UNEP YEAR BOOK

An Overview of Our Changing Environment

2008

UNEP United Nations Environment Programme

ISBN: 978-92-807-2877-4

UNEP/GCSS/X/INF/2

DEW/1006/NA

Disclaimers

The content and views expressed in this publication do not necessarily reflect the views or policies of the contributory experts, organizations, or the United Nations Environment Programme (UNEP) and neither do they imply any endorsement.

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of UNEP concerning the legal status of any country, territory, or city or its authorities, or concerning the delimitation of its frontiers and boundaries.

Mention of a non-profit foundation or commercial company or product in this publication does not imply the endorsement of UNEP.

© Maps, photos, and illustrations as specified.
Photo Credits for Chapter covers:
Global Overview: © F.X. Pelletier/ Still Pictures
Feature Focus: © P. Frischmuth/ Still Pictures
Emerging Challenges: © S. Kazlowski/ Still Pictures

Reproduction

Produced by
Division of Early Warning and Assessment (DEWA)
United Nations Environment Programme
P.O. Box 30552
Nairobi 00100, Kenya

Tel: (+254) 20 7621234
Fax: (+254) 20 7623927
E-mail: uneppub@unep.org
Web: www.unep.org
UNEP Year Book web site: http://www.unep.org/geo/yearbook

Editor: Paul Harrison
Graphics, layout, and printing: Phoenix Design Aid, Denmark
Distribution: SMI (Distribution Services) Ltd. UK

This publication is available from Earthprint.com http://www.earthprint.com

UNEP promotes environmentally sound practices globally and in its own activities. This publication is printed on 100 per cent chlorine and acid free paper from sustainable forests. Our distribution policy aims to reduce UNEP's carbon footprint.

UNEP YEAR BOOK

An Overview of
Our Changing Environment

2008

UNEP

Contents

Preface	iii
Global Overview	**1**
Calendar of selected events in 2007	2
Focus on climate change	4
Significant climate anomalies and events	8
Pressures on biodiversity	10
Environmental governance	14
Feature Focus: Putting the Pieces Together: Using Markets and Finance to Fight Climate Change	**17**
Introduction	18
Taking responsibility	19
Carbon markets–cap-and-trade	24
The future for emissions trading	29
The role of governments	32
Emerging Challenges: Methane from the Arctic	**37**
Arctic climate feedback	38
Methane from thawing permafrost	39
Methane from hydrates	41
Changes in nature	43
Looking ahead	46
Acronyms and abbreviations	49
Acknowledgements	50

Preface

The momentum on climate change was nothing short of breathtaking in 2007, culminating in the adoption of the Bali Road Map at the climate convention meetings in Indonesia. Climate change and its implications for endangered ecosystems, geopolitical stability, and economic security have ceased to be the preoccupation of scientists and negotiators. It is now recognized as a universal public issue that will dominate global attention for at least a generation.

This 2008 UNEP Year Book documents some of the many insights, events, and issues that have emerged during 2007 and, not surprisingly, it is dominated by the theme of climate change. The findings of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change—established by UNEP and the World Meteorological Organization—put an end to the issue of whether climate change is happening and outlined in great clarity the likely impacts.

Together with the conclusions from other 2007 reports, such as the 4th UNEP Global Environment Outlook (GEO-4), these findings clarify the climatic but also wider challenges that intensifying environmental changes pose to ecosystem integrity and human well-being, and especially to the socio-economic systems that define this age.

The **Global Overview** of this UNEP Year Book highlights recent insights about accelerating carbon emissions including increasing ocean acidification, weather pattern variations, and global ice melt and the implications for sea level rise. The Overview also examines mounting pressures on biodiversity and provides quick guides to significant environmental events and climate anomalies in 2007, as well as an overview of progress in international environmental governance.

The 2008 **Feature Focus** refines the Environment and Globalization theme of the 2007 Feature Focus by examining how market and financial mechanisms have been devised and tested over the last decade to respond to the crisis of climate change—led by the UN, civil society, and business and financial sectors. The evolving carbon market is one such mechanism, which provides valuable lessons for governments on how to put the pieces together and develop effective policy incentives that support the transition to an environmentally-sound economy. The demands for efficiencies and innovations in consumption and production that will emerge from this transition offer extraordinary opportunities. Extraordinary because the demands have the potential to transcend all environmental, economic, social, and security structures of our world. To cope we need to learn from the ingenuity that is already creating new tools and shaping new approaches in the rapidly globalizing marketplace.

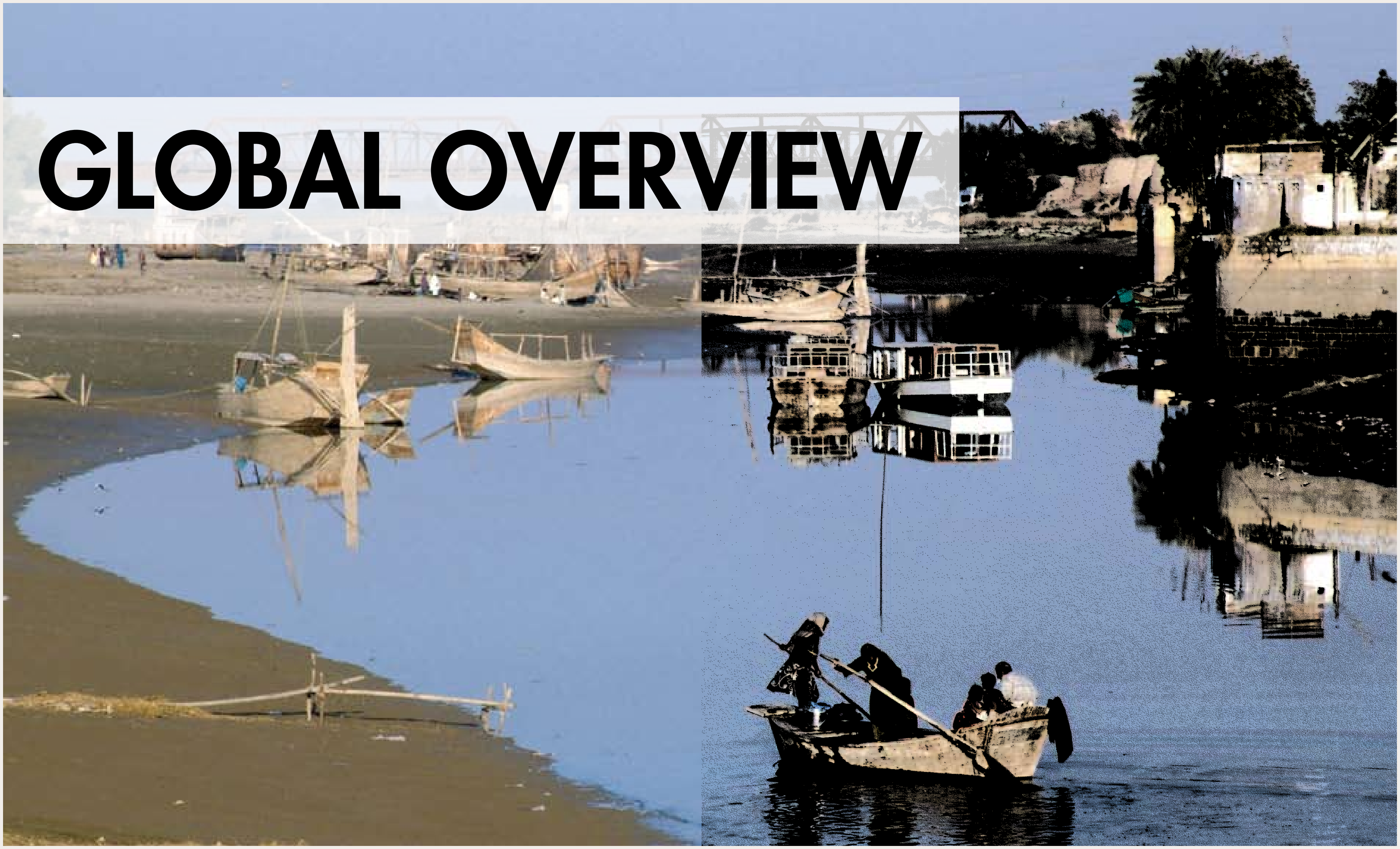
The impact of climate change on physical and biological systems in the Arctic is well-documented: The Arctic, a key component of the global climate system, is warming at nearly twice the rate as the rest of the world. New findings in the **Emerging Challenges** confirm that major feedback mechanisms active in the Arctic are enhancing the release of methane, a potent greenhouse gas, from thawing permafrost and marine hydrate deposits—deposits that could be tapped as a clean-burning fuel source. At the regional scale, the feedback mechanisms that amplify warming will likely dominate over the next century, so continuing methane release from the Arctic is inevitable. The unknowns about the amount and rate of methane release from the thawing Arctic region make it a wildcard when considering climate change risks.

The UNEP Year Book seeks to bridge science and policy-making and in doing so it aims to inform environment ministers and other decision-makers of new and emerging issues of global environmental importance. Some policy considerations identified in the UNEP Year Book 2008 include increasing investments in climate and energy research, building strategic knowledge partnerships, and developing global responses that facilitate the stable transition to an environmentally-sound, low-carbon economy.

You may have noticed that we have renamed the Year Book to the UNEP Year Book. This was done to better reflect the wider participation of experts within UNEP in the production of the Year Book. We have streamlined the overall content to ensure that we can address significant environmental developments in a timely fashion once the year draws to an end. This allows us to provide the complete UNEP Year Book in all UN languages for your use. I hope the 2008 UNEP Year Book will prove informative and stimulate discussions during this 10th Special Session of the UNEP Governing Council/ Global Ministerial Environment Forum. As always, your feedback is most welcome.

Achim Steiner
United Nations Under-Secretary-General and Executive Director,
United Nations Environment Programme

GLOBAL OVERVIEW



Calendar of Selected Events for 2007
Focus on Climate Change
Significant Climate Anomalies and Events in 2007
Biodiversity
Environmental Governance

Calendar of selected events for 2007

JANUARY

10 January Worldwatch Institute says in its 2007 State of the World report, that rapid and chaotic urbanization takes a massive toll on human health and the environment. By 2008, half of the Earth's population (6.6 billion) will live in cities.

22 January The United States Climate Action Partnership, a group of prominent businesses and leading environmental organizations, calls on the United States federal government to quickly enact strong national legislation requiring significant greenhouse gas (GHG) emissions reductions.

30 January The World Glaciers Monitoring Center reports that from 2000 to 2005 mountain glaciers melted at 1.6 times the average loss rate of the 1990s and 3 times the average loss rate of the 1980s, attributing much of the accelerated change to human-induced climate change.

DELOBELLE JEAN-PHILIPPE / Still Pictures

FEBRUARY

12 February An historic declaration to conserve the "Heart of Borneo" is signed between Brunei Darussalam, Indonesia, and Malaysia. The multilateral declaration will conserve and sustainably manage one of the most important centres of biological diversity in the world.

15-17 March G8 Environment Ministers met with representatives from Brazil, China, India, Mexico, South Africa, the European Commission, the UN, and the IUCN in Potsdam to discuss the global challenges of climate change and loss of biodiversity. The 13 ministers agreed on a "Postdam Initiative" that would calculate the economic costs of dwindling species.

FANCOIS XAVIER PELLETIER / WWF

22 March World Water Day – the WWF's World's Top Rivers at Risk report finds that major rivers on every continent are under threat from dams, pollution, over fishing, invasive species, over extraction of water, or climate change.

APRIL

17 April The UN Security Council discuss climate change for the fist time. The meeting focused on the impact of climate change on peace and security. While some participants raised doubts regarding the Council's role on the issue, others urged the UN to consider holding a global summit.

JUNE

1 June The EU regulation on the Registration, Evaluation and Authorisation of Chemicals (REACH) enters into force. REACH took more than four years to negotiate and has an impact on a variety of industry sectors, from upstream chemicals manufacturers to downstream users of chemical products.

7 June Six of the world's eight largest industrialized nations agree to "at least halve global CO_2 emissions by 2050" and to achieve this goal together. Russia and the US are the only G8 holdouts. As a compromise, all eight nations agree to 'substantial' emissions cuts.

8 June The Russian government creates Zov Tigra, the country's first national park for the Siberian tiger, following years of advocacy and conservation work by WWF and local environmental groups.

J.MALLWITZ / Still Pictures

22 June UNEP releases the Sudan Post-Conflict Environmental Assessment report showing that peace and livelihoods in Darfur and the rest of Sudan are inextricably linked to environmental challenges. The report urges national and local leadership to prioritize environmental awareness and opportunities for sustainable management.

12 July Mexico announces its plan to plant 250 million trees in 2007, representing the single largest pledge made by a country responding to UNEP's *Plant for the Planet: Billion Tree Campaign*.

31 July The Forest Department of the Government of Uttar Pradesh, the most populous State of India, succeeds in planting 10.5 million trees in a single day.

RON GILING/ Still Pictures

AUGUST

9 August Ministers and high level officials of environment and health in South-East and East Asian countries endorse the Bangkok Declaration on Environment and Health in a collective effort to reduce the estimated 6.6 million deaths in Asia each year from various environmental health risks.

OCTOBER

1 October The US National Snow and Ice Data Center announces that Arctic sea ice during the 2007 melt season plummeted to the lowest levels since satellite measurements began in 1979.

SYLVAIN CORDIER / Still Pictures

1-3 October Participants at the Davos Conference on Climate Change and Tourism in Switzerland conclude that the tourism sector must reduce its GHGs, adapt businesses and destinations to alter their practices, increase energy efficiency, and obtain financial resources to assist poor regions and countries.

11 October The European Environment Agency releases its fourth assessment report on the environmental situation in 53 countries, highlighting significant air pollution, biodiversity loss, and poor water quality across the region. The report finds that air pollution is likely to reduce life expectancy of Western and Central Europeans by one year.

12 October The Nobel Peace Prize is awarded jointly to former Vice President Al Gore and the Intergovernmental Panel on Climate Change for their efforts to build up and disseminate greater knowledge about man-made climate change and to lay the foundations for the measures that are needed to counteract such change.

MATT ARTZ

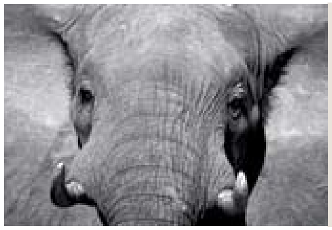
NOVEMBER

1 November Scientists report that the California wildfires that destroyed more than 2 000 homes in October emitted nearly 8 million metric tons of CO_2 into the atmosphere in only one week, representing about one-quarter of California's total monthly fossil fuel emissions.

12-17 November The International Panel on Climate Change releases the summary report of its Fourth Assessment Report which reviews climate changes and impacts, adaptation options, and future scenarios.

20 November Congo announces the establishment of the Sankuru Nature Reserve to protect the bonobo, one of humans' closest ape relatives, from poachers and deforestation. The 30 570 square kilometre reserve is being created in partnership with the US and Congolese conservation groups and government agencies.

26 February A new study published in the Proceedings of the US National Academy of Science says illegal ivory trade has risen to a level not seen in two decades that threatens to undermine efforts to save the African elephant from extinction.


MARTIN HARVEY / Still Pictures

26 February At the 79th Annual Academy Awards, the Oscar for Best Documentary goes to the director and producers of the film "An Inconvenient Truth," former US Vice President Al Gore's cautionary documentary about the dangers of climate change.

27 February China sets a target of increasing renewable energy use, mainly wind power and biomass, from 10 to 20 per cent of the total energy consumption by 2020 to meet the increasing demand and reduce the greenhouse effect.

MARCH

8 March At the Spring Council meeting of European Union (EU) heads of government, the 27 EU members approve a new target to cut their collective GHG emissions by 20 per cent from the 1990 level in 2020. Europe currently generates 15 per cent of the world's carbon dioxide (CO_2) emissions.

20 April More than 600 business leaders and experts attend the Global Business Summit for the Environment in Singapore, the first of its kind in Asia. The event raised awareness about corporate environmental responsibility and how the private sector can address the challenges of climate change.

24 April The six winners of the prestigious Goldman Environmental Prize include an Irish farmer jailed for his work in opposing Shell Oil's gas pipeline through his land and an Icelandic entrepreneur saving North Atlantic wild salmon by brokering innovative fishing rights buyouts.

MAY

14-17 May Leaders of municipal governments and businesses from over 30 of the world's largest cities convene in New York for the second C40 Large Cities Climate Summit. In a joint communiqué, all participating cities call on national governments to empower cities to tackle climate change.

16 May China partners with UNEP and the secretariats of several Multilateral Environmental Agreements to launch a programme to address the illegal trade of chlorofluorocarbons (CFCs) and other ozone-depleting substances. The initiative aims at training customs officials to tackle an environmental crime industry valued at tens of billion US dollars annually.

28 May India's environment minister announces that the country's current environmental policies together with energy efficiency, conservation measures, power sector reform, fuel switching to cleaner energy, and afforestation efforts will enable India to reduce GHG emissions by more than 25 per cent by the year 2020.

28 June The US Fish and Wildlife Service announces that the bald eagle has recovered and has been removed from the US list of endangered and threatened species, along with distinct segments of the Western Great Lakes gray wolf population and the Yellowstone grizzly bear population.


ALLOFS THEO / Still Pictures

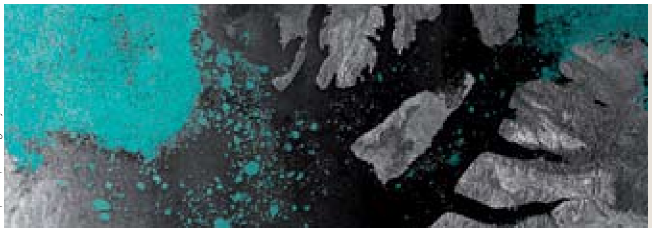
JULY

1 July China, the world's largest producer of CFCs and halon, shuts down five of its six remaining plants, putting the country two and a half years ahead of the Montreal Protocol's 2010 deadline for phase-out of the two ozone depleting chemicals in developing countries.

1 July The Organization for Economic Cooperation and Development releases its first ever environmental performance review of China highlighting that rapid economic development, industrialization, and urbanization have generated growing pressures on the environment, significant damage to human health, and depletion of natural resources.

6 July At the UN Global Compact Leaders Summit, chief executives of 153 companies worldwide commit to speeding up action on climate change and call on governments to agree on measures to secure workable and inclusive climate market mechanisms post 2012, when the Kyoto Protocol's commitment period expires.

28 August Scientists report that the Northwest Passage, the normally frozen sea route running along the Arctic coastline of North America, is open to navigation. It has less ice than at any time since monitoring began in 1972.


European Space Agency

SEPTEMBER

20 September Remote cloud forests in Vietnam, hundreds of atolls in Micronesia, and mangroves in El Salvador feature in the 23 ecosystems added by UNESCO to the World Network of Biosphere Reserves, set up to fight biodiversity loss and promote sustainable development to help local communities.

24 September UN Secretary-General Ban Ki-moon convenes the largest-ever gathering of world leaders on climate change at UN Headquarters in New York. Ban Ki-moon urged top officials from 150 nations to forge a coalition to accelerate a global response to an issue which he has identified as one of his top priorities.

25 October After five years of intensive consultation with stakeholders in all regions of the world UNEP launches the 4th Global Environment Outlook Assessment Report. The report, entitled *Environment for Development,* reveals findings on the state of the environment and highlights emerging issues that require policy attention.

25 October The Canadian government announces the creation of a National Marine Conservation Area encompassing 10 000 square kilometres of Lake Superior. It will become the largest freshwater marine protected area in the world.

26 October Nine African countries sign a new agreement to better protect gorillas at a meeting held in Paris hosted by the government of France and the Convention on Migratory Species of Wild Animals (CMS).

30 October A report published by the National Institute for Space Research in Brazil shows a resurgence of deforestation rates in Amazonia to pre-2004 levels. In December the Ministry of the Environment states that while deforestation rates have risen from 0.5% in 1976 to 17% in 2006, rates have decreased by 20% in the last reporting year.


MARK EDWARDS/ STILL PICTURES

27 November EU fisheries ministers agree on a multi-annual stock reconstitution plan for bluefin tuna, the highly-prized yet threatened fish species popularly used for sashimi and sushi. In September the European Commission closed EU fisheries for bluefin tuna until 2008, after discovering that its annual quota of 16 779.5 metric tons had already been exhausted.

28-30 November A symposium is held in Hawaii to commemorate the 50th Anniversary of the global CO_2 record. The symposium highlighted the importance of long-term global records in enabling society to manage its path into the future.

DECEMBER

3 December Australia's new Prime Minister, Kevin Rudd, declares that the nation has signed and ratified the Kyoto Protocol. Under the treaty, Australia has a target of restricting GHG emissions to 108 per cent of 1990 levels during the 2008-12 commitment period. However, Rudd warns that Australia will likely overshoot the target by one per cent.


IISD/ EARTH NEGOTIATIONS BULLETIN

3-14 December The UN Climate Change meetings in Bali agree on the Bali Road Map which lays out a negotiating path for the next two years to reach an agreement on a post-2012 arrangement.

Global overview

In 2007, climate change concerns gained global attention. The Fouth Assessment Report from the Intergovernmental Panel on Climate Change removed all reasonable doubt about the scope and dangers of the changing climate. Implications for biodiversity are particularly troubling, as pressures from other human activities—such as deforestation, bottom trawling, and biofuel production—threaten ecosystems.

Hundreds of vehicles on the streets in Jinan, China make their way through heavy smog, air pollution, and chronic traffic congestion. In 2007, China experienced a massive increase in car sales, according to the China Association of Automobile Manufacturers.
Source: Sinopictures / Still Pictures

FOCUS ON CLIMATE CHANGE

The Fourth Assessment Report (AR4) from the Intergovernmental Panel on Climate Change (IPCC) appeared in four releases during 2007. The IPCC's Working Group 1 report covered the scientific understanding, Working Group 2 addressed the impacts and adaptation issues, and Working Group 3 analysed economics and mitigation options. Finally, in late November, the IPCC released its Synthesis Report of the total assessment. Each release ratcheted global awareness of climate change issues higher (IPCC 2007a-d). As well, the year witnessed a steady stream of reports from economic, development, and environmental sources that emphasized how climate change would affect the concerns and objectives of various sectors (for instance, Christian Aid 2007, International Alert 2007, UNDP 2007, Lehman Brothers 2007, Oxfam 2007).

Atmospheric GHG concentrations are increasing

The AR4 considered scientific research formally published by the beginning of 2006. Since then the Global Carbon Project, an international consortium of research programmes established to study the Earth's carbon cycle, has released findings that suggest the growth rate of CO_2 emissions is increasing faster than projected in even the most fossil-fuel intensive scenario used by the IPCC (Canadell and others 2007, IPCC 2007a). From 1990 to 1999 the growth rate of CO_2 emissions averaged around 1.1 per cent per year. From 2000-2005 the growth rate climbed to more than 3.3 per cent per year (Raupach and others 2007).

Constant or slightly increasing rates of carbon intensity characterize energy use in both developed and developing countries: no region is decarbonising energy supply as both population and per capita GDP increase (Canadell and others 2007, USCCP 2007).

The growth rate in emissions is strongest in rapidly industrializing developing countries, particularly China. While developing countries—80 per cent of the human population—accounted for 73 per cent of the increase in emissions during 2004, they accounted for 41 per cent of the total emissions during 2004 and only 23 per cent of the accumulated global

Box 1: Acid oceans

If the Earth's oceans were not absorbing nearly half the carbon overload that human activities emit into the atmosphere, the effects of climate change would be much worse. But this load of carbon changes the oceans by changing their pH balance—how acidic or alkaline they are.

Normally the oceans are slightly alkaline but when CO_2 dissolves in seawater, hydrogen ions (H^+) are released. The more CO_2 dissolves, the higher the H^+ concentration and that increases the acidity. Researchers know that the oceans have not been absorbing carbon at present rates for perhaps 20 million years. In those years, marine life has evolved to thrive in mildly alkaline waters—at a pH of 8.0 to 8.3.

The effect of ocean acidification on marine ecosystems and organisms that inhabit them has only recently been recognized. The most threatened creatures are the mollusks—oysters, clams, mussels, and whelks—that excrete calcium carbonate to build shells and the coelenterate polyps that fabricate complex coral reefs.

At current rates of anthropogenic CO_2 emissions, by the end of the 21st century ocean acidification will completely inhibit molluscs and calcareous plankton from processing the calcium they need to survive. And coral reefs may collapse. The multifaceted ecosystems that coral reefs support—the nursery habitats for many marine fish species—will only survive in pictures.

Sources: UNEP 2007, Plymouth Marine Laboratory 2007, Stone 2007 emissions since industrialization began (Raupach and others 2007).

Atmospheric CO_2 concentration is increasing for another alarming reason: CO_2 absorption by oceans is decreasing (Canadell and others 2007). Since atmospheric CO_2 concentrations were first recorded in 1957, scientists tracking carbon cycle sources and sinks realized that the oceans have served as a significant sink for anthropogenic carbon dioxide emissions. They have absorbed almost half of all CO_2 emissions from fossil fuel and other industrial sources since 1800 and currently they still absorb 25-30 per cent (Sabine and others 2004) (**Box 1**).

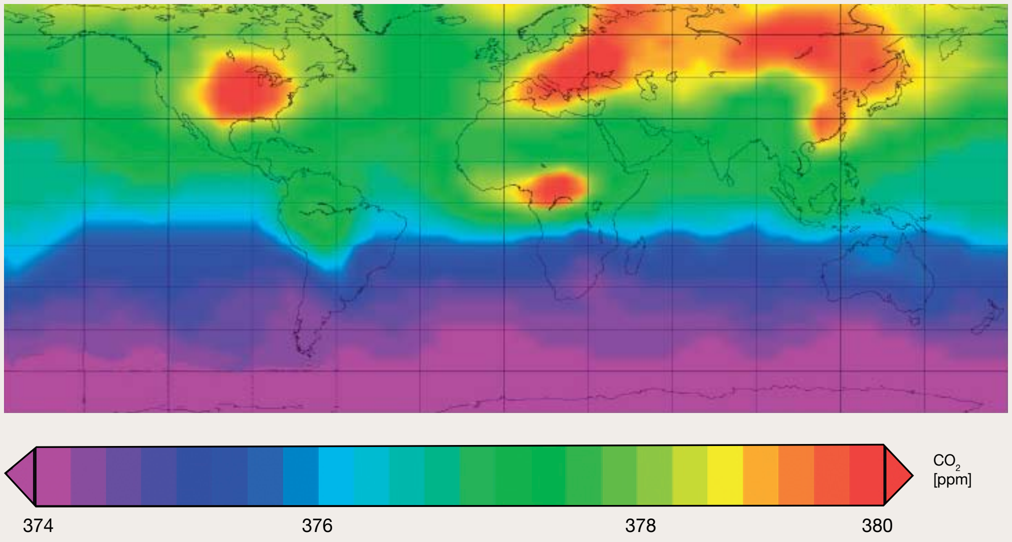
One study analysed observations from ships in the North Atlantic, a region considered to have significant sink capacity due to the strong vertical circulation resulting from the density of the water at low temperatures and high salinity. It found that CO_2 uptake in the study region declined by more than 50 per cent between the mid 1990s and the period 2002-2005. This decline is attributed to less vertical mixing and decreasing buffer capacity in surface waters as carbon concentrations in the oceans increase (Schuster and Watson 2007).

Another study suggests that the Southern Ocean's annual capacity to absorb CO_2 weakened by 80 million metric tons per decade between 1981 and 2004, compared to a mean Southern Ocean carbon sink annual capacity between 100 and 600 million metric tons. This decline may be due to changes in wind patterns—they are now inhibiting the delivery of CO_2 from the surface to the ocean depths (Le Quere and others 2007).

Dendronephthya Soft Coral Garden, Fiji.

Source: Paul Humann/ fishid

Figure 1: Carbon Tracker shows atmospheric concentrations of CO_2



The CarbonTracker is a tool that monitors the carbon flux of industrial and biological processes at scales ranging from global and regional to city level. The monitoring began in 2000, when the same colour scale bar covered 368 to 372 parts per million, and the latest complete data sets are from 2005, with the colour spectrum bar covering 374 to 380 parts per million. It was developed by NOAA to inform the US Climate Change Science Program's First State of the Carbon Cycle Report published in November 2007.

The column average CO_2 mole fraction (ppm) for 2005 calculated from NOAA's Carbon Tracker model (see: http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/). Blue regions have relatively low CO_2 and red regions have relatively high CO_2

Source: NOAA Research 2007, USCCSP 2007

Both studies consider complex and interrelated causes for the phenomena they examine but climate change is a significant factor in their explanations.

The World Meteorological Organization released figures for 2006 atmospheric GHG concentrations that show the highest levels of CO_2 and N_2O on record while methane concentrations are holding steady (WMO 2007) (**Table 1**). Increasing levels of atmospheric CO_2 concentrations characterize a carbon cycle that is generating climate changes sooner and stronger than expected (Canadell and others 2007) (**Figure 1**).

Precipitation patterns and storm activity

Recently published studies have attributed humidity and precipitation changes at the global scale to human influence (Willett and others 2007, Zhang and others 2007). The changes are larger than those estimated from model simulations. They may have already had significant effects on ecosystems, agriculture, and human health in regions that are sensitive to changes in precipitation, such as the Sahel (Zhang and others 2007). Variations in precipitation patterns and humidity are important factors in human heat stress events, surface hydrology, ecosystem integrity, and geographic distribution and intensity of storms (Willett and others 2007).

Table 1: Trends in GHG abundance

Global abundance of key greenhouse gases as averaged over the twelve months of 2006 and in context of historical trends.

	CO_2 (ppm)	CH_4 (ppb)	N_2O (ppm)
2006 Global	381.2	1785	320.1
2006 relative to 1750**	136%	255%	119%
Mean annual increase since 1997	1.93	2.4	0.76

**Assuming a pre-industrial mixing ratio of 280ppm for CO_2 700ppb for CH_4 and 270 ppb for N_2O

Source: WMO GHG Bulletin 2007

Consistent with most scientists' expectations from a changing climate, the year brought many storms and unusual weather patterns but two events merit particular attention because they illustrate the value of early warning and disaster preparedness.

Tropical Cyclone Gonu was the strongest storm on record in the Arabian Sea, where most storm systems dissipate on approaching the arid Arabian Peninsula, and it matched the strongest storm recorded in the whole of Northern Indian Ocean that includes the Bay of Bengal, where cyclones are quite common (JTWC 2007, NASA 2007). Oil rigs were closed down and some were evacuated. In Oman, 20 000 people were evacuated from the capital Muscat and surrounding areas, as well as the full populations of two islands. They were housed in government-provided dwellings stocked with supplies and medicine. In Iran, 40 000 were evacuated from coastal regions. The Iranian Red Crescent and National Disaster Task Force were fully mobilized. Both countries had the situation well under control (ReliefWeb 2007a).

A Bangladeshi boy walks his bike through the wrecked market in the town of Sarankhola in the aftermath of Cyclone Sidr. More than 2 million people were evacuated before Sidr ravished low-lying coastal areas. While the death toll was relatively small considering the cyclone's severity, more than 4 million people have been left in ruin.
Source: Ruth Fremson/ The New York Times

In November, Tropical Cyclone Sidr made landfall on the western side of the Ganges Delta. It hit the most heavily populated low-lying area in the world, with a history of severe casualities from previous storms due to both direct flooding and storm surge. In 1970, a storm that made landfall in the same vicinity caused 300 000 deaths and was one of the most deadly natural disasters in modern history. Another 138 000 people perished in 1991 from a similar cyclone. This time, over 3 000 people lost their lives but millions lost their livelihoods, proving that substantial investment in disaster preparedness pays off but produces significant challenges nevertheless (ReliefWeb 2007b).

For the last decade the relationship between hurricane activity in the North Atlantic and climate change has been vigorously discussed. Correlations with sea surface temperature and the El Niño-Southern Oscillation cycles are recognized. Researchers suggest 10 year, 12 year, and 40 year cycles (Goldenberg and others 2001, NASA 2001). In 2007, scientists from the US National Center for Atmospheric Research suggested that hurricane occurrence has doubled in the Atlantic basin since 1900. They have detected three steps to the increase of tropical storms with 1995 as the threshold of the most recent increase and with a close correlation to rising sea surface temperatures. The proportion of hurricanes to storms—about 55 per cent—has remained the same as the total has increased. However, the proportion of major hurricanes, those with wind speeds over 175 kilometres per hour, has increased significantly (Holland and Webster 2007).

The very active 2004 and 2005 hurricane seasons in the North Atlantic sparked a significant increase in research addressing the variables affecting hurricane formation. The relatively mild 2006 and 2007 seasons could be explained by the influence of massive dust storms that build over the Sahara from May to August and move westward, delivering very dry air to the Atlantic basin. The dry air absorbs the humidity, and heat, from the air near the ocean surface, dampening wind speeds. As well, the dust may shield the ocean surface from direct summer sun allowing it to cool (Evan and others 2006, Klotzbach and Gray 2007).

