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). However, it should be noted that transformational adaptation can result in either positive or negative outcomes, as the greater level of investment and or shift in fundamental values and expectations required for transformational change may create greater resistance .

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. 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.[99]

In South Asia, successful adaptation will depend upon developing resilience in the face of uncertainty.[100]

Image:
Neil Palmer, CIAT | Burning field stubble, India

The good news is that South Asia 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 South Asia 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.[101]

In South Asia, rapid population growth, urbanisation, economic growth and changes in land use could interact with climate change to increase vulnerabilities. Adapting to foreseeable change will be important in securing the health and wellbeing of South Asian citizens and the region as a whole. The *Fifth Assessment Report* indicates where governments could work to limit the impacts of climate change in order to protect past and future development gains.

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

"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 of Working Group II

6 South Asia has many adaptation options

Practical experience in adapting to climate change at the regional, national and local level in South Asia is accumulating. The effects of climate change depend as much on the inherent vulnerability of social and ecological systems as on the magnitude of change. Regional cooperation could be important in overcoming resource scarcities and conflicts related to climate change.

6.1. Emerging adaptation experience in South Asia provides options for scaling up in the future

South Asian countries are already accumulating practical experience in adapting to climate change at the regional, national and local levels. Best practices from South Asia show the potential for effective climate adaptation approaches that can be enhanced and scaled up in the future (see case study, 'Ahmedabad Heat Action Plan', p32).

In the agriculture sector, for example, South Asian countries are adopting climate adaptation strategies and practices for particular crops and geographic areas. Other adaptation options highlighted in the *Fifth Assessment Report* for the Asia region as a whole are presented in Table 2, below. Tactics to reduce vulnerability include social protection schemes, adapting technologies and infrastructure, ecosystem-based programmes, diversifying livelihoods and reducing risks associated with disasters.

Many South Asian countries take a holistic development approach to adaptation. They integrate programmes for managing water and irrigation; promoting sustainable agricultural practices and appropriate technologies; innovating to address shorter growing seasons, extreme temperatures, droughts, and floods; and strategies for dealing with water shortages, food security and loss of livelihoods. In the future, policies for adapting to climate change could build on the local and indigenous coping strategies of farmers who have been adapting to climatic risks for generations. Breeding crop varieties suited to high temperatures could also be a promising option for adapting to climate change in South Asia.[102]

Many South Asian countries take a holistic development approach to adaptation. They integrate programmes for managing water and irrigation; promoting sustainable agricultural practices and appropriate technologies; innovating to address shorter growing seasons, extreme temperatures, droughts, and floods; and strategies for dealing with water shortages, food security and loss of livelihoods.

Community-based approaches help identify adaptation strategies that address poverty and livelihoods issues.[103] These techniques capture information at the grassroots, help integrate disaster risk reduction, development and climate change adaptation, connect local communities and outsiders, address the location-specific nature of adaptation, help facilitate community-learning processes and help design location-specific solutions.[104] However, new activities may make some groups become more vulnerable to change after being 'locked into' specialised livelihood patterns, as with fish farmers in India.[105]

Good practice in mainstreaming adaptation into development is most advanced in official development assistance programmes. Donor agencies and international financial institutions have made significant progress in taking climate-change adaptation into account in loan and grant making processes.[106] Regional cooperation could be important in overcoming resource scarcities and conflicts related to climate change.[107]

"In Asia, community based approaches are a means to address poverty and livelihoods as well as facilitate integration of disaster risk reduction, development and climate change adaptation (*limited evidence, high agreement*)"
IPCC[108]

Box 8: Low-regrets adaptation measures

Managing natural resources to improve ecosystem resilience is a low-regrets adaptation strategy for vulnerable rural communities (*high confidence*).[109]
Two widespread practices that address desertification – natural regeneration of trees and water harvesting – build resilient ecosystems and help rural communities adapt to changes in climate. Community-based natural resource management groups have the flexibility to incorporate measures to adapt to changing climatic conditions into existing projects. Working on sustainable adaptation through these groups leverages synergies between ecosystem services and poverty reduction.

Given so many uncertainties in Asia, building resilience is a low-regrets route to successful adaptation. Opportunities to build resilience include:

- Improving water and land governance;
- Ensuring security of tenure over land and vital assets;
- Building social protection systems, social services and safety nets;
- Enhancing water storage, water harvesting and post-harvest services; and
- Giving stakeholders more opportunities to get involved in planning.

Box 9: Proven principles for effective adaptation

The IPCC identifies five principles for adapting to climate change and building adaptive capacity;[110]

i) Support autonomous adaptation through policies that recognise the multiple stresses on vulnerable people's livelihoods;

(ii) Attend to cultural, ethical and rights issues in adaptation by involving more women, youth, and poor and vulnerable people in developing and implementing adaptation policies;

(iii) Combine 'soft' options, such as ecosystem-based adaptation approaches as opposed to hard engineering solutions, and flexible and iterative learning approaches with technological and infrastructural approaches, and blend scientific, local and indigenous knowledge when developing adaptation strategies;

(iv) Build resilience and implement low-regrets adaptation (relatively low cost and relatively large benefits under predicted future climates) in synergy with development when faced with future climate and socioeconomic uncertainties; and

(v) Build adaptive management and social and institutional learning into adaptation processes at all levels.

Image: Shutterstock | Tree planting

Approaches to selecting adaptation options continue to emphasise incremental change to reduce impacts, while achieving benefits. But there is increasing evidence that managing for climate-related risks may involve experimenting with larger scale, new or more transformational adaptation measures than those already tried, and additional planning and investment. Such measures can include, for instance, changes in livelihoods from cropping to livestock or by migrating to take up livelihood opportunities elsewhere[111] (see also 'Migration as a coping mechanism in Bangladesh, p32).

Table 2: Options for adapting to key climate-related risks in South Asia

Vulnerabilities compounded by climate impacts in South Asia	Adaptation options
Unsustainable consumption of groundwater for irrigation and other uses is considered to be the main cause of groundwater depletion in several Indian states and will compound any disrupted rainfall that occurs as a result of climate change.	Water infrastructure development in the Ganges river basin, increasing water productivity in the Indus and Ganges river basins and integrated management between Bangladesh, India, Nepal and Pakistan for the Indus and Ganges-Brahmaputra-Meghna river basins.[112]
Sea level rise will be a key issue for many coastal areas as rich agricultural lands may be submerged and taken out of production.	Where possible, agricultural areas can contribute to 'soft' engineering coastal defences, maintaining and restoring natural shorelines in agricultural zones.[113]
Disruption of basic services such as water supply, sanitation, energy provision and transportation systems caused by flooding have implications for local economies, which can lead to mass migration and reinforce inequalities.	'No regrets' solutions to new infrastructure investments, taking advantage of opportunities for climate-resilient design, financing and management.[114]
Human health is a major area of focus for (South) Asia, where effects depend on socio-economic and demographic factors, health systems, the natural and built environment, land use changes, and migration, in relation to local adaptive capacity. The role of institutions is critical, influencing vulnerabilities arising from gender, caste and ethnicity and wealth inequality.	Disaster preparedness on a local community level could include a combination of indigenous coping strategies, early-warning systems and adaptive measures. New working practices to avoid heat stress in outdoor worker, early warning systems for disease and disaster risks. Livelihood diversification and climate-resilient livelihoods leading to reductions in vulnerabilities, including ecosystem-based adaptations and financial support measures.

6.2. South Asian countries face barriers to adaptation but there are strategies to overcome these

There can be barriers that impede or limit adaptation. These include challenges related to competing national priorities, awareness and capacity, financial resources for adaptation implementation, institutional barriers, biophysical limits to ecosystem adaptation, and social and cultural factors. Issues with resource availability might not only result from climate change, but also from weak governance mechanisms and the breakdown of policy and regulatory structures.[115]

Poor and vulnerable countries have limited options for coping with changes in climate and so are at greater risk of inequity and loss of livelihoods than richer countries – although in many cases, social capital, an indicator of equity in income distribution within countries, is a more important factor in vulnerability and resilience than GDP per capita.

Many factors limit individuals' and institutions' coping mechanisms, such as poverty, illiteracy, poor access to resources, information and technology, poor health care, low investment, and poor management skills. The overexploitation of land resources, including forests, increases in population, desertification and land degradation pose additional threats, particularly in the developing countries in South Asia that depend heavily on natural resources. Provision of adequate resources based on burden sharing and equity could strengthen adaptation policies and measures in these circumstances.

Gaps in data and research constrain decision-making in reducing vulnerability, building resilience, and in planning and implementing adaptation strategies in South Asia (*high confidence*).[116]

The main gaps are in:

- Data management, monitoring climate and developing climate-change scenarios;
- Monitoring the effects of climate change by sector;
- Researching and improving methods to assess and quantify the effects of climate change on different sectors and systems; and
- Socioeconomic research on the consequences of loss of ecosystems, economic activities, mitigation choices, such as biofuels, and adaptation strategies.

6.3. Development strategies must be crafted in ways that increase climate resilience – and do not weaken it

Adaptation generally needs to be considered in the context of development, particularly in developing countries (*high confidence*).[117] Development and adaptation may be complementary or incompatible. Strengthening the links between development and building resilience could help to improve the level of adaptation in Asia and reduce the risk of maladaptation (*high confidence*). Development and adaptation may be complementary or competitive. Many aspects of development, such as improving education and health, facilitate adaptation to a changing climate. Likewise, adaptation strategies, such as more efficient use of water and more robust crop varieties, are beneficial for development even when future climate impacts are uncertain. 'Mainstreaming' or integrating adaptation into existing policies maximises synergies.

Image: RUAF Foundation | Urban agriculture, Western Province, Sri Lanka

Effective development measures that would also build resilience are:

- Improving social protection, social services and safety nets;
- Improving water and land governance, and providing secure tenure over land and productive assets;
- Enhancing water storage, water harvesting and post-harvest services;
- Strengthening and involving civil society in planning; and
- Paying more attention to urban and peri-urban areas heavily affected by migration of poor people.

Managing natural resources to improve ecosystem resilience is a low-regrets adaptation strategy for vulnerable rural communities (*high confidence*) . Two widespread practices that address desertification – natural regeneration of trees and water harvesting – build resilient ecosystems and help rural communities adapt to changes in climate. Community-based natural resource management groups have the flexibility to incorporate measures to adapt to changing climatic conditions into existing projects. Working on sustainable adaptation through these groups leverages synergies between ecosystem services and poverty reduction.

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 sectoral adaptation strategies can lower resilience in other sectors or ecosystems.

Overall, South Asian countries' adaptive capacity to manage complex social and ecological change, especially at local government level, is generally weak and could be significantly strengthened. The range and scale of recent disasters in South Asian cities indicates a growing need for new mechanisms to support local governments and local civil society organisations in addressing risks and the root causes of vulnerability.

Local governments can now use tools such as geographic information systems to assess vulnerability and formulate climate-change adaptation policies to deal with such climate impacts as flooding and coastal inundation. Such tools can help local governments in Asian coastal cities and zones to analyse the likely impacts of climate change, identify vulnerable populations and assess location-specific adaptation options. Tools often integrate top-down and bottom-up (community-based) approaches. Top-down approaches provide local people with scientific knowledge. Community-based approaches draw on the

experience of local people to strengthen knowledge and expertise in coping and adapting. Although community-based approaches make local people responsible they do not necessarily build their capacity. Adaptive capacity depends on social capital and institutions, which vary from community to community, meaning that such approaches should be tailored to a specific community's social and political context.

Box 10: Avoiding 'maladaptation'[118]

Maladaptation is where an intervention in one location or sector could increase the vulnerability of another location or sector, or increase the vulnerability of the intended beneficiaries to future climate change. Maladaptation is a cause of increasing concern to adaptation planners and the definition used in the *Fifth Assessment Report* has changed to recognise that maladaptation arises not only from inadvertent, badly planned adaptation actions, but also from deliberate decisions. For instance, where wider considerations place greater emphasis on short-term outcomes ahead of longer-term threats, or decision-makers fail to consider the full range of interactions arising from planned actions.

Beyond the *Fifth Assessment Report*: Migration as a coping mechanism in Bangladesh[119]

Bangladesh is ranked as one of the most climate-vulnerable countries in the world. It is at extreme risk of floods, tropical cyclones, sea level rise and drought, all of which could drive millions of people to migrate. Although climate-related migration in Bangladesh is significant, surprisingly, there have been to date very few empirical studies carried out specifically on how climate change influences migration and its wider implications. This has made it hard to identify adaptation measures to deal with this major issue. As a result current policies and plans in Bangladesh do not sufficiently address the growing problem of climate-induced displacement, especially large-scale migration. The Government of Bangladesh recognised this shortcoming and commissioned a study of the growing migration phenomenon.

The study finds that millions of rural Bangladeshis are affected by climate variability. Many are increasingly resorting to migration as a coping mechanism. It concludes that climate stresses and shocks play an important role in people's decisions on whether to migrate.

While acknowledging that climatic stresses will increase migration, the study finds that instead of looking at migration as a threat, migration can be transformed into an effective adaptation tool through policy reforms. For example, rural-urban migrants are among the most vulnerable social groups who often end up living in disaster-prone urban areas and informal settlements. Future migration policies can be designed to support internal migratory movements and focus on providing safe environments and facilities for migrants in areas of settlement. Policy options could include enhancing access to migration finance, and drafting an internal migration policy.

Image: iStock | Rickshaw caught in flash flood

Beyond the *Fifth Assessment Report*: South Asia's first heat-related health action plan[120]

Higher daily peak temperatures and longer, more intense heat waves are becoming increasingly frequent in South Asia as a result of climate change. A new scale of coordinated action is essential to protect communities, especially their most vulnerable members, from the dangerous health effects of extreme heat.

Ahmedabad, in India's western province of Gujarat, is the first city in South Asia to comprehensively address these risks through a Heat Action Plan. The city government became convinced of the need for such a plan when the city experienced an intense heat wave in May 2010. Peak temperatures of 46.8°C (116°F)

caused a spike in reported heat-related illness and death.

A coalition of academic, health and environmental groups from within and outside government joined together to create an early warning system and heat preparedness plan.

The plan is based on robust scientific research, builds public awareness of the risks of extreme heat, trains medical and community workers to prevent and respond to heat-related illnesses, and coordinates an interagency emergency response effort when heat waves occur. The city government now has a dedicated budget and team for implementation of specific actions to help save lives – such as keeping tree-shaded public parks open for longer and moving particularly vulnerable groups such as pregnant women to cooler surroundings.

The Union Minister for Health in India has asked all cities to learn from Ahmedabad and put in place similar adaptation measures for extreme heat. There is growing awareness that extreme heat is not just a way of life in India, but something which needs concerted action.

Image: Indian Institute for Public Health | Health clinic, Ahmedabad

"In Asia, community based approaches are a means to address poverty and livelihoods as well as facilitate integration of disaster risk reduction, development and climate change adaptation (*limited evidence, high agreement*)"
IPCC[121]

Beyond the *Fifth Assessment Report*: Building flood resilience in Gorakhpur, India[122]

Gorakhpur District is recognised as one of the most flood-prone districts in Eastern Uttar Pradesh, India. Over the past 100 years, there has been a considerable increase in the intensity and frequency of floods. Gorakhpur District is home to 4.4 million people, most of whom live in rural areas. Roughly 20% of the population is affected by floods, and in some areas, flooding has become an annual occurrence. All of the district's blocks are highly prone to recurrent floods, causing huge loss of life, health and livelihoods for the poor inhabitants, and extensive damage to public and private property.

An initiative at district level has strengthened the capacity of government departments and the District Disaster Risk Management Authority on practical approaches to vulnerability assessment and strengthening climate resilience. The programme has helped raise awareness of the ways in which climate change may manifest itself, especially at district level, by providing relevant and scientific analysis of climate change projections in a form that conveys the urgency, relevance and implications of climate change to each department's plans and programmes. This involved a detailed analysis of extreme events, showing changes in the magnitude and frequency of storm durations across various best-fit climate models.

As a result, climate change concerns have been integrated with existing disaster management activities, including flood risk reduction. Measures such as retrofitting houses to raise them above flood levels are underway. The experience shows that with adequate capacity-building in place, the District Disaster Management Plans created as a result of India's Disaster Management Act (2005) can be an effective mechanism for promoting climate-sensitive planning at district level. A key area of learning is that climate projections must be appropriately interpreted and presented to district government departments in a way that fosters understanding of their implications for development programmes.

Image: Aditya Bahadur | Community consultation, Gorakhpur district, India

Box 11: Building resilience to tropical cyclones

Strong wind, torrential rain, high waves and storm surges associated with tropical cyclones, also referred to as hurricanes or typhoons, cause major damage to society and ecosystems. Bangladesh and India account for 86% of deaths from tropical cyclones.