Cyclone Gonu left a path of destruction—flooding streets, downing power lines, damaging water supplies, and undermining coastal infrastructure.
Source: Dilip Correa/ Daijiworld.com

Melting ice and accelerating sea level rise

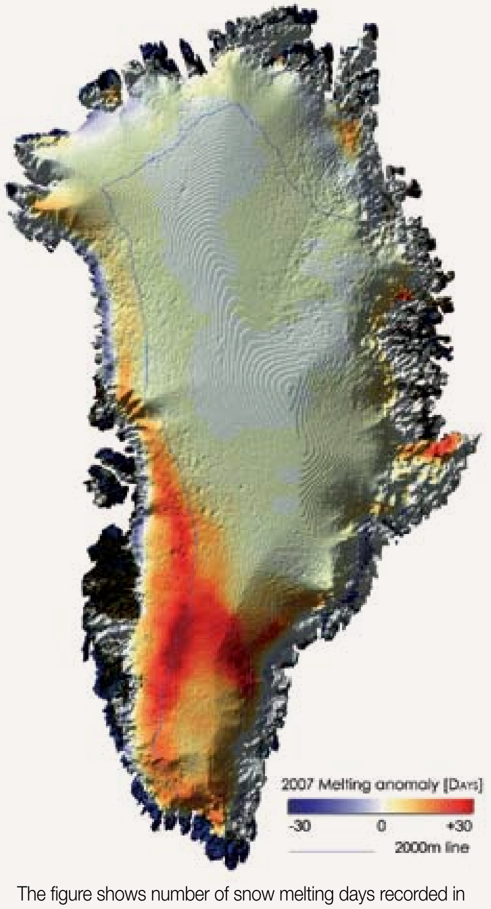
Sea levels are also rising faster than expected. The IPCC AR4 considered thermal expansion of the oceans and melt of glaciers as causes of current sea level rise, but assumed little contribution from melt of the ice sheets on Greenland and Antarctica (IPCC 2007c). Ice melt currently accounts for most of the observed sea level rise not attributable to expansion from ocean warming. At least 60 per cent of ice melt is from glaciers and ice caps (areas of terrestrial ice covering less than 50 000 km^2) rather than from the two ice sheets (Meier and others 2007).

The contribution of these glaciers and ice caps has accelerated since the late 1990s, due in part to extensive thinning and retreat of glaciers that terminate in the ocean. The accelerated ice loss from marine-terminating glaciers is likely due to dynamic instabilities where the submarine contact between the glacier and the sea-floor weakens and allows inland ice to flow out quickly and sub-glacial water to drain. Such instabilities are not well represented in climate models and present the possibility of additional sea level rise. This acceleration of glacier melt may cause 0.1–0.25 metres of additional sea level rise by

2100, beyond that estimated by the AR4 (Meier et al 2007). However, inventories of glacier loss are underway around the world, based on a model using the very well documented Alps as a paradigm. Estimates indicate that glaciers in the European Alps lost about half their total volume between 1850 and 1975, another 25 per cent of the remaining amount between 1975 and 2000, and an additional 10–15 per cent of what was left between 2000 and 2005 (Haeberli and others 2007).

Researchers cannot yet incorporate changes in ice sheet dynamics into their models. Examples of such changes include the effects of warmer sea currents beneath ice shelves that lead to thinning

Figure 2: Seasonal melting of the Greenland Ice Sheet 2007



The figure shows number of snow melting days recorded in Greenland in 2007. Areas with more than 20 melting days over the average are indicated with red (Tedesco 2007).

and instability and the effects of melted water seeping through vertical ice chimneys, or moulins, and lubricating the contact between ice and rock at the base of the sheet. The subglacial water lubrication is especially important in parts of the Greenland ice sheet where melting took place 25-30 days longer in 2007 than the observed average in the previous 19 years. According to the most recent findings, 2007 marked an overall rise in the melting trend over the entire Greenland ice sheet and melting in high-altitude areas surpassed any previously recorded, at 150 per cent more than average (Tedesco 2007) (**Figure 2**).

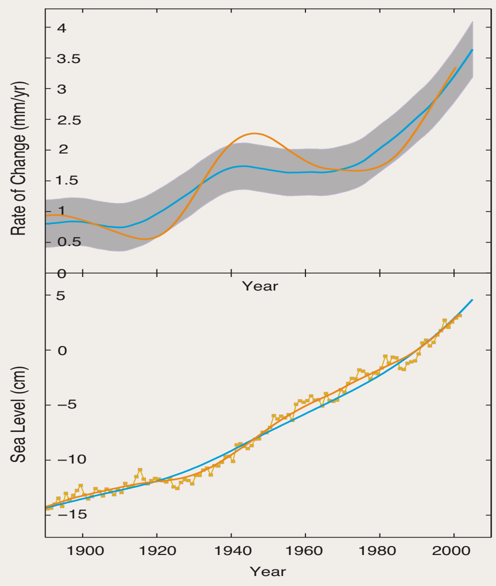
Data show that Antarctica is also losing mass overall. The combined loss from Greenland and Antarctica is estimated to be about 125 gigatons of ice per year at current rates. This is enough to raise sea level by 0.35 millimetres per year. The present rate of sea-level rise is 3.0 millimetres per year. Combining the additional contribution from Antarctica and Greenland ice loss with the contibution from marine-terminating glaciers brings a potential contribution from these sources to 15-20 per cent more annual sea level rise than projected by the AR4 (Shepherd and Wingham 2007).

Understanding of the variables interacting to produce sea level rise remains limited, but some scientists have drawn a simple correlation between global atmospheric temperatures and sea level rise (Rahmstorf 2007) (**Figure 3**). Using the observed sea level rise of the past century to calibrate a linear projection of future sea level, warming expected from a business-as-usual emissions path will lead to a sea level rise of 0.5 to 1.4 metres in this century. The correlation works because the significant contributions to sea level rise came only from thermal expansion of ocean water and melting of mountain glaciers—significant contributions from the Antarctic and Greenland ice sheets had not yet begun (Rahmstorf 2007, Hansen 2007).

Arctic political positioning

In 2007 the sea ice in the Arctic Ocean shrank to its smallest extent on record (ESA 2007). A high-pressure system persisted over the Arctic in June and July, producing three effects that enhance ice melt—clear skies and sunshine during the long Arctic days, winds bearing warm air north,

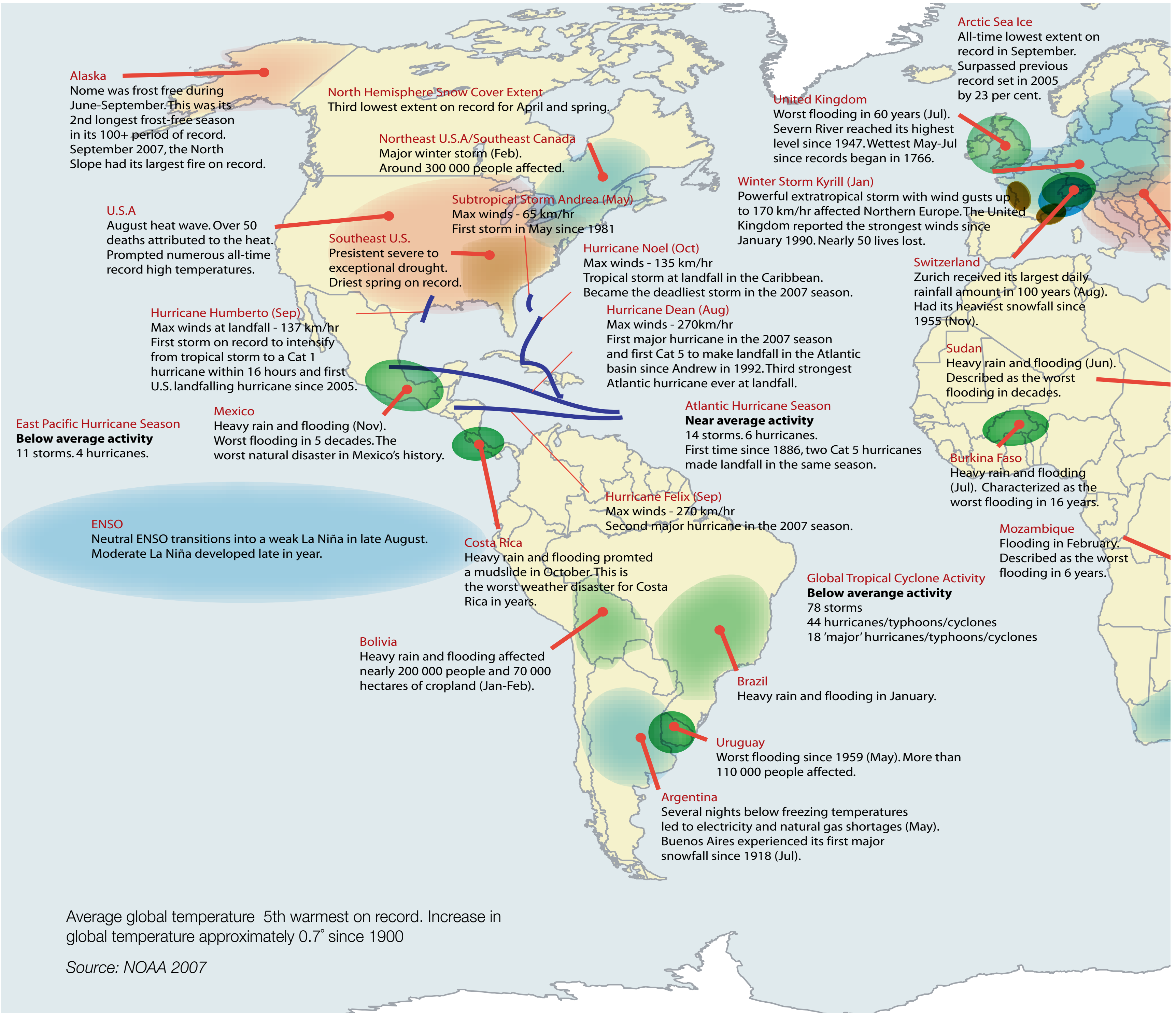
Figure 3: Correlations between sea level rise and temperature increases

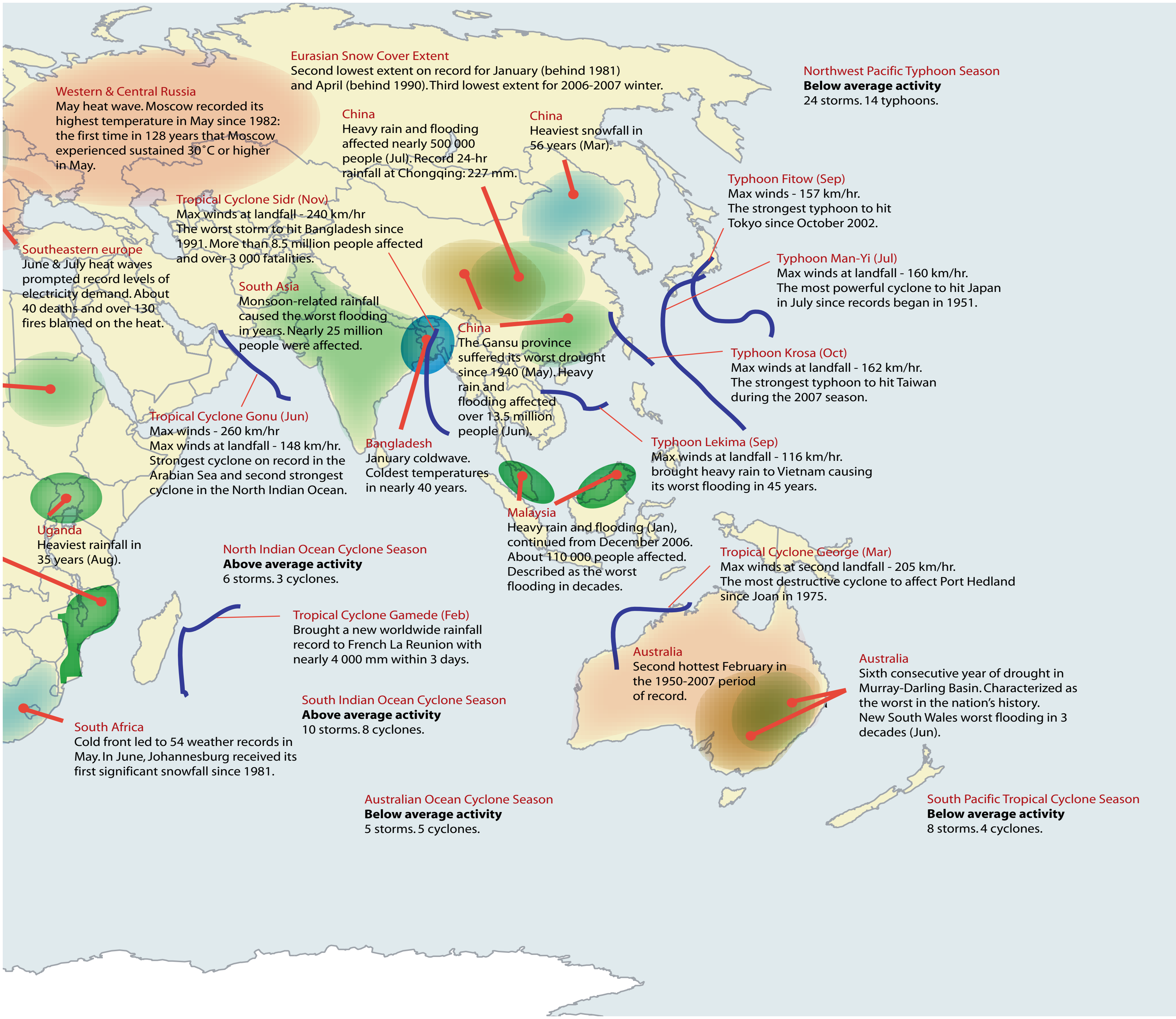


These graphs show general correlations between temperature and sea level rise from thermal expansion and glacier melt. Top: Rate of change (mm per year)—Red line is smoothed sea level rise according to tidal gauge observations, blue line is computed from global mean temperatures. Bottom: Sea level change (cm)—Same data with sea level rise relative to 1990, brown line unsmoothed annual sea-level data (Rahmstorf 2007).

and currents that carried ice away from Siberia, exposing huge areas of open water (NSIDC 2007). In the AR4, projections suggest that the Arctic will be ice free in summers by 2100 (IPCC 2007b). However, some studies project an ice free Arctic by 2040 and in late 2007 researchers proposed that the Arctic summer may be ice free by 2013 (Holland and others 2006, Borenstein 2007). The prospect of extensive open water seasons led to international claims for dominance over the region. Russia planted a flag on the sea bed beneath the North Pole, while Canada and Denmark continued collaboration of a long-term research programme to map the Lomonsov Ridge (Continental Shelf Project 2006). The ridge is believed to contain oil and gas deposits and is claimed as a continental-shelf extension by each of the three sovereignties under provisions of the Law of the Sea. The USA claims that the whole Arctic Ocean is international waters (Shukman 2007).

Significant climate anomalies and events in 2007





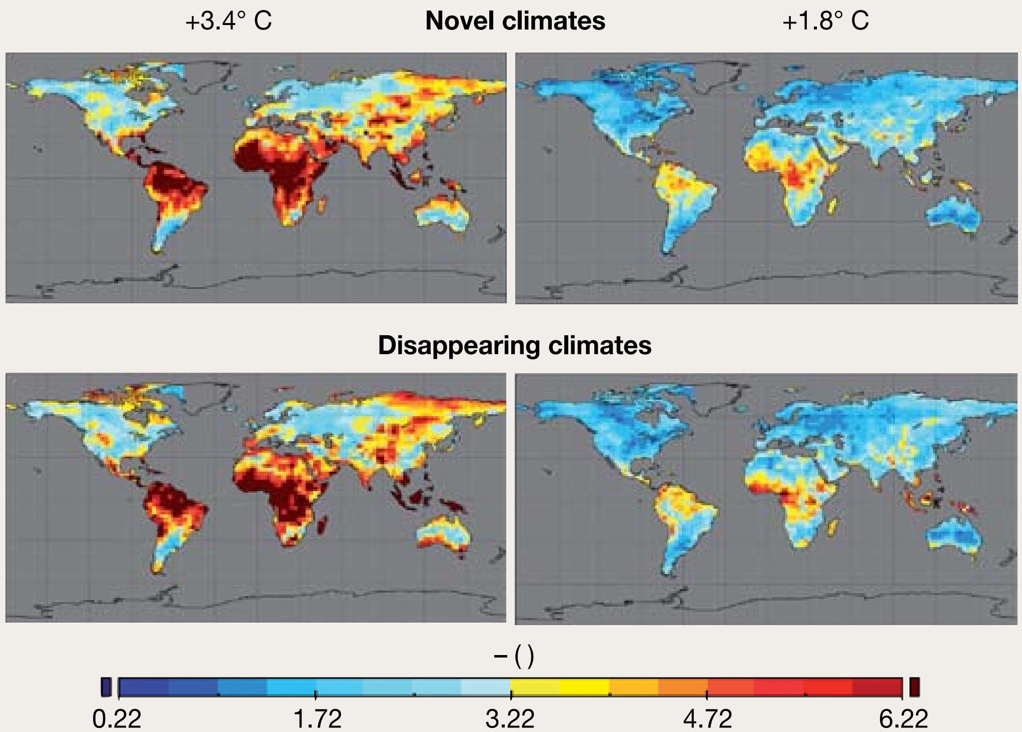
Eurasian Snow Cover Extent
Second lowest extent on record for January (behind 1981) and April (behind 1990). Third lowest extent for 2006-2007 winter.
Northwest Pacific Typhoon Season
Below average activity
24 storms. 14 typhoons.
Western & Central Russia
May heat wave. Moscow recorded its highest temperature in May since 1982: the first time in 128 years that Moscow experienced sustained 30˚C or higher in May.
China
Heavy rain and flooding affected nearly 500 000 people (Jul). Record 24-hr rainfall at Chongqing: 227 mm.
China
Heaviest snowfall in 56 years (Mar).
Typhoon Fitow (Sep)
Max winds - 157 km/hr.
The strongest typhoon to hit Tokyo since October 2002.
Tropical Cyclone Sidr (Nov)
Max winds at landfall - 240 km/hr
The worst storm to hit Bangladesh since 1991. More than 8.5 million people affected and over 3 000 fatalities.
Southeastern europe
June & July heat waves prompted record levels of electricity demand. About 40 deaths and over 130 fires blamed on the heat.
Typhoon Man-Yi (Jul)
Max winds at landfall - 160 km/hr.
The most powerful cyclone to hit Japan in July since records began in 1951.
South Asia
Monsoon-related rainfall caused the worst flooding in years. Nearly 25 million people were affected.
China
The Gansu province suffered its worst drought since 1940 (May). Heavy rain and flooding affected over 13.5 million people (Jun).
Typhoon Krosa (Oct)
Max winds at landfall - 162 km/hr.
The strongest typhoon to hit Taiwan during the 2007 season.
Tropical Cyclone Gonu (Jun)
Max winds - 260 km/hr
Max winds at landfall - 148 km/hr.
Strongest cyclone on record in the Arabian Sea and second strongest cyclone in the North Indian Ocean.
Bangladesh
January coldwave.
Coldest temperatures in nearly 40 years.
Typhoon Lekima (Sep)
Max winds at landfall - 116 km/hr.
brought heavy rain to Vietnam causing its worst flooding in 45 years.
Malaysia
Heavy rain and flooding (Jan), continued from December 2006. About 110 000 people affected. Described as the worst flooding in decades.
Uganda
Heaviest rainfall in 35 years (Aug).
North Indian Ocean Cyclone Season
Above average activity
6 storms. 3 cyclones.
Tropical Cyclone George (Mar)
Max winds at second landfall - 205 km/hr.
The most destructive cyclone to affect Port Hedland since Joan in 1975.
Tropical Cyclone Gamede (Feb)
Brought a new worldwide rainfall record to French La Reunion with nearly 4 000 mm within 3 days.
Australia
Second hottest February in the 1950-2007 period of record.
Australia
Sixth consecutive year of drought in Murray-Darling Basin. Characterized as the worst in the nation's history.
New South Wales worst flooding in 3 decades (Jun).
South Indian Ocean Cyclone Season
Above average activity
10 storms. 8 cyclones.
South Africa
Cold front led to 54 weather records in May. In June, Johannesburg received its first significant snowfall since 1981.
Australian Ocean Cyclone Season
Below average activity
5 storms. 5 cyclones.
South Pacific Tropical Cyclone Season
Below average activity
8 storms. 4 cyclones.

PRESSURES ON BIODIVERSITY

Climate change will seriously affect biodiversity. A paleontological study of fossil records over the past 520 million years—since animals with skeletons appeared—demonstrated that warmer phases correlate with lower levels of biodiversity. Studying the possible relationships between ocean surface temperature proxy data and biodiversity represented in the fossil record, researchers detected a correlation between climate change of any kind with extinctions. But they also detected a correlation between warming temperatures and biodiversity loss. As well, they detected a lag time before adaptations allowed new species to evolve from those that survived the warming and to re-populate ecosystem niches (Mayhew and others 2007).

A new geographical analysis identified regions most likely threatened by climate changes that could drive ecosystems and associated species to extinction (**Figure 4**). This study used IPCC scenarios to project changes under possible temperature increases. If average global temperatures increase 3.4° C by 2100, existing climates could disappear over 10-48 per cent of the Earth's land surface. Some climates, concentrated in tropical mountains and the high latitudes of continents, may disappear altogether. These endangered climates, and the vulnerable ecosystems that have evolved within them, include tropical montane forests—particularly cloud forests in the Andes—the fynbos of South Africa, and some Arctic climates (See Emerging Challenges). During this same timeframe, 12-39 per cent of the Earth's surface—mostly in the tropics and subtropics—may develop novel climates.

Figure 4: Projected novel and disappearing climates by 2100



World map of disappearing climates and novel climates under two of the IPCC scenarios, one that projects a 3.4° C temperature increase and one that projects an increase of 1.8° C. Changes occur almost everywhere—yellows and reds indicate more change from current conditions, blue indicates less change (Williams and others 2007).

Female Western Lowland Gorilla with her baby in the Democratic Republic of Congo.
Source: Vernay Pierre / Still Pictures

The areas of disappearing climates closely overlay regions identified as critical hotspots of biological diversity and endemism—including the Andes, Mesoamerica, southern and eastern Africa, Himalayas, Philippines, and the islands between Australia and the Malay Peninsula. At ground level, there is not much correlation between areas projected to develop novel climates and areas projected to have disappearing climates, so the most threatened species may not have the opportunity to adapt to novel climates. Human settlements and activities will inhibit spontaneous migration. However, corridors of connected reserves and deliberate conservation and relocation efforts may help species to diffuse and adapt to novel climates.

If global temperatures increase by only 1.8° C then the potential threat would be much reduced: 4-20 per cent of the Earth's surface would experience loss of existing climates by 2100, with a similar gain for novel climates (Williams and others 2007).

Endangered species

Current data suggest a picture of ongoing decline in biodiversity that has been called a global extinction crisis (Eldredge 2001). On The World Conservation Union (IUCN) 2007 Red List, the number of threatened species increased to 16 306, up from 16 118 in 2006 (IUCN 2007a).

All the great apes, recognized as key indicator species for vulnerable ecosystems, are now classified as endangered or critically endangered—the highest threat status. In 2007, the Western Gorilla (*Gorilla gorilla*) was reclassified from endangered to critically endangered. The population of the main subspecies, the Western Lowland Gorilla (*G. gorilla gorilla*), has decreased by more than 60 per cent over the last 20-25 years, due to the bushmeat trade and the Ebola virus (IUCN 2007a). The seriously vulnerable situation of the Mountain Gorilla (*G. beringei beringei*) gained attention when, in the space of several months, nine gorillas were killed in the Virunga National Park of the Democratic Republic of the Congo—a region where conflict and complex emergencies have dominated recent history (Leakey 2007).

On a more positive note, nine gorilla range states—Central African Republic, Uganda, Democratic Republic of Congo, Republic of Congo, Nigeria, Equatorial Guinea, Angola, Cameroon, and Gabon—approved the Gorilla Agreement, a legally binding agreement under the Convention on Migratory Species of Wild Animals, to combat gorilla poaching, support law enforcement, and build legal and judicial capacity (IISD 2007). And the Democratic Republic of the Congo created the new Sankuru Nature Reserve to protect endangered bonobos. The reserve, encompassing more than 3 million hectares of tropical rainforest, is the world's largest contiguous protected area for great apes (Bonobo Conservation Initiative 2007).

Corals under threat

For the first time in its history, the 2007 Red List included ocean coral species. Ten Galápagos coral species, affected by El Niño and climate change, were added to the list, two as critically endangered and one as vulnerable. All the Galápagos Islands were added to the list of World Heritage sites in danger following a recommendation from IUCN. An IUCN-UNESCO mission found that annual visitors to the islands have increased from 40 000 to 120 000 between 1996 and 2007, while tourism-driven immigration is increasing the local population by 4 per cent a year. Alien and invasive plant species now outnumber native ones, and 180 of the 500 native plant species in the Galápagos are on the IUCN Red List (IUCN 2007b).

Coral reef ecosystems face continued threats from pollution, bottom trawling, diving, collecting, and climate change (**Box 2**). A review of Indo-Pacific coral reef surveys found that for 2003 the average coral cover was only 22 per cent, compared to a pre-industrial level of around 50 per cent (Bruno and Selig 2007). Coral cover decreased 1 per cent per year over the last twenty years, around 150 000 hectares, but reached over 2 per cent, 316 800 hectares per year, between 1997 and 2003. This rate of coral cover loss exceeds loss rates of tropical rainforest (IUCN 2007b).

Conservation works

There were some hopeful signs in biodiversity conservation. African elephant numbers may be increasing. The African Elephant Status Report 2007 estimated that there were 554 973 African elephants in 2007, counting both definite and probable numbers. Comparison of repeat surveys

Box 2: Restrictions on bottom trawling expand

The year 2007 saw some major advances in restricting bottom trawling. In March, the UN General Assembly adopted Resolution 61/105, on improving the sustainability of fisheries. This resolution calls on nations and regional fisheries management organizations (RFMOs) to take steps to prevent 'significant adverse impacts' by bottom trawling on vulnerable marine ecosystems (VMEs), particularly seamounts, hydrothermal vents, coldwater corals, and sponge fields.

A number of RFMOs are answering the call. In January, the Northwest Atlantic Fisheries Organization closed four seamount areas to all bottom trawling until December 2010. In June the North Pacific Fishery Management Council closed around 46 million hectares of the northern Bering Sea to bottom trawling, protecting areas where fish stocks may retreat in a warming world. Bottom trawling will be limited in the southern Bering Sea to areas where the practice has already damaged the sea-floor ecosystems.

In September 2007, countries working towards the creation of the South Pacific Regional Fisheries Management Organization (SPRFMO) agreed a comprehensive set of interim measures for the region. Until at least 2010, fishing on VMEs will be strictly controlled. Fishing operations will be assessed on the basis of working within the controls and member states will be expected to monitor and report on any exploitation affecting VMEs.

Many limitations constrain the comprehensive protection that is needed. Most VMEs have not been well mapped: knowledge about their characteristics, interdependencies, and processes is minimal. The SPRFMO is an objective and does not yet exist, so compliance and enforcement is voluntary. Nations outside the SPRFMO will not bound by the agreement and ships with flags of convenience may continue to bottom trawl in the South Pacific outside the Exclusive Economic Zones of the participants.

Sources: Alaska Marine Conservation Council 2007, Clark and others 2006, GEO4 2007, Kitchingman and Lai 2004, SPRFMO 2007a, SPRFMO 2007b, UN 2006

Bottom trawling involves dragging trawl nets along the sea-floor to harvest bottom-dwelling fish species. The fishing technique damages seabed ecosystems extensively and conservationists condemn the practice. These trawlers are churning mud from the sea-floor near the mouth of the Changjiang (Yangtze) River in China.

Source: J. Allen/ NASA Earth Observatory

Jatropha oil plant on an experimental farm in Bhavnagar, India is grown for the production of bio-diesel. One of India's largest private sector companies in the oil industry, Reliance Industries, has launched a major pilot initiative to grow jatropha. A plantation of 100 000 hectares is expected to yield etween 250 000-300 000 metric tons of crude jatropha oil per year.
Source: J. Boethling/ Still Pictures

in Southern and Eastern Africa (where two thirds of the range area is located) shows an increase of 66 302 elephants in the definite category, a growth rate of 4 per cent per year since the last survey in 2002 (Blanc and others 2007).

The year 2007 also saw the creation of extensive protected areas in important centres of biological diversity. Brunei Darussalam, Indonesia, and Malaysia agreed to conserve and sustainably manage 22 million hectares of equatorial rainforests in Borneo—almost one third of the island (WWF 2007). And the Government of Madagascar created 15 protected areas covering more than a million hectares (Conservation International 2007).

Threats and promises from biofuels

Biofuels have been widely promoted as a way of avoiding greenhouse gas emissions from fossil fuels. During 2007 the controversy over biofuels intensified while the production and area of biofuel crops expanded and food prices rose. In April of 2007, UN-Energy—a consortium of 20 United Nations agencies—released a report that asked important questions regarding biofuels: Will biofuels push out food crops, raise food prices, and exacerbate food security? Will biofuel production further degrade ecosystems that are already endangered? Do biofuels exacerbate the climate crisis when the entire production chain is considered? And what effect will a shift to biofuel production have on women, small farmers, and the integrity of rural communities? The report recommends a fully developed stakeholder process to map out biofuel use for sustainable development (UN-Energy 2007).

Biofuels have been used since humans started using fire. Over the last decades, biofuel, in the form of locally generated biogas, has been revolutionizing energy consumption in small communities in India, Nepal, and China. In Nepal, 72 per cent of the biogas plants connect to latrines, so human health and sanitation conditions have been significantly improved at the same time.

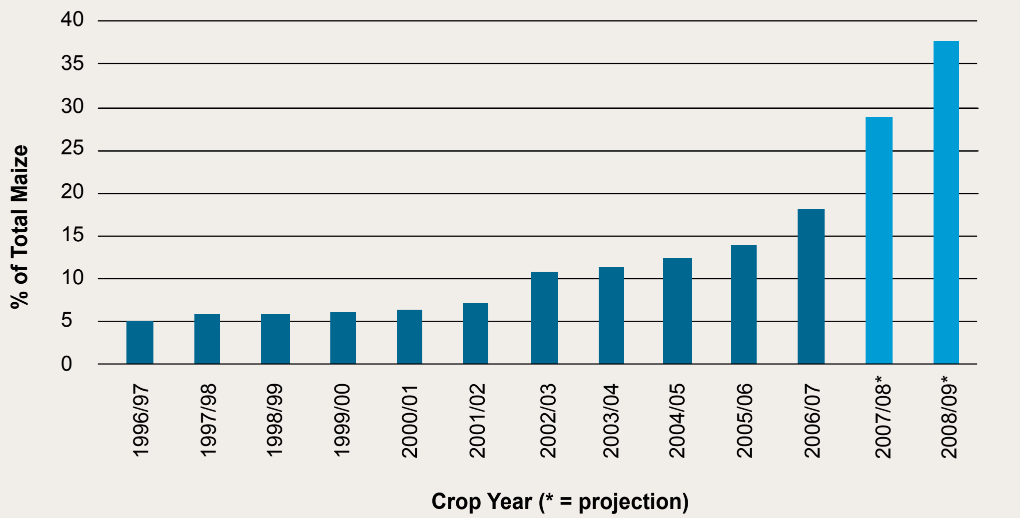
The current controversy concerns agricultural biofuels, called agrofuels by some. These are fuels derived from maize, oil palm, sugar, canola, jatropha, miscanthus, sorghum, wheat, and other plants and mostly used to replace fossil fuels in the transportation sector (USDA 2007).

Many countries have introduced mandatory proportions of biofuels, particularly ethanol, in their fuel mix: In Europe, the requirement is that 10 per cent of the transportation fuels should come from biofuels by 2020. Requirements for a 10 per cent ethanol content in fuels have been introduced in Colombia, Venezuela, and Thailand. In China, a 10 per cent mandatory blend is required in the five provinces with the most transportation fuel consumption.

These legal requirements have produced a rapid increase in the area devoted to raising biofuel crops. Soaring demand for palm oil has led to extensive deforestation in southeast Asia (UN-Energy 2007). Rising food commodity prices around the world, especially those of maize, are attributed in part to investment in raising crops for biofuel production (Economist 2007, Pachauri and Hazell 2006) (**Figure 5**).

Rising cereal prices affect the costs of many other foods, including meat and dairy products.

Figure 5: Maize used for ethanol production (1996-2009)



Source: Aakre 2007

The rapid growth of meat and dairy consumption in Asia has significant implications since it takes 13 kilograms of high protein cereal to produce one kilogram of meat (Pimental and Pimental 2003).

Many development agencies are concerned about the effect biofuel production will have on the livelihoods of rural communities and the ecosystems they depend upon. Crops for biofuels could create jobs in rural area where many of the world's poor are living—ideally, smaller scale production could provide a stimulus to such communities. But biofuel production favours large-scale industrial agriculture that excludes the traditional crop production roles of women especially, and of most men in rural communities (UN-Energy 2007).

Another problem with agri-business biofuel production is the likelihood of increased water consumption per hectare of productive land—once again this will greatly affect local communities and those who have to transport family water supplies, usually the women. Loss of soil productivity and the effects of fertilizer and pesticide applications could also bring real health hazards to local communities. These complications would likely lead to rural people being driven from their land (UN-Energy 2007).

Biofuel production has real potential to help achieve the transition to a low-carbon economy, but it must also help achieve sustainable development. Supporting the development of community-based cooperative farming enterprises, similar to those that maintain certified forests and other resources, could address some of the challenges presented to small farmers and local communities. Large-scale monocropping would likely lead to soil erosion, nutrient leaching, and biodiversity loss through threats to ecosystems and to genetic resources (**Box 3**). But with careful management and a smaller-scale bottom-up approach, biofuel production can contribute to a sustainable future (UN-Energy 2007, UNEP 2007).

Primary tropical rainforest in Sarawak Borneo, Malaysia, one of the world's richest and oldest ecosystems, is under constant threat from development and illegal logging to clear land for palm oil production. Native people have mounted protests and blockades against logging operations, subsequently many have been arrested and imprisoned.