About 90 tropical cyclones occur globally each year, although there is considerable variability between years. The IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX, 2012) concluded that changes to trends in tropical cyclones arising from climate change are likely to vary by region. The frequency is likely to decrease or remain unchanged in the 21st century, while the intensity (maximum wind speed and rainfall) is likely to increase. Confidence in region-specific projections is low.

The long-term effects of storm surges and damaging waves associated with tropical cyclones are salinisation of coastal soils and water supplies, and food and water insecurity. However, preparing development plans for these areas and improving governance could reduce the damage cyclones cause and build resilience to long-term changes in climate.

Expanding urban areas in densely populated Asian deltas are particularly vulnerable to tropical cyclones. Extreme cyclones in Asia since 1970, for example, Bhola (1970), Gorky (1991), Thelma (1998), Gujarat (1998), Orissa (1999), Sidr (2007) and Nargis (2008), have caused over half a million deaths.

Comparing the responses to cyclone Sidr in Bangladesh in 2007 and Nargis in Myanmar in 2008 demonstrates how disaster risk-reduction measures could successfully apply to climate change adaptation. Sidr, of similar strength to Nargis, caused far fewer fatalities (3,400 compared to over 138,000) because Bangladesh used the experience gained in previous cyclones such as Bhola and Gorky. Bangladesh's responses included building multi-storey cyclone shelters, improving forecasting and warning, establishing a coastal volunteer network and reforesting coastal mangroves. Disaster risk management strategies for coastal areas that protect against and anticipate and plan for extreme events increase the resilience of exposed communities. Integrating education, training and activities to raise awareness into ongoing processes and practices could successfully reduce risks and help manage disasters. However, although combining risk-reduction and climate-change adaptation strategies could be desirable, different spatial and time scales, and different norms and types of knowledge relating to risk reduction and adaptation could make such a combination ineffective.

Box 12: The economics of climate adaptation[123]

Trade-offs. Where there are limited resources, adaptation choices will mean trade-offs among multiple policy goals (*high confidence*). Alternative policy goals include development and climate change mitigation. 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 to include 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 resulting 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.

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.

Beyond the *Fifth Assessment Report*: Economic assessment of climate impacts in Nepal's key sectors[124]

For the Government of Nepal, climate change is a development question of the utmost importance. In a 2014 report, it has outlined exactly how much climate change is costing the economy today, and in the future, for three major risk areas: agriculture, hydroelectricity and water-induced disasters. It finds that the equivalent of 2–3% of current GDP/year by mid-century will be lost due to climate change. This will put at risk the Government's development objectives of raising the standard of living for the 25% of the population currently under the poverty line. The Government has therefore committed to mainstream adaptation to climate change into its development plans and policies. The report suggests that to fully address medium-term risks in these three areas, a major increase in investment is required, estimated at US$2.4 billion by 2030 (present value).

Image: Neil Palmer, CIAT | Nepali farmer

6.4. National and subnational levels must be linked effectively

Complementary action across all levels of government can enhance adaptation planning and implementation.[125] National governments could coordinate local and subnational adaptation efforts, for example by protecting vulnerable groups, by supporting economic diversification, and by providing information, policy, legal frameworks and financial support. Local government and the private sector are critical to advancing adaptation given their roles in scaling-up adaptation in communities, households and civil society, and in managing risk information and financing.

Few urban governments in South Asia have money to invest in adaptation and mitigation as most revenues pay for salaries and other recurrent expenditure. To secure adaptation finance, governments need to plan and cost climate strategies. Bangladesh is an 'early mover' in planning urban adaptation but the framework to manage adaptation funds is not yet in place. National Adaptation Plans of Action (NAPAs) often do not explicitly include urban projects.

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. 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.

In cities and neighbourhoods where infrastructure is incomplete and household incomes limited, communities themselves offer a rich resource of adaptive capacity. Community-based responses support local change but are often reactive and limited in scope. Communities can build and maintain water supplies, toilets and washing facilities, or construct or improve drainage, as in cities in Pakistan, but they cannot provide the infrastructure on which these services depend. Building links between communities and local government can support city-wide responses.

Global institutions, both within and outside the United Nations Framework Convention on Climate Change (UNFCCC), are critically important for South Asia to move forward on adaptation. Regional institutions that focus on specific ecosystems 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.

6.5. South Asia has options for enhancing climate-related disaster risk management

South Asian decision-makers have a range of strategies at their disposal for increasing preparedness and reducing exposure and vulnerability to climate-related disaster risk.[126] Strategies to adapt to floods could include land-use planning, relocation, flood protection for infrastructure and services, and assistance for vulnerable sectors and households. Strategies to prepare for disasters could include early warning systems and local coping mechanisms. Systems issuing warnings of the danger to health in heat waves, urban planning to reduce heat islands and improving the built environment could lessen risks of heat-related mortality.

Disaster preparedness at the community level could combine indigenous coping strategies, early warning systems and adaptive measures. For example, in Dhaka, households prepare for floods by putting barriers across doors, raising furniture, building floors or shelves above the flood line and investing in portable cookers.

On rivers and coasts, defences such as sea walls, bunds and dams could protect agriculture and human settlements from flooding but may have negative effects on natural ecosystems and carbon sequestration by preventing natural adjustment to changing conditions. Conversely, setting aside landward buffer zones along coasts and rivers would both benefit ecosystems and sequester carbon. The organic-rich soils in mangroves and peat swamp forests have very good potential for storing carbon. Restoring degraded forests would combine adaptation with mitigation.

Transport is important for effectively responding to disasters, particularly for evacuating people before storms, or for providing food, water and emergency services. Many urban areas in low- and middle-income countries do not have all-weather roads and paths that allow access for emergency vehicles and rapid evacuation. For instance, in Chittagong, Bangladesh, very narrow roads prevent emergency vehicles reaching many districts.

Early warning systems: Capacity to assess and monitor risks has grown. As a result, early warning systems are emerging. The *Fifth Assessment Report* finds that heat warnings have successfully prevented deaths in groups at risk in South Asia. Early warning systems for preventing the spread of infectious diseases and vector control programmes are being developed, for malaria in Bhutan and dengue fever across the region for example.

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.

Insurance: Financial approaches to diversifying livelihoods include providing microfinance and insurance as ways for the rural poor to work their way out of poverty and accumulate assets.

Box 13: Challenges in reducing the risk of disasters

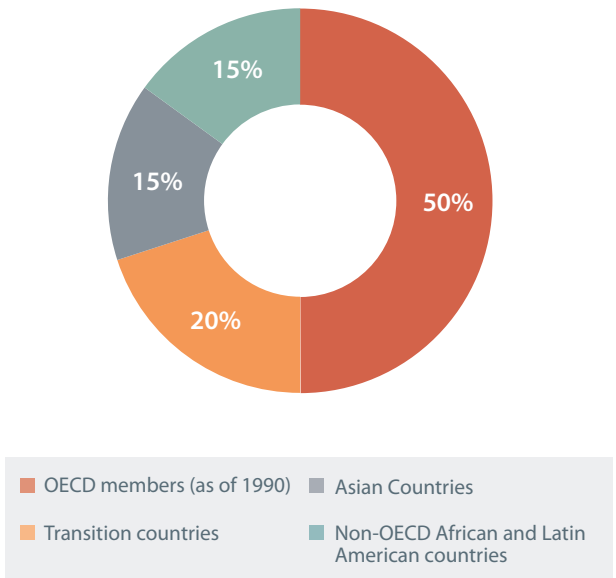
The challenges in translating early warning into early action include political and institutional barriers in:

- 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.

7 Low-emissions development offers opportunities for South Asia

South Asia, particularly the low income countries of the region, has contributed relatively little to historic greenhouse gas emissions. South Asian countries can gain from low-carbon solutions: as they grow their economies and meet pressing development needs, there are abundant opportunities for South Asian countries to adopt clean, efficient low-carbon technologies and measures. This could enable them to leapfrog some of the inefficient, fossil fuel-dependent infrastructure that more developed countries are already 'locked in' to. What is more, Asian 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.

Figure 7: Source of cumulative global emmisions[127]



7.1. Asia has had large increases in per capita emissions since 1970

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

The IPCC has assessed historic emissions for the Asia region as a whole (excluding those countries that were OECD members as of 1990), but not specifically for South Asia. The following section summarises the IPCC's findings for the larger Asia region.[128]

Fossil fuel use (Asia): The data to 2010 show that most of the rise in emissions from Asia stems from an increase in the use of fossil fuel resulting from population and economic growth. The increase in fossil fuel emissions from Asia is the result of the sustained, dramatic increase in per capita gross domestic production (GDP) from the 1970s to 2010. Improvements in energy intensity (energy consumption per unit of gross domestic product) and per capita energy use did not offset the rise in emissions from per capita GDP and population growth.

Urbanisation (Asia): Urbanisation plays an important role in greenhouse gas emissions. Estimates suggest that urban areas account for 30%–70% of all emissions, although estimates depend on how urban areas are defined.[129] Large urban populations tend to generate more emissions per person than small urban populations because of differences in income, lifestyles and the energy sources available. Globally, the rate of urbanisation rose from 36% in 1970 to 52% in 2011. However, the links between urbanisation and greenhouse gas emissions are complex, shaped by factors such as economic growth, technologies and energy, as well as urban growth patterns.[130] Urbanisation and urban population growth are expected to continue and will contribute to an increase in urban emissions in Asia as in the world as a whole.

Population structure and household size (Asia): The evidence on the effect of age structure and household size on greenhouse gas emissions is conflicting. National studies show that emissions from aging populations tend to be lower than emissions from younger populations as fewer people work, and a smaller working population consumes

less energy and emits less greenhouse gases. Household studies, however, show the opposite. Older people tend to use more energy and emit more greenhouse gases than younger people. Older people often live in small households where energy intensity is greater than in large households. Overall, the effects of age and household structure on emissions are not clear. The *Fifth Assessment Report* shows that most studies associate ageing populations, small households and high rates of urbanisation with high energy use and greenhouse gas emissions.

Economic growth (Asia): Economic growth has also contributed to the rise in emissions from Asia. Studies suggest a strong correlation between the growth of GDP and rising CO_2 emissions. Per capita emissions positively correlate with per capita income. This correlation is particularly evident in Asia where, between 1970 and 2010, GDP and emissions per capita both increased.

Various factors may affect the correlation between the growth in GDP and growth in emissions. How a country grows may determine its level of emissions. Middle-income countries using clean, efficient technology and increasing productivity are driving down emissions. The *Fifth Assessment Report* indicates that although economic growth could increase emissions, where clean technologies drive economic growth, then emissions could fall.[131]

Energy per capita (Asia): 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 Asia, per capita energy use increased by 200%, although per capita energy use is much lower than in OECD90 and transition countries.[132]

Energy intensity (Asia): In Asia as a whole, energy intensity – the ratio of energy per unit of gross domestic product – fell significantly in the last few decades but is still higher than in OECD90 countries. The relationship between the use of energy and GDP is complicated but, as incomes rise, so does the use of energy; depending on which one increases faster, energy intensity will either fall (if GDP increases more) or increase (if energy use increases more).[133]

Agriculture, forestry and land use (Asia): Asia is the largest producer of greenhouse gas emissions from the agriculture, forestry and land use sector (AFOLU). Most emissions are from the soil, livestock and deforestation. Emissions from livestock and synthetic fertilisers have increased but emissions from rice cultivation have slowed.[134]

Energy (Asia): Rapid growth of the primary energy supply in Asia increased emissions from the energy supply sector by a factor of 16.8 between 1970 and 2010. For 2001–2010, total emissions from the energy supply sector in Asia and the annual growth rate of emissions was the highest of all regions globally.[135]

Transport (Asia): Between 1970 and 2010 emissions from the transport sector in Asia grew faster than in any other region, mostly from road traffic. In Asia, as elsewhere, road traffic accounts for most emissions from the transport sector.

Industry (Asia): The industrial sector in Asia produces over half (54%) of all emissions from industry globally. The growth rate in emissions from Asian industry between 1970 and 2010 was the highest (7.4%) in the world.[136]

7.2. The IPCC maps future scenarios for Asian emissions

The IPCC's scenarios for emissions trends are presented for the entire Asia region, and there are no disaggregated projections for South Asia alone. The mid-term scenarios presented by the IPCC to 2030 (Table 7) assume either stringent reductions in CO_2 to 430–530 ppm (parts per million) equivalent (66% likely to keep warming below 2°C by 2100) or slightly less stringent reductions in CO_2 to 530–650 ppm equivalent (less likely to keep warming below 2°C but still acceptable). In the less stringent mid-term scenario, emissions will peak in Asia by 2040, increasing by 34% (vis-à-vis 2010. On the other hand, if full mitigation measures were implemented, there would be only be a 1% increase in emissions, peaking in 2030.

Table 3: Mid-term scenarios for regional emissions[137]

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%

By embracing low-carbon investments now, Asian countries could enhance their development (including, for example, by leap-frogging to cleaner and more efficient forms of industrial development).

For Asia, with its urgent development and poverty reduction needs, decision-makers have the opportunity to take advantage of these benefits, and in so doing, avoid some of the fossil fuel dependency and associated greenhouse gas emissions of 'business as usual' development.

7.3. South Asia 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, employment, limiting pollution and providing clean safe water.

Climate mitigation policies can be established in ways that maximise synergies with development goals – in Asia including South Asia, where considerable development infrastructure is still due to be built in the years ahead, there are particularly opportunities to invest in infrastructure that is low carbon from the offset, rather than polluting and fossil fuel dependent.

Assessing the co-benefits of mitigation policies involves looking at positive synergies with development policies but also understanding where mitigation policies and development policies may clash. The IPCC's overall message is that mitigation involves both benefits and risks to development and 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.

A government policy or a measure intended to achieve one objective (such as climate change mitigation) will also affect other objectives (such as local air quality). To the extent these side effects are positive, they can be deemed 'co-benefits'; otherwise, they are 'adverse side effects'.

Climate change 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 effects 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.

Image:
iStock | Solar panels

7.4. Policy options for climate mitigation are wide-ranging

Understanding how the mitigation options set out in the *Fifth Assessment Report* could inform policy making in Asia is not simple. The mitigation options proposed in the report are geographically very general. However, the report recommends broad policy options that could facilitate mitigation.

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 or encourage 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. The *Fifth Assessment Report* stresses the importance of synergies between policies. as countries also have other developmental objectives to consider. Mitigation policies can either benefit their development objectives or hinder them.

Legal frameworks provide governance – clarity, transparency, enforceability – for mitigation and how governance operates 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 laws.

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 emit more over their life-cycle 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 make them more inclined to acknowledge risks.

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.

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

Education and human resources: Effectively implementing mitigation policies and measures depends on having people with the right skills to do so, and citizens that acknowledge the risks and benefits. Decision makers can gear education systems to provide the skills in mitigation technologies and to teach citizens about climate change and the risks of climate change. Education initiatives can also campaign for behaviour changes (i.e. increased recycling, changes to consumption patterns or greater use of non-polluting vehicles etc.) which can influence mitigation efforts.

Population: The *Fifth Assessment Report* shows that most of the rise in emissions from Asia stems from an increase in the use of fossil fuel resulting from population and economic growth. 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: 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

Image: iStock | Solar cooker, Nepal

institutional perceptions that putting systems to mitigate emissions in place is irrelevant. Institutional reform could build human (technical) capacity, remove dis-incentives that promote inefficiency and strengthen capacity to implement policies.

Material resources: Access to capital (machinery) or resources (wind to power wind farms or rare earth minerals to produce solar photovoltaic panels) may not be available. 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 Asia 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.

Table 4: Summary of mitigation options across sectors, from the *Fifth Assessment Report*[138]

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 • Subsidised loans
Regulatory approaches	• Efficiency of environmental performance standards • Renewable portfolio standards for renewable energy	• Fuel economy performance standards • Fuel quality standards • Greenhouse 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	

Beyond the *Fifth Assessment Report*: Urban and peri-urban agriculture and forestry in Sri Lanka[139]

The Western Province in Sri Lanka is the most urbanised province in the country. Rapid urban growth has posed a number of problems. Increasing vehicle traffic and commercial industries have contributed to increased environmental and air pollution. Food and construction are two major sources of greenhouse gas emissions, including those generated through transport. Large areas of agricultural lands have been converted for residential and commercial land uses, significantly altering natural water flows and drainage. This, coupled with an increase in average rainfall as well as heavy rainfall events, has resulted in recurrent flooding and related damages to infrastructure, utility supply and the urban economy.

The Western Province is promoting urban and peri-urban agriculture and forestry as a strategy to reduce vulnerability to climate change, while at the same time enhancing urban liveability and livelihoods. It is the first provincial government in Sri Lanka to include urban and peri-urban agriculture and forestry in its climate change adaptation action strategy.

Image: RUAF Foundation | Seedlings distributed from nursery, Sri Lanka

The province is promoting the rehabilitation of flood zones through their productive use for urban farming, as a strategy to improve storm water infiltration and mitigate flood risks. The provincial government also supports local agriculture to reduce dependency on imports, to lower greenhouse gas emissions and energy requirements for food production, transport and storage, and to improve local food security and livelihoods.

Future up-scaling of these interventions will need new urban design concepts and the development of a provincial climate change action plan. In parallel, local and national policies will need to be revised to ensure that they are supportive and not at cross-purposes with local efforts to integrate climate adaptation, mitigation and development. Achieving progress at the policy level will require improved impact monitoring and awareness raising at all levels of government, together with extended partnerships, capacity-building and local financing.

Beyond the *Fifth Assessment Report*: Achieving adaptation, mitigation and development

Conservation agriculture and agroforestry. The IPCC notes that since its last assessment, Asia has accumulated experience in integrating pro-poor adaptation and mitigation into development via carbon-offset schemes that use agroforestry, farmer-assisted tree regeneration and conservation agriculture. These kinds of sustainable land management programmes are particularly useful when it comes to integrating adaptation and mitigation with ongoing development. However, the suitability of on and off farm techniques for integrating adaptation and mitigation depends on environmental, political and institutional factors.

Agroforestry systems store carbon and could prevent soil erosion, build resilience against floods, landslides and drought, increase soil organic matter and soften the financial consequences of crop failure. Agroforestry is also more biodiverse than most other agricultural systems.[140]

Reforestation would need to consider the effects of changes in climate. For example, reforestation relying on one tree species would be more susceptible to changes in climate than reforestation involving several species.

Image: iStock | Seedlings for reforestation

Adaptation measures could support mitigation; for example, a project to prevent fires or restore degraded forests would also prevent the release of greenhouse gases.[141] Growing biofuel crops on abandoned and marginal agricultural land could make a significant contribution to mitigating carbon emissions from fossil fuels.[142] Mechanisms, such as the United Nations reducing emissions from deforestation and degradation (REDD+) programme that put a price on land-use emissions, could reduce the risk of negative consequences, but incentive structures would need to be worked out carefully.[143] New initiatives aim to deliver multiple benefits – less poverty, restored ecosystems – and profit from carbon markets. However, carbon-offset systems involving community forestry require supportive land-use policies.

Urban planning provides another area for potential synergies among climate mitigation, adaptation and development. Cities in South Asia are expanding rapidly. Many city planners advocate for more compact city structures that would accommodate South Asia's growing urban population while curbing greenhouse gas emissions by reducing the need for transport. However, compact urban development may conflict with adaptation strategies, such as providing urban green spaces to counter urban heat island effects and moderate storm water run-off by increasing water filtration into the soil. Typical adaptation responses in urban heat islands involve installing air conditioning to maintain tolerable indoor comfort levels, but air conditioning contributes to greenhouse gas emissions. Displacement, especially of the urban poor, destruction of property and loss of livelihoods are common impacts of storm surges. Protection against storm surges requires heavy investment in flood defences, sea walls or drainage channels.

Planners need to consider the higher temperatures and changing rainfall patterns that climate change will bring need when designing urban infrastructure, in order to prevent damage from extremes, and lessen disruption to businesses and inhabitants. Smart adaptation to current and future climate stresses affecting South Asian cities is an imperative. Plans for low-carbon infrastructure and land use must harmonise with needs for adaptation.

"By upgrading the drainage system in Mumbai, losses associated with a 1-in-100 year flood event today could be reduced by as much as 70%"
IPCC[148]

Box 14: Gaining development benefits from climate mitigation and avoiding adverse effects

The IPCC highlights many of the substantial development benefits that low-carbon development can achieve. The *Fifth Assessment Report* also warns that mitigation action can pose risks to development if not managed carefully.[144] It states: "Climate policy intersects with other societal goals creating the possibility of co-benefits or adverse side effects. These intersections, if well managed, can strengthen the basis for undertaking climate action."[145]

For example, new techniques to deliver climate-smart agriculture – especially if they involve changes in land tenure and land-use rights – bear the risk of marginalising smallholder farmers and forest users. However, given appropriate arrangements and incentives to manage these risks, such measures could provide social benefits and promote equity.[146]

Identifying the downside risks of mitigation action and ensuring that low-carbon choices support inclusive, sustainable development requires robust institutions and decision-making processes.

7.5. Immediate action on adaptation and mitigation has many benefits – and lowers costs

Climate change calls for new approaches to sustainable development that take into account the complex interactions between climate and social and ecological systems. Climate-resilient approaches combine adaptation and mitigation to realise sustainable development. These approaches are iterative and continually evolve to manage change.[147]

With sustainable development as the ultimate goal, mitigation approaches could limit climate change to moderate rather than extreme levels. Adaptation approaches could anticipate and manage impacts that are unavoidable under future climate-change scenarios. In most cases, climate-resilient sustainable development will involve building capacity for managing risk. Responses will differ from situation to situation, but all will call for a broad perspective that takes account of socioeconomic, cultural, biophysical and institutional contexts. Most situations share at least one fundamental characteristic – the threat to sustainable development is greater under substantial climate change than under moderate climate change. Likewise, opportunities for sustainable development are greater under moderate climate change than under substantial climate change.

Beyond the *Fifth Assessment Report*: Energy efficient, climate-resilient construction in Pakistan[149]

Monsoon flooding in 2010 and 2011 caused widespread damage across Pakistan. The Punjab Disaster Management Authority (PDMA) has realised that there is now an annual risk of flooding, and that they should be building homes that can withstand the impact of heavy rainfall. In 2012, the PDMA worked with private contractors on climate compatible construction guidelines to use in the design and development of model villages. These guidelines were tested at a village in Mianwali, a highly vulnerable area of Pakistan, and also circulated across provincial departments and sectors for consideration. The guidelines provide instruction on using building material and design practices that make houses energy efficient as well as able to withstand floods and earthquakes. The discussion with multi-sectoral agencies sparked interest in initiating construction codes and by-laws for rural areas in the future.

In an important partnership among the Government of Pakistan, the private sector, and others in the development community, these new guidelines are demonstrating the 'triple wins' of reducing greenhouse gas emissions, building resilience and promoting development.

Image: Mott MacDonald | Model climate compatible village, Mianwali, Pakistan

Mitigation actions have consequences that must be carefully managed

Climate-resilient pathways are strategies, choices and actions that reduce climate change and its impacts. These pathways involve ensuring that effective risk management and adaptation can be implemented and sustained (*high confidence, high agreement, medium evidence*). Adaptation and mitigation responses have the potential to both contribute to and impede sustainable development, and sustainable development strategies and choices have the potential to both contribute to and impede climate change responses. Both kinds of responses need to work together to minimise risks of disruptions from climate change. There may well be trade-offs between adaptation and mitigation, and between economic and environmental goals. In some cases, adaptation measures may increase greenhouse gas emissions, through more air conditioning based on fossil energy because of higher temperatures for example. Likewise, some mitigation measures may impede adaptation. For example, measures to cut emissions may reduce energy availability in countries with growing populations. In many cases, there are very close links between strategies for dealing with climate change and strategies for sustainable development.

Integrating adaptation and mitigation measures can, in some cases, bring both adaptation and mitigation benefits and benefit development (*moderately high confidence; medium high agreement, medium evidence*). In many cases, reducing the risks associated with climate change can enhance capacity to manage other risks.

If society does not take action on climate change today, we will limit our subsequent ability to respond

Both mitigation and adaptation are essential to manage the risks associated with climate change at all scales (*high confidence; high agreement, medium evidence*). Prospects for climate-resilient pathways depend on what happens globally to mitigate climate change. However, if climate impacts become so serious that communities and societies cannot adapt to them – then the opportunities for synergies between adaptation and mitigation will be lost.

Beyond a certain degree and rate of climate change, the impacts on most systems would be such that sustainable development might no longer be possible in many systems and locations. At the local scale, governments, businesses, communities and individuals in many developing regions have limited capacity to mitigate climate change because they contribute very little to global emissions. Their income, education, health, security, political power and access to technology may be such that they also have relatively limited capacity to adapt. At all scales, however, mitigation and adaptation measures are fundamental to effective climate risk management and reduction.

Nationally appropriate, transformative approaches may be needed[150]

Promoting climate-resilient pathways for sustainable development may involve significant transformation (*high confidence, high agreement, medium evidence*). Transformation in economic, social, technological and political decisions and actions can enable climate-resilient pathways. Although transformation may be reactive, forced or prompted by a variety of other factors, social and political processes can also deliberately bring about transformation and do so in ways that are appropriate to national contexts. It is possible to identify enabling conditions that support transformation in relation to mitigation, adaptation and sustainable development. Nonetheless, there are legitimate concerns about the equity and ethical dimensions of transformation. Climate-resilient strategies and actions pursued now will, at the same time, help to improve livelihoods, social and economic well being, and responsible environmental management (*high confidence; high agreement, medium evidence*). Actions can emphasise co-benefits and iterative learning. Risk management strategies and capacities can be continually refined as evidence, knowledge and experience accumulate.

Delays in action now may restrict options for taking climate-resilient paths in the future (*high confidence, high agreement, medium evidence*). In some parts of the world, failure to act has already eroded the foundations for sustainable development and offset earlier gains. The window of opportunity for devising climate-resilient pathways that also improve livelihoods, and social and economic well-being, is still open.

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

8.1. Opportunities in the agriculture forestry and fisheries sectors

South Asia's agriculture, forestry and fisheries sectors are vulnerable to climate change[151]

Agriculture and food security: Projections indicate that climate change could affect food security by the middle of the 21st century. Most of the people who would be food insecure would be in South Asia, where changes in climate could affect food production and food security because of a decline in agricultural productivity (*medium confidence*). In the Indo-Gangetic Plains, yields of wheat in the most favourable and high yielding wheat areas could fall by 50% because of heat stress. A rise in sea level could inundate low-lying areas and would especially affect rice-growing areas.

Understanding of the impacts of climate change on farming systems and cropping areas in Asia has improved since the *Fourth Assessment Report*. Crop production is likely to shift northwards as heat stress threatens current cropland (*medium agreement, medium evidence*). Cooler regions are likely to benefit from warmer temperatures leading to an increase in the arable area (*high agreement, medium evidence*). Food production and food security could be vulnerable to rising temperatures. Warmer temperatures could depress yields of major crops such as rice. However, warmer temperatures could also make some areas more favourable for food production and more carbon dioxide in the atmosphere could boost crop yields.

Rice, a key staple in the region, is most vulnerable in the northern part of South Asia but changes in climate may boost wheat production in parts of Pakistan where warmer temperatures would make it possible to grow at least two crops (wheat and maize) a year in mountainous areas. A rise in sea level could submerge and curtail production in many rich agricultural areas along coasts.

The *Fifth Assessment Report* identified more crop failures and lower productivity (*medium confidence*) because of higher temperatures, and temperature extremes, more frequent extreme rainfall and drying events, a rise in sea level and damaging cyclones as risks to food security in Asia. At present and in the near term (2030–2040), projections indicate that the risk of more crop failures and lower crop productivity is '*medium*' and could be reduced to '*low*' through adaptation. In the long term (2080–2100), projections indicate that the risk is '*high*' regardless of adaptation with 4°C warming, and '*high*' but could be reduced to '*medium*' through adaptation with 2°C warming.

Projected temperature rises of 1.5°C and 3°C could lead to a fall in wheat yields in some mountain districts of Pakistan and a rise in yields in others. In the Indo-Gangetic Plains, which produces 90 million tons of wheat a year (about 14–15% of global production), projections indicate a substantial fall in yields unless there is a shift to appropriate cultivars and crop management practices. Projections indicate similar trends for wheat across South Asia but no substantial change in rice yields, although rice growing could shift as rising sea level threatens coastal and deltaic areas, such as those in Bangladesh. In India, changes in climate could gradually reduce monsoon sorghum yields during the 21st century.

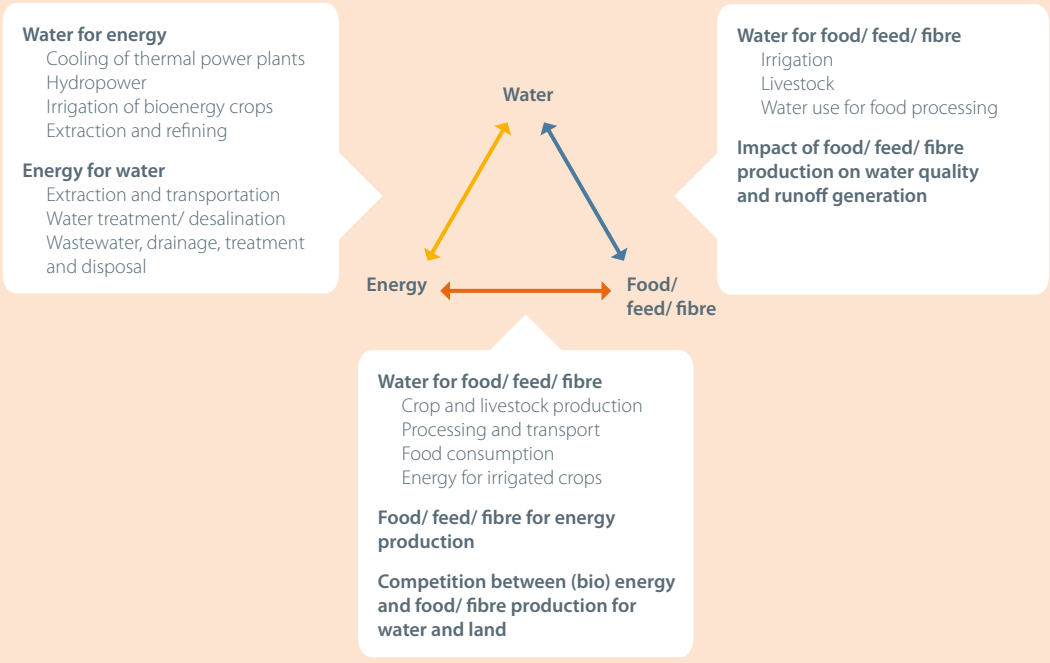
Fisheries and aquaculture: Fish production is a vital component of livelihoods throughout the larger Asia region and is important in South Asia. The effects of climate change on inland fisheries will be hard to separate from the ongoing effects of overfishing, loss of habitats, abstraction of water, drainage of wetlands, pollution and construction of dams. Most concern is about how rising water temperatures and changes in flow regimes could affect fish reproduction. Projections indicate that a rise in sea level rise could affect both capture fisheries and aquaculture in river deltas.

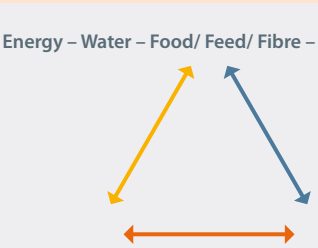
The negative effects of climate change on marine productivity could be substantial because coral reefs are vulnerable to both warming and ocean acidification caused by greenhouse gas emissions. Degradation of coral reefs is a key risk (*high confidence*). At present, the risk of coral reefs degrading is '*medium*' with or without adaptation. In the near term (2030–2040), the risk is '*high*' but could be reduced to '*medium*' through adaptation. In the long term (2080–2100), the risk is '*very high*' regardless of adaptation with 4°C warming and '*very high*' but could be reduced to '*high*' through adaptation with 2°C warming.

Box 15: The water, energy, food, feed and fibre nexus[152]

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.





Nutritionally appropriate low meat diet or low water consuming vegetarian diet generally reduces water and energy demand as well as greenhouse gas emissions per person.

Use of agricultural, livestock and food waste may reduce conventional energy use and reenhouse gas emissions.

Climate change tends to increase energy demand for cooling as well as water demand.

South Asia has adaptation options in its agricultural and forestry sectors – although relatively fewer options in fisheries[153]

Asia has longstanding experience in managing natural resources and biodiversity. Harnessing the experience gained in afforestation, rangeland regeneration, catchment rehabilitation and community-based natural resource management programmes could drive effective and ecologically sustainable local adaptation strategies (*high confidence*).

Managing natural resources to improve ecosystem resilience is a low-regrets adaptation strategy for vulnerable rural communities (*high confidence*). Two widespread practices that address desertification – natural regeneration of trees and water harvesting – build resilient ecosystems and help rural communities adapt to changes in climate. Community-based natural resource management groups have the flexibility to incorporate measures to adapt to changing climatic conditions into existing projects. Working on sustainable adaptation through these groups leverages synergies between ecosystem services and poverty reduction.

Given so many uncertainties in Asia, there are many low-regrets measures that build resilience and could lead to successful adaptation. The measures outlined in Chapter 6 above, such as clarifying use rights and involving stakeholders in planning, are particularly relevant to the natural resources sectors. National policies that disregard cultural, traditional and local issues could hamper adaptation. Narrowly conceived development and sectoral adaptation strategies could also risk lowering resilience in other sectors and ecosystems.