Source: N. Dickinson/ Still Pictures

Box 3: The Svalbard Global Seed Vault

In June, the Norwegian Government started construction on an international seed depository near the town of Longyearbyen on Spitsbergen Island, in the Svalbard archipelago. The facility will provide secure long-term cold storage for preserving plant resources. Once completed, the Svalbard depository could maintain up to 4.5 million different seed varieties: ideally, samples of every variety of almost every important food crop in the world. The facility and its collection efforts are supported by donations from the Gates Foundation, the Global Crop Diversity Trust, and other non-profit organizations.

The vast collection is intended as insurance against disaster so food production can be restarted anywhere should it be threatened by a regional or global catastrophe. When the depository was originally conceived in the early 1980s, the perceived threats came from nuclear war and geopolitical uncertainty. When the idea resurfaced in 2002, following the adoption by the UN of the International Treaty on Plant Genetic Resources for Food and Agriculture, critical biodiversity losses and climate change brought new urgency and motivation to the concept.

The Svalbard facility will depend on seeds acquired according to strict protocols from sources around the world. If dried and packaged with the proper moisture content and stored at the right temperature, seeds from most major food crops will remain viable for hundreds to thousands of years. The seed collection will be maintained at optimal conditions for their long-term storage, maintained at a temperature of -18°C through the use of the naturally cold temperatures deep within Spitsbergen's permafrost and an artificial cooling system. The vault has been excavated out of sandstone—120 metres inside a mountain and lined with a metre of reinforced concrete. The facility is among the most energy-efficient and reliable structures in the world, with low operating costs and virtually no maintenance.

While no location can possibly provide 100 per cent insurance against the threat of natural and human dangers, Svalbard offers a level of protection that is difficult to match. At 78 degrees latitude—roughly 1 000 kilometres north of the northernmost tip of continental Norway—the location is suitably cold and isolated. The absence of volcanic or significant seismic activity in the region and the site's elevation above projected potential sea level rise also contribute to the ideal long-term storage conditions. As well, the area offers excellent infrastructure including a dependable power supply and a nearby airport.

Depositors retain ultimate ownership of the materials held in storage. However, the facility is owned by the Government of Norway and will be managed by the Nordic Gene Bank, which has been conserving seeds since 1984 in a facility located within an abandoned coal mine in Sweden.

Source: Evjen 2006, Fowler 2007, NORAGRIC 2006, Skovmand 2007

Construction workers stand beneath scaffording at the enterance to the Svalbard Global Seed Vault.

Source: M. Tefre/ Global Crop Diversity Trust

International environmental governance: Progress in 2007

The year 2007 witnessed a series of international meetings related to international environmental agreements (MEAs), global trade negotiations, and other intergovermental processes in response to existing and emerging global environmental challenges (**Box 1 and Box 2**). Progress was made on prominent issues such as climate change, depletion of the stratospheric ozone layer, persistent organic pollutants, and biodiversity loss **(Figure 1**).

Climate change was at the centre of environmental governance discussions in 2007. In April, the UN Security Council debated for the first time the effects climate change will have on peace and security and a record 55 delegations participated. Some governments raised doubts regarding the Council's role on the issue while others, such as small island developing states, welcomed the initiative (UN 2007a). In September, the UN Secretary-General held a high level event on climate change the day before the opening of the 62nd session of the General Assembly in New York in anticipation of the meetings in Bali, Indonesia in December 2007 (UN 2007b). In Bali, at the 13th Conference of Parties to the UN Framework Convention on Climate Change and its Kyoto Protocol's 3rd Meeting of Parties, government representatives from 187 countries agreed to launch negotiations and a course of international action leading to final negotiations in 2009 to ensure that a new deal can enter into force by 2013, when the first phase of the Kyoto Protocol ends (UNFCCC 2007).

The Montreal Protocol on Substances that Deplete the Ozone Layer celebrated its 20th anniversary in September in its home city by accelerating the phase out of ozone depleting and greenhouse enhancing hydrocloroflourocarbon (HCFC) to 2020 for industrialized countries and to 2030 for developing countries. Protocol Parties have reduced 70 per cent of ozone depleting substances over the last 20 years (IISD 2007b, UNEP 2007b).

In Dakar, Senegal, representatives from more than 180 governments, intergovernmental agencies, and non-governmental organizations met in May to discuss how to advance and finance the Stockholm Convention of Persistent Organic Pollutants (POPs) implementation. Implementation plans include global monitoring, establishment of regional centres for technical assistance, and national applications of the plans. Participants also took practical steps in support of the implementation agenda: to carry out an effectiveness evaluation and to establish regional groups of coordination (IPEN 2007, IISD 2007c).

Governments met in Bangkok in November 2007 at an ad hoc open-ended working group on mercury issues established by the UNEP Governing Council in February. Delegates made progress on whether to use enhanced voluntary measures, existing international legal instruments, or new instruments. The UNEP Governing Council will receive from the working group a progress report in February 2008 and a final report in February 2009 to decide on a global course of action (IISD 2007d).

Illegal trade in wildlife and effective enforcement of regulations were the major concerns for governments at the 14th Conference of the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), held in The Hague, the Netherlands in June. Representatives decided on a CITES Strategic Vision 2008-2013 setting out goals on compliance and enforcement, a guide for compliance with the Convention, and management of annual expert quotas. A major achievement was the consensus reached by African range states on the future of ivory

Figure 1: Ratification of multilateral environmental agreements by region

	Vienna/Montreal	UNFCCC	Kyoto	CBD	Cartagena	CITES	CMS	UNCCD	Heritage	UNCLOS	Ramsar	Basel	Rotterdam	Stockholm
Africa (53)	53	52	46	53	41	52	33	53	50	41	47	45	32	41
Asia and and the Pacfic (46)	45	46	40	48	31	33	10	46	40	34	28	33	23	32
Europe (50)	47	48	46	46	40	46	37	46	49	42	47	47	30	30
Latin America and the Caribbean (34)	33	33	32	32	24	32	11	33	32	27	27	30	16	23
North America (2)	2	2	1	1	0	2	0	2	2	1	2	1	1	1
West Asia (12)	10	10	10	10	6	7	3	10	11	9	5	10	7	7
Global (197)	190	191	175	190	142	172	94	190	184	154	156	166	109	134
Increase in number of parties from 2006 to 2007.	2	9	19	3	4	0	12	1	3	7	11	0	3	3

Multilateral environmental agreements (MEAs) are one of the main components of international environmental governance (UNEP 2002 and UNEP 2007a). There were about 58 new Parties in 2007, most from the Asia and the Pacific (19) and Africa (16), to the 14 MEAs included in this overview. The Cartagena Protocol on biosafety (9) and the Kyoto Protocol on greenhouse gas emissions (19), including Australia's ratification of the latter on 3 December, received significant numbers of ratifications. The agreements of the Stockholm Convention on Persistent Organic Pollutants (10) and the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (7) also continued to receive ratifications.

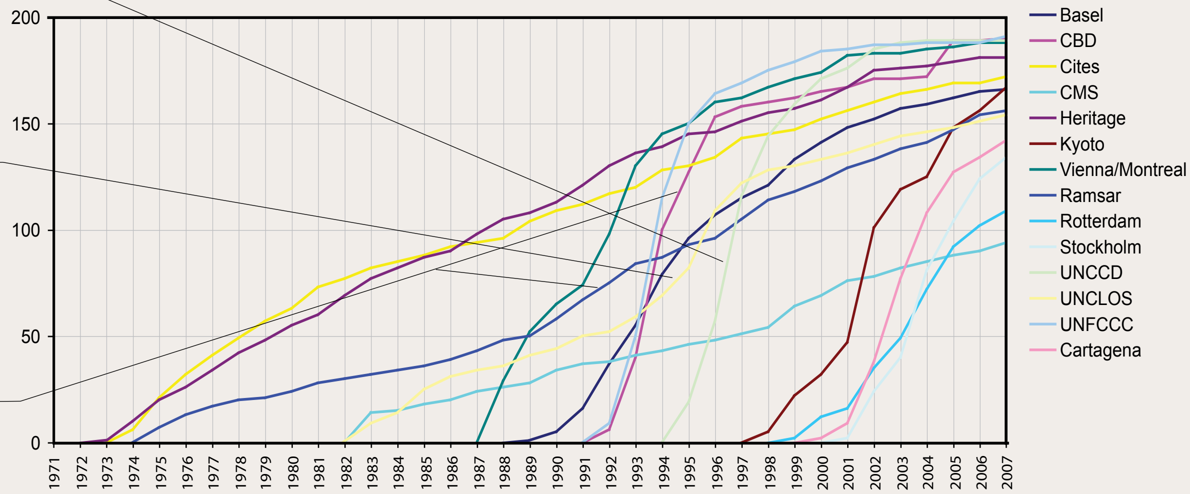
Note: *Parties to MEAs are those countries and international organizations, which have deposited their instrument of ratification, accession, acceptance, or approval. Data are up to 19 December 2007. Montenegro (Europe) and Timor-Leste (Asia and the Pacific) were added to the regional lists of countries in 2007.*

Source: UNEP GEO Data Portal, compiled from various MEA Secretariats.

Luc Gnacadja, Benin, was appointed new Executive Secretary of UNCCD in September. Worsened by climate change, desertification is affecting 100 countries, including one-third of United States land, one-fifth of Spain, one-quarter of Latin America and the Caribbean, and two-thirds of Africa. In China, hundreds of millions of people are affected.

The year 2007 marked the 25th anniversary of the opening for signature of UNCLOS. It was the first multilateral treaty providing for compulsory dispute settlement mechanisms entailing binding decisions. The depletion of the world's fisheries and degradation of marine environment by pollution from growing coastal populations, as well as climate change, pose serious environmental challenges.

CBD and Ramsar released a joint report on water, wetlands, biodiversity, and climate change in May 2007, raising concerns about the continued degradation of wetlands. Wetlands are amongst the world's most threatened ecosystems. Although wetlands cover only 6 per cent of the Earth's surface they store about 35 per cent of global terrestrial carbon.



trade and African elephant conservation. The increase of organized crime in the illicit trade in ivory has gone hand-in-hand with the globalization of African markets and is a serious challenge to the successful implementation of CITES trade regulations (IISD 2007e, TRAFFIC 2007, CITES 2007).

The Doha Round of global trade negotiations hosted by the World Trade Organisation (WTO) re-commenced in February. The WTO Committee on Trade and Environment resumed its special negotiating sessions on the MEA/WTO relationship in the following month. The Committee hopes to clarify the relationship between WTO rules and specific trade obligations in MEAs. The most important issues are whether a dispute settlement panel should seek out and defer to MEA expertise on appropriate issues and whether to grant permanent observer status to some MEA secretariats for the rest of the Doha Round (IISD 2007f).

Box 1: Building blocks for a strengthened international environmental governance system

International environmental governance discussions focus on the appropriate response to ecosystem changes, environmental degradation, and how to ease the heavy burden of reporting and meeting obligations. In June 2007, a report from the Informal Consultative Process on the Institutional Framework for the United Nations' Environmental Activities suggested building blocks for an enhanced environmental governance system. Among the suggestions are:

- to include UNEP in the joint liaison group, established in 2001 to enhance collaboration among the three Rio conventions on biodiversity, climate change, and desertification;
- to establish a process under guidance from UNGA to cluster thematic, programmatic, and administrative aspects of MEAs;
- to improve coordination of country-level activities of MEAs with the government of the host country and within the UN system; and
- to make UNEP and MEAs formal observers on relevant committees of the World Trade Organization (UNGA 2007).

Negotiations on international environmental governance related to the Information Consultative Process will continue throughout the 62nd UNGA into 2008 (IISD 2007g).

Box 2: Joint implementation on chemicals at global and national levels

Progress continued on cooperation and coordination among the chemicals conventions: the Stockholm Convention on Persistent Organic Pollutants, the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. These three closely-related conventions are using joint implementation as a way to streamline reporting and monitoring obligations of parties to the conventions. The ad hoc joint working group on enhancing cooperation among the three conventions held its first sessions in 2007. Governments discussed practical aspects of cooperation and coordination. They also developed guiding principles and priorities for the working group's future work and identified national needs. Development of proactive environmental management tools, use of environmentally sound technologies, public education and awareness raising, and mobilization of financial resources are some of the areas that need to be targeted at national levels (Ad Hoc Joint Working Group 2007).

REFERENCES

Aakre, W. (2007). Biofuels Industry and Impacts on Agriculture. North Dakota State University, Extension Services, January 2007 http://www.ag.ndsu.nodak.edu/aginfo/farmmgmt/farmmgmt.htm [Accessed 10 December 2007]

Ad Hoc Joint Working Group (2007). Official Documents for the second meeting of AHJWG. http://ahjwg.chem.unep.ch/index.php?option=com_content&task=section&id=11&Itemid=61 [Accessed 17 December 2007]

Alaska Marine Conservation Council (2007). *Bering Sea Bottom Trawl Boundary*. http://www.akmarine.org/our-work/conserve-fisheries-marine-life/bering-sea-bottom- trawl-boundary [Accessed 5 November 2007]

BBC (2007). Canada to strengthen Arctic claim. *BBC News*, 10 August. http://news.bbc.co.uk/2/hi/americas/6941426.stm [Accessed 14 September 2007]

Blanc, J.J., Barnes R.F.W., Craig, G.C., Dublin, H.T., Thouless, C.R., Douglas Hamilton, I. and Hart, J.A. (2007). *African Elephant Status Report 2007*. IUCN-The World Conservation Union, Gland

Bonobo Conservation Initiative (2007). *Massive New Rainforest Reserve Established in the Democratic Republic of Congo*. www.bonobo.org/newreserve.html

Bruno, J.F. and Selig, E.R. (2007). Regional Decline of Coral Cover in the Indo-Pacific: Timing, Extent, and Subregional Comparisons. *PLoS ONE 2*(8), e711. doi:10.1371/journal.pone.0000711

Canadell, J.G., Le Quéré, C., Raupach, M.R., Field, C.B., Buitenhuis, E.T., Ciais, P., Conway, T.J., Gillett, N.P., Houghton, R.A. and Marland G. (2007). Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks. Proc Natl Acad Sci U S A. 2007 Oct 25

Christian Aid (2007). *Human tide: the real migration crisis*. A Christian Aid Report. May 2007 http://www.christianaid.org.uk/stoppoverty/climatechange/resources/human_tide.aspx

CITES (2007). CITES conference to consider new trade rules for marine, timber and other wildlife species. Press Release. http://www.cites.org/eng/news/press/2007/0705_presskit.shtml [Accessed 7 December 2007]

Clark, M.R., Tittensor, D., Rogers, A.D., Brewin, P., Schlacher, T., Rowden, A., Stocks, K. and Consalvey, M. (2006). *Seamounts, deep-sea corals and fisheries: vulnerability of deep-sea corals to fishing on seamounts beyond areas of national jurisdiction*. UNEP-WCMC, Cambridge UK

Conservation International (2007). M*adagascar Creates 1 Million Hectares of New Protected Areas*. Press release, April 30, 2007 http://web.conservation.org/xp/news/press_releases/2007/043007a.xml [Accessed 10 September 2007]

Continental Shelf Project (2006) *LORITA-1 Lomonosov Ridge Test of Appurtenance* http://a76.dk/expeditions_uk/lorita-1_uk/ [Accessed 15 November 2007]

Economist (2007). Food Prices: Cheap No More. 6 December 2007

Eldridge, N. (2001). *The Sixth Extinction* http://www.actionbioscience.org/newfrontiers/eldredge2.html [Accessed 15 November 2007]

ESA (2007). *Satellites witness lowest Arctic ice coverage in history*. European Space Agency. http://www.esa.int/esaCP/SEMYTC13J6F_index_1.html [Accessed 20 November 2007]

Evan, A. T., Dunion, J., Foley, J., Heidinger, A., and Velden, C. (2006) New evidence for a relationship between Atlantic tropical cyclone activity and African dust outbreaks. *Geophys. Res. Lett.*, 33, L19813

Evjen, G.H. (2006). Seeds of the world to be conserved on Svalbard. Norwegian Government Press Centre. 30 May 2006

Fowler, C. (2007). Norway to build 'fail-safe' conservation site on Arctic Archipelago: A publication about agricultural biodiversity. Global Crop Diversity Trust.

Goldenberg, S.B, Landsea, C.W., Mestas-Nuñez, A.M. and Gray, W.M. (2001) The Recent Increase in Atlantic Hurricane Activity: Causes and Implications *Science* 20 July 2001: 474-479.

Haeberli, W., Hoelzle, M., Paul, F., Zemp, M. (2007). Integrated monitoring of mountain glaciers as key indicators of global climate change: the European Alps. *Annals of Glaciology*, 46, 2007

Hansen, J. (2007). Scientific reticence and sea level rise. *Environ. Res. Lett*. 2,024002 doi:10.1088/1748-9326/2/2/024002

IISD (2007a). *Briefing Note On The Negotiation Of The Paris Agreement. Earth Negotia- tions Bulletin*. International Institute for Sustainable Development. http://www.iisd.ca/cms/brief/CMS_Gorilla_Agreement_Brief.html [Accessed 15 November 2007]

IISD (2007b). MEA Bulletin. 33. http://www.iisd.ca/email/mea-l.htm [Accessed 1 December 2007]

IISD (2007c). Earth Negotiations Bulletin. 15 (149, 152). http://www.mail-archive.com/enb@lists.iisd.ca/ [Accessed 7 December 2007]

IISD (2007d). Earth Negotiations Bulletin. 16 (59). http://www.iisd.ca/vol16/enb1659e.html [Accessed 7 December 2007]

IISD (2007e). Earth Negotiations Bulletin. 21 (61). http://www.iisd.ca/download/pdf/enb2161e.pdf [Accessed 7 December 2007]

IISD (2007f). MEA Linkages Bulletin. 23, 26, 36. http://www.iisd.ca/mea-l/ [Accessed 1 December 2007]

IISD (2007g). MEA Linkages Bulletin. 28. http://www.iisd.ca/mea-l/ [Accessed 7 December 2007]

IPCC (2007a). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp

IPCC (2007b). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (eds. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., 851 pp

IPCC (2007c). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (eds. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp

International Alert (2007). *A Climate of Conflict: The links between climate change, peace and war*. November 2007 http://wwwinternational-alert.org/climate_change.php

IPCC (2007d). *IPCC Fourth Assessment Report Summary for Policymakers of the AR4 Synthesis Report*. IPCC, Geneva

IPEN (2007). International POPs Elimination Network Newsletter, June 2007. http://www.ipen.org/ipenweb/news/cop3_report.pdf [Accessed 7 December 2007]

IUCN (2007a). *2007 Red List of Threatened Species*. IUCN - the World Conservation Union, Gland. Online at http://www.iucn.org/themes/ssc/redlist.htm [Accessed 20 November 2007]

IUCN (2007b). *Galapagos Islands added to the World Heritage Danger List*. Press release. IUCN - the World Conservation Union, Gland

JTWC (2007a) Current Northwest Pacific/North Indian Ocean* Tropical Systems. Joint Typhoon Warning Center https://metocph.nmci.navy.mil/jtwc.php [Accessed 7 June 2007]

JTWC (2007b) *Current Northwest Pacific/North Indian Ocean* Tropical Systems*. Joint Typhoon Warning Center https://metocph.nmci.navy.mil/jtwc.php [Accessed 16 November 2007]

Kitchingman, A. and.Lai, S. (2004). Inferences on potential seamount locations from mid-resolution bathymetric data. In *Seamounts: Biodiversity and Fisheries* (eds. Morato, T. and Pauly, D.). UBC Fisheries Centre, Vancouver

Klotzbach, P.J. and Gray, W. M. Gray (2007). Summary of 2007 Atlantic Tropical Cyclone Activity and Verification of Author's Seasonal and Monthly Forecasts. The Tropical Meteorology Project http://hurricane.atmos.colostate.edu/forecasts

Leakey, R. (2007). Conservation alone is not enough. BBC News , 10 September 2007. http://news.bbc.co.uk/1/hi/sci/tech/6983914.stm [Accessed 20 November 2007]

Lehman Brothers (2007). *The Business of Climate Change II: Policy is accelerating with major implications for companies and investors*. Lehman Brothers, September 2007

Le Quéré, C., Rödenbeck, C., Buitenhuis, E.T., Conway, T.J., Langenfelds, R., Gomez, A., Labuschagne, C., Ramonet, M., Nakazawa, T., Metzl, T., Gillett, N. and Heimann, M. (2007). Saturation of the Southern Ocean CO2 Sink Due to Recent Climate Change. Science , 316, 1735 Mayhew, P., Jenkins, B.J. and Benton, T.G. (2007). A long-term association between global temperature and biodiversity, origination and extinction in the fossil record. Proc. R. Soc. B

Meier, M.F., Dyurgerov, M.B., Rick, U.K., O'Neel, S., Pfeffer, W. T., Anderson, R. S., Anderson, S.P., Glazovsky, A.F. (2007). Glaciers Dominate Eustatic Sea-Level Rise in the 21st Century. *Science*, online. doi: 10.1126/science.1143906

Morton, O. (2007). Is This What It Takes To Save The World? *Nature*, 447, 132

NASA (2001). *Scientists: Future Atlantic Hurricane Picture is Highly Complex*. http://earthobservatory.nasa.gov/Newsroom/MediaAlerts/2001/200109205219.html [Accessed 24 November 2007]

NASA (2007c) *Tropical Cyclone Gonu*. http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php3?img_id=14293 [Accessed 20 August 2007]

NCDC (2007). *The Monthly Global (land and ocean combined into an anomaly) Index (degrees C)*. ftp://ftp.ncdc.noaa.gov/pub/data/anomalies/monthly.land_and_ocean.90S.90N.df_1901-2000mean.dat [Accessed 19 November 2007]

NORAGRIC (2006). Study to Assess the Feasibility of Establishing a Svalbard Arctic Seed Depository for the International Community. Centre for International Environment and Development Studies (NORAGRIC). 19 June 2006.

NSIDC (2007) *Arctic Sea Ice News Fall 2007* http://nsidc.org/news/press/2007_seaiceminimum/20070810_index.html [Accessed 15 November 2007]

Oxfam (2007). Climate Alarm: Disasters Increase Climate Change Bites. *In*: From Weather Alert to Climate Alarm, Oxfam International Briefing Paper, November 2007

Pachauri, R.K. and Hazell, P. (2006). Bioenergy and Agriculture: Promises and Challenges. International Food Policy Research Institute, Washington, DC.

Plymouth Marine Lab (2007). Ocean Acidification—the other half of the CO_2 problem. *Fact Sheet 7: EUR-OCEANS Knowledge Transfer Unit*. http://www.eur-oceans.eu/WP9/Factsheets/FS7/FS7_webprint.pdf

Rahmstorf, S. (2007). A semi-empirical approach to projecting future sea-level rise, *Science*, 315, 368–70

Rahmstorf, S., Cazenave, A., Church, J.A., Hansen, J.E., Keeling, R.F., Parker, D.E. and Somerville R.C.J. (2007). Recent Climate Observations Compared to Projections. *Science*, 316, 709

Raupach, M.R., Marland, G., Ciais, P., Le Quéré, C., Canadell, J.G., Klepper, G. and Field, C.B. (2007). Global and regional drivers of accelerating CO2 emissions. *Proc Natl Acad Sci* 104(24), 10288-93 ReliefWeb (2007) Oman/Iran Cyclone Gonu, OCHA Situation Map No.1, 07 June, 2007. http://www.reliefweb.int/rw/RWB.NSF/db900SID/JOPA-73YHLA?OpenDocument&rc=3&emid=TC-2007-000075-OMN [Accessed 16 June 2007]

ReliefWeb (2007b). Bangladesh: Disaster Management Information Centre situation report 08 Dec 2007 18:00 http://www.reliefweb.int/rw/rwb.nsf/db900SID/THOU-79R2WL/$File/Full_Report.pdf [Accessed 1 December 2007]

Sabine,C.L., Feely,R.A. Gruber, N., Key, R.M., Lee, K., Bullister,J.L., Wanninkhof, R. Wong, C.S., Wallace, D.W.R., Tilbrook, B., Millero, F.J. Peng, T-H., Kozyr,A., Ono,T., Rios, A.F. (2004). The oceanic sink for anthropogenic CO_2. *Science* 305, 367

Schuster, U. and Watson, A. (2007). A variable and decreasing sink for atmospheric CO 2 in the North Atlantic. *Journal of Geophysical Research*, 112, C11006

Shepherd, A. and Wingham, D. (2007). Recent Sea-Level Contributions of the Antarctic and Greenland Ice Sheets. *Science* 315, 5818

Shukman, D. (2007). Ice melt raises passage tension. BBC News, 8 October 2007. http://news.bbc.co.uk/2/hi/science/nature/7033498.stm [Accessed 1 November 2007]

Skovmand, B. (2007). The Svalbard International Seed Depository. The Nordic Genebank, Norway. www.ecpgr.cgiar.org/SteeringCommittee/SC10/InfNewDev/SISD.doc [Accessed 30 November 2007]

SPRFMO (2007a). *Draft Benthic Assessment Framework*. SPRFMO-IV-SWG-06. http://www.southpacificrfmo.org/event.fourth-meeting/?operation=documents [Accessed 10 November 2007]

SPRFMO (2007b). *Report of the Science Working Group*. http://www.southpacificrfmo.org/event.fourth-meeting/?operation=documents [Accessed 15 November 2007]

Stone, R. (2007). "A World Without Corals?". *Science* 316 (5825): 678-681

Tedesco, M. (2007). *NASA Finds Greenland Snow Melting Hit Record High in High Places*. http://www.nasa.gov/centers/goddard/news/topstory/2007/greenland_recordhigh.html [Accessed 15 November 2007]

TRAFFIC (2007). Fourteenth meeting of the Conference of the Parties: Interpretation and implementation of the Convention. Species trade and conservation issues: Elephants. http://www.cites.org/eng/cop/14/doc/E14-53-2.pdf [Accessed 7 December 2007]

UN (2007a). UN Security Council 5663rd Meeting. Press Release. http://www.un.org/News/Press/docs/2007/sc9000.doc.htm [Accessed 7 December 2007]

UN (2007b). The Future in our Hands: Addressing the Leadership Challenge of Climate Change. Press Release. http://www.un.org/climatechange/2007highlevel/ [Accessed 13 December 2007]

UNDP (2007). *Human Development Report 2007/2008, Fighting Climate Change: Hu- man Solidarity in a Divided World*. United Nations Development Programme, New York

UNEP (2007a). *Global Environmental Outlook 4: Environment for Development*. United Nations Environment Programme, Nairobi

UNEP (2007b). Speech by Achim Steiner at the Opening of the 19th Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer. http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=518&ArticleID=5667&l=en [Accessed 3 December 2007]

UN-Energy (2007). *Sustainable Bioenergy: A framework for Decision Makers*. United Nations Energy. http://esa.un.org/un-energy/pdf/susdev.Biofuels.FAO.pdf [Accessed 25 November 2007]

UNFCCC (2007). UN Breakthrough on climate change reached in Bali. http://unfccc.int/files/press/news_room/press_releases_and_advisories/application/pdf/20071215_bali_final_press_release.pdf [Accessed 17 December 2007]

UNGA (2007). Informal Consultative Process on the Institutional Framework for the United Nations' Environmental Activities: Co-Chair's Options Paper. http://www.un.org/ga/president/61/follow-up/environment/EG-OptionsPaper.PDF [Accessed 26 November 2007]

USCCSP (2007). *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle*. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research.

USDA (2007). USDA Global Conference on Agricultural Biofuels: Research and Economics. Minneapolis, Minnesota August 20-22, 2007

Willett, K.M., Gillet, N.P., Jones, P.D.and Thorne, P.W., Attribution of observed surface humidity changes to human influence, *Nature* 449, 710

Williams, J.W., Jackson, S.T., and Kutzbach, J. E. (2007). Projected distributions of novel and disappearing climates by 2100 AD. *Proc Natl Acad Sci*, 104(14):5738-42

WMO (2007) *WMO Greenhouse Gas Bulletin, No.3, November 23 2007* http://www.wmo.ch/pages/prog/arep/gaw/ghg/documents/ghg-bulletin-3.pdf

WWF (2007). *A third of Borneo to be conserved under new rainforest declaration*. Press release, 12 Feb 2007. http://www.panda.org/news_facts/newsroom/index.cfm?uNewsID=93980

Zhang, X., Zwiers, F.W., Heger, G.C., Lambert, F.H., Gillett, N.P., Solomon, S. Stott, P.A. and Nozawa, T. (2007). Detection of human influence on twentieth-century precipitation trends. *Nature*, online.l doi:10.1038/nature06025

Putting the Pieces Together:

Using markets and finance to fight climate change

Introduction
Taking Responsibility
Carbon Markets—Cap-and-Trade
The Future of Emissions Trading
The Role of Governments

Putting the pieces together: Using markets and finance to fight climate change

New developments are converging in unprecedented ways to respond to the climate crisis. The private sector is increasingly addressing environmental, social, and governance issues, encouraged by civil society pressures. National governments need to facilitate these responses by setting standards, supporting research, and providing incentives for the transition to an environmentally-sound, low-carbon economy, while preserving equity and helping the poorest.

INTRODUCTION

Human activities are depleting resources and producing wastes faster than the Earth's natural systems can regenerate and process them. Concern about this problem is growing—especially in the case of greenhouse gas (GHG) emissions and the climate crisis they are causing. Innovative thinkers realize that business, markets, and financial mechanisms have a major role to play, along with civil society efforts and the momentum they have instigated at sub-national levels of government. While many national governments are more and more concerned about the implications of climate changes, they need to make progress with coordinated and supportive policies to facilitate and accelerate the many initiatives underway.

UN Secretary-General Ban Ki-moon said, "Climate change is one of the most complex, multifaceted and serious threats the world faces. The response to this threat is fundamentally linked to pressing concerns of sustainable development and global fairness; of vulnerability and resilience; of economy, poverty reduction and society; and of the world we want to hand down to our children... We cannot go on this way for long...We cannot continue with business as usual. The time has come for decisive action on a global scale" (Ban 2007).

Emissions from the Eggborough coal-fired power station in Yorkshire, UK. The relentless growth of coal-dependant energy production—China plans to build 544 new coal-fired stations in the next decade—presents a serious challenge to avoiding climate change.
Source: C. James/ Still Pictures

According to the Fourth Assessment Report from the Intergovernmental Panel on Climate Change, there is a 95 per cent probability that "…human activities have exerted a substantial net warming influence on climate since 1750" (IPCC 2007). Those activities include industrial processes, power plants, transportation, agricultural production—the development of a global market place for goods and services—that have increased the greenhouse gas component of the planet's atmosphere to the point of causing climate change. As the human population has increased ~10 fold since 1750, people's aspirations have led to pursuit of higher standards of living that require more products from that global market place (IPCC 2007).

In October of 2007 the Fourth Global Environment Outlook Report concluded that: "There has been a remarkable lack of urgency in tackling GHG emissions…Climate change is a major global challenge. Impacts are already evident and changes in water availability, food security, and sea level rise are projected to dramatically affect many millions of people…To prevent future severe impacts from climate change, drastic steps are necessary to reduce emissions from energy, transport, forest, and agricultural sectors" (UNEP 2007).

The UNDP Human Development Report for 2007/2008 emphasizes the equity challenges that are amplified by climate change: "Climate change is the defining human development issue of our generation...Climate change threatens to erode human freedoms and limit choice. It calls into question the Enlightenment principle that human progress will make the future look better than the past...Across developing countries, millions of the world's poorest people are already being forced to cope with the impacts of climate change...The world lacks neither the financial resources nor the technological capabilities to act. If we fail to prevent climate change it will be because we were unable to foster the political will to cooperate. Such an outcome would represent not just a failure of political imagination and leadership, but a moral failure on a scale unparalleled in history" (UNDP 2007).

The stakes are unprecedented, the challenge is immense. But ingenuity is already creating new tools and new approaches to respond to the crisis presented by climate change. Much of this objective-driven ingenuity results from the developments over the last decades in the concept of the relationship between economic advancement and social stability.

This feature will examine some of the developments that civil society pressures on the private sector have produced to address environmental, social, and governance issues. These developments are converging in unprecedented ways to respond to the climate crisis. A case is made that national governments have an important role in facilitating these responses through setting standards, supporting research, and providing incentives for transitioning to an environmentally-sound economy.

TAKING RESPONSIBILITY

The components of a healthy and sustainable society are intertwined. Efficient use of land, water, energy, and other natural resources supports sustainable livelihoods, makes enterprises more productive, and reduces disposal and clean-up costs. Safe products and working conditions attract conscientious clients and minimize tragic and costly accidents. Education, health care, and equal opportunity cultivate stable communities and a productive workforce. Good governance, the rule of law, and defined property rights are essential for security, efficiency, and innovation (Porter and Kramer 2006).