Many Asian countries take a holistic development approach to adaptation. They integrate programmes for combating land degradation, and managing water and irrigation, with strategies promoting sustainable agricultural practices and the use of appropriate technologies and innovations to address shorter growing seasons, extreme temperatures, droughts, and floods, and approaches to deal with water shortages, food security and loss of livelihoods.

Crop production: Options for adapting crop production to the impacts of climate change include:

- Technological adaptation responses (e.g. stress-tolerant crop varieties, efficient irrigation);
- 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-oriented policies; and,
- Agronomic adaptation responses (e.g. agroforestry, conservation agriculture (e.g. Sri Lanka urban agriculture, page 44).

Forests: Forests and forestry management often provide resilient livelihoods and lessen poverty. Secure rights to resources, such as reducing emissions from deforestation and degradation (REDD+) schemes that respect and promote community forest tenure, could help poor indigenous and traditional people to derive greater livelihood benefits from forests. Indigenous groups could bridge the gap between protecting biodiversity and adapting to climate change in ecosystems. An argument against REDD+ is that the schemes do not lessen poverty because they do not promote productive use of forests and so may trap communities in perpetual poverty. A contrasting view is that REDD+ schemes can work in forests that are managed for timber production, particularly when measures such as low-impact logging, assurances of the legality of forest products, certificates of responsible management and devolving control over forests to empowered local communities are in place.

Fisheries: Higher ocean temperatures and ocean acidification threaten coral reefs in the region and the millions of people who depend on them. There are not many options for adapting the management of coral reefs to climate change. Adaptation strategies to date have focused on minimising non-climatic pressures on natural resources. Identifying and protecting areas likely to suffer the least damage from climate change – such as marine protected areas where sea surface temperatures are expected to change least and where reefs are expected to be most resilient – could provide "climate refugia" or safe havens. Such refugia could minimise the effects of climate change on marine fisheries.

"Asia has longstanding experience in managing natural resources and biodiversity. Harnessing the experience gained in afforestation, rangeland regeneration, catchment rehabilitation and community-based natural resource management programmes could drive effective and ecologically sustainable local adaptation strategies (*high confidence*)."
IPCC[154]

Table 5: 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 or structures that contribute to risk and vulnerability or impede practical transformation, changes in beliefs, worldviews that influence climate change responses

Source: See Table 1, above.

South Asia's agriculture, forestry and land-use change are a source of greenhouse gas emissions

Agriculture, forestry and other land use are important for mitigation because plants sequester carbon dioxide (CO_2) from the atmosphere into biomass and soil. Plants also release greenhouse gases – CO_2, methane (CH_4) and nitrous oxide (N_2O) – by 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 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 between 1970 and 2010. Livestock rearing also increased, contributing to a rise in methane emissions, particularly in Asia. Global daily per capita food availability also increased, and in Asia increased by 32%. Consumption of animal products also increased in Asia (from 7% of food consumption to 16%) and decreased in OECD90 countries.[155] Land is one of the most important resources in the agriculture, forestry and other land use sector. Because land provides food, fibre and fuel, supports livelihoods and because land is a finite resource, mitigation measures can have positive or negative social, environmental or economic effects.

The *Fifth Assessment Report* indicates that it is difficult to differentiate between natural emissions and emissions caused by humans in the agriculture, forestry and other land use sector. One reason is that it is difficult to gather the data needed to estimate emissions and another is that methods of estimation can be quite different, which means that the results seldom agree.

The larger Asia region as a whole (including South Asia) is the region that emits most greenhouse gases from the agriculture, forestry and other land uses. Direct emissions from Asia increased up to 2010. Between 1990 and 2010 the area of forested land in Asia showed relatively little change, the area of pasture increased slightly and the area of cropland increased. Asia used more fertiliser than any other region. There were also more livestock in Asia than in any other region and the number of all types of livestock increased.

Livestock: Globally, emissions from livestock (enteric fermentation) grew from 1.4 Gt CO_2eq a year to 2.1 Gt CO_2eq emissions a year between 1961 and 2010. The average growth of emissions was 0.7% a year. Emissions slowed in

iStock | Forests, Western Ghat mountains, India

the 1990s but picked up again in the 2000s. Around 75% of total emissions were from developing countries, with Asia making the largest contribution. Between 1961 and 2010, emissions rose by an average of 2% a year. Cattle, buffalo, sheep and goats accounted for most enteric emissions up to 2010.

Manure: Globally, emissions from manure nearly doubled between 1961 and 2010. Most of the increase in emissions from manure was due to the increase in the number of livestock rather than because manure was used as a fertiliser. Developing countries accounted for 80% of the emissions from manure and Asia, together with Africa and Latin America, was one of the main sources. Emissions from manure in Asia increased by 2.3% a year 1961–2010 and emissions from manure used as fertiliser were higher in Asia than in any other region, although the annual rate of growth was lower than in Africa.

Fertiliser: Globally emissions from synthetic fertiliser increased nine-fold between 1961 and 2010. Emissions from synthetic fertiliser will likely continue to rise and overtake emissions from manure in the long term. The *Fifth Assessment Report* indicates that developing countries are a major source of emissions from synthetic fertiliser. Emissions from fertiliser in Asia increased more quickly (5.3% a year) than from any other region.

Rice: Emissions from paddy rice rose from 0.37 Gt CO_2eq a year in 1961 to 0.52 Gt CO_2eq a year in 2010. Emissions from Asian paddy rice slowed to 0.4% a year, matching the global slowdown in rice emissions.

Forestry and other land uses: Non-agricultural emissions from forestry and other land use accounted for 12% of anthropogenic emissions in 2009. Estimates of trends vary widely. Overall for Asia, non-agricultural emissions are, by the highest estimates, the second highest globally after Latin America and, by the lowest estimates, significantly higher than OECD90 countries. The mean of estimates indicates that in 2000 Asia and Latin America emitted most non-agricultural greenhouse gases from forestry and other land uses.

Climate mitigation action in South Asia's agriculture and forestry sectors can bring significant benefits – and risks which must be managed carefully

The main opportunities for mitigating climate change in the agriculture, forestry and other land use sector are to remove greenhouse gases and reduce emissions by managing land and livestock differently. Taking these opportunities could be cost-effective but would require large scale changes in

the ways in which land and energy are used. Such changes would have implications for sustainable development, for example choosing between producing biofuels or food crops or limiting the expansion of agriculture in order to conserve forest.

Mitigation in agriculture, forestry and other land use could contribute between 20% and 60% to total abatement by 2030 and between 15% and 45% by 2100. A quarter of anthropogenic greenhouse gas emissions are from agriculture, forestry and other land use, mostly from deforestation and agriculture. The potential for mitigation is uncertain since it depends on factors such as population growth, economic and technological developments, changes in behaviour and demand for food, fodder and fuel, as well as developments in agriculture, aquaculture and forestry. Changes in soil and forest carbon stocks, biodiversity, conservation, land degradation and water scarcity will also have an influence. Mitigation in the agriculture, forestry and other land use sector focuses on three strategies:

1. Reducing and preventing atmospheric emissions of greenhouse gases, conserving existing carbon stocks in soil or plant matter and reducing methane and nitrous oxide emissions. For example by:
    - Conserving carbon in vegetation and in soil – controlling deforestation, forest fires and pests;
    - Sustainably managing timber production – reducing damage from logging, reducing waste and conserving soil; and
    - Reducing carbon losses from biota and soils – improving land management and land use practices.
2. Sequestering greenhouse gases, increasing the amount of carbon stored in reservoirs and removing CO_2 from the atmosphere. For example by:
    - Increasing biomass – afforestation and reforestation;
    - Increasing the capacity of forests to sequester greenhouse gases – restoring and protecting degraded forests;
    - Increasing the carbon sequestration in biota and soils – increasing the density of vegetation in forests.
3. Replacing fossil fuels and energy-intensive products. For example by:
    - Replacing high-emissions products with low-emissions products – replacing concrete and steel with wood, and fossil fuels with biofuels.

Certain climate mitigation approaches integrate all three strategies. Agricultural practices that use less fertiliser, store more carbon or involve less carbon-intensive inputs could be applied to both cropping and grazing. Improvements in agricultural water efficiency could reduce nitrous oxide emissions from excess nitrogen fertiliser in irrigation run off. Changes in livestock management practices to reduce methane emissions could be especially important in Asia because of the number of livestock in the region.

Reversibility and permanence: Agriculture, forestry and other land use play fundamental roles in mitigation emissions by retaining carbon in vegetation. Permanence and reversibility indicate the effectiveness of mitigation. For example, sequestered carbon released into the atmosphere reverses initial sequestration. Similarly, uncontrolled or accidental forest fire could reverse the positive effects of afforestation. Reducing the use of fertiliser and thus emissions of nitrous oxide or switching from fossil fuel to bioenergy, however, could be permanent. The longevity of the stock used to sequester carbon – how long carbon remains sequestered – also determines permanence.

Saturation and leakage: Saturation is another factor in mitigation. Carbon sequestration in both soils and vegetation cannot continue indefinitely – when soil and biomass carbon reach equilibrium no new carbon is sequestered. Some theories, however, propose that saturation may not actually happen. Human and natural processes could either improve retention, such as by forestation, or reduce it, such as by burning. Finally, displacement and leakage – changes in land use in one place that could have a negative or positive impact on carbon stocks elsewhere – are also factors.

Trade-offs: Each opportunity for mitigation in agriculture, forestry and other land use has ecological and socioeconomic consequences. Mitigation objectives may affect other, sometimes conflicting, objectives. There may be conflicts between demand for food and bioenergy driven by economic and population growth (see Box 16, 'Bioenergy'), or between demand for land for urbanisation and conservation. Climate mitigation activity in the forestry sector could displace food production, and affect food prices and food consumption. Loss of food production incurred by converting agricultural land to forest could be minimised by improving agricultural yields elsewhere but certain intensification methods could also lead to nutrient leaching or soil degradation.

Demand-side options in the agriculture, forestry and other land use sector that could drive mitigation include:

- **Reducing losses along the food supply chain:** Globally, 30–40% of food produced is lost between harvest and consumption. In developing countries, food losses, mainly in transportation, storage and distribution, are as much as 40%. Unavoidable loss, for example inedible parts of food crops, account for around 18% of all food waste. Investment in improving harvesting, and storage and transport systems

and facilities, together with campaigns to change household consumption patterns, could minimise food waste.

- **Changes in diets:** Greenhouse gas emissions for most plant-based food products are lower than for animal-based food products. Changes in diet could have a significant effect on emissions. A switch from livestock products to crop, vegetable and fruit products could lower emissions. Projections for emissions from livestock production under business-as-usual scenarios indicate 15.3 Gt CO_2eq/yr by 2055. This could fall to 9.8 Gt CO_2eq/yr by improving livestock management, to 4.3 Gt CO_2eq/yr by reducing livestock production, and to 2.5 Gt CO_2eq/yr by combining improvements in livestock management with reducing livestock production. A benefit of changes in diets away from animal-based food products could be better health in regions where consumption of animal products is high.
- **Management of wood fuel supplies:** Switching from fossil fuel to fuels based on wood for energy or heating may not reduce emissions unless the wood harvested (carbon store) is replaced. Recycling paper, or more use of wood from sustainably managed forests, could help reduce emissions. Using wood products with a long life, such as long-lasting construction materials, and using by-products or waste to generate energy, could also help reduce emissions.

Economic mitigation potential: The economic mitigation potential is the potential that could be realised at a given carbon price over a specific period. Economic potential tends to be context-specific and complicated to quantify because of competing land uses and ecosystem services.

At the global level, restoring organic soils has the most economic potential (US$100/t Co_2eq). Improving management of cropland has less economic potential (US$20/t Co_2eq). Asia has some of the highest economic mitigation potential of all world regions, and particularly in restoring cultivated organic soils and degraded land. The highest economic mitigation potential in Asia is in forestry management and afforestation, although reducing deforestation also has significant potential and should not be discounted.

Barriers to mitigation in agriculture, forestry and other land use sectors can be overcome

Access to finance, poverty, institutions, technologies, and diffusion and transfer mechanisms could hinder efforts to mitigate climate change in the agriculture, forestry and other land use sectors.

Socioeconomic: Access to finance, poverty, and cultural and social values are potential barriers to mitigation. Appropriate design and coverage of financing mechanisms could overcome the barrier of access to finance. Arrangements could be made to cover transaction and monitoring costs that might be a barrier to mitigation. Finance for small and medium enterprises and farmers, the most likely to need funds for mitigation, could be particularly problematic in Asia. Poverty is a barrier as priorities for the poor are food and education rather than mitigation. Culture also influences the acceptability of mitigation measures and is a barrier that is context-specific.

Institutional: Rights to land, tenure arrangements and limited institutional capacity can prevent enforcement of mitigation measures and make it difficult to assign responsibilities for carbon emissions.

Ecological: Land and water resources are finite. Climate change mitigation is one among many demands on land and water. Region-specific water and soil conditions and region-specific mitigation potential could limit the effectiveness of mitigation measures.

Technological: Technologies to improve cropland management and afforestation are already widely used. Other technologies are still being developed. Technological barriers could be overcome by strengthening abilities to adapt and apply mitigation techniques to local conditions.

South Asia can benefit widely from mitigation in the agriculture, forestry and land use sectors, but must also manage the risks

Climate change mitigation policies in agriculture, forestry and other land use will inevitably affect policies in other sectors, both internationally and nationally. Linking policies in sub-sectors such as forestry and land will be particularly important since the sub-sectors are closely related. Policies will be likely to be more successful if they address these relationships. Policies fall into three categories: economic, regulatory and informational.

Economic incentives: Emissions trading schemes (both voluntary and enforced) can help reduce carbon emissions by monetising emissions as a tradable commodity. However, the success of trading schemes depends on how they are designed, funded and implemented. Official international schemes have operated under the Kyoto Protocol. National and voluntary carbon trading schemes tend to operate independently. Incentives to reduce emissions from deforestation, such as reducing emissions from deforestation and degradation (REDD+), include financial incentives for reducing deforestation, improving forest management and afforestation. Taxes and subsidies, such as taxes on nitrogen to reduce the use of nitrogen-based fertilisers, could be used to control emissions.

Regulatory approaches: Regulations controlling deforestation and land use could help decrease the rate of deforestation. This approach could be particularly applicable in Asia. Controlling deforestation would be one of the more cost-effective mitigation options. Policies to control agricultural expansion could limit deforestation and protect biodiversity. Environmental regulations could help deal with

pollution. Bioenergy targets (Box xy) could improve energy sustainability and reduce greenhouse gas emissions from producing energy.

Eco-labelling and consumer awareness: Less than 2% of Asia's forest is certified for its sustainable management practices. Certification schemes could be an effective way to spread and implement mitigation measures in forestry. However, the cost of developing and rolling out such schemes determines their efficiency. Communicating policies and educating stakeholders about certification involves creating new organisations or adapting existing organisations to facilitate knowledge flows and to set up schemes to support sustainable forestry and agricultural practices.

Mitigation actions in agriculture, forestry and other land use sectors could affect economic, social or institutional development objectives. The benefits and risks will depend on the development context as well as the design of the specific mitigation intervention. Generalising the effects is difficult; however, a general principle holds: maximising development benefits could make mitigation measures more efficient.

Mitigation measures that change land tenure and land use rights could affect groups that depend on natural resources. A 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 policies in other sectors but could also clash with them. 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.

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 will 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.

Box 16: 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 populations. Asia also 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 Asia. Releasing carbon into the atmosphere by burning biomass reduces carbon stocks. Shifting land use from forests to biofuel production could threaten biodiversity.

Twelve countries in the Asia-Pacific region have set bioenergy targets. These countries are developing bioenergy in order to meet a range of development objectives – in 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, or between commodities such as vegetable oil or food and biofuel. Developing biofuels can also lead to international trade disputes. Some countries have already limited imports of biofuels and some subsidise national biofuel production.

Table 6: Climate mitigation policy in the agriculture, forestry and land-use sectors: benefits and risks[156]

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

South Asia has ample opportunities to integrate combined adaptation-mitigation approaches in the agriculture, forestry and fisheries sectors

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 would bolster climate resilience.

Even 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. Waste-to-compost projects in Bangladesh take advantage of adaptation-mitigation synergies.

Agroforestry systems have the potential to both mitigate climate change and help adapt to climate change, depending on how the changes are made. Agroforestry systems store carbon and could prevent soil erosion, build resilience against floods, landslides and drought, increase soil organic matter and soften the financial consequences of crop failure. Agroforestry is also more biodiverse than most other agricultural systems.