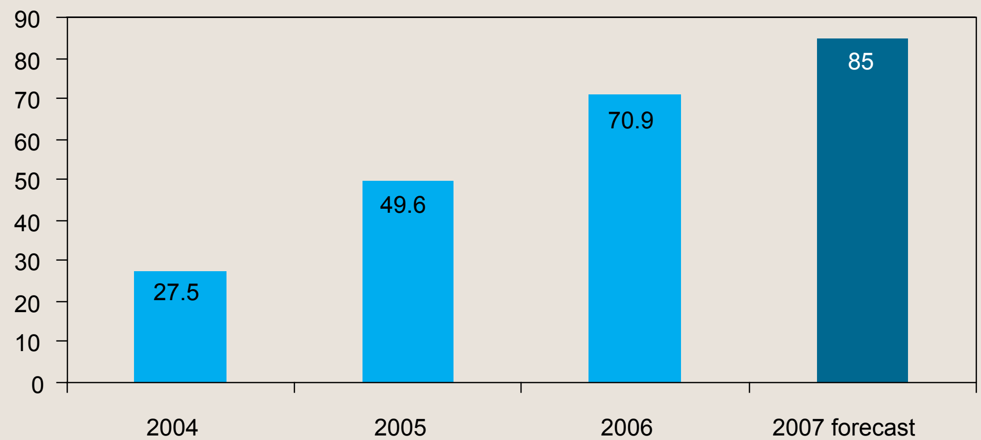
Historically, economic productivity has been closely related to growth in energy consumption—particularly energy derived from fossil fuels. Since 1750, economic development has been literally fuelled by levelling forests and burning wood, then coal, oil, and gas (IEA 2007). However, it is possible to decouple growth and carbon use. More efficient use can spur economic growth while total energy consumption declines—and energy efficiency has phenomenal potential to address other pollution problems. Between 1990 and 2005, some industrialized regions appeared to achieve this decoupling of carbon consumption and national productivity to reduce carbon intensities, but the possible 'trend' is not entrenched and is currently not growing, according to the latest data (Lovins 2006, Raupach and others 2007) (See Global Overview).

With an increasing proportion of sustainable energy sources, the link between energy use and greenhouse gas emissions can be decoupled. Innovations in photovoltaic technologies, geo-thermal systems, micro-hydro, wind turbines, and other renewable energies over the last decades show clearly that pollution is not an unavoidable side effect of development (**Figure 1**).

Responses to the threat of changing climate are underway around the globe and at every scale, ranging from top-down national government follow-up to commitments made under the UN Framework Convention on Climate Change's (UNFCCC) Kyoto Protocol through sub-national and municipal government commitments and partnerships to bottom-up initiatives motivated by civil society and the corporate sector (Walker 2007).

Wind turbine in the Lower Saxony region of Germany.
Source: H. Pieper/ Still Pictures

Figure 1: Global investment in sustainable energy, 2004-2007 (billions of US$)



Worldwide investment in sustainable energy more than doubled over a two-year period, from 2004 to 2006, and continues to attract strong capital investment at all stages of the financing lifecycle, with US$85 billion forecast for 2007.
Note: This figure represents new investment only, and excludes venture capital and private equity buy-outs and acquisitions.
Source: adapted from Greenwood and others 2007, New Energy Finance 2006

Box 1: The Global 100—Most sustainable corporations in the world

In 2004 Corporate Knights Incorporated and Innovest Strategic Value Advisors initiated 'The Global 100', a private partnership project to call attention to the world's most sustainable corporations. More specifically, Global 100 investigates the role of corporations in society, strengthens existing corporate sustainability initiatives by promoting better managed and performing corporations, and assists the public to understand corporations in a broader sense.

The Global 100 is essentially a list—released annually at the Davos World Economic Forum—that includes a select group of publicly-traded companies demonstrating exceptional capacity to address sector-specific challenges to achieving sustainability. Based on the research and analysis of Innovest, a US-based international investment advisory firm, companies are evaluated according to how effectively they manage their environmental, social, and governance risks and opportunities. Drawn from a pool of some 1800 international corporations, each company is analyzed according to 71 specific evaluation categories and ranked in relation to their industry peers. However, the process does not appraise companies on absolute performance or assign absolute sustainability ratings. Rather, the final 'best-in-class' list is simply published alphabetically. The rational for this, according to Global 100's methodology, is that different industries are confronted with vastly different social, environmental, and operating dynamics and therefore comparing one company to another from different sectors (i.e., oil and gas vs. telecommunications) would be uninformative.

Corporations are increasingly using sustainability as a unifying concept to help understand complex topics as climate change, biodiversity, energy prices and scarcity, income distribution, social justice, and governance. Mathew Kierman, CEO of Innovest, recently noted that Global 100 companies are "...proactive in their response to investors and other stakeholder demands for better management of risks such as climate change." Now entering its fourth year, proponents of the Global 100 initiative believe that companies who are leaders in sustainability are well-positioned to capitalize on the emerging wave of capital investment—trillions of dollars—resulting from increased environmental scrutiny and regulatory action.

Source: Global100 2007

Box 2: Principles for corporate responsibility: Global Compact

In 2000, to mark the new millennium, about 30 companies joined a United Nations-sponsored Global Compact on corporate citizenship that exemplifies environmental, social, and governance efforts. By the beginning of 2007 the membership had reached 3 800 governments, businesses, labour, and civil society organizations. Global Compact members believe that responsible business practices can build social capital as well as profit, contributing to broad-based development and sustainable markets.

To achieve their objectives, the Global Compact aims to mainstream ten principles for responsible business activities around the world, in the areas of human rights, labour, environment, and anti-corruption.

Businesses should:

1. support and respect the protection of internationally proclaimed human rights
2. make sure that they are not complicit in human rights abuses
3. uphold the freedom of association and the effective recognition of the right to collective bargaining
4. uphold the elimination of all forms of forced and compulsory labour
5. uphold the effective abolition of child labour
6. uphold the elimination of discrimination in respect of employment and occupation
7. support a precautionary approach to environmental challenges
8. undertake initiatives to promote greater environmental responsibility
9: encourage the development and diffusion of environmentally friendly technologies
10. work against corruption in all its forms, including extortion and bribery

Source: Global Compact 2007

Corporate Standards on Environmental, Social, and Governance Issues

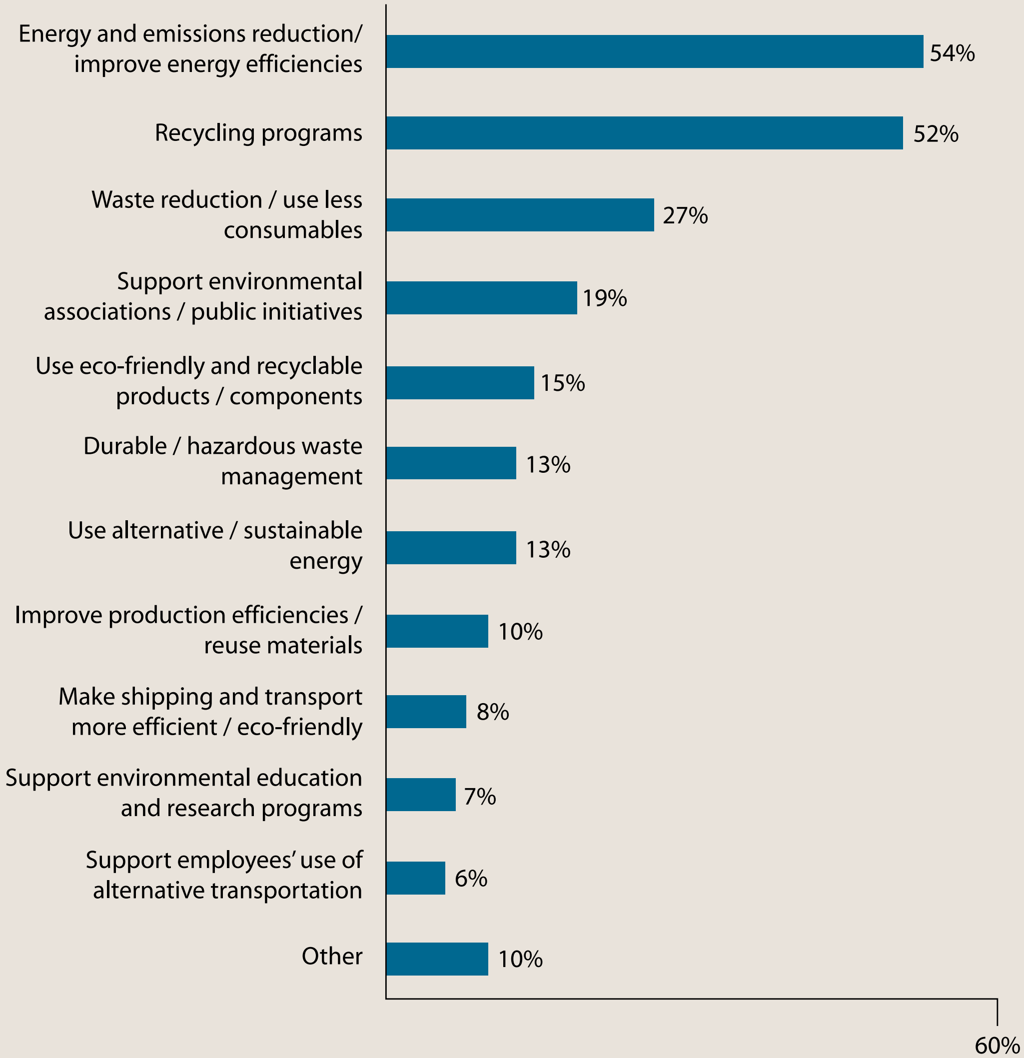
Some of the most promising activities have been in the private sector, through establishing corporate standards that address environmental, social, and governance (ESG) issues. These concerns are fundamental to sustainable development. Over the last decade, recognition of the interdependencies among them has generated new approaches to perennial problems (**Boxes 1 and 2**).

A decade ago, suspicion greeted announcements from many companies about their embrace of sustainability: 'green-wash' accusations criticized the money and time companies spent on advertising their green credentials rather than on environmentally-sound practices. The criticisms were followed up by civil society consumer action against many companies, including those involved in oil, chemical, logging, mining, cosmetics, and food products supply.

Today that situation has changed radically. More and more managers are considering the real long-term benefits of addressing ESG issues—benefits that go far beyond mere public relations concerns. With creative thinking, often in consultation with civil society advisors, many firms have discovered they can deliver societal 'goods' that reach beyond their products and services. The prime example has been company efforts to increase efficiency by cutting energy costs and minimizing waste throughout their operations (Lovins 2006) (**Figure 2**).

Most of the private sector's commitment to ESG issues is now solid and backed by action. The last decade has seen the creation of a range of industry associations, consultancies, and specialized MBA courses designed to help businesses to integrate sustainability into strategy and operations. These include specialized initiatives such as the Business Leaders Initiative on Human Rights, which addresses barriers that prevent companies from realizing their role in supporting universal human rights. Another example is the Extractive Industries Transparency Initiative, which supports improved governance in resource-rich countries through the verification and full publication of company payments and government revenues from oil, gas, and mining (BLIHR 2007, EITI 2007).

Figure 2: Environmental initiatives



Results of a survey conducted on 150 companies showing the importance of environmental initiatives within Corporate Social Responsibility programs. Respondents were asked to describe the environmental initiatives that their companies are currently involved in or plan to be involved in within the next 12 months. The survey found that 70 per cent of companies were actively engaged in various initiatives with the highest number of companies looking to reduce their overall energy consumption.

Source: Montgomery and Prior 2007, AMR Research inc. 2007

This new attitude of corporate social responsibility (CSR) creates opportunities in which corporations can utilize "...shared value...not only to foster economic and social development but to change the way companies and society think about each other..." according to Michael Porter of the Harvard Business School's Institute for Strategy and Competitiveness. When looked at strategically, CSR develops into a source of tremendous social progress, as businesses apply their considerable resources, expertise, and insights to activities that benefit society as a whole (Porter and Kramer 2006).

Corporate social responsibility and investors

Corporate social responsibility has become an important business credential to attract clients and customers, but it can also lead to long-term profit and attention from potential investors. Institutional asset owners such as pension funds now control an estimated 86 per cent of investment in the world (Ambachtsheer 2006). Many of these institutional asset owners are dominant players in their respective capital markets and have significant potential to shape the character of economic growth.

Typically these asset owners are risk-averse because their overriding priority is fiduciary responsibility—trustees are bound by the duty to act and make investment decisions in the best long-term interests of shareholders or beneficiaries. Simply put, anything that can have a material impact on beneficiary investment value must be accounted for in investment decision making (Ambachtsheer 2006, Hawley 2006, Walker 2007).

It is now widely recognized that climate change will have a massive effect on investment values. This realization is embodied in the United Nations Principles for Responsible Investment, an integration of ESG objectives into the investment process that was developed by a group of investors, in a process facilitated by the UNEP Finance Initiative and the UN Global Compact. Members who have signed up to the Principles include around 240 asset owners, asset managers, and investment service providers with combined assets of over US$10 trillion (PRI 2007).

Significantly, these institutional asset owners ask their asset managers and analysts to scrutinize companies according to the company's management of environmental, social, and governance issues. And through 'active ownership' strategies, investors are engaging with companies directly by asking for improvements in ESG objectives in certain decisions that investors view as risks to value. These investment strategies reward companies that follow best ESG practices by raising their profile among fellow investors. And by withholding recommendations, they encourage companies that don't follow best ESG practice to improve their performance (**Box 3**).

But here, too, the concept of responsibility is evolving. While debate continues about 'to whom' a corporation is responsible—shareholders or all stakeholders—the growing understanding of the interdependencies of the global economy adds a new dimension to the idea of responsibility. Those with fiduciary responsibility must be aware of emerging but persisting conditions that may affect investment value. In our globalized and resource-constrained world, these conditions include: water as a commodity, forests for carbon sequestration, biodiversity as a resource for future innovations, good community relations as an asset, and value added by environmental legislation and labour standards. And in our globalized and communication-enabled world, citizens are acting as witnesses to corporate activities and broadcasting their findings to an increasingly conscious global community. Without careful attention to the risks and opportunities associated with environmental, social, and governance issues, companies may make poor decisions with long-term negative consequences on portfolios that many thousands of people depend upon. One way citizens keep track of corporate activities is by following their CSR reports (Walker 2007) (**Figure 3**).

Responsible investment is moving towards the concept of 'universal ownership'. This recognizes that large institutions such as pension funds own interests in a broad cross-section of the

Box 3: Investors' networks for addressing environmental, social, and governance issues

Several collaborative platforms exist through which investors put pressure on companies over environmental, social, and governance issues such as the climate crisis:

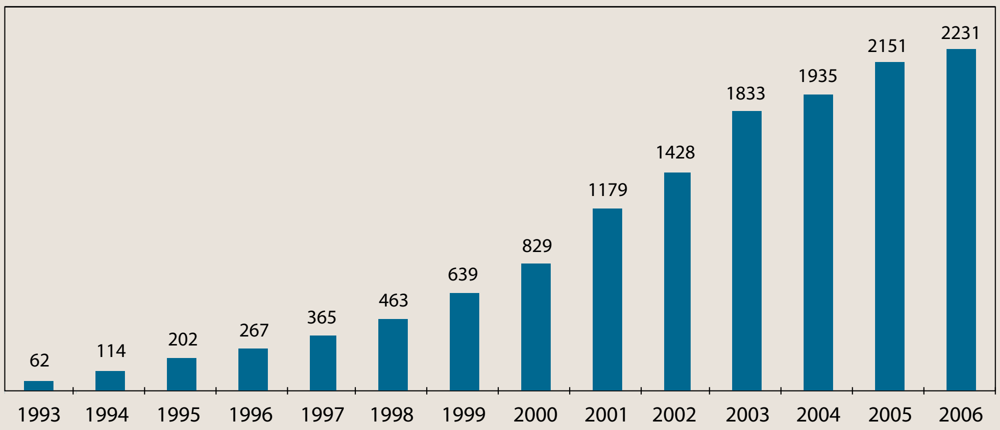
The International Corporate Governance Network (ICGN) is a non-profit association providing an investor-led network that exchanges views and information about corporate governance issues internationally as well as developing and encouraging adherence to corporate governance standards and guidelines. Membership of ICGN is open to those who are committed to the development of good corporate governance. As of 2007, ICGN members are estimated to hold assets exceeding US$10 trillion (IGCN 2007).

The Council of Institutional Investors is the premier US shareholder-rights organization. It is a non-profit association of 130 public, labour, and corporate pension funds with assets exceeding US$3 trillion. The Council works to educate members and the public about corporate governance and to advocate for strong governance standards on issues ranging from executive compensation to the election of corporate directors (CII 2007).

The Institutional Investors Group on Climate Change (IIGCC) is a forum for collaboration between pension funds and other institutional investors on issues related to climate change. IIGCC seeks to encourage companies and markets in which members invest to address any material risks and opportunities to their businesses associated with climate change and the shift to a lower carbon economy (IIGCC 2007).

The Investor Network on Climate Risk is a network of institutional investors and financial institutions dedicated to promoting better understanding of the financial risks and investment opportunities posed by climate change. INCR was launched at the first Institutional Investor Summit on Climate Risk at the United Nations in November 2003, and now includes more than 50 institutional investors that collectively manage over US$3 trillion in assets. Members engage companies and policy makers through educational forums, shareholder resolutions, and other actions to ensure the long-term health of their investments (INCR 2007).

Figure 3: Growth in corporate social responsibility reporting 1993-2006



Note: Data covers number of companies reporting on CSR—from a possible total of 3644 companies across 91 countries.
Source: Greenwood and others 2007, CorporateRegister.com 2007

Ecuador is seeking compensation for preserving a a portion of the Amazon rainforest and abandoning development of a giant oil field that could generate annual revenues of US$350 million. Ecuadorian President Rafael Correa asserts that the international community has a duty to share in the sacrifice in recognition of the global environmental benefits that would be generated by keeping the forest intact and the oil underground.
Source: P.C. Vega/ Majority Wor

global economy through diversified portfolios of stocks, bonds, and other assets. This level of diversification means that investors in these funds own small fractions of nearly the whole market economy. So if one company that they hold shares in pollutes, another company that they hold shares in may have its profits damaged by the pollution. In more formal language, a fund's overall investment returns will be affected by the positive and negative externalities generated by its individual holdings: some holdings will bear the costs of other holdings' externalities. If none of the companies they hold shares in pollute, then there is less pollution to damage the interests of other companies they hold shares in (Ambachtscheer 2006).

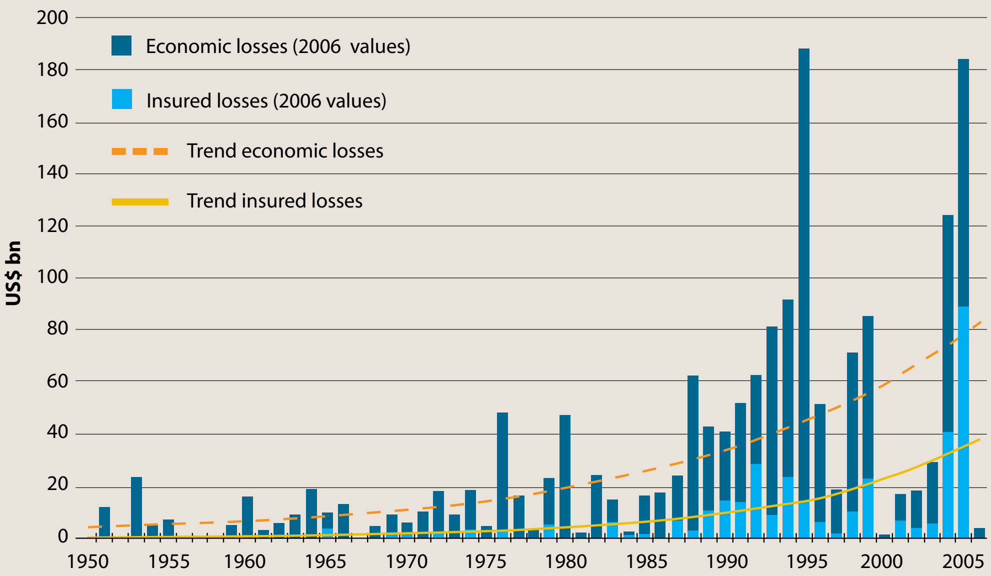
The essential point is that universal owners have an incentive to minimize the negative external effects (such as pollution or corruption or slave labour) and to maximize the positive external effects (such as corporate social responsibility) that influence every single one of their portfolio holdings. Such an approach minimizes risk and optimizes the long-term return to all their investors.

Corporate responsibility and the carbon economy

The insurance and re-insurance industries are particularly aware of and responsive to the threats of climate change. Their interest is due to risk factors posed by direct impacts of climate change—the worse the floods or droughts, the more the insurance industry has to pay out. If they take too many risks and pay out too much, insurance industries and the re-insurers that back them up go out of business. The industries' involvement grew through membership on national and international committees of the International Decade of Disaster Reduction during the 1990s, as the relationship between rising weather-related disaster costs and climate change became evident. Since its inception, the Intergovernmental Panel on Climate Change has enjoyed contributions and participation from the insurance representatives. Munich Re, one of the world's largest re-insurers, has launched the Munich Climate Insurance Initiative with the aim of developing insurance solutions designed to contend with the increasing losses from extreme weather events, especially in developing countries (Munich Re 2007) (**Figure 4**) (**Box 4**).

For most corporate decision makers, the central question narrows to whether their decisions optimize share value. And the evidence suggests that higher levels of corporate social responsibility are associated with higher share values. A report released in July of 2007 by Goldman Sachs, one of the world's leading investment banks, showed that among six sectors covered—energy, mining, steel, food, beverages, and media—companies that are considered leaders in implementing ESG policies created sustained competitive advantage and outperformed the general stock market by 25 per cent since August 2005. In addition, 72 per cent of these companies outperformed their peers in the same industries over the same period (Goldman Sachs 2007).

Figure 4: Global costs of extreme weather events from 1950–2006 (adjusted for inflation)



Source: IPCC 2001, Rauch 2007

Box 4: Microinsurance: Supporting enterprise in developing countries

The Alliance of Small Island States (AOSIS) first proposed the idea of insurance-related solutions to address the effects of climate change in 1991, in the form of a fund financed by industrialized countries. Article 4.8 of the UNFCCC and Article 3.14 of the Kyoto Protocol both call on industrialized countries to develop measures that enable developing countries to react to climate change, and insurance is mentioned as an option.

International insurance coverage data show that access to insurance varies significantly. Covers for catastrophic events are rarely even available in Africa, Asia, and Latin America, much less purchased. Of the 2.5 billion people worldwide who have less than two dollars a day at their disposal, it has been estimated that only ten million are able to purchase insurance.

Analysts suggest three reasons for this. First, many people are unable to afford insurance. Second, the necessary infrastructure is frequently lacking, especially in rural areas. And third, the concept of commercial insurance is virtually unknown in some cultures.

Microinsurance can play an important part in overcoming these hurdles. A successful start is underway in developing country agricultural sectors. Weather insurance schemes based on rainfall indices are currently being developed. The cover is paid if the rainfall drops below a certain level within a given period of time. In this way, farmers can protect themselves against the effects of droughts, which are expected to increase due to climate change (Munich Re 2007, UNEP FI 2006).

The best performing companies are increasingly addressing their contributions to the changing climate as an integral part of their CSR. The FT500 is a ranking of the top 500 corporations worldwide as measured by revenue, compiled annually by the Financial Times newspaper. The non-profit Carbon Disclosure Project (CDP) has been tracking the engagement on climate change issues by the FT500 since 2000. In their 2007 Report, CDP reveals that 77 per cent of the FT500 companies are disclosing their carbon performance. Of those 383 companies, 76 per cent are implementing GHG emission reduction initiatives, a dramatic increase from 48 per cent in 2006. The highest carbon disclosure rate was achieved by carbon-intensive companies—oil and gas industries; international electric utilities; North American electric power companies; and the metals, mining, and steel sectors. Participants in the 2007 Carbon Disclosure Project represent US$41 trillion of institutional investments (CDP 2007 Report) (**Figure 5**).

How do these giant corporations implement GHG emission reductions? They do it in the same ways individuals do it. First, they reduce their emissions as much as they possibly can through gaining efficiencies and following through on cost-benefit analysis. When they approach the point at which the cost of reducing emissions becomes very expensive, they look at carbon markets to offset their remaining carbon burden. An offset is the purchase of a commodity that compensates for emitting carbon. The more expensive offsets are, the more likely a corporation will reduce emissions within their operation. If the company is operating in a country that has commitments under the Kyoto Protocol, then they are subject to specific national verifications of their own reductions and to particular offsetting rules that are determined by government.

Theoretically, buying offsets will become more expensive over the years by the design of the emissions market, while the cost of reducing emissions will decrease over the years by use of new technologies and introduction of efficiencies.

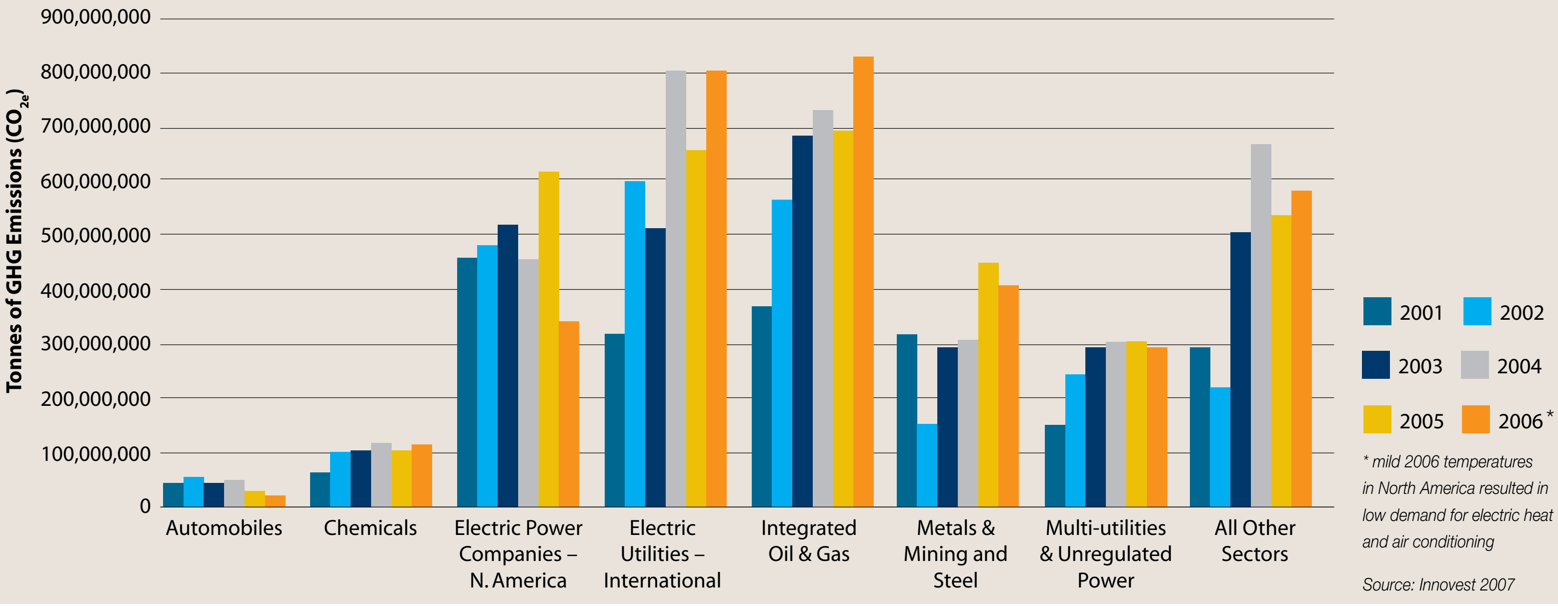
CARBON MARKETS—CAP-AND-TRADE

The price of carbon is set by the growing global market in carbon offsets. The model used for setting up carbon markets was the sulphur trading market in the United States of America. In 1990, US legislators set an overall national limit on sulphur dioxide emissions—a major cause of acid rain—requiring a 50 per cent cut by 2010. Under a conventional command-and-control regime, coal-fired utilities would have had little choice but to purchase expensive pollution control technologies to reach the lower targets. Instead, a market-based 'cap-and-trade' system was adopted. Utilities could either reduce emissions themselves directly, or they could purchase allowances from other companies that had cut emissions even lower than their targets. Companies were motivated to reduce emissions because they could sell their unused allowances, while those that did not make cuts had to buy more allowances or face expensive fines (IETA 2007).

Creating a commodity from carbon emissions

In 1997 the Kyoto Protocol established reduction commitments for carbon dioxide equivalent emissions for industrialized countries. Once a country ratified the Protocol, it would be bound to meet those commitments for the period from 2008 to 2012. To help parties meet commitments, the Protocol established three mechanisms—the Clean Development Mechanism (CDM), Joint Implementation (JI), and International Emissions Trading. These were designed to reduce emissions

Figure 5: Carbon-intensive industry emissions 2001– 2006



** mild 2006 temperatures in North America resulted in low demand for electric heat and air conditioning*

Source: Innovest 2007

and, just as importantly, to support sustainable development (UNFCCC 2007).

There are several carbon markets in existence today and, for the most part, carbon markets trade independently of one another and at different price levels. As more and more CDM and JI credits enter the European Union's emissions trading scheme, prices in these markets may eventually converge. Prices and trading volumes reflect many factors, including differences in the rigor of emission caps, enforcement standards, transaction costs, project monitoring, and auditing. Like currency notes, the paper itself is worthless: carbon credits are only as valuable as the credibility of the organizations that back them (Victor and Cullenward 2007).

Clean Development Mechanism

The clean development mechanism is designed to stimulate reductions in carbon emissions and to support sustainable development, as well as allowing industrialized countries some flexibility in meeting their emission reduction targets. The traded commodities in the CDM market are Certified Emissions Reductions (CERs) which are measured in metric tons of CO_2 equivalent.

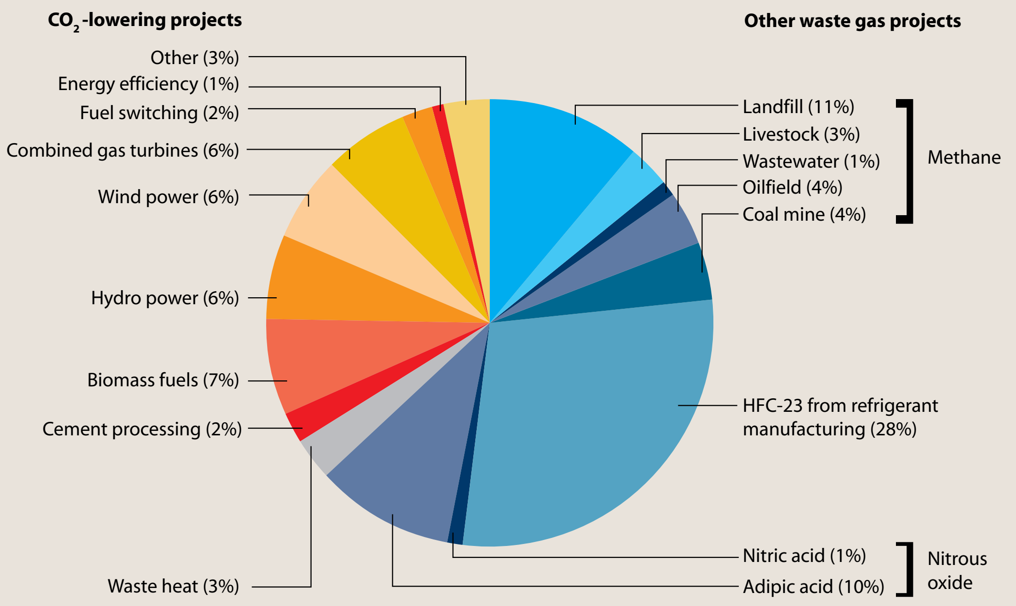
The CDM scheme was launched in November 2001. The first project was registered about three years later and the first CERs were issued in October 2005. The mechanism allows emission-reducing projects in developing countries to earn CERs that project participants can then sell to buyers in industrialized countries. Projects range from wind farms to hydroelectric power installations and include energy efficiency projects as well as those that reduce non-CO_2 industrial greenhouse gases. Rules for additional types of projects were adopted later: large-scale afforestation and reforestation projects in December 2003, small-scale afforestation and reforestation projects in December 2004, and programmes (or bundles) of emission reduction activities in December 2005 (**Figure 6**). Projects must qualify through a rigorous registration process designed to ensure real and measurable emission reductions that are additional to what would have occurred without the project.

The mechanism is overseen by an executive board, answerable ultimately to the countries that have ratified the Kyoto Protocol. As of 28 November 2007, 852 projects had been registered in 49 countries. These projects are expected to earn US$1.08 billion worth of CERs to the end of the first Kyoto commitment period in 2012. When the projects in the project approval pipeline are included, the number of expected CERs is in excess of US$2.5 billion (UNFCC 2007). As of October 2007, US$85.9 million CERs have been issued by the CDM Executive Board (CDM EB 2007). While CDM has suffered from a relatively slow start, the mechanism is now gaining good momentum with more than 2 600 projects currently in the global pipeline (UNFCCC 2007).

Some environmental NGOs and market observers have voiced doubts about the environmental integrity of some of these CERs—and thus their relevance to actual sustainable development. Almost 40 per cent of the existing CDM projects are dedicated to reducing industrial gases, such as HFC-23 and N_2O. The 25 per cent of total CERs that have been paid to destroy HFC-23 is the common example used to challenge sustainable development objectives in CDM projects. In developing countries, industries manufacture a refrigerant, HCFC, which was presented as a magic bullet to replace the ozone-depleting refrigerant CFC in the early 1990s. However, HCFC production creates a by-product gas called HFC-23, which has a global warming potential of 11 700. This implies that reducing emissions of one metric ton of HFC-23 is equivalent to reducing 11 700 metric tons of CO_2. Refrigerant companies find it relatively cheap to install an incinerator to burn the HFC-23 and, once that is converted into CERs, each metric ton of HFC-23 destroyed can be sold as 11 700 carbon credits. Analysts claim that all the HFC-23 could be eliminated at US$0.30 per metric ton by providing the incinerators and paying producers to capture and destroy HFC-23 instead of buying CDM credits from them at around US$15 per metric ton (Wara 2007).

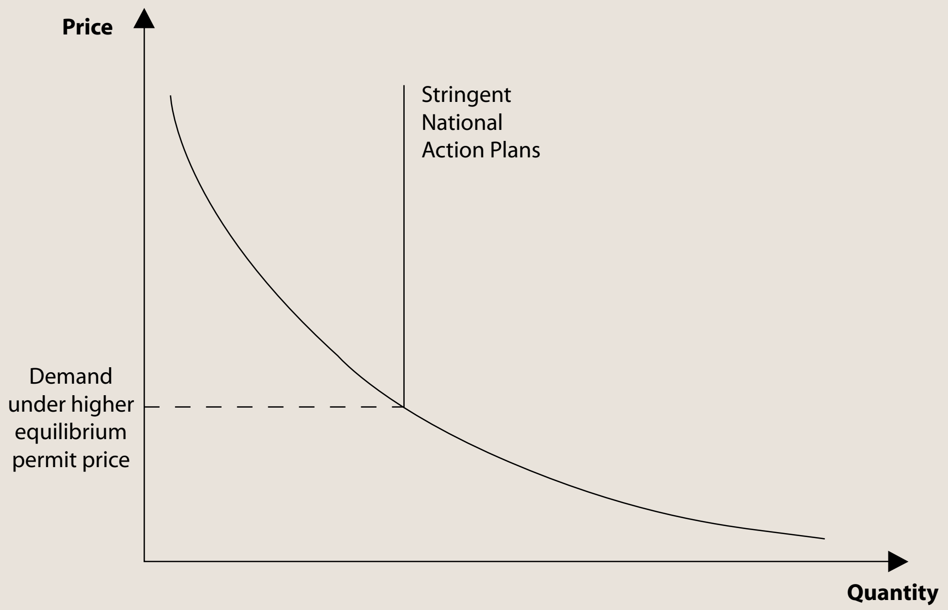
Defenders of the CDM claim that CERs to date, especially those allotted to destroy HFC-23, have been the 'lowest hanging fruit' and that more stringent activities are about to be undertaken. The concept of 'lowest hanging fruit' or the most profitable projects was always understood as a lure for engaging sceptical participants early in the development of the CDM's market. In a newly created market, distortions are inevitable and will be reduced by allowing the market to reach equilibrium.

Figure 6: Existing projects in the global carbon market



Source: Wara 2007

Figure 7: Marginal cost of abatement supply and demand curve for carbon allowances



The curve illustrates relationships among the total volume of allowances available under the EU ETS, the marginal cost of carbon abatement, and the price at which allowances would be expected to trade on the free market.

The marginal cost of abatement curve determines demand for allowances. It traces out how the marginal cost of additional abatement increases as the stock of available allowances decreases. Its shape indicates how much harder each additional unit of abatement becomes as abatement increases. The price of an allowance will be set where this curve intersects with the fixed stock of allowances.

Source: Frontier Economics 2006

Joint Implementation

Through Joint Implementation (JI), a country with an emission reduction commitment under the Kyoto Protocol can be involved in an emission-reducing project in any other country with a commitment and can count its share of the resulting emission reductions towards meeting its own Kyoto target. JI projects earn Emission Reduction Units (ERUs), each equivalent to one metric ton of CO_2.

The mechanism is similar to CDM in terms of verification and oversight, but it targets projects in industrialized countries, especially those with Economies in Transition. As with the CDM, all emission reductions must be real, measurable, and additional to what would have occurred without the project. The JI mechanism has a supervisory committee, under the control of the Parties to the Protocol. The JI verification procedure has been operating only since early 2007, so project evaluation is limited and the first ERUs will be issued sometime in 2008 (JI 2007).

Carbon emissions as a commodity in the compliance market

The European Union Emission Trading Scheme (EU ETS) is the largest multi-national greenhouse gas emissions trading scheme in the world. The scheme, in which all 25 member states of the European Union participate, began to operate on 1 January 2005. Particular GHG emission sources are required to participate through regulations established by the countries that have adopted commitments as Parties to the Kyoto Protocol.

Under the scheme, large emitters of carbon dioxide within the EU must monitor and annually report their CO_2 emissions and they are obliged every year to account to their government for an amount of emission allowances that is equivalent to their CO_2 emissions in that year. The emitters may get the allowances for free from the government or they may purchase them from others. If an emitter has received more free allowances than it needs, it may sell them to anybody.

To ensure that real trading emerges (and that CO_2 emissions are reduced), EU governments should ensure that the total amount of allowances issued to emitters is less than the amount that would have been emitted under a business as usual scenario. The total quantity to be allocated by each Member State is defined in the Member State National Allocation Plan (NAP). However, in the 2005-2007 pilot phase, some countries allocated too many allowances and many companies profited by selling allowances to companies in countries that did not over-allocate, without actually reducing emissions (**Figure 7**).

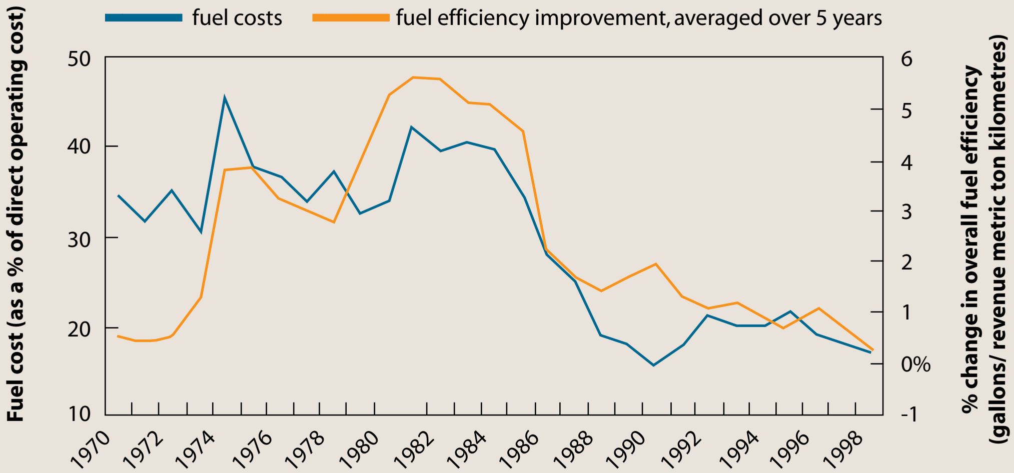
In this 2005-2007 phase, the EU ETS included 12 000 large emitters representing approximately 40 per cent of EU CO_2 emissions, covering energy activities (combustion installations, mineral oil refineries, coke ovens); production and processing of ferrous metals; mineral industry (cement clinker, glass and ceramic bricks); and pulp, paper, and board activities.

The second phase covering 2008 to 2012 will expand the scope significantly. All greenhouse gases will be included, not just CO_2; aviation emissions are expected to be included; and four non-EU members, Norway, Iceland, Liechtenstein, and Switzerland, are expected to join the scheme. The inclusion of aviation is an important step because of the large and rapidly growing emissions of the sector. The inclusion of aviation is expected to lead to an increase in demand of allowances of about 10-12 million metric tons of CO_2 per year (ETS 2007, Point Carbon 2007) (**Figure 8**).

Efforts to establish direct links between the EU ETS and the CDM and JI schemes—by routinely applying CDM-produced CERs and JI-produced ERUs to compensate for EU countries' allowance

Exhaust trails from a commercial airliner. Carbon dioxide is the principle GHG emission from aircraft, however, planes also release water vapour and nitrous oxide. It is estimated that the world's 16 000 commercial jet aircraft produce 600 million metric tons of carbon dioxide per year, nearly equal to the amount produced by all human activities in Africa per year.
Source: J. Khandani/ Still Pictures

Figure 8: Developments in fuel costs and overall fuel efficiency of EU carriers



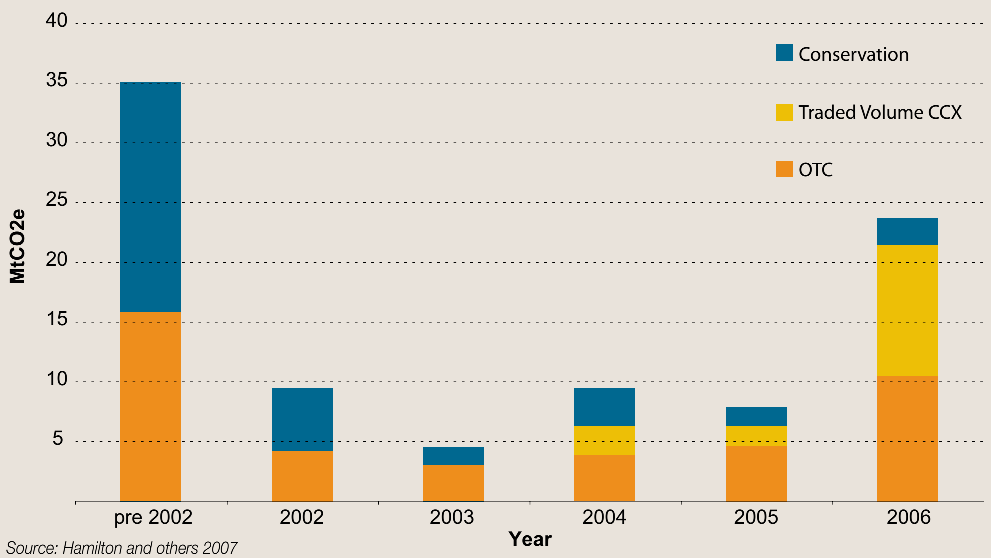
This figure illustrates the historic effect that fuel prices have generally had on overall changes in fuel efficiency in the aviation sector. Due to the direct relationship between fuel burn and CO_2 emissions, the figure also demonstrates the relationship between rises in fuel costs and fuel efficiency measures which leads to lower CO_2 missions. The aviation industry's inclusion in the EU ETS should stimulate more permanent fuel efficiency measures.

Source: Frontier Economics 2006

deficits—are subject to questions of environmental integrity. When suggestions were made to fast-track access to CDM and JI credits to meet EU member commitments, civil society representatives questioned whether that reduced the incentive to achieve emission reductions domestically inside the EU. The argument maintains that those reductions, if achieved domestically, would produce additional benefits to Europeans such as cleaner air, more jobs, new technologies, and a transition to an environmentally-sound economy (CAN-E 2007). According to some critics of carbon offsetting, the fast track between the EU ETS and the CDM and JI will just make avoiding responsibility easier: All companies have to do is buy enough CERs or ERUs and they can continue polluting (CAN-E 2007).

After extensive negotiations, civil society—represented by the Climate Action Network-Europe—agreed to the fast track with the caveat that all CERs or ERUs bought to meet EU commitments must be environmentally sound and support sustainability. Unfortunately, this condition was not retained in the final text about direct links (CAN-E 2007).

Figure 9: Historically traded volumes in the voluntary carbon market



Source: Hamilton and others 2007

Carbon reduction under voluntary schemes

Voluntary emission reduction markets include commodity exchanges that deal in legally binding transactions and companies or organizations that sell over the counter (OTC) offsets. The exchanges have rigorous standards and they offer companies verifiable offsets. OTC organisations vary in dependability but efforts are underway to impose standards (**Figures 9 and 10**).

Legally Binding Offset Exchanges

The Chicago Climate Exchange (CCX) has become the model for other voluntary carbon market exchanges set up in the UK, Australia, India, and Canada. The founders of the CCX were involved in establishing the USA sulphur trading system and in negotiating the Kyoto Protocol's financial mechanisms. Despite the USA's failure to ratify the Protocol, they launched the Exchange in 2003. By 2007, more than 330 companies, cities, states, and other entities from developed and developing countries had joined. CCX members sign legally binding contracts to participate in the Exchange-administered cap-and-trade programme.

An essential motivation for participants in CCX is the learning experience in carbon markets that the CCX offers, in anticipation of cap-and–trade rules expected for the future (Fahey 2007). These participants also gain the benefit of demonstrating their vanguard roles in corporate social responsibility. Among these members are municipalities, electric power producers, auto manufacturers, coal mines, forestry companies, steel producers, and others from the USA, Brazil, Germany, Canada, and other countries (CCX 2007).

CCX members make voluntary but legally binding commitments to meet annual GHG emission reduction targets they have assumed according to an agreed schedule. Members that reduce below their annual targets earn allowances to sell within the exchange or to bank for future compliance. Those that emit more than their annual targets comply by purchasing Carbon Financial Instruments (CFI), the standard unit of trade on CCX.

Each CFI contract represents the equivalent of 100 metric tons of CO_2. CFI contracts are comprised of allowances and offsets. Allowances are issued to emitting members in accordance with their emission baseline and the schedule. Offsets are issued to owners or aggregators of eligible projects that sequester, destroy, or displace GHGs. Offsets are issued after mitigation occurs and verification documentation is presented to CCX.

Eligible offset project categories include rangeland soil carbon sequestration; landfill methane; energy efficiency and fuel switching; renewable energy projects such as wind, solar, hydropower, and biofuels; agricultural methane collection and combustion at livestock operations such as digesters and covered lagoons; agricultural soil carbon sequestration by, for example, continuous conservation tillage and grass planting; forestry carbon such as afforestation and forest enrichment, urban tree planting, and, in specified regions, combined afforestation and forest conservation projects (CCX 2007, Fahey 2007) (**Box 5**).

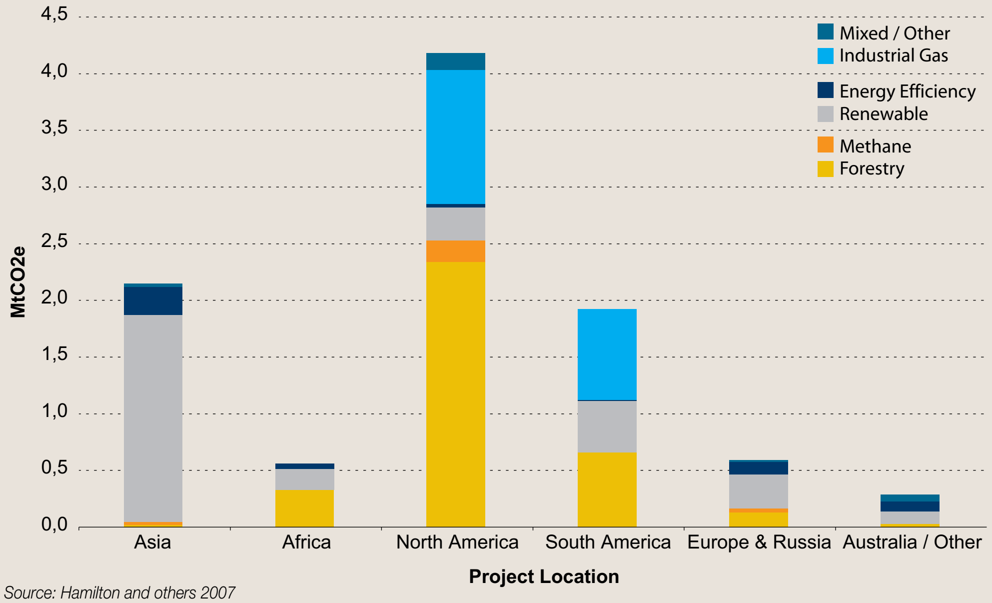
Over the Counter Offsets

Recent criticisms of the OTC offset market have been ruthless because so many of the projects are unregulated in any way (Davies 2007b). Customers do not know if the project exists; if it exists, the customer does not know if the emissions have already been counted or if the price is right. Many popular projects involve planting trees but even such an admirable activity can be loaded with problems. Trees sequester carbon over decades, but how does one account for varying rates of sequestration through drought and flood? Large tree growing projects have been criticized for disrupting water supplies, displacing villagers, removing grazing rights of herders, and planting in soils that release more carbon than is sequestered (Davies 2007b).

Schemes are emerging to guarantee to purchasers that carbon offsets represent genuine emission reductions, without harmful environmental side effects. The Voluntary Carbon Standard (VCS) was launched in November 2007 to instil confidence into an OTC market for carbon offsets that suffered severe and uncompomising scrutiny earlier in the year. The standards were developed through the work of the Carbon Project, the International Emissions Trading Association, and the World Business Council for Sustainable Development in consultation with market specialists, NGOs, and industry (VCS 2007). The VCS is endorsed by the International Organization for Standardization (ISO) acknowledging compliance with the ISO 14064 and 14065 series on quantification and reporting of GHG emissions and on assertions and accreditation requirements at organizational and project levels, respectively (VCS 2007, ISO 2007).

The Gold Standard is a system of options for offsetting carbon emissions, accredited by

Figure 10: Regional distribution of voluntary carbon market projects by type



Source: Hamilton and others 2007

Table 1: GHG Emissions trading markets: Scope and scale

	2006 volume (million metric tons CO_2 equivalents)	2006 value (US$ million)
GHG offset market		
Total Voluntary Market	23.7	91
Voluntary OTC*	13.4	54.9
Chicago Climate Exchange†	10.3	36.1
Other GHG trading schemes		
EU Emissions Trading Scheme‡	1,101	24,357
Primary Clean Development Mechanism	450	4,813
Secondary Clean Development Mechanism	25	444
Joint Implementation	16	141
New South Wales	20	225

*'Over-the-counter'

†North America's only marketplace for integrating voluntary legally binding emissions reductions with emissions trading and offsets for greenhouse gases.

‡Launched in January 2005, the largest regulatory-based multi-country, multi-sector GHG emissions trading scheme worldwide.

Source: Gillenwater and others 2007

nearly 50 civil society organisations. The Gold Standard only approves renewable energy and energy efficiency projects if they are focused on a fundamental change in energy consumption and represent a real shift from the fossil fuel based economy. The Gold Standard approves CDM and JI credits according to the characteristics of the energy efficiencies and the replacement of fossil fuel development with renewables (CDM GS 2007).

Box 5: Payment for biogas projects

In 2003, the Indian non-profit organization Andhyodaya set up a programme in the Kerala region that used animal waste to produce biogas for the local community. Before the programme began, the community used wood for their fuel needs and many hours every day were spent foraging for fuel—and the foragers were the young girls whose daily task prevented them from attending school. The biogas system allowed those girls to attend classes for the first time in their lives. After two years with no maintenance, the biogas system failed and there was little incentive to repair it as the girls could just be taken out of school again and set back on their foraging track.

However, an Andhyodaya project manager had heard about the ideas of offset projects and discussed the concept of the biogas programme with CCX representatives. Together they assessed the potential for carbon offsets from the system, repaired the technical flaws, trained local representatives in basic maintenance techniques, established monitoring and auditing programmes, and re-instated the home biogas supply.

The payments from the offset carbon flow directly to the communities themselves so there is a steady income derived from maintaining the biogas system. The girls are back in school, the programme is under expansion, and the community has a separate income stream that can provide added security in their precarious lives (Kurian 2004, CCX 2007).

There is potential for convergence within the voluntary market. While the Gold Standard stoutly rejects sequestration of any kind it does not reject the validity of other schemes. The Exchanges already promote GHG reductions through soil sequestration as well as though forestry projects. The Voluntary Carbon Standard is seeking to bring its ISO level challenge to all the carbon credits traded on international markets, including those acquired through sequestration in all its forms (VCS 2007).

THE FUTURE FOR EMISSIONS TRADING

Communication and collaboration at various levels assure eventual convergence of interests within a global carbon market—the only question is when (CCX 2007, GS 2007) (**Table 1**). Currently there are many transactions among the various emissions trading programmes. For instance, on 24 September 2007, the Chicago Climate Futures Exchange—CCX's wholly owned subsidiary for

Large deforested areas of ancient coastal temperate rainforest in British Columbia, Canada. According to the IPCC Fourth Assessment Report, global deforestation accounts for 20 per cent of total GHG emissions.
Source: D. Garcia / Still Pictures

derivatives trading—auctioned CER allowances representing 163 784 metric tons of CO_2 that had been issued by the UNFCCC to a wind-energy farm in India. The event was thirteen times oversubscribed and marked the first time that an auction of CERs was done on a regulated exchange. And both CDM and JI offer credits that are approved by Gold Standard—restricted, of course, to energy efficiency and renewable energy projects.

As for additional project types under consideration, sequestration follows efficiency and fuel-switching in its ease of implementation and potential financial benefits. Carbon sequestration can be biological or geological. Biological sequestration is the result of absorbing CO_2 through photosynthesis and storing the carbon within cellulose and lignin molecules as wood or other plant material. In terms of carbon markets, biological sequestration refers to afforestation and reforestation—projects that plant and cultivate forests. Geological sequestration is the chemical interaction between atmospheric CO_2 and minerals to form carbonate rocks, usually calcites and dolomites. In nature it is called weathering but in the carbon markets geological sequestration is commonly referred to as carbon capture and storage (CCS).

Biological sequestration

Sequestration through afforestation and reforestation serves as a model for the developing field of payment for ecosystem services (PES). One concept under consideration for CDM/JI sequestration is avoided carbon emissions—currently promoted as reduced emissions from avoided deforestation and degradation (REDD). Instead of capturing CO_2 from the atmosphere and sequestering it in trees, this type of 'carbon reduction' pays for not adding carbon to the atmosphere through deforestation—for keeping it sequestered. It can be compared to carbon reduction credits for choosing to use renewable energy sources or from energy efficiency—the accounting considers carbon that does not enter the atmosphere. The CCX already sponsors this through their offset projects in 'forest enrichment' and 'forest conservation'. Deforestation contributes 20 per cent of total greenhouse gas emissions, more than all the world's transportation combined. According to any carbon cycle accounting method, preservation of existing forests is an essential element of any response to the climate crisis (UNEP 2007).

Some see that acceptance of REDD as a viable CDM/JI mechanism could be a catalyst for developing PES beyond carbon sequestration. The protection of ecosystems through REDD provides an opportunity to define a broader 'bundle' of ecosystem services from a given area. In the carbon market, the bundled credit would have value as a carbon offset but would supply added value to the buyer through its biodiversity conservation aspects or its traditional livelihood preservation elements (BioEcon 2007, UNEPFI 2007) (**Box 6**).

An example of REDD in action came in October 2007, when the World Bank announced the establishment of a Forest Carbon Partnership Facility (FCPF) designed to encourage countries to preserve their forests. By assigning economic value for their standing tropical forests, the FCPF will initially work with Liberia, Democratic Republic of Congo, Guyana, Suriname, and other developing countries to generate new revenue for poverty alleviation without having to sell off forest logging rights. At the same time the programme will help maintain the natural benefits that forests

Box 6: Payment for ecosystem services evolving in the carbon markets

International payment for ecosystem services (PES) is a smart tool for advancing gender and socio-economic equity in the transition to an environmentally-sound economy. Ecosystem services such as climate and flood regulation, water quality maintenance through filtration, and soil formation are provided by nature and often maintained by indigenous communities. PES schemes pay those who engage in meaningful and measurable activities to secure the supply of ecosystem services (UNEP 2007). PES programmes and projects are emerging in many countries and examples include efforts organized top-down and bottom-up.

Tanzania: One of the greatest obstacles to including rural communities in markets for ecosystem services is the high cost and technological complexity of monitoring and measuring the services produced. Kyoto: Think Global, Act Local (K: TGAL) is a research and capacity-building programme sponsored by the Government of the Netherlands that supports community-based management of existing forest to be included as an eligible carbon mitigation activity under future international climate change agreements. K:TGAL has a number of pilot projects to develop Geographic Information System (GIS) technologies and protocols that are simple and inexpensive and to train rural community members in using them to measure the carbon sequestered by community forests.

Village Forest Council members practice with GPS/GIS tools in Tanzania
Sources: J.J. Verplanke/ International Institute for Geo-Information Science and Earth Observation (ITC)

Under the umbrella of K:TGAL, a team of researchers and project coordinators trained a total of four to seven villagers from each of four Tanzanian Village Forest Councils in forest inventory and mapping techniques to assess changes in carbon stocks. The villagers learned to map the forest area, stratify the forest by ecotype, accurately locate permanent sample plots using hand held Global Positioning Systems (GPS), measure parameters relating to forest biomass in the field, reliably record data in small lap top computers, analyze the collected data, draw conclusions, and retrieve the permanent sample plots for future assessment.

Each village forest was found to sequester 1 300 metric tons of carbon per year on average. The team estimated that, at current rates, carbon could be sold for an average of US$6 500 per year per village. The research team's results suggest that this level of income generation would likely be sufficient incentive for villages to conserve their forests. However, they also suggest that selling the bundled ecosystem services produced by these forests, including water and biodiversity conservation, could provide an even more substantial incentive and greater relief to the poverty experienced in the majority of these villages (K: TGAL 2007, EMCF 2007).

Mexico: After years of trying to develop and market a carbon sequestration project for the CDM/JI market, Mexico's Grupo Ecológico Sierra Gorda and its partner organization Bosque Sustentable changed course and decided to pursue voluntary markets that recognize the added value of poverty alleviation and biodiversity conservation. Bosque Sustentable completed its first sale in the voluntary market in 2006 to the United Nations Foundation, which wanted to offset its carbon footprint as well as support a UN-sponsored project that also helped alleviate poverty.

Bosque Sustentable is now in the final stages of concluding a second sale with the United Nations Foundation as well as a sale to the World Land Trust, based in the U.K. The World Land Trust will be selling Sierra Gorda Carbon and Environmental Offsets to a range of voluntary European buyers. These sales highlight a principal advantage of voluntary markets in relation to regulatory markets in allowing Bosque Sustentable to access buyers that are interested in more than just carbon sequestration (EMCF 2007, UN Foundation 2007).

provide for local populations, such as fresh water, food, and medicines.

To qualify for the FCPF programme, countries will have to demonstrate that they have physically reduced deforestation rates. They will have to determine the present state of their forests, as a baseline against which future preservation rates can be assessed. In addition, they have to establish the carbon content in forests, to prove they are actually maintaining a level of carbon sequestration and forest cover throughout their territory. The scheme won't work if forests are preserved in one part of the country while deforestation runs rampant in another (World Bank 2007).

Geological sequestration

Carbon capture and storage (CCS) has been discussed for decades as a potential solution for the climate crisis. Currently it involves capturing CO_2 resulting from fossil fuel production and storing it in geological formations that originally hosted the fossil fuel. To date, CCS only reduces the amount of emissions from fossil fuel production and processing. With current technologies it doesn't eliminate all emissions into the atmosphere and it doesn't remove existing carbon from the atmosphere.

The oil industry commonly injects CO_2 into depleted oil deposits to increase pressure that facilitates migration of the remaining oil to the wellbore and enhances overall recovery rates. There are economic benefits resulting from the practice. In most fossil fuel production facilities, especially in countries where there are no associated economic benefits for capturing and storing carbon, such as reducing carbon taxes, CCS is not currently economically feasible. It will only become feasible when the cost of emitting GHGs goes up. Carbon capture and storage is not only applicable in the fossil fuel industry. Lime, cement, and concrete production is an industry that will be very dependent on developing CCS techniques under strict cap-and-trade regimes. The industry currently claims that carbon offset payments are essential as 'subsidies'. But once a cap-and-trade system is operating as it should, carbon emissions will become so expensive that CCS will become economically feasible for cement and fossil fuel industries (IPCC 2005).

Box 7: Geo-engineering: Global-scale technical fixes?

The climate crisis has motivated a number of proposals for large-scale interventions, referred to as geo-engineering, to counter-act the impacts of global warming. These interventions include launching reflectors into space and releasing sulphur into the upper atmosphere—both with the intention of increasing the reflectivity of the Earth (See Emerging Challenges). These two particular schemes have been closely scrutinized by scientists through cost and system-modelling analyses. The analyses suggest these interventions would be expensive, require international cooperation, and could inflict significant damages to whole regions, if implemented.

A different type of intervention is the idea of exploiting CO_2 sequestration potential in parts of the ocean that are nutrient rich but do not support plankton growth due to a lack of iron. Supplying large amounts of iron to these areas of the ocean could stimulate plankton blooms that will bind carbon molecules and eventually sequester them on the deep sea-floor. Many small-scale experiments have been conducted over the last two decades, showing some success at producing plankton blooms. The experiments also produced strong reactions for and against the concept of 'iron fertilization'. The most serious concern, voiced by scientists, suggests that the practice could intervene in nutrient cycles that feed ocean life. Disruption of that cycle would constitute a serious challenge to marine ecosystems already overexploited and endangered by human activities (See Global Overview). In November 2007, the Convention on the Prevention of Marine Pollution released a statement that "...planned operations for large-scale fertilization operations using micro-nutrients—for example, iron—to sequester carbon dioxide are currently not justified."

Another approach involves a completely artificial CO_2 collector that emulates the sequestration capability of photosynthesizing trees. Based on technology used in fish tank filters and developed by scientists from Columbia University's Earth Institute, this method, called 'air capture' would remove CO_2 directly from the atmosphere. Its advantage over the carbon capture and storage technologies currently in development is that it can collect the CO_2 at the location of the ideal geological deposits for storage. The Government of Iceland and the Earth Institute have high hopes for matching air capture and geological sequestration in basalts. Whether this scheme becomes a viable contribution in solving the climate crisis will depend on the success of ongoing experiments and the financial support it receives, as well as the regulatory constraints involved.

Sources: Lackner 2003, Lackner and Sachs 2005, IMO 2007, Morton 2007

Artist conception of air capture devices capable of pulling carbon dioxide out of the air.
Source: ©Stonehaven CCS

More creative possibilities are on the horizon. An experiment is underway in Iceland to test theories about carbon sequestration, sponsored by the national government and scientific research institutions in Iceland, France, and the USA. To minimize costs entailed in the transport—often the source of significant expense—the CO_2 is collected from a local industrial process. It is injected into the calcium and magnesium rich basalt formations that underlie Iceland, with the goal of reproducing the natural processes that form calcite and dolomite deposits, binding carbon molecules for millions of years. These deposit types are common on every continent (Gislason and others 2007).

CCS and associated schemes may provide additional and solid options to choose from when responding to our climate crisis (**Box 7**). But they cannot replace energy efficiency, development of renewable energy sources, and biological sequestration. CCS can compliment these other options.

THE ROLE OF GOVERNMENTS

The creation of the global carbon market has changed attitudes towards response to the climate crisis. After a decade of practice, the pilot phase of carbon marketing can be considered over. This shift from demonstration project to full-scale operation has occurred just in time. The future for emissions trading and the carbon market—and for every other effective response to climate change—is scale-up, fine-tune, and hurry.

The innovations produced by a decade of experimentation with environmental commodity formation and market design have generated a genuine eagerness for the possibilities of a new economy. That new economy is already in the early stages of formation. Many of the technologies required are already known. A significant proportion of the most successful market players and financial decision makers are demonstrating their commitment to building a new economy, efficiently fuelled by sustainable energy sources. They are increasingly following environmental, social, and governance principles for corporate activities, while investment funds are increasingly investing in accordance with the concept of universal ownership, which views the world economy and environment as interdependent wholes.

Incentives and disincentives

The global economy is growing rapidly and populations are continuing to expand, but improvements in energy intensity seen in previous years are no longer sustained. Atmospheric concentrations of CO_2 and other GHGs are mounting, while the oceans' capacity to absorb carbon is declining (Point Carbon 2007, GEO Portal 2007, Raupach et al 2007, Canadell 2007) (See Global Overview).

For new developments to reach the scale and scope that are needed, governments must play a stronger stimulation and facilitation role. There are still obstacles, old habits of taxation and subsidy that encourage us to persist in the old ways and only governments can change these. There are incentives and stimuli for good habits, and disincentives for bad habits, that only governments can provide. What has been missing so far is the political will and policy coordination that is needed to unleash the full creative capacity of the private sector and civil society partners.

The policy options for promoting the transition to a sustainable energy future are many. We need to shift away from taxing 'goods' such as income, to taxing 'bads' such as resource inefficiency, pollution, and greenhouse gas emissions. We need to remove the many and significant perverse incentives and subsidies that still persist for using fossil fuels and inefficient technologies. We need positive incentives to encourage efficient and low-carbon energy sources. Positive incentives include financial elements such as tax credits, subsidies, direct funding, loan guarantees, procurement policies, and feed-in tariffs. These direct economic interventions need to be complemented by publicly-funded research, development, and deployment programmes; investments in infrastructure; technical assistance and extension services; awareness-raising through education, information dissemination, and eco-labelling initiatives; and award and recognition programmes. Such incentives can be balanced by disincentives and restrictive policy options including emission taxes; cap-and-trade programmes; and minimum standards for efficiency, emissions, and portfolios. (Goldemburg and Chu 2006).

Adapting to persistent drought, farmers remove water with buckets and pumps from an excavated fresh water spring in Wangcheng, China.
Sources: Sinopictures/ Still Pictures

Setting standards

Many governments and local and regional authorities are already taking the initial steps. In October 2007 the International Carbon Action Partnership (ICAP) was launched by a group of countries, US states, Canadian provinces, and the European Union that are already actively pursuing the development of carbon markets through mandatory cap-and-trade systems. The partnership is based on the idea that a global carbon market will provide a cost-effective part of the climate change solution. ICAP realizes that tackling climate change requires a large shift of private investment into clean technologies and low-carbon approaches and aims to coordinate and support its members' involvement in carbon markets (ICAP 2007).

The most progressive private companies recognize the need for active government leadership on these issues. In 2007, many of the biggest carbon intensive companies in the United States of America joined lobbying coalitions in support of federal mandatory legislation on GHG emissions. One coalition, the United States Climate Action Partnership (USCAP) includes Dow Chemical, Caterpillar, ConocoPhillips, BP America, DuPont, General Electric, John Deere, PepsiCo, General Motors, and Ford among its founding members. USCAP has called for a mandatory, economy-wide cap-and-trade programme to provide regulatory certainty and create economic opportunity (CDP 2007, USCAP 2007).

Equity and fairness

Markets may be effective in determining the efficient allocation of scarce resources, but markets inherently do not have an ability to account for equity and fairness. It is the essential role and moral responsibility of governments to consider issues of equity and fairness. In everything governments must do to accelerate the transition to the new, more efficient, low-carbon economy, issues of fairness and equity must be addressed.