Since the *Fourth Assessment Report* Asia has accumulated experience in integrating pro-poor adaptation and mitigation into development, many of which involve sustainable land management. Farmers and local communities participate in carbon offset schemes that involve agroforestry, farmer-assisted tree regeneration and conservation agriculture programmes. The suitability of on- and off-farm techniques for integrating adaptation and mitigation with ongoing development depends on environmental , political and institutional factors. New initiatives aim to deliver multiple benefits – less poverty, restored ecosystems and profit from carbon markets. For instance, Reduced Emissions from Deforestation and forest Degradation (REDD+) programmes may provide a source of revenue from public and/or private sources. However, carbon offset schemes involving community forestry require supportive land use policies in order to improve the income and wellbeing of local people.

8.2. Opportunities in the energy sector

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

Climate change will affect energy sources such as water, wind and solar radiation, and energy technologies differently, depending on the resource, the process, for example cooling, and the location, for example coast or floodplain (*high agreement, robust evidence*). Gradual changes in temperature, rainfall, wind and cloud cover, and changes in the frequency and intensity of extreme weather events will have cumulative effects. Climate-induced changes in the availability and temperature of water for cooling are the main issue for thermal and nuclear power plants, and may increase costs. Climate change may also have an effect on the integrity and reliability of pipelines and electricity grids (*medium agreement, medium evidence*).[157]

Solar energy: All forms of solar energy are sensitive to changes in sunlight. For example, an increase in cloud cover would reduce the intensity of solar radiation and hence the output of heat or electricity. Solar power installations may also be vulnerable to harsh weather.

Thermal energy: Rising temperatures and decreasing water availability will lower the efficiency of thermal power generation.

Hydropower: Hydropower is currently by far the largest source of renewable energy globally. Assessing the effects of climate change on hydropower is complicated. Competition for water because of changes in population and economic activities (especially irrigation) is difficult to predict.

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

South Asia's energy sector emissions are increasing rapidly

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 total *global* primary energy supply grew by 27% or 2.4% a year, but after 2010 slowed to 2% a year. The highest rate of growth was in Asia. The growth in coal consumption in South Asia was driven mainly by India, the fifth largest coal producer in the world. South Asia accounted for 44% of the global growth in energy consumption between 2001 and 2010.

For the Asia region as a whole, consumption of oil has risen over this period and has not countered falling demand in OECD90 countries. Oil's share of the global energy supply fell between 2001 and 2012. Demand for both conventional and non-conventional oil in Asia, however, has spurred the growth of a global oil market and has raised concerns about oil prices and the security of oil supplies in countries where demand for oil is growing.

From 2001–2010, consumption of natural gas grew most rapidly in Africa and Asia. The low density of gas means that transport and storage account for a large part of the total cost. International trade in liquefied natural gas now accounts for 32% of the global gas trade.

By 2010, renewable energy accounted for 13.5% of the 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.

By 2010, the energy sector accounted for 35% of anthropogenic greenhouse gas emissions. Greenhouse gas emissions from the energy sector grew faster 2001–2010 than in any previous period. Between 1991 and 2000, emissions rose by 1.7% a year and between 2001 and 2010 they rose 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 emissions from South Asia was partly due to significantly more emissions from India, which now emits more greenhouse gases than Russia.

The rise in energy emissions is partly due to population growth. The *Fifth Assessment Report* indicates that population growth accounts for 39.7% of the rise in greenhouse gas emissions. Slow decarbonisation of global energy led to the paradox whereby 2001–2010 saw carbon mitigation policies put in place at the same time as emissions were growing at the fastest rate for around 30 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 Asia increased 16.8 times between 1970 and 2010. Emissions from producing electricity, heat and from refining petrol rose the most quickly, although emissions from fuel production and transmission continued to be important. In 1990, energy supply sectors in OECD90 countries were the largest emitters of greenhouse gases. However, by 2010, Asia dominated energy supply emissions. Asia had the highest rate of growth in emissions from the energy supply sector 2001–2010 (7.89%) because of high growth rates and more use of fossil fuel.

Box 17: 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.

South Asia has options to invest in clean energy and avoid emissions

Lessening the severity or intensity of changes in climate will mean limiting and reducing CO_2 emissions generated in the production of energy. This will involve replacing fossil fuels with renewable or nuclear energy, and reducing emissions from extracting, transporting and converting fossil fuel into energy: namely, improving energy production efficiency; and reducing energy transmission losses. Measures to reduce emissions could boost countries' energy security and reduce dependence on imported and increasingly costly fossil fuels.

Without mitigation, CO_2 emissions from the energy sector will continue to rise. Emissions from fossil fuel will rise from the current 55 $GtCO_2$ a year (globally) to 70 $GtCO_2$ by 2050. The mitigation options presented in the *Fifth Assessment Report* focus on electricity but could also apply to heating or transport. The principal options presented are:

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 7) 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

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

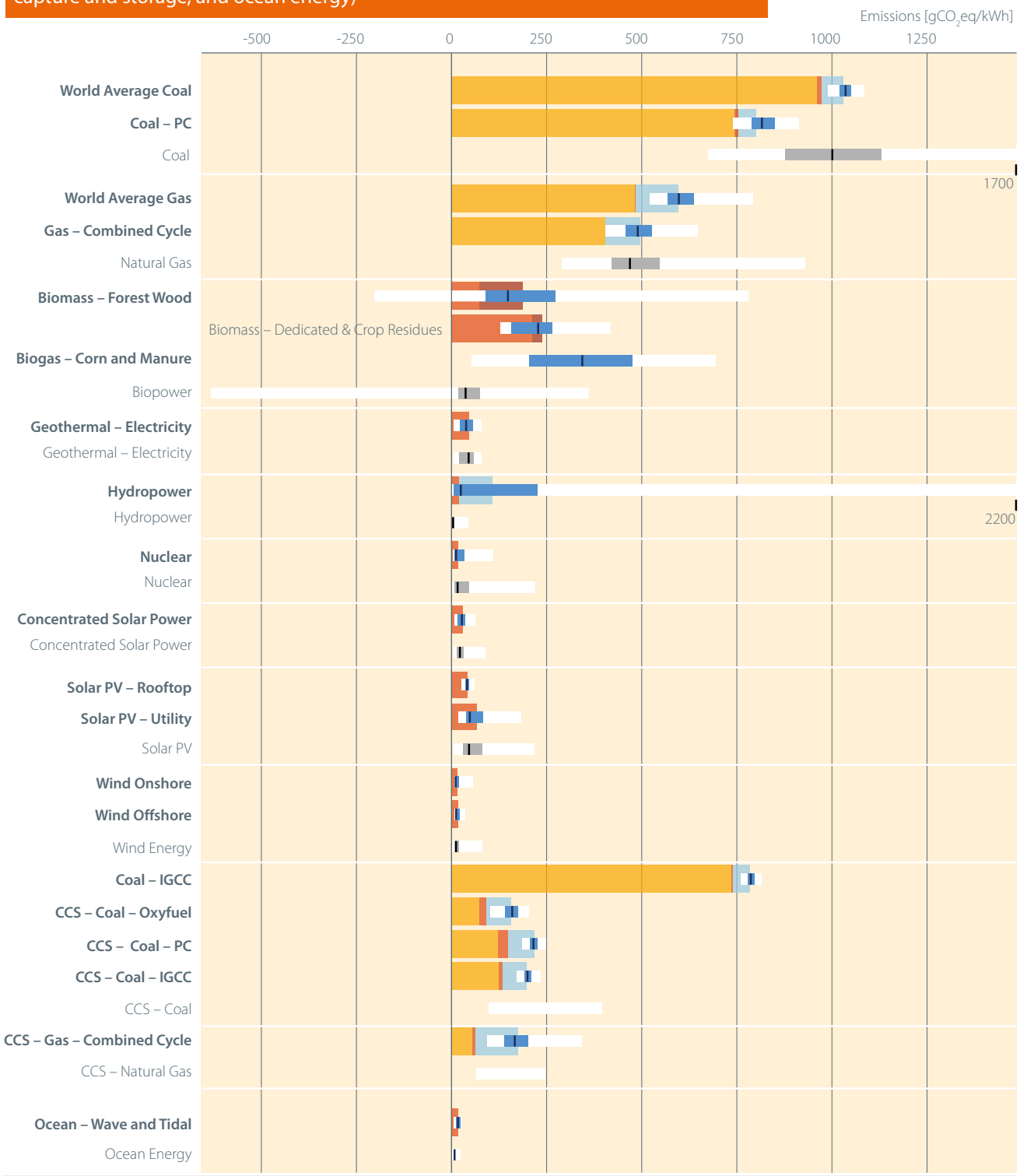
Asian countries already generate some electricity from large and decentralised photovoltaic systems. Life-cycle emissions from hydropower plants vary widely depending on the construction materials used. Large hydropower schemes would emit more than small run-of-the-river dams.

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. 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%. For Asia, 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 Asia 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

Figure 7: 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)[158]



25th percentile 75th percentile

Minimum Median Maximum

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.

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 technologies for extracting relatively lower-carbon fossil fuel reserves: Hydraulic fracturing and horizontal drilling technologies (fracking) in the gas sector have increased energy 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 Asia.

Preventing emissions: Fugitive emissions (unintended releases) contribute to air pollution and climate change. Reducing fugitive emissions, especially of methane, include preventing leaks in gas pipelines. Preventing fugitive emissions could be important given that many coal-based energy systems will or already are switching to gas as the price of gas falls and the global market for gas grows.

Improving electricity transmission and distribution: Losses in electricity 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 could help lower losses and related emissions because less electricity would need to be produced and electricity generated would be more efficiently distributed.

Nuclear energy: Nuclear electricity accounted for 11% of global electricity generation in 2012. The growing demand for electricity, the need to diversify energy production and to meet greenhouse gas emission targets are strong drivers for investment in nuclear energy. Currently, 69 nuclear power plants are being built in 14 countries. Although emissions from nuclear reactors are lower than from fossil fuels, there are issues of nuclear proliferation and nuclear waste management to consider. Estimates of nuclear energy potential are based on current extraction technologies. *Globally*, current resources are estimated to be sufficient to meet demand for more than 130 years, or up to 250 years if all known uranium sources are taken into account. Other materials such as thorium and recycled (from spent uranium) plutonium could also be used to power nuclear generators.

Carbon capture and storage: The technologies to capture and store carbon to produce energy are not yet commercially viable. Currently, on a worldwide scale, there are only 13 carbon capture and storage facilities serving industry although more are likely. Research into making carbon capture and storage viable for generating electricity is underway but there are concerns about the long-term integrity of CO_2 stores, the toxicity of stored carbon and operational safety. Carbon capture and storage at a scale large enough to be significant in reducing greenhouse gas emissions would need to use large, deep basins and serve several regions. Mitigation technologies such as carbon capture and storage could reduce CO_2 emissions from coal-fired power stations by 70–290 gCO_2eq/kWh and by 120–170 gCO_2eq/kWh from natural gas power plants.

Infrastructure upgrades: Reducing emissions in the energy sector will require significant investment in infrastructure to balance energy demand and supply. Insufficient power can hinder economic and social progress. Supplies from renewable energies such as wind power are variable meaning that energy systems would need to connect several sources of energy in order to ensure reliable supplies. Investing in high upfront but low operating cost technologies such as nuclear power could guarantee base-load electricity supplies. Storing energy could become important in balancing supply and demand, for example, storage dams for hydropower systems.

Existing infrastructure would need to be made more robust and efficient in order to transmit and distribute renewable energy. Upgrading infrastructure would allow distribution of excess power to areas where there is demand. Decentralised systems are often more technically and economically practical in developing countries such as Nepal but emissions from energy supply systems would rise as demand for energy rises and would also need to be taken into account. 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.

Mitigation action in the energy sector provides benefits and also risks that must be carefully managed

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: 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 in Asia could include wider access to energy through decentralised renewable energy systems, benefitting productive sectors such as agriculture. Developing biofuels could also stimulate rural growth in Asia.

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 benefits.

Broader sustainability aspects of low-carbon energy development: Hydropower could play a key role in alleviating energy poverty. However, investment in hydropower needs to consider environmental and social sustainability, equitable sharing of costs and benefits, and climate-proofing infrastructure. International development investment supporting hydropower projects needs to ensure that they do not result in maladaptation (see *Glossary*). Producing biofuel also has positive implications for energy security and economic growth. However, large-scale biofuel production in Asia carries significant risks for environmental and social sustainability (see section 8.1., Agriculture).

Barriers to mitigation in Asia's energy sector: The main barriers to mitigation in the energy sector are financial and technical. Investment in renewable energy in developing countries fell by 29% in 2012. Financial markets to provide capital (such as loans) for investment in renewable energy are not well developed. The scarcity of technical skills is also a constraint. Education systems do not produce enough 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 existing infrastructure is still commercially and technically viable.

Reducing CO_2 concentrations from the energy sector would be easier to achieve by improving efficiency and curtailing demand, as fewer emissions would be generated. Where demand for energy continues to grow, stabilising emissions would require rapid replacement of fossil fuel energy by renewable energy.

Table 8: Energy mitigation policy co-benefits and risks[159]

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

Image: iStockphoto | Agriculture, Jaipur, India

A range of policy options can support clean energy development in South Asia

Policies to stabilise greenhouse gas concentrations combine economic, regulatory and informational measures.[160]

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. The European Union's Emissions Trading Scheme is probably the most important of these schemes. Taxes allow emitters to save money by cutting emissions. Only six countries have implemented taxes on emissions. In the long term, carbon pricing should reduce emissions if sufficiently stringent caps are set, and would support low-emission energy technologies.

Regulations: Rules setting targets for low-carbon technologies allow companies to assess whether or not 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.

8.3. Opportunities in the transport sector

South Asia's transport sector is vulnerable to climate change impacts

Generally, 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. Little is known about the relationship between mitigation and adaptation in the transport sector.

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 be less safe.

Changes in sea or river levels because of climate change may affect shipping routes. Where routes become shorter there could be a positive effect on emissions but where they lengthen, the effect could be negative. New routes

could also increase pollution if emissions are not regulated. Climate change will shift agricultural production, which means that freight routes will also change. Food chains could shorten or lengthen.

The *Fifth Assessment Report* does not present adaptation options for the transportation sector and therefore, they are not covered here, but rather, more detail is given below about the mitigation and development opportunities in the sector.

Emissions from Asia's transport sector as a whole are burgeoning

The IPCC does not provide disaggregated emissions data for the South Asia sub-region but only for Asia region as a whole, and for OECD90 versus non-OECD90 countries.

Transport emissions from non-OECD90 countries will probably be twice as much as transport emissions from OECD90 countries by 2050. Emissions from cars will likely stay at lower levels in non-OECD90 countries than in OECD90 countries. Most emissions from transport in developing countries will be from public transportation.

Reducing emissions from transport will be difficult given growing demand and existing investment in vehicles and infrastructure in developing countries. As countries shift from agriculture to industry, and subsequently into services, emissions from transport and the share of emissions from transport rise significantly. Car ownership is also expected to double – globally – in the next few decades. Developing countries, with their rising demand for transport, will account for nearly two-thirds of the increase. Nonetheless, a relative scarcity of vehicles and infrastructure, if not addressed, could overwhelm public transport systems.

Air pollution from vehicle emissions has significant environmental impacts. Black carbon emissions from biomass and coal combustion could become more significant as demand for transport grows.

Investing in infrastructure that safely and sustainably combines walking and cycling with public transport, and prioritising public over personal transport, could have multiple environment and development benefits.

The potential for the transport sector and emissions from transport to grow in Asia is significant. Emissions from the transport sector in Asia rose from 0.14 Mt CO_2 eq in 1970 to 1.15 Mt CO_2 eq in 2010. Transport sector emissions as a share of total emissions factored against per capita gross domestic production have remained relatively stable. It is not clear whether this could be because of changes in emissions or because of changes in incomes between 1970 and 2010.

Road traffic now accounts for most emissions from the transport sector. Emissions from other forms of transport barely register. The pattern in Asia is not unique. Emissions from road traffic predominate in all other regions and the growth in vehicle emissions is a global phenomena. Growth is not expected to peak in developing countries for the foreseeable future, which means that emissions from road traffic will continue to rise.

Transport infrastructure plays an important part in transport emissions. In OECD90 countries, travellers favour cars. In Asia, travellers currently 'prefer' buses and are increasingly using trains. Geography and the costs of travel will shape travel preferences and thus the emissions related to the different forms of travel.

Oil provides 94% of the energy for transport and accounts for 53% of primary oil consumption. Vehicle emissions range from around 2 CO_2/t-km for bulk shipping to about 1,700 CO_2/t-km for short-haul aircraft, and about 20–300 CO_2/t-km for passenger vehicles.

Projections indicate that both passenger and freight transport will double in developing countries by 2050. The benefits could be better access to markets, jobs, education and health, leading to less poverty and inequality. But, for benefits to materialise, well-managed transport infrastructure would be required. The transport sector's share of emissions ranges from 30% in high-income countries to as low as 2% in some developing countries.