One of the most challenging tasks of the transition to more efficient and low-carbon energy sources is to support development goals simultaneously. While governments work to address the essential need for development of billions of poor people, that development must incorporate strategies for adaptation to an accelerating climate crisis. Climate change is already hitting hardest among the poorest people and regions, so their adaptation needs should be folded into development plans already underway, as well as those planned for the future.

In developing countries, the poor depend heavily on ecosystem services for their well-being and the exchange of these resources is usually done through non-market channels. Bringing these ecosystem services into the formal market may push some groups of people—especially women, the elderly, and the orphaned—into destitution. Similarly, placing a price on services which people are accustomed to consider as free—such as clean water for personal consumption, clean air to breathe, or wetlands for flood regulation—raises issues of ethics and rights. So some form of compensation or redistribution mechanism, preferably built upon bottom-up community-based programmes, needs to be introduced at the same time as pricing or markets are implemented (Goldemberg and Chu 2007).

Sino-Italian ecological and energy-efficient building at Tsinghua University, Beijing

A new state-of-the-art building on the campus of Tsinghua University in Beijing is taking energy efficiency to new heights. The new building will serve as the University's education, training, and research centre for environmental protection and energy conservation. The facility was conceived to maximize solar capabilities by utilizing both passive and active strategies, including 1 000 square metres of photovoltaic panels. The panels are integrated into the structural design of the building in a manner that effectively captures energy while providing shade for the structure's terraces. The University and the architects who conceptualized the structure hope the building will also serve to educate and emphasize innovative possibilities for energy-efficient building, particularly in regard to CO_2 emissions.

Source: © D. Domenicali/ ddphoto.it courtesy of MCA

Promoting efficiency

There are many possible avenues for government to promote the transition to the new economy, in cooperation with the private sector and community organizations. One initiative that illustrates the potential is the Energy Efficiency Building Retrofit Programme—a global project of the Clinton Climate Initiative (CCI) focused on urban areas. Urban areas are responsible for approximately 75 per cent of all energy use and greenhouse gas emissions in the world. Buildings account for nearly 40 per cent of global greenhouse gas emissions—in cities such as New York and London this figure is close to 70 per cent.

CCI brings together four of the world's largest energy service companies, five of the world's largest banks, and sixteen of the world's largest cities to reduce energy consumption in existing buildings. Participating cities agree to make their municipal buildings more energy efficient and to provide incentives for private building owners to retrofit their buildings with energy saving technologies. CCI and its partners will assist participating cities to initiate and develop programmes to train local workers in the installation and maintenance of energy saving and clean energy products. By retrofitting existing buildings this programme aims to attain energy savings of 20 to 50 per cent (CCI 2007).

Energy efficiency diffusion and financial mechanisms must target the poor and smaller communities. CCI's Energy Efficiency Building Retrofit Programme and other high profile programmes promoting energy efficiency and renewable energy souces can serve as models for more humble initiatives. These models can be customized to meet the development needs of the urban poor also. For example, water and sanitation servicing to slums can proceed alongside energy efficient power supplies. Sanitation installations with biogas recovery, at community or neighbourhood scale, would produce income from carbon offsets, as well as providing better health and security to residents. Such schemes can be managed by women and the elderly, community members that tend to use such facilities throughout the day (Asian Power Magazine 2007, GAIN 2007, Ho 2005) (See Global Overview).

Research, development, deployment

Governments have an important role and responsibility in supporting the basic research and development (R&D) that any wise response to the climate crisis requires. This R&D goes beyond the hard technology approach of mega-engineering projects and industrial solutions, while those will be important contributions to the global effort. Applied systems analysis and green design principles need to be incorporated into community adaptation options that are based on complementarity and integration through various scales. This will require support to gain insights into how people and communities adapt to change and how to ensure that they do not choose maladaptive paths that can lead to ecosystem destruction and future conflict. Another field of inquiry is to determine and to implement situation-specific means to monitor and evaluate the successes and failures of the variety of economic instruments currently being introduced (**Boxes 7 and 8**).

Here are a few areas where immediate research and development support can accelerate our response to the climate crisis:

1) Ecosystem valuation will facilitate assignment of the proper price for carbon in plants, soils, and wetlands, as well as that in emissions. Done properly, valuation can provide understanding of the consequences that various biological sequestration schemes have on gender equity and community integrity.
2) Appropriate energy efficiency techniques and technologies need to be developed and deployed to the rich and poor in developed and developing countries, while considering gender and equity issues in distribution and implementation.
3) A massive investment in renewable energy sources and appropriate technology and distribution systems will accelerate progress towards a stable transition to an environmentally-sound economy.
4) The processes and materials that can expedite efficient biological and geological carbon capture storage techniques require support for scientific experimentation and assessment of socio-economic implications at a basic level.
5) Biofuel production must be monitored for actual carbon cycling efficiency, ecosystem damage, soil fertility, effect on availability of basic foodstuffs, and consequences for equity and fairness concerns (See Global Overview).

Source: David Klein. Reprinted with permission of the artist.

Box 7: Summary of key messages

– A decade of demonstration and learning has led to a US$ billion annual carbon market—but now the time has come to scale-up and fine-tune.
– Civil society, the private sector, and sub-national governments are calling for national government progress on setting global standards for cap-and-trade carbon markets.
– Support for increasing energy efficiency at every scale in the production and consumption cycle can bring significant progress in the transition to an environmentally-sound economy.
– Investment in research and development in climate and energy is a vital part of the transition but deployment of knowledge—technology and techniques gained through partnerships and through ground-level experiences—needs to gain massive support from all sectors.
– The transition to an environmentally-sound, low-carbon economy offers tremendous opportunities for innovators—and it offers tremendous opportunities to deliver true clean development to poor and disadvantaged groups through renewable energy sources and community-level ecosystem service provision.

Box 8: Options for policy consideration

Developed countries must take the lead in the transition to an environmentally-sound economy. They carry the burden of historic responsibility for the climate change problem. They have the financial resources and technical capabilities to initiate deep and early cuts in emissions and to assist developing countries to follow suit. In both developed and developing countries, policies that support the following goals will expedite the transition to an environmentally-sound economy:

1) Establish a price for carbon by establishing local, national, and international cap-and-trade and/or revenue neutral carbon tax regimes.
2) Implement energy efficiency programmes at every scale and in every sector.
3) Support massive research, development, and deployment of renewable energy technologies and techniques.
4) Meet the basic energy needs of the poorest people in a sustainable way as adaptation to changing climate impacts receives priority status in development financing and implementation.
5) Ensure that equity and fairness principles are addressed from the start of the new energy and adaptation policy design process, not as an afterthought.
6) Speed up development of technologies for capturing and sequestering carbon from industrial processes.
7) Manage biofuel production for sustainability objectives and ecosystem service protection.

REFERENCES

Ambachtsheer, J. (2006). *Responsible Investment: What Is It All About?* Mercer Investment Consulting. http://www.pensionsatwork.ca/english/pdfs/lectures/AmbachtsheerSlides.pdf [Accessed 12 October 2007]

Ban, K.M. (2007). *Address to High-level Event On Climate Change*. http://www.un.org/webcast/climatechange/highlevel/2007/pdfs/sg.pdf [Accessed 31 October 2007]

Baue, B. (2007). Emissions Trading Commodifies Carbon, But Does It Really Help Solve Climate Change? *Social Funds*, October 15, 2007. http://www.socialfunds.com/news/article.cgi/2393.html [Accessed 25 October 2007]

BHLRI (2007). *The Business Leaders Initiative on Human Rights*. http://www.blihr.org/ [Accessed 2 November 2007]

BioEcon (2007) *Economics and Institutions for Biodiversity Conservation*, Ninth Annual BioEcon Conference, Kings College Cambridge, UK; September 20-21, 2007

Canadell, J.G., Le Quéré, C., Raupach, M.R., Field, C.B., Buitenhuis, E.T., Ciais, P., Conway, T.J., Gillett, N.P., Houghton, R.A. and Marland G. (2007). Contributions to accelerating atmospheric CO2 growth from economic activity, carbon intensity, and efficiency of natural sinks. *Proc Natl Acad Sci*, U S A. 2007 Oct 25 www.pnas.org_cgi_doi_10.1073_pnas.0702737104 [Accessed 3 November 2007]

CAN-E (2007) ECCP EU ETS Review Process. Written comments CAN-Europe, WWF, Greenpeace, and Friends of the Earth Europe http://www.climnet.org/EUenergy/ET/072007NGO_EUETSreview_submission.pdf

CCI (2007). *Clinton Climate Initiative*. http://www.clintonfoundation.org/cf-pgm-cci-home.htm [Accessed 22 October 2007]

CCX (2007). *Chicago Climate Exchange*. http://www.chicagoclimatex.com/ [Accessed 14 September 2007]

CII (2007). *The Council of Institutional Investors*. http://www.cii.org/about/index.html [Accessed 2 November 2007]

Davies, N. (2007). Truth about Kyoto: huge profits, little carbon saved. *The Guardian*, Saturday June 2 http://www.guardian.co.uk/environment/2007/jun/02/india.greenpolitics [Accessed 20 August 2007]

Davies, N. (2007b). The inconvenient truth about the carbon offset industry. *The Guardian*, Saturday June 16 2007. http://www.guardian.co.uk/environment/2007/jun/16/climatechange.climatechange [Accessed 20 August 2007]

EITI (2007). *Extractive Industries Transparency Initiative*. http://www.eitransparency.org/ [Accessed 2 November 2007]

EU ETS (2007). *European Union Emission Trading Scheme*. http://ec.europa.eu/environment/climat/emission.htm [Accessed 30 September 2007]

Fahey, M., (2007). The Chicago Climate Exchange: A Precursor of What's to Come, *Urban Land* September

Frontier Economics (2006). Economic consideration of extending the EU ETS to include aviation. A REPORT PREPARED FOR THE EUROPEAN LOW FARES AIRLINE ASSOCIATION (ELFAA). March 2006. Frontier Economics Ltd, London.

Gillenwater, M., Broekhoff, D., Trexler, M., Hyman, J. and Fowler, R. (2007). Policing the voluntary carbon market. Nature Reports Climate Change 11 October 2007 doi:10.1038/climate.2007.58 http://www.nature.com/climate/2007/0711/full/climate.2007.58.html [Accessed 30 November 2007]

Gislason, S.R., Gunnlaugsson, E., Broecker, W.S., Oelkers, E.H., Matter, J.M., Stefansson, A., Arnorsson, S., Bjornsson, G., Fridriksson, T., and Lackner, K. (2007). Permanent CO2 Sequestration Into Basalt: the Hellisheidi, Iceland Project. *Geophysical Research Abstracts,* 9, 07153

Global100 (2007). Global 100 Most Sustainable Corporations in the World. www.global100.org [Accessed 1 December 2007]

Goldman Sachs (2007). Introducing GS SUSTAIN. Goldman Sachs Global Investment Research. http://www.unglobalcompact.org/docs/summit2007/gs_esg_embargoed_until030707pdf.pdf [Accessed 2 November 2007]

Greenwood, C., Hohler, A., Liebreich, M., Sonntag-O'Brien, V. and Usher, E. (2007). Global Trends in Sustainable Energy Investment 2007: Analysis of Trends and Issues in the Financing of Renewable Energy and Energy Efficiency in OECD and Developing Countries. United Nations Environment Programme and New Energy Finance Ltd.

Hamilton, K., Bayon, R., Turner, G and Higgins, D. (2007). State of the Voluntary Carbon Market 2007: Picking Up Steam

Hawley, J.P. and Williams, A.T. (2000). *The Rise of Fiduciary Capitalism: How Institutional Investors Can Make Corporate America More Democratic*. University of Pennsylvania Press, Philadelphia

IAC (2007). *Lighting the Way: Toward a Sustainable Energy Future*. InterAcademy Council, Amsterdam. http://www.interacademycouncil.net [Accessed 2 November 2007]

ICGN (2007). *International Corporate Governance Network*. http://www.icgn.org/organisation/index.php [Accessed 2 November 2007]
IEA (2006). *World Energy Outlook 2006*. International Energy Agency, Paris

IIGCC (2007). *The Institutional Investors Group on Climate Change*. http://www.iigcc.org/ [Accessed 2 November 2007]

IMO (2007). Large-scale ocean fertilization operations not currently justified. Press briefing, International Marine Organization. www.imo.org/includes/blastData.asp/doc_id=8708/Press%20briefing%2016-11-07.doc [Accessed 21 November 2007]

INCR (2007). *The Investor Network on Climate Risk*. http://www.incr.com/NETCOMMUNITY/Page.aspx?pid=198&srcid=-2 [Accessed 2 November 2007]

Innovest (2007). *Carbon Disclosure Project Report 2007: Global FT500*. Innovest Strategic Value Advisors. http://www.cdproject.net/ [Accessed 25 October 2007]

IPCC (2001). Climate Change 2001: Synthesis Report. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK

IPCC (2005). *Special Report on Carbon Dioxide Capture and Storage Prepared by Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK

IPCC (2007). Climate Change 2007: The Physical Science Basis. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK

IPCC (2007b). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK

ISO (2007). *International Organization for Standardization*. http://www.iso.org/iso/home.htm [Accessed 20 November 2007]

ITEA (2007). *International Trading Emissions Association*. http://www.ieta.org/ieta/www/pages/index.php [Accessed 2 November 2007]

Lackner, K.S. (2003). A Guide to CO2 Sequestration. *Science*, 300, 1677

Lackner, K.S. and Sachs, J.D. (2005). A Robust Strategy for Sustainable Energy. Project Muse: Brookings Paper on Economic Activity, Columbia University

Lovins, L.H. (2006). *The Business Case for Climate Protection*. Natural Capital Solutions, Eldorado Springs, CO. http://summits.ncat.org/docs/BusinessCase_forClimateProtection.pdf [Assessed 2 October 2007]

Kurian, P.K., (2004) *Socio-economic and environmental impact of Bio Gas Programme with special reference to the Karunapuram and Kanchiyar Panchayaths of Idukki District*. Kerala Research Programme on Local Level Development

MA (2005). *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC. Millennium Ecosystem Assessment. http://www.meaeb.org/en/products.aspx [Assessed 10 November 2007]

MCII (2007). *Munich Re Group: Munich Climate Insurance Initiative*. http://www.climate-insurance.org/front_content.php [Accessed 20 November 2007]

Morton, O. (2007). Is This What it Takes to Save the World? Nature, 447, 132

Nature (2007). Carbon copies. Nature 445, 584-585. doi:10.1038/445595a. http://www.nature.com/nature/journal/v445/n7128/full/445584a.html [Accessed 25 November 2007]

Porter, M.E. and Kramer, M.R. (2006). Strategy and Society: The Link Between Competitive Advantage and Corporate Social Responsibility. *Harvard Business Review*, 84(12), 78-92

Rauch, E. (2007). Climate Change: A Relevant Risk of Change. In: *Risk Prevention Congress, 3 February 2007 Bruxelles*. Prepared by Geo Risks Research Munich Re

Raupach, M.R., Marland, G., Ciais, P., Le Quéré, C., Canadell, J.G., Klepper, G., and Field, C.B. (2007). Global and regional drivers of accelerating CO2 emissions. *Proc Natl Acad Sci*, 104(24) 10288-10293. http://www.pnas.org/cgi/content/short/104/24/10288

Shah, A. (2007). *Flexibility Mechanisms*. Global Issues. http://www.globalissues.org/EnvIssues/GlobalWarming/Mechanisms.asp [Accessed 25 November 2007]

UNDP (2007). *Human Development Report 2007/2008, Fighting Climate Change: Human Solidarity in a Divided World*. United Nations Development Programme, New York. http://hdr.undp.org/en/reports/global/hdr2007-8/

UNEP (2007). *Global Environmental Outlook 4: Environment for Development*. United Nations Environment Programme, Nairobi

UNEP FI (2006). *Adaptation and Vulnerability to Climate Change: The Role of the Finance Sector*. United Nations Environment Programme Finance Initiative. http://www.unepfi.org/fileadmin/documents/CEO_briefing_adaptation_vulnerability_2006.pdf [Accessed 20 August 2007]

UNEP FI (2007) *Bloom or Bust: Biodiversity and Ecosystem Services-A Financial Sector Briefing*. UNEP FI Biodiversity and Ecosystems Services Work Stream http://www.unepfi.org/fileadmin/documents/CEOBriefing_biodiversity_01.pdf [Accessed 20 August 2007]

UN Global Compact (2007). *The Global Compact: Ten Principles*. United Nations Global Compact. http://www.unglobalcompact.org/AboutTheGC/TheTenPrinciples/index.html [Accessed 10 October 2007]

United Nations (2007). *Mechanisms to Help Reduce Emission*s. Gateway to the UN System's Work on Climate Change. http://www.un.org/climatechange/background/mechanisms.shtml [Accessed 20 October 2007]

UNFCCC (2007). *Joint Implementation*. United Nations Framework Convention on Climate Change. http://unfccc.int/kyoto_protocol/mechanisms/joint_implementation/items/1674.php [Accessed 10 August 2007]

UNFCCC CDM (2007). *Clean Development Mechanism*. United Nations Framework Convention on Climate Change. http://cdm.unfccc.int/index.html [Accessed 10 August 2007]

UNPRI (2007). *Principles for Responsible Investment*. UNEP Finance Initiative and the UN Global Compact, New York. http://www.unpri.org/files/pri.pdf [Accessed 2 November 2007]

USCAP (2007). *A Call for Action. Consensus Principles and Recommendations from the U.S. Climate Action Partnership*. United States Climate Action Partnership, Washington DC, www.us-cap.org/USCAPCallForAction.pdf [Accessed 20 November 2007]

VCS (2007). *The Voluntary Carbon Standard*. http://www.v-c-s.org/ [Accessed 27 November 2007]

Victor, D.G. and Cullenward, D. (2007). Making Carbon Markets Work: Limiting climate change without damaging the world economy depends on stronger and smarter market signals to regulate carbon dioxide. Scientific American, September 24, 2007 http://www.sciam.com/article.cfm?articleID=29896DAF-E7F2-99DF-3CB3CA01486CA951 [Accessed 24 September 2007]

Walker, P. (2007). Sustainable Profits. *Africa Investor* Nov-Dec 2007 http://www.africa-investor.com/article_mag.asp?id=2177&magazineid=21 [Accessed 27 November 2007]

Wara, M. (2007). Is the global carbon market working? Nature 445, 595-596. http://www.nature.com/nature/journal/v445/n7128/full/445595a.html [Accessed 10 October 2007]

World Bank CF (2007). *Forest Carbon Partnership Facility*. The World Bank Carbon Finance Unit. http://carbonfinance.org/Router.cfm?ItemID=3&Page=Funds [Accessed 20 November 2007]

World Bank Group (2007). *Environmental Valuation*. The World Bank Group. http://lnweb18.worldbank.org/ESSD/envext.nsf/PrintFriendly/2452A2007BF697D685256D21006E77F0?Opendocument [Accessed 20 November 2007]

EMERGING CHALLENGES

Methane from the Arctic:
Global warming wildcard

Arctic Climate Feedbacks
Methane from Thawing Permafrost
Methane from Hydrates
Changes in Nature
Looking Ahead

Methane from the Arctic: Global warming wildcard

Warming Arctic temperatures could lead to the release of significant methane emissions from thawing permafrost and marine deposits. Sub-regional scale decreases in reflectivity result from loss of snow cover and advancing shrub and tree lines and lead to more warming, permafrost thaw, and methane release. Feedbacks from sub-regional processes produce more methane emissions that then feed into global scale warming trends. These new findings bring an added sense of urgency to advance climate and energy policy decisions.

ARCTIC CLIMATE FEEDBACKS

The Arctic, a key component of the global climate system, is warming at nearly twice the rate as the rest of the world. This warming trend, which is already affecting arctic ecosystems and the people who depend upon them, has been closely monitored over recent decades and is projected to continue throughout the 21st century (ACIA 2004, ACIA 2005). Accelerated warming in the Arctic results from the accumulated effects of 'positive feedback' mechanisms that operate there.

A positive feedback is a reaction to an initial stimulus that amplifies the effects of that stimulus. A negative feedback dampens the effects of the initial stimulus. In the Arctic, both positive and negative feedbacks to warming are at work, but the positive feedbacks dominate present conditions. Some feedbacks are widely known and well understood, while others have been recognized only recently. The rapid reduction in sea ice is one of several significant arctic climate feedbacks that have received a good deal of attention. Another relates to changes in ocean circulation stemming from an increase of freshwater entering the ocean from melting of both land-based ice and sea ice, as well as more precipitation and river runoff.

This chapter will briefly review the major feedbacks, with a focus on one potential feedback which could have very serious global consequences: the release of methane from thawing permafrost soils and from deposits of methane hydrates.

Although methane has a relatively short life-span in the atmosphere of about 10 years, it is a very powerful greenhouse gas with 25 times the warming potential of carbon dioxide (IPCC 2007). Recent findings about potential methane releases from thawing permafrost and hydrate deposits suggest serious cause for concern. Global methane emissions from all sources, both natural and human-induced, are calculated to be about 500-600 million metric tons per year. Recent estimates put current methane emissions from the world's soils at between 150 and 250 million metric

Warming trends are already affecting communities like Cape Dorset, Nunavit, Canada. Ice formation occurs about a month later and ice break up occurs about a month earlier than in the 1960s. This shortened sea ice travel season limits the community's accessibilty to neighbors and to desirable hunting destinantions.
Source: Goujon / Still Pictures

tons of methane per year. A quarter to a third of the total is emitted from the wet soils of the Arctic, making them one of the largest sources of methane emissions on Earth (IPCC 2007).

The consequences of significant increases in methane releases, especially the additional warming, would be felt around the world. Any additional warming will lead to additional ice melt—of glaciers, ice caps, and ice sheets—that will raise sea level around the globe.

METHANE FROM THAWING PERMAFROST

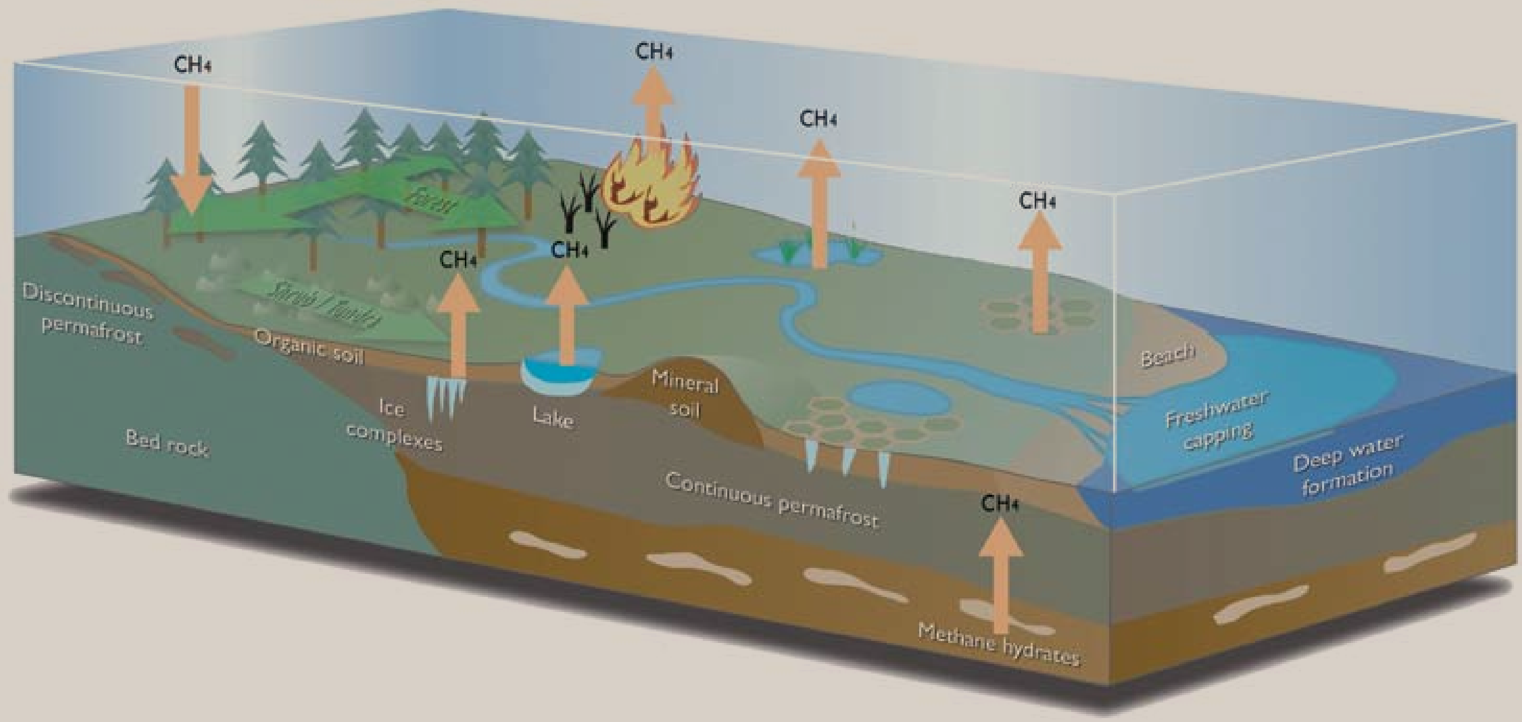
Soil microbes produce and consume methane. The thawing of permafrost in the Arctic creates low-oxygen (anaerobic) and water-logged soil conditions in which microorganisms that produce methane dominate (**Figure 1**). Most of the microbe activity that consumes methane takes place in oxygen-rich (aerobic) and well-drained soils outside of the northern high latitudes (IPCC 2007).

Current methane emissions from arctic soils and lakes

Modelled and measured estimates of methane emissions from northern high latitude land ecosystems in the late 20th century range from 31 to 106 million metric tons per year. This range of uncertainty has increased in recent years as new feedbacks have been recognized. Estimates of methane absorption are much lower, ranging from 0 to 15 million metric tons (Zhuang and others 2004). A recent process-modelling study has estimated that the annual net methane emission rate at the end of the 20th century for the region was 51 million metric tons. Net methane emissions from permafrost regions north of 45°N include 64 per cent from Russia, 11 per cent from Canada, and 7 per cent from Alaska (Zhuang and others 2004).

Recent research points to the potential importance of arctic lakes as methane sources (Walter and others 2006). Permafrost is ground that has remained frozen for two or more consecutive years. It underlies most arctic landscapes, varying from a few to several hundred metres thick. Permafrost promotes the formation and persistence of lakes, and in some Arctic regions as much as 20 to 30 per cent of the land area is covered by lakes. (Smith and others 2007, Riordan and others 2006). When permafrost thaws it creates thermokarst: a landscape of collapsed and subsiding ground with new or enlarged lakes, wetlands, and craters on the surface. Large expanses of modern boreal and subarctic regions are remnants of past thermokarst. A broad survey reported significant methane emissions from boreal, subarctic, and arctic lakes (Bastviken and others 2004). Few studies have attempted to estimate lake methane fluxes for the whole of the northern high latitudes, but a recent study, using data from Siberia and Alaska, estimated that arctic

Figure 1: Major Arctic methane sources



Methane (CH_4) comes from a variety of sources in the Arctic. These include emissions generated by microbes in thawing permafrost soils, from lakes and ponds, from fires, and from methane hydrates.
Sources: ACIA 2004 and ACIA 2005.

Hotspots, seen at the surface here as slushy circular areas, are created by methane bubbling up from a lake bottom in Northern Siberia.
Source: Katey Walter

lakes emit 15 to 35 million metric tons of methane per year (Walter and others 2007a).

Changes in future methane emissions from arctic soils and lakes

Business-as-usual climate scenarios for the 21st century estimate that the Arctic region's methane emissions, resulting from more permafrost thawing and rising soil temperatures, will range from 54 to 105 million metric tons of methane per year—the upper figure doubles the current level (Zhuang and others 2006). A coupled model of wetland and climate dynamics also projects that emissions from this region will double (Gedney and others 2004).

These scenarios do not consider the complex interactions among thermokarst dynamics, fires, and changing hydrology in wetlands and peatlands (Jorgenson and others 2007, Zimov and others 2006). Such interactions in thermokarst could lead to higher methane emissions than simulated. These estimates also do not include the potentially huge contribution from the thawing of decayed organic matter in thermokarst lakes (**Box 1**).

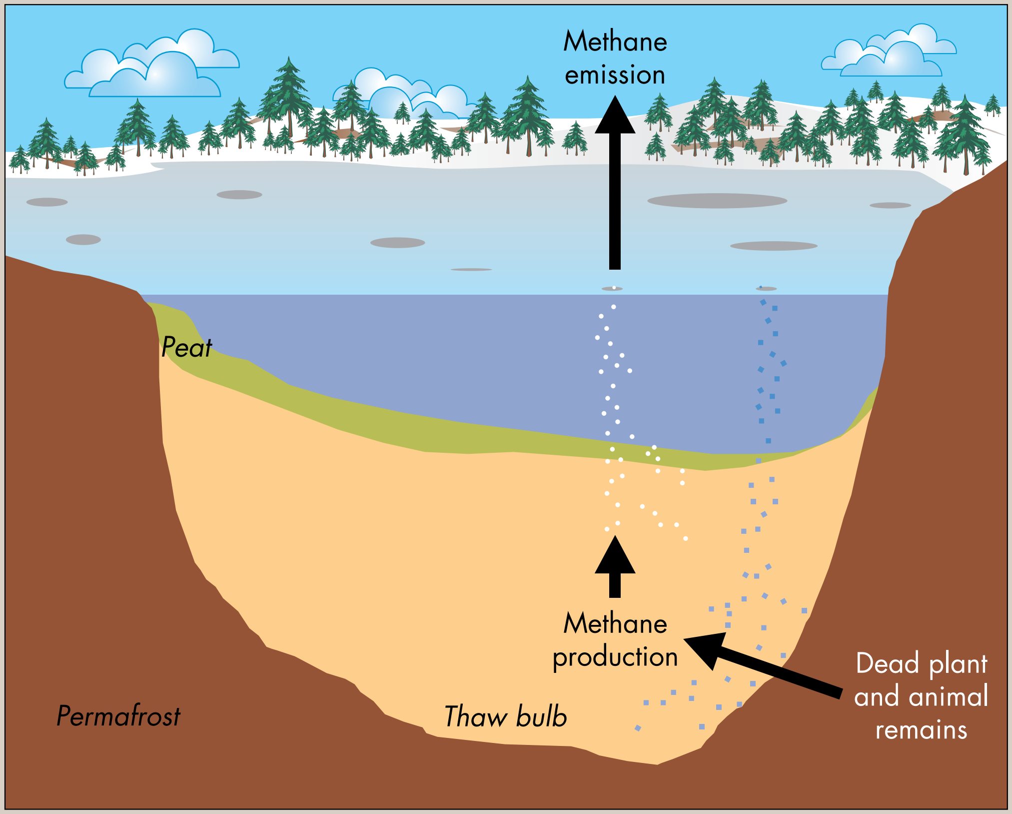
Dramatic increases in these emissions are likely to take place if permafrost thaws at an increasing pace and critical surface portions of soil and lake environments become warmer and wetter. There are at least three different mechanisms behind increased methane emissions:

Box 1: Methane emissions from arctic lakes associated with degradation of permafrost

A potentially very large arctic source of methane to the atmosphere is the decay of organic matter in the form of dead plant, animal, and microbial remains that have been frozen in shallow permafrost (1-25 metres below the surface) for tens of thousands of years. This important source of atmospheric methane is not currently considered in modelled projections of future warming.

The amount of carbon stored in the organic matter of arctic permafrost is staggering. It is estimated to be around 750 to 950 billion metric tons—equal to or larger than the nearly 800 billion metric tons of carbon currently in the atmosphere in the form of carbon dioxide (Zimov and others 2006, ACIA 2005, Smith and others 2004). This figure does not include carbon contained in deeper permafrost, in hydrates within or under the permafrost, or other non-permafrost soil carbon pools.

About 500 billion metric tons of carbon are now preserved in the high ice-content permafrost in northeast Siberia (Zimov and others 2006). If this territory warms as rapidly as projected under business-as-usual greenhouse gas emission scenarios, carbon compounds bubbling up from newly thawed bulbs in thermokarst lakes could become a powerful amplifying feedback to warming. One estimate is that an additional 50 billion metric tons of methane could be released to the atmosphere from Siberian thermokarst lakes alone, an amount that is ten times the current atmospheric methane burden (Walter and others 2007a). The expansion and formation of thaw lakes in northeast Siberia observed over the past few decades suggest that this feedback may already be happening (Walter and others 2006).



The figure shows a cross section of a thermokarst lake and methane bubbling dynamics.
Significant methane production and emission is associated with the initial thaw of permafrost, as organic matter from permafrost becomes available in lake bottom sediments to fuel methane-producing microbes. Methane produced in youger sediments at the top of a thaw bulb escapes broadly across lake surfaces at low bubbling rates. Methane produced at greater depths in older lake sediments, or in previously frozen soils that thawed beneath lakes, is emitted from thaw bulbs at lake bottoms through columns that bubble up to the surface. These point-sources and hotspots of bubbling have exceptionally high rates of emission. Thermokarst lakes form on time scales of decades to centuries and persist as long as several hundred to 10 000 years.
Source: Walter and others 2007a, Walter and others 2007c.

1. The thawed or active layer reaches deeper and the soils stay wet, producing anaerobic conditions that favor methane-producing microbes to break down organic matter and stored peat.
2. The expansion and warming of thermokarst lakes leads to increased breakdown of old organic matter as it thaws and becomes more available to methane-producing microbes.
3. When the thawing reaches layers where methane is trapped with frozen water, forming hydrate deposits, destabilization of pressure and temperature regimes could release huge amounts of methane from terrestrial and submarine permafrost areas.