The main drivers that affect transport emissions are travel-time budgets, cost of transport, income and socio-cultural factors.

Travel-time budgets: Travel-time budgets measure the cost and time taken to move goods and people. Urban travel-time budgets usually range between 1.1 and 1.3 hours of travel per traveller per day in both developed anddeveloping countries. Dense urban areas consume less fuel but create dense traffic. New roads can cut travel time in the short term but not in the long run as good roads encourage more traffic.

Costs and prices: In OECD90 countries, the rising cost of travel as a proportion of income has led to growing demand for public transport. The price of fuel and availability of mass-transit systems influence use of cars or public transport. Fuel prices influence both passenger and freight road and rail traffic. High fuel prices also induce vehicle manufacturers to improve fuel efficiency. These are experiences which may, in turn, be reflected in developing countries such as those of the South Asia region but the evidence is not yet there.

Social, cultural and economic factors: Population growth is the main driver of growing demand for transport. Structural changes in economies can also stimulate demand for travel. Specialisation and rising participation in workforces can lengthen the distances travelled. Walking is important in India; where it accounts for nearly 50% of daily movement and keeps Indian energy consumption at less than 2 giga joule per capita (GJ/capita) compared to over 100 GJ/capita in the USA. When household incomes rise, cars become affordable and extremely popular, in spite of the high initial

cost. In developing countries, car ownership is rising rapidly. In India, there is a visible shift towards cars.

Mitigation action in South Asia'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 spill-overs, such as more efficient engines and batteries.

Planning infrastructure to reduce emissions could avoid lock-in to potentially high-emissions systems. Meanwhile, low-carbon materials and low-carbon fuels could reduce emissions from building and operating transport infrastructure.

Urban transport systems can be planned so as to minimise emissions, by giving priority to pedestrians, cyclists and public transport, for example. Low-density development with sprawling road networks creates more 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 transport. Non-motorised transport becomes more feasible as density increases but employment density, street design and connectivity are also important.

There is considerable scope to reduce emissions by improving internal combustion engines and by developing hybrid vehicles – as demonstrated by technological advances in vehicle fuel efficiency, spurred by regulations in the European Union, the United States and Japan.

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. Fuels derived from low-carbon electricity, biofuel, natural gas and hydrogen could directly reduce CO_2 emissions. Compressed methane can replace petrol as a fuel for cars and could 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 by 10%–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 if 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 to grow biofuel crops 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 fuel-efficient vehicles, policy-makers could set fuel economy standards and lower taxes on efficient vehicles.
- **Fuel economy and eco-driving:** Poor driving habits 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 expenditure on fuel accounts for a high proportion of household income, such as in developing countries.

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

Table 7: Climate mitigation policies in the transport sector: co-benefits and risks[161]

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

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 low-emissions options. The trend is for significant efficiencies in costs and emissions across the global transportation, providing many opportunities for businesses and consumers in South Asia:

Vehicles: Cars 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 electricity generation is high carbon, emissions saved by electric vehicles are minimal. If generation is very low-carbon, the mitigation cost (the cost to reduce one ton of carbon emissions) is US$200/t CO_2. Better batteries in electric cars would bring mitigation costs down to between US$0/t CO_2 and US$100/t CO_2.

Aircraft and ships: New aircraft are more efficient than old ones and have already reduced their 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. 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.

Oil accounts for 94% of transport fuel. Energy security in the transport sector is a thus a concern, especially for oil-importing countries. Oil is also a source of emissions. Changing to low-carbon public transport, providing cycling infrastructure, and controlling fuel prices and land use could have significant economic and health benefits. Low-carbon public transport systems could address traffic congestion, save fuel, reduce accidents and boost energy security. Low-carbon public transport systems could also create jobs. However, there is insufficient data to assess the net effect of a shift towards low-carbon transport on welfare and social costs. Advances in transport technologies could have spillover effects on other sectors, for example, new batteries could also have uses in consumer electronics.

Barriers to mitigation in the transport sector: Transport is a key development area. However, only 42 of 6,707 Clean Development Mechanism projects are in the transport sector. The Global Environment Fund has approved only 28 transport projects in its 20 years of operation. Transport projects account for only 17% of the World Bank's Clean Technology Fund. Yet the transport sector will account for 80% of energy-related emissions by 2050, up from 22% in 2009. Nationally appropriate mitigation actions could help attract international development financing for low-carbon transport. Multi-lateral development banks could also play an important role in providing financial support.

Shifting to low-carbon transport would mean setting up institutions to apply international standards, coordinate infrastructure such as docking stations for electrical vehicles and running campaigns to change consumer attitudes to low-emission vehicles for example. There would also be cultural barriers to overcome, such as dependence on cars. Legal barriers could prevent the development of high-density urban areas. Green growth programmes could help overcome these barriers. Those government and business planners who act early to adopt low-carbon approaches stand to benefit the most.

Image: Fotostock | Traffic in Jaipur, India

Box 18: Policy options in road, rail, water and air transport

Road transport: Urban and population growth, and migration from rural to urban areas, will continue in developing countries. This means that demand for transport will increase. Where car ownership is currently low, authorities have opportunities to manage demand and keep emissions down. Promoting the use of biofuels, and hydrogen and electricity as fuels could help minimise emissions. However, it is important to understand the risks associated with producing biofuels, such as competition with food production and to bear in mind the variable life cycle emissions of biofuels – some offer considerable mitigation benefits while others do not, when measured over their lifecycle.

Policies to improve vehicle efficiency, such as the policies in place in the European Union and United States, have the greatest potential for reducing transport emissions by 2050. Many countries, such as India and China, already have aggressive targets for improving vehicle efficiency. Taxing high-emission vehicles, subsidising low-carbon vehicles and setting standards for low-emissions low-energy vehicles could also minimise emissions.

Rail transport: Rail transport has relatively low carbon and energy intensity compared to other forms of transport. However, as electricity powers most rail travel, decarbonising the electricity supply would be the main opportunity for reducing emissions.

Water transport: Shipping freight is relatively more carbon-efficient than other types of freight transport. The International Maritime Organisation (IMO) emissions reduction policies for international shipping are a standard that could be adopted by countries. The IMO policies could also be models for collaborating on climate change in other sectors. The IMO Energy Efficiency Design Index 2013–2025 sets technical standards for energy efficiency. However, emission targets may not be met if the volume of shipping increases at a greater rate than efficiency measures can compensate for. New ships that meet the standard could reduce emissions by up to a 70%. The Energy Efficiency Design Index is expected to help reduce total shipping emissions by between 25% and 30%.

Aviation: In 2010 the International Civil Aviation Organization (ICAO) set goals for reducing emissions from international aviation. The Kyoto Protocol had already set targets and limits for Annex I countries. Regulations, on fuel efficiency and emissions for example, combined with emissions trading schemes and voluntary measures, could reduce overall emissions from aviation. National policies on aviation emissions are also important because within-countries air traffic accounts for about a third of total air travel. National aviation authorities could implement both regulatory and market-based instruments. Fiscal instruments such as fuel or emissions taxes, at both national and international levels, could reduce demand for travel, but depend on price elasticity. There are currently no plans to introduce biofuels in the aviation sector through policy instruments, but the potential for biofuels to reduce emissions from aviation is high. Aircraft efficiency has greatly improved without any policy direction.

8.4. Opportunities in the industrial sector

Climate vulnerability could be a consideration for certain parts of South Asia's industrial sector

Mining and quarrying: Climate change will affect exploration, extraction, production and shipping in the mining and quarrying industry. An increase in climate-related hazards, such as forest fires, flooding and high winds, would affect the viability of mining operations and potentially increase operating, transport and decommissioning costs. Most existing infrastructure in mining and quarrying was built for a stable climate, and is thus not adapted to climate change.

Manufacturing: Climate change will affect manufacturing in three ways. First, climate change affects primary economic activities, which affect the prices and qualities of manufacturing inputs. Second, supply chains and product quality may be affected. The impact of climate change on energy demand is well understood. Labour productivity could fall because of the spread of malaria, vector-borne diseases and heat, but could be offset by advances in technology. Some manufacturing activity is location specific, because it is tied to an input or product market, and would thus have to adapt to cope with changes in climate. Other manufacturing has discretion over its location (and hence its climate). Third, climate change affects demand for products. This is pronounced for manufacturers that supply primary sectors and construction material. These effects have not been well quantified.

The Asia region's are the largest share of the world's industrial emissions

Globally, emissions from industry and wastewater globally rose from 10.42 $GtCO_2eq$ in 1990 to 15.51 $GtCO_2eq$ in 2010. Emissions from industry were higher than emissions from transport and building and, in 2010, represented 30% of global greenhouse gas emissions

Current direct industrial emissions from the Asia region as a whole are now the highest globally and are rising the most

rapidly (7.4% a year). Over half (54%) of the greenhouse gas emissions from industry and waste now come from Asia.[162]

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 account for quite significant emissions in some countries, although not particularly significant in South Asia. India is a major source of emissions from the use of metallic minerals.

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.

India is a major producer of energy-intensive industrial goods. The annual growth rate in the production of iron ore in India is 8% and India accounts for 8% of total global iron ore production. Steel production in India is growing at 8% and India accounts for 5% of global production. Production of cement is rising at 8% a year and is 7% of total global production. India also contributes significant emissions from waste (3% of national CO_2 emission equivalents), of which industry accounts for 38%.

Least developed countries' share of mining as a percentage of gross domestic production has risen but the value of manufacturing has generally fallen. Manufacturing in least developed countries tends to concentrate on low-technology products. In 2009, the share of low-technology products manufactured in least developed countries was 71% compared to 30% in developing countries and 21% in developed countries.

Industrial development in least developed countries could continue to be labour and resource intensive or could move towards higher technology production. The evolution of industrial sectors in least developed countries could be most successful when matched with available resources and low-energy production technologies.

The IPCC offers some pointers for mitigation policies in the industrial sector

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.

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. No single policy could deal with mitigating industrial emissions. Broadly, there are six options for mitigating greenhouse gas emissions from industry.[163]

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.

Greenhouse gas cap-and-trade schemes and carbon taxes encourage energy efficiency and are already in place in some developed and developing countries. Globally, uptake of regulations such as energy efficiency standards and target-driven emissions policies has also increased. Companies, especially small- and medium-size enterprises, which have low energy costs and relatively limited information on energy efficiency, tend to allocate hardly any resources to using energy more efficiently. Energy audits may prompt such companies to adopt energy-efficient measures more quickly than they would otherwise. Benchmarking energy use may also speed up adoption of best practices.

Emissions efficiency: Switching the fuels used by industry, for example from coal to natural gas, would help reduce emissions. Carbon sequestration 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. Voluntary agreements can be cost-effective and efficient in reducing emissions provided there is a strong governance framework, and that companies receive support such as technical assistance or subsidised energy audits. Policies directed to improving energy efficiency often also improve emissions efficiency. Support and fiscal incentives to switch to fuels that emit less CO_2, or for research and development in capturing and storing carbon, can improve policy outcomes. Programmes such as the Clean Development Mechanism provide monetary incentives for reducing greenhouse gas emissions.

Efficient use of resources: Policies can promote efficient use of materials to reduce greenhouse gas emissions but governments need to back up these policies by effectively communicating the advantages to industry. Waste management policies that tax or charge for waste disposal can also reduce waste, and thus emissions.

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. Substituting materials, although possible, may not be best for mitigation since producing substitute materials may emit carbon either in production or extraction processes.

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. Options exist in all industrial sub-sectors to save money and cut emissions by shifting to best practice technologies and/or by switching fuels; and there are also some limited mitigation options in the cost ranges of 0–20 and 20–50 US$/tCO2eq. To reduce emissions to zero, longer-term investments such as carbon capture and storage would be needed. These investments would increase costs to 50–150 US$/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.

Table 9: Industry mitigation policy co-benefits and risks[164]

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	

Box 19: How could transformation look in South Asian countries' industrial sectors?[165]

By 2100, 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.

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. Opportunities for green growth are greatest where industries are growing.

8.5. Opportunities for urban areas

Asia's urban areas are highly vulnerable to climate impacts

The Asian region experienced the most weather- and climate-related disasters in the world between 2000 and 2008 and suffered the second highest proportion (27.5%) of total global economic loss. The risk of mortality from floods is concentrated in Asia. Growing capacity to deal with the risks to life associated with major weather-related hazards, such as floods, means that mortality rates are falling.

Urban exposure and vulnerability to hazards related to climate change are rising rapidly. Densely populated low-lying coastal zones and coastal cities in Asia are particularly vulnerable to a rise in sea level, storm surges and typhoons. Delhi, for example, one of the world's five largest cities, is susceptible to floods. The risk of floods, and loss of life and property associated with floods, is highest in India and Bangladesh. By the 2070s, the *Fifth Assessment Report* indicates that the Asian port cities that could be most at risk, in terms of population and assets exposed to coastal flooding, will be Kolkata, Mumbai (Box 5) and Dhaka. The assets exposed to risk in cities such as Dhaka and Kolkata could be 60 times what they are now.[166]

Risks to peri-urban areas could also be significant. Urban areas in Asia with less than a million inhabitants are where most population growth is expected. These smaller centres often have the least capacity to adapt to climate change.[167]

Urban mortality rates: In Bangladesh, people have suffered from heat stress, a condition that often affects urban populations in low- and middle-income countries. In urban areas where child mortality is high, extreme temperatures have led to more child deaths. Some occupations and groups are more at risk than others. Workers in certain occupations may be exposed to high temperatures for extended periods. Heat waves may disrupt or limit income-earning opportunities for low-income households.

Health and quality of life in urban areas: Changes in climate could also affect air quality, pollution and health in urban areas. Energy has a major influence on economic development in urban areas. Any climate change-related disruption or unreliability in power or fuel supplies can have far-reaching consequences, affecting urban businesses, infrastructure, services and residents, as well as water treatment and supply. Climate change will alter patterns of urban energy consumption, particularly energy for cooling or heating. While little is known about demand for energy in low- and middle-income countries where large sections of the urban population still have no electricity, higher average temperatures and more frequent heat waves projected for South Asia will affect demand.

Impacts on urban industry and infrastructure: Climate change could have profound effects on urban functions, infrastructure and services. Changes in climate will interact with and exacerbate existing stresses, and affect links with other urban areas, sources of food and resources (see section 8.4. above). The effects on urban industries will be both direct, on production, and indirect, because of the mitigation measures industries might have to take.

Districts with poor infrastructure on the east coast of India are the most vulnerable. For people in these areas the effects of extreme events would be catastrophic. Moreover, poorer the infrastructure and growth in an area, the more vulnerable people in these areas will be to extreme events. In 2008, the embankments of the Kosi River, a tributary of the Ganges, broke, displacing over 60,000 people in Nepal and 3.5 million in India, and disrupting transport and power across large areas. However, the embankment failed not because of an extreme event but because of complex social, political and environmental issues relating to physical infrastructure and institutional relationships.

Urban services and transport: Disruptions in services such as water supply, sanitation, energy and transport affect urban economies and livelihoods and, in some cases, lead to mass migration.[168] These disruptions may have different effects on different regions and cities, sectors of the economy and socioeconomic groups but tend to reinforce existing inequalities, disturb the social fabric of cities and exacerbate poverty.

Climate change could damage transport infrastructure (*high agreement, limited evidence*). For example, temperature extremes damage paved roads and rainfall extremes damage unpaved roads and bridges. Ports could be affected by higher temperatures, a rise in sea level, more severe storms, and more rainfall. More storms on shipping routes could raise transport costs.

Image: Daniel J. Rao | Stranded Hindu pilgrims wait for flood waters of river Ganges to subside, Varanasi, India

Climate change could also challenge transport systems. Most transport systems are already sensitive to fluctuations in rainfall, temperature, winds, visibility and, in coastal cities, changes in sea level leading to floods and damage. Just-in-time delivery systems risk losses from disruptions to transport because of extreme weather.

South Asia has options for increasing resilience in its climate-vulnerable towns and cities

Planning options: Rapid urban population growth in Asia in the last decade has led to an increase in high-rise living and working (vertical density). High-density urban areas can conserve resources but can also pose challenges for planning and urban management.

'Climate-smart' planning combines pro-poor development with climate-change adaptation and mitigation. As South Asia embarks on large-scale development of infrastructure there is much potential in the region for "no-regrets" adaptation. No-regrets adaptation could deliver effective development and lessen vulnerability to climate change. Adapting infrastructure in urban areas to deal with the uncertainties and unprecedented challenges posed by climate change would require changes in planning, management, governance and institutions. Local governments could address both adaptation and mitigation by, for example, putting in place building standards and planning transport infrastructure. By linking institutions responsible for different aspects of planning trade-offs could be avoided or moderated.

Insurance options for the urban poor: Private sector investors or insurers seldom target low-income urban dwellers. Around half the population of Mumbai lives in informal settlements without protective infrastructure and at increasing risk of floods. Low-income groups rely on community solidarity and government assistance when disaster strikes. Schemes such as micro-credit, micro-insurance and micro-savings can help households and small entrepreneurs without access to formal insurance or commercial credit take measures to adapt. Some communities with high social capital have pooled savings in, for example, city development funds. These pooled savings provide members with loans for disaster rehabilitation among other things.

Barriers to adaptation: Structural factors affect vulnerability and adaptive capacity. 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.

Table 10: Low-regrets actions in urban climate adaptation

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

(Source: Table 1, above.)

Box 20: Urban-rural interaction

Rural areas 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 emerging. 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.

Rural-urban interface. Changes in agricultural potential, economic marginalisation and human health in rural-urban interfaces can be overlooked because they are neither in the rural nor in the urban domain. Agricultural extension services may 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.

Emissions from Asia's urban areas are growing rapidly as they increase in size[169]

Globally, the shift from rural to urban societies will have significant effects on greenhouse gas emissions and thus also on mitigation. The current scale and speed of urbanisation is unprecedented. By 2050, 64–69% of the global population could be urban. Development may not keep pace with urban growth. In urban areas in developing countries where populations will grow rapidly, some districts may be connected to gas and electricity services while others may have to rely on biomass or fossil fuels.

The *Fifth Assessment Report* indicates that globally most urban development will be in small- to medium-size urban areas in developing countries. Urban areas account for 80% of global gross domestic product, 67% of primary energy use and 76% of final energy use. The area urbanised is increasing twice as fast as the urban population and could grow by 51% to 310% by 2030 compared to 2000. In Asia, urban areas will experience some of the highest growth rates in the world. However, projections are based on just a few studies and there are discrepancies in how urban areas are defined.

The scenarios presented in the *Fifth Assessment Report* predict rising urban populations, albeit varying by country and region. Uncertainties regarding the speed and nature of urban growth mean that projections of urban emissions are also uncertain.

South Asia has relatively high urban CO_2 energy-related emissions. Estimates for urban emissions in Asia vary but in South Asia range from about 30% to 70% of total emissions.[170] Rural populations tend to consume less energy per capita than urban populations in developing countries, mainly because rural areas have limited access to energy. This means that in developing countries most energy-related emissions come from urban areas.

No single factor explains variations in per capita emissions between cities; cities in the same country show significant differences. Physical, economic and social factors influence urban emissions as well as the development and urbanisation history of each city. Key influences on urban emissions include the income levels, population dynamics, urban layout, location, economic structure and market failures. Cities in United Nations Framework Convention on Climate Change Annex I countries (industrialised countries and economies in transition) tend to have below average per capita final energy use and emissions, while energy use and emissions tend to tend to be above average in cities in non-Annex I countries.

Increases in urban emissions relate to:

Urban population dynamics: Most urbanisation globally is likely to occur in Africa and Asia as people move from rural to urban areas.

Urban land use: Built-up areas will expand. Urban population densities in developing countries tend to be four times higher than in high-income countries. Urban population densities in Asia are expected to fall as they have in Europe and North America, but the area of urbanised land will likely increase.

Urban economies: Urban areas drive economic growth and contribute significantly to national gross domestic product.

South Asian decision-makers have ample climate mitigation options in urban areas – and these options offer many development benefits

Rapidly urbanising countries have the most opportunities for mitigation in urban areas:[171]

Macro scale: Regional strategies and plans could help minimise climate-unfriendly urbanisation and maximise the climate-resilience of large infrastructure projects. Urban containment and live-work developments could encourage cities to grow inwards and upwards, thus minimising emissions.

Meso scale: Urban districts or 'corridors' could be developed.

Micro scale: Urban regeneration is an option, which involves making cities compact, cycle- and pedestrian-friendly, with pedestrian and car-restricted zones, and 'transit-oriented development' where neighbourhoods are hubs of city-wide public transport systems.

Opportunities for climate change mitigation in towns and cities vary according to urban development trajectories. Policies are more effective when bundled together. Policy options include:

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

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

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

Climate change mitigation in South Asia's urban areas has the potential to provide quite significant benefits, including improving public health and economic productivity.

Urban air quality improvements: 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 South Asia, as in many urban areas there is severe air pollution.

Energy security improvements: 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 inhabitants. Reducing urban traffic could also improve cardiovascular health and reduce sleep disturbances.

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, as discussed earlier in this document.

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 will be implemented. Lack of coordination and fragmented responsibilities undermine mitigation efforts.

Financing for urban infrastructure comes from many sources meaning that it is difficult to earmark funds for mitigation. Cities in developing countries that have secured financing for mitigation have tended to tap international climate change financing schemes. Local taxes could help raise funds for mitigation, but taxes on urban development could push development to rural areas where there are no or lower taxes.

Table 11: Urbanisation mitigation policies co-benefits and risks[172]

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	

8.6. Opportunities in the water, sanitation and health sector

South Asia faces considerable climate vulnerability in the water, health and sanitation sector

Availability of freshwater resources: Freshwater resources are very important in South Asia because of the massive population and heavy economic dependence on agriculture, but water availability is highly uneven and adequate water supply is one of the major challenges in many regions. Soaring populations, increasing domestic use, due to urbanisation and thriving economic growth, and increasing use of irrigation drive growing demand for water. For instance, unsustainable consumption of groundwater for irrigation and other uses is considered to be the main cause of groundwater depletion in the Indian states of Rajasthan, Punjab and Haryana. There is high confidence that irrigation demand will increase significantly (by more than 40%) in parts of Asia, whereas other parts, including major irrigated areas in India and Pakistan, might experience a slight decrease in irrigation demand under some scenarios, due to higher rainfall for example.[173]

Apart from water availability, there is *medium confidence* that climate change leads to degradation of water quality in most regions of Asia, although this is heavily influenced by human activities. Groundwater sources, which are affordable means of high-quality water supply in cities in developing countries, are threatened due to over-withdrawals. Aquifer levels have fallen by 10–20 metres in some cities. The drop in groundwater levels often results in land subsidence, which can enhance hazard exposure due to coastal inundation and sea-level rise, especially in settlements near the coast, and deterioration of groundwater quality. Cities susceptible to human-induced subsidence (mainly, developing country cities in deltaic regions with rapidly growing populations) could see significant increases in exposure. Settlements in unstable slopes or landslide-prone areas face increased prospects or rainfall-induced landslides.

Projected impacts of climate change on future water availability in Asia differ substantially among river basins and seasons. For example, projections for the Mahanadi River Basin in India indicate increasing possibility of floods in September but increasing water scarcity in April. In the Ganges, an increase in river run-off could offset the large increases in water demand due to population growth in a +4°C world, due to a projected large increase in average rainfall, although high uncertainties remain at the seasonal scale.

Adaptation of freshwater resources to climate change can be identified as developing adaptive or integrated water resource management of the trade-offs balancing water availability against increasing demand, in order to cope with uncertainty and change. Examples of the options include developing water saving technologies in irrigation and water infrastructure development in the Ganges river basin. Water management in river basins would benefit from integrated coordination among countries. For example, the Indus and Ganges-Brahmaputra-Meghna river basins concern India, Nepal and Pakistan.

Health impacts of climate change: Climate change affects health in three ways. First, directly, for example mortality and morbidity due to extreme heat events, floods and other extreme weather events in which climate change may play a role. Secondly, indirectly because of environmental and ecosystem changes, such as shifts in patterns of disease-carrying mosquitoes and ticks, or increases in water-borne diseases due to warmer conditions, increased precipitation and run-off. Lastly, indirect impacts mediated through societal shifts, such as undernutrition and mental illness from altered agricultural production and food insecurity, stress and undernutrition and violent conflict caused by population displacement, economic losses due to widespread heat extreme impacts on labourers, or other environmental stressors, and damage to health care systems by extreme weather events.

Epidemics have been reported after floods and storms as a result of decreased drinking water quality, increased number of mosquitoes and exposure to rodent-borne diseases. Contaminated urban flood waters have caused exposure to disease and toxic compounds, for example in India and Pakistan. Mental disorders and post-traumatic stress syndrome have also been observed in disaster prone areas, and, in India, have been linked to age and gender.

The incidence of many diseases increases at higher temperatures as the pathogens and parasites that cause them multiply faster. Studies from South Asia have shown an association between diarrheal outbreaks and a combination of higher temperatures and heavy rainfall. Cholera outbreaks in coastal populations in South Asia have been associated with increased temperatures and algal blooms. Climate phenomena, such as the El Nino, have been associated with cholera epidemics in Bangladesh.

Increasing temperatures affect vector-borne diseases facilitating larger vector populations and enhanced disease transmission. Dengue outbreaks in South Asia are associated with temperature and rainfall. Outbreaks of vaccine-preventable Japanese encephalitis have been linked to rainfall in studies from the Himalayan regions, and to rainfall and temperature in South Asia. Malaria prevalence is often influenced by non-climate related factors, but studies from India and Nepal have found associations with rainfall. Climate change will affect the local transmission of many climate-sensitive diseases in certain areas.

Other climate-sensitive vulnerabilities in the health sector are:

Malnutrition: Climate change is projected to increase the burden of malnutrition (medium confidence), with the highest toll expected in children. It has been noted that any

increase in food insecurity due to climate change would be expected to further compromise the poor nutrition of people living with HIV/AIDS. Undernutrition, with its potential for life-long impacts on health and development and its associated increase in vulnerability to malaria and diarrheal diseases, can result from changing crop yields, migration due to weather and climate extremes, and other factors.

Heatwaves and high ambient temperatures: An emerging health concern in Asia is increasing mortality and morbidity due to heat waves. An ageing population will increase the number of people at risk, especially those with existing heart and respiratory problems. Urban heat island effects have increased, although local adaptation of the built environment and urban planning will determine the impacts on public health. Heat stress disorders among workers, and resulting productivity losses have also been reported.

The report identifies an increase in mortality related to heat (*high confidence*) resulting from rising temperatures and temperature extremes as a key risk for Asia.[174] At present, the risk of heat-related mortality is '*medium*' and could be reduced to '*low*' by adopting adaptation measures. In the near term (2030–2040), the risk is '*high*' and could be reduced to '*medium*' by adopting adaptation measures. In the long term (2080–2100), the risk is '*very high*' regardless of adaptation with 4°C warming, and '*very high*' but could be reduced to '*high*' through adaptation with 2°C warming.

Air quality: Climate change is anticipated to affect the sources of air pollutants as well as the ability of pollutants to be dispersed. Potentially, the health effects associated with air pollution will become a more serious problem in affected areas, particularly urban areas.

Forced migration: Weather extremes and longer-term environmental change lead to both more people displaced and increase in populations that are effectively trapped. This trend is likely to be more pronounced under extreme levels of warming. The health risks associated with forced displacement include undernutrition, food- and water-borne illnesses, diseases related to overcrowding such as measles, meningitis and acute respiratory infections, sexually-transmitted diseases, increased maternal mortality and mental health disorders.

Health programmes may have to adapt to take climate impacts into account[175]

Climate change may threaten the progress that has been made in reducing the burden of climate-related disease. The degree to which programmes and measures will need to adapt to address additional pressures from climate change will depend on factors such as: the current burden of ill-health; the effectiveness of current interventions; projections of where, when and how the health burden could change with climate change; the feasibility of implementing additional programmes; and other stressors that could increase or decrease resilience and the social, economic and political context for intervention.

There is evidence that poverty alleviation, public health interventions such as provision of water and sanitation, and early warning and response systems for disasters and epidemics will help to protect human health from climate risks. The key uncertainty is the extent to which society and policy-makers will strengthen these services, including taking into account the risks posed by climate change. With a strong response, climate change health effects are expected to be relatively small in the next few decades, but otherwise climate-attributable cases of disease and injury will steadily increase.

Vulnerabilities arise from policies and measures implemented in other sectors, including adaptation and mitigation options. There are options for vulnerability reduction through development and planning ("low-regrets" measures). These include improved access to nutrition and health facilities, improved water and sanitation measures and provision of adequate services.

Entry points for climate change adaptation include technological options, such as early warning systems for epidemics, and improved services, including vaccination programmes, essential public health services, enhanced emergency medical services.

Other sectors, including ecosystems, water supply and sanitation, agriculture, infrastructure, energy and transportation, land use management and others play an important part in determining the risks of disease and injury resulting from climate change. It is important to be aware that climate change adaptation in other sectors may influence health in a positive manner (e.g. re-vegetation of watersheds to improve water quality) or can exacerbate health risks (e.g. dam construction designed for flood control or agricultural irrigation may promote mosquito breeding). Therefore, collaboration between sectors is essential.

Mitigation action in the broader economy offers significant water, health and sanitation co-benefits

Many climate change mitigation measures that reduce emissions of climate-altering pollutants have important direct health benefits in addition to reducing the risk of climate change. This relationship is called "co-benefits". For example, sustainable cities with fewer fossil-fuel driven vehicles and more trees and greenery would have a number of co-benefits, including public health – a promising strategy for "triple win" interventions. Other examples include efforts to decarbonise electricity production in India that are projected to decrease mortality due to reduced air pollution, policies to increases public transportation, promote walking and cycling, and reduce

private cars that will increase air quality and decrease the health burden, particularly in urban environments as projected in India, and abandoning use of biomass fuels or coal for indoor cooking and heating to improve indoor air quality and health among, in particular, women and children in India. Conversely, actions to reduce current environmental-public health issues may often have beneficial mitigation effects, like traffic emissions reductions in India.

Energy efficiency and reducing reliance on coal for electricity regeneration not only reduces emissions of greenhouse gases, but also reduces emissions of fine particles, which cause many premature deaths, particularly in countries which are highly reliant on coal combustion. A major share of greenhouse gas emissions from the food and agriculture sector arises from cows, sheep and goats – ruminants that create the greenhouse gas methane as part of their digestive process. Reducing consumption of meat and dairy products from these animals may reduce heart disease and some forms of cancer.

Another example is increased access to reproductive health services, which can act to moderate population sizes, and therefore consumption of resources and emissions, in regions where both high fertility rates and high vulnerability to climate change can potentially significantly reduce human suffering as climate change proceeds.

Mitigation strategies that can reduce the use of fossil fuels could result in cuts in black carbon, sulphur dioxide, nitrogen oxides and mercury, all of which are major air pollutants which have detrimental health effects. Previous studies within the *Fourth Assessment Report* have shown that the monetary benefits of reduced air pollution on health could be as great as the mitigation benefits themselves; however there is also a (highly uncertain) possibility that reduced pollution levels could lead to more radiative warming of the atmosphere.[176]

Long term low-carbon development trajectories to 2100 that aim for a 430 to 530 ppm CO_2 concentration level could be correlated with major co-benefits in terms of air pollution i.e. reductions in CO_2 emissions would entail significant reductions in pollution levels. Reductions in emissions by 2030 could lead to a decrease of 10 million DALY [Disability Adjusted Life Year][177] of which most of the benefits could occur in urban areas in developing countries; this is a decrease of over on third compared to the reference scenario.

In regards to water, some climate change mitigation activities could increase competition for scarce freshwater resources, including competition for use of water for direct human consumption, including drinking and sanitation. The economic impacts of, for example, floods, water scarcity and cross-sectoral competition for water, are not well understood. Water scarcity and competition for water, driven by institutional, economic or social factors, may mean that water is not available in sufficient quantity or quality for some uses or in some locations.