Recent findings suggest that these changes are already occurring. Studies in Alaska, Canada, and northern Scandinavia have found wetter ground surface conditions in areas where the permafrost margin is receding (Walter and others 2006, Walter and others 2007a). This increases methane emissions over the landscape as a whole (Christensen and others 2004, Johansson and others 2006). There is also clear evidence that the number and area of thermokarst lakes in northern Siberia are increasing—as are their associated methane emission hotspots. These landscape changes have profound implications for the global atmospheric methane budget (Walter and others 2006, Walter and others 2007a).

METHANE FROM HYDRATES

An enormous amount of methane on Earth—storing more carbon than all the proven reserves of coal, oil, and gas—is frozen into an icy material known as methane clathrates or hydrates. Clathrate is a general term for a chemical compound in which molecules of one substance are physically enclosed within a cage-like structure formed by molecules of another kind. Hydrate is the specific term when the cage is made of frozen water molecules. Most of the hydrates that exist on Earth are filled with methane and they are dispersed at low concentrations and under pressure deep within sediments around the globe.

Methane hydrates become unstable as temperature increases or pressure decreases, and the methane escapes to the atmosphere where it functions as a powerful greenhouse gas. Gradually, methane reacts with atmospheric oxygen and converts into carbon dioxide and water. Carbon from methane hydrates will eventually accumulate in the atmosphere as carbon dioxide just as carbon from fossil fuels does. Stability calculations show that methane hydrates will become destabilized in response to warming of only a few degrees Celsius. Given the tremendous reservoir of carbon in methane hydrate deposits, any large-scale destabilization of methane hydrates could have enormous global consequences.

Ocean hydrates

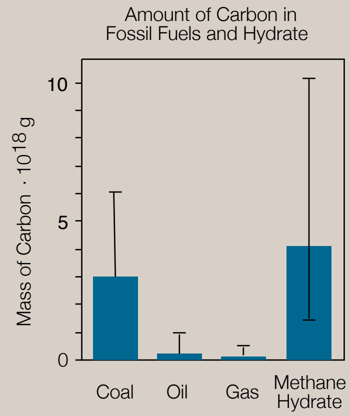
Most methane hydrates are in sediments of the world's oceans, including those of the Arctic Ocean. These hydrate-bearing sediments are deeply buried in layered deposits up to several hundred metres below the sea-floor. The deposits are formed when organic carbon, produced by phytoplankton in the sunlit surface layer of the ocean, sinks to the sea-floor and may become buried along with plankton shells and terrestrial clays. Sediments continue to accumulate for centuries and millennia. Eventually, hundreds of metres below the sea-floor, microbes produce methane from the remains of plankton. If enough methane is produced, some of it gets trapped at high pressure into methane hydrates. In locations of very active methane generation, methane hydrate can migrate up toward the sea-floor and produce massive solid lenses of frozen gas hydrate.

Oceanic gas hydrate deposits hold an estimated 2 000 to 5 000 billion metric tons of carbon as methane, with some estimates ranging up to 10 000 billion metric tons (Buffett and Archer 2004, Milkov 2004). For comparison, coal, the most abundant fossil fuel, is estimated to hold about 5 000 billion metric tons of carbon (Rogner 1997) (**Figure 2**). Methane originating from sub-marine hydrate deposits can leave the sediment in three possible forms: dissolved, bubbles, and hydrate pieces. Dissolved methane is chemically unstable in the oxygen-containing water column of the ocean where it converts to carbon dioxide. Bubbles of methane are typically only able to rise a few hundred metres in an ocean column before they dissolve. Hydrate pieces float in water just like regular ice does, carrying methane to the atmosphere much more efficiently than in solution or as bubbles (Brewer and others 2002).

Currently, methane emissions from hydrates (including both ocean and permafrost sources) are estimated to be about 5 million metric tons per

The ice worm *Hesiocaeca methanicola* was first discovered on this methane hydrate lens emerging from the sea-floor of the Gulf of Mexico (Fisher and others 2000).
Source: Ian R. MacDonald, Texas A&M University

Figure 2: Comparing amounts of carbon in methane hydrates and fossil fuels



Proven reserves of fossil fuels (solid bars) and potential unconventional resources, (thin lines), such as tar sands and oil shales. Estimates of methane in hydrate deposits are shown as a range (thin lines) and best estimate (bar).
Sources: Archer 2007, Rogner 1997.

year, with a possible range of 0.4 to 12.2 million metric tons (Wuebbles and Hayhoe 2002).

Gas hydrates associated with permafrost soils

Hydrates can be found in deposits associated with permafrost in the Arctic. However, because hydrate stability depends on conditions of relatively high pressure, they are not likely to persist in shallow permafrost. Sediment and soil permeability is another factor that can influence hydrate persistence. Sometimes freezing groundwater creates a sealed ice layer in the soil, which can raise the pressure in pore spaces in the rock or soil below (Dallimore and Collett 1995).

The total amount of methane hydrates in permafrost soils is not clear—estimates range from 7.5 to 400 billion metric tons of carbon (Gornitz and Fung 1994). The likelihood of sudden destabilization of these methane hydrates in response to climate change is also not clear.

Methane hydrates locked in sediments and soils may become exposed to the waters of the ocean along melting arctic coastlines. As the ice melts and soils thaw, the land surface collapses and more ice, soils, and sediments are exposed to ocean erosion. The northern coast of Siberia is particularly vulnerable to erosion and entire islands have disappeared in historical time (Romankevich 1984). Concentrations of dissolved methane in seas along that shelf were measured at 25 times the atmospheric concentration, suggesting the escape of methane hydrates as well as emissions of methane from thawing permafrost in the shallow marine environment and biological activity (Shakhova and others 2005).

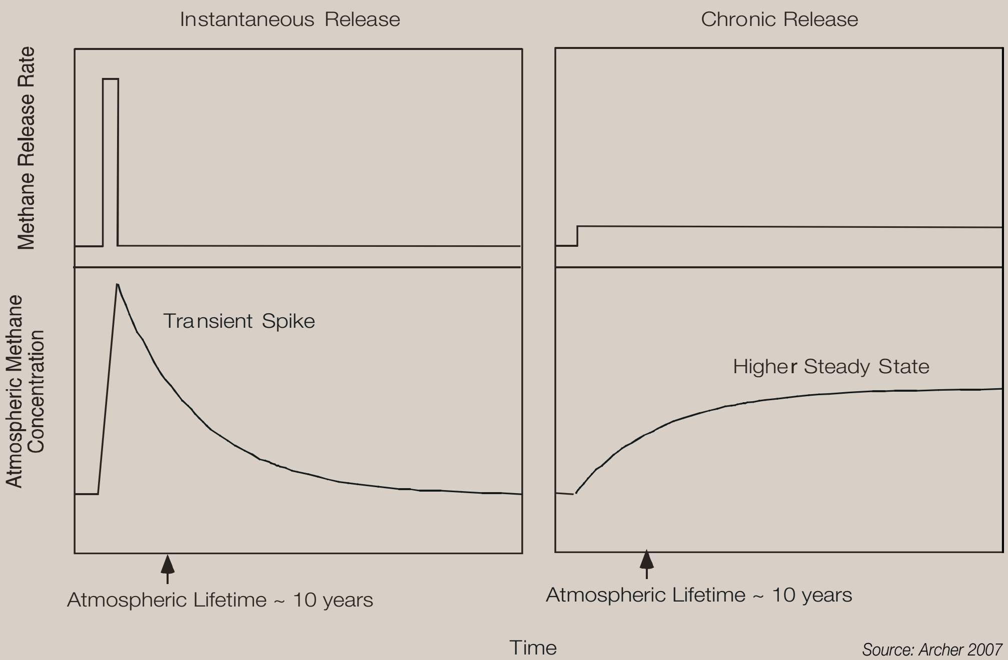
The future of methane hydrates

Methane hydrate research is opening up new avenues to scientists, including the possibility of extracting methane hydrates for energy purposes (**Box 2**).

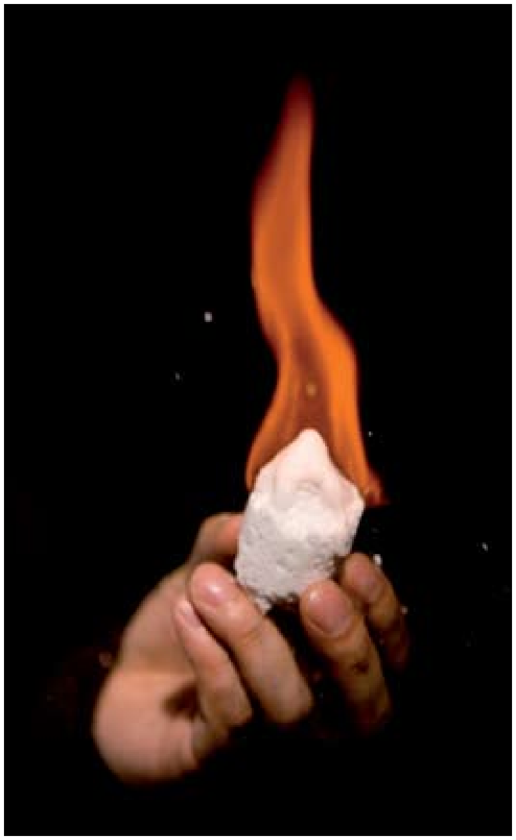
When considering the potential effect of methane hydrates on climate change, the difficult questions that scientists have not yet resolved include:

- how much methane hydrate exists
- how it might destabilize in response to ongoing warming, and
- how and at what rate the methane released by hydrate melting could reach the ocean or atmosphere.

Figure 3: How the methane release rate affects atmospheric methane concentrations



Source: Archer 2007



The icy material of methane hydrates looks like ice, but burns if ignited.
Source: National Research Council Canada

While methane is a powerful GHG, once it oxidizes its carbon element still affects the climate as carbon dioxide. The consequences of increased amounts of methane entering the atmosphere depend on whether it is released instantaneously or at a slow, chronic pace (**Figure 3**).

One scenario poses a sudden release over a short period of enough methane to significantly change proportions of atmospheric components. This would generate a spike in methane concentration, which would then decline. Currently, there are 5 billion metric tons of methane in the atmosphere. It would take another 50 billion metric tons of methane to double the warming effect we are already experiencing from the carbon dioxide build-up in the atmosphere. Some scientists believe that methane spikes have entered the atmosphere in the past but finding a credible mechanism that could release so much methane so fast remains a challenge (Archer 2007, Schiermeier 2003).

Box 2: Methane hydrates as a possible energy source?

Estimates of the total inventory of methane in hydrate deposits globally are comparable to or larger than the rest of the traditional fossil fuel deposits combined, raising the notion of extracting the hydrate methane as a source of fossil energy. Burning methane emits carbon dioxide, but compared to other fossil fuels substantially less of it is emitted for the energy produced.

Most of the methane hydrate deposits are probably not concentrated enough for economic extraction (Milkov and Sassen 2002). The most likely near-term targets for methane hydrate extraction are deposits associated with permafrost soils on land and in the shallow ocean. At least 50 wells were drilled in the Messoyakha field in Siberia (Krason 2000). An international consortium has drilled a series of wells in the Mallik field on Canada's Mackenzie delta (Chatti and others 2005, Kerr 2004). Porous and permeable hydrate-bearing marine sediments that are relatively accessible lie offshore of Japan and the Pacific Northwest of North America, and in the Gulf of Mexico. In other places such as the Blake Ridge off the coast of South Carolina in the United States, access to methane hydrates is limited by impermeable sediments and/or low concentrations, making economic extraction unlikely in the near term (Kvenvolden 1999).

Mining of methane hydrates has risks. There is a possibility that methane extraction could destabilize parts of the continental slope (Chatti and others 2005, Grauls 2001, Kvenvolden 1999). Some have considered replacing methane hydrates with carbon dioxide hydrates, thereby sequestering carbon dioxide and maintaining the stability of the continental slope in the process (Warzinski and Holder 1998).

The prognosis for methane hydrate mining is that it could perhaps supply about 10 per cent of our methane extraction around 10 years from now, similar to growth in coal-bed methane over the last 30 years (Grauls 2001, Kerr 2004). Methane hydrates could thus be a significant source of energy—but not as large as might be inferred from the estimates of total methane in the global hydrate reservoir.

A more likely possibility for our future is a gradual increase in the continual rate of methane emission to the atmosphere from hydrate and thermokarst sources over a longer period. Human-induced methane sources, such as rice paddies, the fossil fuel industry, and livestock, have already doubled the methane concentration in the atmosphere since the 1800s. A source of about 50 billion metric tons of carbon released over 100 years would double atmospheric methane yet again. A methane flux this large from hydrates in the coming century is difficult to predict, but is well within what is possible.

CHANGES IN NATURE

Methane feedbacks operate within the context of a wider set of Arctic climate feedbacks (**Box 3**). Some of these climate feedbacks are already changing the natural environment and are associated with surface reflectivity changes and the release and uptake of other greenhouse gases besides methane.

Changes in reflectivity

Under climatic conditions that have prevailed for millennia, the surface of the Arctic is very bright because of the cover of snow, ice, and sparse vegetation that reflects much of the Sun's radiation back into space. Earlier snowmelt in spring and later snow cover onset in autumn substantially reduce reflectivity—from about 80 per cent of incoming short-wave radiation reflected away to only 20 per cent. This heats up the region in addition to the global average temperature

Box 3: Major climate feedbacks operating in the Arctic

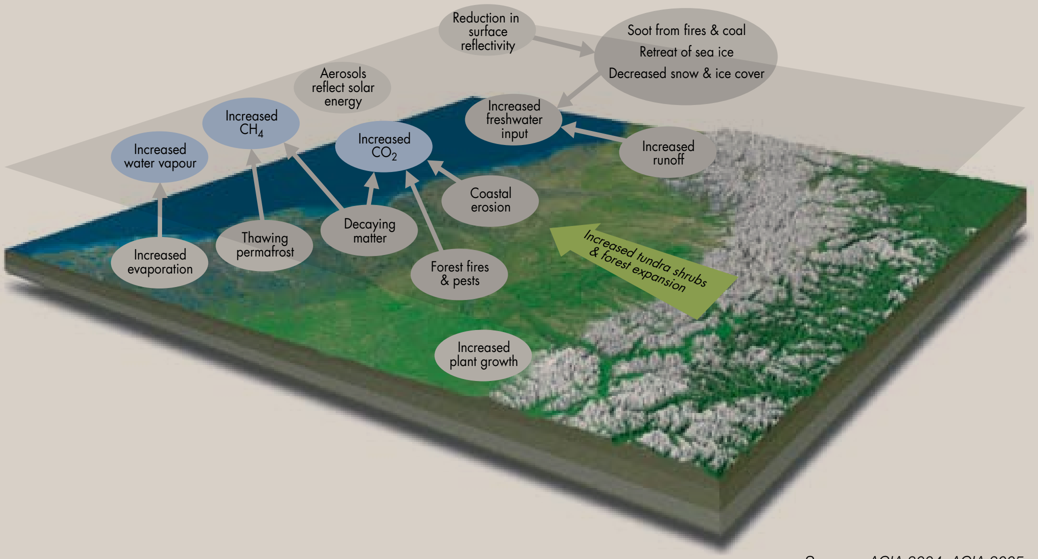
Major Arctic feedbacks that increase warming

- Warming leads to more evaporation and thus more water vapor—a key greenhouse gas—in the atmosphere.
- Warming melts snow and ice, reducing surface reflectivity, thus increasing absorption of solar heat. Increased tundra shrubs and soot from increasing wildfires and fossil fuel burning that darken snow and ice also reduce reflectivity.
- Warming leads to thawing permafrost, more rapid decomposition of soil organic matter, more frequent fire and insect disturbances, and increased coastal erosion followed by decomposition of the eroded material. All of these lead to more releases of the greenhouse gases methane (CH_4) and carbon dioxide (CO_2).

Major Arctic feedbacks that reduce warming

- Tiny particles (aerosols) put into the atmosphere from increasing fires can reflect solar energy away.
- Warming leads to increased plant growth, which takes up more carbon dioxide. Boreal forest ecosystems that migrate northward sequester even more carbon in vegetation and soils.
- As ice melts and precipitation and runoff increase, there is increased freshwater input to the oceans. This slows the thermohaline circulation and reduces ocean heat transport to the region.

Source: McGuire and others 2006.



Sources: ACIA 2004, ACIA 2005.

increases that help melt the snow and ice in the first place (**Figures 4 and 5**).

In the Alaskan tundra, for example, from 1970 to 2000 the increase in atmospheric heating due to earlier snowmelt and the resulting decrease in reflectivity is estimated to be 10.5 watts per square metre (Chapin and others 2005). To put this estimate in context, the global average amount of solar energy that reaches the Earth's surface per second is about 168 watts per square metre. Across all Arctic lands, changes in the seasonality and duration of snow cover are estimated to have increased atmospheric heating by around 3 watts per square metre between 1970 and 2000 (Euskirchen and others 2007).

The Arctic snow cover is expected to continue to decrease in this century. One warming scenario that assumes business-as-usual increases in GHG emissions in the 21st century estimates that the annual number of snow cover days across the Arctic will decrease by about 40 days. Currently the arctic snow cover lasts for about 200 days every year. A change of this magnitude will likely bring an increase in Arctic atmospheric heating of more than 10 watts per square metre during the 21st century. This is about 2.5 times the warming expected from a doubling of atmospheric carbon dioxide concentrations (4.4 watts per square metre) (Houghton and others 2001).

Soot or black carbon settles as a surface deposit in the Arctic from increasingly frequent wildfires in the boreal forest and from coal and diesel fuel burned locally and in other regions. It falls on snow and ice and further reduces reflectivity (Stohl and others 2006, Flanner and others 2007). Fire frequency is increasing in boreal North America (Kasischke and Turetsky 2006) and elsewhere in the Arctic and the additional deposition of soot could further increase warming.

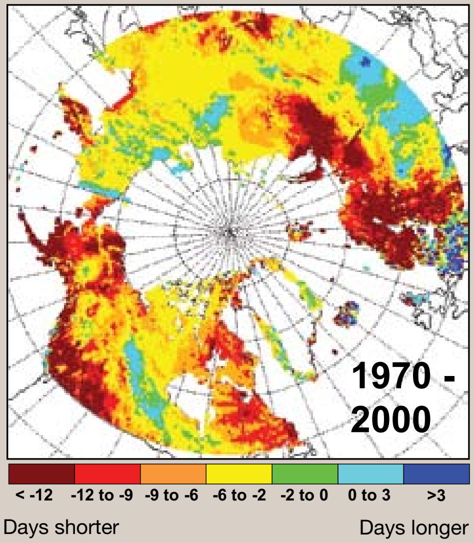
Shrub cover is also increasing. Experimental studies demonstrate that arctic summer warming of 1˚C significantly increases the growth of existing shrubs within a decade (Arft and others 1999). In general, there appears to be increased shrub growth throughout much of the Arctic (Callaghan and others 2005) (**Figure 6**). This is best documented in arctic Alaska, where shrub cover has increased about 16 per cent since 1950 (Tape and others 2006). Although vegetation changes to date appear to have had minimal effects on atmospheric heating in arctic Alaska, complete conversion to shrub tundra has the potential to increase summer heating in the region by about 8.9 watts per square metre (Chapin and others 2005).

Trees are also advancing northward and upslope in the Arctic. Over the last 50 years, tree line advances have been documented in Russia, Canada, and Alaska (McGuire and others 2007). In mountainous areas of Scandinavia, the tree line has moved upslope over the last 50 years as temperatures have warmed (Callaghan and others 2004). If the tundra in northern Alaska converted completely to tree cover, local summertime heating would increase by around 26 watts per square metre (Chapin and others 2005).

Masking of the snow by increased shrub and tree cover in early spring and increased heat energy capture by increased shrub and tree cover in summer act as strong positive feedbacks to climate warming (Chapin and others 2005). Modelling of vegetation change in the Barents Region of the Arctic projects that by 2080 the changes could decrease reflectivity nearly 18 per cent in both summer and winter (Wolf and others in press).

All of these reflectivity-reducing feedbacks amplify warming and outweigh the negative feedbacks at work. One example of a negative feedback is the production of aerosols by wildfires—when soot remains airborne individual particles may refect sunlight and result in some cooling. The small particles may also accelerate cloud formation at altitudes that could reflect

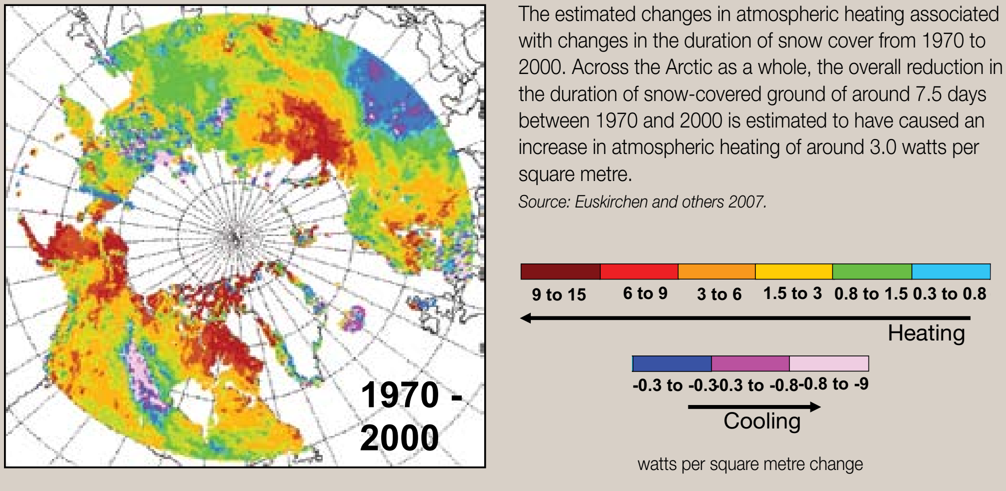
Figure 4: Change in the duration of snow covered ground, 1970-2000



Change in duration of snow-covered ground north of 50º N. The number of days in a year in which the ground is snow covered has decreased by an estimated average of 7.5 days from 1970 to 2000.

Source: Euskirchen and others 2007.

Figure 5: Change in atmospheric heating, 1970-2000



The estimated changes in atmospheric heating associated with changes in the duration of snow cover from 1970 to 2000. Across the Arctic as a whole, the overall reduction in the duration of snow-covered ground of around 7.5 days between 1970 and 2000 is estimated to have caused an increase in atmospheric heating of around 3.0 watts per square metre.

Source: Euskirchen and others 2007.

sunlight. But the potential cooling effects of aerosol soot are outweighed by the warming effect of soot deposited on the surface of the Earth.

Carbon release and uptake

On the amplifying, positive feedback side, warming leads to increased carbon dioxide release by the decomposition of organic matter in soils, by more frequent fires, by insect disturbances that cause trees to die and decay in forests, and by increased coastal erosion and decay of the eroded material. On the damping-down, negative feedback side, warming also increases consumption of carbon dioxide by plant life on the land and in the sea, which helps to moderate carbon dioxide concentrations in the atmosphere. Because this carbon consumption has dominated for millennia in the Arctic, large amounts of carbon have accumulated in tundra and, to a greater degree, in boreal forest soils. As boreal forest ecosystems move northward, replacing tundra ecosystems, the forest soils could increase carbon storage in the Arctic substantially (Betts 2000, Callaghan and others 2005).

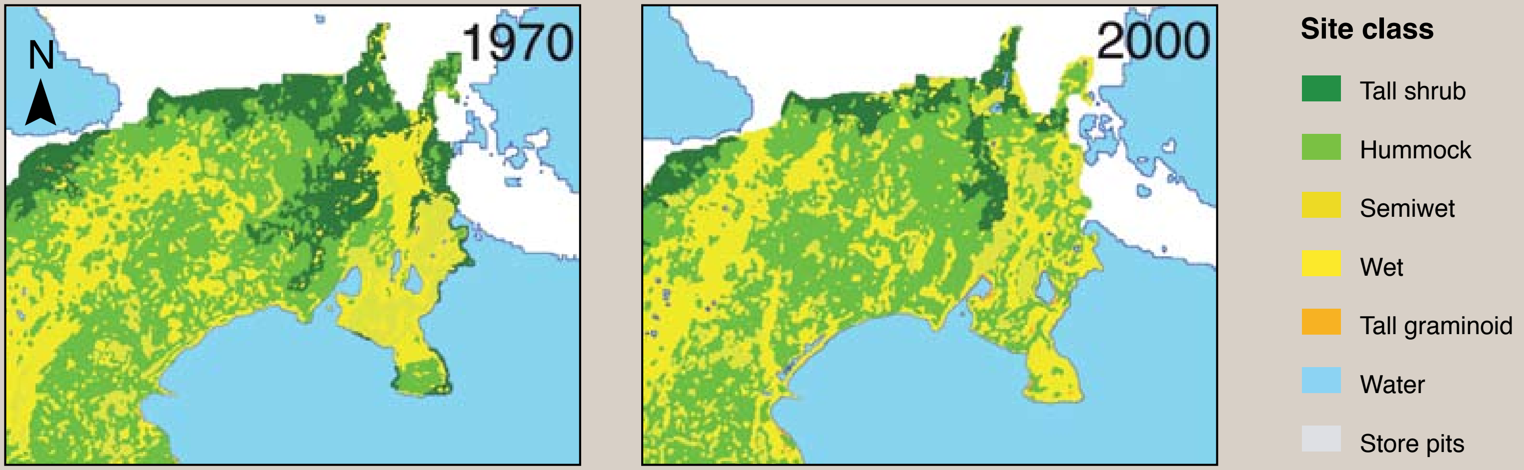
Analyses so far indicate that the warming effect will dominate. The warming caused by reductions in snow and increases in shrub and tree cover will have a stronger effect on the climate system than the cooling effect caused by increased carbon storage (Betts 2000, Chapin and others 2005, Euskirchen and others 2006, Euskirchen and others 2007).

The presence of calcareous soils and the varied landscape relief in the Northern boreal forest belt in Kuusamo, Finland provides for vegetation that is relatively rich in species.

Source: K. Salminen/ Still Pictures

Projected changes in snow and vegetation are also likely to have substantial effects on biodiversity and on northern indigenous peoples. Warming-induced increases in both shrub growth and wildfire reduce the abundance and diversity of lichens, an important winter food for the reindeer on which local people depend (Cornelissen and others 2001, Rupp and others 2006). Other species such as moose may thrive, signifying a broader change in the quantity and types of subsistence resources available to indigenous peoples, who are already faced with shrinking river and sea ice seasons that reduce hunters' access to resources. In Sami, Inuit, Nenets, and other northern cultures with strong traditional ties to the land and sea, these

Figure 6: Vegetation change in Stordalen mire, Sweden 1970-2000



The images show northward colonization by tall shrub species and substantial vegetation change between 1970 and 2000 following permafrost thaw and associated increase in methane flux. This detail is part of an extensive and continuously monitored research programme studying Stordalen mire, which is located about 150 kilometres north of the Arctic Circle in Sweden. The distribution of vegetation site classes have been distinguished through interpretation of colour Infrared aerial images.

Source: Malmer and others 2005

changes have profound nutritional and cultural consequences. As treelines and shrub cover move northward, new species and resources will follow. According to ecosystem research, the Arctic will experience both disappearing climates, with associated ecosystem decline, and novel climates with niches to be filled (see Global Overview). Some of the changes evident in the Arctic are also occurring in high mountain systems at every latitude. Melting ice, deposits of soot, and subsequent changes in surface reflectivity as well as thawing permafrost and encroaching vegetation are altering weather patterns far beyond the regions where so much climate change is underway (**Box 4**).

LOOKING AHEAD

Methane release due to thawing permafrost in the Arctic is a global warming wildcard. The balance of evidence suggests that Arctic feedbacks that amplify warming, globally and regionally, will dominate during the next 50 to 100 years (McGuire and others 2006) (**Box 5**).

As warming continues, these feedbacks will likely intensify. We may be approaching thresholds that are difficult to predict precisely, but crossing such thresholds could have serious global consequences (see Global Overview). This highlights the urgent need for policy responses to reduce future warming—to avoid crossing such thresholds (**Box 6**).

Our understanding of the interactions, relative importance, and projected net balance among the various feedbacks at work in the Arctic is far from complete. In light of these uncertainties and vulnerabilities, it is important that we improve our understanding of how changes in the Arctic will influence global climate. An important step will be to map the locations and to determine the quantities of methane hydrates, their possible responses to further climate change, and the routes and rates by which they could enter the ocean or atmosphere.

It is already clear that the global climate is vulnerable to Arctic feedbacks and that the consequences of those feedbacks could be disastrous. The only way to reduce the magnitude of these consequences is to dramatically reduce and stabilze concentrations of GHGs in the atmosphere. In addition to long-term reductions in emissions of carbon dioxide and the other long-lived greenhouse gases, a near-term focus on reducing emissions of methane and soot, which have shorter atmospheric lifetimes, could be of particular value. The potential consequences of large amounts of methane entering the atmosphere, from thawing permafrost or destabilized ocean hydrates, would lead to abrupt changes in the climate that would likely be irreversible. We must not cross that threshold. Reversing current human-induced warming will help us avoid such outcomes entirely (Hansen and others 2007).

Box 4: Melting glaciers and thawing permafrost beyond the Arctic: the Qinghai-Tibet Plateau

Source: Xinhua News Agency

Source: Jicheng He/Chinese Academy of Sciences

Thawing permafrost is affecting high altitude environments as well as those at high latitudes. The Qinghai-Tibet Plateau contains about 5.94 million hectares of glaciers with 5 590 km^3 of ice. It is also underlain by 150 million hectares of permafrost. The permafrost ice volume is more than double that of the glaciers. This Plateau is the source of the Changjiang (Yangtze) and Huanghe (Yellow) Rivers, which are at the heart of agriculture, forestry, fisheries, and other aspects of downstream economic activities and environments. These rivers also carry large amounts of soil to their lower basins.

The persistent increase of ice melting on the Qinghai-Tibet Plateau due to continued warming will inevitably affect the economy and environment in China and surrounding regions. During the last half century, global warming has accelerated melting on the Plateau. Its glaciers decreased by seven per cent, leading to a 5.5 per cent increase in runoff in northwest China. However, the high temperatures that caused the glaciers to melt also caused increased evaporation across northwest China and triggered more droughts, expanded desertification through soil erosion, and increased sand and dust storms. Northern China has suffered from severe dust storms which have been attributed to desertification in the northwest. For example, on April 17, 2006, a single dust storm dumped about 336 000 metric tons of dust on Beijing, causing hazardous air quality in the capital (Yao and others 2007).

Changes in snow and vegetation are likely to have substantial effects on biodiversity. Here, reindeer dig for lichens after a recent heavy snowfall.
Source: Inger Marie Gaup Eira/www.ealat.org

Box 5: Summary of key messages

- Arctic methane emissions are projected to at least double in this century. This doubling is due to an increase in the area of wetlands created by thawing and continued warming of these wet organic soils. These factors will lead to increased global warming.
- Thawing permafrost in northern Siberia alone is projected to release an amount of methane ten times the current atmospheric methane burden by bubbling out of thermokarst lakes.
- Methane hydrates represent a future source of long-term ongoing methane emissions.
- Reductions in arctic snow cover have reduced surface reflectivity, causing nearly as much local heating as the carbon dioxide forcing over the past 30 years. The effects of this feedback loop are expected to increase with future warming.
- If shrubs expand to cover all the arctic tundra, this could increase local summer heating by twice as much as the current carbon dioxide forcing.
- Arctic climate feedbacks have global implications, because they produce significant contributions to global atmospheric carbon concentrations. The increase in GHGs causes climate change that brings rising sea levels, intensified storms, and threatened ecosystems on a global scale.

Box 6: Policy considerations

Investments in climate and energy research
There is a critical need to substantially increase research investments for understanding the processes of climate change, assessing the likely impacts on people and places, and expanding the adaptive capabilities of human and natural systems. This discussion of Arctic and global feedbacks emphasizes the urgency of meeting the huge technological challenge we face: how to manage the transition to low-carbon energy systems. This transition includes increasing energy efficiency, reducing carbon intensity, and promoting biological and geological sequestration of the carbon dioxide produced by fossil fuels. Investments directed towards methane-related research and development should provide a better understanding of methane hydrates and their potential as a cleaner fuel source, as well as integrate methane cycles into global process models, including those that model climate changes.

Knowledge Partnerships
It is essential that decision makers have a thorough knowledge base upon which to craft policies and fully understand the consequences of different pathways, including the risks of unintended consequences that cross dangerous thresholds. As new energy options are considered, a complete analysis of the risks and benefits should be undertaken, considering both local and global effects. Knowledge about climate change and its impact on nature and people, as well as technological and policy solutions, should be shared broadly through a range of facilitating partnerships to communicate the urgency of the challenge and the wealth of opportunities. Specifically, better understanding of methane cycles and how they affect, and are affected by, climate change feedbacks will depend on the ability of knowledge partnerships to bridge the gap between science and policy.

Global political responses
Addressing the emerging challenges presented by the warming of the Arctic and resulting in increasing methane emissions will require global responses in the near and foreseeable future. Recent analyses suggest that the transition to a more efficient and low-carbon energy system could provide substantial economic opportunities and have a minimal or very modest effect on gross domestic product at the global scale (IPCC 2007, Stern 2006). The ability to integrate economic incentives into global climate policy responses will play a key role in engaging and energizing the best in our institutions of government, industry, and society and across the emerging economies, the developing world, and industrialized nations.