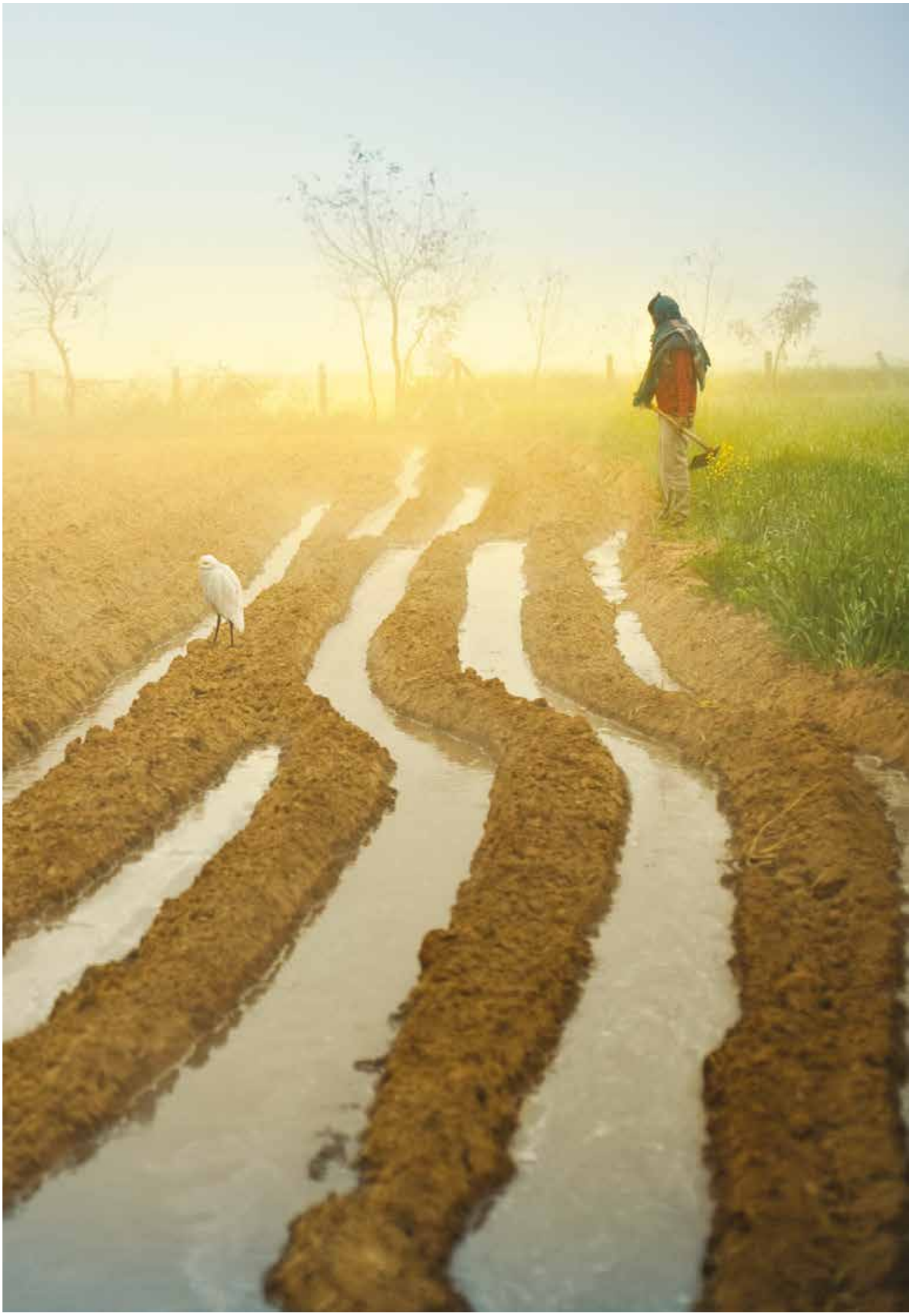
In terms of water management, allocations of water to generate energy and for irrigation may have economy-wide implications. Climate-smart development strategies could address likely impacts on water. Better water management strategies could help ease water scarcity. Examples include developing water saving technologies in irrigation, building reservoirs, increasing water productivity, changing cropping systems and water reuse.

The use of renewable energy systems such as photovoltaics and wind power could lead to reduced freshwater use for the cooling of energy production, an important feature of fossil fuel power systems. Certain mitigation options such as carbon capture and storage may require greater use of freshwater for their effective function. The amount of water used through the cultivation of bioenergy sources (i.e. biofuels) will be determined by the type of crops or plants being grown. Impacts on water of reforestation and afforestation measure impacts on water will also vary depending on the local water situation.

Integrated modelling scenarios do however suggest that stringent mitigation action, when combined with heightened water-efficiency, could lead to significant reductions in global water demand over the next decades up to a potential decline of 25% of demand by 2050.[178]

Climate change will have impacts – positive, negative and varying in scale and intensity – on water supplies, water infrastructure and water demand (high agreement, robust evidence).[179]

Image:
iStock | Indian farmer channels water in plowed field



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.*

South Asian 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 increasing the difficulty of transitioning, globally, towards a low-emissions development pathway as countries invest in low-cost but potentially carbon-intensive infrastructure.[180] 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.[181]

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 South Asia by 2030 then decline.[182] 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 South Asia.

In 2010, governmental Parties to the United Nations Framework Convention on Climate Change (UNFCCC) meeting in Cancun[183] 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.

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.[184] As such, South Asian 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 new investment patterns will be needed to achieve the scale of transition to climate-resilient, low-carbon economies required; the low-income and most climate-vulnerable countries and localities of South Asia will need substantial external financial assistance to achieve this transition, notwithstanding the inherent strengths.[185]

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 South Asia.[186]

A robust case for adaptation action now

The cost of climate change to human wellbeing and ecosystems in South Asia is, and will continue to be, large: causing illness, death and mass displacements. Throughout the 21st century, climate change impacts are projected to slow down economic growth, and make poverty reduction more difficult. South Asia is one of the most vulnerable regions to the impacts of climate change due to its high exposure and low adaptive capacity. The IPCC's assessment of significant impacts in a world that has warmed by 2°C by the end of the 21st century shows that even under high levels of mitigation and adaptation, there could be very high levels of risk for South Asia. To manage these risks, action on climate mitigation and adaptation 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 South Asia, 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 low-emissions technologies and approaches are most appropriate for them. 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 provides evidence base on low-emissions solutions, and urges robust planning and governance mechanisms to ensure that possible adverse consequences are reduced or avoided. For example, the IPCC calls for a much wider embrace of land-based mitigation solutions such as reforestation and reducing emissions from deforestation and forest degradation (REDD+). These could provide an opportunity for South Asian 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 South Asian 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.

The IPCC demonstrates how-carbon development choices can offer very significant improvements in human development and quality of life. For example, improved urban planning and transport investments generate public health benefits make cities more liveable, as well as strengthening climate resilience. At a broader economy-wide scale, the IPCC documents how mitigation actions, particularly actions in the industrial sector such as increasing resource and energy efficiency, could underpin green growth.

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 South Asia 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 South Asia, particularly for the low-income countries in the sub-region.

What's next for South Asian voters and leaders

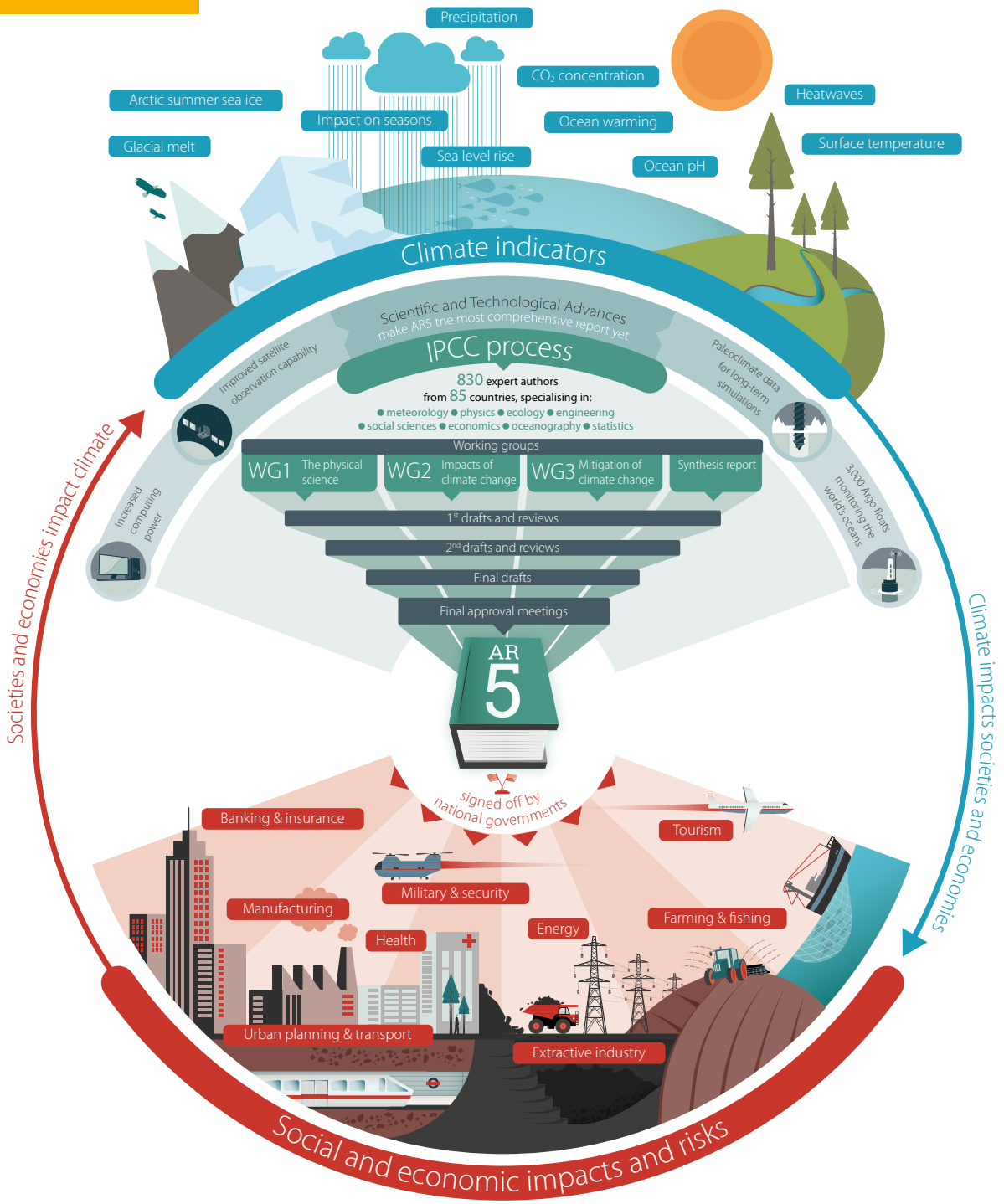
The *Fifth Assessment Report* is clear that the global community must commit to far higher ambition in cutting greenhouse gas emissions. However, the 'policy relevant but not policy prescriptive' IPCC does not offer guidance on the relative burden that different countries should bear with regard to their 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,[187] but could be the basis for something more ambitious. This is what the international process must deliver.

South Asian 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.

International cooperation on climate change involves ethical considerations, including equitable effort-sharing.[188]

How the IPCC works[189]



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Dr Mulugetta is a Coordinating Lead Author of the Fifth Assessment's Working Group III report (chapter on energy systems) and member of the core writing team of the Synthesis Report. Dr van Aalst is a Lead Author of the Fifth Assessment's Working Group II report (chapter on regional context) and Technical Summary. He was also a Coordinating Lead Author of the IPCC's Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX, chapter on determinants of risk), and member of the core writing team of the SREX Summary for Policymakers.

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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

1 The IPCC defines the greater Asia region as including all three of the following groupings:
   i) Centrally Planned Asia and China: Cambodia, China, Hong Kong, Korea (DPR), Laos (PDR), Mongolia, Viet Nam
   ii) South Asia: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka
   iii) Other Pacific Asia: American Samoa, Brunei Darussalam, Fiji, French Polynesia, Gilbert-Kiribati, Indonesia, Malaysia, Myanmar, New Caledonia, Papua New Guinea, Philippines, Republic of Korea, Singapore, Solomon Islands, Taiwan, Thailand, Tonga, Vanuatu, Western Samoa

2 IPCC (2013). *Climate Change 2013: The Physical Science Basis. Headline Statements from the Summary for Policymakers*.

3 IPCC (2013). *Climate Change 2013: The Physical Science Basis. Summary for Policymakers* (p4).

4 The range shown is 0.65–1.06°C. IPCC (2013). *Climate Change 2013: The Physical Science. Summary for Policymakers* (p5).

5 "The rate of sea level rise has been greater than the mean rate during the previous two millennia (*high confidence*)." IPCC (2013). *Climate Change 2013: The Physical Science. Summary for Policymakers* (p11).

6 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summary for Policymakers* (p4).

7 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Chapter 24 (p3).

8 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Chapter 18.

9 IPCC (2013). *Climate Change 2013: The Physical Science Basis. Headline Statements from the Summary for Policymakers*.

10 Ibid.

11 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summary for Policymakers*.

12 IPCC (2013). *Climate Change 2013: The Physical Science Basis. Summary for Policymakers* (p23).

13 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* (pp9–10).

14 RCP 2.6, see Box 3 and Figure 4.

15 Where the high-emissions scenario is RCP 8.5. See also: IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Chapter 24 (pp6–7).

16 IPCC (2013). *Climate Change 2013: The Physical Science. Summary for Policymakers* (p9).

17 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Chapter 24 (p15).

18 IPCC (2013). *Climate Change 2013: The Physical Science. Summary for Policymakers* (p9).

19 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Chapter 24 (p21).

20 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summary for Policymakers*.

21 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Technical Summary* (p48).

22 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Chapter 20.

23 Ibid.

24 Ibid.

25 Ibid.

26 Ibid.

27 IPCC (2014) *Climate Change 2014: Mitigation of Climate Change*. Chapters 5, 6, 7, 8, 10, 11.

28 Ibid. Chapters 5, 6.

29 Ibid. Chapter 8.

30 Ibid.

31 Ibid.

32 Ibid.

33 Ibid.

34 Ibid.

35 IPCC (2014). *Climate Change 2014: Mitigation of Climate Change. Technical Summary* (Section TS.3.1.3).

36 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Chapter 24 (p27).

37 Ibid.

38 IPCC (2014). *Climate Change 2014: Mitigation of Climate Change. Technical Summary*.

39 http://cancun.unfccc.int

40 IPCC (2014) *Climate Change 2014: Mitigation of Climate Change. Summary for Policymakers* (p5).

41 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Chapter 24.

42 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summary for Policymakers* (p6).

43 Observed temperature and precipitation data are given in IPCC (2013). *Climate Change 2013: The Physical Science. Summary for Policymakers* (pp6, 8). Observed temperature and observed precipitation maps are also presented in IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Technical Summary* (Figure TS.5, pp64–65).
44 Ibid.
45 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Chapter 18.
46 Ibid. (p19).
47 Ibid. (p13).
48 Ibid.
49 Ibid. (p20).
50 Ibid. (pp21–22).
51 Ibid.
52 Ibid.
53 Ibid.
54 Ibid.
55 Ibid.
56 Ibid. (p10).
57 Ibid. (p13).
58 Ibid.
59 IPCC (2014). Climate Change 2014: *Impacts, Adaptation, and Vulnerability. Summary for Policymakers* (Figure TS.1, p60).
60 IPCC (2014). Climate Change 2014: I*mpacts, Adaptation, and Vulnerability.* Chapter 24.
61 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* (pp9–10).
62 IPCC (2013). *Climate Change 2013: The Physical Science. Summary for Policymakers* (p23).
63 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summary for Policymakers* (Figure SPM.4).
64 IPCC (2013). *Climate Change 2013: The Physical Science. Summary for Policymakers* (p23).
65 Current and future changes in average temperature compared to those in the late 20th century (1986–2005). All analysis in Box 3 and accompanying figure are derived from IPCC (2013). *The Physical Science. Technical Summary,* Figure TS-15 (p89).
66 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Chapter 16 (p3).
67 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summary for Policymakers* (p9).
68 IPCC (2014). Ibid. (p13).
69 Ibid. (p9).
70 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Chapter 24 (pp6–7).
71 Ibid.
72 Ibid.
73 IPCC (2013). *Climate Change 2013: The Physical Science Basis. Summary for Policymakers* (p11).
74 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Chapter 24 (Section 24.4).
75 IPCC (2013). *Climate Change 2013: The Physical Science Basis. Summary for Policymakers.*
76 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Chapter 24.
77 Data in this figure derived from IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Technical Summary* (Table TS.6, p52); also from *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Chapter 24 (pp6–9, also Figure 24-2, p66).
78 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summary for Policymakers.*
79 Ibid.
80 Ibid.
81 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Chapter 24.
82 IPCC (2013). *Climate Change 2013: The Physical Science. Summary for Policymakers* (p9).
83 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summary for Policymakers.*
84 Ibid.
85 Ibid. (p16).
86 Ibid.
87 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Chapter 24.
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89 Ibid. Glossary (p1).
90 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Chapter 24 (p4).
91 IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Summary for Policymakers* (Table SPM.1, p28).
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96 IPCC (2014). Climate Change *2014: Impacts, Adaptation, and Vulnerability.* Chapter 20.
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106 Ibid.

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111 Ibid. (pp3–5).
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113 Ibid., Chapter 24 (p15).
114 Ibid., Chapter 24 (p20).
115 Ibid., Chapter 24 (p26).
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133 Ibid. Chapter 7.
134 Ibid. Chapter 11.
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140 IPCC (2014) *Climate Change 2014: Mitigation of Climate Change. Technical Summary* (pp66–71).
141 Ibid.
142 Ibid.
143 Ibid. (p40).
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174 Ibid.
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185 Ibid. (Section TS. 4.5.)
186 Ibid. (p5).
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189 Information is Beautiful. Graphic adapted from Information is Beautiful graphic, from a project developed and released by the European Climate Foundation and the Cambridge Institute for Sustainability Leadership.

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