REFERENCES

ACIA (2004). *Impacts of a Warming Arctic, synthesis report of the Arctic Climate Impact Assessment*. Cambridge University Press Cambridge, UK

ACIA (2005). *Arctic Climate Impact Assessment Scientific Report.* Cambridge University Press, Cambridge, UK

Archer, D.E. (2007). Methane hydrate stability and anthropogenic climate change. *Biogeosciences*, 4, 993-1057

Arft, A.M., Walker, M.D., Gurevitch, J., Alatalo, J.M., Bret-Harte, M.S., Dale, M., Diemer, M., Gugerli, F., Henry, G.H.R., Jones, M.H., Hollister, R., Jónsdóttir, I.S., Laine, K., Lévesque, E., Marion, G.M., Molau, U., Mølgaard, P., Nordenhäll, U., Raszhivin, V., Robinson, C.H., Starr, G., Stenström, A., Stenström, M., Totland, Ø., Turner, L., Walker, L., Webber, P., Welker, J.M. and Wookey, P.A. (1999). Response patterns of tundra plant species to experimental warming: A meta-analysis of the International Tundra Experiment. *Ecological Monographs*, 69, 491-511

Bastviken, D., Cole, J., Pace M. and Tranvik, L. (2004). Methane emissions from lakes: Dependence of lake characteristics, two regional assessments, and a global estimate. *Global Biogeochemical Cycles*, 18, GB4009

Betts, R.A. (2000). Offset of the potential carbon sink from boreal forestation by decreases in surface albedo. *Nature*, 408, 187-190

Brewer, P.G., Paull, C., Peltzer, E.T. Ussler,W., Rehder, G. and Friederich, G. (2002). Measurements of the fate of gas hydrates during transit through the ocean water column. *Geophysical Research Letters*, 29(22), 2081

Buffett, B. and Archer, D.E. (2004). Global inventory of methane clathrate: Sensitivity to changes in environmental conditions. *Earth and Planetary Science Letters*, 227, 185-199

Callaghan, T.V., Bjorn, L.O., Chapin, F.S., III, Chernov, Y., Christensen, T.R., Huntley, B., Ims, R., Johansson, M., Jolly, D., Jonasson, S., Matveyeva, N., Oechel, W.C., Panikov, N. and Shaver, G.R. (2005). Arctic Tundra and Polar Desert Ecosystems. In *Arctic Climate Impact Assessment* (ed. R. Corell). Cambridge University Press, Cambridge, UK, pp 243-352

Chapin, F.S., III, Sturm, M., Serreze, M.C., McFadden, J.P., Key, J.R., Lloyd, A.H., McGuire, A.D., Rupp, T.S., Lynch, A.H., Schimel, J.P., Beringer, J., Chapman, W.L., Epstein, H.E., Euskirchen, E., Hinzman, L.D., Jia, G., Ping, C.L., Tape, K.D., Thompson, C.D., Walker, D.A. and Welker, J.M. (2005). Role of land-surface changes in arctic summer warming. *Science*, 310, 657-660

Chatti, I., Delahaye, A., Fournaison, L. and Petitet, J.P. (2005). Benefits and drawbacks of clathrate hydrates: A review of their areas of interest. *Energy Conversion and Management*, 46 (9-10), 1333-1343

Christensen, T.R., Johansson, T., Malmer, N., Åkerman, J., Friborg, T., Crill, P., Mastepanov, M. and Svensson, B. (2004). Thawing sub-arctic permafrost: Effects on vegetation and methane emissions. *Geophysical Research Letters*, 31, L04501

Cornelissen, J.H.C., Callaghan, T.V., Alatalo, J.M. Michelsen, A., Graglia, E., Hartley, A.E., Hik, D.S., Hobbie, S.E., Press, M.C., Robinson, C.H., Henry, G.H.R., Shaver, G.R., Phoenix, G.K., Gwynn Jones, D., Jonasson, S., Chapin, F.S., III, Molau, U., Neill, C., Lee, J.A., Melillo, J.M., Sveinbjornsson, B. and Aerts, R. (2001). Global change and arctic ecosystems: Is lichen decline a function of increases in vascular plant biomass? *Journal of Ecology*, 89, 984-994

Dallimore, S.R. and Collett, T.S. (1995). Intrapermafrost gas hydrates from a deep core-hole in the Mackenzie Delta, Northwest-Territories, Canada. *Geology*, 23 (6), 527-530

Euskirchen, S.E., McGuire, A.D., Kicklighter, D.W., Zhuang, Q., Clein, J.S., Dargaville, R.J., Dye, D.G., Kimball, J.S., McDonald, K.C., Melillo, J.M., Romanovsky, V.E. and Smith, N.V. (2006). Importance of recent shifts in soil thermal dynamics on growing season length, productivity, and carbon sequestration in terrestrial high-latitude ecosystems. *Global Change Biology*, 12, 731-750

Euskirchen, S.E., McGuire, A.D. and Chapin, F.S., III (2007). Energy feedbacks to the climate system due to reduced high latitude snow cover during 20th century warming. *Global Change Biology*, in press

Fisher, C.R., MacDonald, I.R., Sassen, R., Young, C.M., Macko, S.A., Hourdez, S., Carney, R.S., Joye, S. and McMullin, E. (2000) Methane Ice Worms: *Hesiocaeca methanicola* Colonizing Fossil Fuel Reserves, *Naturwissenschaften*, 87, 4, 184-187

Flanner, M.G., Zender, C.S., Randerson, J.T. and Rasch, P.J. (2007). Present-day climate forcing and response from black carbon in snow. *Journal of Geophysical Research*, 112, D11202

Gedney, N., Cox, P.M. and Huntingford C. (2004). Climate feedback from wetland methane emissions. *Geophysical Research Letters*, 31, L20503

Gornitz, V. and Fung, I. (1994). Potential distribution of methane hydrate in the world's oceans. *Global Biogeochemical Cycles*, 8, 335-347

Grauls, D. (2001). Gas hydrates: Importance and applications in petroleum exploration. *Marine and Petroleum Geology*, 18(4), 519-523

Hansen, J. and Sato, M. (2007). *Global Warming: East-West Connections*. NASA Goddard Institute for Space Studies and Columbia University Earth Institute. www.columbia.edu/~jeh1/East-West_070925.pdf

Houghton, J.T., Ding,Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Dai, X., Maskell, K. and Johnson, C.A. (eds.) (2001). *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge

IPCC, Intergovernmental Panel on Climate Change (2007). *Climate Change 2007 - The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the IPCC. http://ipccwg1.ucar.edu/wg1/wg1-report.html

Johansson, T., Malmer, N., Crill, P.M., Mastepanov, M. and Christensen, T.R. (2006). Decadal vegetation changes in a northern peatland, greenhouse gas fluxes and net radiative forcing. *Global Change Biology*, 12(12), 2352–2369

Jorgenson, M.T. and Shur, Y. (2007). Evolution of lakes and basins in northern Alaska and discussion of the thaw lake cycle. *Journal of Geophysical Research*, 112, F02S17. doi:10.1029/2006JF000531

Kasischke, E.S. and Turetsky, M.R. (2006). Recent changes in the fire regime across the North American boreal region- spatial and temporal patterns of burning across Canada and Alaska. *Geophysical Research Letters*, 33, L09703

Kerr, R.A., (2004). Energy - Gas hydrate resource: Smaller but sooner, *Science*, 303(5660), 946-947

Krason, J. (2000). Messoyakh Gas Field (W. Siberia) - A model for development of the methane hydrate deposits of Mackenzie Delta. In *Gas Hydrates: Challenges for the Future* (eds G.D. Holder and P.R. Bishnoi). Annals of the New York Academy of Sciences, 912: 173-188

Kvenvolden, K.A. (1999). Potential effects of gas hydrate on human welfare. *Proc. Natl. Acad. Sci.* USA, 96, 3420-3426

Malmer, N., Johansson, T., Olsrud, M. and Christensen, T. (2005). Vegetation, climatic changes and net carbon sequestration in a North-Scandinavian subarctic mire over 30 years. Global Change Biology, 2005(11), 1895-1909

McGuire, A.D., Chapin, F.S., III, Walsh, J.E. and Wirth, C. (2006). Integrated Regional Changes in Arctic Climate Feedbacks: Implications for the global climate system. *Annual Review of Environment and Resources*, 31, 61-91

McGuire, A.D., Chapin, F.S., III, Wirth, C., Apps, M., Bhatti, J., Callaghan, T., Christensen, T.R., Clein, J.S., Fukuda, M., Maximov, T., Onuchin, A., Shvidenko, A. and Vaganov, E. (2007). Responses of high latitude ecosystems to global change: Potential consequences for the climate system. In T*errestrial Ecosystems in a Changing World*. (eds. J.G. Canadell, D.E. Pataki and L.F. Pitelka) The IGBP Series, Springer-Verlag, Berlin Heidelberg

Milkov, A.V. (2004). Global estimates of hydrate-bound gas in marine sediments: how much is really out there? *Earth-Science Reviews*, 66(3-4), 183-197

Milkov, A.V. and Sassen R. (2002). Economic geology of offshore gas hydrate accumulations and provinces. *Marine and Petroleum Geology*, 19(1), 1-11

Riordan, B., Verbyla, D. and McGuire, A.D. (2006). Shrinking ponds in subarctic Alaska based on 1950–2002 remotely sensed images. *Journal of Geophysical Research*, 11, G04002

Rogner, H-H. (1997) An assessment of world hydrocarbon resources. *Annual Review of Energy and the Environment*, 22, 217-262

Romankevich, E.A. (1984). *Geochemistry of Organic Matter in the Ocean*, Springer, New York

Rupp, T. S., Olson, M., Henkelman, J., Adams, L., Dale, B., Joly, K., Collins W. and Starfield, A.M. (2006). Simulating the influence of a changing fire regime on Caribou winter foraging habitat. *Ecological Applications*, 16, 1730-1743

Schiermeier. Q. (2003). Gas Leak! *Nature*, 423, 681-2

Shakhova, N., Semiletov, I. and Panteleev, G. (2005). The distribution of methane on the Siberian arctic shelves: Implications for the marine methane cycle. *Geophysical Research Letters*, 32, L09601

Smith, L.C., MacDonald, G.M., Velichko, A.A., Beilman, D.W., Borisova, O.K., Frey, K.E., Kremenetski, K.V. and Sheng, Y. (2004). Siberian peatlands a net carbon sink and global methane source since the early Holocene. *Science*, 303, 353–356

Smith, L.C., Sheng, Y. and MacDonald, G.M. (2007). A first pan-arctic assessment of the influence of glaciation, permafrost, topography and peatlands on northern lake distribution. *Permafrost Periglac. Processes*, 18(2)

Stern, N. (2006). *Stern Review on the economics of climate change*. http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

Stohl, A., Andrews, E., Burkhart, J.F., Forster, C., Herber, A., Hoch, S.W., Kowal, D., Lunder, C., Mefford, T., Ogren, J.A., Sharma, S., Spichtinger, N., Stebel, K., Stone, R., Ström, J., Tørseth, K., Wehrli, C. and Yttri, K.E. (2006). Pan-Arctic enhancements of light absorbing aerosol concentrations due to North American boreal forest fires during summer 2004. *Journal of Geophysical Research*, 111, D22214

Tape, K., Sturm, M. and Racine, C. (2006). The evidence for shrub expansion in Northern Alaska and the Pan-Arctic. *Global Change Biology*, 12, 686-702

Walter, K.M., Zimov, S.A., Chanton, J.P. Verbyla, D. and Chapin, F.S., III (2006). Methane bubbling from Siberian thaw lakes as a positive feedback to climate warming, *Nature*, 443, 71-75

Walter, K.M., Smith, L.C. and Chapin, F.S., III (2007a). Methane bubbling from northern lakes: Present and future contributions to the global methane budget. *Philosophical Transactions of the Royal Society A*, 365, 1657-1676

Walter, K. M., Duguay, C., Jeffries, M., Engram, M. and Chapin, F.S., III (2007b). Potential use of synthetic aperture radar (SAR) for estimating methane ebullition from arctic lakes. *Journal of the American Water Research Association*, in press

Walter, K.M., Edwards, M.E., Grosse, G., Zimov, S.A., and Chapin, F.S., III (2007c). Thermokarst Lakes as a Source of Atmospheric CH4 During the Last Deglaciation, *Science*, 318, 633-636

Warzinski, R. and Holder, G. (1998). Gas clathrate hydrates. *Energy & Fuels*, 12(2), 189–190

Wolf, A., Larsson, K. and Callaghan, T.V. (2007). Future vegetation changes in the Barents Region. *Climatic Change*, in press

Wuebbles, D.J. and Hayhoe, K. (2002). Atmospheric methane and global change. *Earth-Science Reviews*, 57, 177–210

Yao, T., Pu, J., Lu, A., Wang, Y. and Yu, W. (2007). Recent Glacial Retreat and Its Impact on Hydrological Processes on the Tibetan Plateau, China, and Surrounding Regions. Arctic, Antarctic, and Alphine Research 39(4), 642-650

Zhuang, Q., Melillo, J.M., Kicklighter, D.W., Prinn, R.G., McGuire, D.A., Steudler, P.A., Felzer, B.S. and Hu, S. (2004). Methane fluxes between terrestrial ecosystems and the atmosphere at northern high latitudes during the past century: A retrospective analysis with a process-based biogeochemistry model. *Global Biogeochemical Cycles*, 18, GB3010

Zhuang, Q., Melillo, J.M., Sarofim, M.C., Kicklighter, D.W., McGuire, A.D., Felzer, B.S., Sokolov, A., Prinn, R.G., Steudler, P.A. and Hu, S. (2006). CO2 and CH4 exchanges between land ecosystems and the atmosphere in northern high latitudes over the 21st century. *Geophysical Research Letters*, 33, L17403

Zimov, S.A., Schuur, E.A.G. and Chapin, F.S., III (2006). Permafrost and the global carbon budget. *Science*, 312, 1612-1613

Acronyms and abbreviations

ACIA	Arctic Climate Impact Assessment
AOSIS	Alliance of Small Island States
AR4	Fourth Assessment Report from the Intergovernmental Panel on Climate Change
BLIHR	Business Leaders Initiative on Human Rights
BP	Beyond Petroleum (formerly British Petroleum)
CAN-E	Climate Action Network-Europe
CAP	Carbon Action Partnership
Cartagena Protocol	Cartagena Protocol on Biosafety to the Convention on Biological Diversity
CBD	Convention on Biological Diversity
CCFE	Chicago Climate Futures Exchange
CCI	Clinton Climate Initiative
CCS	Carbon Capture and Storage
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CDP	Carbon Disclosure Project
CER	Certified Emissions Reductions
CFC	chlorofluorocarbon
CFI	Carbon Financial Instrument
CH_4	methane
CII	Council of Institutional Investors
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
cm	centimeter
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CO_2	carbon dioxide
CO_{2eq}	carbon dioxide equivalent
COP	Conference of Parties
CSR	Corporate Social Responsibility
DRC	Democratic Republic of the Congo
EB	Executive Board
EITI	Extractive Industries Transparency Initiative
ELFAA	European Low Fares Airline Association
ERU	Emission Reduction Units
ESA	European Space Agency
ESG	Environmental, social, and governance
ETS	Emissions Trading Scheme (European Union)
EU	European Union
FCPF	Forest Carbon Partnership Facility
GDP	Gross Domestic Product
GEO	Global Environment Outlook (of UNEP)
GHG	Greenhouse gas
GIS	Geographic Information System
GPS	Global Positioning System
GS	Goldman Sachs
GWP	Global Warming Potential
H^+	hydrogen ions
HCFC	hydrochlorofluorocarbon
Heritage Convention	Concerning the Protection of the World Cultural and Natural Heritage
HFC-23	triflurομethane
IAC	InterAcademy Council
ICAP	International Carbon Action Partnership
ICGN	International Corporate Governance Network
IDNDR	International Decade of Natural Disaster Reduction
IEA	International Energy Agency
IETA	International Emissions Trading Association
IIGCC	Institution Investors Group on Climate Change
IISD	International Institute for Sustainable Development
IMF	International Monetary Fund
IMO	International Marine Organization
INCR	Investor Network on Climate Risk
IPEN	International POPs (Persistent Organic Pollutants) Elimination Network
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IUCN	The World Conservation Union
JI	Joint Implementation
JTWC	Joint Typhoon Warning Center
K:TGAL	Kyoto: Think Global, Act Local
Kyoto Protocol	Kyoto Protocol to the UN Framework Convention on Climate Change
MA	Millennium Ecosystem Assessment
MBA	Masters of Business Administration
MCII	Munich Climate Insurance Initiative
MEAs	Multilateral Environmental Agreements
mm	millimeter
mt	Metric tons
N_2O	nitrous oxide
NAP	National Allocation Plan
NASA	National Aeronautics and Space Administration (of the United States)
NGO	non-governmental organization
NOAA	National Oceanographic and Atmospheric Administration (of the United States)
NSIDC	The National Snow and Ice Data Center
OECD	Organization for Economic Co-operation and Development
OTC	Over The Counter
PES	Payment for Ecosystem Services
POPs	Persistent Organic Pollutants
ppb	parts per billion
ppm	parts per million
PRI	Principles for Responsible Investment
Ramsar Convention	Convention on Wetlands of International Importance Especially as Waterfowl Habitat
R&D	Research and Development
REDD	reduced emissions from avoided deforestation and forest degradation
RFMOs	Regional Fisheries Management Organizations
Rotterdam Convention	Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade
SPRFMO	South Pacific Regional Fisheries Management Organisation
Stockholm Convention	Stockholm Convention on Persistent Organic Pollutants
UK	United Kingdom
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNEP	United Nations Environment Programme
UNEP FI	United Nations Environment Programme Finance Initiative
UNFCCC	UN Framework Convention on Climate Change
UNGA	United Nations General Assembly
UNPRI	United Nations Principles for Responsible Investment
US	United States of America
US$	United States Dollar
USA	United States of America
USCAP	United States Climate Action Partnership
USCCSP	United States Climate Change Science Program
USDA	United States Department of Agriculture
VCS	Voluntary Carbon Standard
Vienna Convention/ Montreal Protocol	Vienna Convention for the Protection of the Ozone Layer and its Montreal Protocol on Substances that Deplete the Ozone Layer
VMEs	Vulnerable Marine Ecosystems
WBCSD	World Business Council for Sustainable Development
WMO	World Meteorological Organization
WTO	World Trade Organization
WWF	World Wide Fund for Nature, World Wildlife Fund

Acknowledgements

Global Overview

Lead Authors:
Paul Harrison
Catherine McMullen, UNEP DEWA, Nairobi, Kenya

Contributors:
Susanne Bech and **Jason Jabbour**, UNEP DEWA, Nairobi, Kenya
Masaharu Nagai, UNEP DELC, Nairobi, Kenya
Benjamin Simmons, UNEP DTIE, Geneva, Switzerland
Michael Raupach and **Josep Canadell ,** Global Carbon Project, Commonwealth Scientific and Industrial Research Organisation, Marine and Atmospheric Research, Canberra, Australia

Reviewers:
Joana Akrofi, Marion Cheatle, Volodymyr Demkine, R. Norberto Fernandez, Peter Gilruth, and **Christian Lambrechts** UNEP DEWA, Nairobi, Kenya
Julian Blanc, UNEP DELC, Nairobi, Kenya
Monika MacDevette, UNEP-WCMC, Cambridge, UK
Melanie Virtue, Johannes Refisch, and **Matthew Woods** UNEP GRASP, Nairobi, Kenya

Feature Focus: Putting the Pieces Together: Using Markets and Finance to Fight Climate Change

Lead Authors:
Catherine McMullen, UNEP DEWA, Nairobi, Kenya
Philip Walker, UNEP FI, Cape Town, South Africa

Lead Experts:
L. Hunter Lovins, Presidio School of Management, San Francisco; President, Natural Capitalism Solutions, Eldorado Springs, USA
Richard L. Sandor, Kellogg Graduate School of Management, Northwestern University, Evanston; CEO, Chicago Climate Exchange, Chicago, USA

Contributors:
Paul Clements-Hunt and **Louise Gallagher** UNEP FI, Geneva, Switzerland
Jason Jabbour, **UNEP DEWA, Nairobi, Kenya**
Sami Kamel UNEP GRID, Roskilde, Denmark
Fulai Sheng, UNEP DTIE, Geneva, Switzerland
Qian Yi, Tsinghua University, Beijing, China
Klaus Lackner, Earth Engineering Center, Columbia University, New York, USA

Reviewers:
Susanne Bech, Marion Cheatle, and **R. Norberto Fernandez**, UNEP DEWA, Nairobi, Kenya
Anantha Duraiappah, UNEP DEPI, Nairobi, Kenya
Will Ferretti, Chicago Climate Exchange, Chicago, USA
Julie Gorte, Calvert Group, Bethesda, USA
Janos Pasztor, UNEMG, Geneva, Switzerland
Lisa Petrovic, UNEP FI, Toronto, Canada
Mark Radka, UNEP DTIE, Paris, France
Nathalie Ryan and **Susan Steinhagen** UNEP FI, Geneva, Switzerland

Emerging Challenges: Methane from the Arctic: Global Warming Wildcard

Lead Authors:
Robert W. Corell, H. John Heinz III Center for Science, Economics and the Environment, Washington D.C., USA
Susan Joy Hassol, Climate Communication, Basalt, USA
Jerry Melillo, Marine Biological Laboratory, Woods Hole, USA

Contributors:
David Archer, University of Chicago, Chicago, USA
Eugenie Euskirchen and **F. Stuart Chapin**, Institute of Arctic Biology, University of Alaska, Fairbanks, USA
A. David McGuire, U.S. Geological Survey, University of Alaska, Fairbanks, USA
Torben R. Christensen, Lund University, Lund, Sweden
Veronique Plocq Fichelet, Scientific Committee on Problems of the Environment, Paris, France
Katey Walter, University of Alaska, Fairbanks, USA
Qianlai Zhuang, Purdue University, West Lafayette, USA
Terry Callaghan, Abisko Scientific Research Station, Abisko, Sweden/Sheffield Centre for Arctic Ecology, Sheffield, UK
Susanne Bech and **Catherine McMullen**, UNEP DEWA, Nairobi, Kenya

Reviewers:
Ivan Conesa Alcolea, European Commission Research Directorate-General, Brussels, Belgium
Ray Boswell, U.S. Department of Energy – National Energy Technology Laboratory, Morgantown, USA
Marion Cheatle and **Jason Jabbour**, UNEP DEWA, Nairobi, Kenya
Joan Eamer and **Svein Tveitdal**, UNEP/Global Resource Information Database-Arendal, Arendal, Norway
Peter Kouwenhoven, International Global Change Institute/University of Waikato, Hamilton, New Zealand
Valery P. Kukhar, National Academy of Sciences of Ukraine, Kiev, Ukraine
Jeff Price, California State University, Chico, USA
Hans Martin Seip, University of Oslo, Oslo, Norway

PRODUCTION

Nairobi Production Team:
Susanne Bech
R. Norberto Fernandez
Jason Jabbour
Catherine McMullen

Support Team:
Marion Cheatle
Volodymyr Demkine
Salif Diop
Martin Embeletobbo
Peter Gilruth
Christian Lambrechts
Graciela Metternicht
Caroline Mutua
Gemma Shepherd
Jaap van Woerden
Jinhua Zhang

Outreach:
Beth Ingraham
Francis Njoroge
Nick Nuttal
Audrey Ringler

Editor:
Paul Harrison

United Nations Environment Programme (UNEP) Year Book 2008: Questionnaire

Please take a few minutes to fill out this questionnaire and share your opinion about this document – Thank you!

The UNEP Year Book 2008 (formerly the GEO Year Book) is the fifth annual report on the changing environment produced by the United Nations Environment Programme in collaboration with many world environmental experts.

1. How would you rate the overall usefulness of the content of each section in the UNEP Year Book?

	Very Useful	Useful	Not Very Useful	Not Useful at All	No Opinion
Global Overview: A brief annual review of selected global environmental issues of the previous year likely to have a major impact on the environment, for better or worse.					
Feature Focus: Putting the Pieces Together: Using markets and finance to fght climate change					
Emerging Challenges: Methane from the Arctic: Global warming wildcard.					
Calendar of selected events in 2007					
Insights and progress on environmental governance in 2007					

Please provide any addition comments on the content of the sections indicated above.

2. How informative did you find the UNEP Year Book (UYB) with respect to the following statements?

	Very Informative	Informative	Not Very Informative	Not Informative at All	No Opinion
Providing a succinct overview of global environmental issues of key significance over the year					
Specific policy-related information on current and emerging environmental issues					
An overview of environmental changes and trends					
Information on progress made in strengthening international environmental governance and policy frameworks					
Awareness of environmental action and events at national, regional, or global level					

3. Please briefly describe the most important way(s) that the UNEP Year Book will be, or has been, used by you (i.e., information only, background for research, decision-making, etc.):

4. About yourself

Please specify the type of organization you belong to:

__ Government

__ Development organization

__ Non-governmental/civil society

__ Academic/Research institution

__ International organisation

__ Private sector

__ Press or media

Other (please specify): ____________________________

Your position:

__ Minister/Director

__ Manager

__ Advisor

__ Scientist

__ Student

__ Technical specialist

__ Journalist

Other (please specify): ____________________________

Thank you!

Please mail your completed questionnaire to:

EarthPrint Limitied
P.O. Box 119
Stevenage, Hertfordshire
SG14TP, England

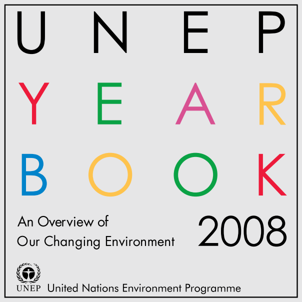
You can also complete this questionnaire on-line at www.unep.org/unep/geo/yearbook/yb2008/

Order form

Please send me the NEW! UNEP Year Book 2008 @ US$20.00 in the following languages/quantities:

Year Book 2008

Language		Quantity	Total price US$
English	(ISBN: 978-92-807-2877-4)	________	______________
French	(ISBN: 978-92-807-2878-1)	________	______________
Spanish	(ISBN: 978-92-807-2880-4)	________	______________
Russian	(ISBN: 978-92-807-2879-8)	________	______________
Arabic	(ISBN: 978-92-807-2875-0)	________	______________
Chinese	(ISBN: 978-92-807-2876-7)	________	______________



Purchase any of the previous Year Books (2003, 2004/05, 2006 or 2007) at a discounted rate of US$10.00 each, please specify languages and quantites:

Previous Year Books

Language	Years	Quantity	Total price US$
English	________	________	______________
French	________	________	______________
Spanish	________	________	______________
Russian	________	________	______________
Arabic	________	________	______________
Chinese	________	________	______________

Discounted price for developing countries 25%
To order please return this completed form to the address below. You can also email us or place your order online at our bookstore www.earthprint.com.

EarthPrint Limited
P.O. Box 119, Stevenage, Hertfordshire SG14TP, England
Tel: +44 1438 748 111 • Fax: +44 1438 748 844 • Email: unep@earthprint.com

- ☐ Europe/UK postage: US$6.00 for first item plus US$3.00 for each subsequent item.
- ☐ Rest of the world: US$10.00 for first item plus US$3.00 for each subsequent item.
- ☐ Please find enclosed a cheque for US$________ (made payable to EarthPrint Ltd.).
- ☐ Please invoice our institution/organization.
- ☐ Please charge my credit card (Amex/Visa/Mastercard).

Card No.: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ Expiry Date: ☐☐/☐☐/☐☐

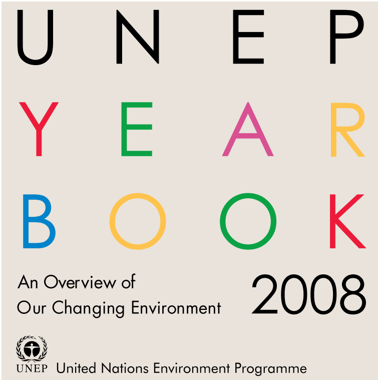
Name: ______________________________ Organization: ______________________

Address: ____ Country: ______________

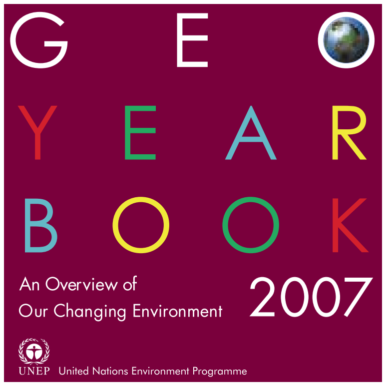
Email or Fax No: ____

For other UNEP publications please visit www.earthprint.com

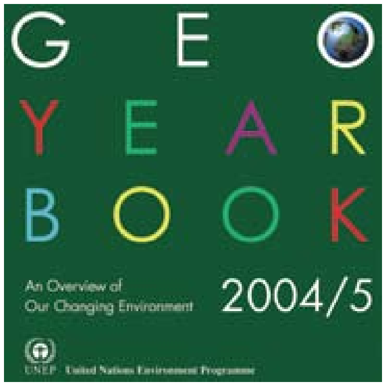
The Year Book Collection



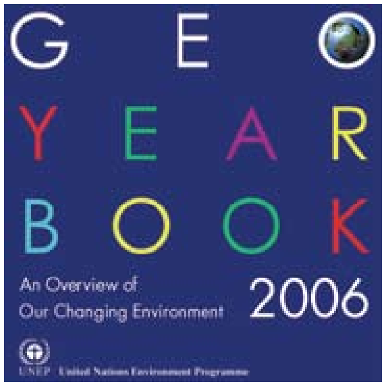
Year Book 2008
In 2008 the UNEP Year Book's Feature Focus examines how market and financial mechanisms can advance the transition to a low-carbon and environmentally-sound economy. The section emphasizes the need for sound policy response to support these mechanisms. The Emerging Challenge section explains some of the complexities presented by methane release from a warming Arctic and the regional feedbacks that enhance uncertainties about the risks these processes present.



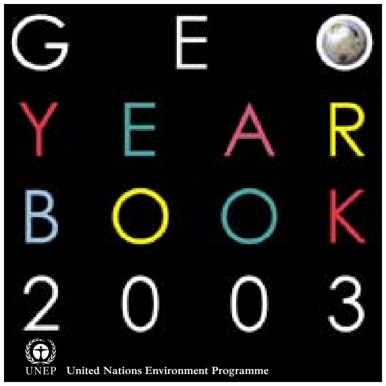
Year Book 2007
The opportunities and risks examined in the Feature Focus of GYB 2007 on the interface between Environment and Globalization are considered from a dynamic and interactive approach. With responsible management, risks can be defused or even transformed into opportunities. With no management or with mismanagement, opportunities can all too easily degrade into risks. The impact of nanotechnologies on the environment and human health are examined in the Emerging Challenges section.



Year Book 2004/5
The Feature Focus of the 2004/2005 Year Book looks at the links among gender, poverty, and environment. The Emerging Challenges section explores how environmental change can trigger the emergence or re-emergence of infectious diseases, demonstrating the role of good environmental management in minimizing adverse trends. It also presents an overview of recent changes in ocean salinity and a step-by-step explanation of why this could have serious consequences.



Year Book 2006
The GYB's 2006 Feature Focus elaborates on the environmental, socio-economic and public health impacts of energy-related air pollution. Associated with the energy consumption that contributes to air pollution are increasing global concerns over climate change and energy security and access. The section on Emerging Challenges addresses two topics of policy interest related to food security. The first topic explores the issue of crop production in a changing climate, while the second identifies environmental effects and best practices related to fish and shellfish farming in marine ecosystems.



Year Book 2003
Water is the topic of the Feature Focus in the Year Book 2003. Water plays an important role in realizing various internationally-agreed development goals, including those contained in the Millennium Declaration which arose out of the UN Millennium Summit of Heads of State and Governments convened in 2000. The section on Emerging Challenges focuses on science and research findings related to the nitrogen cycle and marine fisheries.

Download the latest version online free of charge from http://www.unep.org/geo/yearbook/ or buy print copies of the Year Book at www.earthprint.com. Buy the complete set of Year Books for a reduced price. Available in English, French, Spanish, Russian, Arabic, and Chinese.

The UNEP Year Book 2008 (formerly the GEO Year Book) is the fifth annual report on the changing environment produced by the United Nations Environment Programme in collaboration with many world environmental experts.

The UNEP Year Book 2008 highlights the increasing complexity and interconnections of climate change, ecosystem integrity, human well-being, and economic development. It examines the emergence and influence of economic mechanisms and market driven approaches for addressing environmental degradation. It describes recent research findings and policy decisions that affect our awareness of and response to changes in our global environment.

In three sections, the UNEP Year Book 2008 focuses on recent environmental events, developments, and scientific findings:

The **Global Overview** surveys the significant environmental events that gained prominence during 2007. Using graphs, charts, and photos with examples from regional experiences, the overview also tracks new scientific and policy developments on the environmental front.

The **Feature Focus** documents some of the creative efforts already working in markets and financial circles to fight the growing climate crisis. The section also examines patterns that are emerging after a decade of carbon market experimentation. Finally, it attempts to map the next important steps that will assist the transition to an environmentally-sound economy.

The **Emerging Challenge** examines recent scientific findings on the role of arctic climate feedbacks. Release of methane from thawing permafrost and from hydrate deposits are amplifiying warming trends. The section emphasizes the urgent need for increased investments in climate and energy research, knowledge partnerships, and global political responses to meet these serious challenges.

The UNEP Year Book 2008 is essential, informative, and authoritative reading for anyone with a role or an interest in our changing environment.

www.unep.org
United Nations Environment Programme
P.O. Box 30552, Nairobi 00100, Kenya
Tel: (+254) 20 7621234
Fax: (+254) 20 7623927
Email: uneppub@unep.org

978-92-807-2877-4
DEW/1006/NA